

**COSE: A Message Based Security Solution for CBOR**  
**draft-ietf-cose-msg-13**

Abstract

Concise Binary Object Representation (CBOR) is data format designed for small code size and small message size. There is a need for the ability to have the basic security services defined for this data format. This document defines the CBOR Object Signing and Encryption (COSE) specification. This specification describes how to create and process signature, message authentication codes and encryption using CBOR for serialization. This specification additionally specifies how to representat cryptographic keys using CBOR.

Contributing to this document

The source for this draft is being maintained in GitHub. Suggested changes should be submitted as pull requests at <<https://github.com/cose-wg/cose-spec>>. Instructions are on that page as well. Editorial changes can be managed in GitHub, but any substantial issues need to be discussed on the COSE mailing list.

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## Table of Contents

<a href="#">1.</a>	<a href="#">Introduction</a>	<a href="#">4</a>
<a href="#">1.1.</a>	<a href="#">Design changes from JOSE</a>	<a href="#">5</a>
<a href="#">1.2.</a>	<a href="#">Requirements Terminology</a>	<a href="#">6</a>
<a href="#">1.3.</a>	<a href="#">CBOR Grammar</a>	<a href="#">6</a>
<a href="#">1.4.</a>	<a href="#">CBOR Related Terminology</a>	<a href="#">7</a>
<a href="#">1.5.</a>	<a href="#">Document Terminology</a>	<a href="#">7</a>
<a href="#">2.</a>	<a href="#">Basic COSE Structure</a>	<a href="#">8</a>
<a href="#">3.</a>	<a href="#">Header Parameters</a>	<a href="#">10</a>
<a href="#">3.1.</a>	<a href="#">Common COSE Headers Parameters</a>	<a href="#">11</a>
<a href="#">4.</a>	<a href="#">Signing Objects</a>	<a href="#">15</a>
<a href="#">4.1.</a>	<a href="#">Signing with One or More Signers</a>	<a href="#">15</a>
<a href="#">4.2.</a>	<a href="#">Signing with One Signer</a>	<a href="#">17</a>
<a href="#">4.3.</a>	<a href="#">Externally Supplied Data</a>	<a href="#">18</a>
<a href="#">4.4.</a>	<a href="#">Signing and Verification Process</a>	<a href="#">19</a>
<a href="#">4.5.</a>	<a href="#">Computing Counter Signatures</a>	<a href="#">20</a>
<a href="#">5.</a>	<a href="#">Encryption Objects</a>	<a href="#">21</a>
<a href="#">5.1.</a>	<a href="#">Enveloped COSE Structure</a>	<a href="#">21</a>
<a href="#">5.1.1.</a>	<a href="#">Recipient Algorithm Classes</a>	<a href="#">23</a>
<a href="#">5.2.</a>	<a href="#">Single Recipient Encrypted</a>	<a href="#">24</a>
<a href="#">5.3.</a>	<a href="#">Encryption Algorithm for AEAD algorithms</a>	<a href="#">24</a>
<a href="#">5.4.</a>	<a href="#">Encryption algorithm for AE algorithms</a>	<a href="#">26</a>
<a href="#">6.</a>	<a href="#">MAC Objects</a>	<a href="#">28</a>
<a href="#">6.1.</a>	<a href="#">MACed Message with Recipients</a>	<a href="#">28</a>
<a href="#">6.2.</a>	<a href="#">MACed Messages with Implicit Key</a>	<a href="#">29</a>
<a href="#">6.3.</a>	<a href="#">How to compute and verify a MAC</a>	<a href="#">30</a>
<a href="#">7.</a>	<a href="#">Key Structure</a>	<a href="#">31</a>
<a href="#">7.1.</a>	<a href="#">COSE Key Common Parameters</a>	<a href="#">32</a>
<a href="#">8.</a>	<a href="#">Signature Algorithms</a>	<a href="#">35</a>
<a href="#">8.1.</a>	<a href="#">ECDSA</a>	<a href="#">36</a>
<a href="#">8.1.1.</a>	<a href="#">Security Considerations</a>	<a href="#">37</a>
<a href="#">8.2.</a>	<a href="#">Edwards-curve Digital Signature Algorithms (EdDSA)</a>	<a href="#">38</a>

Schaad

Expires December 19, 2016

[Page 2]

8.2.1.	Security Considerations . . . . .	39
9.	Message Authentication (MAC) Algorithms . . . . .	39
9.1.	Hash-based Message Authentication Codes (HMAC) . . . . .	40
9.1.1.	Security Considerations . . . . .	41
9.2.	AES Message Authentication Code (AES-CBC-MAC) . . . . .	41
9.2.1.	Security Considerations . . . . .	42
10.	Content Encryption Algorithms . . . . .	43
10.1.	AES GCM . . . . .	43
10.1.1.	Security Considerations . . . . .	44
10.2.	AES CCM . . . . .	45
10.2.1.	Security Considerations . . . . .	48
10.3.	ChaCha20 and Poly1305 . . . . .	48
10.3.1.	Security Considerations . . . . .	49
11.	Key Derivation Functions (KDF) . . . . .	49
11.1.	HMAC-based Extract-and-Expand Key Derivation Function (HKDF) . . . . .	50
11.2.	Context Information Structure . . . . .	52
12.	Recipient Algorithm Classes . . . . .	55
12.1.	Direct Encryption . . . . .	56
12.1.1.	Direct Key . . . . .	56
12.1.2.	Direct Key with KDF . . . . .	57
12.2.	Key Wrapping . . . . .	58
12.2.1.	AES Key Wrapping . . . . .	59
12.3.	Key Encryption . . . . .	60
12.4.	Direct Key Agreement . . . . .	60
12.4.1.	ECDH . . . . .	61
12.4.2.	Security Considerations . . . . .	64
12.5.	Key Agreement with KDF . . . . .	65
12.5.1.	ECDH . . . . .	65
13.	Keys . . . . .	67
13.1.	Elliptic Curve Keys . . . . .	67
13.1.1.	Double Coordinate Curves . . . . .	68
13.2.	Octet Key Pair . . . . .	69
13.3.	Symmetric Keys . . . . .	70
14.	CBOR Encoder Restrictions . . . . .	71
15.	Application Profiling Considerations . . . . .	71
16.	IANA Considerations . . . . .	73
16.1.	CBOR Tag assignment . . . . .	73
16.2.	COSE Header Parameters Registry . . . . .	73
16.3.	COSE Header Algorithm Labels Registry . . . . .	74
16.4.	COSE Algorithms Registry . . . . .	74
16.5.	COSE Key Common Parameters Registry . . . . .	75
16.6.	COSE Key Type Parameters Registry . . . . .	76
16.7.	COSE Elliptic Curve Parameters Registry . . . . .	77
16.8.	Media Type Registrations . . . . .	77
16.8.1.	COSE Security Message . . . . .	77
16.8.2.	COSE Key media type . . . . .	78
16.9.	CoAP Content Format Registrations . . . . .	80

Schaad

Expires December 19, 2016

[Page 3]

<a href="#">16.10. Expert Review Instructions</a>	<a href="#">81</a>
<a href="#">17. Implementation Status</a>	<a href="#">82</a>
<a href="#">17.1. Author's Versions</a>	<a href="#">83</a>
<a href="#">17.2. COSE Testing Library</a>	<a href="#">83</a>
<a href="#">18. Security Considerations</a>	<a href="#">84</a>
<a href="#">19. References</a>	<a href="#">86</a>
<a href="#">19.1. Normative References</a>	<a href="#">86</a>
<a href="#">19.2. Informative References</a>	<a href="#">87</a>
<a href="#">Appendix A. Making Mandatory Algorithm Header Optional</a>	<a href="#">89</a>
<a href="#">A.1. Algorithm Identification</a>	<a href="#">90</a>
<a href="#">A.2. Counter Signature Without Headers</a>	<a href="#">93</a>
<a href="#">Appendix B. Two Layers of Recipient Information</a>	<a href="#">93</a>
<a href="#">Appendix C. Examples</a>	<a href="#">95</a>
<a href="#">C.1. Examples of Signed Message</a>	<a href="#">96</a>
<a href="#">C.1.1. Single Signature</a>	<a href="#">96</a>
<a href="#">C.1.2. Multiple Signers</a>	<a href="#">97</a>
<a href="#">C.1.3. Counter Signature</a>	<a href="#">98</a>
<a href="#">C.1.4. Signature w/ Criticality</a>	<a href="#">99</a>
<a href="#">C.2. Single Signer Examples</a>	<a href="#">100</a>
<a href="#">C.2.1. Single ECDSA signature</a>	<a href="#">100</a>
<a href="#">C.3. Examples of Enveloped Messages</a>	<a href="#">101</a>
<a href="#">C.3.1. Direct ECDH</a>	<a href="#">101</a>
<a href="#">C.3.2. Direct plus Key Derivation</a>	<a href="#">102</a>
<a href="#">C.3.3. Counter Signature on Encrypted Content</a>	<a href="#">103</a>
<a href="#">C.3.4. Encrypted Content with External Data</a>	<a href="#">105</a>
<a href="#">C.4. Examples of Encrypted Messages</a>	<a href="#">105</a>
<a href="#">C.4.1. Simple Encrypted Message</a>	<a href="#">105</a>
<a href="#">C.4.2. Encrypted Message w/ a Partial IV</a>	<a href="#">106</a>
<a href="#">C.5. Examples of MACed messages</a>	<a href="#">106</a>
<a href="#">C.5.1. Shared Secret Direct MAC</a>	<a href="#">106</a>
<a href="#">C.5.2. ECDH Direct MAC</a>	<a href="#">107</a>
<a href="#">C.5.3. Wrapped MAC</a>	<a href="#">108</a>
<a href="#">C.5.4. Multi-recipient MACed message</a>	<a href="#">109</a>
<a href="#">C.6. Examples of MAC0 messages</a>	<a href="#">110</a>
<a href="#">C.6.1. Shared Secret Direct MAC</a>	<a href="#">110</a>
<a href="#">C.7. COSE Keys</a>	<a href="#">111</a>
<a href="#">C.7.1. Public Keys</a>	<a href="#">111</a>
<a href="#">C.7.2. Private Keys</a>	<a href="#">112</a>
<a href="#">Acknowledgments</a>	<a href="#">114</a>
<a href="#">Author's Address</a>	<a href="#">115</a>

## **1. Introduction**

There has been an increased focus on the small, constrained devices that make up the Internet of Things (IoT). One of the standards that has come out of this process is the Concise Binary Object Representation (CBOR) [[RFC7049](#)]. CBOR extended the data model of the JavaScript Object Notation (JSON) [[RFC7159](#)] by allowing for binary

Schaad

Expires December 19, 2016

[Page 4]

data, among other changes. CBOR is being adopted by several of the IETF working groups dealing with the IoT world as their encoding of data structures. CBOR was designed specifically to be both small in terms of messages transport and implementation size, as well having a schema free decoder. A need exists to provide message security services for IoT and using CBOR as the message encoding format makes sense.

The JOSE working group produced a set of documents [[RFC7515](#)][RFC7516][[RFC7517](#)][RFC7518] using JSON that specified how to process encryption, signatures and message authentication (MAC) operations, and how to encode keys using JSON. This document defines the CBOR Object Encryption and Signing (COSE) standard which does the same thing for the CBOR encoding format. While there is a strong attempt to keep the flavor of the original JOSE documents, two considerations are taken into account:

- o CBOR has capabilities that are not present in JSON and are appropriate to use. One example of this is the fact that CBOR has a method of encoding binary directly without first converting it into a base64 encoded string.
- o COSE is not a direct copy of the JOSE specification. In the process of creating COSE, decisions that were made for JOSE were re-examined. In many cases different results were decided on as the criteria was not always the same.

### **1.1. Design changes from JOSE**

- o Define a single top message structure so that encrypted, signed and MACed messages can easily identified and still have a consistent view.
- o Signed messages separate the concept of protected and unprotected parameters that are for the content and the signature.
- o MACed messages are separated from signed messages.
- o MACed messages have the ability to use the same set of recipient algorithms as enveloped messages for obtaining the MAC authentication key.
- o Use binary encodings for binary data rather than base64url encodings.
- o Combine the authentication tag for encryption algorithms with the cipher text.





- o The set of cryptographic algorithms has been expanded in some directions, and trimmed in others.

## **1.2. Requirements 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 [\[RFC2119\]](#).

When the words appear in lower case, their natural language meaning is used.

## **1.3. CBOR Grammar**

There currently is no standard CBOR grammar available for use by specifications. We therefore describe the CBOR structures in prose.

The document was developed by first working on the grammar and then developing the prose to go with it. An artifact of this is that the prose was written using the primitive type strings defined by CBOR Data Definition Language (CDDL) [\[I-D.greevenbosch-appsawg-cbor-cddl\]](#). In this specification, the following primitive types are used:

any - non-specific value that permits all CBOR values to be placed here.

bool - a boolean value (true: major type 7, value 21; false: major type 7, value 20).

bstr - byte string (major type 2).

int - an unsigned integer or a negative integer.

nil - a null value (major type 7, value 22).

nint - a negative integer (major type 1).

tstr - a UTF-8 text string (major type 3).

uint - an unsigned integer (major type 0).

As well as the prose description, a version of a CBOR grammar is presented in CDDL. Since CDDL has not been published as an RFC, this grammar may not work with the final version of CDDL. The CDDL grammar is informational, the prose description is normative.



The collected CDDL can be extracted from the XML version of this document via the following XPath expression below. (Depending on the XPath evaluator one is using, it may be necessary to deal with &gt; as an entity.)

```
//artwork[@type='CDDL']/text()
```

CDDL expects the initial non-terminal symbol to be the first symbol in the file. For this, reason the first fragment of CDDL is presented here.

```
start = COSE_Messages / COSE_Key / COSE_KeySet / Internal_Types
```

```
; This is defined to make the tool quieter:
```

```
Internal_Types = Sig_structure / Enc_structure / MAC_structure /  
                COSE_KDF_Context
```

The non-terminal Internal\_Types is defined for dealing with the automated validation tools used during the writing of this document. It references those non-terminals that are used for security computations, but are not emitted for transport.

#### **1.4. CBOR Related Terminology**

In JSON, maps are called objects and only have one kind of map key: a string. In COSE, we use strings, negative integers and unsigned integers as map keys. The integers are used for compactness of encoding and easy comparison. Since the word "key" is mainly used in its other meaning, as a cryptographic key, we use the term "label" for this usage as a map key.

The presence of a label in a COSE map which is not a string or an integer is an error. Applications can either fail processing or process messages with incorrect labels, however they MUST NOT create messages with incorrect labels.

A CDDL grammar fragment is defined that defines the non-terminals 'label', as in the previous paragraph and 'values', which permits any value to be used.

```
label = int / tstr  
values = any
```

#### **1.5. Document Terminology**

In this document, we use the following terminology:

Byte is a synonym for octet.



Constrained Application Protocol (CoAP) is a specialized web transfer protocol for use in constrained systems. It is defined in [[RFC7252](#)].

Authenticated Encryption (AE) algorithms are those encryption algorithms which provide an authentication check of the contents algorithm with the encryption service.

Authenticated Encryption with Authenticated Data (AEAD) algorithms provide the same content authentication service as AE algorithms, but additionally provide for authentication of non-encrypted data as well.

## **2. Basic COSE Structure**

The COSE object structure is designed so that there can be a large amount of common code when parsing and processing the different security messages. All of the message structures are built on the CBOR array type. The first three elements of the array always contain the same information:

1. The set of protected header parameters wrapped in a bstr.
2. The set of unprotected header parameters as a map.
3. The content of the message. The content is either the plain text or the cipher text as appropriate. The content may be detached, but the location is still used. The content is wrapped in a bstr when present and is a nil value when detached.

Elements after this point are dependent on the specific message type.

Identification of which type of message has been presented is done by the following method:

1. The specific message type is known from the context. This may be defined by a marker in the containing structure or by restrictions specified by the application protocol.
2. The message type is identified by a CBOR tag. Messages with a CBOR tag are known in this specification as tagged messages, while those without the CBOR tag are known as untagged messages. This document defines a CBOR tag for each of the message structures. These tags can be found in Table 1.
3. When a COSE object is carried in a media type of application/cose, the optional parameter 'cose-type' can be used to identify the embedded object. The parameter is OPTIONAL if the tagged version of the structure is used. The parameter is REQUIRED if



the untagged version of the structure is used. The value to use with the parameter for each of the structures can be found in Table 1.

4. When a COSE object is carried as a CoAP payload, the CoAP Content-Format Option can be used to identify the message content. The CoAP Content-Format values can be found in Table 26. The CBOR tag for the message structure is not required as each security message is uniquely identified.

CBOR Tag	cose-type	Data Item	Semantics
TBD1	cose-sign	COSE_Sign	COSE Signed Data Object
TBD7	cose-sign1	COSE_Sign1	COSE Single Signer Data Object
TBD2	cose-encrypt	COSE_Encrypt	COSE Encrypted Data Object
TBD3	cose-encrypt1	COSE_Encrypt0	COSE Single Recipient Encrypted Data Object
TBD4	cose-mac	COSE_Mac	COSE Mac-ed Data Object
TBD6	cose-mac0	COSE_Mac0	COSE Mac w/o Recipients Object

Table 1: COSE Message Identification

The following CDDL fragment identifies all of the top messages defined in this document. Separate non-terminals are defined for the tagged and the untagged versions of the messages.

COSE\_Messages = COSE\_Untagged\_Message / COSE\_Tagged\_Message

COSE\_Untagged\_Message = COSE\_Sign / COSE\_Sign1 /  
COSE\_Encrypt / COSE\_Encrypt0 /  
COSE\_Mac / COSE\_Mac0

COSE\_Tagged\_Message = COSE\_Sign\_Tagged / COSE\_Sign1\_Tagged /  
COSE\_Encrypt\_Tagged / COSE\_Encrypt0\_Tagged /  
COSE\_Mac\_Tagged / COSE\_Mac0\_Tagged





### 3. Header Parameters

The structure of COSE has been designed to have two buckets of information that are not considered to be part of the payload itself, but are used for holding information about content, algorithms, keys, or evaluation hints for the processing of the layer. These two buckets are available for use in all of the structures except for keys. While these buckets are present, they may not all be usable in all instances. For example, while the protected bucket is defined as part of the recipient structure, some of the algorithms used for recipient structures do not provide for authenticated data. If this is the case, the protected bucket is left empty.

Both buckets are implemented as CBOR maps. The map key is a 'label' ([Section 1.4](#)). The value portion is dependent on the definition for the label. Both maps use the same set of label/value pairs. The integer and string values for labels has been divided into several sections with a standard range, a private range, and a range that is dependent on the algorithm selected. The defined labels can be found in the "COSE Header Parameters" IANA registry ([Section 16.2](#)).

Two buckets are provided for each layer:

**protected:** Contains parameters about the current layer that are to be cryptographically protected. This bucket **MUST** be empty if it is not going to be included in a cryptographic computation. This bucket is encoded in the message as a binary object. This value is obtained by CBOR encoding the protected map and wrapping it in a bstr object. Senders **SHOULD** encode an empty protected map as a zero length binary object (i.e., the byte string h'a0'). This encoding is used because it is both shorter and the version used in the serialization structures for cryptographic computation. Recipients **MUST** accept both a zero length binary value and a zero length map encoded in the binary value. The wrapping allows for the encoding of the protected map to be transported with a greater chance that it will not be altered in transit. (Badly behaved intermediates could decode and re-encode, but this will result in a failure to verify unless the re-encoded byte string is identical to the decoded byte string.) This avoids the problem of all parties needing to be able to do a common canonical encoding.

**unprotected:** Contains parameters about the current layer that are not cryptographically protected.

Only parameters that deal with the current layer are to be placed at that layer. As an example of this, the parameter 'content type' describes the content of the message being carried in the message. As such, this parameter is placed only in the content layer and is



not placed in the recipient or signature layers. In principle, one should be able to process any given layer without reference to any other layer. (With the exception of the COSE\_Sign structure, the only data that needs to cross layers is the cryptographic key.)

The buckets are present in all of the security objects defined in this document. The fields in order are the 'protected' bucket (as a CBOR 'bstr' type) and then the 'unprotected' bucket (as a CBOR 'map' type). The presence of both buckets is required. The parameters that go into the buckets come from the IANA "COSE Header Parameters" registry ([Section 16.2](#)). Some common parameters are defined in the next section, but a number of parameters are defined throughout this document.

Labels in each of the maps MUST be unique. When processing messages, if a label appears multiple times, the message MUST be rejected as malformed. Applications SHOULD perform the same checks that the same label does not occur in both the protected and unprotected headers. If the message is not rejected as malformed, attributes MUST be obtained from the protected bucket before they are obtained from the unprotected bucket.

The following CDDL fragment represents the two header buckets. A group Headers is defined in CDDL that represents the two buckets in which attributes are placed. This group is used to provide these two fields consistently in all locations. A type is also defined which represents the map of common headers.

```

Headers = (
    protected : empty_or_serialized_map,
    unprotected : header_map
)

header_map = {
    Generic_Headers,
    * label => values
}

empty_or_serialized_map = bstr .cbor header_map / bstr .size 0

```

### [3.1.](#) Common COSE Headers Parameters

This section defines a set of common header parameters. A summary of these parameters can be found in Table 2. This table should be consulted to determine the value of label, and the type of the value.

The set of header parameters defined in this section are:



**alg** This parameter is used to indicate the algorithm used for the security processing. This parameter MUST be present at each layer of a signed, encrypted or authenticated message except the COSE\_Sign structure. When the algorithm supports authenticating associated data, this parameter MUST be in the protected header bucket. The value is taken from the "COSE Algorithms" Registry (see [Section 16.4](#)).

**crit** The parameter is used to indicate which protected header labels an application that is processing a message is required to understand. Parameters defined in this document do not need to be included as they should be understood by all implementations. When present, this parameter MUST be placed in the protected header bucket. The array MUST have at least one value in it. Not all labels need to be included in the 'crit' parameter. The rules for deciding which header labels are placed in the array are:

- \* Integer labels in the range of 0 to 8 SHOULD be omitted.
- \* Integer labels in the range -1 to -255 can be omitted as they are algorithm dependent. If an application can correctly process an algorithm, it can be assumed that it will correctly process all of the common parameters associated with that algorithm. (The algorithm range is -1 to -65536; the higher end is for more optional algorithm specific items.)
- \* Labels for parameters required for an application MAY be omitted. Applications should have a statement if the label can be omitted.

The header parameter values indicated by 'crit' can be processed by either the security library code or by an application using a security library; the only requirement is that the parameter is processed. If the 'crit' value list includes a value for which the parameter is not in the protected bucket, this is a fatal error in processing the message.

**content type** This parameter is used to indicate the content type of the data in the payload or cipher text fields. Integers are from the "CoAP Content-Formats" IANA registry table. Text values following the syntax of Content-Type defined in [Section 5.1 of \[RFC2045\]](#) omitting the prefix string "Content-Type:". Leading and trailing whitespace is also omitted. Textual content values along with parameters and subparameters can be located using the IANA "Media Types" registry. Applications SHOULD provide this parameter if the content structure is potentially ambiguous.



**kid** This parameter identifies one piece of data that can be used as input to find the needed cryptographic key. The value of this parameter can be matched against the 'kid' member in a COSE\_Key structure. Other methods of key distribution can define an equivalent field to be matched. Applications MUST NOT assume that 'kid' values are unique. There may be more than one key with the same 'kid' value, so all of the keys may need to be checked to find the correct one. The internal structure of 'kid' values is not defined and cannot be relied on by applications. Key identifier values are hints about which key to use. They are not directly a security critical field. For this reason, they can be placed in the unprotected headers bucket.

**Initialization Vector** This parameter holds the Initialization Vector (IV) value. For some symmetric encryption algorithms this may be referred to as a nonce. As the IV is authenticated by the encryption process, it can be placed in the unprotected header bucket.

**Partial Initialization Vector** This parameter holds a part of the IV value. When using the COSE\_Encrypt0 structure, a portion of the IV can be part of the context associated with the key. This field is used to carry a value that causes the IV to be changed for each message. As the IV is authenticated by the encryption process, this value can be placed in the unprotected header bucket. The 'Initialization Vector' and 'Partial Initialization Vector' parameters MUST NOT both be present in the same security layer. The message IV is generated by the following steps:

1. Left pad the partial IV with zeros to the length of IV.
2. XOR the padded partial IV with the context IV.

**counter signature** This parameter holds one or more counter signature values. Counter signatures provide a method of having a second party sign some data. The counter signature can occur as an unprotected attribute in any of the following structures: COSE\_Sign, COSE\_Sign1, COSE\_Signature, COSE\_Encrypt, COSE\_recipient, COSE\_Encrypt0, COSE\_Mac and COSE\_Mac0. These structures all have the same beginning elements so that a consistent calculation of the counter signature can be computed. Details on computing counter signatures are found in [Section 4.5](#).





name	label	value type	value registry	description
alg	1	int / tstr	COSE Algorithms registry	Cryptographic algorithm to use
crit	2	[+ label]	COSE Header Labels registry	Critical headers to be understood
content type	3	tstr / uint	CoAP Content - Formats or Media Types registry	Content type of the payload
kid	4	bstr		key identifier
IV	5	bstr		Full Initialization Vector
Partial IV	6	bstr		Partial Initialization Vector
counter signature	7	COSE_Signature / [+ COSE_Signature ]		CBOR encoded signature structure

Table 2: Common Header Parameters

The CDDL fragment that represents the set of headers defined in this section is given below. Each of the headers is tagged as optional because they do not need to be in every map; headers required in specific maps are discussed above.



```

Generic_Headers = (
    ? 1 => int / tstr,    ; algorithm identifier
    ? 2 => [+label],      ; criticality
    ? 3 => tstr / int,    ; content type
    ? 4 => bstr,          ; key identifier
    ? 5 => bstr,          ; IV
    ? 6 => bstr,          ; Partial IV
    ? 7 => COSE_Signature / [+COSE_Signature] ; Counter signature
)

```

## 4. Signing Objects

COSE supports two different signature structures. COSE\_Sign allows for one or more signers to be applied to a single content. COSE\_Sign1 is restricted to a single signer. The structures cannot be converted between each other; as the signature computation includes a parameter identifying which structure is being used, the converted structure will fail signature validation.

### 4.1. Signing with One or More Signers

The COSE\_Sign structure allows for one or more signatures to be applied to a message payload. There are provisions for parameters about the content and parameters about the signature to be carried along with the signature itself. These parameters may be authenticated by the signature, or just present. An example of a parameter about the content is the content type. Examples of parameters about the signature would be the algorithm and key used to create the signature and counter signatures.

When more than one signature is present, the successful validation of one signature associated with a given signer is usually treated as a successful signature by that signer. However, there are some application environments where other rules are needed. An application that employs a rule other than one valid signature for each signer must specify those rules. Also, where simple matching of the signer identifier is not sufficient to determine whether the signatures were generated by the same signer, the application specification must describe how to determine which signatures were generated by the same signer. Support of different communities of recipients is the primary reason that signers choose to include more than one signature. For example, the COSE\_Sign structure might include signatures generated with the Edwards Digital Signature Algorithm (EdDSA) signature algorithm and with the Elliptic Curve Digital Signature Algorithm (ECDSA) signature algorithm. This allows recipients to verify the signature associated with one algorithm or the other. (The original source of this text is [[RFC5652](#)].) More



detailed information on multiple signature evaluation can be found in [\[RFC5752\]](#).

The signature structure can be encoded either as tagged or untagged depending on the context it will be used in. A tagged COSE\_Sign structure is identified by the CBOR tag TBD1. The CDDL fragment that represents this is:

```
COSE_Sign_Tagged = #6.991(COSE_Sign) ; Replace 991 with TBD1
```

A COSE Signed Message is defined in two parts. The CBOR object that carries the body and information about the body is called the COSE\_Sign structure. The CBOR object that carries the signature and information about the signature is called the COSE\_Signature structure. Examples of COSE Signed Messages can be found in [Appendix C.1](#).

The COSE\_Sign structure is a CBOR array. The fields of the array in order are:

protected as described in [Section 3](#).

unprotected as described in [Section 3](#).

payload contains the serialized content to be signed. If the payload is not present in the message, the application is required to supply the payload separately. The payload is wrapped in a bstr to ensure that it is transported without changes. If the payload is transported separately ("detached content"), then a nil CBOR object is placed in this location and it is the responsibility of the application to ensure that it will be transported without changes.

Note: When a signature with message recovery algorithm is used ([Section 8](#)), the maximum number of bytes that can be recovered is the length of the payload. The size of the payload is reduced by the number of bytes that will be recovered. If all of the bytes of the payload are consumed, then the payload is encoded as a zero length binary string rather than as being absent.

signatures is an array of signatures. Each signature is represented as a COSE\_Signature structure.

The CDDL fragment that represents the above text for COSE\_Sign follows.



```
COSE_Sign = [
    Headers,
    payload : bstr / nil,
    signatures : [+ COSE_Signature]
]
```

The COSE\_Signature structure is a CBOR array. The fields of the array in order are:

protected as described in [Section 3](#).

unprotected as described in [Section 3](#).

signature contains the computed signature value. The type of the field is a bstr.

The CDDL fragment that represents the above text for COSE\_Signature follows.

```
COSE_Signature = [
    Headers,
    signature : bstr
]
```

#### **[4.2](#). Signing with One Signer**

The COSE\_Sign1 signature structure is used when only one signer is going to be placed on a message. The parameters dealing with the content and the signature are placed in the same pair of buckets rather than having the separation of COSE\_Sign.

The structure can be encoded either tagged or untagged depending on the context it will be used in. A tagged COSE\_Sign1 structure is identified by the CBOR tag TBD7. The CDDL fragment that represents this is:

```
COSE_Sign1_Tagged = #6.997(COSE_Sign1) ; Replace 997 with TBD7
```

The CBOR object that carries the body, the signature, and the information about the body and signature is called the COSE\_Sign1 structure. Examples of COSE\_Sign1 messages can be found in [Appendix C.2](#).

The COSE\_Sign1 structure is a CBOR array. The fields of the array in order are:

protected as described in [Section 3](#).





unprotected as described in [Section 3](#).

payload as described in [Section 4.1](#).

signature contains the computed signature value. The type of the field is a bstr.

The CDDL fragment that represents the above text for COSE\_Sign1 follows.

```
COSE_Sign1 = [
    Headers,
    payload : bstr / nil,
    signature : bstr
]
```

#### **[4.3](#). Externally Supplied Data**

One of the features supplied in the COSE document is the ability for applications to provide additional data to be authenticated as part of the security, but that is not carried as part of the COSE object. The primary reason for supporting this can be seen by looking at the CoAP message structure [[RFC7252](#)], where the facility exists for options to be carried before the payload. Examples of data that can be placed in this location would be the CoAP code, CoAP token, or CoAP options. If the data is in the header section, then it is available for routers to help in performing the replay detection and prevention. However, it may also be desired to protect these values so that if they are modified in transit, it can be detected.

This document describes the process for using a byte array of externally supplied authenticated data; however, the method of constructing the byte array is a function of the application. Applications that use this feature need to define how the externally supplied authenticated data is to be constructed. Such a construction needs to take into account the following issues:

- o If multiple items are included, care needs to be taken that data cannot bleed between the items. This is usually addressed by making fields fixed width and/or encoding the length of the field. Using options from CoAP [[RFC7252](#)] as an example, these fields use a TLV structure so they can be concatenated without any problems.
- o If multiple items are included, an order for the items needs to be defined. Using options from CoAP as an example, an application could state that the fields are to be ordered by the option number.



- o Applications need to ensure that the byte stream is going to be the same on both sides. Using options from CoAP might give a problem if the same relative numbering is kept. An intermediate node could insert or remove an option, changing how the relative number is done. An application would need to specify that the relative number must be re-encoded to be relative only to the options that are in the external data.

#### **4.4. Signing and Verification Process**

In order to create a signature, a well-defined byte stream is needed. This algorithm takes in the body information (COSE\_Sign or COSE\_Sign1), the signer information (COSE\_Signature), and the application data (External). A CBOR array is used to construct the byte stream. The fields of the array in order are:

1. A text string identifying the context of the signature. The context string is:  
  
"Signature" for signatures using the COSE\_Signature structure.  
  
"Signature1" for signatures using the COSE\_Sign1 structure.  
  
"CounterSignature" for signatures used as counter signature attributes.
2. The protected attributes from the body structure encoded in a bstr type. If there are no protected attributes, a bstr of length zero is used.
3. The protected attributes from the signer structure encoded in a bstr type. If there are no protected attributes, a bstr of length zero is used. This field is omitted for the COSE\_Sign1 signature structure.
4. The protected attributes from the application encoded in a bstr type. If this field is not supplied, it defaults to a zero length binary string. (See [Section 4.3](#) for application guidance on constructing this field.)
5. The payload to be signed encoded in a bstr type. The payload is placed here independent of how it is transported.

The CDDL fragment that describes the above text is.



```

Sig_structure = [
  context : "Signature" / "Signature1" / "CounterSignature",
  body_protected : empty_or_serialized_map,
  ? sign_protected : empty_or_serialized_map,
  external_aad : bstr,
  payload : bstr
]

```

How to compute a signature:

1. Create a Sig\_structure and populate it with the appropriate fields.
2. Create the value ToBeSigned by encoding the Sig\_structure to a byte string, using the encoding described in [Section 14](#).
3. Call the signature creation algorithm passing in K (the key to sign with), alg (the algorithm to sign with), and ToBeSigned (the value to sign).
4. Place the resulting signature value in the 'signature' field of the array.

How to verify a signature:

1. Create a Sig\_structure object and populate it with the appropriate fields.
2. Create the value ToBeSigned by encoding the Sig\_structure to a byte string, using the encoding described in [Section 14](#).
3. Call the signature verification algorithm passing in K (the key to verify with), alg (the algorithm used sign with), ToBeSigned (the value to sign), and sig (the signature to be verified).

In addition to performing the signature verification, one must also perform the appropriate checks to ensure that the key is correctly paired with the signing identity and that the signing identity is authorized before performing actions.

#### **[4.5](#). Computing Counter Signatures**

Counter signatures provide a method of having a different signature occur on some piece of content. This is normally used to provide a signature on a signature allowing for a proof that a signature existed at a given time (i.e., a Timestamp). In this document, we allow for counter signatures to exist in a greater number of environments. As an example, it is possible to place a counter



signature in the unprotected attributes of a COSE\_Encrypt object. This would allow for an intermediary to either verify that the encrypted byte stream has not been modified, without being able to decrypt it, or for the intermediary to assert that an encrypted byte stream either existed at a given time or passed through it in terms of routing (i.e., a proxy signature).

An example of a counter signature on a signature can be found in [Appendix C.1.3](#). An example of a counter signature in an encryption object can be found in [Appendix C.3.3](#).

The creation and validation of counter signatures over the different items relies on the fact that the structure of the objects have the same structure. The elements are a set of protected attributes, a set of unprotected attributes, and a body, in that order. This means that the Sig\_structure can be used in a uniform manner to get the byte stream for processing a signature. If the counter signature is going to be computed over a COSE\_Encrypt structure, the body\_protected and payload items can be mapped into the Sig\_structure in the same manner as from the COSE\_Sign structure.

It should be noted that only a signature algorithm with appendix (see [Section 8](#)) can be used for counter signatures. This is because the body should be able to be processed without having to evaluate the counter signature, and this is not possible for signature schemes with message recovery.

## **5. Encryption Objects**

COSE supports two different encryption structures. COSE\_Encrypt0 is used when a recipient structure is not needed because the key to be used is known implicitly. COSE\_Encrypt is used the rest of the time. This includes cases where there are multiple recipients or a recipient algorithm other than direct is used.

### **[5.1.](#) Enveloped COSE Structure**

The enveloped structure allows for one or more recipients of a message. There are provisions for parameters about the content and parameters about the recipient information to be carried in the message. The protected parameters associated with the content are authenticated by the content encryption algorithm. The protected parameters associated with the recipient are authenticated by the recipient algorithm (when the algorithm supports it). Examples of parameters about the content are the type of the content and the content encryption algorithm. Examples of parameters about the recipient are the recipient's key identifier and the recipient's encryption algorithm.





The same techniques and structures are used for encrypting both the plain text and the keys used to protect the text. This is different from the approach used by both CMS [RFC5652] and JSON Web Encryption (JWE) [RFC7516] where different structures are used for the content layer and for the recipient layer. Two structures are defined: COSE\_Encrypt to hold the encrypted content and COSE\_recipient to hold the encrypted keys for recipients. Examples of encrypted messages can be found in [Appendix C.3](#).

The COSE\_Encrypt structure can be encoded either tagged or untagged depending on the context it will be used in. A tagged COSE\_Encrypt structure is identified by the CBOR tag TBD2. The CDDL fragment that represents this is:

```
COSE_Encrypt_Tagged = #6.992(COSE_Encrypt) ; Replace 992 with TBD2
```

The COSE\_Encrypt structure is a CBOR array. The fields of the array in order are:

protected as described in [Section 3](#).

unprotected as described in [Section 3](#). '

ciphertext contains the cipher text encoded as a bstr. If the cipher text is to be transported independently of the control information about the encryption process (i.e., detached content) then the field is encoded as a nil value.

recipients contains an array of recipient information structures. The type for the recipient information structure is a COSE\_recipient.

The CDDL fragment that corresponds to the above text is:

```
COSE_Encrypt = [
    Headers,
    ciphertext : bstr / nil,
    recipients : [+COSE_recipient]
]
```

The COSE\_recipient structure is a CBOR array. The fields of the array in order are:

protected as described in [Section 3](#).

unprotected as described in [Section 3](#).



`ciphertext` contains the encrypted key encoded as a `bstr`. If there is not an encrypted key, then this field is encoded as a `nil` value.

`recipients` contains an array of recipient information structures. The type for the recipient information structure is a `COSE_recipient`. (An example of this can be found in [Appendix B](#).) If there are no recipient information structures, this element is absent.

The CDDL fragment that corresponds to the above text for `COSE_recipient` is:

```
COSE_recipient = [
    Headers,
    ciphertext : bstr / nil,
    ? recipients : [+COSE_recipient]
]
```

#### **[5.1.1.1](#). Recipient Algorithm Classes**

An encrypted message consists of an encrypted content and an encrypted CEK for one or more recipients. The CEK is encrypted for each recipient, using a key specific to that recipient. The details of this encryption depend on which class the recipient algorithm falls into. Specific details on each of the classes can be found in [Section 12](#). A short summary of the five recipient algorithm classes is:

`direct`: The CEK is the same as the identified previously distributed symmetric key or derived from a previously distributed secret. No CEK is transported in the message.

`symmetric key-encryption keys`: The CEK is encrypted using a previously distributed symmetric KEK.

`key agreement`: The recipient's public key and a sender's private key are used to generate a pairwise secret, a KDF is applied to derive a key, and then the CEK is either the derived key or encrypted by the derived key.

`key transport`: The CEK is encrypted with the recipient's public key. No key transport algorithms are defined in this document.

`passwords`: The CEK is encrypted in a KEK that is derived from a password. No password algorithms are defined in this document.



## 5.2. Single Recipient Encrypted

The COSE\_Encrypt0 encrypted structure does not have the ability to specify recipients of the message. The structure assumes that the recipient of the object will already know the identity of the key to be used in order to decrypt the message. If a key needs to be identified to the recipient, the enveloped structure ought to be used.

Examples of encrypted messages can be found in [Appendix C.3](#).

The COSE\_Encrypt0 structure can be encoded either tagged or untagged depending on the context it will be used in. A tagged COSE\_Encrypt0 structure is identified by the CBOR tag TBD3. The CDDL fragment that represents this is:

```
COSE_Encrypt0_Tagged = #6.993(COSE_Encrypt0) ; Replace 993 with TBD3
```

The COSE\_Encrypt structure is a CBOR array. The fields of the array in order are:

protected as described in [Section 3](#).

unprotected as described in [Section 3](#).

ciphertext as described in [Section 5.1](#).

The CDDL fragment for COSE\_Encrypt0 that corresponds to the above text is:

```
COSE_Encrypt0 = [
    Headers,
    ciphertext : bstr / nil,
]
```

## 5.3. Encryption Algorithm for AEAD algorithms

The encryption algorithm for AEAD algorithms is fairly simple. The first step is to create a consistent byte stream for the authenticated data structure. For this purpose, we use a CBOR array. The fields of the array in order are:

1. A text string identifying the context of the authenticated data structure. The context string is:

"Encrypt0" for the content encryption of a COSE\_Encrypt0 data structure.



"Encrypt" for the first layer of a COSE\_Encrypt data structure (i.e., for content encryption).

"Enc\_Recipient" for a recipient encoding to be placed in an COSE\_Encrypt data structure.

"Mac\_Recipient" for a recipient encoding to be placed in a MACed message structure.

"Rec\_Recipient" for a recipient encoding to be placed in a recipient structure.

2. The protected attributes from the body structure encoded in a bstr type. If there are no protected attributes, a bstr of length zero is used.
3. The protected attributes from the application encoded in a bstr type. If this field is not supplied, it defaults to a zero length bstr. (See [Section 4.3](#) for application guidance on constructing this field.)

The CDDL fragment that describes the above text is:

```
Enc_structure = [  
  context : "Encrypt" / "Encrypt0" / "Enc_Recipient" /  
    "Mac_Recipient" / "Rec_Recipient",  
  protected : empty_or_serialized_map,  
  external_aad : bstr  
]
```

How to encrypt a message:

1. Create an Enc\_structure and populate it with the appropriate fields.
2. Encode the Enc\_structure to a byte stream (AAD), using the encoding described in [Section 14](#).
3. Determine the encryption key (K). This step is dependent on the class of recipient algorithm being used. For:

No Recipients: The key to be used is determined by the algorithm and key at the current layer.

Direct and Direct Key Agreement: The key is determined by the key and algorithm in the recipient structure. The encryption algorithm and size of the key to be used are inputs into the





KDF used for the recipient. (For direct, the KDF can be thought of as the identity operation.)

Other: The key is randomly generated.

4. Call the encryption algorithm with K (the encryption key), P (the plain text) and AAD. Place the returned cipher text into the 'ciphertext' field of the structure.
5. For recipients of the message, recursively perform the encryption algorithm for that recipient, using K (the encryption key) as the plain text.

How to decrypt a message:

1. Create a Enc\_structure and populate it with the appropriate fields.
2. Encode the Enc\_structure to a byte stream (AAD), using the encoding described in [Section 14](#).
3. Determine the decryption key. This step is dependent on the class of recipient algorithm being used. For:

No Recipients: The key to be used is determined by the algorithm and key at the current layer.

Direct and Direct Key Agreement: The key is determined by the key and algorithm in the recipient structure. The encryption algorithm and size of the key to be used are inputs into the KDF used for the recipient. (For direct, the KDF can be thought of as the identity operation.)

Other: The key is determined by decoding and decrypting one of the recipient structures.

4. Call the decryption algorithm with K (the decryption key to use), C (the cipher text) and AAD.

#### **5.4. Encryption algorithm for AE algorithms**

How to encrypt a message:

1. Verify that the 'protected' field is empty.
2. Verify that there was no external additional authenticated data supplied for this operation.



3. Determine the encryption key. This step is dependent on the class of recipient algorithm being used. For:

No Recipients: The key to be used is determined by the algorithm and key at the current layer.

Direct and Direct Key Agreement: The key is determined by the key and algorithm in the recipient structure. The encryption algorithm and size of the key to be used are inputs into the KDF used for the recipient. (For direct, the KDF can be thought of as the identity operation.)

Other: The key is randomly generated.

4. Call the encryption algorithm with K (the encryption key to use) and the P (the plain text). Place the returned cipher text into the 'ciphertext' field of the structure.
5. For recipients of the message, recursively perform the encryption algorithm for that recipient, using K (the encryption key) as the plain text.

How to decrypt a message:

1. Verify that the 'protected' field is empty.
2. Verify that there was no external additional authenticated data supplied for this operation.
3. Determine the decryption key. This step is dependent on the class of recipient algorithm being used. For:

No Recipients: The key to be used is determined by the algorithm and key at the current layer.

Direct and Direct Key Agreement: The key is determined by the key and algorithm in the recipient structure. The encryption algorithm and size of the key to be used are inputs into the KDF used for the recipient. (For direct, the KDF can be thought of as the identity operation.)

Other: The key is determined by decoding and decrypting one of the recipient structures.

4. Call the decryption algorithm with K (the decryption key to use), and C (the cipher text).



## 6. MAC Objects

COSE supports two different MAC structures. COSE\_MAC0 is used when a recipient structure is not needed because the key to be used is implicitly known. COSE\_MAC is used for all other cases. These include a requirement for multiple recipients, the key being unknown, and a recipient algorithm of other than direct.

In this section, we describe the structure and methods to be used when doing MAC authentication in COSE. This document allows for the use of all of the same classes of recipient algorithms as are allowed for encryption.

When using MAC operations, there are two modes in which they can be used. The first is just a check that the content has not been changed since the MAC was computed. Any class of recipient algorithm can be used for this purpose. The second mode is to both check that the content has not been changed since the MAC was computed, and to use the recipient algorithm to verify who sent it. The classes of recipient algorithms that support this are those that use a pre-shared secret or do static-static key agreement (without the key wrap step). In both of these cases, the entity that created and sent the message MAC can be validated. (This knowledge of sender assumes that there are only two parties involved and you did not send the message yourself.)

### 6.1. MACed Message with Recipients

The multiple recipient MACed message uses two structures, the COSE\_Mac structure defined in this section for carrying the body and the COSE\_recipient structure ([Section 5.1](#)) to hold the key used for the MAC computation. Examples of MACed messages can be found in [Appendix C.5](#).

The MAC structure can be encoded either tagged or untagged depending on the context it will be used in. A tagged COSE\_Mac structure is identified by the CBOR tag TBD4. The CDDL fragment that represents this is:

```
COSE_Mac_Tagged = #6.994(COSE_Mac) ; Replace 994 with TBD4
```

The COSE\_Mac structure is a CBOR array. The fields of the array in order are:

protected as described in [Section 3](#).

unprotected as described in [Section 3](#).



payload contains the serialized content to be MACed. If the payload is not present in the message, the application is required to supply the payload separately. The payload is wrapped in a bstr to ensure that it is transported without changes. If the payload is transported separately (i.e., detached content), then a nil CBOR value is placed in this location and it is the responsibility of the application to ensure that it will be transported without changes.

tag contains the MAC value.

recipients as described in [Section 5.1](#).

The CDDL fragment that represents the above text for COSE\_Mac follows.

```
COSE_Mac = [
  Headers,
  payload : bstr / nil,
  tag : bstr,
  recipients :[+COSE_recipient]
]
```

## 6.2. MACed Messages with Implicit Key

In this section, we describe the structure and methods to be used when doing MAC authentication for those cases where the recipient is implicitly known.

The MACed message uses the COSE\_Mac0 structure defined in this section for carrying the body. Examples of MACed messages with an implicit key can be found in [Appendix C.6](#).

The MAC structure can be encoded either tagged or untagged depending on the context it will be used in. A tagged COSE\_Mac0 structure is identified by the CBOR tag TBD6. The CDDL fragment that represents this is:

```
COSE_Mac0_Tagged = #6.996(COSE_Mac0) ; Replace 996 with TBD6
```

The COSE\_Mac0 structure is a CBOR array. The fields of the array in order are:

protected as described in [Section 3](#).

unprotected as described in [Section 3](#).

payload as described in [Section 6.1](#).





tag contains the MAC value.

The CDDL fragment that corresponds to the above text is:

```
COSE_Mac0 = [
    Headers,
    payload : bstr / nil,
    tag : bstr,
]
```

### **6.3. How to compute and verify a MAC**

In order to get a consistent encoding of the data to be authenticated, the MAC\_structure is used to have a canonical form. The MAC\_structure is a CBOR array. The fields of the MAC\_structure in order are:

1. A text string that identifies the structure that is being encoded. This string is "MAC" for the COSE\_Mac structure. This string is "MAC0" for the COSE\_Mac0 structure.
2. The protected attributes from the COSE\_MAC structure. If there are no protected attributes, a zero length bstr is used.
3. The protected attributes from the application encoded as a bstr type. If this field is not supplied, it defaults to a zero length binary string. (See [Section 4.3](#) for application guidance on constructing this field.)
4. The payload to be MAC-ed encoded in a bstr type. The payload is placed here independent of how it is transported.

The CDDL fragment that corresponds to the above text is:

```
MAC_structure = [
    context : "MAC" / "MAC0",
    protected : empty_or_serialized_map,
    external_aad : bstr,
    payload : bstr
]
```

The steps to compute a MAC are:

1. Create a MAC\_structure and populate it with the appropriate fields.
2. Create the value ToBeMaced by encoding the MAC\_structure to a byte stream, using the encoding described in [Section 14](#).



3. Call the MAC creation algorithm passing in K (the key to use), alg (the algorithm to MAC with) and ToBeMaced (the value to compute the MAC on).
4. Place the resulting MAC in the 'tag' field of the COSE\_Mac structure.
5. Encrypt and encode the MAC key for each recipient of the message.

How to verify a MAC are:

1. Create a MAC\_structure object and populate it with the appropriate fields.
2. Create the value ToBeMaced by encoding the MAC\_structure to a byte stream, using the encoding described in [Section 14](#).
3. Obtain the cryptographic key from one of the recipients of the message.
4. Call the MAC creation algorithm passing in K (the key to use), alg (the algorithm to MAC with) and ToBeMaced (the value to compute the MAC on).
5. Compare the MAC value to the 'tag' field of the COSE\_Mac structure.

## **[7.](#) Key Structure**

A COSE Key structure is built on a CBOR map object. The set of common parameters that can appear in a COSE Key can be found in the IANA "COSE Key Common Parameters" registry ([Section 16.5](#)). Additional parameters defined for specific key types can be found in the IANA "COSE Key Type Parameters" registry ([Section 16.6](#)).

A COSE Key Set uses a CBOR array object as its underlying type. The values of the array elements are COSE Keys. A Key Set MUST have at least one element in the array.

Each element in a key set MUST be processed independently. If one element in a key set is either malformed or uses a key that is not understood by an application, that key is ignored and the other keys are processed normally.

The element "kty" is a required element in a COSE\_Key map.

The CDDL grammar describing COSE\_Key and COSE\_KeySet is:



```

COSE_Key = {
    key_kty => tstr / int,
    ? key_ops => [+ (tstr / int) ],
    ? key_alg => tstr / int,
    ? key_kid => bstr,
    ? key_baseIV => bstr,
    * label => values
}

COSE_KeySet = [+COSE_Key]

```

### 7.1. COSE Key Common Parameters

This document defines a set of common parameters for a COSE Key object. Table 3 provides a summary of the parameters defined in this section. There are also parameters that are defined for specific key types. Key type specific parameters can be found in [Section 13](#).

name	label	CBOR type	registry	description
kty	1	tstr / int	COSE Key Common Parameters	Identification of the key type
alg	3	tstr / int	COSE Algorithm Values	Key usage restriction to this algorithm
kid	2	bstr		Key Identification value - match to kid in message
key_ops	4	[+ (tstr/int)]		Restrict set of permissible operations
Base IV	5	bstr		Base IV to be xor-ed with Partial IVs

Table 3: Key Map Labels

kty: This parameter is used to identify the family of keys for this structure, and thus the set of key type specific parameters to be found. The set of values defined in this document can be found in



Table 21. This parameter MUST be present in a key object. Implementations MUST verify that the key type is appropriate for the algorithm being processed. The key type MUST be included as part of the trust decision process.

alg: This parameter is used to restrict the algorithm that is used with the key. If this parameter is present in the key structure, the application MUST verify that this algorithm matches the algorithm for which the key is being used. If the algorithms do not match, then this key object MUST NOT be used to perform the cryptographic operation. Note that the same key can be in a different key structure with a different or no algorithm specified, however this is considered to be a poor security practice.

kid: This parameter is used to give an identifier for a key. The identifier is not structured and can be anything from a user provided string to a value computed on the public portion of the key. This field is intended for matching against a 'kid' parameter in a message in order to filter down the set of keys that need to be checked.

key\_ops: This parameter is defined to restrict the set of operations that a key is to be used for. The value of the field is an array of values from Table 4. Algorithms define the values of key ops that are permitted to appear and are required for specific operations.

Base IV: This parameter is defined to carry the base portion of an IV. It is designed to be used with the partial IV header parameter defined in [Section 3.1](#). This field provides the ability to associate a partial IV with a key that is then modified on a per message basis with the partial IV.

Extreme care needs to be taken when using a Base IV in an application. Many encryption algorithms lose security if the same IV is used twice.

If different keys are derived for each sender, starting at the same base IV is likely to satisfy this condition. If the same key is used for multiple senders, then the application needs to provide for a method of dividing the IV space up between the senders. This could be done by providing a different base point to start from or a different partial IV to start with and restricting the number of messages to be sent before re-keying.





name	value	description
sign	1	The key is used to create signatures. Requires private key fields.
verify	2	The key is used for verification of signatures.
encrypt	3	The key is used for key transport encryption.
decrypt	4	The key is used for key transport decryption. Requires private key fields.
wrap key	5	The key is used for key wrapping.
unwrap key	6	The key is used for key unwrapping. Requires private key fields.
derive key	7	The key is used for deriving keys. Requires private key fields.
derive bits	8	The key is used for deriving bits. Requires private key fields.
MAC create	9	The key is used for creating MACs.
MAC verify	10	The key is used for validating MACs.

Table 4: Key Operation Values

The following provides a CDDL fragment that duplicates the assignment labels from Table 3.

```

;key_labels
key_kty=1
key_kid=2
key_alg=3
key_ops=4
key_baseIV=5

```



## 8. Signature Algorithms

There are two signature algorithm schemes. The first is signature with appendix. In this scheme, the message content is processed and a signature is produced, the signature is called the appendix. This is the scheme used by algorithms such as ECDSA and RSASSA-PSS. (In fact the SSA in RSASSA-PSS stands for Signature Scheme with Appendix.)

The signature functions for this scheme are:

```
signature = Sign(message content, key)
```

```
valid = Verification(message content, key, signature)
```

The second scheme is signature with message recovery. (An example of such an algorithm is [PVSig](#).) In this scheme, the message content is processed, but part of it is included in the signature. Moving bytes of the message content into the signature allows for smaller signatures, the signature size is still potentially large, but the message content has shrunk. This has implications for systems implementing these algorithms and for applications that use them. The first is that the message content is not fully available until after a signature has been validated. Until that point the part of the message contained inside of the signature is unrecoverable. The second is that the security analysis of the strength of the signature is very much based on the structure of the message content. Messages that are highly predictable require additional randomness to be supplied as part of the signature process. In the worst case, it becomes the same as doing a signature with appendix. Finally, in the event that multiple signatures are applied to a message, all of the signature algorithms are going to be required to consume the same number of bytes of message content. This means that mixing of the different schemes in a single message is not supported, and if a recovery signature scheme is used, then the same amount of content needs to be consumed by all of the signatures.

The signature functions for this scheme are:

```
signature, message sent = Sign(message content, key)
```

```
valid, message content = Verification(message sent, key, signature)
```

Signature algorithms are used with the COSE\_Signature and COSE\_Sign1 structures. At this time, only signatures with appendixes are defined for use with COSE, however considerable interest has been expressed in using a signature with message recovery algorithm due to



the effective size reduction that is possible. Implementations will need to keep this in mind for later possible integration.

### 8.1. ECDSA

ECDSA [[DSS](#)] defines a signature algorithm using ECC.

The ECDSA signature algorithm is parameterized with a hash function (h). In the event that the length of the hash function output is greater than the group of the key, the left-most bytes of the hash output are used.

The algorithms defined in this document can be found in Table 5.

name	value	hash	description
ES256	-7	SHA-256	ECDSA w/ SHA-256
ES384	-35	SHA-384	ECDSA w/ SHA-384
ES512	-36	SHA-512	ECDSA w/ SHA-512

Table 5: ECDSA Algorithm Values

This document defines ECDSA to work only with the curves P-256, P-384 and P-521. This document requires that the curves be encoded using the 'EC2' key type. Implementations need to check that the key type and curve are correct when creating and verifying a signature. Other documents can define it to work with other curves and points in the future.

In order to promote interoperability, it is suggested that SHA-256 be used only with curve P-256, SHA-384 be used only with curve P-384 and SHA-512 be used with curve P-521. This is aligned with the recommendation in [Section 4 of \[RFC5480\]](#).

The signature algorithm results in a pair of integers (R, S). These integers will the same length as length of the key used for the signature process. The signature is encoded by converting the integers into byte strings of the same length as the key size. The length is rounded up to the nearest byte and is left padded with zero bits to get to the correct length. The two integers are then concatenated together to form a byte string that is the resulting signature.

Using the function defined in [\[RFC3447\]](#) the signature is:



Signature = I2OSP(R, n) | I2OSP(S, n)  
where n = ceiling(key\_length / 8)

When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'EC2'.
- o If the 'alg' field is present, it MUST match the ECDSA signature algorithm being used.
- o If the 'key\_ops' field is present, it MUST include 'sign' when creating an ECDSA signature.
- o If the 'key\_ops' field is present, it MUST include 'verify' when verifying an ECDSA signature.

#### **8.1.1. Security Considerations**

The security strength of the signature is no greater than the minimum of the security strength associated with the bit length of the key and the security strength of the hash function.

Systems that have poor random number generation can leak their keys by signing two different messages with the same value 'k' (the per-message random value). [[RFC6979](#)] provides a method to deal with this problem by making 'k' be deterministic based on the message content rather than randomly generated. Applications that specify ECDSA should evaluate the ability to get good random number generation and require deterministic signatures where poor random number generation exists.

Note: Use of this technique is a good idea even when good random number generation exists. Doing so both reduces the possibility of having the same value of 'k' in two signature operations and allows for reproducible signature values, which helps testing.

There are two substitution attacks that can theoretically be mounted against the ECDSA signature algorithm.

- o Changing the curve used to validate the signature: If one changes the curve used to validate the signature, then potentially one could have a two messages with the same signature each computed under a different curve. The only requirement on the new curve is that its order be the same as the old one and it be acceptable to the client. An example would be to change from using the curve secp256r1 (aka P-256) to using secp256k1. (Both are 256 bit curves.) We current do not have any way to deal with this version





of the attack except to restrict the overall set of curves that can be used.

- o Change the hash function used to validate the signature: If one has either two different hash functions of the same length, or one can truncate a hash function down, then one could potentially find collisions between the hash functions rather than within a single hash function. (For example, truncating SHA-512 to 256 bits might collide with a SHA-256 bit hash value.) This attack can be mitigated by including the signature algorithm identifier in the data to be signed.

## 8.2. Edwards-curve Digital Signature Algorithms (EdDSA)

[I-D.irtf-cfrg-eddsa] describes the elliptic curve signature scheme Edwards-curve Digital Signature Algorithm (EdDSA). In that document, the signature algorithm is instantiated using parameters for edwards25519 and edwards448 curves. The document additionally describes two variants of the EdDSA algorithm: Pure EdDSA, where no hash function is applied to the content before signing and, HashEdDSA where a hash function is applied to the content before signing and the result of that hash function is signed. For use with COSE, only the pure EdDSA version is used. This is because it is not expected that extremely large contents are going to be needed and, based on the arrangement of the message structure, the entire message is going to need to be held in memory in order to create or verify a signature. Thus, the use of an incremental update process would not be useful. Applications can provide the same features by defining the content of the message as a hash value and transporting the COSE object and the content as separate items.

The algorithms defined in this document can be found in Table 6. A single signature algorithm is defined, which can be used for multiple curves.

+-----+-----+-----+-----+				
name	value	description		
+-----+-----+-----+-----+				
EdDSA	-8	EdDSA		
+-----+-----+-----+-----+				

Table 6: EdDSA Algorithm Values

[I-D.irtf-cfrg-eddsa] describes the method of encoding the signature value.

When using a COSE key for this algorithm the following checks are made:



- o The 'kty' field MUST be present and it MUST be 'OKP'.
- o The 'crv' field MUST be present, and it MUST be a curve defined for this signature algorithm.
- o If the 'alg' field is present, it MUST match 'EdDSA'.
- o If the 'key\_ops' field is present, it MUST include 'sign' when creating an EdDSA signature.
- o If the 'key\_ops' field is present, it MUST include 'verify' when verifying an EdDSA signature.

#### **8.2.1. Security Considerations**

The Edwards curves for EdDSA and ECDH are distinct and should not be used for the other algorithm.

If batch signature verification is performed, a well-seeded cryptographic random number generator is REQUIRED. Signing and non-batch signature verification are deterministic operations and do not need random numbers of any kind.

### **9. Message Authentication (MAC) Algorithms**

Message Authentication Codes (MACs) provide data authentication and integrity protection. They provide either no or very limited data origination. (One cannot, for example, be used to prove the identity of the sender to a third party.)

MACs use the same scheme as signature with appendix algorithms. The message content is processed and an authentication code is produced. The authentication code is frequently called a tag.

The MAC functions are:

```
tag = MAC_Create(message content, key)
```

```
valid = MAC_Verify(message content, key, tag)
```

MAC algorithms can be based on either a block cipher algorithm (i.e., AES-MAC) or a hash algorithm (i.e., HMAC). This document defines a MAC algorithm using each of these constructions.

MAC algorithms are used in the COSE\_Mac and COSE\_Mac1 structures.



### 9.1. Hash-based Message Authentication Codes (HMAC)

The Hash-base Message Authentication Code algorithm (HMAC) [RFC2104][RFC4231] was designed to deal with length extension attacks. The algorithm was also designed to allow for new hash algorithms to be directly plugged in without changes to the hash function. The HMAC design process has been shown as solid since, while the security of hash algorithms such as MD5 has decreased over time, the security of HMAC combined with MD5 has not yet been shown to be compromised [RFC6151].

The HMAC algorithm is parameterized by an inner and outer padding, a hash function (h), and an authentication tag value length. For this specification, the inner and outer padding are fixed to the values set in [RFC2104]. The length of the authentication tag corresponds to the difficulty of producing a forgery. For use in constrained environments, we define a set of HMAC algorithms that are truncated. There are currently no known issues with truncation, however the security strength of the message tag is correspondingly reduced in strength. When truncating, the left-most tag length bits are kept and transmitted.

The algorithms defined in this document can be found in Table 7.

name	value	Hash	Tag Length	description
HMAC 256/64	4	SHA-256	64	HMAC w/ SHA-256 truncated to 64 bits
HMAC 256/256	5	SHA-256	256	HMAC w/ SHA-256
HMAC 384/384	6	SHA-384	384	HMAC w/ SHA-384
HMAC 512/512	7	SHA-512	512	HMAC w/ SHA-512

Table 7: HMAC Algorithm Values

Some recipient algorithms carry the key while others derive a key from secret data. For those algorithms that carry the key (such as AES-KeyWrap), the size of the HMAC key SHOULD be the same size as the underlying hash function. For those algorithms that derive the key



(such as ECDH), the derived key MUST be the same size as the underlying hash function.

When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'Symmetric'.
- o If the 'alg' field present, it MUST match the HMAC algorithm being used.
- o If the 'key\_ops' field is present, it MUST include 'MAC create' when creating an HMAC authentication tag.
- o If the 'key\_ops' field is present, it MUST include 'MAC verify' when verifying an HMAC authentication tag.

Implementations creating and validating MAC values MUST validate that the key type, key length, and algorithm are correct and appropriate for the entities involved.

#### **9.1.1. Security Considerations**

HMAC has proved to be resistant to attack even when used with weakened hash algorithms. The current best method appears to be a brute force attack on the key. This means that key size is going to be directly related to the security of an HMAC operation.

#### **9.2. AES Message Authentication Code (AES-CBC-MAC)**

AES-CBC-MAC is defined in [MAC]. (Note this is not the same algorithm as AES-CMAC [RFC4493]).

AES-CBC-MAC is parameterized by the key length, the authentication tag length and the IV used. For all of these algorithms, the IV is fixed to all zeros. We provide an array of algorithms for various key lengths and tag lengths. The algorithms defined in this document are found in Table 8.





name	value	key length	tag length	description
AES-MAC 128/64	14	128	64	AES-MAC 128 bit key, 64-bit tag
AES-MAC 256/64	15	256	64	AES-MAC 256 bit key, 64-bit tag
AES-MAC 128/128	25	128	128	AES-MAC 128 bit key, 128-bit tag
AES-MAC 256/128	26	256	128	AES-MAC 256 bit key, 128-bit tag

Table 8: AES-MAC Algorithm Values

Keys may be obtained either from a key structure or from a recipient structure. Implementations creating and validating MAC values MUST validate that the key type, key length and algorithm are correct and appropriate for the entities involved.

When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'Symmetric'.
- o If the 'alg' field present, it MUST match the AES-MAC algorithm being used.
- o If the 'key\_ops' field is present, it MUST include 'MAC create' when creating an AES-MAC authentication tag.
- o If the 'key\_ops' field is present, it MUST include 'MAC verify' when verifying an AES-MAC authentication tag.

### **9.2.1. Security Considerations**

A number of attacks exist against CBC-MAC that need to be considered.

- o A single key must only be used for messages of a fixed and known length. If this is not the case, an attacker will be able to generate a message with a valid tag given two message, tag pairs. This can be addressed by using different keys for different length messages. The current structure mitigates this problem, as a



specific encoding structure that includes lengths is build and signed. (CMAC also addresses this issue.)

- o If the same key is used for both encryption and authentication operations, using CBC modes an attacker can produce messages with a valid authentication code.
- o If the IV can be modified, then messages can be forged. This is addressed by fixing the IV to all zeros.

## **10. Content Encryption Algorithms**

Content Encryption Algorithms provide data confidentiality for potentially large blocks of data using a symmetric key. They provide integrity on the data that was encrypted, however they provide either no or very limited data origination. (One cannot, for example, be used to prove the identity of the sender to a third party.) The ability to provide data origination is linked to how the CEK is obtained.

COSE restricts the set of legal content encryption algorithms to those that support authentication both of the content and additional data. The encryption process will generate some type of authentication value, but that value may be either explicit or implicit in terms of the algorithm definition. For simplicity sake, the authentication code will normally be defined as being appended to the cipher text stream. The encryption functions are:

```
ciphertext = Encrypt(message content, key, additional data)
```

```
valid, message content = Decrypt(cipher text, key, additional data)
```

Most AEAD algorithms are logically defined as returning the message content only if the decryption is valid. Many but not all implementations will follow this convention. The message content MUST NOT be used if the decryption does not validate.

These algorithms are used in COSE\_Encrypt and COSE\_Encrypt0.

### **10.1. AES GCM**

The GCM mode is a generic authenticated encryption block cipher mode defined in [[AES-GCM](#)]. The GCM mode is combined with the AES block encryption algorithm to define an AEAD cipher.

The GCM mode is parameterized by the size of the authentication tag and the size of the nonce. This document fixes the size of the nonce at 96 bits. The size of the authentication tag is limited to a small



set of values. For this document however, the size of the authentication tag is fixed at 128 bits.

The set of algorithms defined in this document are in Table 9.

name	value	description
A128GCM	1	AES-GCM mode w/ 128-bit key, 128-bit tag
A192GCM	2	AES-GCM mode w/ 192-bit key, 128-bit tag
A256GCM	3	AES-GCM mode w/ 256-bit key, 128-bit tag

Table 9: Algorithm Value for AES-GCM

Keys may be obtained either from a key structure or from a recipient structure. Implementations encrypting and decrypting MUST validate that the key type, key length and algorithm are correct and appropriate for the entities involved.

When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'Symmetric'.
- o If the 'alg' field present, it MUST match the AES-GCM algorithm being used.
- o If the 'key\_ops' field is present, it MUST include 'encrypt' or 'key wrap' when encrypting.
- o If the 'key\_ops' field is present, it MUST include 'decrypt' or 'key unwrap' when decrypting.

#### **10.1.1. Security Considerations**

When using AES-GCM, the following restrictions MUST be enforced:

- o The key and nonce pair MUST be unique for every message encrypted.
- o The total amount of data encrypted for a single key MUST NOT exceed  $2^{39} - 256$  bits. An explicit check is required only in environments where it is expected that it might be exceeded.

Consideration was given to supporting smaller tag values; the constrained community would desire tag sizes in the 64-bit range.



Doing so drastically changes both the maximum messages size (generally not an issue) and the number of times that a key can be used. Given that CCM is the usual mode for constrained environments, restricted modes are not supported.

## **10.2. AES CCM**

Counter with CBC-MAC (CCM) is a generic authentication encryption block cipher mode defined in [\[RFC3610\]](#). The CCM mode is combined with the AES block encryption algorithm to define a commonly used content encryption algorithm used in constrained devices.

The CCM mode has two parameter choices. The first choice is M, the size of the authentication field. The choice of the value for M involves a trade-off between message growth (from the tag) and the probability that an attacker can undetectably modify a message. The second choice is L, the size of the length field. This value requires a trade-off between the maximum message size and the size of the Nonce.

It is unfortunate that the specification for CCM specified L and M as a count of bytes rather than a count of bits. This leads to possible misunderstandings where AES-CCM-8 is frequently used to refer to a version of CCM mode where the size of the authentication is 64 bits and not 8 bits. These values have traditionally been specified as bit counts rather than byte counts. This document will follow the convention of using bit counts so that it is easier to compare the different algorithms presented in this document.

We define a matrix of algorithms in this document over the values of L and M. Constrained devices are usually operating in situations where they use short messages and want to avoid doing recipient specific cryptographic operations. This favors smaller values of both L and M. Less constrained devices will want to be able to user larger messages and are more willing to generate new keys for every operation. This favors larger values of L and M.

The following values are used for L:

16 bits (2) limits messages to  $2^{16}$  bytes (64 KiB) in length. This is sufficiently long for messages in the constrained world. The nonce length is 13 bytes allowing for  $2^{(13*8)}$  possible values of the nonce without repeating.

64 bits (8) limits messages to  $2^{64}$  bytes in length. The nonce length is 7 bytes allowing for  $2^{56}$  possible values of the nonce without repeating.





The following values are used for M:

64 bits (8) produces a 64-bit authentication tag. This implies that there is a 1 in  $2^{64}$  chance that a modified message will authenticate.

128 bits (16) produces a 128-bit authentication tag. This implies that there is a 1 in  $2^{128}$  chance that a modified message will authenticate.

name	value	L	M	k	description
AES-CCM-16-64-128	10	16	64	128	AES-CCM mode 128-bit key, 64-bit tag, 13-byte nonce
AES-CCM-16-64-256	11	16	64	256	AES-CCM mode 256-bit key, 64-bit tag, 13-byte nonce
AES-CCM-64-64-128	12	64	64	128	AES-CCM mode 128-bit key, 64-bit tag, 7-byte nonce
AES-CCM-64-64-256	13	64	64	256	AES-CCM mode 256-bit key, 64-bit tag, 7-byte nonce
AES-CCM-16-128-128	30	16	128	128	AES-CCM mode 128-bit key, 128-bit tag, 13-byte nonce
AES-CCM-16-128-256	31	16	128	256	AES-CCM mode 256-bit key, 128-bit tag, 13-byte nonce
AES-CCM-64-128-128	32	64	128	128	AES-CCM mode 128-bit key, 128-bit tag, 7-byte nonce
AES-CCM-64-128-256	33	64	128	256	AES-CCM mode 256-bit key, 128-bit tag, 7-byte nonce

Table 10: Algorithm Values for AES-CCM

Keys may be obtained either from a key structure or from a recipient structure. Implementations encrypting and decrypting MUST validate that the key type, key length and algorithm are correct and appropriate for the entities involved.



When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'Symmetric'.
- o If the 'alg' field present, it MUST match the AES-CCM algorithm being used.
- o If the 'key\_ops' field is present, it MUST include 'encrypt' or 'key wrap' when encrypting.
- o If the 'key\_ops' field is present, it MUST include 'decrypt' or 'key unwrap' when decrypting.

#### **10.2.1. Security Considerations**

When using AES-CCM, the following restrictions MUST be enforced:

- o The key and nonce pair MUST be unique for every message encrypted.
- o The total number of times the AES block cipher is used MUST NOT exceed  $2^{61}$  operations. This limitation is the sum of times the block cipher is used in computing the MAC value and in performing stream encryption operations. An explicit check is required only in environments where it is expected that it might be exceeded.

[RFC3610] additionally calls out one other consideration of note. It is possible to do a pre-computation attack against the algorithm in cases where portions of the plaintext are highly predictable. This reduces the security of the key size by half. Ways to deal with this attack include adding a random portion to the nonce value and/or increasing the key size used. Using a portion of the nonce for a random value will decrease the number of messages that a single key can be used for. Increasing the key size may require more resources in the constrained device. See sections [5](#) and [10](#) of [[RFC3610](#)] for more information.

#### **10.3. ChaCha20 and Poly1305**

ChaCha20 and Poly1305 combined together is an AEAD mode that is defined in [[RFC7539](#)]. This is an algorithm defined to be a cipher that is not AES and thus would not suffer from any future weaknesses found in AES. These cryptographic functions are designed to be fast in software-only implementations.

The ChaCha20/Poly1305 AEAD construction defined in [[RFC7539](#)] has no parameterization. It takes a 256-bit key and a 96-bit nonce, as well as the plain text and additional data as inputs and produces the



cipher text as an option. We define one algorithm identifier for this algorithm in Table 11.

name	value	description
ChaCha20/Poly1305	24	ChaCha20/Poly1305 w/ 256-bit key, 128-bit tag

Table 11: Algorithm Value for AES-GCM

Keys may be obtained either from a key structure or from a recipient structure. Implementations encrypting and decrypting MUST validate that the key type, key length and algorithm are correct and appropriate for the entities involved.

When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'Symmetric'.
- o If the 'alg' field present, it MUST match the ChaCha algorithm being used.
- o If the 'key\_ops' field is present, it MUST include 'encrypt' or 'key wrap' when encrypting.
- o If the 'key\_ops' field is present, it MUST include 'decrypt' or 'key unwrap' when decrypting.

### **10.3.1. Security Considerations**

The pair of key, nonce MUST be unique for every invocation of the algorithm. Nonce counters are considered to be an acceptable way of ensuring that they are unique.

## **11. Key Derivation Functions (KDF)**

Key Derivation Functions (KDFs) are used to take some secret value and generate a different one. The secret value comes in three flavors:

- o Secrets that are uniformly random: This is the type of secret that is created by a good random number generator.
- o Secrets that are not uniformly random: This is type of secret that is created by operations like key agreement.





- o Secrets that are not random: This is the type of secret that people generate for things like passwords.

General KDF functions work well with the first type of secret, can do reasonably well with the second type of secret, and generally do poorly with the last type of secret. None of the KDF functions in this section are designed to deal with the type of secrets that are used for passwords. Functions like PBES2 [[RFC2898](#)] need to be used for that type of secret.

The same KDF function can be setup to deal with the first two types of secrets in a different way. The KDF function defined in [Section 11.1](#) is such a function. This is reflected in the set of algorithms defined for HKDF.

When using KDF functions, one component that is included is context information. Context information is used to allow for different keying information to be derived from the same secret. The use of context based keying material is considered to be a good security practice.

This document defines a single context structure and a single KDF function. These elements are used for all of the recipient algorithms defined in this document that require a KDF process. These algorithms are defined in [Section 12.1.2](#), [Section 12.4.1](#), and [Section 12.5.1](#).

### **[11.1](#). HMAC-based Extract-and-Expand Key Derivation Function (HKDF)**

The HKDF key derivation algorithm is defined in [[RFC5869](#)].

The HKDF algorithm takes these inputs:

secret - a shared value that is secret. Secrets may be either previously shared or derived from operations like a DH key agreement.

salt - an optional value that is used to change the generation process. The salt value can be either public or private. If the salt is public and carried in the message, then the 'salt' algorithm header parameter defined in Table 13 is used. While [[RFC5869](#)] suggests that the length of the salt be the same as the length of the underlying hash value, any amount of salt will improve the security as different key values will be generated. This parameter is protected by being included in the key computation and does not need to be separately authenticated. The salt value does not need to be unique for every message sent.



length - the number of bytes of output that need to be generated.

context information - Information that describes the context in which the resulting value will be used. Making this information specific to the context in which the material is going to be used ensures that the resulting material will always be tied to that usage. The context structure defined in [Section 11.2](#) is used by the KDF functions in this document.

PRF - The underlying pseudo-random function to be used in the HKDF algorithm. The PRF is encoded into the HKDF algorithm selection.

HKDF is defined to use HMAC as the underlying PRF. However, it is possible to use other functions in the same construct to provide a different KDF function that is more appropriate in the constrained world. Specifically, one can use AES-CBC-MAC as the PRF for the expand step, but not for the extract step. When using a good random shared secret of the correct length, the extract step can be skipped. For the AES algorithm versions, the extract step is always skipped.

The extract step cannot be skipped if the secret is not uniformly random, for example, if it is the result of an ECDH key agreement step. (This implies that the AES HKDF version cannot be used with ECDH.) If the extract step is skipped, the 'salt' value is not used as part of the HKDF functionality.

The algorithms defined in this document are found in Table 12.

name	PRF	description
HKDF SHA-256	HMAC with SHA-256	HKDF using HMAC SHA-256 as the PRF
HKDF SHA-512	HMAC with SHA-512	HKDF using HMAC SHA-512 as the PRF
HKDF AES-MAC-128	AES-CBC-MAC-128	HKDF using AES-MAC as the PRF w/ 128-bit key
HKDF AES-MAC-256	AES-CBC-MAC-256	HKDF using AES-MAC as the PRF w/ 256-bit key

Table 12: HKDF algorithms



+-----+	+-----+	+-----+	+-----+
name	label	type	description
+-----+	+-----+	+-----+	+-----+
salt	-20	bstr	Random salt
+-----+	+-----+	+-----+	+-----+

Table 13: HKDF Algorithm Parameters

## 11.2. Context Information Structure

The context information structure is used to ensure that the derived keying material is "bound" to the context of the transaction. The context information structure used here is based on that defined in [SP800-56A]. By using CBOR for the encoding of the context information structure, we automatically get the same type and length separation of fields that is obtained by the use of ASN.1. This means that there is no need to encode the lengths for the base elements as it is done by the encoding used in JOSE ([Section 4.6.2 of \[RFC7518\]](#)).

The context information structure refers to PartyU and PartyV as the two parties that are doing the key derivation. Unless the application protocol defines differently, we assign PartyU to the entity that is creating the message and PartyV to the entity that is receiving the message. By doing this association, different keys will be derived for each direction as the context information is different in each direction.

The context structure is built from information that is known to both entities. This information can be obtained from a variety of sources:

- o Fields can be defined by the application. This is commonly used to assign fixed names to parties, but can be used for other items such as nonces.
- o Fields can be defined by usage of the output. Examples of this are the algorithm and key size that are being generated.
- o Fields can be defined by parameters from the message. We define a set of parameters in Table 14 that can be used to carry the values associated with the context structure. Examples of this are identities and nonce values. These parameters are designed to be placed in the unprotected bucket of the recipient structure. (They do not need to be in the protected bucket since they already are included in the cryptographic computation by virtue of being included in the context structure.)



name	label	type	description
PartyU identity	-21	bstr	Party U identity Information
PartyU nonce	-22	bstr / int	Party U provided nonce
PartyU other	-23	bstr	Party U other provided information
PartyV identity	-24	bstr	Party V identity Information
PartyV nonce	-25	bstr / int	Party V provided nonce
PartyV other	-26	bstr	Party V other provided information

Table 14: Context Algorithm Parameters

We define a CBOR object to hold the context information. This object is referred to as `CBOR_KDF_Context`. The object is based on a CBOR array type. The fields in the array are:

**AlgorithmID** This field indicates the algorithm for which the key material will be used. This normally is either a Key Wrap algorithm identifier or a Content Encryption algorithm identifier. The values are from the "COSE Algorithm Value" registry. This field is required to be present. The field exists in the context information so that if the same environment is used for different algorithms, then completely different keys will be generated for each of those algorithms. (This practice means if algorithm A is broken and thus is easier to find, the key derived for algorithm B will not be the same as the key derived for algorithm A.)

**PartyUInfo** This field holds information about party U. The `PartyUInfo` is encoded as a CBOR array. The elements of `PartyUInfo` are encoded in the order presented, however if the element does not exist no element is placed in the array. The elements of the `PartyUInfo` array are:

**identity** This contains the identity information for party U. The identities can be assigned in one of two manners. Firstly, a protocol can assign identities based on roles. For example,





the roles of "client" and "server" may be assigned to different entities in the protocol. Each entity would then use the correct label for the data they send or receive. The second way for a protocol to assign identities is to use a name based on a naming system (i.e., DNS, X.509 names).

We define an algorithm parameter 'PartyU identity' that can be used to carry identity information in the message. However, identity information is often known as part of the protocol and can thus be inferred rather than made explicit. If identity information is carried in the message, applications SHOULD have a way of validating the supplied identity information. The identity information does not need to be specified and is set to nil in that case.

nonce This contains a nonce value. The nonce can either be implicit from the protocol or carried as a value in the unprotected headers.

We define an algorithm parameter 'PartyU nonce' that can be used to carry this value in the message. However, the nonce value could be determined by the application and the value determined from elsewhere.

This option does not need to be specified and is set to nil in that case

other This contains other information that is defined by the protocol.

This option does not need to be specified and is set to nil in that case

PartyVInfo This field holds information about party V. The content of the structure are the same as for the PartyUInfo but for partyV.

SuppPubInfo This field contains public information that is mutually known to both parties.

keyDataLength This is set to the number of bits of the desired output value. (This practice means if algorithm A can use two different key lengths, the key derived for longer key size will not contain the key for shorter key size as a prefix.)

protected This field contains the protected parameter field. If there are no elements in the protected field, then use a zero length bstr.

other The field other is for free form data defined by the application. An example is that an application could defined two different strings to be placed here to generate different



keys for a data stream vs a control stream. This field is optional and will only be present if the application defines a structure for this information. Applications that define this SHOULD use CBOR to encode the data so that types and lengths are correctly included.

**SuppPrivInfo** This field contains private information that is mutually known private information. An example of this information would be a pre-existing shared secret. (This could, for example, be used in combination with an ECDH key agreement to provide a secondary proof of identity.) The field is optional and will only be present if the application defines a structure for this information. Applications that define this SHOULD use CBOR to encode the data so that types and lengths are correctly included.

The following CDDL fragment corresponds to the text above.

```
PartyInfo = (
    identity : bstr / nil,
    nonce : bstr / int / nil,
    other : bstr / nil,
)

COSE_KDF_Context = [
    AlgorithmID : int / tstr,
    PartyUInfo : [ PartyInfo ],
    PartyVInfo : [ PartyInfo ],
    SuppPubInfo : [
        keyDataLength : uint,
        protected : empty_or_serialized_map,
        ? other : bstr
    ],
    ? SuppPrivInfo : bstr
]
```

## **12. Recipient Algorithm Classes**

Recipient algorithms can be defined into a number of different classes. COSE has the ability to support many classes of recipient algorithms. In this section, a number of classes are listed and then a set of algorithms are specified for each of the classes. The names of the recipient algorithm classes used here are the same as are defined in [\[RFC7516\]](#). Other specifications use different terms for the recipient algorithm classes or do not support some of the recipient algorithm classes.



### **12.1. Direct Encryption**

The direct encryption class algorithms share a secret between the sender and the recipient that is used either directly or after manipulation as the CEK. When direct encryption mode is used, it MUST be the only mode used on the message.

The COSE\_Encrypt structure for the recipient is organized as follows:

- o The 'protected' field MUST be a zero length item unless it is used in the computation of the content key.
- o The 'alg' parameter MUST be present.
- o A parameter identifying the shared secret SHOULD be present.
- o The 'ciphertext' field MUST be a zero length item.
- o The 'recipients' field MUST be absent.

#### **12.1.1. Direct Key**

This recipient algorithm is the simplest; the identified key is directly used as the key for the next layer down in the message. There are no algorithm parameters defined for this algorithm. The algorithm identifier value is assigned in Table 15.

When this algorithm is used, the protected field MUST be zero length. The key type MUST be 'Symmetric'.

+-----+	+-----+	+-----+
name	value	description
+-----+	+-----+	+-----+
direct	-6	Direct use of CEK
+-----+	+-----+	+-----+

Table 15: Direct Key

#### **12.1.1.1. Security Considerations**

This recipient algorithm has several potential problems that need to be considered:

- o These keys need to have some method to be regularly updated over time. All of the content encryption algorithms specified in this document have limits on how many times a key can be used without significant loss of security.



- o These keys need to be dedicated to a single algorithm. There have been a number of attacks developed over time when a single key is used for multiple different algorithms. One example of this is the use of a single key both for CBC encryption mode and CBC-MAC authentication mode.
- o Breaking one message means all messages are broken. If an adversary succeeds in determining the key for a single message, then the key for all messages is also determined.

#### **12.1.2. Direct Key with KDF**

These recipient algorithms take a common shared secret between the two parties and applies the HKDF function ([Section 11.1](#)), using the context structure defined in [Section 11.2](#) to transform the shared secret into the CEK. The 'protected' field can be of non-zero length. Either the 'salt' parameter of HKDF or the partyU 'nonce' parameter of the context structure MUST be present. The salt/nonce parameter can be generated either randomly or deterministically. The requirement is that it be a unique value for the shared secret in question.

If the salt/nonce value is generated randomly, then it is suggested that the length of the random value be the same length as the hash function underlying HKDF. While there is no way to guarantee that it will be unique, there is a high probability that it will be unique. If the salt/nonce value is generated deterministically, it can be guaranteed to be unique and thus there is no length requirement.

A new IV must be used for each message if the same key is used. The IV can be modified in a predictable manner, a random manner or an unpredictable manner (i.e., encrypting a counter).

The IV used for a key can also be generated from the same HKDF functionality as the key is generated. If HKDF is used for generating the IV, the algorithm identifier is set to "IV-GENERATION".

When these algorithms are used, the key type MUST be 'symmetric'.

The set of algorithms defined in this document can be found in Table 16.





name	value	KDF	description
direct+HKDF-SHA-256	-10	HKDF SHA-256	Shared secret w/ HKDF and SHA-256
direct+HKDF-SHA-512	-11	HKDF SHA-512	Shared secret w/ HKDF and SHA-512
direct+HKDF-AES-128	-12	HKDF AES- MAC-128	Shared secret w/ AES- MAC 128-bit key
direct+HKDF-AES-256	-13	HKDF AES- MAC-256	Shared secret w/ AES- MAC 256-bit key

Table 16: Direct Key

When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'Symmetric'.
- o If the 'alg' field present, it MUST match the algorithm being used.
- o If the 'key\_ops' field is present, it MUST include 'deriveKey' or 'deriveBits'.

#### [12.1.2.1.](#) Security Considerations

The shared secret needs to have some method to be regularly updated over time. The shared secret forms the basis of trust. Although not used directly, it should still be subject to scheduled rotation.

While these methods do not provide for PFS, as the same shared secret is used for all of the keys generated, if the key for any single message is discovered only the message (or series of messages) using that derived key are compromised. A new key derivation step will generate a new key which requires the same amount of work to get the key.

#### [12.2.](#) Key Wrapping

In key wrapping mode, the CEK is randomly generated and that key is then encrypted by a shared secret between the sender and the recipient. All of the currently defined key wrapping algorithms for COSE are AE algorithms. Key wrapping mode is considered to be



superior to direct encryption if the system has any capability for doing random key generation. This is because the shared key is used to wrap random data rather than data that has some degree of organization and may in fact be repeating the same content. The use of Key Wrapping loses the weak data origination that is provided by the direct encryption algorithms.

The COSE\_Encrypt structure for the recipient is organized as follows:

- o The 'protected' field MUST be absent if the key wrap algorithm is an AE algorithm.
- o The 'recipients' field is normally absent, but can be used. Applications MUST deal with a recipient field present, not being able to decrypt that recipient is an acceptable way of dealing with it. Failing to process the message is not an acceptable way of dealing with it.
- o The plain text to be encrypted is the key from next layer down (usually the content layer).
- o At a minimum, the 'unprotected' field MUST contain the 'alg' parameter and SHOULD contain a parameter identifying the shared secret.

#### **12.2.1. AES Key Wrapping**

The AES Key Wrapping algorithm is defined in [\[RFC3394\]](#). This algorithm uses an AES key to wrap a value that is a multiple of 64 bits. As such, it can be used to wrap a key for any of the content encryption algorithms defined in this document. The algorithm requires a single fixed parameter, the initial value. This is fixed to the value specified in [Section 2.2.3.1 of \[RFC3394\]](#). There are no public parameters that vary on a per invocation basis. The protected header field MUST be empty.

Keys may be obtained either from a key structure or from a recipient structure. Implementations encrypting and decrypting MUST validate that the key type, key length and algorithm are correct and appropriate for the entities involved.

When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'Symmetric'.
- o If the 'alg' field is present, it MUST match the AES Key Wrap algorithm being used.



- o If the 'key\_ops' field is present, it MUST include 'encrypt' or 'key wrap' when encrypting.
- o If the 'key\_ops' field is present, it MUST include 'decrypt' or 'key unwrap' when decrypting.

name	value	key size	description
A128KW	-3	128	AES Key Wrap w/ 128-bit key
A192KW	-4	192	AES Key Wrap w/ 192-bit key
A256KW	-5	256	AES Key Wrap w/ 256-bit key

Table 17: AES Key Wrap Algorithm Values

#### [12.2.1.1.](#) Security Considerations for AES-KW

The shared secret needs to have some method to be regularly updated over time. The shared secret is the basis of trust.

#### [12.3.](#) Key Encryption

Key Encryption mode is also called key transport mode in some standards. Key Encryption mode differs from Key Wrap mode in that it uses an asymmetric encryption algorithm rather than a symmetric encryption algorithm to protect the key. This document does not define any Key Encryption mode algorithms.

When using a key encryption algorithm, the COSE\_Encrypt structure for the recipient is organized as follows:

- o The 'protected' field MUST be absent.
- o The plain text to be encrypted is the key from next layer down (usually the content layer).
- o At a minimum, the 'unprotected' field MUST contain the 'alg' parameter and SHOULD contain a parameter identifying the asymmetric key.

#### [12.4.](#) Direct Key Agreement

The 'direct key agreement' class of recipient algorithms uses a key agreement method to create a shared secret. A KDF is then applied to the shared secret to derive a key to be used in protecting the data.



This key is normally used as a CEK or MAC key, but could be used for other purposes if more than two layers are in use (see [Appendix B](#)).

The most commonly used key agreement algorithm is Diffie-Hellman, but other variants exist. Since COSE is designed for a store and forward environment rather than an on-line environment, many of the DH variants cannot be used as the receiver of the message cannot provide any dynamic key material. One side-effect of this is that perfect forward secrecy (see [\[RFC4949\]](#)) is not achievable. A static key will always be used for the receiver of the COSE object.

Two variants of DH that are supported are:

Ephemeral-Static DH: where the sender of the message creates a one-time DH key and uses a static key for the recipient. The use of the ephemeral sender key means that no additional random input is needed as this is randomly generated for each message.

Static-Static DH: where a static key is used for both the sender and the recipient. The use of static keys allows for recipient to get a weak version of data origination for the message. When static-static key agreement is used, then some piece of unique data for the KDF is required to ensure that a different key is created for each message.

When direct key agreement mode is used, there MUST be only one recipient in the message. This method creates the key directly and that makes it difficult to mix with additional recipients. If multiple recipients are needed, then the version with key wrap needs to be used.

The COSE\_Encrypt structure for the recipient is organized as follows:

- o At a minimum, headers MUST contain the 'alg' parameter and SHOULD contain a parameter identifying the recipient's asymmetric key.
- o The headers SHOULD identify the sender's key for the static-static versions and MUST contain the sender's ephemeral key for the ephemeral-static versions.

#### **12.4.1. ECDH**

The mathematics for Elliptic Curve Diffie-Hellman can be found in [\[RFC6090\]](#). In this document, the algorithm is extended to be used with the two curves defined in [\[RFC7748\]](#).

ECDH is parameterized by the following:





- o Curve Type/Curve: The curve selected controls not only the size of the shared secret, but the mathematics for computing the shared secret. The curve selected also controls how a point in the curve is represented and what happens for the identity points on the curve. In this specification, we allow for a number of different curves to be used. A set of curves are defined in Table 22. The math used to obtain the computed secret is based on the curve selected and not on the ECDH algorithm. For this reason, a new algorithm does not need to be defined for each of the curves.
- o Computed Secret to Shared Secret: Once the computed secret is known, the resulting value needs to be converted to a byte string to run the KDF function. The X coordinate is used for all of the curves defined in this document. For curves X25519 and X448, the resulting value is used directly as it is a byte string of a known length. For the P-256, P-384 and P-521 curves, the X coordinate is run through the I2OSP function defined in [\[RFC3447\]](#), using the same computation for n as is defined in [Section 8.1](#).
- o Ephemeral-static or static-static: The key agreement process may be done using either a static or an ephemeral key for the sender's side. When using ephemeral keys, the sender MUST generate a new ephemeral key for every key agreement operation. The ephemeral key is placed in the 'ephemeral key' parameter and MUST be present for all algorithm identifiers that use ephemeral keys. When using static keys, the sender MUST either generate a new random value or otherwise create a unique value. For the KDF functions used, this means either in the 'salt' parameter for HKDF (Table 13) or in the 'PartyU nonce' parameter for the context structure (Table 14) MUST be present. (Both may be present if desired.) The value in the parameter MUST be unique for the pair of keys being used. It is acceptable to use a global counter that is incremented for every static-static operation and use the resulting value. When using static keys, the static key should be identified to the recipient. The static key can be identified either by providing the key ('static key') or by providing a key identifier for the static key ('static key id'). Both of these parameters are defined in Table 19.
- o Key derivation algorithm: The result of an ECDH key agreement process does not provide a uniformly random secret. As such, it needs to be run through a KDF in order to produce a usable key. Processing the secret through a KDF also allows for the introduction of context material: how the key is going to be used, and one-time material for static-static key agreement. All of the algorithms defined in this document use one of the HKDF algorithms defined in [Section 11.1](#) with the context structure defined in [Section 11.2](#).



- o Key Wrap algorithm: No key wrap algorithm is used. This is represented in Table 18 as 'none'. The key size for the context structure is the content layer encryption algorithm size.

The set of direct ECDH algorithms defined in this document are found in Table 18.

name	value	KDF	Ephemeral-Static	Key Wrap	description
ECDH-ES + HKDF-256	-25	HKDF - SHA-256	yes	none	ECDH ES w/ HKDF - generate key directly
ECDH-ES + HKDF-512	-26	HKDF - SHA-512	yes	none	ECDH ES w/ HKDF - generate key directly
ECDH-SS + HKDF-256	-27	HKDF - SHA-256	no	none	ECDH SS w/ HKDF - generate key directly
ECDH-SS + HKDF-512	-28	HKDF - SHA-512	no	none	ECDH SS w/ HKDF - generate key directly

Table 18: ECDH Algorithm Values



name	label	type	algorithm	description
ephemeral key	-1	COSE_Key	ECDH-ES	Ephemeral Public key for the sender
static key	-2	COSE_Key	ECDH-ES	Static Public key for the sender
static key id	-3	bstr	ECDH-SS	Static Public key identifier for the sender

Table 19: ECDH Algorithm Parameters

This document defines these algorithms to be used with the curves P-256, P-384, P-521, X25519, and X448. Implementations MUST verify that the key type and curve are correct. Different curves are restricted to different key types. Implementations MUST verify that the curve and algorithm are appropriate for the entities involved.

When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'EC2' or 'OKP'.
- o If the 'alg' field present, it MUST match the Key Agreement algorithm being used.
- o If the 'key\_ops' field is present, it MUST include 'derive key' or 'derive bits' for the private key.
- o If the 'key\_ops' field is present, it MUST be empty for the public key.

#### **12.4.2. Security Considerations**

Some method of checking that points provided from external entities are valid. For the 'EC2' key format, this can be done by checking that the x and y values form a point on the curve. For the 'OKP' format, there is no simple way to do point validation.

Consideration was given to requiring that the public keys of both entities be provided as part of the key derivation process. (As recommended in [section 6.1 of \[RFC7748\]](#).) This was not done as COSE is used in a store and forward format rather than in on line key exchange. In order for this to be a problem, either the receiver



public key has to be chosen maliciously or the sender has to be malicious. In either case, all security evaporates anyway.

A proof of possession of the private key associated with the public key is recommended when a key is moved from untrusted to trusted. (Either by the end user or by the entity that is responsible for making trust statements on keys.)

### **12.5. Key Agreement with KDF**

Key Agreement with Key Wrapping uses a randomly generated CEK. The CEK is then encrypted using a Key Wrapping algorithm and a key derived from the shared secret computed by the key agreement algorithm.

The COSE\_Encrypt structure for the recipient is organized as follows:

- o The 'protected' field is fed into the KDF context structure.
- o The plain text to be encrypted is the key from next layer down (usually the content layer).
- o The 'alg' parameter MUST be present in the layer.
- o A parameter identifying the recipient's key SHOULD be present. A parameter identifying the sender's key SHOULD be present.

#### **12.5.1. ECDH**

These algorithms are defined in Table 20.

ECDH with Key Agreement is parameterized by the same parameters as for ECDH [Section 12.4.1](#) with the following modifications:

- o Key Wrap Algorithm: Any of the key wrap algorithms defined in [Section 12.2.1](#) are supported. The size of the key used for the key wrap algorithm is fed into the KDF function. The set of identifiers are found in Table 20.





name	value	KDF	Ephemeral- Static	Key Wrap	description
ECDH-ES + A128KW	-29	HKDF - SHA-256	yes	A128KW	ECDH ES w/ Concat KDF and AES Key wrap w/ 128 bit key
ECDH-ES + A192KW	-30	HKDF - SHA-256	yes	A192KW	ECDH ES w/ Concat KDF and AES Key wrap w/ 192 bit key
ECDH-ES + A256KW	-31	HKDF - SHA-256	yes	A256KW	ECDH ES w/ Concat KDF and AES Key wrap w/ 256 bit key
ECDH-SS + A128KW	-32	HKDF - SHA-256	no	A128KW	ECDH SS w/ Concat KDF and AES Key wrap w/ 128 bit key
ECDH-SS + A192KW	-33	HKDF - SHA-256	no	A192KW	ECDH SS w/ Concat KDF and AES Key wrap w/ 192 bit key
ECDH-SS + A256KW	-34	HKDF - SHA-256	no	A256KW	ECDH SS w/ Concat KDF and AES Key wrap w/ 256 bit key

Table 20: ECDH Algorithm Values

When using a COSE key for this algorithm, the following checks are made:

- o The 'kty' field MUST be present and it MUST be 'EC2' or 'OKP'.



- o If the 'alg' field present, it MUST match the Key Agreement algorithm being used.
- o If the 'key\_ops' field is present, it MUST include 'derive key' or 'derive bits' for the private key.
- o If the 'key\_ops' field is present, it MUST be empty for the public key.

### 13. Keys

The COSE\_Key object defines a way to hold a single key object. It is still required that the members of individual key types be defined. This section of the document is where we define an initial set of members for specific key types.

For each of the key types, we define both public and private members. The public members are what is transmitted to others for their usage. Private members allow for the archival of keys by individuals. However, there are some circumstances in which private keys may be distributed to entities in a protocol. Examples include: entities that have poor random number generation, centralized key creation for multi-cast type operations, and protocols in which a shared secret is used as a bearer token for authorization purposes.

Key types are identified by the 'kty' member of the COSE\_Key object. In this document, we define four values for the member:

name	value	description
OKP	1	Octet Key Pair
EC2	2	Elliptic Curve Keys w/ X,Y Coordinate pair
Symmetric	4	Symmetric Keys
Reserved	0	This value is reserved

Table 21: Key Type Values

#### 13.1. Elliptic Curve Keys

Two different key structures could be defined for Elliptic Curve keys. One version uses both an x and a y coordinate, potentially with point compression ('EC2'). This is the traditional EC point representation that is used in [RFC5480]. The other version uses



only the x coordinate as the y coordinate is either to be recomputed or not needed for the key agreement operation ('OKP').

Applications MUST check that the curve and the key type are consistent and reject a key if they are not.

name	key type	value	description
P-256	EC2	1	NIST P-256 also known as secp256r1
P-384	EC2	2	NIST P-384 also known as secp384r1
P-521	EC2	3	NIST P-521 also known as secp521r1
X25519	OKP	4	X25519 for use w/ ECDH only
X448	OKP	5	X448 for use w/ ECDH only
Ed25519	OKP	6	Ed25519 for use w/ EdDSA only
Ed448	OKP	7	Ed448 for use w/ EdDSA only

Table 22: EC Curves

#### **13.1.1. Double Coordinate Curves**

The traditional way of sending EC curves has been to send either both the x and y coordinates, or the x coordinate and a sign bit for the y coordinate. The latter encoding has not been recommended in the IETF due to potential IPR issues. However, for operations in constrained environments, the ability to shrink a message by not sending the y coordinate is potentially useful.

For EC keys with both coordinates, the 'kty' member is set to 2 (EC2). The key parameters defined in this section are summarized in Table 23. The members that are defined for this key type are:

**crv** contains an identifier of the curve to be used with the key.

The curves defined in this document for this key type can be found in Table 22. Other curves may be registered in the future and private curves can be used as well.

**x** contains the x coordinate for the EC point. The integer is converted to an octet string as defined in [SEC1]. Leading zero octets MUST be preserved.



y contains either the sign bit or the value of y coordinate for the EC point. When encoding the value y, the integer is converted to an octet string (as defined in [SEC1]) and encoded as a CBOR bstr. Leading zero octets MUST be preserved. The compressed point encoding is also supported. Compute the sign bit as laid out in the Elliptic-Curve-Point-to-Octet-String Conversion function of [SEC1]. If the sign bit is zero, then encode y as a CBOR false value, otherwise encode y as a CBOR true value. The encoding of the infinity point is not supported.

d contains the private key.

For public keys, it is REQUIRED that 'crv', 'x' and 'y' be present in the structure. For private keys, it is REQUIRED that 'crv' and 'd' be present in the structure. For private keys, it is RECOMMENDED that 'x' and 'y' also be present, but they can be recomputed from the required elements and omitting them saves on space.

name	key	value	type	description
	type			
crv	2	-1	int / tstr	EC Curve identifier - Taken from the COSE Curves registry
x	2	-2	bstr	X Coordinate
y	2	-3	bstr / bool	Y Coordinate
d	2	-4	bstr	Private key

Table 23: EC Key Parameters

### 13.2. Octet Key Pair

A new key type is defined for Octet Key Pairs (OKP). Do not assume that keys using this type are elliptic curves. This key type could be used for other curve types (for example, mathematics based on hyper-elliptic surfaces).

The key parameters defined in this section are summarized in Table 24. The members that are defined for this key type are:

crv contains an identifier of the curve to be used with the key.

The curves defined in this document for this key type can be found





in Table 22. Other curves may be registered in the future and private curves can be used as well.

x contains the x coordinate for the EC point. The octet string represents a little-endian encoding of x.

d contains the private key.

For public keys, it is REQUIRED that 'crv' and 'x' be present in the structure. For private keys, it is REQUIRED that 'crv' and 'd' be present in the structure. For private keys, it is RECOMMENDED that 'x' also be present, but it can be recomputed from the required elements and omitting it saves on space.

name	key	value	type	description
	type			
crv	1	-1	int / tstr	EC Curve identifier - Taken from the COSE Key Common Parameters registry
x	1	-2	bstr	X Coordinate
d	1	-4	bstr	Private key

Table 24: EC Key Parameters

### 13.3. Symmetric Keys

Occasionally it is required that a symmetric key be transported between entities. This key structure allows for that to happen.

For symmetric keys, the 'kty' member is set to 3 (Symmetric). The member that is defined for this key type is:

k contains the value of the key.

This key structure does not have a form that contains only public members. As it is expected that this key structure is going to be transmitted, care must be taking that it is never transmitted accidentally or insecurely. For symmetric keys, it is REQUIRED that 'k' be present in the structure.



name	key type	value	type	description
k	4	-1	bstr	Key Value

Table 25: Symmetric Key Parameters

#### 14. CBOR Encoder Restrictions

There has been an attempt to limit the number of places where the document needs to impose restrictions on how the CBOR Encoder needs to work. We have managed to narrow it down to the following restrictions:

- o The restriction applies to the encoding the Sig\_structure, the Enc\_structure, and the MAC\_structure.
- o The rules for Canonical CBOR ([Section 3.9 of RFC 7049](#)) MUST be used in these locations. The main rule that needs to be enforced is that all lengths in these structures MUST be encoded such that they are encoded using definite lengths and the minimum length encoding is used.
- o Applications MUST NOT generate messages with the same label used twice as a key in a single map. Applications MUST NOT parse and process messages with the same label used twice as a key in a single map. Applications can enforce the parse and process requirement by using parsers that will fail the parse step or by using parsers that will pass all keys to the application and the application can perform the check for duplicate keys.

#### 15. Application Profiling Considerations

This document is designed to provide a set of security services, but not to provide implementation requirements for specific usage. The interoperability requirements are provided for how each of the individual services are used and how the algorithms are to be used for interoperability. The requirements about which algorithms and which services are needed are deferred to each application.

Applications are therefore intended to profile the usage of this document. This section provides a set of guidelines and topics that applications need to consider when using this document.

- o Applications need to determine the set of messages defined in this document that they will be using. The set of messages corresponds



fairly directly to the set of security services that are needed and to the security levels needed.

- o Applications may define new header parameters for a specific purpose. Applications will often times select specific header parameters to use or not to use. For example, an application would normally state a preference for using either the IV or the partial IV parameter. If the partial IV parameter is specified, then the application would also need to define how the fixed portion of the IV would be determined.
- o When applications use externally defined authenticated data, they need to define how that data is encoded. This document assumes that the data will be provided as a byte stream. More information can be found in [Section 4.3](#).
- o Applications need to determine the set of security algorithms that are to be used. When selecting the algorithms to be used as the mandatory to implement set, consideration should be given to choosing different types of algorithms when two are chosen for a specific purpose. An example of this would be choosing HMAC-SHA512 and AES-CMAC as different MAC algorithms; the construction is vastly different between these two algorithms. This means that a weakening of one algorithm would be unlikely to lead to a weakening of the other algorithms. Of course, these algorithms do not provide the same level of security and thus may not be comparable for the desired security functionality.
- o Applications may need to provide some type of negotiation or discovery method if multiple algorithms or message structures are permitted. The method can be as simple as requiring preconfiguration of the set of algorithms to providing a discovery method built into the protocol. S/MIME provided a number of different ways to approach the problem that applications could follow:
  - \* Advertising in the message (S/MIME capabilities) [[RFC5751](#)].
  - \* Advertising in the certificate (capabilities extension) [[RFC4262](#)].
  - \* Minimum requirements for the S/MIME, which have been updated over time [[RFC2633](#)][[RFC5751](#)].



## **16. IANA Considerations**

### **16.1. CBOR Tag assignment**

It is requested that IANA assign the following tags from the "Concise Binary Object Representation (CBOR) Tags" registry. It is requested that the tags for COSE\_Sign1, COSE\_Encrypt0, and COSE\_Mac0 be assigned in the 1 to 23 value range (one byte long when encoded). It is requested that the rest of the tags be assigned in the 24 to 255 value range (two bytes long when encoded).

The tags to be assigned are in Table 1.

### **16.2. COSE Header Parameters Registry**

It is requested that IANA create a new registry entitled "COSE Header Parameters". The registry is to be created as Expert Review Required. Expert review guidelines are provided in [Section 16.10](#).

The columns of the registry are:

**name** The name is present to make it easier to refer to and discuss the registration entry. The value is not used in the protocol. Names are to be unique in the table.

**label** This is the value used for the label. The label can be either an integer or a string. Registration in the table is based on the value of the label requested. Integer values between 1 and 255 and strings of length 1 are designated as Standards Track Document required. Integer values from 256 to 65535 and strings of length 2 are designated as Specification Required. Integer values of greater than 65535 and strings of length greater than 2 are designated as expert review. Integer values in the range -1 to -65536 are delegated to the "COSE Header Algorithm Labels" registry. Integer values less than -65536 are marked as private use.

**value** This contains the CBOR type for the value portion of the label.

**value registry** This contains a pointer to the registry used to contain values where the set is limited.

**description** This contains a brief description of the header field.

**specification** This contains a pointer to the specification defining the header field (where public).





The initial contents of the registry can be found in Table 2 and Table 27. The specification column for all rows in that table should be this document.

Additionally, the label of 0 is to be marked as 'Reserved'.

### **16.3. COSE Header Algorithm Labels Registry**

It is requested that IANA create a new registry entitled "COSE Header Algorithm Labels". The registry is to be created as Expert Review Required. Expert review guidelines are provided in [Section 16.10](#).

The columns of the registry are:

name The name is present to make it easier to refer to and discuss the registration entry. The value is not used in the protocol.

algorithm The algorithm(s) that this registry entry is used for. This value is taken from the "COSE Algorithm Values" registry. Multiple algorithms can be specified in this entry. For the table, the algorithm, label pair MUST be unique.

label This is the value used for the label. The label is an integer in the range of -1 to -65536.

value This contains the CBOR type for the value portion of the label.

value registry This contains a pointer to the registry used to contain values where the set is limited.

description This contains a brief description of the header field.

specification This contains a pointer to the specification defining the header field (where public).

The initial contents of the registry can be found in Table 13, Table 14, and Table 19. The specification column for all rows in that table should be this document.

### **16.4. COSE Algorithms Registry**

It is requested that IANA create a new registry entitled "COSE Algorithms Registry". The registry is to be created as Expert Review Required. Expert review guidelines are provided in [Section 16.10](#).

The columns of the registry are:



**value** The value to be used to identify this algorithm. Algorithm values MUST be unique. The value can be a positive integer, a negative integer or a string. Integer values between -256 and 255 and strings of length 1 are designated as Standards Track Document required. Integer values from -65536 to 65535 and strings of length 2 are designated as Specification Required. Integer values of greater than 65535 and strings of length greater than 2 are designated as expert review. Integer values less than -65536 are marked as private use.

**description** A short description of the algorithm.

**specification** A document where the algorithm is defined (if publicly available).

The initial contents of the registry can be found in Table 10, Table 9, Table 11, Table 5, Table 7, Table 8, Table 15, Table 16, Table 17, and Table 18. The specification column for all rows in that table should be this document.

NOTE: The assignment of algorithm identifiers in this document was done so that positive numbers were used for the first layer objects (COSE\_Sign, COSE\_Sign1, COSE\_Encrypt, COSE\_Encrypt0, COSE\_Mac, and COSE\_Mac0). Negative numbers were used for second layer objects (COSE\_Signature and COSE\_recipient). Expert reviewers should consider this practice, but are not expected to be restricted by this precedent.

### **16.5. COSE Key Common Parameters Registry**

It is requested that IANA create a new registry entitled "COSE Key Common Parameters" registry. The registry is to be created as Expert Review Required. Expert review guidelines are provided in [Section 16.10](#).

The columns of the registry are:

**name** This is a descriptive name that enables easier reference to the item. It is not used in the encoding.

**label** The value to be used to identify this algorithm. Key map labels MUST be unique. The label can be a positive integer, a negative integer or a string. Integer values between 0 and 255 and strings of length 1 are designated as Standards Track Document required. Integer values from 256 to 65535 and strings of length 2 are designated as Specification Required. Integer values of greater than 65535 and strings of length greater than 2 are designated as expert review. Integer values in the range -1 to



-65536 are used for key parameters specific to a single algorithm delegated to the "COSE Key Type Parameter Labels" registry. Integer values less than -65536 are marked as private use.

CBOR Type This field contains the CBOR type for the field.

registry This field denotes the registry that values come from, if one exists.

description This field contains a brief description for the field.

specification This contains a pointer to the public specification for the field if one exists

This registry will be initially populated by the values in [Section 7.1](#). The specification column for all of these entries will be this document.

#### **[16.6](#). COSE Key Type Parameters Registry**

It is requested that IANA create a new registry "COSE Key Type Parameters". The registry is to be created as Expert Review Required. Expert review guidelines are provided in [Section 16.10](#).

The columns of the table are:

key type This field contains a descriptive string of a key type. This should be a value that is in the COSE Key Common Parameters table and is placed in the 'kty' field of a COSE Key structure.

name This is a descriptive name that enables easier reference to the item. It is not used in the encoding.

label The label is to be unique for every value of key type. The range of values is from -256 to -1. Labels are expected to be reused for different keys.

CBOR type This field contains the CBOR type for the field.

description This field contains a brief description for the field.

specification This contains a pointer to the public specification for the field if one exists.

This registry will be initially populated by the values in Table 23 and Table 25. The specification column for all of these entries will be this document.



### **16.7. COSE Elliptic Curve Parameters Registry**

It is requested that IANA create a new registry "COSE Elliptic Curve Parameters". The registry is to be created as Expert Review Required. Expert review guidelines are provided in [Section 16.10](#).

The columns of the table are:

name This is a descriptive name that enables easier reference to the item. It is not used in the encoding.

value This is the value used to identify the curve. These values MUST be unique. The integer values from -256 to 255 are designated as Standards Track Document Required. The integer values from 256 to 65535 and -65536 to -257 are designated as Specification Required. Integer values over 65535 are designated as expert review. Integer values less than -65536 are marked as private use.

key type This designates the key type(s) that can be used with this curve.

description This field contains a brief description of the curve.

specification This contains a pointer to the public specification for the curve if one exists.

This registry will be initially populated by the values in Table 21. The specification column for all of these entries will be this document.

### **16.8. Media Type Registrations**

#### **16.8.1. COSE Security Message**

This section registers the "application/cose" media type in the "Media Types" registry. These media types are used to indicate that the content is a COSE\_MSG.

Type name: application

Subtype name: cose

Required parameters: N/A

Optional parameters: cose-type

Encoding considerations: binary





Security considerations: See the Security Considerations section of RFC TBD.

Interoperability considerations: N/A

Published specification: RFC TBD

Applications that use this media type: To be identified

Fragment identifier considerations: N/A

Additional information:

- \* Magic number(s): N/A

- \* File extension(s): cbor

- \* Macintosh file type code(s): N/A

Person & email address to contact for further information:  
iesg@ietf.org

Intended usage: COMMON

Restrictions on usage: N/A

Author: Jim Schaad, ietf@augustcellars.com

Change Controller: IESG

Provisional registration? No

#### **16.8.2. COSE Key media type**

This section registers the "application/cose-key" and "application/cose-key-set" media types in the "Media Types" registry. These media types are used to indicate, respectively, that content is a COSE\_Key or COSE\_KeySet object.

Type name: application

Subtype name: cose-key

Required parameters: N/A

Optional parameters: N/A

Encoding considerations: binary



Security considerations: See the Security Considerations section of RFC TBD.

Interoperability considerations: N/A

Published specification: RFC TBD

Applications that use this media type: To be identified

Fragment identifier considerations: N/A

Additional information:

- \* Magic number(s): N/A

- \* File extension(s): cbor

- \* Macintosh file type code(s): N/A

Person & email address to contact for further information:  
iesg@ietf.org

Intended usage: COMMON

Restrictions on usage: N/A

Author: Jim Schaad, ietf@augustcellars.com

Change Controller: IESG

Provisional registration? No

Type name: application

Subtype name: cose-key-set

Required parameters: N/A

Optional parameters: N/A

Encoding considerations: binary

Security considerations: See the Security Considerations section of RFC TBD.

Interoperability considerations: N/A

Published specification: RFC TBD



Applications that use this media type: To be identified

Fragment identifier considerations: N/A

Additional information:

- \* Magic number(s): N/A

- \* File extension(s): cbor

- \* Macintosh file type code(s): N/A

Person & email address to contact for further information:  
iesg@ietf.org

Intended usage: COMMON

Restrictions on usage: N/A

Author: Jim Schaad, ietf@augustcellars.com

Change Controller: IESG

Provisional registration? No

#### **16.9. CoAP Content Format Registrations**

This section registers a set of content formats for CoAP. ID assignment in the 24-255 range is requested.



Media Type	Encoding	ID	Reference
application/cose; cose-type="cose-sign"		TBD10	[This Document]
application/cose; cose-type="cose-sign1"		TBD11	[This Document]
application/cose; cose-type="cose-encrypt"		TBD12	[This Document]
application/cose; cose-type="cose-encrypt1"		TBD13	[This Document]
application/cose; cose-type="cose-mac"		TBD14	[This Document]
application/cose; cose-type="cose-mac0"		TBD15	[This Document]
application/cose-key		TBD16	[This Document]
application/cose-key-set		TBD17	[This Document]

Table 26

#### **16.10. Expert Review Instructions**

All of the IANA registries established in this document are defined as expert review. This section gives some general guidelines for what the experts should be looking for, but they are being designated as experts for a reason so they should be given substantial latitude.

Expert reviewers should take into consideration the following points:

- o Point squatting should be discouraged. Reviewers are encouraged to get sufficient information for registration requests to ensure that the usage is not going to duplicate one that is already registered and that the point is likely to be used in deployments. The zones tagged as private use are intended for testing purposes and closed environments, code points in other ranges should not be assigned for testing.





- o Specifications are required for the standards track range of point assignment. Specifications should exist for specification required ranges, but early assignment before a specification is available is considered to be permissible. Specifications are needed for the first-come, first-serve range if they are expected to be used outside of closed environments in an interoperable way. When specifications are not provided, the description provided needs to have sufficient information to identify what the point is being used for.
- o Experts should take into account the expected usage of fields when approving point assignment. The fact that there is a range for standards track documents does not mean that a standards track document cannot have points assigned outside of that range. Some of the ranges are restricted in range, items that are not expected to be common or are not expected to be used in restricted environments should be assigned to values which will encode to longer byte strings.
- o When algorithms are registered, vanity registrations should be discouraged. One way to do this is to require applications to provide additional documentation on security analysis of algorithms. Another thing that should be considered is to request for an opinion on the algorithm from the Cryptographic Forum Research Group. Algorithms that do not meet the security requirements of the community and the messages structures should not be registered.

## **17. Implementation Status**

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [[RFC6982](#)]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to [[RFC6982](#)], "this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature.



It is up to the individual working groups to use this information as they see fit".

### **17.1. Author's Versions**

There are three different implementations that have been created by the author of the document both to create the examples that are included in the document and to validate the structures and methodology used in the design of COSE.

Implementation Location: <https://github.com/cose-wg>

Primary Maintainer: Jim Schaad

Languages: There are three different languages that are currently supported: Java, C# and C.

Cryptography: The Java and C# libraries use Bouncy Castle to provide the required cryptography. The C version uses OPENSSL Version 1.0 for the cryptography.

Coverage: The libraries currently do not have full support for counter signatures of either variety. They do have support to allow for implicit algorithm support as they allow for the application to set attributes that are not to be sent in the message.

Testing: All of the examples in the example library are generated by the C# library and then validated using the Java and C libraries. All three libraries have tests to allow for the creating of the same messages that are in the example library followed by validating them. These are not compared against the example library. The Java and C# libraries have unit testing included. Not all of the MUST statements in the document have been implemented as part of the libraries. One such statement is the requirement that unique labels be present.

Licensing: Revised BSD License

### **17.2. COSE Testing Library**

Implementation Location: <https://github.com/cose-wg/Examples>

Primary Maintainer: Jim Schaad

Description: A set of tests for the COSE library is provided as part of the implementation effort. Both success and fail tests



have been provided. All of the examples in this document are part of this example set.

Coverage: An attempt has been made to have test cases for every message type and algorithm in the document. Currently examples dealing with counter signatures, EdDSA, and ECDH with Curve24459 and Goldilocks are missing.

Licensing: Public Domain

## **18. Security Considerations**

There are a number of security considerations that need to be taken into account by implementers of this specification. The security considerations that are specific to an individual algorithm are placed next to the description of the algorithm. While some considerations have been highlighted here, additional considerations may be found in the documents listed in the references.

Implementations need to protect the private key for any individuals. There are some cases in this document that need to be highlighted on this issue.

- o Using the same key for two different algorithms can leak information about the key. It is therefore recommended that keys be restricted to a single algorithm.
- o Use of 'direct' as a recipient algorithm combined with a second recipient algorithm, either directly in a separate message, exposes the direct key to the second recipient.
- o Several of the algorithms in this document have limits on the number of times that a key can be used without leaking information about the key.

The use of ECDH and direct plus KDF (with no key wrap) will not directly lead to the private key being leaked; the one way function of the KDF will prevent that. There is however, a different issue that needs to be addressed. Having two recipients requires that the CEK be shared between two recipients. The second recipient therefore has a CEK that was derived from material that can be used for the weak proof of origin. The second recipient could create a message using the same CEK and send it to the first recipient, the first recipient would, for either static-static ECDH or direct plus KDF, make an assumption that the CEK could be used for proof of origin even though it is from the wrong entity. If the key wrap step is added, then no proof of origin is implied and this is not an issue.



Although it has been mentioned before, the use of a single key for multiple algorithms has been demonstrated in some cases to leak information about a key, provide for attackers to forge integrity tags, or gain information about encrypted content. Binding a key to a single algorithm prevents these problems. Key creators and key consumers are strongly encouraged not only to create new keys for each different algorithm, but to include that selection of algorithm in any distribution of key material and strictly enforce the matching of algorithms in the key structure to algorithms in the message structure. In addition to checking that algorithms are correct, the key form needs to be checked as well. Do not use an 'EC2' key where an 'OKP' key is expected.

Before using a key for transmission, or before acting on information received, a trust decision on a key needs to be made. Is the data or action something that the entity associated with the key has a right to see or a right to request? A number of factors are associated with this trust decision. Some of the ones that are highlighted here are:

- o What are the permissions associated with the key owner?
- o Is the cryptographic algorithm acceptable in the current context?
- o Have the restrictions associated with the key, such as algorithm or freshness, been checked and are correct?
- o Is the request something that is reasonable, given the current state of the application?
- o Have any security considerations that are part of the message been enforced (as specified by the application or crit parameter)?

One area that has been starting to get exposure is doing traffic analysis of encrypted messages based on the length of the message. This specification does not provide for a uniform method of providing padding as part of the message structure. An observer can distinguish between two different strings (for example, 'YES' and 'NO') based on length for all of the content encryption algorithms that are defined in this document. This means that it is up to applications to document how content padding is to be done in order to prevent or discourage such analysis. (For example, the strings could be defined as 'YES' and 'NO '.)





## **19. References**

### **19.1. Normative References**

- [AES-GCM] Dworkin, M., "NIST Special Publication 800-38D: Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC.", Nov 2007.
- [DSS] U.S. National Institute of Standards and Technology, "Digital Signature Standard (DSS)", July 2013.
- [MAC] NIST, N., "FIPS PUB 113: Computer Data Authentication", May 1985.
- [RFC2104] Krawczyk, H., Bellare, M., and R. Canetti, "HMAC: Keyed-Hashing for Message Authentication", [RFC 2104](#), DOI 10.17487/RFC2104, February 1997, <<http://www.rfc-editor.org/info/rfc2104>>.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), DOI 10.17487/RFC2119, March 1997, <<http://www.rfc-editor.org/info/rfc2119>>.
- [RFC3394] Schaad, J. and R. Housley, "Advanced Encryption Standard (AES) Key Wrap Algorithm", [RFC 3394](#), DOI 10.17487/RFC3394, September 2002, <<http://www.rfc-editor.org/info/rfc3394>>.
- [RFC3610] Whiting, D., Housley, R., and N. Ferguson, "Counter with CBC-MAC (CCM)", [RFC 3610](#), DOI 10.17487/RFC3610, September 2003, <<http://www.rfc-editor.org/info/rfc3610>>.
- [RFC5869] Krawczyk, H. and P. Eronen, "HMAC-based Extract-and-Expand Key Derivation Function (HKDF)", [RFC 5869](#), DOI 10.17487/RFC5869, May 2010, <<http://www.rfc-editor.org/info/rfc5869>>.
- [RFC6090] McGrew, D., Igoe, K., and M. Salter, "Fundamental Elliptic Curve Cryptography Algorithms", [RFC 6090](#), DOI 10.17487/RFC6090, February 2011, <<http://www.rfc-editor.org/info/rfc6090>>.
- [RFC7049] Bormann, C. and P. Hoffman, "Concise Binary Object Representation (CBOR)", [RFC 7049](#), DOI 10.17487/RFC7049, October 2013, <<http://www.rfc-editor.org/info/rfc7049>>.



[RFC7539] Nir, Y. and A. Langley, "ChaCha20 and Poly1305 for IETF Protocols", [RFC 7539](#), DOI 10.17487/RFC7539, May 2015, <<http://www.rfc-editor.org/info/rfc7539>>.

[SEC1] Standards for Efficient Cryptography Group, "SEC 1: Elliptic Curve Cryptography", May 2009.

## **19.2. Informative References**

[I-D.greevenbosch-appsawg-cbor-cddl]  
Vigano, C. and H. Birkholz, "CBOR data definition language (CDDL): a notational convention to express CBOR data structures", [draft-greevenbosch-appsawg-cbor-cddl-08](#) (work in progress), March 2016.

[I-D.irtf-cfrg-eddsa]  
Josefsson, S. and I. Liusvaara, "Edwards-curve Digital Signature Algorithm (EdDSA)", [draft-irtf-cfrg-eddsa-05](#) (work in progress), March 2016.

[PVSig] Brown, D. and D. Johnson, "Formal Security Proofs for a Signature Scheme with Partial Message Recover", February 2000.

[RFC2045] Freed, N. and N. Borenstein, "Multipurpose Internet Mail Extensions (MIME) Part One: Format of Internet Message Bodies", [RFC 2045](#), DOI 10.17487/RFC2045, November 1996, <<http://www.rfc-editor.org/info/rfc2045>>.

[RFC2633] Ramsdell, B., Ed., "S/MIME Version 3 Message Specification", [RFC 2633](#), DOI 10.17487/RFC2633, June 1999, <<http://www.rfc-editor.org/info/rfc2633>>.

[RFC2898] Kaliski, B., "PKCS #5: Password-Based Cryptography Specification Version 2.0", [RFC 2898](#), DOI 10.17487/RFC2898, September 2000, <<http://www.rfc-editor.org/info/rfc2898>>.

[RFC3447] Jonsson, J. and B. Kaliski, "Public-Key Cryptography Standards (PKCS) #1: RSA Cryptography Specifications Version 2.1", [RFC 3447](#), DOI 10.17487/RFC3447, February 2003, <<http://www.rfc-editor.org/info/rfc3447>>.

[RFC4231] Nystrom, M., "Identifiers and Test Vectors for HMAC-SHA-224, HMAC-SHA-256, HMAC-SHA-384, and HMAC-SHA-512", [RFC 4231](#), DOI 10.17487/RFC4231, December 2005, <<http://www.rfc-editor.org/info/rfc4231>>.



- [RFC4262] Santesson, S., "X.509 Certificate Extension for Secure/Multipurpose Internet Mail Extensions (S/MIME) Capabilities", [RFC 4262](#), DOI 10.17487/RFC4262, December 2005, <<http://www.rfc-editor.org/info/rfc4262>>.
- [RFC4493] Song, JH., Poovendran, R., Lee, J., and T. Iwata, "The AES-CMAC Algorithm", [RFC 4493](#), DOI 10.17487/RFC4493, June 2006, <<http://www.rfc-editor.org/info/rfc4493>>.
- [RFC4949] Shirey, R., "Internet Security Glossary, Version 2", FYI 36, [RFC 4949](#), DOI 10.17487/RFC4949, August 2007, <<http://www.rfc-editor.org/info/rfc4949>>.
- [RFC5480] Turner, S., Brown, D., Yiu, K., Housley, R., and T. Polk, "Elliptic Curve Cryptography Subject Public Key Information", [RFC 5480](#), DOI 10.17487/RFC5480, March 2009, <<http://www.rfc-editor.org/info/rfc5480>>.
- [RFC5652] Housley, R., "Cryptographic Message Syntax (CMS)", STD 70, [RFC 5652](#), DOI 10.17487/RFC5652, September 2009, <<http://www.rfc-editor.org/info/rfc5652>>.
- [RFC5751] Ramsdell, B. and S. Turner, "Secure/Multipurpose Internet Mail Extensions (S/MIME) Version 3.2 Message Specification", [RFC 5751](#), DOI 10.17487/RFC5751, January 2010, <<http://www.rfc-editor.org/info/rfc5751>>.
- [RFC5752] Turner, S. and J. Schaad, "Multiple Signatures in Cryptographic Message Syntax (CMS)", [RFC 5752](#), DOI 10.17487/RFC5752, January 2010, <<http://www.rfc-editor.org/info/rfc5752>>.
- [RFC5990] Randall, J., Kaliski, B., Brainard, J., and S. Turner, "Use of the RSA-KEM Key Transport Algorithm in the Cryptographic Message Syntax (CMS)", [RFC 5990](#), DOI 10.17487/RFC5990, September 2010, <<http://www.rfc-editor.org/info/rfc5990>>.
- [RFC6151] Turner, S. and L. Chen, "Updated Security Considerations for the MD5 Message-Digest and the HMAC-MD5 Algorithms", [RFC 6151](#), DOI 10.17487/RFC6151, March 2011, <<http://www.rfc-editor.org/info/rfc6151>>.
- [RFC6979] Pornin, T., "Deterministic Usage of the Digital Signature Algorithm (DSA) and Elliptic Curve Digital Signature Algorithm (ECDSA)", [RFC 6979](#), DOI 10.17487/RFC6979, August 2013, <<http://www.rfc-editor.org/info/rfc6979>>.



- [RFC6982] Sheffer, Y. and A. Farrel, "Improving Awareness of Running Code: The Implementation Status Section", [RFC 6982](#), DOI 10.17487/RFC6982, July 2013, <<http://www.rfc-editor.org/info/rfc6982>>.
- [RFC7159] Bray, T., Ed., "The JavaScript Object Notation (JSON) Data Interchange Format", [RFC 7159](#), DOI 10.17487/RFC7159, March 2014, <<http://www.rfc-editor.org/info/rfc7159>>.
- [RFC7252] Shelby, Z., Hartke, K., and C. Bormann, "The Constrained Application Protocol (CoAP)", [RFC 7252](#), DOI 10.17487/RFC7252, June 2014, <<http://www.rfc-editor.org/info/rfc7252>>.
- [RFC7515] Jones, M., Bradley, J., and N. Sakimura, "JSON Web Signature (JWS)", [RFC 7515](#), DOI 10.17487/RFC7515, May 2015, <<http://www.rfc-editor.org/info/rfc7515>>.
- [RFC7516] Jones, M. and J. Hildebrand, "JSON Web Encryption (JWE)", [RFC 7516](#), DOI 10.17487/RFC7516, May 2015, <<http://www.rfc-editor.org/info/rfc7516>>.
- [RFC7517] Jones, M., "JSON Web Key (JWK)", [RFC 7517](#), DOI 10.17487/RFC7517, May 2015, <<http://www.rfc-editor.org/info/rfc7517>>.
- [RFC7518] Jones, M., "JSON Web Algorithms (JWA)", [RFC 7518](#), DOI 10.17487/RFC7518, May 2015, <<http://www.rfc-editor.org/info/rfc7518>>.
- [RFC7748] Langley, A., Hamburg, M., and S. Turner, "Elliptic Curves for Security", [RFC 7748](#), DOI 10.17487/RFC7748, January 2016, <<http://www.rfc-editor.org/info/rfc7748>>.
- [SP800-56A] Barker, E., Chen, L., Roginsky, A., and M. Smid, "NIST Special Publication 800-56A: Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography", May 2013.

## **[Appendix A](#). Making Mandatory Algorithm Header Optional**

There has been a portion of the working group who have expressed a strong desire to relax the rule that the algorithm identifier be required to appear in each level of a COSE object. There are two basic reasons that have been advanced to support this position. First, the resulting message will be smaller if the algorithm identifier is omitted from the most common messages in a CoAP





environment. Second, there is a potential bug that will arise if full checking is not done correctly between the different places that an algorithm identifier could be placed (the message itself, an application statement, the key structure that the sender possesses and the key structure the recipient possesses).

This appendix lays out how such a change can be made and the details that an application needs to specify in order to use this option. Two different sets of details are specified: Those needed to omit an algorithm identifier and those needed to use a variant on the counter signature attribute that contains no attributes about itself.

### **A.1. Algorithm Identification**

In this section are laid out three sets of recommendations. The first set of recommendations apply to having an implicit algorithm identified for a single layer of a COSE object. The second set of recommendations apply to having multiple implicit algorithms identified for multiple layers of a COSE object. The third set of recommendations apply to having implicit algorithms for multiple COSE object constructs.

[RFC 2119](#) language is deliberately not used here. This specification can provide recommendations, but it cannot enforce them.

This set of recommendations applies to the case where an application is distributing a fixed algorithm along with the key information for use in a single COSE object. This normally applies to the smallest of the COSE objects, specifically COSE\_Sign1, COSE\_Mac0, and COSE\_Encrypt0, but could apply to the other structures as well.

The following items should be taken into account:

- o Applications need to list the set of COSE structures that implicit algorithms are to be used in. Applications need to require that the receipt of an explicit algorithm identifier in one of these structures will lead to the message being rejected. This requirement is stated so that there will never be a case where there is any ambiguity about the question of which algorithm should be used, the implicit or the explicit one. This applies even if the transported algorithm identifier is a protected attribute. This applies even if the transported algorithm is the same as the implicit algorithm.
- o Applications need to define the set of information that is to be considered to be part of a context when omitting algorithm identifiers. At a minimum, this would be the key identifier (if needed), the key, the algorithm, and the COSE structure it can be



used for. Applications should restrict the use of a single key to a single algorithm. As noted for some of the algorithms in this document, the use of the same key in different related algorithms can lead to leakage of information about the key, leakage about the data or the ability to perform forgeries.

- o In many cases, applications that make the algorithm identifier implicit will also want to make the context identifier implicit for the same reason. That is, omitting the context identifier will decrease the message size (potentially significantly depending on the length of the identifier). Applications that do this will need to describe the circumstances where the context identifier is to be omitted and how the context identifier is to be inferred in these cases. (Exhaustive search over all of the keys would normally not be considered to be acceptable.) An example of how this can be done is to tie the context to a transaction identifier. Both would be sent on the original message, but only the transaction identifier would need to be sent after that point as the context is tied into the transaction identifier. Another way would be to associate a context with a network address. All messages coming from a single network address can be assumed to be associated with a specific context. (In this case the address would normally be distributed as part of the context.)
- o Applications cannot rely on key identifiers being unique unless they take significant efforts to ensure that they are computed in such a way as to create this guarantee. Even when an application does this, the uniqueness might be violated if the application is run in different contexts (i.e., with a different context provider) or if the system combines the security contexts from different applications together into a single store.
- o Applications should continue the practice of protecting the algorithm identifier. Since this is not done by placing it in the protected attributes field, applications should define an application specific external data structure that includes this value. This external data field can be used as such for content encryption, MAC, and signature algorithms. It can be used in the SuppPrivInfo field for those algorithms which use a KDF function to derive a key value. Applications may also want to protect other information that is part of the context structure as well. It should be noted that those fields, such as the key or a base IV, are protected by virtue of being used in the cryptographic computation and do not need to be included in the external data field.



The second case is having multiple implicit algorithm identifiers specified for a multiple layer COSE object. An example of how this would work is the encryption context that an application specifies contains a content encryption algorithm, a key wrap algorithm, a key identifier, and a shared secret. The sender omits sending the algorithm identifier for both the content layer and the recipient layer leaving only the key identifier. The receiver then uses the key identifier to get the implicit algorithm identifiers.

The following additional items need to be taken into consideration:

- o Applications that want to support this will need to define a structure that allows for, and clearly identifies, both the COSE structure to be used with a given key and the structure and algorithm to be used for the secondary layer. The key for the secondary layer is computed per normal from the recipient layer.

The third case is having multiple implicit algorithm identifiers, but targeted at potentially unrelated layers or different COSE objects. There are a number of different scenarios where this might be applicable. Some of these scenarios are:

- o Two contexts are distributed as a pair. Each of the contexts is for use with a COSE\_Encrypt message. Each context will consist of distinct secret keys and IVs and potentially even different algorithms. One context is for sending messages from party A to party B, the second context is for sending messages from party B to party A. This means that there is no chance for a reflection attack to occur as each party uses different secret keys to send its messages, a message that is reflected back to it would fail to decrypt.
- o Two contexts are distributed as a pair. The first context is used for encryption of the message; the second context is used to place a counter signature on the message. The intention is that the second context can be distributed to other entities independently of the first context. This allows these entities to validate that the message came from an individual without being able to decrypt the message and see the content.
- o Two contexts are distributed as a pair. The first context contains a key for dealing with MACed messages, the second context contains a key for dealing with encrypted messages. This allows for a unified distribution of keys to participants for different types of messages that have different keys, but where the keys may be used in coordinated manner.



For these cases, the following additional items need to be considered:

- o Applications need to ensure that the multiple contexts stay associated. If one of the contexts is invalidated for any reason, all of the contexts associated with it should also be invalidated.

## **A.2. Counter Signature Without Headers**

There is a group of people who want to have a counter signature parameter that is directly tied to the value being signed and thus the authenticated and unauthenticated buckets can be removed from the message being sent. The focus on this is an even smaller size, as all of the information on the process of creating the counter signature is implicit rather than being explicitly carried in the message. This includes not only the algorithm identifier as presented above, but also items such as the key identification is always external to the signature structure. This means that the entities that are doing the validation of the counter signature are required to infer which key is to be used from context rather than being explicit. One way of doing this would be to presume that all data coming from a specific port (or to a specific URL) is to be validated by a specific key. (Note that this does not require that the key identifier be part of the value signed as it does not serve a cryptographic purpose. If the key validates the counter signature, then it should be presumed that the entity associated with that key produced the signature.)

When computing the signature for the bare counter signature header, the same Sig\_structure defined in [Section 4.4](#). The sign\_protected field is omitted, as there is no protected header field in in this counter signature header. The value of "CounterSignature0" is placed in the context field of the Sig\_structure.

name	label	value type	description
counter signature w/o headers	9	bstr	

Table 27

## **Appendix B. Two Layers of Recipient Information**

All of the currently defined recipient algorithms classes only use two layers of the COSE\_Encrypt structure. The first layer is the message content and the second layer is the content key encryption. However, if one uses a recipient algorithm such as RSA-KEM (see





[Appendix A](#) of RSA-KEM [[RFC5990](#)]), then it makes sense to have three layers of the COSE\_Encrypt structure.

These layers would be:

- o Layer 0: The content encryption layer. This layer contains the payload of the message.
- o Layer 1: The encryption of the CEK by a KEK.
- o Layer 2: The encryption of a long random secret using an RSA key and a key derivation function to convert that secret into the KEK.

This is an example of what a triple layer message would look like. The message has the following layers:

- o Layer 0: Has a content encrypted with AES-GCM using a 128-bit key.
- o Layer 1: Uses the AES Key wrap algorithm with a 128-bit key.
- o Layer 2: Uses ECDH Ephemeral-Static direct to generate the layer 1 key.

In effect, this example is a decomposed version of using the ECDH-ES+A128KW algorithm.

Size of binary file is 184 bytes



```

992(
  [
    / protected / h'a10101' / {
      \ alg \ 1:1 \ AES-GCM 128 \
    } / ,
    / unprotected / {
      / iv / 5:h'02d1f7e6f26c43d4868d87ce'
    },
    / ciphertext / h'64f84d913ba60a76070a9a48f26e97e863e2852948658f0
811139868826e89218a75715b',
    / recipients / [
      [
        / protected / h'',
        / unprotected / {
          / alg / 1:-3 / A128KW /
        },
        / ciphertext / h'dbd43c4e9d719c27c6275c67d628d493f090593db82
18f11',
        / recipients / [
          [
            / protected / h'a1013818' / {
              \ alg \ 1:-25 \ ECDH-ES + HKDF-256 \
            } / ,
            / unprotected / {
              / ephemeral / -1:{
                / kty / 1:2,
                / crv / -1:1,
                / x / -2:h'b2add44368ea6d641f9ca9af308b4079aeb519f11
e9b8a55a600b21233e86e68',
                / y / -3:false
              },
              / kid / 4:'meriadoc.brandybuck@buckland.example'
            },
            / ciphertext / h''
          ]
        ]
      ]
    ]
  )

```

## Appendix C. Examples

This appendix includes a set of examples that show the different features and message types that have been defined in this document. To make the examples easier to read, they are presented using the extended CBOR diagnostic notation (defined in [\[I-D.greevenbosch-appsawg-cbor-cddl\]](#)) rather than as a binary dump.



A GitHub project has been created at <https://github.com/cose-wg/Examples> that contains not only the examples presented in this document, but a more complete set of testing examples as well. Each example is found in a JSON file that contains the inputs used to create the example, some of the intermediate values that can be used in debugging the example and the output of the example presented in both a hex and a CBOR diagnostic notation format. Some of the examples at the site are designed failure testing cases; these are clearly marked as such in the JSON file. If errors in the examples in this document are found, the examples on github will be updated and a note to that effect will be placed in the JSON file.

As noted, the examples are presented using the CBOR's diagnostic notation. A Ruby based tool exists that can convert between the diagnostic notation and binary. This tool can be installed with the command line:

```
gem install cbor-diag
```

The diagnostic notation can be converted into binary files using the following command line:

```
diag2cbor.rb < inputfile > outputfile
```

The examples can be extracted from the XML version of this document via an XPath expression as all of the artwork is tagged with the attribute type='CBORdiag'. (Depending on the XPath evaluator one is using, it may be necessary to deal with &gt; as an entity.)

```
//artwork[@type='CDDL']/text()
```

## **C.1. Examples of Signed Message**

### **C.1.1. Single Signature**

This example uses the following:

- o Signature Algorithm: ECDSA w/ SHA-256, Curve P-256-1

Size of binary file is 104 bytes



```

991(
  [
    / protected / h'',
    / unprotected / {},
    / payload / 'This is the content.',
    / signatures / [
      [
        / protected / h'a10126' / {
          \ alg \ 1:-7 \ ECDSA 256 \
        } / ,
        / unprotected / {
          / kid / 4:'11'
        },
        / signature / h'ae868ecc176883766c5dc5ba5b8dca25dab3c2e56a5
51ce5705b793914348e14eea4aee6e0c9f09db4ef3ddeca8f3506cd1a98a8fb64327
be470355c9657ce0'
      ]
    ]
  ]
)

```

#### **C.1.2. Multiple Signers**

This example uses the following:

- o Signature Algorithm: ECDSA w/ SHA-256, Curve P-256-1
- o Signature Algorithm: ECDSA w/ SHA-512, Curve P-521

Size of binary file is 278 bytes





```

991(
  [
    / protected / h'',
    / unprotected / {},
    / payload / 'This is the content.',
    / signatures / [
      [
        / protected / h'a10126' / {
          \ alg \ 1:-7 \ ECDSA 256 \
        } / ,
        / unprotected / {
          / kid / 4:'11'
        },
        / signature / h'0dc1c5e62719d8f3cce1468b7c881eee6a8088b46bf8
36ae956dd38fe93199199951a6a5e02a24aed5edde3509748366b1c539aaef7dea34
f2cd618fe19fe55d'
      ],
      [
        / protected / h'a1013823' / {
          \ alg \ 1:-36
        } / ,
        / unprotected / {
          / kid / 4:'bilbo.baggins@hobbiton.example'
        },
        / signature / h'012ce5b1dfe8b5aa6eaa09a54c58a84ad0900e4fdf27
59ec22d1c861cccd75c7e1c4025a2da35e512fc2874d6ac8fd862d09ad07ed2deac2
97b897561e04a8d42476017c11a4a34e26c570c9eff22c1dc84d56cdf6e03ed34bc9
e934c5fdf676c7948d79e97dfe161730217c57748aadb364a0207cee811e9dde65ae
37942e8a8348cc91'
      ]
    ]
  ]
)

```

### **C.1.3. Counter Signature**

This example uses the following:

- o Signature Algorithm: ECDSA w/ SHA-256, Curve P-256-1
- o The same parameters are used for both the signature and the counter signature.

Size of binary file is 181 bytes



```

991(
  [
    / protected / h'',
    / unprotected / {
      / countersign / 7:[
        / protected / h'a10126' / {
          \ alg \ 1:-7 \ ECDSA 256 \
        } / ,
        / unprotected / {
          / kid / 4:'11'
        },
        / signature / h'c9d3402485aa585cee3efc69b14496c0b00714584b26
0f8e05764b7dbc70ae2b23b89812f5895b805f07a792f7ce77ef6d63875dc37d6a78
ef4d175da45c9a51'
      ]
    },
    / payload / 'This is the content.',
    / signatures / [
      [
        / protected / h'a10126' / {
          \ alg \ 1:-7 \ ECDSA 256 \
        } / ,
        / unprotected / {
          / kid / 4:'11'
        },
        / signature / h'ea868ecc176883766c5dc5ba5b8dca25dab3c2e56a5
51ce5705b793914348e14eea4aee6e0c9f09db4ef3ddeca8f3506cd1a98a8fb64327
be470355c9657ce0'
      ]
    ]
  ]
)

```

#### [C.1.4.](#) Signature w/ Criticality

This example uses the following:

- o Signature Algorithm: ECDSA w/ SHA-256, Curve P-256-1
- o There is a criticality marker on the "reserved" header parameter

Size of binary file is 126 bytes



```

991(
  [
    / protected / h'a2687265736572766564f40281687265736572766564' /
  {
    "reserved":false,
    \ crit \ 2:[
      "reserved"
    ]
  } / ,
  / unprotected / {},
  / payload / 'This is the content.',
  / signatures / [
    [
      / protected / h'a10126' / {
        \ alg \ 1:-7 \ ECDSA 256 \
      } / ,
      / unprotected / {
        / kid / 4:'11'
      },
      / signature / h'cae868ecc176883766c5dc5ba5b8dca25dab3c2e56a5
51ce5705b793914348e1ff259ead2c38d8a7d8a9c87c2ce534d762dab059773115a6
176fa780e85b6b25'
    ]
  ]
)

```

## [C.2.](#) Single Signer Examples

### [C.2.1.](#) Single ECDSA signature

This example uses the following:

- o Signature Algorithm: ECDSA w/ SHA-256, Curve P-256-1

Size of binary file is 100 bytes



```

997(
  [
    / protected / h'a10126' / {
      \ alg \ 1:-7 \ ECDSA 256 \
    } / ,
    / unprotected / {
      / kid / 4:'11'
    },
    / payload / 'This is the content.',
    / signature / h'ea868ecc176883766c5dc5ba5b8dca25dab3c2e56a551ce
5705b793914348e19f43d6c6ba654472da301b645b293c9ba939295b97c4bdb84778
2bff384c5794'
  ]
)

```

### [C.3.](#) Examples of Enveloped Messages

#### [C.3.1.](#) Direct ECDH

This example uses the following:

- o CEK: AES-GCM w/ 128-bit key
- o Recipient class: ECDH Ephemeral-Static, Curve P-256

Size of binary file is 152 bytes





```

992(
  [
    / protected / h'a10101' / {
      \ alg \ 1:1 \ AES-GCM 128 \
    } / ,
    / unprotected / {
      / iv / 5:h'c9cf4df2fe6c632bf7886413'
    },
    / ciphertext / h'7adbe2709ca818fb415f1e5df66f4e1a51053ba6d65a1a0
c52a357da7a644b8070a151b0',
    / recipients / [
      [
        / protected / h'a1013818' / {
          \ alg \ 1:-25 \ ECDH-ES + HKDF-256 \
        } / ,
        / unprotected / {
          / ephemeral / -1:{
            / kty / 1:2,
            / crv / -1:1,
            / x / -2:h'98f50a4ff6c05861c8860d13a638ea56c3f5ad7590bbf
bf054e1c7b4d91d6280',
            / y / -3:true
          },
          / kid / 4:'meriadoc.brandybuck@buckland.example'
        },
        / ciphertext / h''
      ]
    ]
  ]
)

```

### **C.3.2. Direct plus Key Derivation**

This example uses the following:

- o CEK: AES-CCM w/128-bit key, truncate the tag to 64 bits
- o Recipient class: Use HKDF on a shared secret with the following implicit fields as part of the context.
  - \* salt: "aabbccddeeffgghh"
  - \* APU identity: "lighting-client"
  - \* APV identity: "lighting-server"
  - \* Supplementary Public Other: "Encryption Example 02"



Size of binary file is 92 bytes

```
992(
  [
    / protected / h'a1010a' / {
      \ alg \ 1:10 \ AES-CCM-16-64-128 \
    } / ,
    / unprotected / {
      / iv / 5:h'89f52f65a1c580933b5261a76c'
    },
    / ciphertext / h'753548a19b1307084ca7b2056924ed95f2e3b17006dfe93
1b687b847',
    / recipients / [
      [
        / protected / h'a10129' / {
          \ alg \ 1:-10
        } / ,
        / unprotected / {
          / salt / -20:'aabbccddeeffgghh',
          / kid / 4:'our-secret'
        },
        / ciphertext / h''
      ]
    ]
  ]
)
```

### **C.3.3. Counter Signature on Encrypted Content**

This example uses the following:

- o CEK: AES-GCM w/ 128-bit key
- o Recipient class: ECDH Ephemeral-Static, Curve P-256

Size of binary file is 327 bytes



```

992(
  [
    / protected / h'a10101' / {
      \ alg \ 1:1 \ AES-GCM 128 \
    } / ,
    / unprotected / {
      / iv / 5:h'c9cf4df2fe6c632bf7886413',
      / countersign / 7:[
        / protected / h'a1013823' / {
          \ alg \ 1:-36
        } / ,
        / unprotected / {
          / kid / 4:'bilbo.baggins@hobbiton.example'
        },
        / signature / h'00aa98cbfd382610a375d046a275f30266e8d0faacb9
069fde06e37825ae7825419c474f416ded0c8e3e7b55bff68f2a704135bdf99186f6
6659461c8cf929cc7fb300f5e2b33c3b433655042ff719804ff73b0be3e988ecebc0
c70ef6616996809c6eb59a918dbe0a5edb0d15137ece0aba2a0b0f68ad2631cb62f2
ea4d7099804218b0'
      ],
    },
    / ciphertext / h'7adbe2709ca818fb415f1e5df66f4e1a51053ba6d65a1a0
c52a357da7a644b8070a151b0',
    / recipients / [
      [
        / protected / h'a1013818' / {
          \ alg \ 1:-25 \ ECDH-ES + HKDF-256 \
        } / ,
        / unprotected / {
          / ephemeral / -1:{
            / kty / 1:2,
            / crv / -1:1,
            / x / -2:h'98f50a4ff6c05861c8860d13a638ea56c3f5ad7590bbf
bf054e1c7b4d91d6280',
            / y / -3:true
          },
          / kid / 4:'meriadoc.brandybuck@buckland.example'
        },
        / ciphertext / h''
      ]
    ]
  ]
)

```



#### **C.3.4. Encrypted Content with External Data**

This example uses the following:

- o CEK: AES-GCM w/ 128-bit key
- o Recipient class: ECDH static-Static, Curve P-256 with AES Key Wrap
- o Externally Supplied AAD: h'0011bbcc22dd44ee55ff660077'

Size of binary file is 174 bytes

```

992(
  [
    / protected / h'a10101' / {
      \ alg \ 1:1 \ AES-GCM 128 \
    } / ,
    / unprotected / {
      / iv / 5:h'02d1f7e6f26c43d4868d87ce'
    },
    / ciphertext / h'64f84d913ba60a76070a9a48f26e97e863e28529d8f5335
e5f0165eee976b4a5f6c6f09d',
    / recipients / [
      [
        / protected / h'a101381f' / {
          \ alg \ 1:-32 \ ECHD-SS+A128KW \
        } / ,
        / unprotected / {
          / static kid / -3:'peregrin.took@tuckborough.example',
          / kid / 4:'meriadoc.brandybuck@buckland.example',
          / U nonce / -22:h'0101'
        },
        / ciphertext / h'41e0d76f579dbd0d936a662d54d8582037de2e366fd
e1c62'
      ]
    ]
  ]
)

```

#### **C.4. Examples of Encrypted Messages**

##### **C.4.1. Simple Encrypted Message**

This example uses the following:

- o CEK: AES-CCM w/ 128-bit key and a 64-bit tag

Size of binary file is 54 bytes





```

993(
  [
    / protected / h'a1010a' / {
      \ alg \ 1:10 \ AES-CCM-16-64-128 \
    } / ,
    / unprotected / {
      / iv / 5:h'89f52f65a1c580933b5261a78c'
    },
    / ciphertext / h'5974e1b99a3a4cc09a659aa2e9e7fff161d38ce7edd5617
388e77baf'
  ]
)

```

#### **C.4.2. Encrypted Message w/ a Partial IV**

This example uses the following:

- o CEK: AES-CCM w/ 128-bit key and a 64-bit tag
- o Prefix for IV is 89F52F65A1C580933B52

Size of binary file is 43 bytes

```

993(
  [
    / protected / h'a1010a' / {
      \ alg \ 1:10 \ AES-CCM-16-64-128 \
    } / ,
    / unprotected / {
      / partial iv / 6:h'61a7'
    },
    / ciphertext / h'252a8911d465c125b6764739700f0141ed09192da5c69e5
33abf852b'
  ]
)

```

### **C.5. Examples of MACed messages**

#### **C.5.1. Shared Secret Direct MAC**

This example uses the following:

- o MAC: AES-CMAC, 256-bit key, truncated to 64 bits
- o Recipient class: direct shared secret

Size of binary file is 58 bytes



```

994(
  [
    / protected / h'a1010f' / {
      \ alg \ 1:15 \ AES-CBC-MAC-256//64 \
    } / ,
    / unprotected / {},
    / payload / 'This is the content.',
    / tag / h'9e1226ba1f81b848',
    / recipients / [
      [
        / protected / h'',
        / unprotected / {
          / alg / 1:-6 / direct / ,
          / kid / 4:'our-secret'
        },
        / ciphertext / h''
      ]
    ]
  ]
)

```

#### **C.5.2. ECDH Direct MAC**

This example uses the following:

- o MAC: HMAC w/SHA-256, 256-bit key
- o Recipient class: ECDH key agreement, two static keys, HKDF w/ context structure

Size of binary file is 215 bytes



```

994(
  [
    / protected / h'a10105' / {
      \ alg \ 1:5 \ HMAC 256//256 \
    } / ,
    / unprotected / {},
    / payload / 'This is the content.',
    / tag / h'81a03448acd3d305376eaa11fb3fe416a955be2cbe7ec96f012c99
4bc3f16a41',
    / recipients / [
      [
        / protected / h'a101381a' / {
          \ alg \ 1:-27 \ ECDH-SS + HKDF-256 \
        } / ,
        / unprotected / {
          / static kid / -3:'peregrin.took@tuckborough.example',
          / kid / 4:'meriadoc.brandybuck@buckland.example',
          / U nonce / -22:h'4d8553e7e74f3c6a3a9dd3ef286a8195cbf8a23d
19558ccfec7d34b824f42d92bd06bd2c7f0271f0214e141fb779ae2856abf585a583
68b017e7f2a9e5ce4db5'
        },
        / ciphertext / h''
      ]
    ]
  ]
)

```

### [C.5.3.](#) Wrapped MAC

This example uses the following:

- o MAC: AES-MAC, 128-bit key, truncated to 64 bits
- o Recipient class: AES keywrap w/ a pre-shared 256-bit key

Size of binary file is 110 bytes



```

994(
  [
    / protected / h'a1010e' / {
      \ alg \ 1:14 \ AES-CBC-MAC-128//64 \
    } / ,
    / unprotected / {},
    / payload / 'This is the content.',
    / tag / h'36f5afaf0bab5d43',
    / recipients / [
      [
        / protected / h'',
        / unprotected / {
          / alg / 1:-5 / A256KW / ,
          / kid / 4:'018c0ae5-4d9b-471b-bfd6-eef314bc7037'
        },
        / ciphertext / h'711ab0dc2fc4585dce27effa6781c8093eba906f227
b6eb0'
      ]
    ]
  ]
)

```

#### [C.5.4.](#) Multi-recipient MACed message

This example uses the following:

- o MAC: HMAC w/ SHA-256, 128-bit key
- o Recipient class: Uses three different methods
  1. ECDH Ephemeral-Static, Curve P-521, AES-Key Wrap w/ 128-bit key
  2. AES-Key Wrap w/ 256-bit key

Size of binary file is 310 bytes





```

994(
  [
    / protected / h'a10105' / {
      \ alg \ 1:5 \ HMAC 256//256 \
    } / ,
    / unprotected / {},
    / payload / 'This is the content.',
    / tag / h'bf48235e809b5c42e995f2b7d5fa13620e7ed834e337f6aa43df16
1e49e9323e',
    / recipients / [
      [
        / protected / h'a101381c' / {
          \ alg \ 1:-29 \ ECHD-ES+A128KW \
        } / ,
        / unprotected / {
          / ephemeral / -1:{
            / kty / 1:2,
            / crv / -1:3,
            / x / -2:h'0043b12669acac3fd27898ffba0bcd2e6c366d53bc4db
71f909a759304acfb5e18cdc7ba0b13ff8c7636271a6924b1ac63c02688075b55ef2
d613574e7dc242f79c3',
            / y / -3:true
          },
          / kid / 4:'bilbo.baggins@hobbiton.example'
        },
        / ciphertext / h'339bc4f79984cdc6b3e6ce5f315a4c7d2b0ac466fce
a69e8c07dfbca5bb1f661bc5f8e0df9e3eff5'
      ],
      [
        / protected / h'',
        / unprotected / {
          / alg / 1:-5 / A256KW / ,
          / kid / 4:'018c0ae5-4d9b-471b-bfd6-eef314bc7037'
        },
        / ciphertext / h'0b2c7cfce04e98276342d6476a7723c090dfdd15f9a
518e7736549e998370695e6d6a83b4ae507bb'
      ]
    ]
  ]
)

```

## [C.6.](#) Examples of MAC0 messages

### [C.6.1.](#) Shared Secret Direct MAC

This example uses the following:

- o MAC: AES-CMAC, 256-bit key, truncated to 64 bits



- o Recipient class: direct shared secret

Size of binary file is 39 bytes

```
996(  
  [  
    / protected / h'a1010f' / {  
      \ alg \ 1:15 \ AES-CBC-MAC-256//64 \  
    } / ,  
    / unprotected / {},  
    / payload / 'This is the content.',  
    / tag / h'726043745027214f'  
  ]  
)
```

Note that this example uses the same inputs as [Appendix C.5.1](#).

## **[C.7.](#) COSE Keys**

### **[C.7.1.](#) Public Keys**

This is an example of a COSE Key set. This example includes the public keys for all of the previous examples.

In order the keys are:

- o An EC key with a kid of "meriadoc.brandybuck@buckland.example"
- o An EC key with a kid of "peregrin.took@tuckborough.example"
- o An EC key with a kid of "bilbo.baggins@hobbiton.example"
- o An EC key with a kid of "11"

Size of binary file is 481 bytes



```
[
  {
    -1:1,
    -2:h'65eda5a12577c2bae829437fe338701a10aaa375e1bb5b5de108de439c0
8551d',
    -3:h'1e52ed75701163f7f9e40ddf9f341b3dc9ba860af7e0ca7ca7e9eecd008
4d19c',
    1:2,
    2:'meriadoc.brandybuck@buckland.example'
  },
  {
    -1:1,
    -2:h'bac5b11cad8f99f9c72b05cf4b9e26d244dc189f745228255a219a86d6a
09eff',
    -3:h'20138bf82dc1b6d562be0fa54ab7804a3a64b6d72ccfed6b6fb6ed28bbf
c117e',
    1:2,
    2:'11'
  },
  {
    -1:3,
    -2:h'0072992cb3ac08ecf3e5c63dedec0d51a8c1f79ef2f82f94f3c737bf5de
7986671eac625fe8257bbd0394644caaa3aaf8f27a4585fbbcad0f2457620085e5c8
f42ad',
    -3:h'01dca6947bce88bc5790485ac97427342bc35f887d86d65a089377e247e
60baa55e4e8501e2ada5724ac51d6909008033ebc10ac999b9d7f5cc2519f3fe1ea1
d9475',
    1:2,
    2:'bilbo.baggins@hobbiton.example'
  },
  {
    -1:1,
    -2:h'98f50a4ff6c05861c8860d13a638ea56c3f5ad7590bbfbf054e1c7b4d91
d6280',
    -3:h'f01400b089867804b8e9fc96c3932161f1934f4223069170d924b7e03bf
822bb',
    1:2,
    2:'peregrin.took@tuckborough.example'
  }
]
```

### **C.7.2. Private Keys**

This is an example of a COSE Key set. This example includes the private keys for all of the previous examples.

In order the keys are:



- o An EC key with a kid of "meriadoc.brandybuck@buckland.example"
- o A shared-secret key with a kid of "our-secret"
- o An EC key with a kid of "peregrin.took@tuckborough.example"
- o A shared-secret key with a kid of "018c0ae5-4d9b-471b-bfd6-eef314bc7037"
- o An EC key with a kid of "bilbo.baggins@hobbiton.example"
- o An EC key with a kid of "11"

Size of binary file is 816 bytes

```
[
  {
    1:2,
    2:'meriadoc.brandybuck@buckland.example',
    -1:1,
    -2:h'65eda5a12577c2bae829437fe338701a10aaa375e1bb5b5de108de439c0
8551d',
    -3:h'1e52ed75701163f7f9e40ddf9f341b3dc9ba860af7e0ca7ca7e9eecd008
4d19c',
    -4:h'aff907c99f9ad3aae6c4cdf21122bce2bd68b5283e6907154ad911840fa
208cf'
  },
  {
    1:2,
    2:'11',
    -1:1,
    -2:h'bac5b11cad8f99f9c72b05cf4b9e26d244dc189f745228255a219a86d6a
09eff',
    -3:h'20138bf82dc1b6d562be0fa54ab7804a3a64b6d72ccfed6b6fb6ed28bbf
c117e',
    -4:h'57c92077664146e876760c9520d054aa93c3afb04e306705db609030850
7b4d3'
  },
  {
    1:2,
    2:'bilbo.baggins@hobbiton.example',
    -1:3,
    -2:h'0072992cb3ac08ecf3e5c63dedec0d51a8c1f79ef2f82f94f3c737bf5de
7986671eac625fe8257bbd0394644caaa3aaf8f27a4585fbbcad0f2457620085e5c8
f42ad',
    -3:h'01dca6947bce88bc5790485ac97427342bc35f887d86d65a089377e247e
60baa55e4e8501e2ada5724ac51d6909008033ebc10ac999b9d7f5cc2519f3fe1ea1
d9475',
```





```

-4:h'00085138ddabf5ca975f5860f91a08e91d6d5f9a76ad4018766a476680b
55cd339e8ab6c72b5facdb2a2a50ac25bd086647dd3e2e6e99e84ca2c3609fdf177f
eb26d'
},
{
  1:4,
  2:'our-secret',
  -1:h'849b57219dae48de646d07dbb533566e976686457c1491be3a76dcea6c4
27188'
},
{
  1:2,
  -1:1,
  2:'peregrin.took@tuckborough.example',
  -2:h'98f50a4ff6c05861c8860d13a638ea56c3f5ad7590bbfbf054e1c7b4d91
d6280',
  -3:h'f01400b089867804b8e9fc96c3932161f1934f4223069170d924b7e03bf
822bb',
  -4:h'02d1f7e6f26c43d4868d87ceb2353161740aacf1f7163647984b522a848
df1c3'
},
{
  1:4,
  2:'our-secret2',
  -1:h'849b5786457c1491be3a76dcea6c4271'
},
{
  1:4,
  2:'018c0ae5-4d9b-471b-bfd6-eef314bc7037',
  -1:h'849b57219dae48de646d07dbb533566e976686457c1491be3a76dcea6c4
27188'
}
]

```

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