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CBOR Object Signing and Encryption (COSE): Countersignatures

Abstract

Concise Binary Object Representation (CBOR) is a data format designed for small code size and small message size. CBOR Object Signing and Encryption (COSE) defines a set of security services for CBOR. This document defines a countersignature algorithm along with the needed header parameters and CBOR tags for COSE.

Contributing to this document

This note is to be removed before publishing as an RFC.

The source for this draft is being maintained in GitHub. Suggested changes should be submitted as pull requests at <https://github.com/cose-wg/countersign>. 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.

Status of This Memo

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Table of Contents

1.	Introduction
1.1.	Requirements Terminology
1.2.	CBOR Grammar
1.3.	Document Terminology
2.	Countersignature Header Parameters
3.	Version 2 Countersignatures
3.1.	Full Countersignatures
3.2.	Abbreviated Countersignatures
3.3.	Signing and Verification Process
4.	CBOR Encoding Restrictions
5.	IANA Considerations
5.1.	CBOR Tag Assignment
5.2.	COSE Header Parameters Registry
6.	Security Considerations
7.	Implementation Status
7.1.	Author's Versions
7.2.	COSE Testing Library
8.	References
8.1.	Normative References
8.2.	Informative References
	Appendix A. Examples
A.1.	Use of Early Code Points
A.2.	Examples of Signed Messages
A.2.1.	Countersignature
A.3.	Examples of Signed1 Messages
A.3.1.	Countersignature
A.4.	Examples of Enveloped Messages
A.4.1.	Countersignature on Encrypted Content
A.5.	Examples of Encrypted Messages
A.5.1.	Countersignature on Encrypted Content
A.6.	Examples of MACed Messages
A.6.1.	Countersignature on MAC Content
A.7.	Examples of MAC0 Messages
A.7.1.	Countersignature on MAC0 Content
	Acknowledgments
	Authors' Addresses

1. Introduction

There has been an increased focus on small, constrained devices that make up the Internet of Things (IoT). One of the standards that has come out of this process is "Concise Binary Object Representation (CBOR)" [[I-D.ietf-cbor-7049bis](#)]. CBOR extended the data model of the JavaScript Object Notation (JSON) [[STD90](#)] by allowing for binary data, among other changes. CBOR has been adopted by several of the IETF working groups dealing with the IoT world as their encoding of data structures. CBOR was designed specifically both to be small in terms of messages transported and implementation size and to be a schema-free decoder. A need exists to provide message security services for IoT, and using CBOR as the message-encoding format makes sense.

During the process of advancing COSE to an Internet Standard, it was noticed the description of the security properties of countersignatures was incorrect for the COSE_Sign1 structure. Since the security properties that were described, those of a true countersignature, were those that the working group desired, the decision was made to remove all of the countersignature text from [[I-D.ietf-cose-rfc8152bis-struct](#)] and create a new document to both deprecate the old countersignature algorithm and to define a new one with the desired security properties.

The problem with the previous countersignature algorithm was that the cryptographically computed value was not always included. The initial assumption that the cryptographic value was in the third slot of the array was known not to be true at the time, but in the case of the MAC structures this was not deemed to be an issue. The new algorithm is more aggressive about the set of values included in the countersignature computation so that the cryptographic computed values is included. The exception to this is the COSE_Signature structure where there is no cryptographic computed value.

The new algorithm is designed to produce the same countersignature value in those cases where the cryptographic computed value was already included. This means that for those structures the only thing that would need to be done is to change the value of the header parameter.

1.1. 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 BCP 14 [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

1.2. CBOR Grammar

CBOR grammar in the document is presented using CBOR Data Definition Language (CDDL) [[RFC8610](#)].

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 `>` as an entity.)

```
//sourcecode[@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_Countersignature_Tagged / Internal_Types
```

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

```
Internal_Types = Countersign_structure / COSE_Countersignature0
```

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.

1.3. 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](#)].

Context is used throughout the document to represent information that is not part of the COSE message. Information which is part of the context can come from several different sources including: Protocol interactions, associated key structures, and program configuration. The context to use can be implicit, identified using the 'kid context' header parameter defined in [[RFC8613](#)], or identified by a protocol-specific identifier. Context should generally be included in the cryptographic construction; for more details see [Section 4.3](#) of [[I-D.ietf-cose-rfc8152bis-struct](#)].

The term 'byte string' is used for sequences of bytes, while the term 'text string' is used for sequences of characters.

2. Countersignature Header Parameters

This section defines a set of common header parameters. A summary of these header parameters can be found in [Table 1](#). 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:

V2 countersignature: This header parameter holds one or more countersignature values. Countersignatures provide a method of having a second party sign some data. The countersignature header parameter can occur as an unprotected attribute in any of the following structures: COSE_Sign1, COSE_Signature, COSE_Encrypt, COSE_recipient, COSE_Encrypt0, COSE_Mac, and COSE_Mac0. Details on version 2 countersignatures are found in [Section 3](#).

Name	Label	Value Type	Value Registry	Description
counter signature version 2	TBD10	COSE_Countersignature / [+ COSE_Countersignature]		V2 counter signature attribute
counter signature 0 version 2	TBD11	COSE_Countersignature0		Abbreviated Counter signature vesion 2

Table 1: Common Header Parameters

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

```
Generic-Headers /= (  
  ? TBD10 => COSE_Countersignature / [+COSE_Countersignature]  
  ; V2 Countersignature  
  ? TBD11 => COSE_Countersignature0 ; V2 Countersignature0  
)
```

3. Version 2 Countersignatures

A countersignature is normally defined as a second signature that confirms a primary signature. A normal example of a countersignature

is the signature that a notary public places on a document as witnessing that you have signed the document. Thus applying a countersignature to either the COSE_Signature or COSE_Sign1 objects match this traditional definition. This document extends the context of a countersignature to allow it to be applied to all of the security structures defined. It needs to be noted that the countersignature needs to be treated as a separate operation from the initial operation even if it is applied by the same user as is done in [[I-D.ietf-core-groupcomm-bis](#)].

COSE supports two different forms for countersignatures. Full countersignatures use the structure COSE_Countersignature. This is same structure as COSE_Signature and thus it can have protected and unprotected attributes, including chained countersignatures. Abbreviated countersignatures use the structure COSE_Countersignature0. This structure only contains the signature value and nothing else. 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.

The version 2 countersignature changes the algorithm used for computing the signature from the original version [Section 4.5](#) of [[RFC8152](#)]. The new version now includes the cryptographic material generated for all of the structures rather than just for a subset.

COSE was designed for uniformity in how the data structures are specified. One result of this is that for COSE one can expand the concept of countersignatures beyond just the idea of signing a signature to being able to sign most of the structures without having to create a new signing layer. When creating a countersignature, one needs to be clear about the security properties that result. When done on a COSE_Signature or COSE_Sign1, the normal countersignature semantics are preserved. That is the countersignature makes a statement about the existence of a signature and, when used as a timestamp, a time point at which the signature exists. When done on a COSE_Sign, this is the same as applying a second signature to the payload and adding a parallel signature as a new COSE_Signature is the preferred method. When done on a COSE_Mac or COSE_Mac0, the payload is included as well as the MAC value. When done on a COSE_Encrypt or COSE_Encrypt0, the existence of the encrypted data is attested to. It should be noted that there is a big difference between attesting to the encrypted data as opposed to attesting to the unencrypted data. If the latter is what is desired, then one needs to apply a signature to the data and then encrypt that. It is always possible to construct cases where the use of two different keys will appear to result in a successful decryption (the tag check success), but which produce two

completely different plaintexts. This situation is not detectable by a countersignature on the encrypted data.

3.1. Full Countersignatures

The COSE_Countersignature structure allows for the same set of capabilities as a COSE_Signature. This means that all of the capabilities of a signature are duplicated with this structure. Specifically, the countersigner does not need to be related to the producer of what is being countersigned as key and algorithm identification can be placed in the countersignature attributes. This also means that the countersignature can itself be countersigned. This is a feature required by protocols such as long-term archiving services. More information on how countersignatures is used can be found in the evidence record syntax described in [\[RFC4998\]](#).

The full countersignature structure can be encoded as either tagged or untagged depending on the context it is used in. A tagged COSE_Countersignature structure is identified by the CBOR tag TBD0. The countersignature structure is the same as that used for a signer on a signed object. The CDDL fragment for full countersignatures is:

```
COSE_Countersignature_Tagged = #6.9999(COSE_Countersignature)
COSE_Countersignature = COSE_Signature
```

The details of the fields of a countersignature can be found in [Section 4.1](#) of [\[I-D.ietf-cose-rfc8152bis-struct\]](#).

An example of a countersignature on a signature can be found in [Appendix A.2.1](#). An example of a countersignature in an encryption object can be found in [Appendix A.4.1](#).

It should be noted that only a signature algorithm with appendix (see [Section 8](#) of [\[I-D.ietf-cose-rfc8152bis-struct\]](#)) can be used for countersignatures. This is because the body should be able to be processed without having to evaluate the countersignature, and this is not possible for signature schemes with message recovery.

3.2. Abbreviated Countersignatures

Abbreviated countersignatures were designed primarily to deal with the problem of encrypted group messaging, but where it is required to know who originated the message. The objective was to keep the countersignature as small as possible while still providing the needed security. For abbreviated countersignatures, there is no provision for any protected attributes related to the signing operation. Instead, the parameters for computing or verifying the

abbreviated countersignature are provided by the same context used to describe the encryption, signature, or MAC processing.

The CDDL fragment for the abbreviated countersignatures is:

```
COSE_Countersignature0 = bstr
```

The byte string representing the signature value is placed in the Countersignature0 attribute. This attribute is then encoded as an unprotected header parameter. The attribute is defined below.

3.3. Signing and Verification Process

In order to create a signature, a well-defined byte string is needed. The Countersign_structure is used to create the canonical form. This signing and verification process takes in countersignature target structure, the signer information (COSE_Signature), and the application data (external source). A Countersign_structure is a CBOR array. The target structure of the countersignature needs to have all of its cryptographic functions finalized before computing the signature. The fields of the Countersign_structure in order are:

1. A context text string identifying the context of the signature. The context text string is:

"CounterSignature" for signatures using the COSE_Countersignature structure when other_fields is absent.

"CounterSignature0" for signatures using the COSE_Countersignature0 structure when other_fields is absent.

"CounterSignatureV2" for signatures using the COSE_Countersignature structure when other_fields is present.

"CounterSignature0V2" for signatures using the COSE_Countersignature0 structure when other_fields is present.

2. The protected attributes from the target structure encoded in a bstr type. If there are no protected attributes, a zero-length byte string is used.
3. The protected attributes from the signer structure encoded in a bstr type. If there are no protected attributes, a zero-length

byte string is used. This field is omitted for the Countersignature0V2 attribute.

4. The externally supplied data from the application encoded in a bstr type. If this field is not supplied, it defaults to a zero-length byte string. (See [Section 4.3](#) of [[I-D.ietf-cose-rfc8152bis-struct](#)] 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.
6. If there are only two bstr fields in the target structure, this field is omitted. The field is an array of all bstr fields after the second. As an example, this would be an array of one element for the COSE_Sign1 structure containing the signature value.

The CDDL fragment that describes the above text is:

```
Countersign_structure = [  
  context : "CounterSignature" / "CounterSignature0" /  
            "CounterSignatureV2" / "CounterSignature0V2" /,  
  body_protected : empty_or_serialized_map,  
  ? sign_protected : empty_or_serialized_map,  
  external_aad : bstr,  
  payload : bstr,  
  ? other_fields : [ + bstr ]  
]
```

How to compute a countersignature:

1. Create a Countersign_structure and populate it with the appropriate fields.
2. Create the value ToBeSigned by encoding the Countersign_structure to a byte string, using the encoding described in [Section 4](#).
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 correct location. This is the 'signature' field of the COSE_Countersignature structure. This is the value of the Countersignature0 attribute.

The steps for verifying a countersignature are:

1. Create a Countersign_structure and populate it with the appropriate fields.
2. Create the value ToBeSigned by encoding the Countersign_structure to a byte string, using the encoding described in [Section 4](#).
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, the application performs 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. CBOR Encoding Restrictions

In order to always regenerate the same byte string for the "to be signed" value, the deterministic encoding rules defined in [Section 4.2](#) of [[I-D.ietf-cbor-7049bis](#)]. These rules match the ones laid out in [Section 11](#) of [[I-D.ietf-cose-rfc8152bis-struct](#)].

5. IANA Considerations

The registries and registrations listed below were created during processing of RFC 8152 [[RFC8152](#)]. The majority of the actions are to update the references to point to this document.

5.1. CBOR Tag Assignment

IANA is requested to register a new tag for the CounterSignature type.

*Tag: TBD0

*Data Item: COSE_Countersignature

*Semantics: COSE standalone V2 countersignature

*Reference: [[this document]]

5.2. COSE Header Parameters Registry

IANA created a registry titled "COSE Header Parameters" as part of processing [[RFC8152](#)].

IANA is requested to register the following new items in the registry. For these entries, the Value Registry column will be blank and the Reference column will be [[This Document]].

Name	Label	Value Type	Description
counter signature version 2	TBD10	COSE_Countersignature / [+ COSE_Countersignature]	V2 countersignature attribute
Countersignature0 version 2	TBD11	COSE_Countersignature0	Abbreviated Counter signature version 2

Table 2: New Common Header Parameters

IANA is requested to modify the Description field for "counter signature" and "CounterSignature0" to include the words "(Deprecated by [[This Document]])".

6. Security Considerations

There are a number of security considerations that need to be taken into account by implementers of this specification. 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 material for any individuals. There are some cases that need to be highlighted on this issue.

- *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.

- *Use of 'direct' as a recipient algorithm combined with a second recipient algorithm exposes the direct key to the second recipient.

- *Several of the algorithms in [[I-D.ietf-cose-rfc8152bis-algs](#)] 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 that key, provide the opportunity 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:

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

Analysis of the size of encrypted messages can provide information about the plaintext messages. This specification does not provide a uniform method for padding messages prior to encryption. An observer can distinguish between two different messages (for example, 'YES' and 'NO') based on the length for all of the content encryption algorithms that are defined in [[I-D.ietf-cose-rfc8152bis-algs](#)]. This means that it is up to the applications to specify how content padding is to be done to prevent or discourage such analysis. (For example, the text strings could be defined as 'YES' and 'NO '.)

When either COSE_Encrypt and COSE_Mac is used and more than two parties share the key, data origin authentication is not provided. Any party that knows the message-authentication key can compute a valid authentication tag; therefore, the contents could originate from any one of the parties that share the key.

Countersignatures of COSE_Encrypt and COSE_Mac with short authentication tags do not provide the security properties associated with the same algorithm used in COSE_Sign. To provide 128-bit security against collision attacks, the tag length MUST be at least 256-bits. A countersignature of a COSE_Mac with AES-MAC 256/128 provides at most 64 bits of integrity protection. Similarly, a countersignature of a COSE_Encrypt with AES-CCM-16-64-128 provides at most 32 bits bits of integrity protection.

7. Implementation Status

This section is to be removed before publishing as an RFC.

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 [\[RFC7942\]](#). 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 [\[RFC7942\]](#), "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".

7.1. 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 and C#.

*Cryptography: The Java and C# libraries use Bouncy Castle to provide the required cryptography.

*Coverage: Both implementations can produce and consume both the old and new countersignatures.

*Testing: All of the examples in the example library are generated by the C# library and then validated using the Java and C libraries. Both 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

7.2. 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 countersignatures, and ECDH with Curve25519 and Goldilocks are missing.

*Licensing: Public Domain

8. References

8.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.

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Internet-Draft, draft-ietf-cbor-7049bis-16, 30 September 2020, <<https://tools.ietf.org/html/draft-ietf-cbor-7049bis-16>>.

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8.2. Informative References

[RFC8610] Birkholz, H., Vigano, C., and C. Bormann, "Concise Data Definition Language (CDDL): A Notational Convention to Express Concise Binary Object Representation (CBOR) and JSON Data Structures", RFC 8610, DOI 10.17487/RFC8610, June 2019, <<https://www.rfc-editor.org/info/rfc8610>>.

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[RFC4998] Gondrom, T., Brandner, R., and U. Pordesch, "Evidence Record Syntax (ERS)", RFC 4998, DOI 10.17487/RFC4998, August 2007, <<https://www.rfc-editor.org/info/rfc4998>>.

[I-D.ietf-core-groupcomm-bis] Dijk, E., Wang, C., and M. Tiloca, "Group Communication for the Constrained Application Protocol (CoAP)", Work in Progress, Internet-Draft, draft-ietf-core-groupcomm-bis-03, 22 February 2021,

<<https://tools.ietf.org/html/draft-ietf-core-groupcomm-bis-03>>.

[I-D.ietf-cose-rfc8152bis-struct]

Schaad, J., "CBOR Object Signing and Encryption (COSE): Structures and Process", Work in Progress, Internet-Draft, draft-ietf-cose-rfc8152bis-struct-15, 1 February 2021, <<https://tools.ietf.org/html/draft-ietf-cose-rfc8152bis-struct-15>>.

[RFC8613] Selander, G., Mattsson, J., Palombini, F., and L. Seitz, "Object Security for Constrained RESTful Environments (OSCORE)", RFC 8613, DOI 10.17487/RFC8613, July 2019, <<https://www.rfc-editor.org/info/rfc8613>>.

Appendix A. 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 [[RFC8610](#)]) rather than as a binary dump.

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 sourcecode is tagged with the attribute `type='CBORDdiag'`. (Depending on the XPath evaluator one is using, it may be necessary to deal with `>` as an entity.)

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


A.1. Use of Early Code Points

This section is to be removed before publishing as an RFC.

The examples in this Appendix use code points proposed for early allocation by IANA. When IANA makes the allocation, these examples will be updated as needed.

A.2. Examples of Signed Messages

A.2.1. Countersignature

This example uses the following:

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

- *The same header parameters are used for both the signature and the countersignature.

Size of binary file is 180 bytes

```

98(
  [
    / protected / h'',
    / unprotected / {
      / countersign / 11:[
        / protected h'a10126' / << {
          / alg / 1:-7 / ECDSA 256 /
        } >>,
        / unprotected / {
          / kid / 4:'11'
        },
        / signature / h'5ac05e289d5d0e1b0a7f048a5d2b643813ded50bc9e4
9220f4f7278f85f19d4a77d655c9d3b51e805a74b099e1e085aacd97fc29d72f887e
8802bb6650cceb2c'
      ]
    },
    / payload / 'This is the content.',
    / signatures / [
      [
        / protected h'a10126' / << {
          / alg / 1:-7 / ECDSA 256 /
        } >>,
        / unprotected / {
          / kid / 4:'11'
        },
        / signature / h'e2aeafd40d69d19dfe6e52077c5d7ff4e408282cbefb
5d06cbf414af2e19d982ac45ac98b8544c908b4507de1e90b717c3d34816fe926a2b
98f53afd2fa0f30a'
      ]
    ]
  ]
)

```

A.3. Examples of Signed1 Messages

A.3.1. Countersignature

This example uses the following:

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

*Countersignature Algorithm: ECDSA w/ SHA-512, Curve P-521

Size of binary file is 275 bytes

```

18(
  [
    / protected h'A201260300' / << {
      / alg / 1:-7, / ECDSA 256 /
      / ctyp / 3:0
    } >>,
    / unprotected / {
      / kid / 4: "11",
      / countersign / 11: [
        / protected h'A1013823' / << {
          / alg / 1:-36 / ECDSA 512 /
        } >>,
        / unprotected / {
          / kid / 4: "bilbo.baggins@hobbiton.example"
        },
        / signature / h'01B1291B0E60A79C459A4A9184A0D393E034B34AF069
A1CCA34F5A913AFFFF698002295FA9F8FCBFB6FDFF59132FC0C406E98754A98F1FBF
E81C03095F481856BC470170227206FA5BEE3C0431C56A66824E7AAF692985952E31
271434B2BA2E47A335C658B5E995AEB5D63CF2D0CED367D3E4CC8FFFD53B70D115BA
A9E86961FBD1A5CF'
      ]
    },
    / payload / 'This is the content.',
    / signature / h'BB587D6B15F47BFD54D2CBFCECEF75451E92B08A514BD439
FA3AA65C6AC92DF0D7328C4A47529B32ADD3DD1B4E940071C021E9A8F2641F1D8E3B
053DDD65AE52'
  ]
)

```

A.4. Examples of Enveloped Messages

A.4.1. Countersignature on Encrypted Content

This example uses the following:

*CEK: AES-GCM w/ 128-bit key

*Recipient class: ECDH Ephemeral-Static, Curve P-256

*Countersignature Algorithm: ECDSA w/ SHA-512, Curve P-521

Size of binary file is 326 bytes

```

96(
  [
    / protected h'a10101' / << {
      / alg / 1:1 / AES-GCM 128 /
    } >>,
    / unprotected / {
      / iv / 5:h'c9cf4df2fe6c632bf7886413',
      / countersign / 11:[
        / protected h'a1013823' / << {
          / alg / 1:-36 / ES512 /
        } >> ,
        / unprotected / {
          / kid / 4:'bilbo.baggins@hobbiton.example'
        },
        / signature / h'00929663c8789bb28177ae28467e66377da12302d7f9
594d2999afa5dfa531294f8896f2b6cdf1740014f4c7f1a358e3a6cf57f4ed6fb02f
cf8f7aa989f5dfd07f0700a3a7d8f3c604ba70fa9411bd10c2591b483e1d2c31de00
3183e434d8fba18f17a4c7e3dfa003ac1cf3d30d44d2533c4989d3ac38c38b71481c
c3430c9d65e7ddff'
      ]
    },
    / 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''
      ]
    ]
  ]
)

```

A.5. Examples of Encrypted Messages

A.5.1. Countersignature on Encrypted Content

This example uses the following:

*CEK: AES-GCM w/ 128-bit key

*Countersignature algorithm: EdDSA with Curve Ed25519

Size of binary file is 136 bytes

```
16(
  [
    / protected h'A10101' / << {
      / alg / 1:1 / AES-GCM 128 /
    } >>,
    / unprotected / {
      / iv / 5: h'02D1F7E6F26C43D4868D87CE',
      / countersign / 11: [
        / protected h'A10127' / << {
          / alg / 1:-8 / EdDSA with Ed25519 /
        } >>,
        / unprotected / {
          / kid / 4: '11'
        },
        / signature / h'E10439154CC75C7A3A5391491F88651E0292FD0FE0E0
2CF740547EAF6677B4A4040B8ECA16DB592881262F77B14C1A086C02268B17171CA1
6BE4B8595F8C0A08'
      ]
    },
    / ciphertext / h'60973A94BB2898009EE52ECFD9AB1DD25867374B162E2C0
3568B41F57C3CC16F9166250A'
  ]
)
```

A.6. Examples of MACed Messages

A.6.1. Countersignature on MAC Content

This example uses the following:

*MAC algorithm: HMAC/SHA-256 with 256-bit key

*Countersignature algorithm: EdDSA with Curve Ed25519

Size of binary file is 159 bytes

```

97(
  [
    / protected h'A10105' / << {
      / alg / 1:5 / HS256 /
    } >>,
    / unprotected / {
      / countersign / 11: [
        / protected h'A10127' / << {
          / alg / 1:-8 / EdDSA /
        } >>,
        / unprotected / {
          / kid / 4: '11'
        },
        / signature / h'602566F4A311DC860740D2DF54D4864555E85BC036EA
5A6CF7905B96E499C5F66B01C4997F6A20C37C37543ADEA1D705347D38A5B13594B2
9583DD741F455101'
      ]
    },
    / payload / 'This is the content.',
    / tag / h'2BDCC89F058216B8A208DDC6D8B54AA91F48BD63484986565105C9
AD5A6682F6',
    / recipients / [
      [
        / protected / h'',
        / unprotected / {
          / alg / 1: -6, / direct /
          / kid / 4: 'our-secret'
        },
        / ciphertext / h''
      ]
    ]
  ]
)

```

A.7. Examples of MAC0 Messages

A.7.1. Countersignature on MAC0 Content

This example uses the following:

*MAC algorithm: HMAC/SHA-256 with 256-bit key

*Countersignature algorithm: EdDSA with Curve Ed25519

Size of binary file is 159 bytes

```

17(
  [
    / protected h'A10105' / << {
      / alg / 1:5 / HS256 /
    } >>,
    / unprotected / {
      / countersign / 11: [
        / protected h'A10127' / << {
          / alg / 1:-8 / EdDSA /
        } >>,
        / unprotected / {
          / kid / 4: '11'
        },
        / signature / h'968A315DF6B4F26362E11F4CFD2F2F4E76232F39657B
F1598837FF9332CDDD7581E248116549451F81EF823DA5974F885B681D3D6E38FC41
42D8F8E9E7DC8F0D'
      ]
    },
    / payload / 'This is the content.',
    / tag / h'A1A848D3471F9D61EE49018D244C824772F223AD4F935293F1789F
C3A08D8C58'
  ]
)

```

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Jim Schaad and Jonathan Hammell provided the examples in the Appendix.

{{{ RFC EDITOR: Please remove Russ Housley as an author of this document at publication. Jim Schaad should be listed as the sole author. }}}}

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