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TOC

JSON Web Encryption (JWE)
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Abstract

JSON Web Encryption (JWE) is a means of representing encrypted content using JavaScript Object Notation (JSON) data structures. Cryptographic algorithms and identifiers for use with this specification are described in the separate JSON Web Algorithms (JWA) specification. Related digital signature and MAC capabilities are described in the separate JSON Web Signature (JWS) specification.

Table of Contents

1. Introduction
   1.1. Notational Conventions
2. Terminology
3. JSON Web Encryption (JWE) Overview
   3.1. Example JWE using RSAES OAEP and AES GCM
   3.2. Example JWE using RSAES-PKCS1-V1_5 and AES_128_CBC_HMAC_SHA_256
4. JWE Header
   4.1. Reserved Header Parameter Names
      4.1.1. "alg" (Algorithm) Header Parameter

4.1.2. "enc" (Encryption Method) Header Parameter
4.1.3. "epk" (Ephemeral Public Key) Header Parameter
4.1.4. "zip" (Compression Algorithm) Header Parameter
4.1.5. "jku" (JWK Set URL) Header Parameter
4.1.6. "jwk" (JSON Web Key) Header Parameter
4.1.7. "x5u" (X.509 URL) Header Parameter
4.1.8. "x5t" (X.509 Certificate Thumbprint) Header Parameter
4.1.9. "x5c" (X.509 Certificate Chain) Header Parameter
4.1.10. "kid" (Key ID) Header Parameter
4.1.11. "typ" (Type) Header Parameter
4.1.12. "cty" (Content Type) Header Parameter
4.1.13. "apu" (Agreement PartyUInfo) Header Parameter
4.1.14. "apv" (Agreement PartyVInfo) Header Parameter
4.1.15. "crit" (Critical) Header Parameter
4.2. Public Header Parameter Names
4.3. Private Header Parameter Names
5. Producing and Consuming JWEs
5.1. Message Encryption
5.2. Message Decryption
5.3. String Comparison Rules
6. Encrypting JWEs with Cryptographic Algorithms
6.1. CEK Encryption
7. JSON Serialization
7.1. Example JWE-JS
8. Implementation Considerations
9. IANA Considerations
9.1. Registration of JWE Header Parameter Names
9.1.1. Registry Contents
9.2. JSON Web Signature and Encryption Type Values Registration
9.2.1. Registry Contents
9.3. Media Type Registration
9.3.1. Registry Contents
10. Security Considerations
11. References
11.1. Normative References
11.2. Informative References
Appendix A. JWE Examples
A.1. Example JWE using RSAES OAEP and AES GCM
A.1.1. JWE Header
A.1.2. Encoded JWE Header
A.1.3. Content Encryption Key (CEK)
A.1.4. Key Encryption
A.1.5. Encoded JWE Encrypted Key
A.1.6. Initialization Vector
A.1.7. Additional Authenticated Data Parameter
A.1.8. Plaintext Encryption
A.1.9. Encoded JWE Ciphertext
A.1.10. Encoded JWE Authentication Tag
A.1.11. Complete Representation
A.1.12. Validation
A.2. Example JWE using RSAES-PKCS1-V1_5 and AES_128_CBC_HMAC_SHA_256
A.2.1. JWE Header
A.2.2. Encoded JWE Header
A.2.3. Content Encryption Key (CEK)
A.2.4. Key Encryption
A.2.5. Encoded JWE Encrypted Key
A.2.6. Initialization Vector
A.2.7. Additional Authenticated Data Parameter
A.2.8. Plaintext Encryption
A.2.9. Encoded JWE Ciphertext
A.2.10. Encoded JWE Authentication Tag
A.2.11. Complete Representation
A.2.12. Validation
A.3. Example JWE using AES Key Wrap and AES GCM
A.3.1. JWE Header
A.3.2. Encoded JWE Header
A.3.3. Content Encryption Key (CEK)

A.3.4. Key Encryption
A.3.5. Encoded JWE Encrypted Key
A.3.6. Initialization Vector
A.3.7. Additional Authenticated Data Parameter
A.3.8. Plaintext Encryption
A.3.9. Encoded JWE Ciphertext
A.3.10. Encoded JWE Authentication Tag
A.3.11. Complete Representation
A.3.12. Validation
Appendix B. Example AES_128_CBC_HMAC_SHA_256 Computation
B.1. Extract MAC_KEY and ENC_KEY from Key
B.2. Encrypt Plaintext to Create Ciphertext
B.3. Create 64 Bit Big Endian Representation of AAD Length
B.4. Initialization Vector Value
B.5. Create Input to HMAC Computation
B.6. Compute HMAC Value
B.7. Truncate HMAC Value to Create Authentication Tag
Appendix C. Possible Compact Serialization for Multiple Recipients
Appendix D. Acknowledgements
Appendix E. Document History
§ Authors' Addresses

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1. Introduction

TOC

JSON Web Encryption (JWE) is a compact encryption format intended for space constrained environments such as HTTP Authorization headers and URI query parameters. It represents this content using JavaScript Object Notation (JSON) **[RFC4627]** based data structures. The JWE cryptographic mechanisms encrypt and provide integrity protection for arbitrary sequences of octets.

Cryptographic algorithms and identifiers for use with this specification are described in the separate JSON Web Algorithms (JWA) **[JWA]** specification. Related digital signature and MAC capabilities are described in the separate JSON Web Signature (JWS) **[JWS]** specification.

1.1. Notational Conventions

TOC

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in Key words for use in RFCs to Indicate Requirement Levels **[RFC2119]**.

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2. Terminology

TOC

JSON Web Encryption (JWE)
: A data structure representing an encrypted message. The structure represents five values: the JWE Header, the JWE Encrypted Key, the JWE Initialization Vector, the JWE Ciphertext, and the JWE Authentication Tag.

Authenticated Encryption
: An Authenticated Encryption algorithm is one that provides an integrated content integrity check. Authenticated Encryption algorithms accept two inputs, the Plaintext and the Additional Authenticated Data value, and produce two outputs, the Ciphertext and the Authentication Tag value. AES Galois/Counter Mode (GCM) is one such algorithm.

Plaintext
: The sequence of octets to be encrypted -- a.k.a., the message. The plaintext can contain an arbitrary sequence of octets.

Ciphertext
: An encrypted representation of the Plaintext.

Additional Associated Data (AAD)

An input to an Authenticated Encryption operation that is integrity protected but not encrypted.

Authentication Tag
: An output of an Authenticated Encryption operation that ensures the integrity of the Ciphertext and the Additional Associated Data.

Content Encryption Key (CEK)
: A symmetric key for the Authenticated Encryption algorithm used to encrypt the Plaintext for the recipient to produce the Ciphertext and the Authentication Tag.

JSON Text Object
: A UTF-8 **[RFC3629]** encoded text string representing a JSON object; the syntax of JSON objects is defined in Section 2.2 of **[RFC4627]**.

JWE Header
: A JSON Text Object that describes the encryption operations applied to create the JWE Encrypted Key, the JWE Ciphertext, and the JWE Authentication Tag.

JWE Encrypted Key
: The result of encrypting the Content Encryption Key (CEK) with the intended recipient's key using the specified algorithm. Note that for some algorithms, the JWE Encrypted Key value is specified as being the empty octet sequence.

JWE Initialization Vector
: A sequence of octets containing the Initialization Vector used when encrypting the Plaintext. Note that some algorithms may not use an Initialization Vector, in which case this value is the empty octet sequence.

JWE Ciphertext
: A sequence of octets containing the Ciphertext for a JWE.

JWE Authentication Tag
: A sequence of octets containing the Authentication Tag for a JWE.

Base64url Encoding
: The URL- and filename-safe Base64 encoding described in **RFC 4648** [RFC4648], Section 5, with the (non URL-safe) '=' padding characters omitted, as permitted by Section 3.2. (See Appendix C of **[JWS]** for notes on implementing base64url encoding without padding.)

Encoded JWE Header
: Base64url encoding of the JWE Header.

Encoded JWE Encrypted Key
: Base64url encoding of the JWE Encrypted Key.

Encoded JWE Initialization Vector
: Base64url encoding of the JWE Initialization Vector.

Encoded JWE Ciphertext
: Base64url encoding of the JWE Ciphertext.

Encoded JWE Authentication Tag
: Base64url encoding of the JWE Authentication Tag.

Header Parameter Name
: The name of a member of the JWE Header.

Header Parameter Value
: The value of a member of the JWE Header.

JWE Compact Serialization
: A representation of the JWE as the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Authentication Tag in that order, with the five strings being separated by four period ('.') characters. This results in a compact, URL-safe representation.

JWE JSON Serialization
: A representation of the JWE as a JSON structure containing Encoded JWE Header, Encoded JWE Encrypted Key, Encoded JWE Initialization Vector, Encoded JWE Ciphertext, and Encoded JWE Authentication Tag values. Unlike the JWE Compact Serialization, the JWE JSON Serialization enables the same content to be encrypted to multiple parties. This representation is neither compact nor URL-safe.

Collision Resistant Namespace
: A namespace that allows names to be allocated in a manner such that they are highly unlikely to collide with other names. For instance, collision resistance can be achieved through administrative delegation of portions of the namespace or through use of collision-resistant name allocation functions. Examples of Collision Resistant Namespaces include: Domain Names, Object Identifiers (OIDs) as defined in the ITU-T X.660 and X.670 Recommendation series, and Universally Unique IDentifiers (UUIDs) **[RFC4122]**. When using an administratively delegated namespace, the definer of a name needs to take reasonable precautions to ensure they are in control of the portion of the namespace they use to define the name.

StringOrURI
: A JSON string value, with the additional requirement that while arbitrary string values MAY be used, any value containing a ":" character MUST be a URI **[RFC3986]**. StringOrURI values are compared as case-sensitive strings with no transformations or canonicalizations applied.

Key Management Mode
: A method of determining the Content Encryption Key (CEK) value to use. Each algorithm used for determining the CEK value uses a specific Key Management Mode. Key Management Modes employed by this specification are Key Encryption, Key Wrapping, Direct Key Agreement, Key Agreement with Key Wrapping, and Direct Encryption.

Key Encryption
: A Key Management Mode in which the Content Encryption Key (CEK) value is encrypted to the intended recipient using an asymmetric encryption algorithm.

Key Wrapping
: A Key Management Mode in which the Content Encryption Key (CEK) value is encrypted to the intended recipient using a symmetric key wrapping algorithm.

Direct Key Agreement
: A Key Management Mode in which a key agreement algorithm is used to agree upon the Content Encryption Key (CEK) value.

Key Agreement with Key Wrapping
: A Key Management Mode in which a key agreement algorithm is used to agree upon a symmetric key used to encrypt the Content Encryption Key (CEK) value to the intended recipient using a symmetric key wrapping algorithm.

Direct Encryption
: A Key Management Mode in which the Content Encryption Key (CEK) value used is the secret symmetric key value shared between the parties.

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3. JSON Web Encryption (JWE) Overview

TOC

JWE represents encrypted content using JSON data structures and base64url encoding. Five values are represented in a JWE: the JWE Header, the JWE Encrypted Key, the JWE Initialization Vector, the JWE Ciphertext, and the JWE Authentication Tag. In the Compact Serialization, the five values are base64url-encoded for transmission, and represented as the concatenation of the encoded strings in that order, with the five strings being separated by four period ('.') characters. A JSON Serialization for this information is also defined in **Section 7**.

JWE utilizes authenticated encryption to ensure the confidentiality and integrity of the Plaintext.

3.1. Example JWE using RSAES OAEP and AES GCM

TOC

This example encrypts the plaintext "The true sign of intelligence is not knowledge but imagination." to the recipient using RSAES OAEP and AES GCM.

The following example JWE Header declares that:

- the Content Encryption Key is encrypted to the recipient using the RSAES OAEP algorithm to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES GCM algorithm with a 256 bit key to produce the Ciphertext.

```
{"alg":"RSA-OAEP","enc":"A256GCM"}
```

Base64url encoding the octets of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ
```

The remaining steps to finish creating this JWE are:

- Generate a random Content Encryption Key (CEK)
- Encrypt the CEK with the recipient's public key using the RSAES OAEP algorithm to produce the JWE Encrypted Key
- Base64url encode the JWE Encrypted Key to produce the Encoded JWE Encrypted Key
- Generate a random JWE Initialization Vector
- Base64url encode the JWE Initialization Vector to produce the Encoded JWE Initialization Vector
- Concatenate the Encoded JWE Header value, a period ('.') character, and the Encoded JWE Encrypted Key to create the Additional Authenticated Data parameter
- Encrypt the Plaintext with AES GCM using the CEK as the encryption key, the JWE Initialization Vector, and the Additional Authenticated Data value, requesting a 128 bit Authentication Tag output
- Base64url encode the Ciphertext to create the Encoded JWE Ciphertext
- Base64url encode the Authentication Tag to create the Encoded JWE Authentication Tag
- Assemble the final representation: The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Authentication Tag in that order, with the five strings being separated by four period ('.') characters.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ.
ApfOLCaDbqs_JXPYy2I937v_xmrzj-Iss1mG6NAHmeJViM6j2l0MHvfseIdHVyU2
BIoGVu9ohvkkWiRq5DL2jYZTPA9TAdwq3FUIVyoH-Pedf6elHIVFi2KGDEspYMtQ
ARMMSBcS7pslx6flh1Cfh3GBKysztVMEhZ_maFkm4PYVCsJsvq6Ct3fg2CJPOs0X
1DHuxZKoIGIqcbeK4XEO5a0h5TAuJObKdfO0dKwfNSSbpu5sFrpRFwV2FTTYoqF4
zI46N9-_hMIznlEpftRXhScEJuZ9HG8C8CHB1WRZ_J48PleqdhF4o7fB5J1wFqUX
BtbtuGJ_A2Xe6AEhrlzCOw.
48V1_ALb6US04U3b.
5eym8TW_c8SuK0ltJ3rpYIzOeDQz7TALvtu6UG9oMo4vpzs9tX_EFShS8iB7j6ji
SdiwkIr3ajwQzaBtQD_A.
ghEgxninkHEAMp4xZtB2mA
```

See **Appendix A.1** for the complete details of computing this JWE.

3.2. Example JWE using RSAES-PKCS1-V1_5 and AES_128_CBC_HMAC_SHA_256

TOC

This example encrypts the plaintext "Live long and prosper." to the recipient using RSAES-PKCS1-V1_5 and AES_128_CBC_HMAC_SHA_256.

The following example JWE Header (with line breaks for display purposes only) declares that:

- the Content Encryption Key is encrypted to the recipient using the RSAES-PKCS1-V1_5 algorithm to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES_128_CBC_HMAC_SHA_256 algorithm to produce the Ciphertext.

```
{"alg":"RSA1_5","enc":"A128CBC-HS256"}
```

Base64url encoding the octets of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDK0hTMjU2In0
```

The remaining steps to finish creating this JWE are the same as for the previous example, but using RSAES-PKCS1-v1_5 instead of RSAES OAEP and using the AES_128_CBC_HMAC_SHA_256 algorithm (which is specified in Sections 4.8 and 4.8.3 of JWA) instead of AES GCM.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0.
nJa_uE2D0wlKz-OcwSbKFzj302xYSI-RLBM6hbVGmP4axtJQPA9S0po3s3NMkmOm
kkawnfwPNjpc0mc3z79cuQWkQPFQo-mDxmogz8dxBcheaTUg3ZvpbGCXxZjDYENR
WiZ5M9BiLy09BIF5mHp85QL6XED1JEZMOh-1uT1lqPDcDD79qWtrCfEJmNmfsx5f
cB2PfAcVtQ0t_YmOXx5_Gu0it1nILKXLR2Ynf9mfLhEcC5LebpWyEHW6WzQ4iH9S
IcIupPV1iKCzmJcPrDBJ5Fc_KMBcXBinaS__wftNywaGgfi_NSsx24LxtK6fIkej
RlMBmCfxv0Tg8CtxpURigg.
AxY8DCtDaGlsbGljb3RoZQ.
KDlTtXchhZTGufMYmOYGS4HffxPSUrfmqCHXaI9wOGY.
fY2U_Hx5VcfXmipEldHhMA
```

See **Appendix A.2** for the complete details of computing this JWE.

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4. JWE Header

TOC

The members of the JSON object represented by the JWE Header describe the encryption applied to the Plaintext and optionally additional properties of the JWE. The Header Parameter Names within this object MUST be unique; JWEs with duplicate Header Parameter Names MUST be rejected.

Implementations are required to understand the specific header parameters defined by this specification that are designated as "MUST be understood" and process them in the manner defined in this specification. All other header parameters defined by this specification that are not so designated MUST be ignored when not understood. Unless listed as a critical header parameter, per **Section 4.1.15**, all other header parameters MUST be ignored when not understood.

There are two ways of distinguishing whether a header is a JWS Header or a JWE Header. The first is by examining the `alg` (algorithm) header parameter value. If the value represents a digital signature or MAC algorithm, or is the value `none`, it is for a JWS; if it represents a Key Encryption, Key Wrapping, Direct Key Agreement, Key Agreement with Key Wrapping, or Direct Encryption algorithm, it is for a JWE. A second method is determining whether an `enc` (encryption method) member exists. If the `enc` member exists, it is a JWE; otherwise, it is a JWS. Both methods will yield the same result for all legal input values.

There are three classes of Header Parameter Names: Reserved Header Parameter Names, Public Header Parameter Names, and Private Header Parameter Names.

4.1. Reserved Header Parameter Names

TOC

The following Header Parameter Names are reserved with meanings as defined below. All the names are short because a core goal of this specification is for the resulting representations using the JWE Compact Serialization to be compact.

Additional reserved Header Parameter Names MAY be defined via the IANA JSON Web Signature and Encryption Header Parameters registry **[JWS]**. As indicated by the common registry, JWSs and JWEs share a common header parameter space; when a parameter is used by both specifications, its usage must be compatible between the specifications.

4.1.1. "alg" (Algorithm) Header Parameter

TOC

The alg (algorithm) header parameter identifies the cryptographic algorithm used to encrypt or determine the value of the Content Encryption Key (CEK). The algorithm specified by the alg value MUST be supported by the implementation and there MUST be a key for use with that algorithm associated with the intended recipient or the JWE MUST be rejected. alg values SHOULD either be registered in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]** or be a value that contains a Collision Resistant Namespace. The alg value is a case sensitive string containing a StringOrURI value. Use of this header parameter is REQUIRED. This header parameter MUST be understood by implementations.

A list of defined alg values can be found in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]**; the initial contents of this registry are the values defined in Section 4.1 of the JSON Web Algorithms (JWA) **[JWA]** specification.

TOC

4.1.2. "enc" (Encryption Method) Header Parameter

The enc (encryption method) header parameter identifies the block encryption algorithm used to encrypt the Plaintext to produce the Ciphertext. This algorithm MUST be an Authenticated Encryption algorithm with a specified key length. The algorithm specified by the enc value MUST be supported by the implementation or the JWE MUST be rejected. enc values SHOULD either be registered in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]** or be a value that contains a Collision Resistant Namespace. The enc value is a case sensitive string containing a StringOrURI value. Use of this header parameter is REQUIRED. This header parameter MUST be understood by implementations.

A list of defined enc values can be found in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]**; the initial contents of this registry are the values defined in Section 4.2 of the JSON Web Algorithms (JWA) **[JWA]** specification.

TOC

4.1.3. "epk" (Ephemeral Public Key) Header Parameter

The epk (ephemeral public key) value created by the originator for the use in key agreement algorithms. This key is represented as a JSON Web Key **[JWK]** value. Use of this header parameter is OPTIONAL, although its use is REQUIRED with some alg algorithms. When its use is REQUIRED, this header parameter MUST be understood by implementations.

TOC

4.1.4. "zip" (Compression Algorithm) Header Parameter

The zip (compression algorithm) applied to the Plaintext before encryption, if any. If present, the value of the zip header parameter MUST be the case sensitive string "DEF". Compression is performed with the DEFLATE **[RFC1951]** algorithm. If no zip parameter is present, no compression is applied to the Plaintext before encryption. Use of this header parameter is OPTIONAL. This header parameter MUST be understood by implementations.

TOC

4.1.5. "jku" (JWK Set URL) Header Parameter

The jku (JWK Set URL) header parameter is a URI **[RFC3986]** that refers to a resource for a set of JSON-encoded public keys, one of which is the key to which the JWE was encrypted; this can be used to determine the private key needed to decrypt the JWE. The keys MUST be encoded as a JSON Web Key Set (JWK Set) **[JWK]**. The protocol used to acquire the resource MUST provide integrity protection; an HTTP GET request to retrieve the certificate MUST use TLS **[RFC2818]** **[RFC5246]**; the identity of the server MUST be validated, as per Section 3.1 of HTTP Over TLS **[RFC2818]**. Use of this header parameter is OPTIONAL.

TOC

4.1.6. "jwk" (JSON Web Key) Header Parameter

TOC

The `jwk` (JSON Web Key) header parameter is the public key to which the JWE was encrypted; this can be used to determine the private key needed to decrypt the JWE. This key is represented as a JSON Web Key **[JWK]**. Use of this header parameter is OPTIONAL.

4.1.7. "x5u" (X.509 URL) Header Parameter

TOC

The `x5u` (X.509 URL) header parameter is a URI **[RFC3986]** that refers to a resource for the X.509 public key certificate or certificate chain **[RFC5280]** containing the key to which the JWE was encrypted; this can be used to determine the private key needed to decrypt the JWE. The identified resource MUST provide a representation of the certificate or certificate chain that conforms to **RFC 5280** [RFC5280] in PEM encoded form **[RFC1421]**. The certificate containing the public key to which the JWE was encrypted MUST be the first certificate. This MAY be followed by additional certificates, with each subsequent certificate being the one used to certify the previous one. The protocol used to acquire the resource MUST provide integrity protection; an HTTP GET request to retrieve the certificate MUST use TLS **[RFC2818]** **[RFC5246]**; the identity of the server MUST be validated, as per Section 3.1 of HTTP Over TLS **[RFC2818]**. Use of this header parameter is OPTIONAL.

4.1.8. "x5t" (X.509 Certificate Thumbprint) Header Parameter

TOC

The `x5t` (X.509 Certificate Thumbprint) header parameter provides a base64url encoded SHA-1 thumbprint (a.k.a. digest) of the DER encoding of the X.509 certificate **[RFC5280]** containing the key to which the JWE was encrypted; this can be used to determine the private key needed to decrypt the JWE. Use of this header parameter is OPTIONAL.

If, in the future, certificate thumbprints need to be computed using hash functions other than SHA-1, it is suggested that additional related header parameters be defined for that purpose. For example, it is suggested that a new `x5t#S256` (X.509 Certificate Thumbprint using SHA-256) header parameter could be defined by registering it in the IANA JSON Web Signature and Encryption Header Parameters registry **[JWS]**.

4.1.9. "x5c" (X.509 Certificate Chain) Header Parameter

TOC

The `x5c` (X.509 Certificate Chain) header parameter contains the X.509 public key certificate or certificate chain **[RFC5280]** containing the key to which the JWE was encrypted; this can be used to determine the private key needed to decrypt the JWE. The certificate or certificate chain is represented as an array of certificate value strings. Each string is a base64 encoded (**[RFC4648]** Section 4 -- not base64url encoded) DER **[ITU.X690.1994]** PKIX certificate value. The certificate containing the public key to which the JWE was encrypted MUST be the first certificate. This MAY be followed by additional certificates, with each subsequent certificate being the one used to certify the previous one. Use of this header parameter is OPTIONAL.

See Appendix B of **[JWS]** for an example `x5c` value.

4.1.10. "kid" (Key ID) Header Parameter

TOC

The `kid` (key ID) header parameter is a hint indicating which key to which the JWE was encrypted; this can be used to determine the private key needed to decrypt the JWE. This parameter allows originators to explicitly signal a change of key to recipients. Should the recipient be unable to locate a key corresponding to the `kid` value, they SHOULD treat that condition as an error. The interpretation of the `kid` value is unspecified. Its value MUST be a string. Use of this header parameter is OPTIONAL.

When used with a JWK, the `kid` value can be used to match a JWK `kid` parameter value.

TOC

4.1.11. "typ" (Type) Header Parameter

The `typ` (type) header parameter is used to declare the type of this object. The type value `JWE` is used to indicate that this object is a JWE using the JWE Compact Serialization. The type value `JWE-JS` is used to indicate that this object is a JWE using the JWE JSON Serialization. The `typ` value is a case sensitive string. Use of this header parameter is OPTIONAL.

MIME Media Type **[RFC2046]** values MAY be used as `typ` values.

`typ` values SHOULD either be registered in the IANA JSON Web Signature and Encryption Type Values registry **[JWS]** or be a value that contains a Collision Resistant Namespace.

TOC

4.1.12. "cty" (Content Type) Header Parameter

The `cty` (content type) header parameter is used to declare the type of the encrypted content (the Plaintext). For example, the JSON Web Token (JWT) **[JWT]** specification uses the `cty` value `JWT` to indicate that the Plaintext is a JSON Web Token (JWT). The `cty` value is a case sensitive string. Use of this header parameter is OPTIONAL.

The values used for the `cty` header parameter come from the same value space as the `typ` header parameter, with the same rules applying.

TOC

4.1.13. "apu" (Agreement PartyUInfo) Header Parameter

The `apu` (agreement PartyUInfo) value for key agreement algorithms using it (such as `ECDH-ES`), represented as a base64url encoded string. Use of this header parameter is OPTIONAL. When the `alg` value used identifies an algorithm for which `apu` is a parameter, this header parameter MUST be understood by implementations.

TOC

4.1.14. "apv" (Agreement PartyVInfo) Header Parameter

The `apv` (agreement PartyVInfo) value for key agreement algorithms using it (such as `ECDH-ES`), represented as a base64url encoded string. Use of this header parameter is OPTIONAL. When the `alg` value used identifies an algorithm for which `apv` is a parameter, this header parameter MUST be understood by implementations.

TOC

4.1.15. "crit" (Critical) Header Parameter

The `crit` (critical) header parameter is array listing the names of header parameters that are present in the JWE Header that MUST be understood and processed by the implementation or if not understood, MUST cause the JWE to be rejected. This list MUST NOT include header parameters defined by this specification, duplicate names, or names that do not occur as header parameters within the JWE. Use of this header parameter is OPTIONAL. This header parameter MUST be understood by implementations.

An example use, along with a hypothetical `exp` (expiration-time) field is:

```
{"alg":"RSA-OAEP",
 "enc":"A256GCM",
 "crit":["exp"],
```

```
  "exp":1363284000
 }
```

4.2. Public Header Parameter Names

TOC

Additional Header Parameter Names can be defined by those using JWEs. However, in order to prevent collisions, any new Header Parameter Name SHOULD either be registered in the IANA JSON Web Signature and Encryption Header Parameters registry **[JWS]** or be a Public Name: a value that contains a Collision Resistant Namespace. In each case, the definer of the name or value needs to take reasonable precautions to make sure they are in control of the part of the namespace they use to define the Header Parameter Name.

New header parameters should be introduced sparingly, as they can result in non-interoperable JWEs.

4.3. Private Header Parameter Names

TOC

A producer and consumer of a JWE may agree to use Header Parameter Names that are Private Names: names that are not Reserved Names **Section 4.1** or Public Names **Section 4.2**. Unlike Public Names, Private Names are subject to collision and should be used with caution.

5. Producing and Consuming JWEs

TOC

5.1. Message Encryption

TOC

The message encryption process is as follows. The order of the steps is not significant in cases where there are no dependencies between the inputs and outputs of the steps.

1. Determine the Key Management Mode employed by the algorithm used to determine the Content Encryption Key (CEK) value. (This is the algorithm recorded in the `alg` (algorithm) header parameter of the resulting JWE.)
2. When Key Wrapping, Key Encryption, or Key Agreement with Key Wrapping are employed, generate a random Content Encryption Key (CEK) value. See **RFC 4086** [RFC4086] for considerations on generating random values. The CEK MUST have a length equal to that required for the block encryption algorithm.
3. When Direct Key Agreement or Key Agreement with Key Wrapping are employed, use the key agreement algorithm to compute the value of the agreed upon key. When Direct Key Agreement is employed, let the Content Encryption Key (CEK) be the agreed upon key. When Key Agreement with Key Wrapping is employed, the agreed upon key will be used to wrap the CEK.
4. When Key Wrapping, Key Encryption, or Key Agreement with Key Wrapping are employed, encrypt the CEK to the recipient (see **Section 6.1**) and let the result be the JWE Encrypted Key.
5. Otherwise, when Direct Key Agreement or Direct Encryption are employed, let the JWE Encrypted Key be the empty octet sequence.
6. When Direct Encryption is employed, let the Content Encryption Key (CEK) be the shared symmetric key.
7. Base64url encode the JWE Encrypted Key to create the Encoded JWE Encrypted Key.
8. Generate a random JWE Initialization Vector of the correct size for the block encryption algorithm (if required for the algorithm); otherwise, let the JWE Initialization Vector be the empty octet sequence.
9. Base64url encode the JWE Initialization Vector to create the Encoded JWE Initialization Vector.
10. Compress the Plaintext if a `zip` parameter was included.
11. Serialize the (compressed) Plaintext into an octet sequence M.

12. Create a JWE Header containing the encryption parameters used. Note that white space is explicitly allowed in the representation and no canonicalization need be performed before encoding.
13. Base64url encode the octets of the UTF-8 representation of the JWE Header to create the Encoded JWE Header.
14. If the JWE JSON Serialization is being used, repeat this process for each recipient.
15. Let the value X be the concatenation of the Encoded JWE Header values computed above, with a tilde ('~') character between each Encoded JWE Header value. (In the single recipient case, X is simply the single Encoded JWE Header value.)
16. Let the value Y be the concatenation of the Encoded JWE Encrypted Key values computed above, with a tilde ('~') character between each Encoded JWE Encrypted Key value. The order of the Encoded JWE Encrypted Key values MUST be the same as the order of the corresponding Encoded JWE Header values in the previous step. (In the single recipient case, Y is simply the single Encoded JWE Encrypted Key value.)
17. Let the Additional Authenticated Data value be the octets of the ASCII representation of the concatenation of X, a period ('.') character, and Y.
18. Encrypt M using the CEK, the JWE Initialization Vector, and the Additional Authenticated Data value using the specified block encryption algorithm to create the JWE Ciphertext value and the JWE Authentication Tag (which is the Authentication Tag output from the encryption operation).
19. Base64url encode the JWE Ciphertext to create the Encoded JWE Ciphertext.
20. Base64url encode the JWE Authentication Tag to create the Encoded JWE Authentication Tag.
21. The five encoded parts are the result values used in both the JWE Compact Serialization and the JWE JSON Serialization representations.
22. Create the desired serialized output. The JWE Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Authentication Tag in that order, with the five strings being separated by four period ('.') characters. The JWE JSON Serialization is described in **Section 7**.

TOC

5.2. Message Decryption

The message decryption process is the reverse of the encryption process. The order of the steps is not significant in cases where there are no dependencies between the inputs and outputs of the steps. If any of these steps fails, the JWE MUST be rejected.

1. Parse the serialized input to determine the values of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Authentication Tag. When using the JWE Compact Serialization, these five values are represented as text strings in that order, separated by four period ('.') characters. The JWE JSON Serialization is described in **Section 7**.
2. The Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Authentication Tag MUST be successfully base64url decoded following the restriction that no padding characters have been used.
3. The resulting JWE Header MUST be completely valid JSON syntax conforming to **RFC 4627** [RFC4627].
4. The resulting JWE Header MUST be validated to only include parameters and values whose syntax and semantics are both understood and supported or that are specified as being ignored when not understood.
5. Determine the Key Management Mode employed by the algorithm specified by the `alg` (algorithm) header parameter.
6. Verify that the JWE uses a key known to the recipient.
7. When Direct Key Agreement or Key Agreement with Key Wrapping are employed, use the key agreement algorithm to compute the value of the agreed upon key. When Direct Key Agreement is employed, let the Content Encryption Key (CEK) be the agreed upon key. When Key Agreement with Key Wrapping is employed, the agreed upon key will be used to decrypt the JWE Encrypted Key.
8. When Key Wrapping, Key Encryption, or Key Agreement with Key Wrapping are employed, decrypt the JWE Encrypted Key to produce the Content Encryption Key

(CEK). The CEK MUST have a length equal to that required for the block encryption algorithm. Note that when there are multiple recipients, each recipient will only be able decrypt any JWE Encrypted Key values that were encrypted to a key in that recipient's possession. It is therefore normal to only be able to decrypt one of the per-recipient JWE Encrypted Key values to obtain the CEK value. To mitigate against attacks described in **RFC 3218** [RFC3218], the recipient MUST NOT distinguish between format, padding, and length errors of encrypted keys. It is strongly recommended, in the event of receiving an improperly formatted key, that the receiver substitute a randomly generated CEK and proceed to the next step, to mitigate timing attacks.

9. Otherwise, when Direct Key Agreement or Direct Encryption are employed, verify that the JWE Encrypted Key value is empty octet sequence.
10. When Direct Encryption is employed, let the Content Encryption Key (CEK) be the shared symmetric key.
11. If the JWE JSON Serialization is being used, repeat this process for each recipient contained in the representation.
12. Let the value X be the concatenation of the Encoded JWE Header values identified above, with a tilde ('~') character between each Encoded JWE Header value. (In the single recipient case, X is simply the single Encoded JWE Header value.)
13. Let the value Y be the concatenation of the Encoded JWE Encrypted Key values identified above, with a tilde ('~') character between each Encoded JWE Encrypted Key value. The order of the Encoded JWE Encrypted Key values MUST be the same as the order of the corresponding Encoded JWE Header values in the previous step. (In the single recipient case, Y is simply the single Encoded JWE Encrypted Key value.)
14. Let the Additional Authenticated Data value be the octets of the ASCII representation of the concatenation of X, a period ('.') character, and Y.
15. Decrypt the JWE Ciphertext using the CEK, the JWE Initialization Vector, the Additional Authenticated Data value, and the JWE Authentication Tag (which is the Authentication Tag input to the calculation) using the specified block encryption algorithm, returning the decrypted plaintext and verifying the JWE Authentication Tag in the manner specified for the algorithm, rejecting the input without emitting any decrypted output if the JWE Authentication Tag is incorrect.
16. Uncompress the decrypted plaintext if a `zip` parameter was included.
17. Output the resulting Plaintext.

5.3. String Comparison Rules

TOC

Processing a JWE inevitably requires comparing known strings to values in JSON objects. For example, in checking what the encryption method is, the Unicode string encoding `enc` will be checked against the member names in the JWE Header to see if there is a matching Header Parameter Name.

Comparisons between JSON strings and other Unicode strings MUST be performed by comparing Unicode code points without normalization as specified in the String Comparison Rules in Section 5.3 of **[JWS]**.

---

6. Encrypting JWEs with Cryptographic Algorithms

TOC

JWE uses cryptographic algorithms to encrypt the Plaintext and the Content Encryption Key (CEK) and to provide integrity protection for the JWE Header, JWE Encrypted Key, and JWE Ciphertext. The JSON Web Algorithms (JWA) **[JWA]** specification specifies a set of cryptographic algorithms and identifiers to be used with this specification and defines registries for additional such algorithms. Specifically, Section 4.1 specifies a set of `alg` (algorithm) header parameter values and Section 4.2 specifies a set of `enc` (encryption method) header parameter values intended for use this specification. It also describes the semantics and operations that are specific to these algorithms.

Public keys employed for encryption can be identified using the Header Parameter methods described in **Section 4.1** or can be distributed using methods that are outside the scope of this specification.

6.1. CEK Encryption

TOC

JWE supports three forms of Content Encryption Key (CEK) encryption:

- Asymmetric encryption under the recipient's public key.
- Symmetric encryption under a key shared between the sender and receiver.
- Symmetric encryption under a key agreed upon between the sender and receiver.

See the algorithms registered for `enc` usage in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]** and Section 4.1 of the JSON Web Algorithms (JWA) **[JWA]** specification for lists of encryption algorithms that can be used for CEK encryption.

7. JSON Serialization

TOC

The JWE JSON Serialization represents encrypted content as a JSON object with a `recipients` member containing an array of per-recipient information, an `initialization_vector` member containing a shared Encoded JWE Initialization Vector value, a `ciphertext` member containing a shared Encoded JWE Ciphertext value, and an `authentication_tag` member containing a shared Encoded JWE Authentication Tag value. Each member of the `recipients` array is a JSON object with a `header` member containing an Encoded JWE Header value and an `encrypted_key` member containing an Encoded JWE Encrypted Key value.

Unlike the JWE Compact Serialization, content using the JWE JSON Serialization MAY be encrypted to more than one recipient. Each recipient requires:

- a JWE Header value specifying the cryptographic parameters used to encrypt the JWE Encrypted Key to that recipient and the parameters used to encrypt the plaintext to produce the JWE Ciphertext; this is represented as an Encoded JWE Header value in the `header` member of an object in the `recipients` array.
- a JWE Encrypted Key value used to encrypt the ciphertext; this is represented as an Encoded JWE Encrypted Key value in the `encrypted_key` member of the same object in the `recipients` array.

Therefore, the syntax is:

```
{"recipients":[
  {"header":"<header 1 contents>",
   "encrypted_key":"<encrypted key 1 contents>"},
  ...
  {"header":"<header N contents>",
   "encrypted_key":"<encrypted key N contents>"}],
 "initialization_vector":"<initialization vector contents>",
 "ciphertext":"<ciphertext contents>",
 "authentication_tag":"<authentication tag contents>"
}
```

The contents of the Encoded JWE Header, Encoded JWE Encrypted Key, Encoded JWE Initialization Vector, Encoded JWE Ciphertext, and Encoded JWE Authentication Tag values are exactly as specified in the rest of this specification. They are interpreted and validated in the same manner, with each corresponding `header` and `encrypted_key` value being created and validated together.

All recipients use the same JWE Ciphertext, JWE Initialization Vector, and JWE Authentication Tag values, resulting in potentially significant space savings if the message is large. Therefore, all header parameters that specify the treatment of the JWE Ciphertext value MUST be the same for all recipients. This primarily means that the `enc` (encryption method) header parameter value in the JWE Header for each recipient MUST be the same.

7.1. Example JWE-JS

This section contains an example using the JWE JSON Serialization. This example demonstrates the capability for encrypting the same plaintext to multiple recipients.

Two recipients are present in this example: the first using the RSAES-PKCS1-V1_5 algorithm to encrypt the Content Encryption Key (CEK) and the second using RSAES OAEP to encrypt the CEK. The Plaintext is encrypted using the AES_128_CBC_HMAC_SHA_256 algorithm and the same block encryption parameters to produce the common JWE Ciphertext value. The two Decoded JWE Header Segments used are:

```
{"alg":"RSA1_5","enc":"A128CBC-HS256"}
```

and:

```
{"alg":"RSA-OAEP","enc":"A128CBC-HS256"}
```

The keys used for the first recipient are the same as those in **Appendix A.2**, as is the Plaintext used. The encryption key used for the second recipient is the same as that used in **Appendix A.3**; the block encryption keys and parameters for the second recipient are the same as those for the first recipient (which must be the case, since the Initialization Vector and Ciphertext are shared). Thus, the same two Encoded JWE Header and JWE Encoded Encrypted Key values are used in this example as are used in those examples.

The value X used as part of the AAD value is the concatenation of the Encoded JWE Header values, separated by a tilde ('~') character. In this example, the value of X (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
~
eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
```

The value Y used as part of the AAD value is the concatenation of the Encoded JWE Encrypted Key values, separated by a tilde ('~') character. In this example, the value of Y (with line breaks for display purposes only) is:

```
nJa_uE2D0wlKz-OcwSbKFzj302xYSI-RLBM6hbVGmP4axtJQPA9S0po3s3NMk
mOmkkawnfwPNjpc0mc3z79cuQWkQPFQo-mDxmogz8dxBcheaTUg3ZvpbGCXxZ
jDYENRWiZ5M9BiLy09BIF5mHp85QL6XED1JEZMOh-1uT1lqPDcDD79qWtrCfE
JmNmfsx5fcB2PfAcVtQ0t_YmOXx5_Gu0it1nILKXLR2Ynf9mfLhEcC5LebpWy
EHW6WzQ4iH9SIcIupPV1iKCzmJcPrDBJ5Fc_KMBcXBinaS__wftNywaGgfi_N
Ssx24LxtK6fIkejRlMBmCfxv0Tg8CtxpURigg
~
6KB707dM9YTIgHtLvtgWQ8mKwboJW3of9locizkDTHzBC2IlrT1oOQ
```

The AAD value used for the block encryption is the octets of the ASCII representation of the concatenation of X, a period ('.') character, and Y. This concatenation (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
~
eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
.
nJa_uE2D0wlKz-OcwSbKFzj302xYSI-RLBM6hbVGmP4axtJQPA9S0po3s3NMk
mOmkkawnfwPNjpc0mc3z79cuQWkQPFQo-mDxmogz8dxBcheaTUg3ZvpbGCXxZ
jDYENRWiZ5M9BiLy09BIF5mHp85QL6XED1JEZMOh-1uT1lqPDcDD79qWtrCfE
JmNmfsx5fcB2PfAcVtQ0t_YmOXx5_Gu0it1nILKXLR2Ynf9mfLhEcC5LebpWy
EHW6WzQ4iH9SIcIupPV1iKCzmJcPrDBJ5Fc_KMBcXBinaS__wftNywaGgfi_N
```

```
Ssx24LxtK6fIkejRlMBmCfxv0Tg8CtxpURigg
~
6KB707dM9YTIgHtLvtgWQ8mKwboJW3of9locizkDTHzBC2IlrT1oOQ
```

The complete JSON Web Encryption JSON Serialization (JWE-JS) for these values is as follows (with line breaks for display purposes only):

```
{"recipients":[
  {"header":
    "eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0",
   "encrypted_key":
    "nJa_uE2D0wlKz-OcwSbKFzj302xYSI-RLBM6hbVGmP4axtJQPA9S0po3s3NMk
     mOmkkawnfwPNjpc0mc3z79cuQWkQPFQo-mDxmogz8dxBcheaTUg3ZvpbGCXxZ
     jDYENRWiZ5M9BiLy09BIF5mHp85QL6XED1JEZMOh-1uT1lqPDcDD79qWtrCfE
     JmNmfsx5fcB2PfAcVtQ0t_YmOXx5_Gu0it1nILKXLR2Ynf9mfLhEcC5LebpWy
     EHW6WzQ4iH9SIcIupPV1iKCzmJcPrDBJ5Fc_KMBcXBinaS__wftNywaGgfi_N
     Ssx24LxtK6fIkejRlMBmCfxv0Tg8CtxpURigg"},
  {"header":
    "eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0",
   "encrypted_key":
    "6KB707dM9YTIgHtLvtgWQ8mKwboJW3of9locizkDTHzBC2IlrT1oOQ"}],
 "initialization_vector":
  "AxY8DCtDaGlsbGljb3RoZQ",
 "ciphertext":
  "KDlTtXchhZTGufMYmOYGS4HffxPSUrfmqCHXaI9wOGY",
 "authentication_tag":
  "LlhRZFfphc2f5X3nTTJP6g"
}
```

---

8. Implementation Considerations

TOC

The JWE Compact Serialization is mandatory to implement. Implementation of the JWE JSON Serialization is OPTIONAL.

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9. IANA Considerations

TOC

9.1. Registration of JWE Header Parameter Names

TOC

This specification registers the Header Parameter Names defined in **Section 4.1** in the IANA JSON Web Signature and Encryption Header Parameters registry **[JWS]**.

9.1.1. Registry Contents

TOC

- Header Parameter Name: `alg`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.1** of [[this document]]

- Header Parameter Name: `enc`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.2** of [[this document]]

- Header Parameter Name: `epk`
- Header Parameter Usage Location(s): JWE

- Change Controller: IETF
- Specification Document(s): **Section 4.1.3** of [[this document]]

- Header Parameter Name: `zip`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.4** of [[this document]]

- Header Parameter Name: `jku`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.5** of [[this document]]

- Header Parameter Name: `jwk`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification document(s): **Section 4.1.6** of [[this document]]

- Header Parameter Name: `x5u`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.7** of [[this document]]

- Header Parameter Name: `x5t`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.8** of [[this document]]

- Header Parameter Name: `x5c`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.9** of [[this document]]

- Header Parameter Name: `kid`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.10** of [[this document]]

- Header Parameter Name: `typ`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.11** of [[this document]]

- Header Parameter Name: `cty`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.12** of [[this document]]

- Header Parameter Name: `apu`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.13** of [[this document]]

- Header Parameter Name: `apv`
- Header Parameter Usage Location(s): JWE
- Change Controller: IETF
- Specification Document(s): **Section 4.1.14** of [[this document]]

- Header Parameter Name: `crit`
- Header Parameter Usage Location(s): JWS
- Change Controller: IETF
- Specification Document(s): **Section 4.1.15** of [[this document]]

9.2. JSON Web Signature and Encryption Type Values Registration

TOC

TOC

9.2.1. Registry Contents

This specification registers the `JWE` and `JWE-JS` type values in the IANA JSON Web Signature and Encryption Type Values registry **[JWS]**:

- "typ" Header Parameter Value: `JWE`
- Abbreviation for MIME Type: application/jwe
- Change Controller: IETF
- Specification Document(s): **Section 4.1.11** of [[this document]]

- "typ" Header Parameter Value: `JWE-JS`
- Abbreviation for MIME Type: application/jwe-js
- Change Controller: IETF
- Specification Document(s): **Section 4.1.11** of [[this document]]

TOC

9.3. Media Type Registration

TOC

9.3.1. Registry Contents

This specification registers the `application/jwe` and `application/jwe-js` Media Types **[RFC2046]** in the MIME Media Type registry **[RFC4288]** to indicate, respectively, that the content is a JWE using the JWE Compact Serialization or a JWE using the JWE JSON Serialization.

- Type Name: application
- Subtype Name: jwe
- Required Parameters: n/a
- Optional Parameters: n/a
- Encoding considerations: JWE values are encoded as a series of base64url encoded values (some of which may be the empty string) separated by period ('.') characters
- Security Considerations: See the Security Considerations section of [[this document]]
- Interoperability Considerations: n/a
- Published Specification: [[this document]]
- Applications that use this media type: OpenID Connect and other applications using encrypted JWTs
- Additional Information: Magic number(s): n/a, File extension(s): n/a, Macintosh file type code(s): n/a
- Person & email address to contact for further information: Michael B. Jones, mbj@microsoft.com
- Intended Usage: COMMON
- Restrictions on Usage: none
- Author: Michael B. Jones, mbj@microsoft.com
- Change Controller: IETF

- Type Name: application
- Subtype Name: jwe-js
- Required Parameters: n/a
- Optional Parameters: n/a
- Encoding considerations: JWE-JS values are represented as a JSON Object; UTF-8 encoding SHOULD be employed for the JSON object.
- Security Considerations: See the Security Considerations section of [[this document]]
- Interoperability Considerations: n/a
- Published Specification: [[this document]]
- Applications that use this media type: TBD
- Additional Information: Magic number(s): n/a, File extension(s): n/a, Macintosh file type code(s): n/a
- Person & email address to contact for further information: Michael B. Jones, mbj@microsoft.com

- Intended Usage: COMMON
- Restrictions on Usage: none
- Author: Michael B. Jones, mbj@microsoft.com
- Change Controller: IETF

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10. Security Considerations

TOC

All of the security issues faced by any cryptographic application must be faced by a JWS/JWE/JWK agent. Among these issues are protecting the user's private and symmetric keys, preventing various attacks, and helping the user avoid mistakes such as inadvertently encrypting a message for the wrong recipient. The entire list of security considerations is beyond the scope of this document.

All the security considerations in the JWS specification also apply to this specification. Likewise, all the security considerations in **XML Encryption 1.1** [W3C.CR-xmlenc-core1-20120313] also apply, other than those that are XML specific.

When decrypting, particular care must be taken not to allow the JWE recipient to be used as an oracle for decrypting messages. **RFC 3218** [RFC3218] should be consulted for specific countermeasures to attacks on RSAES-PKCS1-V1_5. An attacker might modify the contents of the `alg` parameter from `RSA-OAEP` to `RSA1_5` in order to generate a formatting error that can be detected and used to recover the CEK even if RSAES OAEP was used to encrypt the CEK. It is therefore particularly important to report all formatting errors to the CEK, Additional Authenticated Data, or ciphertext as a single error when the JWE is rejected.

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11. References

TOC

11.1. Normative References

TOC

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Appendix A. JWE Examples

This section provides examples of JWE computations.

A.1. Example JWE using RSAES OAEP and AES GCM

This example encrypts the plaintext "The true sign of intelligence is not knowledge but imagination." to the recipient using RSAES OAEP and AES GCM. The representation of this plaintext is:

[84, 104, 101, 32, 116, 114, 117, 101, 32, 115, 105, 103, 110, 32, 111, 102, 32, 105, 110, 116, 101, 108, 108, 105, 103, 101, 110, 99, 101, 32, 105, 115, 32, 110, 111, 116, 32, 107, 110, 111, 119, 108, 101, 100, 103, 101, 32, 98, 117, 116, 32, 105, 109, 97, 103, 105, 110, 97, 116, 105, 111, 110, 46]

A.1.1. JWE Header

The following example JWE Header declares that:

- the Content Encryption Key is encrypted to the recipient using the RSAES OAEP algorithm to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES GCM algorithm with a 256 bit key to produce the Ciphertext.

```
{"alg":"RSA-OAEP","enc":"A256GCM"}
```

A.1.2. Encoded JWE Header

Base64url encoding the octets of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ
```

A.1.3. Content Encryption Key (CEK)

Generate a 256 bit random Content Encryption Key (CEK). In this example, the value is:

[177, 161, 244, 128, 84, 143, 225, 115, 63, 180, 3, 255, 107, 154, 212, 246, 138, 7, 110, 91, 112, 46, 34, 105, 47, 130, 203, 46, 122, 234, 64, 252]

A.1.4. Key Encryption

Encrypt the CEK with the recipient's public key using the RSAES OAEP algorithm to produce the JWE Encrypted Key. In this example, the RSA key parameters are:

Parameter Name	Value
Modulus	[161, 168, 84, 34, 133, 176, 208, 173, 46, 176, 163, 110, 57, 30, 135, 227, 9, 31, 226, 128, 84, 92, 116, 241, 70, 248, 27, 227, 193, 62, 5, 91, 241, 145, 224, 205, 141, 176, 184, 133, 239, 43, 81, 103, 9, 161, 153, 157, 179, 104, 123, 51, 189, 34, 152, 69, 97, 69, 78, 93, 140, 131, 87, 182, 169, 101, 92, 142, 3, 22, 167, 8, 212, 56, 35, 79, 210, 222, 192, 208, 252, 49, 109, 138, 173, 253, 210, 166, 201, 63, 102, 74, 5, 158, 41, 90, 144, 108, 160, 79, 10, 89, 222, 231, 172, 31, 227, 197, 0, 19, 72, 81, 138, 78, 136, 221, 121, 118, 196, 17, 146, 10, 244, 188, 72, 113, 55, 221, 162, 217, 171, 27, 57, 233, 210, 101, 236, 154, 199, 56, 138, 239, 101, 48, 198, 186, 202, 160, 76, 111, 234, 71, 57, 183, 5, 211, 171, 136, 126, 64, 40, 75, 58, 89, 244, 254, 107, 84, 103, 7, 236, 69, 163, 18, 180, 251, 58, 153, 46, 151, 174, 12, 103, 197, 181, 161, 162, 55, 250, 235, 123, 110, 17, 11, 158, 24, 47, 133, 8, 199, 235, 107, 126, 130, 246, 73, 195, 20, 108, 202, 176, 214, 187, 45, 146, 182, 118, 54, 32, 200, 61, 201, 71, 243, 1, 255, 131, 84, 37, 111, 211, 168, 228, 45, 192, 118, 27, 197, 235, 232, 36, 10, 230, 248, 190, 82, 182, 140, 35, 204, 108, 190, 253, 186, 186, 27]
Exponent	[1, 0, 1]
Private Exponent	[144, 183, 109, 34, 62, 134, 108, 57, 44, 252, 10, 66, 73, 54, 16, 181, 233, 92, 54, 219, 101, 42, 35, 178, 63, 51, 43, 92, 119, 136, 251, 41, 53, 23, 191, 164, 164, 60, 88, 227, 229, 152, 228, 213, 149, 228, 169, 237, 104, 71, 151, 75, 88, 252, 216, 77, 251, 231, 28, 97, 88, 193, 215, 202, 248, 216, 121, 195, 211, 245, 250, 112, 71, 243, 61, 129, 95, 39, 244, 122, 225, 217, 169, 211, 165, 48, 253, 220, 59, 122, 219, 42, 86, 223, 32, 236, 39, 48, 103, 78, 122, 216, 187, 88, 176, 89, 24, 1, 42, 177, 24, 99, 142, 170, 1, 146, 43, 3, 108, 64, 194, 121, 182, 95, 187, 134, 71, 88, 96, 134, 74, 131, 167, 69, 106, 143, 121, 27, 72, 44, 245, 95, 39, 194, 179, 175, 203, 122, 16, 112, 183, 17, 200, 202, 31, 17, 138, 156, 184, 210, 157, 184, 154, 131, 128, 110, 12, 85, 195, 122, 241, 79, 251, 229, 183, 117, 21, 123, 133, 142, 220, 153, 9, 59, 57, 105, 81, 255, 138, 77, 82, 54, 62, 216, 38, 249, 208, 17, 197, 49, 45, 19, 232, 157, 251, 131, 137, 175, 72, 126, 43, 229, 69, 179, 117, 82, 157, 213, 83, 35, 57, 210, 197, 252, 171, 143, 194, 11, 47, 163, 6, 253, 75, 252, 96, 11, 187, 84, 130, 210, 7, 121, 78, 91, 79, 57, 251, 138, 132, 220, 60, 224, 173, 56, 224, 201]

The resulting JWE Encrypted Key value is:

[2, 151, 206, 44, 38, 131, 110, 171, 63, 37, 115, 216, 203, 98, 61, 223, 187, 255, 198, 106, 243, 143, 226, 44, 179, 89, 134, 232, 208, 7, 153, 226, 85, 136, 206, 163, 218, 93, 12, 30, 247, 236, 120, 135, 71, 87, 37, 54, 4, 138, 6, 86, 239, 104, 134, 249, 36, 90, 36, 106, 228, 50, 246, 141, 134, 83, 60, 15, 83, 1, 220, 42, 220, 85, 8, 87, 42, 7, 248, 247, 157, 127, 167, 165, 28, 133, 69, 139, 98, 134, 12, 75, 41, 96, 203, 80, 1, 19, 12, 72, 23, 18, 238, 155, 37, 199, 167, 229, 135, 80, 159, 135, 113, 129, 43, 43, 51, 181, 83, 4, 133, 159, 230, 104, 89, 38, 224, 246, 21, 10, 194, 108, 190, 174, 130, 183, 119, 224, 216, 34, 79, 58, 205, 23, 212, 49, 238, 197, 146, 168, 32, 98, 42, 113, 183, 138, 225, 113, 14, 229, 173, 33, 229, 48, 46, 36, 230, 202, 117, 243, 180, 116, 172, 31, 53, 36, 155, 166, 238, 108, 22, 186, 81, 23, 5, 118, 21, 52, 216, 162, 161, 120, 204, 142, 58, 55, 223, 191, 132, 194, 51, 158, 81, 41, 126, 212, 87, 133, 39, 4, 38, 230, 125, 28, 111, 2, 240, 33, 193, 213, 100, 89, 252, 158, 60, 62, 87, 170, 118, 17, 120, 163, 183, 193, 228, 157, 112, 22, 165, 23, 6, 214, 237, 184, 98, 127, 3, 101, 222, 232, 1, 33, 174, 92, 194, 59]

A.1.5. Encoded JWE Encrypted Key

TOC

Base64url encode the JWE Encrypted Key to produce the Encoded JWE Encrypted Key. This result (with line breaks for display purposes only) is:

```
ApfOLCaDbqs_JXPYy2I937v_xmrzj-Iss1mG6NAHmeJViM6j2l0MHvfseIdHVyU2
BIoGVu9ohvkkWiRq5DL2jYZTPA9TAdwq3FUIVyoH-Pedf6elHIVFi2KGDEspYMtQ
ARMMSBcS7pslx6flh1Cfh3GBKysztVMEhZ_maFkm4PYVCsJsvq6Ct3fg2CJPOs0X
1DHuxZKoIGIqcbeK4XEO5a0h5TAuJObKdfO0dKwfNSSbpu5sFrpRFwV2FTTYoqF4
zI46N9-_hMIznlEpftRXhScEJuZ9HG8C8CHB1WRZ_J48PleqdhF4o7fB5J1wFqUX
BtbtuGJ_A2Xe6AEhrlzCOw
```

A.1.6. Initialization Vector

TOC

Generate a random 96 bit JWE Initialization Vector. In this example, the value is:

[227, 197, 117, 252, 2, 219, 233, 68, 180, 225, 77, 219]

Base64url encoding this value yields the Encoded JWE Initialization Vector value:

```
48V1_ALb6US04U3b
```

A.1.7. Additional Authenticated Data Parameter

TOC

Concatenate the Encoded JWE Header value, a period ('.') character, and the Encoded JWE Encrypted Key to create the Additional Authenticated Data parameter. This result (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ.
ApfOLCaDbqs_JXPYy2I937v_xmrzj-Iss1mG6NAHmeJViM6j2l0MHvfseIdHVyU2
BIoGVu9ohvkkWiRq5DL2jYZTPA9TAdwq3FUIVyoH-Pedf6elHIVFi2KGDEspYMtQ
ARMMSBcS7pslx6flh1Cfh3GBKysztVMEhZ_maFkm4PYVCsJsvq6Ct3fg2CJPOs0X
1DHuxZKoIGIqcbeK4XEO5a0h5TAuJObKdfO0dKwfNSSbpu5sFrpRFwV2FTTYoqF4
zI46N9-_hMIznlEpftRXhScEJuZ9HG8C8CHB1WRZ_J48PleqdhF4o7fB5J1wFqUX
BtbtuGJ_A2Xe6AEhrlzCOw
```

The representation of this value is:

[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 83, 85, 48, 69, 116, 84, 48, 70, 70, 85, 67,
73, 115, 73, 109, 86, 117, 89, 121, 73, 54, 73, 107, 69, 121, 78, 84, 90, 72, 81, 48, 48, 105,
102, 81, 46, 65, 112, 102, 79, 76, 67, 97, 68, 98, 113, 115, 95, 74, 88, 80, 89, 121, 50, 73, 57,
51, 55, 118, 95, 120, 109, 114, 122, 106, 45, 73, 115, 115, 49, 109, 71, 54, 78, 65, 72, 109,
101, 74, 86, 105, 77, 54, 106, 50, 108, 48, 77, 72, 118, 102, 115, 101, 73, 100, 72, 86, 121,
85, 50, 66, 73, 111, 71, 86, 117, 57, 111, 104, 118, 107, 107, 87, 105, 82, 113, 53, 68, 76, 50,
106, 89, 90, 84, 80, 65, 57, 84, 65, 100, 119, 113, 51, 70, 85, 73, 86, 121, 111, 72, 45, 80,
101, 100, 102, 54, 101, 108, 72, 73, 86, 70, 105, 50, 75, 71, 68, 69, 115, 112, 89, 77, 116, 81,
65, 82, 77, 77, 83, 66, 99, 83, 55, 112, 115, 108, 120, 54, 102, 108, 104, 49, 67, 102, 104, 51,
71, 66, 75, 121, 115, 122, 116, 86, 77, 69, 104, 90, 95, 109, 97, 70, 107, 109, 52, 80, 89, 86,
67, 115, 74, 115, 118, 113, 54, 67, 116, 51, 102, 103, 50, 67, 74, 80, 79, 115, 48, 88, 49, 68,
72, 117, 120, 90, 75, 111, 73, 71, 73, 113, 99, 98, 101, 75, 52, 88, 69, 79, 53, 97, 48, 104, 53,
84, 65, 117, 74, 79, 98, 75, 100, 102, 79, 48, 100, 75, 119, 102, 78, 83, 83, 98, 112, 117, 53,
115, 70, 114, 112, 82, 70, 119, 86, 50, 70, 84, 84, 89, 111, 113, 70, 52, 122, 73, 52, 54, 78,
57, 45, 95, 104, 77, 73, 122, 110, 108, 69, 112, 102, 116, 82, 88, 104, 83, 99, 69, 74, 117, 90,
57, 72, 71, 56, 67, 56, 67, 72, 66, 49, 87, 82, 90, 95, 74, 52, 56, 80, 108, 101, 113, 100, 104,
70, 52, 111, 55, 102, 66, 53, 74, 49, 119, 70, 113, 85, 88, 66, 116, 98, 116, 117, 71, 74, 95,
65, 50, 88, 101, 54, 65, 69, 104, 114, 108, 122, 67, 79, 119]

A.1.8. Plaintext Encryption

TOC

Encrypt the Plaintext with AES GCM using the CEK as the encryption key, the JWE Initialization Vector, and the Additional Authenticated Data value above, requesting a 128 bit Authentication Tag output. The resulting Ciphertext is:

[229, 236, 166, 241, 53, 191, 115, 196, 174, 43, 73, 109, 39, 122, 233, 96, 140, 206, 120, 52, 51, 237, 48, 11, 190, 219, 186, 80, 111, 104, 50, 142, 47, 167, 59, 61, 181, 127, 196, 21, 40, 82, 242, 32, 123, 143, 168, 226, 73, 216, 176, 144, 138, 247, 106, 60, 16, 205, 160, 109, 64, 63, 192]

The resulting Authentication Tag value is:

[130, 17, 32, 198, 120, 167, 144, 113, 0, 50, 158, 49, 102, 208, 118, 152]

A.1.9. Encoded JWE Ciphertext

TOC

Base64url encode the Ciphertext to create the Encoded JWE Ciphertext. This result (with line breaks for display purposes only) is:

```
5eym8TW_c8SuK0ltJ3rpYIzOeDQz7TALvtu6UG9oMo4vpzs9tX_EFShS8iB7j6ji
SdiwkIr3ajwQzaBtQD_A
```

A.1.10. Encoded JWE Authentication Tag

TOC

Base64url encode the Authentication Tag to create the Encoded JWE Authentication Tag. This result is:

```
ghEgxninkHEAMp4xZtB2mA
```

A.1.11. Complete Representation

TOC

Assemble the final representation: The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Authentication Tag in that order, with the five strings being separated by four period ('.') characters.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ.
ApfOLCaDbqs_JXPYy2I937v_xmrzj-Iss1mG6NAHmeJViM6j2l0MHvfseIdHVyU2
BIoGVu9ohvkkWiRq5DL2jYZTPA9TAdwq3FUIVyoH-Pedf6elHIVFi2KGDEspYMtQ
ARMMSBcS7pslx6flh1Cfh3GBKysztVMEhZ_maFkm4PYVCsJsvq6Ct3fg2CJPOs0X
1DHuxZKoIGIqcbeK4XEO5a0h5TAuJObKdfO0dKwfNSSbpu5sFrpRFwV2FTTYoqF4
zI46N9-_hMIznlEpftRXhScEJuZ9HG8C8CHB1WRZ_J48PleqdhF4o7fB5J1wFqUX
BtbtuGJ_A2Xe6AEhrlzCOw.
48V1_ALb6US04U3b.
5eym8TW_c8SuK0ltJ3rpYIzOeDQz7TALvtu6UG9oMo4vpzs9tX_EFShS8iB7j6ji
SdiwkIr3ajwQzaBtQD_A.
ghEgxninkHEAMp4xZtB2mA
```

A.1.12. Validation

TOC

This example illustrates the process of creating a JWE with RSA OAEP and AES GCM. These results can be used to validate JWE decryption implementations for these algorithms. Note that since the RSAES OAEP computation includes random values, the encryption results above will not be completely reproducible. However, since the AES GCM computation is deterministic, the JWE Encrypted Ciphertext values will be the same for all encryptions performed using these inputs.

TOC

A.2. Example JWE using RSAES-PKCS1-V1_5 and AES_128_CBC_HMAC_SHA_256

This example encrypts the plaintext "Live long and prosper." to the recipient using RSAES-PKCS1-V1_5 and AES_128_CBC_HMAC_SHA_256. The representation of this plaintext is:

[76, 105, 118, 101, 32, 108, 111, 110, 103, 32, 97, 110, 100, 32, 112, 114, 111, 115, 112, 101, 114, 46]

TOC

A.2.1. JWE Header

The following example JWE Header (with line breaks for display purposes only) declares that:

- the Content Encryption Key is encrypted to the recipient using the RSAES-PKCS1-V1_5 algorithm to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES_128_CBC_HMAC_SHA_256 algorithm to produce the Ciphertext.

```
{"alg":"RSA1_5","enc":"A128CBC-HS256"}
```

TOC

A.2.2. Encoded JWE Header

Base64url encoding the octets of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
```

TOC

A.2.3. Content Encryption Key (CEK)

Generate a 256 bit random Content Encryption Key (CEK). In this example, the key value is:

[4, 211, 31, 197, 84, 157, 252, 254, 11, 100, 157, 250, 63, 170, 106, 206, 107, 124, 212, 45, 111, 107, 9, 219, 200, 177, 0, 240, 143, 156, 44, 207]

TOC

A.2.4. Key Encryption

Encrypt the CEK with the recipient's public key using the RSAES-PKCS1-V1_5 algorithm to produce the JWE Encrypted Key. In this example, the RSA key parameters are:

Parameter Name	Value
	[177, 119, 33, 13, 164, 30, 108, 121, 207, 136, 107, 242, 12, 224, 19, 226, 198, 134, 17, 71, 173, 75, 42, 61, 48, 162, 206, 161, 97, 108, 185, 234, 226, 219, 118, 206, 118, 5, 169, 224, 60, 181, 90, 85, 51, 123, 6, 224, 4, 122, 29, 230, 151, 12, 244, 127, 121, 25, 4, 85, 220, 144, 215, 110, 130, 17, 68, 228, 129, 138, 7, 130, 231, 40, 212, 214, 17,

Modulus	179, 28, 124, 151, 178, 207, 20, 14, 154, 222, 113, 176, 24, 198, 73, 211, 113, 9, 33, 178, 80, 13, 25, 21, 25, 153, 212, 206, 67, 154, 147, 70, 194, 192, 183, 160, 83, 98, 236, 175, 85, 23, 97, 75, 199, 177, 73, 145, 50, 253, 206, 32, 179, 254, 236, 190, 82, 73, 67, 129, 253, 252, 220, 108, 136, 138, 11, 192, 1, 36, 239, 228, 55, 81, 113, 17, 25, 140, 63, 239, 146, 3, 172, 96, 60, 227, 233, 64, 255, 224, 173, 225, 228, 229, 92, 112, 72, 99, 97, 26, 87, 187, 123, 46, 50, 90, 202, 117, 73, 10, 153, 47, 224, 178, 163, 77, 48, 46, 154, 33, 148, 34, 228, 33, 172, 216, 89, 46, 225, 127, 68, 146, 234, 30, 147, 54, 146, 5, 133, 45, 78, 254, 85, 55, 75, 213, 86, 194, 218, 215, 163, 189, 194, 54, 6, 83, 36, 18, 153, 53, 7, 48, 89, 35, 66, 144, 7, 65, 154, 13, 97, 75, 55, 230, 132, 3, 13, 239, 71]
Exponent	[1, 0, 1]
Private Exponent	[84, 80, 150, 58, 165, 235, 242, 123, 217, 55, 38, 154, 36, 181, 221, 156, 211, 215, 100, 164, 90, 88, 40, 228, 83, 148, 54, 122, 4, 16, 165, 48, 76, 194, 26, 107, 51, 53, 179, 165, 31, 18, 198, 173, 78, 61, 56, 97, 252, 158, 140, 80, 63, 25, 223, 156, 36, 203, 214, 252, 120, 67, 180, 167, 3, 82, 243, 25, 97, 214, 83, 133, 69, 16, 104, 54, 160, 200, 41, 83, 164, 187, 70, 153, 111, 234, 242, 158, 175, 28, 198, 48, 211, 45, 148, 58, 23, 62, 227, 74, 52, 117, 42, 90, 41, 249, 130, 154, 80, 119, 61, 26, 193, 40, 125, 10, 152, 174, 227, 225, 205, 32, 62, 66, 6, 163, 100, 99, 219, 19, 253, 25, 105, 80, 201, 29, 252, 157, 237, 69, 1, 80, 171, 167, 20, 196, 156, 109, 249, 88, 0, 3, 152, 38, 165, 72, 87, 6, 152, 71, 156, 214, 16, 71, 30, 82, 51, 103, 76, 218, 63, 9, 84, 163, 249, 91, 215, 44, 238, 85, 101, 240, 148, 1, 82, 224, 91, 135, 105, 127, 84, 171, 181, 152, 210, 183, 126, 24, 46, 196, 90, 173, 38, 245, 219, 186, 222, 27, 240, 212, 194, 15, 66, 135, 226, 178, 190, 52, 245, 74, 65, 224, 81, 100, 85, 25, 204, 165, 203, 187, 175, 84, 100, 82, 15, 11, 23, 202, 151, 107, 54, 41, 207, 3, 136, 229, 134, 131, 93, 139, 50, 182, 204, 93, 130, 89]

The resulting JWE Encrypted Key value is:

[156, 150, 191, 184, 77, 131, 211, 9, 74, 207, 227, 156, 193, 38, 202, 23, 56, 247, 211, 108, 88, 72, 143, 145, 44, 19, 58, 133, 181, 70, 152, 254, 26, 198, 210, 80, 60, 15, 82, 210, 154, 55, 179, 115, 76, 146, 99, 166, 146, 70, 176, 157, 252, 15, 54, 58, 92, 210, 103, 55, 207, 191, 92, 185, 5, 164, 64, 241, 80, 163, 233, 131, 198, 106, 32, 207, 199, 113, 5, 200, 94, 105, 53, 32, 221, 155, 233, 108, 96, 151, 197, 152, 195, 96, 67, 81, 90, 38, 121, 51, 208, 98, 47, 45, 61, 4, 129, 121, 152, 122, 124, 229, 2, 250, 92, 64, 245, 36, 70, 76, 58, 31, 181, 185, 61, 101, 168, 240, 220, 12, 62, 253, 169, 107, 107, 9, 241, 9, 152, 217, 159, 179, 30, 95, 112, 29, 143, 124, 7, 21, 181, 13, 45, 253, 137, 142, 95, 30, 127, 26, 237, 34, 183, 89, 200, 44, 165, 203, 71, 102, 39, 127, 217, 159, 46, 17, 28, 11, 146, 222, 110, 149, 178, 16, 117, 186, 91, 52, 56, 136, 127, 82, 33, 194, 46, 164, 245, 117, 136, 160, 179, 152, 151, 15, 172, 48, 73, 228, 87, 63, 40, 192, 92, 92, 24, 167, 105, 47, 255, 193, 251, 77, 203, 6, 134, 129, 248, 191, 53, 43, 49, 219, 130, 241, 180, 174, 159, 34, 71, 163, 70, 83, 1, 152, 39, 241, 191, 68, 224, 240, 43, 113, 165, 68, 98, 130]

A.2.5. Encoded JWE Encrypted Key

TOC

Base64url encode the JWE Encrypted Key to produce the Encoded JWE Encrypted Key. This result (with line breaks for display purposes only) is:

```
nJa_uE2D0wlKz-OcwSbKFzj302xYSI-RLBM6hbVGmP4axtJQPA9S0po3s3NMkmOm
kkawnfwPNjpc0mc3z79cuQWkQPFQo-mDxmogz8dxBcheaTUg3ZvpbGCXxZjDYENR
WiZ5M9BiLy09BIF5mHp85QL6XED1JEZMOh-1uT1lqPDcDD79qWtrCfEJmNmfsx5f
cB2PfAcVtQ0t_YmOXx5_Gu0it1nILKXLR2Ynf9mfLhEcC5LebpWyEHW6WzQ4iH9S
IcIupPV1iKCzmJcPrDBJ5Fc_KMBcXBinaS__wftNywaGgfi_NSsx24LxtK6fIkej
RlMBmCfxv0Tg8CtxpURigg
```

A.2.6. Initialization Vector

TOC

Generate a random 128 bit JWE Initialization Vector. In this example, the value is:

[3, 22, 60, 12, 43, 67, 104, 105, 108, 108, 105, 99, 111, 116, 104, 101]

Base64url encoding this value yields the Encoded JWE Initialization Vector value:

```
AxY8DCtDaGlsbGljb3RoZQ
```

A.2.7. Additional Authenticated Data Parameter

TOC

Concatenate the Encoded JWE Header value, a period ('.') character, and the Encoded JWE Encrypted Key to create the Additional Authenticated Data parameter. This result (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0.
nJa_uE2D0wlKz-OcwSbKFzj302xYSI-RLBM6hbVGmP4axtJQPA9S0po3s3NMkmOm
kkawnfwPNjpc0mc3z79cuQWkQPFQo-mDxmogz8dxBcheaTUg3ZvpbGCXxZjDYENR
WiZ5M9BiLy09BIF5mHp85QL6XED1JEZMOh-1uT1lqPDcDD79qWtrCfEJmNmfsx5f
cB2PfAcVtQ0t_YmOXx5_Gu0it1nILKXLR2Ynf9mfLhEcC5LebpWyEHW6WzQ4iH9S
IcIupPV1iKCzmJcPrDBJ5Fc_KMBcXBinaS__wftNywaGgfi_NSsx24LxtK6fIkej
RlMBmCfxv0Tg8CtxpURigg
```

The representation of this value is:

[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 83, 85, 48, 69, 120, 88, 122, 85, 105, 76, 67, 74, 108, 98, 109, 77, 105, 79, 105, 74, 66, 77, 84, 73, 52, 81, 48, 74, 68, 76, 85, 104, 84, 77, 106, 85, 50, 73, 110, 48, 46, 110, 74, 97, 95, 117, 69, 50, 68, 48, 119, 108, 75, 122, 45, 79, 99, 119, 83, 98, 75, 70, 122, 106, 51, 48, 50, 120, 89, 83, 73, 45, 82, 76, 66, 77, 54, 104, 98, 86, 71, 109, 80, 52, 97, 120, 116, 74, 81, 80, 65, 57, 83, 48, 112, 111, 51, 115, 51, 78, 77, 107, 109, 79, 109, 107, 107, 97, 119, 110, 102, 119, 80, 78, 106, 112, 99, 48, 109, 99, 51, 122, 55, 57, 99, 117, 81, 87, 107, 81, 80, 70, 81, 111, 45, 109, 68, 120, 109, 111, 103, 122, 56, 100, 120, 66, 99, 104, 101, 97, 84, 85, 103, 51, 90, 118, 112, 98, 71, 67, 88, 120, 90, 106, 68, 89, 69, 78, 82, 87, 105, 90, 53, 77, 57, 66, 105, 76, 121, 48, 57, 66, 73, 70, 53, 109, 72, 112, 56, 53, 81, 76, 54, 88, 69, 68, 49, 74, 69, 90, 77, 79, 104, 45, 49, 117, 84, 49, 108, 113, 80, 68, 99, 68, 68, 55, 57, 113, 87, 116, 114, 67, 102, 69, 74, 109, 78, 109, 102, 115, 120, 53, 102, 99, 66, 50, 80, 102, 65, 99, 86, 116, 81, 48, 116, 95, 89, 109, 79, 88, 120, 53, 95, 71, 117, 48, 105, 116, 49, 110, 73, 76, 75, 88, 76, 82, 50, 89, 110, 102, 57, 109, 102, 76, 104, 69, 99, 67, 53, 76, 101, 98, 112, 87, 121, 69, 72, 87, 54, 87, 122, 81, 52, 105, 72, 57, 83, 73, 99, 73, 117, 112, 80, 86, 49, 105, 75, 67, 122, 109, 74, 99, 80, 114, 68, 66, 74, 53, 70, 99, 95, 75, 77, 66, 99, 88, 66, 105, 110, 97, 83, 95, 95, 119, 102, 116, 78, 121, 119, 97, 71, 103, 102, 105, 95, 78, 83, 115, 120, 50, 52, 76, 120, 116, 75, 54, 102, 73, 107, 101, 106, 82, 108, 77, 66, 109, 67, 102, 120, 118, 48, 84, 103, 56, 67, 116, 120, 112, 85, 82, 105, 103, 103]

A.2.8. Plaintext Encryption

TOC

Encrypt the Plaintext with AES_128_CBC_HMAC_SHA_256 using the CEK as the encryption key, the JWE Initialization Vector, and the Additional Authenticated Data value above. The steps for doing this using the values from **Appendix A.3** are detailed in **Appendix B**. The resulting Ciphertext is:

[40, 57, 83, 181, 119, 33, 133, 148, 198, 185, 243, 24, 152, 230, 6, 75, 129, 223, 127, 19, 210, 82, 183, 230, 168, 33, 215, 104, 143, 112, 56, 102]

The resulting Authentication Tag value is:

[125, 141, 148, 252, 124, 121, 85, 199, 215, 154, 42, 68, 149, 209, 225, 48]

A.2.9. Encoded JWE Ciphertext

TOC

Base64url encode the Ciphertext to create the Encoded JWE Ciphertext. This result is:

```
KDlTtXchhZTGufMYmOYGS4HffxPSUrfmqCHXaI9wOGY
```

A.2.10. Encoded JWE Authentication Tag

TOC

Base64url encode the Authentication Tag to create the Encoded JWE Authentication Tag. This result is:

```
fY2U_Hx5VcfXmipEldHhMA
```

A.2.11. Complete Representation

TOC

Assemble the final representation: The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Authentication Tag in that order, with the five strings being separated by four period ('.') characters.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0.
nJa_uE2D0wlKz-OcwSbKFzj302xYSI-RLBM6hbVGmP4axtJQPA9S0po3s3NMkmOm
kkawnfwPNjpc0mc3z79cuQWkQPFQo-mDxmogz8dxBcheaTUg3ZvpbGCXxZjDYENR
WiZ5M9BiLy09BIF5mHp85QL6XED1JEZMOh-1uT1lqPDcDD79qWtrCfEJmNmfsx5f
cB2PfAcVtQ0t_YmOXx5_Gu0it1nILKXLR2Ynf9mfLhEcC5LebpWyEHW6WzQ4iH9S
IcIupPV1iKCzmJcPrDBJ5Fc_KMBcXBinaS__wftNywaGgfi_NSsx24LxtK6fIkej
RlMBmCfxv0Tg8CtxpURigg.
AxY8DCtDaGlsbGljb3RoZQ.
KDlTtXchhZTGufMYmOYGS4HffxPSUrfmqCHXaI9wOGY.
fY2U_Hx5VcfXmipEldHhMA
```

A.2.12. Validation

TOC

This example illustrates the process of creating a JWE with RSAES-PKCS1-V1_5 and AES_CBC_HMAC_SHA2. These results can be used to validate JWE decryption implementations for these algorithms. Note that since the RSAES-PKCS1-V1_5 computation includes random values, the encryption results above will not be completely reproducible. However, since the AES CBC computation is deterministic, the JWE Encrypted Ciphertext values will be the same for all encryptions performed using these inputs.

A.3. Example JWE using AES Key Wrap and AES GCM

TOC

This example encrypts the plaintext "Live long and prosper." to the recipient using AES Key Wrap and AES GCM. The representation of this plaintext is:

[76, 105, 118, 101, 32, 108, 111, 110, 103, 32, 97, 110, 100, 32, 112, 114, 111, 115, 112, 101, 114, 46]

A.3.1. JWE Header

TOC

The following example JWE Header declares that:

- the Content Encryption Key is encrypted to the recipient using the AES Key Wrap

algorithm with a 128 bit key to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES_128_CBC_HMAC_SHA_256 algorithm to produce the Ciphertext.

```
{"alg":"A128KW","enc":"A128CBC-HS256"}
```

A.3.2. Encoded JWE Header

TOC

Base64url encoding the octets of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
```

A.3.3. Content Encryption Key (CEK)

TOC

Generate a 256 bit random Content Encryption Key (CEK). In this example, the value is:

[4, 211, 31, 197, 84, 157, 252, 254, 11, 100, 157, 250, 63, 170, 106, 206, 107, 124, 212, 45, 111, 107, 9, 219, 200, 177, 0, 240, 143, 156, 44, 207]

A.3.4. Key Encryption

TOC

Encrypt the CEK with the shared symmetric key using the AES Key Wrap algorithm to produce the JWE Encrypted Key. In this example, the shared symmetric key value is:

[25, 172, 32, 130, 225, 114, 26, 181, 138, 106, 254, 192, 95, 133, 74, 82]

The resulting JWE Encrypted Key value is:

[232, 160, 123, 211, 183, 76, 245, 132, 200, 128, 123, 75, 190, 216, 22, 67, 201, 138, 193, 186, 9, 91, 122, 31, 246, 90, 28, 139, 57, 3, 76, 124, 193, 11, 98, 37, 173, 61, 104, 57]

A.3.5. Encoded JWE Encrypted Key

TOC

Base64url encode the JWE Encrypted Key to produce the Encoded JWE Encrypted Key. This result is:

```
6KB707dM9YTIgHtLvtgWQ8mKwboJW3of9locizkDTHzBC2IlrT1oOQ
```

A.3.6. Initialization Vector

TOC

Generate a random 128 bit JWE Initialization Vector. In this example, the value is:

[3, 22, 60, 12, 43, 67, 104, 105, 108, 108, 105, 99, 111, 116, 104, 101]

Base64url encoding this value yields the Encoded JWE Initialization Vector value:

```
AxY8DCtDaGlsbGljb3RoZQ
```

A.3.7. Additional Authenticated Data Parameter

TOC

Concatenate the Encoded JWE Header value, a period ('.') character, and the Encoded JWE Encrypted Key to create the Additional Authenticated Data parameter. This result (with line breaks for display purposes only) is:

```
eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0.
6KB707dM9YTIgHtLvtgWQ8mKwboJW3of9locizkDTHzBC2IlrT1oOQ
```

The representation of this value is:

[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 66, 77, 84, 73, 52, 83, 49, 99, 105, 76, 67, 74, 108, 98, 109, 77, 105, 79, 105, 74, 66, 77, 84, 73, 52, 81, 48, 74, 68, 76, 85, 104, 84, 77, 106, 85, 50, 73, 110, 48, 46, 54, 75, 66, 55, 48, 55, 100, 77, 57, 89, 84, 73, 103, 72, 116, 76, 118, 116, 103, 87, 81, 56, 109, 75, 119, 98, 111, 74, 87, 51, 111, 102, 57, 108, 111, 99, 105, 122, 107, 68, 84, 72, 122, 66, 67, 50, 73, 108, 114, 84, 49, 111, 79, 81]

A.3.8. Plaintext Encryption

TOC

Encrypt the Plaintext with AES_128_CBC_HMAC_SHA_256 using the CEK as the encryption key, the JWE Initialization Vector, and the Additional Authenticated Data value above. The steps for doing this using the values from this example are detailed in **Appendix B**. The resulting Ciphertext is:

[40, 57, 83, 181, 119, 33, 133, 148, 198, 185, 243, 24, 152, 230, 6, 75, 129, 223, 127, 19, 210, 82, 183, 230, 168, 33, 215, 104, 143, 112, 56, 102]

The resulting Authentication Tag value is:

[8, 65, 248, 101, 45, 185, 28, 218, 232, 112, 83, 79, 84, 221, 18, 172]

A.3.9. Encoded JWE Ciphertext

TOC

Base64url encode the Ciphertext to create the Encoded JWE Ciphertext. This result is:

```
KDlTtXchhZTGufMYmOYGS4HffxPSUrfmqCHXaI9wOGY
```

A.3.10. Encoded JWE Authentication Tag

TOC

Base64url encode the Authentication Tag to create the Encoded JWE Authentication Tag. This result is:

```
CEH4ZS25HNrocFNPVN0SrA
```

A.3.11. Complete Representation

TOC

Assemble the final representation: The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Authentication Tag in that order, with the five strings being separated by four period ('.') characters.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0.
6KB707dM9YTIgHtLvtgWQ8mKwboJW3of9locizkDTHzBC2IlrT1oOQ.
AxY8DCtDaGlsbGljb3RoZQ.
KDlTtXchhZTGufMYmOYGS4HffxPSUrfmqCHXaI9wOGY.
CEH4ZS25HNrocFNPVN0SrA
```

TOC

A.3.12. Validation

This example illustrates the process of creating a JWE with symmetric key wrap and AES_CBC_HMAC_SHA2. These results can be used to validate JWE decryption implementations for these algorithms. Also, since both the AES Key Wrap and AES GCM computations are deterministic, the resulting JWE value will be the same for all encryptions performed using these inputs. Since the computation is reproducible, these results can also be used to validate JWE encryption implementations for these algorithms.

TOC

Appendix B. Example AES_128_CBC_HMAC_SHA_256 Computation

This example shows the steps in the AES_128_CBC_HMAC_SHA_256 authenticated encryption computation using the values from the example in **Appendix A.3**. As described where this algorithm is defined in Sections 4.8 and 4.8.3 of JWA, the AES_CBC_HMAC_SHA2 family of algorithms are implemented using Advanced Encryption Standard (AES) in Cipher Block Chaining (CBC) mode with PKCS #5 padding to perform the encryption and an HMAC SHA-2 function to perform the integrity calculation - in this case, HMAC SHA-256.

TOC

B.1. Extract MAC_KEY and ENC_KEY from Key

The 256 bit AES_128_CBC_HMAC_SHA_256 key K used in this example is:

[4, 211, 31, 197, 84, 157, 252, 254, 11, 100, 157, 250, 63, 170, 106, 206, 107, 124, 212, 45, 111, 107, 9, 219, 200, 177, 0, 240, 143, 156, 44, 207]

Use the first 128 bits of this key as the HMAC SHA-256 key MAC_KEY, which is:

[4, 211, 31, 197, 84, 157, 252, 254, 11, 100, 157, 250, 63, 170, 106, 206]

Use the last 128 bits of this key as the AES CBC key ENC_KEY, which is:

[107, 124, 212, 45, 111, 107, 9, 219, 200, 177, 0, 240, 143, 156, 44, 207]

Note that the MAC key comes before the encryption key in the input key K; this is in the opposite order of the algorithm names in the identifiers "AES_128_CBC_HMAC_SHA_256" and `A128CBC-HS256`.

TOC

B.2. Encrypt Plaintext to Create Ciphertext

Encrypt the Plaintext with AES in Cipher Block Chaining (CBC) mode using PKCS #5 padding using the ENC_KEY above. The Plaintext in this example is:

[76, 105, 118, 101, 32, 108, 111, 110, 103, 32, 97, 110, 100, 32, 112, 114, 111, 115, 112, 101, 114, 46]

The encryption result is as follows, which is the Ciphertext output:

[40, 57, 83, 181, 119, 33, 133, 148, 198, 185, 243, 24, 152, 230, 6, 75, 129, 223, 127, 19, 210, 82, 183, 230, 168, 33, 215, 104, 143, 112, 56, 102]

B.3. Create 64 Bit Big Endian Representation of AAD Length

TOC

The Additional Authenticated Data (AAD) in this example is:

[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 66, 77, 84, 73, 52, 83, 49, 99, 105, 76, 67, 74, 108, 98, 109, 77, 105, 79, 105, 74, 66, 77, 84, 73, 52, 81, 48, 74, 68, 76, 85, 104, 84, 77, 106, 85, 50, 73, 110, 48, 46, 54, 75, 66, 55, 48, 55, 100, 77, 57, 89, 84, 73, 103, 72, 116, 76, 118, 116, 103, 87, 81, 56, 109, 75, 119, 98, 111, 74, 87, 51, 111, 102, 57, 108, 111, 99, 105, 122, 107, 68, 84, 72, 122, 66, 67, 50, 73, 108, 114, 84, 49, 111, 79, 81]

This AAD is 106 bytes long, which is 848 bits long. The octet string AL, which is the number of bits in AAD expressed as a big endian 64 bit unsigned integer is:

[0, 0, 0, 0, 0, 0, 3, 80]

B.4. Initialization Vector Value

TOC

The Initialization Vector value used in this example is:

[3, 22, 60, 12, 43, 67, 104, 105, 108, 108, 105, 99, 111, 116, 104, 101]

B.5. Create Input to HMAC Computation

TOC

Concatenate the AAD, the Initialization Vector, the Ciphertext, and the AL value. The result of this concatenation is:

[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 66, 77, 84, 73, 52, 83, 49, 99, 105, 76, 67, 74, 108, 98, 109, 77, 105, 79, 105, 74, 66, 77, 84, 73, 52, 81, 48, 74, 68, 76, 85, 104, 84, 77, 106, 85, 50, 73, 110, 48, 46, 54, 75, 66, 55, 48, 55, 100, 77, 57, 89, 84, 73, 103, 72, 116, 76, 118, 116, 103, 87, 81, 56, 109, 75, 119, 98, 111, 74, 87, 51, 111, 102, 57, 108, 111, 99, 105, 122, 107, 68, 84, 72, 122, 66, 67, 50, 73, 108, 114, 84, 49, 111, 79, 81, 3, 22, 60, 12, 43, 67, 104, 105, 108, 108, 105, 99, 111, 116, 104, 101, 40, 57, 83, 181, 119, 33, 133, 148, 198, 185, 243, 24, 152, 230, 6, 75, 129, 223, 127, 19, 210, 82, 183, 230, 168, 33, 215, 104, 143, 112, 56, 102, 0, 0, 0, 0, 0, 0, 3, 80]

B.6. Compute HMAC Value

TOC

Compute the HMAC SHA-256 of the concatenated value above. This result M is:

[8, 65, 248, 101, 45, 185, 28, 218, 232, 112, 83, 79, 84, 221, 18, 172, 50, 145, 207, 8, 14, 74, 44, 220, 100, 117, 32, 57, 239, 149, 173, 226]

B.7. Truncate HMAC Value to Create Authentication Tag

TOC

Use the first half (128 bits) of the HMAC output M as the Authentication Tag output T. This truncated value is:

[8, 65, 248, 101, 45, 185, 28, 218, 232, 112, 83, 79, 84, 221, 18, 172]

Appendix C. Possible Compact Serialization for Multiple Recipients

TOC

The JWE encryption process in **Section 5.1**, and in particular in steps 15 and 16, hint at a possible compact serialization when there are multiple recipients. This possible compact serialization concatenates instances of the per-recipient fields, separating them with tilde ('~') characters, which are URL-safe.

The concatenation of the Encoded JWE Header values goes before the first period ('.') character in the compact serialization. The concatenation of the corresponding Encoded JWE Encoded Key values goes between the first and second period ('.') characters in the compact serialization.

A complete compact serialization of the multi-recipient JWE in **Section 7.1** (with line breaks for display purposes only) would be:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
~
eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
.
nJa_uE2D0wlKz-OcwSbKFzj302xYSI-RLBM6hbVGmP4axtJQPA9S0po3s3NMk
mOmkkawnfwPNjpc0mc3z79cuQWkQPFQo-mDxmogz8dxBcheaTUg3ZvpbGCXxZ
jDYENRWiZ5M9BiLy09BIF5mHp85QL6XED1JEZMOh-1uT1lqPDcDD79qWtrCfE
JmNmfsx5fcB2PfAcVtQ0t_YmOXx5_Gu0it1nILKXLR2Ynf9mfLhEcC5LebpWy
EHW6WzQ4iH9SIcIupPV1iKCzmJcPrDBJ5Fc_KMBcXBinaS__wftNywaGgfi_N
Ssx24LxtK6fIkejRlMBmCfxv0Tg8CtxpURigg
~
6KB707dM9YTIgHtLvtgWQ8mKwboJW3of9locizkDTHzBC2IlrT1oOQ
.
AxY8DCtDaGlsbGljb3RoZQ
.
KDlTtXchhZTGufMYmOYGS4HffxPSUrfmqCHXaI9wOGY
.
LlhRZFfphc2f5X3nTTJP6g
```

Note that the octets of the UTF-8 representation of the first two parts of this serialization, including the period ('.') character separating them, are used as the AAD value in step 17 of the JWE encryption process in **Section 5.1**.

This representation is suggested for those who may desire or require a compact, URL-safe serialization of JWEs with multiple recipients. It is a suggestion to implementers for whom this functionality would be valuable, and not a normative part of this specification.

Appendix D. Acknowledgements

TOC

Solutions for encrypting JSON content were also explored by **JSON Simple Encryption** [JSE] and **JavaScript Message Security Format** [I-D.rescorla-jsms], both of which significantly influenced this draft. This draft attempts to explicitly reuse as many of the relevant concepts from **XML Encryption 1.1** [W3C.CR-xmlenc-core1-20120313] and **RFC 5652** [RFC5652] as possible, while utilizing simple compact JSON-based data structures.

Special thanks are due to John Bradley and Nat Sakimura for the discussions that helped inform the content of this specification and to Eric Rescorla and Joe Hildebrand for allowing the reuse of text from **[I-D.rescorla-jsms]** in this document.

Thanks to Axel Nennker, Emmanuel Raviart, Brian Campbell, and Edmund Jay for validating the examples in this specification.

This specification is the work of the JOSE Working Group, which includes dozens of active and dedicated participants. In particular, the following individuals contributed ideas, feedback, and wording that influenced this specification:

Richard Barnes, John Bradley, Brian Campbell, Breno de Medeiros, Dick Hardt, Jeff Hodges, Edmund Jay, James Manger, Tony Nadalin, Axel Nennker, Emmanuel Raviart, Nat Sakimura, Jim Schaad, Hannes Tschofenig, and Sean Turner.

Jim Schaad and Karen O'Donoghue chaired the JOSE working group and Sean Turner and

Stephen Farrell served as Security area directors during the creation of this specification.

Appendix E. Document History

TOC

[[to be removed by the RFC editor before publication as an RFC]]

-10

- Changed the JWE processing rules for multiple recipients so that a single AAD value contains the header parameters and encrypted key values for all the recipients, enabling AES GCM to be safely used for multiple recipients.
- Added an appendix suggesting a possible compact serialization for JWEs with multiple recipients.

-09

- Added JWE JSON Serialization, as specified by draft-jones-jose-jwe-json-serialization-04.
- Registered `application/jwe-js` MIME type and `JWE-JS` typ header parameter value.
- Defined that the default action for header parameters that are not understood is to ignore them unless specifically designated as "MUST be understood" or included in the new `crit` (critical) header parameter list. This addressed issue #6.
- Corrected `x5c` description. This addressed issue #12.
- Changed from using the term "byte" to "octet" when referring to 8 bit values.
- Added Key Management Mode definitions to terminology section and used the defined terms to provide clearer key management instructions. This addressed issue #5.
- Added text about preventing the recipient from behaving as an oracle during decryption, especially when using RSAES-PKCS1-V1_5.
- Changed from using the term "Integrity Value" to "Authentication Tag".
- Changed member name from `integrity_value` to `authentication_tag` in the JWE JSON Serialization.
- Removed Initialization Vector from the AAD value since it is already integrity protected by all of the authenticated encryption algorithms specified in the JWA specification.
- Replaced `A128CBC+HS256` and `A256CBC+HS512` with `A128CBC-HS256` and `A256CBC-HS512`. The new algorithms perform the same cryptographic computations as **[I-D.mcgrew-aead-aes-cbc-hmac-sha2]**, but with the Initialization Vector and Authentication Tag values remaining separate from the Ciphertext value in the output representation. Also deleted the header parameters `epu` (encryption PartyUInfo) and `epv` (encryption PartyVInfo), since they are no longer used.

-08

- Replaced uses of the term "AEAD" with "Authenticated Encryption", since the term AEAD in the RFC 5116 sense implied the use of a particular data representation, rather than just referring to the class of algorithms that perform authenticated encryption with associated data.
- Applied editorial improvements suggested by Jeff Hodges and Hannes Tschofenig. Many of these simplified the terminology used.
- Clarified statements of the form "This header parameter is OPTIONAL" to "Use of this header parameter is OPTIONAL".
- Added a Header Parameter Usage Location(s) field to the IANA JSON Web Signature and Encryption Header Parameters registry.
- Added seriesInfo information to Internet Draft references.

-07

- Added a data length prefix to PartyUInfo and PartyVInfo values.
- Updated values for example AES CBC calculations.
- Made several local editorial changes to clean up loose ends left over from to the decision to only support block encryption methods providing integrity. One of these changes was to explicitly state that the `enc` (encryption method) algorithm

must be an Authenticated Encryption algorithm with a specified key length.

-06

- Removed the `int` and `kdf` parameters and defined the new composite Authenticated Encryption algorithms `A128CBC+HS256` and `A256CBC+HS512` to replace the former uses of AES CBC, which required the use of separate integrity and key derivation functions.
- Included additional values in the Concat KDF calculation -- the desired output size and the algorithm value, and optionally PartyUInfo and PartyVInfo values. Added the optional header parameters `apu` (agreement PartyUInfo), `apv` (agreement PartyVInfo), `epu` (encryption PartyUInfo), and `epv` (encryption PartyVInfo). Updated the KDF examples accordingly.
- Promoted Initialization Vector from being a header parameter to being a top-level JWE element. This saves approximately 16 bytes in the compact serialization, which is a significant savings for some use cases. Promoting the Initialization Vector out of the header also avoids repeating this shared value in the JSON serialization.
- Changed `x5c` (X.509 Certificate Chain) representation from being a single string to being an array of strings, each containing a single base64 encoded DER certificate value, representing elements of the certificate chain.
- Added an AES Key Wrap example.
- Reordered the encryption steps so CMK creation is first, when required.
- Correct statements in examples about which algorithms produce reproducible results.

-05

- Support both direct encryption using a shared or agreed upon symmetric key, and the use of a shared or agreed upon symmetric key to key wrap the CMK.
- Added statement that "StringOrURI values are compared as case-sensitive strings with no transformations or canonicalizations applied".
- Updated open issues.
- Indented artwork elements to better distinguish them from the body text.

-04

- Refer to the registries as the primary sources of defined values and then secondarily reference the sections defining the initial contents of the registries.
- Normatively reference **XML Encryption 1.1** [W3C.CR-xmlenc-core1-20120313] for its security considerations.
- Reference draft-jones-jose-jwe-json-serialization instead of draft-jones-json-web-encryption-json-serialization.
- Described additional open issues.
- Applied editorial suggestions.

-03

- Added the `kdf` (key derivation function) header parameter to provide crypto agility for key derivation. The default KDF remains the Concat KDF with the SHA-256 digest function.
- Reordered encryption steps so that the Encoded JWE Header is always created before it is needed as an input to the Authenticated Encryption "additional authenticated data" parameter.
- Added the `cty` (content type) header parameter for declaring type information about the secured content, as opposed to the `typ` (type) header parameter, which declares type information about this object.
- Moved description of how to determine whether a header is for a JWS or a JWE from the JWT spec to the JWE spec.
- Added complete encryption examples for both Authenticated Encryption and non-Authenticated Encryption algorithms.
- Added complete key derivation examples.
- Added "Collision Resistant Namespace" to the terminology section.
- Reference ITU.X690.1994 for DER encoding.
- Added Registry Contents sections to populate registry values.
- Numerous editorial improvements.

-02

- When using Authenticated Encryption algorithms (such as AES GCM), use the "additional authenticated data" parameter to provide integrity for the header, encrypted key, and ciphertext and use the resulting "authentication tag" value as the JWE Authentication Tag.
- Defined KDF output key sizes.
- Generalized text to allow key agreement to be employed as an alternative to key wrapping or key encryption.
- Changed compression algorithm from gzip to DEFLATE.
- Clarified that it is an error when a `kid` value is included and no matching key is found.
- Clarified that JWEs with duplicate Header Parameter Names MUST be rejected.
- Clarified the relationship between `typ` header parameter values and MIME types.
- Registered application/jwe MIME type and "JWE" typ header parameter value.
- Simplified JWK terminology to get replace the "JWK Key Object" and "JWK Container Object" terms with simply "JSON Web Key (JWK)" and "JSON Web Key Set (JWK Set)" and to eliminate potential confusion between single keys and sets of keys. As part of this change, the Header Parameter Name for a public key value was changed from `jpk` (JSON Public Key) to `jwk` (JSON Web Key).
- Added suggestion on defining additional header parameters such as `x5t#S256` in the future for certificate thumbprints using hash algorithms other than SHA-1.
- Specify RFC 2818 server identity validation, rather than RFC 6125 (paralleling the same decision in the OAuth specs).
- Generalized language to refer to Message Authentication Codes (MACs) rather than Hash-based Message Authentication Codes (HMACs) unless in a context specific to HMAC algorithms.
- Reformatted to give each header parameter its own section heading.

-01

- Added an integrity check for non-Authenticated Encryption algorithms.
- Added `jpk` and `x5c` header parameters for including JWK public keys and X.509 certificate chains directly in the header.
- Clarified that this specification is defining the JWE Compact Serialization. Referenced the new JWE-JS spec, which defines the JWE JSON Serialization.
- Added text "New header parameters should be introduced sparingly since an implementation that does not understand a parameter MUST reject the JWE".
- Clarified that the order of the encryption and decryption steps is not significant in cases where there are no dependencies between the inputs and outputs of the steps.
- Made other editorial improvements suggested by JOSE working group participants.

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- Created the initial IETF draft based upon draft-jones-json-web-encryption-02 with no normative changes.
- Changed terminology to no longer call both digital signatures and HMACs "signatures".

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