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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.

The Internet Research Task Force is advised that this document is an update of the protocol described in [[RFC6257](#)], reflecting lessons learned. The Internet Research Task Force is requested to mark [[RFC6257](#)] as obsolete.

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[1.](#) Introduction

This document defines security features for the Bundle Protocol (BP) [[I-D.ietf-dtn-bpbis](#)] and is intended for use in Delay Tolerant Networks (DTNs) to provide end-to-end security services.

The Bundle Protocol specification [[I-D.ietf-dtn-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.

The BP might be deployed such that portions of the network cannot be trusted, posing the usual security challenges related to confidentiality and integrity. However, the stressed nature of the BP operating environment imposes unique conditions where usual transport security mechanisms may not be sufficient. For example, the store-carry-forward nature of the network may require protecting data at rest, preventing unauthorized consumption of critical resources such as storage space, and operating without 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.

The Internet Research Task Force is advised that this document is an update of the protocol described in [[RFC6257](#)], reflecting lessons learned. The Internet Research Task Force is requested to mark [[RFC6257](#)] as obsolete.

1.1. Supported Security Services

BPSec provides end-to-end integrity and confidentiality services for BP bundles, as defined in this section.

Integrity services ensure that changes to target data within a bundle can be discovered. Data changes may be caused by processing errors, environmental conditions, or intentional manipulation. In the context of BPSec, integrity services apply to plain-text in the bundle.

Confidentiality services ensure that target data is unintelligible to nodes in the DTN, except for authorized nodes possessing special information. This generally means producing cipher-text from plain-text and generating authentication information for that cipher-text. Confidentiality, in this context, applies to the contents of target data and does not extend to hiding the fact that confidentiality exists in the bundle.

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 detect and therefore hop-by-hop authentication is difficult or impossible to enforce.
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 is a special case of data integrity and can be achieved with the integrity mechanisms defined in this specification. Therefore, a separate authentication service is not necessary.

1.2. 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 during 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.

BPsec addresses only the security of data traveling over the DTN, not the underlying DTN itself. Furthermore, while the BPsec protocol can provide security-at-rest in a store-carry-forward network, it 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.

This specification addresses neither the fitness of externally-defined cryptographic methods nor the security of their implementation. 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. It is expected that separate documents will be standardized to define security contexts and cipher suites compatible with BPsec, to include those that should be used to assess interoperability and those fit for operational use in various network scenarios. A sample security context has been defined ([\[I-D.ietf-dtn-bpsec-interop-sc\]](#)) to support interoperability testing and serve as an exemplar for how security contexts should be defined for this specification.

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.

With the exception of the Bundle Protocol, 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.

1.3. 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 [[I-D.ietf-dtn-bpbis](#)] defines the format and processing of bundles, defines the extension block format used to represent BPsec security blocks, and defines the canonicalization algorithms used by this specification.

The Concise Binary Object Representation (CBOR) format [[RFC7049](#)] defines a data format that allows for small code size, fairly small message size, and extensibility without version negotiation. The block-specific data associated with BPsec security blocks are encoded in this data format.

The Bundle Security Protocol [[RFC6257](#)] and Streamlined Bundle Security Protocol [[I-D.birrane-dtn-sbsp](#)] documents introduced the concepts of using BP extension blocks for security services in a DTN. The BPsec is a continuation and refinement of these documents.

[1.4.](#) 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.

- o Bundle Destination - the node which receives a bundle and delivers the payload of the bundle to an application. Also, the Node ID of the Bundle Protocol Agent (BPA) receiving the bundle. The bundle destination acts as the security acceptor for every security target in every security block in every bundle it receives.
- o Bundle Source - the node which originates a bundle. Also, the Node ID of the BPA originating the bundle.
- o Cipher Suite - a set of one or more algorithms providing integrity and confidentiality services. Cipher suites may define necessary parameters but do not provide values for those parameters.
- o Forwarder - any node that transmits a bundle in the DTN. Also, the Node ID of the BPA that sent the bundle on its most recent hop.

- o Intermediate Receiver, Waypoint, or Next Hop - any node that receives a bundle from a Forwarder that is not the Bundle Destination. Also, the Node ID of the BPA at any such node.
- o 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.
- o Security Acceptor - a bundle node that processes and dispositions one or more security blocks in a bundle. Also, the Node ID of that node.
- o Security Block - a BPSec extension block in a bundle.
- o Security Context - the set of assumptions, algorithms, configurations and policies used to implement security services.
- o 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.
- o Security Service - the security features supported by this specification: either integrity or confidentiality.
- o Security Source - a bundle node that adds a security block to a bundle. Also, the Node ID of that node.
- o Security Target - the block within a bundle that receives a security service as part of a security operation.

2. Design Decisions

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 application security requirements. This section identifies those desirable properties that guide design decisions for this specification and are necessary for understanding the format and behavior of the BPSec protocol.

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.

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 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 can have multiple security blocks and these blocks can have different security sources. BPsec implementations **MUST NOT** assume that all blocks in a bundle have the same security operations and/or 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.

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 bundle source may choose to apply an integrity service to its plain-text payload. Later a waypoint node, representing a gateway to an insecure portion of the DTN, may receive the bundle and choose to apply a confidentiality service. In this case, the integrity security source is the bundle source and the confidentiality security source is the waypoint node.

2.3. Mixed Security Policy

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

Some waypoints might 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 acceptor of the service. For example, a waypoint could choose to verify an integrity service even though the waypoint is not the bundle destination and the integrity service will be needed by other nodes 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 could 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 could understand security blocks but refuse to process them unless they are the bundle destination.

2.4. User-Defined Security Contexts

A security context is the union of security algorithms (cipher suites), policies associated with the use of those algorithms, and configuration values. Different contexts may specify different algorithms, different policies, or different configuration values used in the implementation of their security services. BPSec must provide a mechanism for users to define their own security contexts.

For example, some users might prefer a SHA2 hash function for integrity whereas other users might prefer a SHA3 hash function. The security services defined in this specification must provide a mechanism for determining what cipher suite, policy, and configuration 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 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. Security-aware waypoints add or remove BIBs from bundles in accordance with their security policy. BIBs are never used to sign the cipher-text provided by a BCB.

The 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-aware nodes in the network, up to and including the bundle destination, as a matter of security policy. BCBs additionally provide authentication mechanisms for the cipher-text they generate.

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. It is important to note that any cipher-text integrity mechanism supplied by the BCB is considered part of the confidentiality service and, therefore, unique from the plain-text integrity service provided by the BIB.

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 of blocks would be lost.

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

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

- o 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.
- o 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 MAY 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 can be represented by a single security block when all of the following conditions are true.

- o The security operations apply the same security service. For example, they are all integrity operations or all confidentiality operations.
- o The security context parameters for the security operations are identical.
- o The security source for the security operations is the same. Meaning the set of operations are being added by the same node.
- o No security operations have the same security target, as that would violate the need for security operations to be unique.
- o 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.

It is RECOMMENDED that if a node processes any security operation in a security block that it process all security operations in the security block. This allows security sources to assert that the set of security operations in a security block are expected to be

processed by the same security acceptor. However, the determination of whether a node actually is a security acceptor or not is a matter of the policy of the node itself. In cases where a receiving node determines that it is the security acceptor of only a subset of the security operations in a security block, the node may choose to only process that subset of security operations.

[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 [[I-D.ietf-dtn-bpbis](#)] provides a "Block Number" field suitable for 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 [[I-D.ietf-dtn-bpbis](#)]. That is, each security block is comprised of the following elements:

- o Block Type Code
- o Block Number
- o Block Processing Control Flags
- o CRC Type and CRC Field (if present)
- o Block Data Length
- o 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 identifies the block(s) targeted by the security operation(s) represented by this security block. Each target block is represented by its unique Block Number. 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 entry and each entry MUST represent the Block Number of a block that exists in the bundle. There MUST NOT be duplicate entries in this array.

Security Context Id:

This field identifies the security context 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.

Security Context Flags:

This field identifies which optional fields are present in the security block. This field SHALL be represented as a CBOR unsigned integer whose contents shall be interpreted as a bit field. Each bit in this bit field indicates the presence (bit set to 1) or absence (bit set to 0) of optional data in the security block. The association of bits to security block data is defined as follows.

Bit 1 (the least-significant bit, 0x01): Security Context Parameters Present Flag.

Bit 2 (0x02): Security Source Present Flag.

Bit >2 Reserved

Implementations MUST set reserved bits to 0 when writing this field and MUST ignore the values of reserved bits when reading this field. For unreserved bits, 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):

This field identifies the Endpoint that inserted the security block in the bundle. If the security source field is not present then the source MUST be inferred from other information, such as the bundle source, previous hop, or other

values defined by security policy. This field SHALL be represented by a CBOR array in accordance with [\[I-D.ietf-dtn-bpbis\]](#) rules for representing Endpoint Identifiers (EIDs).

Security Context Parameters (Optional):

This field captures one or more security context 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 security context parameter. A single parameter SHALL also be represented as a CBOR array comprising a 2-tuple of the id and value of the parameter, as follows.

- * Parameter Id. This field identifies which parameter is being specified. This field SHALL be represented as a CBOR unsigned integer. Parameter Ids are selected as described in [Section 3.10](#).
- * Parameter Value. This field captures the value associated with this parameter. This field SHALL be represented by the applicable CBOR representation of the parameter, in accordance with [Section 3.10](#).

The logical layout of the parameters array is illustrated in Figure 1.

Figure 1: Security Context Parameters

Security Results:

This field captures the results of applying a security service to the security targets of the security block. This field SHALL be represented as a CBOR array of target results. Each entry in this array represents the set of security results for a specific security target. The target results MUST be ordered identically to the Security Targets field of the security block. This means that the first set of target results in this array corresponds to the first entry in the Security Targets field of the security block, and so on. There MUST be one entry in this array for each entry in the Security Targets field of the security block.

The set of security results for a target is also represented as a CBOR array of individual results. An individual result is represented as a 2-tuple of a result id and a result value, defined as follows.

- * Result Id. This field identifies which security result is being specified. Some security results capture the primary output of a cipher suite. Other security results contain additional annotative information from cipher suite processing. This field SHALL be represented as a CBOR unsigned integer. Security result Ids will be as specified in [Section 3.10](#).
- * Result Value. This field captures the value associated with the result. This field SHALL be represented by the applicable CBOR representation of the result value, in accordance with [Section 3.10](#).

The logical layout of the security results array is illustrated in Figure 2. In this figure there are N security targets for this security block. The first security target contains M results and the Nth security target contains K results.

Figure 2: Security Results

[3.7](#). Block Integrity Block

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

- o The Block Type Code value is as specified in [Section 11.1](#).
- o The Block Type Specific Data Fields follow the structure of the ASB.
- o 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).
- o The Security Context Id MUST utilize an end-to-end authentication cipher or an end-to-end error detection cipher.
- o The EID of 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 be specified as part of security context information described in [Section 3.10](#).

Notes:

- o It is RECOMMENDED that 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.

- o 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 security context.
- o For some security contexts, (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 bundle destination that has access to the required keying information, in accordance with [Section 3.9](#).

[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 11.1](#).

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 can reference the payload block, a non-security extension block, or a BIB. A BCB MUST NOT include another BCB as a security target. A BCB MUST NOT target the primary block.

The Security Context Id MUST utilize a confidentiality cipher that provides authenticated encryption with associated data (AEAD).

Additional information created by a cipher suite (such as additional authenticated data) can be placed either in a security result field or in the generated cipher-text. The determination of where to place these data is a function of the cipher suite and security context used.

The EID of 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 be specified as part of security context 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 field contains cipher-text, not plain-text. Other block fields remain unmodified, with the exception of the Block Data Length field, which **MUST** be updated to reflect the new length of the Block Type Specific Data field.

Notes:

- o It is **RECOMMENDED** that 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.
- o The BCB block processing control flags can 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.

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 a security target of a BCB is also a security target of a BIB, an undesirable condition occurs where a security aware waypoint would be unable to validate the BIB because one of its security target's contents have been encrypted by a BCB. To address this situation the following processing rules **MUST** be followed.

- o When adding a BCB to a bundle, if some (or all) of the security targets of the BCB also match all of the security targets of an existing BIB, then the existing BIB **MUST** also be encrypted. This can be accomplished by either adding a new BCB that targets the existing BIB, or by adding the BIB to the list of security targets for the BCB. Deciding which way to represent this situation is a matter of security policy.
- o When adding a BCB to a bundle, if some (or all) of the security targets of the BCB match some (but not all) of the security targets of a BIB then that BIB **MUST** be altered in the following way. Any security results in the BIB associated with the BCB security targets **MUST** be removed from the BIB and placed in a new BIB. This newly created BIB **MUST** then be encrypted. The encryption of the new BIB can be accomplished by either adding a new BCB that targets the new BIB, or by adding the new BIB to the

list of security targets for the BCB. Deciding which way to represent this situation is a matter of security policy.

- o A BIB MUST NOT be added for a security target that is already the security target of a BCB. In this instance, the BCB is already providing authentication and integrity of the security target and the BIB would be redundant, insecure, and cause ambiguity in block processing order.
- o A BIB integrity value MUST NOT be evaluated if the BIB is the security target of an existing BCB. In this case, the BIB data is encrypted.
- o A BIB integrity value MUST NOT be evaluated if the security target of the BIB is also the security target of a BCB. In such a case, the security target data contains cipher-text as it has been encrypted.
- o As mentioned in [Section 3.7](#), a BIB MUST NOT have a BCB as its security target.

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.

Since any cipher suite used with a BCB MUST be an AEAD cipher suite, it is inefficient and insecure for a single security source to add both a BIB and a BCB for the same security target. In cases where a security source wishes to calculate both a plain-text integrity mechanism and encrypt a security target, a BCB with a security context that generates such signatures as additional security results MUST be used instead.

[3.10](#). Parameter and Result Identification

Each security context MUST define its own context parameters and results. Each defined parameter and result is represented as the tuple of an identifier and a value. Identifiers are always represented as a CBOR unsigned integer. The CBOR encoding of values is as defined by the security context specification.

Identifiers MUST be unique for a given security context but do not need to be unique amongst all security contexts.

3.11. BSP Block Examples

This section provides two examples of BPSec blocks applied to a bundle. In the first example, a single node adds several security operations to a bundle. In the second example, a waypoint node received the bundle created in the first example and adds additional security operations. In both examples, 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.

3.11.1. Example 1: Constructing a Bundle with Security

In this example a bundle has four non-security-related blocks: the primary block (B1), two extension blocks (B4,B5), and a payload block (B6). The bundle source wishes to provide an integrity signature of the plain-text associated with the primary block, the second extension block, and the payload. The bundle source also wishes to provide confidentiality for the first extension block. The resultant bundle is illustrated in Figure 3 and the security actions are described below.

Figure 3: Security at Bundle Creation

The following security actions were applied to this bundle at its time of creation.

- o An integrity signature applied to the canonicalized primary block (B1), the second extension block (B5) and the payload block (B6). This is accomplished by a single BIB (B2) with multiple targets. A single BIB is used in this case because all three targets share a security source, security context, and security context parameters. Had this not been the case, multiple BIBs could have been added instead.
- o Confidentiality for the first extension block (B4). This is accomplished by a BCB (B3). Once applied, the contents of extension block B4 are encrypted. The BCB MUST hold an authentication signature for the cipher-text either in the cipher-text that now populates the first extension block or as a security result in the BCB itself, depending on which security context is used to form the BCB. A plain-text integrity signature may also exist as a security result in the BCB if one is provided by the selected confidentiality security context.

3.11.2. Example 2: Adding More Security At A New Node

Consider that the bundle as it is illustrated in Figure 3 is now received by a waypoint node that wishes to encrypt the second extension block and the bundle payload. The waypoint security policy is to allow existing BIBs for these blocks to persist, as they may be required as part of the security policy at the bundle destination.

The resultant bundle is illustrated in Figure 4 and the security actions are described below. Note that block IDs provided here are ordered solely for the purpose of this example and not meant to impose an ordering for block creation. The ordering of blocks added to a bundle MUST always be in compliance with [[I-D.ietf-dtn-bpbis](#)].

Figure 4: Security At Bundle Forwarding

The following security actions were applied to this bundle prior to its forwarding from the waypoint node.

- o Since the waypoint node wishes to encrypt blocks B5 and B6, it MUST also encrypt the BIBs providing plain-text integrity over those blocks. However, BIB B2 could not be encrypted in its entirety because it also held a signature for the primary block (B1). Therefore, a new BIB (B7) is created and security results associated with B5 and B6 are moved out of BIB B2 and into BIB B7.
- o Now that there is no longer confusion of which plain-text integrity signatures must be encrypted, a BCB is added to the bundle with the security targets being the second extension block (B5) and the payload (B6) as well as the newly created BIB holding their plain-text integrity signatures (B7). A single new BCB is used in this case because all three targets share a security source, security context, and security context parameters. Had this not been the case, multiple BCBs could have been added instead.

4. Canonical Forms

Security services require consistency and determinism in how information is presented to cipher suites at the security source and at a receiving node. For example, integrity services require that the same target information (e.g., the same bits in the same order) is provided to the cipher suite when generating an original signature and when generating a comparison signature. Canonicalization algorithms are used to construct a stable, end-to-end bit representation of a target block.

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

The canonicalization of the primary block is as specified in [[I-D.ietf-dtn-bpbis](#)].

All non-primary blocks share the same block structure and are canonicalized as specified in [[I-D.ietf-dtn-bpbis](#)] with the following exceptions.

- o 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 solely to convert the Block Type Specific Data Fields from plain-text to cipher-text.
- o 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 and security contexts 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, those algorithms take precedence over this specification.

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.

- o When BIBs and BCBs share a security target, BCBs MUST be evaluated first and BIBs second.

5.1.1. Receiving BCBs

If a received bundle contains a BCB, the receiving node MUST determine whether it is the security acceptor for any of the security operations in the BCB. If so, the node MUST process those operations

and remove any operation-specific information from the BCB prior to delivering data to an application at the node or forwarding the bundle. If processing a security operation fails, the target SHALL be processed according to the security policy. A bundle status report indicating the failure MAY be generated. When all security operations for a BCB have been removed from the BCB, the BCB MUST be removed from 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 MUST process 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 MUST be discarded.

If an encrypted payload block cannot be decrypted (i.e., the cipher-text cannot be authenticated), 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 [[I-D.ietf-dtn-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 operations, each operation processed by the node MUST be treated as if the security operation has been represented by a single BCB with a single security operation for the purposes of report generation and policy processing.

5.1.2. Receiving BIBs

If a received bundle contains a BIB, the receiving node MUST determine whether it is the security acceptor for any of the security operations in the BIB. If so, the node MUST process those operations and remove any operation-specific information from the BIB prior to delivering data to an application at the node or forwarding the bundle. If processing a security operation fails, the target SHALL

be processed according to the security policy. A bundle status report indicating the failure MAY be generated. When all security operations for a BIB have been removed from the BIB, the BIB MUST be removed from the bundle.

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 can occur at any node that has the ability to verify an integrity signature, not just the bundle destination.

If a receiving node is not the security acceptor of a security operation in a BIB it MAY attempt to verify the security operation anyway to prevent forwarding corrupt data. If the verification 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 bundle destination. If the check passes, the node MUST NOT remove the security operation from the BIB prior to forwarding.

If a BIB contains multiple security operations, each operation processed by the node MUST be treated as if the security operation has been represented by a single BIB with a single security operation for the purposes of report generation and policy processing.

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 [[I-D.ietf-dtn-bpbis](#)] MUST be followed. As defined there and summarized here for completeness, only the payload block can 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 management 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.

- o 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.
- o 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.
- o 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.

- o 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.
- o It is recommended that BCBs be allowed to alter the size of extension blocks and the payload block. However, care must be taken to ensure that changing the size of the payload block while the bundle is in transit do not negatively affect bundle processing (e.g., calculating storage needs, scheduling transmission times, caching block byte offsets).
- o 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, a plain-text 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.
- o It is recommended that security policy address whether cipher suites whose cipher-text is larger (or smaller) than the initial plain-text are permitted and, if so, for what types of blocks. Changing the size of a block may cause processing difficulties for networks that calculate block offsets into bundles or predict transmission times or storage availability as a function of bundle size. In other cases, changing the size of a payload as part of encryption has no significant impact.

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.

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. In doing so, it is assumed that the DTN (or significant portions of the DTN) are completely under the control of an attacker.

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:

- o Unprivileged Node: Mallory has not been provisioned within the secure environment and only has access to cryptographic material which has been publicly-shared.
- o 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.
- o 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. Long-lived bundles imply that the data exists in the network for a longer period of time and, thus, there may be more opportunities to capture those bundles. Additionally, bundles that are long-lived imply that the information stored within them may remain relevant and sensitive for long enough that, once captured, there is sufficient time to crack encryption associated with the bundle. 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 either before that bundle reaches its intended destination or before the information in the bundle is no longer considered sensitive.

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 [[I-D.ietf-dtn-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, 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 and the BCB should require an IND-CCA2 encryption scheme. Such an encryption scheme will guard against signature substitution attempts by Mallory. In this case, 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.

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. Security Context Considerations

9.1. Identification and Configuration

Security blocks must uniquely define the security context for their services. This context **MUST** be uniquely identifiable and **MAY** use parameters for customization. Where policy and configuration decisions can be captured as parameters, the security context

identifier may identify a cipher suite. In cases where the same cipher suites are used with differing predetermined configurations and policies, users can define multiple security contexts that use the same cipher suite.

Network operators must determine the number, type, and configuration of security contexts in a system. Networks with rapidly changing configurations may define relatively few security contexts with each context customized with multiple parameters. For networks with more stability, or an increased need for confidentiality, a larger number of contexts can be defined with each context supporting few, if any, parameters.

Security Context Examples

Context Id	Parameters	Definition
1	Key, IV	AES-GCM-256 cipher suite with provided ephemeral key and initialization vector.
2	IV	AES-GCM-256 cipher suite with predetermined key and predetermined key rotation policy.
3	Nil	AES-GCM-256 cipher suite with all info predetermined.

Table 1

9.2. Authorship

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. Developers should consider these conditions to better describe the conditions when those contexts will operate or exhibit vulnerability, and selection of these contexts for implementation should be made with consideration for this reality. There are key differences that may limit the opportunity for a security context to leverage existing cipher suites and technologies that have been developed for use in traditional, more reliable networks:

- o 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.

- o 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.
- o 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 security contexts for use with BPSec, the following information SHOULD be considered for inclusion in these specifications.

- o Security Context Parameters. Security contexts MUST define their parameter Ids, the data types of those parameters, and their CBOR encoding.
- o Security Results. Security contexts MUST define their security result Ids, the data types of those results, and their CBOR encoding.
- o New Canonicalizations. Security contexts may define new canonicalization algorithms as necessary.
- o Cipher-Text Size. Security contexts MUST state whether their associated cipher suites generate cipher-text (to include any authentication information) that is of a different size than the input plain-text.

If a security context does not wish to alter the size of the plain-text, it should consider defining the following policy.

- * Place overflow bytes, authentication signatures, and any additional authenticated data in security result fields rather than in the cipher-text itself.
- * Pad the cipher-text in cases where the cipher-text is smaller than the plain-text.

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 can co-exist within a bundle and can be considered in conformance with BPsec if each of the following requirements are met by any future identified security blocks.

- o Other security blocks (OSBs) MUST NOT reuse any enumerations identified in this specification, to include the block type codes for BIB and BCB.
- o 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.
- o 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.
- o 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 can be waived if the OSB is defined so as to never be the security target of a BIB or a BCB.
- o An OSB definition MUST 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.
- o 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. IANA Considerations

This specification includes fields requiring registries managed by IANA.

11.1. Bundle Block Types

This specification allocates two block types from the existing "Bundle Block Types" registry defined in [[I-D.ietf-dtn-bpbis](#)].

Additional Entries for the Bundle Block-Type Codes Registry:

Value	Description	Reference
11	Block Integrity Block	This document
12	Block Confidentiality Block	This document

Table 2

The Bundle Block Types namespace notes whether a block type is meant for use in BP version 6, BP version 7, or both. The two block types defined in this specification are meant for use with BP version 7.

11.2. Security Context Identifiers

BPsec has a Security Context Identifier field for which IANA is requested to create and maintain a new registry named "BPsec Security Context Identifiers". Initial values for this registry are given below.

The registration policy for this registry is: Specification Required.

The value range is: unsigned 16-bit integer.

BPsec Security Context Identifier Registry

Value	Description	Reference
0	Reserved	This document

Table 3

12. References

12.1. Normative References

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[Appendix A](#). Acknowledgements

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