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Bundle Protocol Security Specification
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Abstract

This document defines a security protocol providing end to end data integrity and confidentiality services for the Bundle Protocol.

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Table of Contents

1. Introduction 3
1.1. Motivation 3
1.2. Supported Security Services 3
1.3. Specification Scope 4
1.4. Related Documents 5
1.5. Terminology 5
2. Key Properties 6
2.1. Block-Level Granularity 6
2.2. Multiple Security Sources 7
2.3. Mixed Security Policy 7
2.4. User-Selected Cipher Suites 8
2.5. Deterministic Processing 8
3. Security Blocks 8
3.1. Block Definitions 9
3.2. Uniqueness 9
3.3. Target Multiplicity 10
3.4. Target Identification 10
3.5. Block Representation 11
3.6. Abstract Security Block 11
3.7. Block Integrity Block 14
3.8. Block Confidentiality Block 15
3.9. Block Interactions 16
3.10. Parameters and Result Types 17
3.11. BSP Block Example 20
4. Canonical Forms 22
4.1. Technical Notes 22
4.2. Primary Block Canonicalization 23
4.3. Non-Primary-Block Canonicalization 23
5. Security Processing 24
5.1. Bundles Received from Other Nodes 24
5.1.1. Receiving BCB Blocks 24
5.1.2. Receiving BIB Blocks 25
5.2. Bundle Fragmentation and Reassembly 26
6. Key Management 26
7. Security Policy Considerations 26
8. Security Considerations 27
8.1. Attacker Capabilities and Objectives 28
8.2. Attacker Behaviors and BPSec Mitigations 29
8.2.1. Eavesdropping Attacks 29
8.2.2. Modification Attacks 29
8.2.3. Topology Attacks 31
8.2.4. Message Injection 31
9. Cipher Suite Authorship Considerations 32
10. Defining Other Security Blocks 33
11. Conformance 34
12. IANA Considerations 34

12.1. Bundle Block Types 34
13. References 34
13.1. Normative References 34
13.2. Informative References 35
Appendix A. Acknowledgements 35
Authors' Addresses 35

1. Introduction

This document defines security features for the Bundle Protocol (BP) [BPBIS]. This BP Security Specification (BPSec) is intended for use in Delay Tolerant Networks (DTNs) to provide end-to-end security services.

1.1. Motivation

The Bundle Protocol specification [BPBIS] defines DTN as referring to "a networking architecture providing communications in and/or through highly stressed environments" where "BP may be viewed as sitting at the application layer of some number of constituent networks, forming a store-carry-forward overlay network". The term "stressed" environment refers to multiple challenging conditions including intermittent connectivity, large and/or variable delays, asymmetric data rates, and high bit error rates.

There is a reasonable expectation that BP may be deployed in such a way that a portion of the network might become compromised, posing the usual security challenges related to confidentiality and integrity. However, the stressed nature of the BP operating environment imposes unique requirements such that the usual security mechanisms to usual security challenges may not apply. For example, the store-carry-forward nature of the network may require protecting data at rest while also preventing unauthorized consumption of critical resources such as storage space. The heterogeneous nature of the networks comprising the BP overlay, and/or associated timing, might prevent the establishment of an end-to-end session to provide a context for a security service. The partitionability of a DTN might prevent regular contact with a centralized security oracle (such as a certificate authority).

An end-to-end security service is needed that operates in all of the environments where the BP operates.

1.2. Supported Security Services

BPSec provides end-to-end integrity and confidentiality services for BP bundles.

Integrity services ensure data within a bundle are not changed. Data changes may be caused by processing errors, environmental conditions, or intentional manipulation. An integrity service is one that provides sufficient confidence to a data receiver that data has not changed since its value was last asserted.

Confidentiality services ensure that only authorized receivers can view those data within a bundle identified as needing to be private amongst the data source and data receivers. A confidentiality services is one that provides confidence to a data receiver that private data was not viewed by other nodes as the bundle traversed the DTN.

NOTE: Hop-by-hop authentication is NOT a supported security service in this specification, for three reasons.

1. The term "hop-by-hop" is ambiguous in a BP overlay, as nodes that are adjacent in the overlay may not be adjacent in physical connectivity. This condition is difficult or impossible to predict in the overlay and therefore makes the concept of hop-by-hop authentication difficult or impossible to enforce at the overlay.

2. Networks in which BPSec may be deployed may have a mixture of security-aware and not-security-aware nodes. Hop-by-hop authentication cannot be deployed in a network if adjacent nodes in the network have different security capabilities.

3. Hop-by-hop authentication can be viewed as a special case of data integrity. As such, a version of authentication can be achieved by using the integrity mechanisms defined in this specification.

1.3. Specification Scope

This document defines the security services provided by the BPSec. This includes the data specification for representing these services as BP extension blocks, and the rules for adding, removing, and processing these blocks at various points in the bundle's traversal of the DTN.

BPSec applies only to those nodes that implement it, known as "security-aware" nodes. There might be other nodes in the DTN that do not implement BPSec. While all nodes in a BP overlay can exchange bundles, BPSec security operations can only happen at BPSec security-aware nodes.

This specification does not address individual cipher suite implementations. Different networking conditions and operational

considerations require varying strengths of security mechanism such that mandating a cipher suite in this specification may result in too much security for some networks and too little security in others. The definition and enumeration of cipher suites is assumed to be undertaken in other, separate specification documents.

This specification does not address the implementation of security policy and does not provide a security policy for the BPSec. Similar to cipher suites, security policies are based on the nature and capabilities of individual networks and network operational concepts. This specification does provide policy considerations when building a security policy.

This specification does not address how to combine the BPSec security blocks with other protocols, other BP extension blocks, or other best practices to achieve security in any particular network implementation.

1.4. Related Documents

This document is best read and understood within the context of the following other DTN documents:

"Delay-Tolerant Networking Architecture" [RFC4838] defines the architecture for DTNs and identifies certain security assumptions made by existing Internet protocols that are not valid in a DTN.

The Bundle Protocol [BPBIS] defines the format and processing of the bundles that both carry the data and the security services operating on those data. This document also defines the extension block format used to capture BPSec security blocks.

The Bundle Security Protocol [RFC6257] and Streamlined Bundle Security Protocol [SBSP] documents introduced the concepts of BP security blocks for security services in a DTN. The BPSec is a continuation and refinement of these documents.

1.5. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

This section defines terminology either unique to the BPSec or otherwise necessary for understanding the concepts defined in this specification.

- Forwarder - any node that transmits a bundle in the DTN. The Node ID of the Bundle Protocol Agent (BPA) that sent the bundle on its most recent hop.

- Intermediate Receiver, Waypoint, or "Next Hop" - any node that receives a bundle from a Forwarder that is not the Destination. The Node ID of the BPA at any such node.

- Path - the ordered sequence of nodes through which a bundle passes on its way from Source to Destination. The path is not necessarily known in advance by the bundle or any BPAs in the DTN.

- Security Block - a BPSec extension block in a bundle.

- Security Operation - the application of a security service to a security target, notated as OP(security service, security target). For example, OP(confidentiality, payload). Every security operation in a bundle MUST be unique, meaning that a security service can only be applied to a security target once in a bundle. A security operation is implemented by a security block.

- Security Service - the security features supported by this specification: integrity and confidentiality.

- Security Source - a bundle node that adds a security block to a bundle.

- Security Target - the block within a bundle that receives a security-service as part of a security-operation.

- Source - the node which originates a bundle. The Node ID of the BPA originating the bundle.

2. Key Properties

The application of security services in a DTN is a complex endeavor that must consider physical properties of the network, policies at each node, and various application security requirements. This section identifies and defines the key properties guiding design decisions for the security services provided by this specification.

2.1. Block-Level Granularity

Security services within this specification MUST allow different blocks within a bundle to have different security services applied to them. As such, each security block within a bundle MUST be associated with a specific security operation.

Blocks within a bundle represent different types of information. The primary block contains identification and routing information. The payload block carries application data. Extension blocks carry a variety of data that may augment or annotate the payload, or otherwise provide information necessary for the proper processing of a bundle along a path. Therefore, applying a single level and type of security across an entire bundle fails to recognize that blocks in a bundle may represent different types of information with different security needs.

For example, a payload block might be encrypted to protect its contents and an extension block containing summary information related to the payload might be integrity signed but unencrypted to provide waypoints access to payload-related data without providing access to the payload.

2.2. Multiple Security Sources

A bundle MAY have multiple security blocks and these blocks MAY have different security sources.

The Bundle Protocol allows extension blocks to be added to a bundle at any time during its existence in the DTN. When a waypoint adds a new extension block to a bundle, that extension block may have security services applied to it by that waypoint. Similarly, a waypoint may add a security service to an existing extension block, consistent with its security policy. For example, a node representing a boundary between a trusted part of the network and an untrusted part of the network may wish to apply payload encryption for bundles leaving the trusted portion of the network.

When a waypoint adds a security service to the bundle, the waypoint is the security source for that service. The security block(s) which represent that service in the bundle may need to record this security source as the bundle destination might need this information for processing. For example, a destination node might interpret policy as it related to security blocks as a function of the security source for that block.

2.3. Mixed Security Policy

The security policy enforced by nodes in the DTN MAY differ.

Some waypoints may not be security aware and will not be able to process security blocks. Therefore, security blocks MUST have their processing flags set such that the block will be treated appropriately by non-security-aware waypoints

Some waypoints will have security policies that require evaluating security services even if they are not the bundle destination or the final intended destination of the service. For example, a waypoint may choose to verify an integrity service even though the waypoint is not the bundle destination and the integrity service will be needed by other node along the bundle's path.

Some waypoints will determine, through policy, that they are the intended recipient of the security service and terminate the security service in the bundle. For example, a gateway node may determine that, even though it is not the destination of the bundle, it should verify and remove a particular integrity service or attempt to decrypt a confidentiality service, before forwarding the bundle along its path.

Some waypoints may understand security blocks but refuse to process them unless they are the bundle destination.

2.4. User-Selected Cipher Suites

The security services defined in this specification rely on a variety of cipher suites providing integrity signatures, cipher-text, and other information necessary to populate security blocks. Users MAY select different cipher suites to implement security services. For example, some users might prefer a SHA-256 based hash for integrity whereas other users may prefer a SHA-384 hash instead. The security services defined in this specification MUST provide a mechanism for identifying what cipher suite has been used to populate a security block.

2.5. Deterministic Processing

Whenever a node determines that it must process more than one security block in a received bundle (either because the policy at a waypoint states that it should process security blocks or because the node is the bundle destination) the order in which security blocks are processed MUST be deterministic. All nodes MUST impose this same deterministic processing order for all security blocks. This specification provides determinism in the application and evaluation of security services, even when doing so results in a loss of flexibility.

3. Security Blocks

3.1. Block Definitions

This specification defines two types of security block: the Block Integrity Block (BIB) and the Block Confidentiality Block (BCB).

The BIB is used to ensure the integrity of its security target(s). The integrity information in the BIB MAY be verified by any node in between the BIB security source and the bundle destination. Security-aware waypoints may add or remove BIBs from bundles in accordance with their security policy.

The BCB indicates that the security target(s) has been encrypted, in whole or in part, at the BCB security source in order to protect its content while in transit. The BCB may be decrypted by security-aware nodes in the network, up to and including the bundle destination, as a matter of security policy.

3.2. Uniqueness

Security operations in a bundle MUST be unique - the same security service MUST NOT be applied to a security target more than once in a bundle. Since a security operation is represented as a security block, this limits what security blocks may be added to a bundle: if adding a security block to a bundle would cause some other security block to no longer represent a unique security operation then the new block MUST NOT be added.

If multiple security blocks representing the same security operation were allowed in a bundle at the same time, there would exist ambiguity regarding block processing order and the property of deterministic processing blocks would be lost.

Using the notation OP(service,target), several examples illustrate this uniqueness requirement.

- Signing the payload twice: The two operations OP(integrity, payload) and OP(integrity, payload) are redundant and cannot both be present in the same bundle at the same time.

- Signing different blocks: The two operations OP(integrity, payload) and OP(integrity, extension_block_1) are not redundant and both may be present in the same bundle at the same time. Similarly, the two operations OP(integrity, extension_block_1) and OP(integrity,extension_block_2) are also not redundant and may both be present in the bundle at the same time.

- Different Services on same block: The two operations OP(integrity,payload) and OP(confidentiality, payload) are not

inherently redundant and may both be present in the bundle at the same time, pursuant to other processing rules in this specification.

3.3. Target Multiplicity

Under special circumstances, a single security block can represent multiple security operations as a way of reducing the overall number of security blocks present in a bundle. In these circumstances, reducing the number of security blocks in the bundle reduces the amount of redundant information in the bundle.

A set of security operations may be represented by a single security block if and only if the following conditions are true.

- The security operations apply the same security service. For example, they are all integrity operations or all confidentiality operations.
- The cipher suite parameters and key information for the security operations are identical.
- The security source for the security operations is the same. Meaning the set of operations are being added/removed by the same node.
- No security operations have the same security target, as that would violate the need for security operations to be unique.
- None of the security operations conflict with security operations already present in the bundle.

When representing multiple security operations in a single security block, the information that is common across all operations is represented once in the security block, and the information which is different (e.g., the security targets) are represented individually. When the security block is processed all security operations represented by the security block MUST be applied/evaluated at that time.

3.4. Target Identification

A security target is a block in the bundle to which a security service applies. This target MUST be uniquely and unambiguously identifiable when processing a security block. The definition of the extension block header from [BPBIS] provides a "Block Number" field for exactly this purpose. Therefore, a security target in a security block MUST be represented as the Block Number of the target block.

3.5. Block Representation

Each security block uses the Canonical Bundle Block Format as defined in [BPBIS]. That is, each security block is comprised of the following elements:

- Block Type Code
- Block Number
- Block Processing Control Flags
- CRC Type and CRC Field (if present)
- Block Data Length
- Block Type Specific Data Fields

Security-specific information for a security block is captured in the "Block Type Specific Data Fields".

3.6. Abstract Security Block

The structure of the security-specific portions of a security block is identical for both the BIB and BCB Block Types. Therefore, this section defines an Abstract Security Block (ASB) data structure and discusses the definition, processing, and other constraints for using this structure. An ASB is never directly instantiated within a bundle, it is only a mechanism for discussing the common aspects of BIB and BCB security blocks.

The fields of the ASB SHALL be as follows, listed in the order in which they MUST appear.

Security Targets:
: This field identifiers the block or blocks that are the target of the security operation(s) represented by this security block. Each security target is identified as the Block Number of the target block. This field SHALL be represented by a CBOR array of data items. Each target within this CBOR array SHALL be represented by a CBOR unsigned integer. This array MUST have at least 1 item.

Cipher Suite Id:
: This field identifies the cipher suite used to implement the security service represented by this block and applied to each security target. This field SHALL be represented by a CBOR unsigned integer.

Cipher Suite Flags:

This field identifiers which optional fields are present in the security block. This field SHALL be represented as a CBOR unsigned integer containing a bit field of 5 bits indicating the presence or absence of other security block fields, as follows.

Bit 1 (the most-significant bit, 0x10): reserved.

Bit 2 (0x08): reserved.

Bit 3 (0x04): reserved.

Bit 4 (0x02): Security Source Present Flag.

Bit 5 (the least-significant bit, 0x01): Cipher Suite Parameters Present Flag.

In this field, a value of 1 indicates that the associated security block field MUST be included in the security block. A value of 0 indicates that the associated security block field MUST NOT be in the security block.

Security Source (Optional Field):

This field identifies the Endpoint that inserted the security block in the bundle. If the security source field is not present then the source MAY be inferred from other information, such as the bundle source or the previous hop, as defined by security policy. This field SHALL be represented by a CBOR array in accordance with [BPBIS] rules for representing Endpoint Identifiers (EIDs).

Cipher Suite Parameters (Optional Field):

This field captures one or more cipher suite parameters that should be provided to security-aware nodes when processing the security service described by this security block. This field SHALL be represented by a CBOR array. Each entry in this array is a single cipher suite parameter. A single cipher suite parameter SHALL also be represented as a CBOR array comprising a 2-tuple of the type and value of the parameter, as follows.

* Parameter Type. This field identifiers which cipher suite parameter is being specified. This field SHALL be represented as a CBOR unsigned integer. Potential parameter types are described in Section 3.10. Other specifications MAY define additional parameter types for use in this field.

* Parameter Value. This field captures the value associated with this parameter. This field SHALL be represented by the applicable CBOR representation of the parameter type. These specifications are given in Section 3.10 for parameter types defined in this specification. Other specifications that define other parameter types MUST include the appropriate CBOR encoding of the parameter value.

Therefore, this field SHALL be represented as a CBOR array of CBOR arrays.

Security Results:

This field captures the results of applying a security service to the security targets in this security block. This field SHALL be represented as a CBOR array. Each entry in this array represents a "target list" of security results for a specific security target. There MUST be one "target list" for each entry in the Security Targets field and target lists in the Security Results field MUST be in the same order as the Security Targets field (e.g., the first "target list" MUST hold results for the first entry in the Security Targets field, and so on).

A "target list" is also represented as a CBOR array of individual security results for that target. An individual security result is also represented as a CBOR array comprising the 2-tuple of the result type and result value, defined as follows.

* Result Type. This field captures the type of security result. Some security result types capture the primary output of a cipher suite. Other security results contain additional annotative information from the cipher suite processing. This field SHALL be represented as a CBOR unsigned integer. Potential result types are described in Section 3.10. Other specifications MAY define additional result types for use in this field.

* Result Value. This field captures the value associated with this result for this target. This field SHALL be represented by the applicable CBOR representation of the result type. These specifications are given in Section 3.10 for result types defined in this specification. Other specifications that define other result types MUST include the appropriate CBOR encoding of the result value.

3.7. Block Integrity Block

A BIB is a bundle extension block with the following characteristics.

- The Block Type Code value is as specified in Section 12.1.
- The Block Type Specific Data Fields follow the structure of the ASB.
- A security target listed in the Security Targets field MUST NOT reference a security block defined in this specification (e.g., a BIB or a BCB).
- The Cipher Suite Id MUST be documented as an end-to-end authentication-cipher suite or as an end-to-end error-detection-cipher suite.
- An EID-reference to the security source MAY be present. If this field is not present, then the security source of the block SHOULD be inferred according to security policy and MAY default to the bundle source. The security source may also be specified as part of key information described in Section 3.10.
- The cipher suite MAY process less than the entire security target. If the cipher suite processes less than the complete, original security target, the cipher suite parameters MUST specify which bytes of the security target are protected.

Notes:

- It is RECOMMENDED that cipher suite designers carefully consider the effect of setting flags that either discard the block or delete the bundle in the event that this block cannot be processed.
- Since OP(integrity, target) is allowed only once in a bundle per target, it is RECOMMENDED that users wishing to support multiple integrity signatures for the same target define a multi-signature cipher suite.
- For some cipher suites, (e.g., those using asymmetric keying to produce signatures or those using symmetric keying with a group key), the security information MAY be checked at any hop on the way to the destination that has access to the required keying information, in accordance with Section 3.9.

- The use of a generally available key is RECOMMENDED if custodial transfer is employed and all nodes SHOULD verify the bundle before accepting custody.

3.8. Block Confidentiality Block

A BCB is a bundle extension block with the following characteristics.

The Block Type Code value is as specified in Section 12.1.

The Block Processing Control flags value can be set to whatever values are required by local policy, except that this block MUST have the "replicate in every fragment" flag set if the target of the BCB is the Payload Block. Having that BCB in each fragment indicates to a receiving node that the payload portion of each fragment represents cipher-text.

The Block Type Specific Data Fields follow the structure of the ASB.

A security target listed in the Security Targets field MAY reference the payload block, a non-security extension block, or a BIB block. A BCB MUST NOT include another BCB as a security target. A BCB MUST NOT target the primary block.

The Cipher Suite Id MUST be documented as a confidentiality cipher suite.

Any additional bytes generated from applying the cipher suite to a security target (such as additional authenticated text) MAY be placed in an appropriate security result (e.g., an Integrity Check Value) in accordance with cipher suite and security policy.

An EID-reference to the security source MAY be present. If this field is not present, then the security source of the block SHOULD be inferred according to security policy and MAY default to the bundle source. The security source may also be specified as part of key information described in Section 3.10.

The BCB modifies the contents of its security target(s). When a BCB is applied, the security target body data are encrypted "in-place". Following encryption, the security target Block Type Specific Data Fields contains cipher-text, not plain-text. Other block fields remain unmodified, with the exception of the Block Data Length field, which may be changed if the BCB is allowed to change the length of the block (see below).

Fragmentation, reassembly, and custody transfer are adversely affected by a change in size of the payload block due to ambiguity about what byte range of the block is actually in any particular fragment. Therefore, when the security target of a BCB is the bundle payload, the BCB MUST NOT alter the size of the payload block body data. This "in-place" encryption allows fragmentation, reassembly, and custody transfer to operate without knowledge of whether or not encryption has occurred.

If a BCB cannot alter the size of the security target (e.g., the security target is the payload block or block length modifications are disallowed by policy) then differences in the size of the cipher-text and plain-text MUST be handled in the following way. If the cipher-text is shorter in length than the plain-text, padding must be used in accordance with the cipher suite policy. If the cipher-text is larger than the plain-text, overflow bytes MUST be placed in overflow parameters in the Security Result field.

Notes:

- It is RECOMMENDED that cipher suite designers carefully consider the effect of setting flags that either discard the block or delete the bundle in the event that this block cannot be processed.

- The cipher suite MAY process less than the entire original security target body data. If the cipher suite processes less than the complete, original security target body data, the BCB for that security target MUST specify, as part of the cipher suite parameters, which bytes of the body data are protected.

- The BCB block processing control flags MAY be set independently from the processing control flags of the security target(s). The setting of such flags SHOULD be an implementation/policy decision for the encrypting node.

- A BCB MAY include information as part of additional authenticated data to address parts of the target block that are not converted to cipher-text.

3.9. Block Interactions

The security block types defined in this specification are designed to be as independent as possible. However, there are some cases where security blocks may share a security target creating processing dependencies.

If confidentiality is being applied to a target that already has integrity applied to it, then an undesirable condition occurs where a security aware waypoint would be unable to check the integrity result of a block because the block contents have been encrypted after the integrity signature was generated. To address this concern, the following processing rules MUST be followed.

- If confidentiality is to be applied to a target, it MUST also be applied to any integrity operation already defined for that target. This means that if a BCB is added to encrypt a block, another BCB MUST also be added to encrypt a BIB also targeting that block.

- An integrity operation MUST NOT be applied to a security target if a BCB in the bundle shares the same security target. This prevents ambiguity in the order of evaluation when receiving a BIB and a BCB for a given security target.

- An integrity value MUST NOT be evaluated if the BIB providing the integrity value is the security target of an existing BCB block in the bundle. In such a case, the BIB data contains cipher-text as it has been encrypted.

- An integrity value MUST NOT be evaluated if the security target of the BIB is also the security target of a BCB in the bundle. In such a case, the security target data contains cipher-text as it has been encrypted.

- As mentioned in Section 3.7, a BIB MUST NOT have a BCB as its security target. BCBs may embed integrity results as part of security results.

These restrictions on block interactions impose a necessary ordering when applying security operations within a bundle. Specifically, for a given security target, BIBs MUST be added before BCBs. This ordering MUST be preserved in cases where the current BPA is adding all of the security blocks for the bundle or whether the BPA is a waypoint adding new security blocks to a bundle that already contains security blocks.

3.10. Parameters and Result Types

Cipher suite parameters and security results may capture multiple types of information in a security block. This section identifies a set of parameters and results that are available in any BPSec implementation for use by any cipher suite. Individual cipher suites MAY define additional parameters and results. A cipher suite MAY

include multiple instances of the same type of parameter or result in a security block.

Parameters and results are represented using CBOR, and any identification of a new parameter or result type MUST include how the value of the type will be represented using the CBOR specification. Types themselves are always represented as a CBOR unsigned integer.

Cipher suite parameter types, as defined by this specification, are as follows.

Cipher Suite Parameter Types.

Type	Name	Description	CBOR Representation
0	Initialization Vector	A random value, typically eight to sixteen bytes.	Byte String
1	Key Information	Material encoded or protected by the key management system and used to transport an ephemeral key protected by a long-term key.	Byte String
2	Content Range	Pair of Unsigned Integers (offset,length) specifying the range of payload bytes to which an operation applies. The offset MUST be the offset within the original bundle, even if the current bundle is a fragment.	CBOR Array comprising a 2-tuple of CBOR unsigned integers.
3	Salt	An IV-like value used by certain confidentiality suites.	Byte Array
4-31	Reserved	Reserve for future BPSec protocol expansion	
>= 32	Unassigned	Unassigned by this specification. Can be assigned by cipher suite specifications.	

Table 1

Security result parameter types, as defined by this specification, are as follows.

Security Result Types.

Type	Name	Description	CBOR Representation
0	Integrity Signatures	Result of BIB digest or other signing operation.	Byte String
1	BCB Integrity Check Value (ICV) / Authentication Tag	Output from certain confidentiality cipher suite operations to be used at the destination to verify that the protected data has not been modified. This value MAY contain padding if required by the cipher suite.	Byte String
2-31	Reserved	Reserve for future BPSec protocol expansion	
>= 32	Unassigned	Unassigned by this specification. Can be assigned by cipher suite specifications.	

Table 2

3.11. BSP Block Example

An example of BPSec blocks applied to a bundle is illustrated in Figure 1. In this figure the first column represents blocks within a bundle and the second column represents the Block Number for the block, using the terminology B1...Bn for the purpose of illustration.

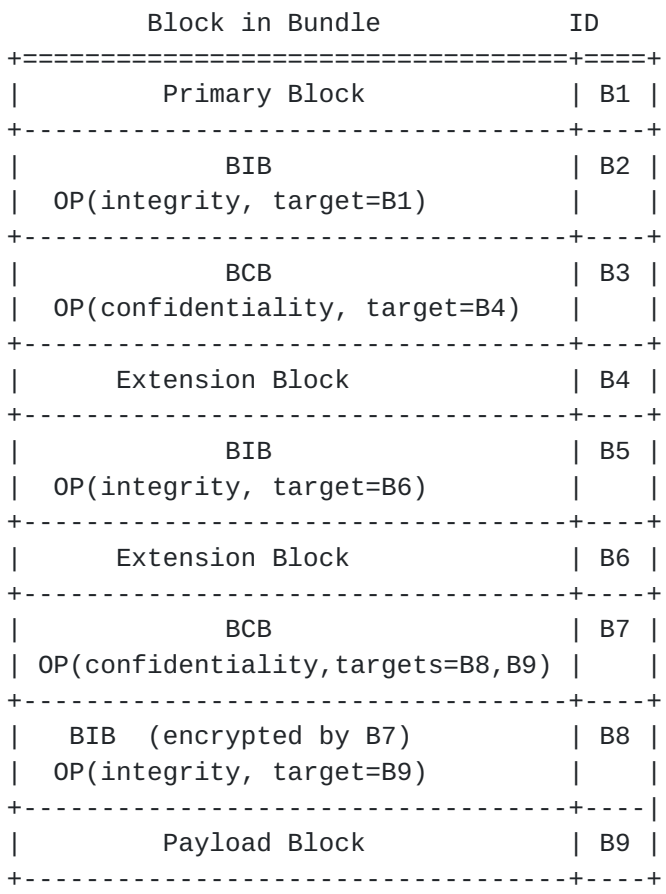


Figure 1: Sample Use of BPSec Blocks

In this example a bundle has four non-security-related blocks: the primary block (B1), two extension blocks (B4,B6), and a payload block (B9). The following security applications are applied to this bundle.

- An integrity signature applied to the canonicalized primary block. This is accomplished by a single BIB (B2).

- Confidentiality for the first extension block (B4). This is accomplished by a BCB block (B3).

- Integrity for the second extension block (B6). This is accomplished by a BIB block (B5). NOTE: If the extension block B6 contains a representation of the serialized bundle (such as a hash over all blocks in the bundle at the time of its last transmission) then the BIB block is also providing an authentication service.

- An integrity signature on the payload (B10). This is accomplished by a BIB block (B8).

- Confidentiality for the payload block and it's integrity signature. This is accomplished by a BCB block, B7, encrypting B8 and B9. In this case, the security source, key parameters, and service are identical, so a single security block MAY be used for this purpose, rather than requiring two BCBs one to encrypt B8 and one to encrypt B9.

4. Canonical Forms

By definition, an integrity service determines whether any aspect of a block was changed from the moment the security service was applied at the security source until the point of evaluation. To successfully verify the integrity of a block, the data passed to the verifying cipher suite MUST be the same bits, in the same order, as those passed to the signature-generating cipher suite at the security source.

This section provides guidance on how to create a canonical form for each type of block in a bundle. This form MUST be used when generating inputs to cipher suites for use by BPSec blocks.

4.1. Technical Notes

The following technical considerations hold for all canonicalizations in this section.

- Any numeric fields defined as variable-length MUST be expanded to their largest unpacked form before being used by a cipher suite. If a field does not specify a maximum size, a maximum size of 32 bits for integer and 64 bits for floating point values SHALL be assumed.

- Canonical forms are not transmitted, they are used to generate input to a cipher suite for security processing at a security-aware node.

- Reserved flags MUST NOT be included in any canonicalization as it is not known if those flags will change in transit.

- These canonicalization algorithms assume that Endpoint IDs do not change from the time at which a security source adds a security block to a bundle and the time at which a node processes that security block.

- Cipher suites MAY define their own canonicalization algorithms and require the use of those algorithms over the ones provided in this specification. In the event of conflicting canonicalization

algorithms, cipher suite algorithms take precedence over this specification.

4.2. Primary Block Canonicalization

The canonicalization of the primary block is as specified in [BPBIS] with the following exceptions.

- The following Bundle Processing Control Flags MAY change as a bundle transits the DTN without indicating an integrity error and, therefore, MUST NOT be included in the canonicalization of the primary block.

  * Bundle is a fragment. (Bit 15, 0x0001)

  * Custody transfer requested for this bundle. (Bit 12, 0x0008)

  * Reserved (Bits 0-2, 0xE000)

  Regardless of the value of these flags in the primary block, they MUST be set to 0 when canonicalized for security processing.

- The CRC field MAY change at each hop - for example, if a bundle becomes fragmented, each fragment will have a different CRC value from the original signed primary block. As such, this field MUST NOT be included in the canonicalization.

4.3. Non-Primary-Block Canonicalization

All non-primary blocks (NPBs) share the same block structure and are canonicalized as specified in [BPBIS] with the following exceptions.

- If the service being applied is a confidentiality service, then the Block Type Code, Block Number, Block Processing Control Flags, CRC Type and CRC Field (if present), and Block Data Length fields MUST NOT be included in the canonicalization. Confidentiality services are used to convert the Block Type Specific Data Fields from plain-text to cipher-text.

- The Block Type Specific Data Field is included, without modification, for both integrity and confidentiality services, with the exception that in some cases only a portion of the payload data is to be processed. In such a case, only those bytes are included in the canonical form and additional cipher suite parameters are required to specify which part of the field is included.

5. Security Processing

This section describes the security aspects of bundle processing.

5.1. Bundles Received from Other Nodes

Security blocks MUST be processed in a specific order when received by a security-aware node. The processing order is as follows.

- All BCB blocks in the bundle MUST be evaluated prior to evaluating any BIBs in the bundle. When BIBs and BCBs share a security target, BCBs MUST be evaluated first and BIBs second.

5.1.1. Receiving BCB Blocks

If a received bundle contains a BCB, the receiving node MUST determine whether it has the responsibility of decrypting the BCB security target and removing the BCB prior to delivering data to an application at the node or forwarding the bundle.

If the receiving node is the destination of the bundle, the node MUST decrypt any BCBs remaining in the bundle. If the receiving node is not the destination of the bundle, the node MAY decrypt the BCB if directed to do so as a matter of security policy.

If the security policy of a security-aware node specifies that a bundle should have applied confidentiality to a specific security target and no such BCB is present in the bundle, then the node MUST process this security target in accordance with the security policy. This MAY involve removing the security target from the bundle. If the removed security target is the payload block, the bundle MAY be discarded.

If the relevant parts of an encrypted payload block cannot be decrypted (i.e., the decryption key cannot be deduced or decryption fails), then the bundle MUST be discarded and processed no further. If an encrypted security target other than the payload block cannot be decrypted then the associated security target and all security blocks associated with that target MUST be discarded and processed no further. In both cases, requested status reports (see [BPBIS]) MAY be generated to reflect bundle or block deletion.

When a BCB is decrypted, the recovered plain-text MUST replace the cipher-text in the security target Block Type Specific Data Fields. If the Block Data Length field was modified at the time of encryption it MUST be updated to reflect the decrypted block length.

If a BCB contains multiple security targets, all security targets MUST be processed when the BCB is processed. Errors and other processing steps SHALL be made as if each security target had been represented by an individual BCB with a single security target.

5.1.2. Receiving BIB Blocks

If a received bundle contains a BIB, the receiving node MUST determine whether it has the final responsibility of verifying the BIB security target and removing it prior to delivering data to an application at the node or forwarding the bundle. If a BIB check fails, the security target has failed to authenticate and the security target SHALL be processed according to the security policy. A bundle status report indicating the failure MAY be generated. Otherwise, if the BIB verifies, the security target is ready to be processed for delivery.

A BIB MUST NOT be processed if the security target of the BIB is also the security target of a BCB in the bundle. Given the order of operations mandated by this specification, when both a BIB and a BCB share a security target, it means that the security target MUST have been encrypted after it was integrity signed and, therefore, the BIB cannot be verified until the security target has been decrypted by processing the BCB.

If the security policy of a security-aware node specifies that a bundle should have applied integrity to a specific security target and no such BIB is present in the bundle, then the node MUST process this security target in accordance with the security policy. This MAY involve removing the security target from the bundle. If the removed security target is the payload or primary block, the bundle MAY be discarded. This action may occur at any node that has the ability to verify an integrity signature, not just the bundle destination.

If a receiving node does not have the final responsibility of verifying the BIB it MAY still attempt to verify the BIB to prevent the needless forwarding of corrupt data. If the check fails, the node SHALL process the security target in accordance to local security policy. It is RECOMMENDED that if a payload integrity check fails at a waypoint that it is processed in the same way as if the check fails at the destination. If the check passes, the node MUST NOT remove the BIB prior to forwarding.

If a BIB contains multiple security targets, all security targets MUST be processed if the BIB is processed by the Node. Errors and other processing steps SHALL be made as if each security target had been represented by an individual BIB with a single security target.

5.2. Bundle Fragmentation and Reassembly

If it is necessary for a node to fragment a bundle payload, and security services have been applied to that bundle, the fragmentation rules described in [BPBIS] MUST be followed. As defined there and summarized here for completeness, only the payload block may be fragmented; security blocks, like all extension blocks, can never be fragmented.

Due to the complexity of payload block fragmentation, including the possibility of fragmenting payload block fragments, integrity and confidentiality operations are not to be applied to a bundle representing a fragment. Specifically, a BCB or BIB MUST NOT be added to a bundle if the "Bundle is a Fragment" flag is set in the Bundle Processing Control Flags field.

Security processing in the presence of payload block fragmentation MAY be handled by other mechanisms outside of the BPSec protocol or by applying BPSec blocks in coordination with an encapsulation mechanism.

6. Key Management

There exist a myriad of ways to establish, communicate, and otherwise manage key information in a DTN. Certain DTN deployments might follow established protocols for key management whereas other DTN deployments might require new and novel approaches. BPSec assumes that key management is handled as a separate part of network design and this specification neither defines nor requires a specific key management strategy.

7. Security Policy Considerations

When implementing BPSec, several policy decisions must be considered. This section describes key policies that affect the generation, forwarding, and receipt of bundles that are secured using this specification. No single set of policy decisions is envisioned to work for all secure DTN deployments.

- If a bundle is received that contains more than one security operation, in violation of BPSec, then the BPA must determine how to handle this bundle. The bundle may be discarded, the block affected by the security operation may be discarded, or one security operation may be favored over another.

- BPAs in the network MUST understand what security operations they should apply to bundles. This decision may be based on the source

of the bundle, the destination of the bundle, or some other information related to the bundle.

- If a waypoint has been configured to add a security operation to a bundle, and the received bundle already has the security operation applied, then the receiver MUST understand what to do. The receiver may discard the bundle, discard the security target and associated BPSec blocks, replace the security operation, or some other action.

- It is recommended that security operations only be applied to the blocks that absolutely need them. If a BPA were to apply security operations such as integrity or confidentiality to every block in the bundle, regardless of need, there could be downstream errors processing blocks whose contents must be inspected or changed at every hop along the path.

- Adding a BIB to a security target that has already been encrypted by a BCB is not allowed. If this condition is likely to be encountered, there are (at least) three possible policies that could handle this situation.

  1. At the time of encryption, an integrity signature may be generated and added to the BCB for the security target as additional information in the security result field.

  2. The encrypted block may be replicated as a new block and integrity signed.

  3. An encapsulation scheme may be applied to encapsulate the security target (or the entire bundle) such that the encapsulating structure is, itself, no longer the security target of a BCB and may therefore be the security target of a BIB.

8. Security Considerations

Given the nature of DTN applications, it is expected that bundles may traverse a variety of environments and devices which each pose unique security risks and requirements on the implementation of security within BPSec. For these reasons, it is important to introduce key threat models and describe the roles and responsibilities of the BPSec protocol in protecting the confidentiality and integrity of the data against those threats. This section provides additional discussion on security threats that BPSec will face and describes how BPSec security mechanisms operate to mitigate these threats.

It should be noted that BPSEC addresses only the security of data traveling over the DTN, not the underlying DTN itself. Additionally, BPSec addresses neither the fitness of externally-defined cryptographic methods nor the security of their implementation. It is the responsibility of the BPSec implementer that appropriate algorithms and methods are chosen. Furthermore, the BPSec protocol does not address threats which share computing resources with the DTN and/or BPSec software implementations. These threats may be malicious software or compromised libraries which intend to intercept data or recover cryptographic material. Here, it is the responsibility of the BPSec implementer to ensure that any cryptographic material, including shared secret or private keys, is protected against access within both memory and storage devices.

The threat model described here is assumed to have a set of capabilities identical to those described by the Internet Threat Model in [RFC3552], but the BPSec threat model is scoped to illustrate threats specific to BPSec operating within DTN environments and therefore focuses on man-in-the-middle (MITM) attackers.

8.1. Attacker Capabilities and Objectives

BPSec was designed to protect against MITM threats which may have access to a bundle during transit from its source, Alice, to its destination, Bob. A MITM node, Mallory, is a non-cooperative node operating on the DTN between Alice and Bob that has the ability to receive bundles, examine bundles, modify bundles, forward bundles, and generate bundles at will in order to compromise the confidentiality or integrity of data within the DTN. For the purposes of this section, any MITM node is assumed to effectively be security-aware even if it does not implement the BPSec protocol. There are three classes of MITM nodes which are differentiated based on their access to cryptographic material:

- Unprivileged Node: Mallory has not been provisioned within the secure environment and only has access to cryptographic material which has been publicly-shared.

- Legitimate Node: Mallory is within the secure environment and therefore has access to cryptographic material which has been provisioned to Mallory (i.e., K_M) as well as material which has been publicly-shared.

- Privileged Node: Mallory is a privileged node within the secure environment and therefore has access to cryptographic material which has been provisioned to Mallory, Alice and/or Bob (i.e.

K_M, K_A, and/or K_B) as well as material which has been publicly-shared.

If Mallory is operating as a privileged node, this is tantamount to compromise; BPSec does not provide mechanisms to detect or remove Mallory from the DTN or BPSec secure environment. It is up to the BPSec implementer or the underlying cryptographic mechanisms to provide appropriate capabilities if they are needed. It should also be noted that if the implementation of BPSec uses a single set of shared cryptographic material for all nodes, a legitimate node is equivalent to a privileged node because K_M == K_A == K_B.

A special case of the legitimate node is when Mallory is either Alice or Bob (i.e., K_M == K_A or K_M == K_B). In this case, Mallory is able to impersonate traffic as either Alice or Bob, which means that traffic to and from that node can be decrypted and encrypted, respectively. Additionally, messages may be signed as originating from one of the endpoints.

8.2. Attacker Behaviors and BPSec Mitigations

8.2.1. Eavesdropping Attacks

Once Mallory has received a bundle, she is able to examine the contents of that bundle and attempt to recover any protected data or cryptographic keying material from the blocks contained within. The protection mechanism that BPSec provides against this action is the BCB, which encrypts the contents of its security target, providing confidentiality of the data. Of course, it should be assumed that Mallory is able to attempt offline recovery of encrypted data, so the cryptographic mechanisms selected to protect the data should provide a suitable level of protection.

When evaluating the risk of eavesdropping attacks, it is important to consider the lifetime of bundles on a DTN. Depending on the network, bundles may persist for days or even years. If a bundle does persist on the network for years and the cipher suite used for a BCB provides inadequate protection, Mallory may be able to recover the protected data before that bundle reaches its intended destination.

8.2.2. Modification Attacks

As a node participating in the DTN between Alice and Bob, Mallory will also be able to modify the received bundle, including non-BPSec data such as the primary block, payload blocks, or block processing control flags as defined in [BPBIS]. Mallory will be able to undertake activities which include modification of data within the blocks, replacement of blocks, addition of blocks, or removal of

blocks. Within BPSec, both the BIB and BCB provide integrity protection mechanisms to detect or prevent data manipulation attempts by Mallory.

The BIB provides that protection to another block which is its security target. The cryptographic mechanisms used to generate the BIB should be strong against collision attacks and Mallory should not have access to the cryptographic material used by the originating node to generate the BIB (e.g., K_A). If both of these conditions are true, Mallory will be unable to modify the security target or the BIB and lead Bob to validate the security target as originating from Alice.

Since BPSec security operations are implemented by placing blocks in a bundle, there is no in-band mechanism for detecting or correcting certain cases where Mallory removes blocks from a bundle. If Mallory removes a BCB block, but keeps the security target, the security target remains encrypted and there is a possibility that there may no longer be sufficient information to decrypt the block at its destination. If Mallory removes both a BCB (or BIB) and its security target there is no evidence left in the bundle of the security operation. Similarly, if Mallory removes the BIB but not the security target there is no evidence left in the bundle of the security operation. In each of these cases, the implementation of BPSec MUST be combined with policy configuration at endpoints in the network which describe the expected and required security operations that must be applied on transmission and are expected to be present on receipt. This or other similar out-of-band information is required to correct for removal of security information in the bundle.

A limitation of the BIB may exist within the implementation of BIB validation at the destination node. If Mallory is a legitimate node within the DTN, the BIB generated by Alice with K_A can be replaced with a new BIB generated with K_M and forwarded to Bob. If Bob is only validating that the BIB was generated by a legitimate user, Bob will acknowledge the message as originating from Mallory instead of Alice. In order to provide verifiable integrity checks, both a BIB and BCB should be used. Alice creates a BIB with the protected data block as the security target and then creates a BCB with both the BIB and protected data block as its security targets. In this configuration, since Mallory is only a legitimate node and does not have access to Alice's key K_A, Mallory is unable to decrypt the BCB and replace the BIB.

8.2.3. Topology Attacks

If Mallory is in a MITM position within the DTN, she is able to influence how any bundles that come to her may pass through the network. Upon receiving and processing a bundle that must be routed elsewhere in the network, Mallory has three options as to how to proceed: not forward the bundle, forward the bundle as intended, or forward the bundle to one or more specific nodes within the network.

Attacks that involve re-routing the packets throughout the network are essentially a special case of the modification attacks described in this section where the attacker is modifying fields within the primary block of the bundle. Given that BPSec cannot encrypt the contents of the primary block, alternate methods must be used to prevent this situation. These methods MAY include requiring BIBs for primary blocks, using encapsulation, or otherwise strategically manipulating primary block data. The specifics of any such mitigation technique are specific to the implementation of the deploying network and outside of the scope of this document.

Furthermore, routing rules and policies may be useful in enforcing particular traffic flows to prevent topology attacks. While these rules and policies may utilize some features provided by BPSec, their definition is beyond the scope of this specification.

8.2.4. Message Injection

Mallory is also able to generate new bundles and transmit them into the DTN at will. These bundles may either be copies or slight modifications of previously-observed bundles (i.e., a replay attack) or entirely new bundles generated based on the Bundle Protocol, BPSec, or other bundle-related protocols. With these attacks Mallory's objectives may vary, but may be targeting either the bundle protocol or application-layer protocols conveyed by the bundle protocol.

BPSec relies on cipher suite capabilities to prevent replay or forged message attacks. A BCB used with appropriate cryptographic mechanisms (e.g., a counter-based cipher mode) may provide replay protection under certain circumstances. Alternatively, application data itself may be augmented to include mechanisms to assert data uniqueness and then protected with a BIB, a BCB, or both along with other block data. In such a case, the receiving node would be able to validate the uniqueness of the data.

9. Cipher Suite Authorship Considerations

Cipher suite developers or implementers should consider the diverse performance and conditions of networks on which the Bundle Protocol (and therefore BPSec) will operate. Specifically, the delay and capacity of delay-tolerant networks can vary substantially. Cipher suite developers should consider these conditions to better describe the conditions when those suites will operate or exhibit vulnerability, and selection of these suites for implementation should be made with consideration to the reality. There are key differences that may limit the opportunity to leverage existing cipher suites and technologies that have been developed for use in traditional, more reliable networks:

- Data Lifetime: Depending on the application environment, bundles may persist on the network for extended periods of time, perhaps even years. Cryptographic algorithms should be selected to ensure protection of data against attacks for a length of time reasonable for the application.

- One-Way Traffic: Depending on the application environment, it is possible that only a one-way connection may exist between two endpoints, or if a two-way connection does exist, the round-trip time may be extremely large. This may limit the utility of session key generation mechanisms, such as Diffie-Hellman, as a two-way handshake may not be feasible or reliable.

- Opportunistic Access: Depending on the application environment, a given endpoint may not be guaranteed to be accessible within a certain amount of time. This may make asymmetric cryptographic architectures which rely on a key distribution center or other trust center impractical under certain conditions.

When developing new cipher suites for use with BPSec, the following information SHOULD be considered for inclusion in these specifications.

- New Parameters. Cipher suites MAY define new parameter types that may appear in security blocks and used to configure the cipher suite.

- New Results. Cipher suites MAY define new security result types that may appear in security blocks and capture the outputs of the cipher suite.

- New Canonicalizations. Cipher suites MAY define new canonicalization algorithms as necessary.

10. Defining Other Security Blocks

Other security blocks (OSBs) may be defined and used in addition to the security blocks identified in this specification. Both the usage of BIB, BCB, and any future OSBs MAY co-exist within a bundle and MAY be considered in conformance with BPSec if each of the following requirements are met by any future identified security blocks.

- Other security blocks (OSBs) MUST NOT reuse any enumerations identified in this specification, to include the block type codes for BIB and BCB.

- An OSB definition MUST state whether it can be the target of a BIB or a BCB. The definition MUST also state whether the OSB can target a BIB or a BCB.

- An OSB definition MUST provide a deterministic processing order in the event that a bundle is received containing BIBs, BCBs, and OSBs. This processing order MUST NOT alter the BIB and BCB processing orders identified in this specification.

- An OSB definition MUST provide a canonicalization algorithm if the default non-primary-block canonicalization algorithm cannot be used to generate a deterministic input for a cipher suite. This requirement MAY be waived if the OSB is defined so as to never be the security target of a BIB or a BCB.

- An OSB definition MAY NOT require any behavior of a BPSEC-BPA that is in conflict with the behavior identified in this specification. In particular, the security processing requirements imposed by this specification MUST be consistent across all BPSEC-BPAs in a network.

- The behavior of an OSB when dealing with fragmentation MUST be specified and MUST NOT lead to ambiguous processing states. In particular, an OSB definition should address how to receive and process an OSB in a bundle fragment that may or may not also contain its security target. An OSB definition should also address whether an OSB may be added to a bundle marked as a fragment.

Additionally, policy considerations for the management, monitoring, and configuration associated with blocks SHOULD be included in any OSB definition.

NOTE: The burden of showing compliance with processing rules is placed upon the standards defining new security blocks and the

identification of such blocks shall not, alone, require maintenance of this specification.

11. Conformance

All implementations are strongly RECOMMENDED to provide some method of hop-by-hop verification by generating a hash to some canonical form of the bundle and placing an integrity signature on that form using a BIB.

12. IANA Considerations

Registries of Cipher Suite IDs, Cipher Suite Flags, Cipher Suite Parameter Types, and Security Result Types will be required.

12.1. Bundle Block Types

This specification allocates two block types from the existing "Bundle Block Types" registry defined in [RFC6255] .

Additional Entries for the Bundle Block-Type Codes Registry:

Value	Description	Reference
TBD	Block Integrity Block	This document
TBD	Block Confidentiality Block	This document

Table 3

13. References

13.1. Normative References

[BPBIS] Burleigh, S., Fall, K., and E. Birrane, "Bundle Protocol", draft-ietf-dtn-bpbis-06 (work in progress), July 2016.

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13.2. Informative References

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[RFC6257] Symington, S., Farrell, S., Weiss, H., and P. Lovell, "Bundle Security Protocol Specification", RFC 6257, May 2011.

[SBSP] Birrane, E., "Streamlined Bundle Security Protocol", draft-birrane-dtn-sbsp-01 (work in progress), October 2015.

Appendix A. Acknowledgements

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