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Abstract

A JSON Web Key (JWK) is a JavaScript Object Notation (JSON) data structure that represents a cryptographic key. This specification also defines a JSON Web Key Set (JWK Set) JSON data structure for representing a set of JWKs. Cryptographic algorithms and identifiers for use with this specification are described in the separate JSON Web Algorithms (JWA) specification and IANA registries defined by that specification.

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Table of Contents

- 1. Introduction**
 - 1.1. Notational Conventions**
- 2. Terminology**
- 3. JSON Web Key (JWK) Format**
 - 3.1. "kty" (Key Type) Parameter**
 - 3.2. "use" (Public Key Use) Parameter**
 - 3.3. "key_ops" (Key Operations) Parameter**
 - 3.4. "alg" (Algorithm) Parameter**
 - 3.5. "kid" (Key ID) Parameter**
 - 3.6. "x5u" (X.509 URL) Parameter**
 - 3.7. "x5c" (X.509 Certificate Chain) Parameter**
 - 3.8. "x5t" (X.509 Certificate SHA-1 Thumbprint) Parameter**
- 4. JSON Web Key Set (JWK Set) Format**

- [4.1. "keys" Parameter](#)
- [5. String Comparison Rules](#)
- [6. Encrypted JWK and Encrypted JWK Set Formats](#)
- [7. IANA Considerations](#)
 - [7.1. JSON Web Key Parameters Registry](#)
 - [7.1.1. Registration Template](#)
 - [7.1.2. Initial Registry Contents](#)
 - [7.2. JSON Web Key Use Registry](#)
 - [7.2.1. Registration Template](#)
 - [7.2.2. Initial Registry Contents](#)
 - [7.3. JSON Web Key Operations Registry](#)
 - [7.3.1. Registration Template](#)
 - [7.3.2. Initial Registry Contents](#)
 - [7.4. JSON Web Key Set Parameters Registry](#)
 - [7.4.1. Registration Template](#)
 - [7.4.2. Initial Registry Contents](#)
 - [7.5. Media Type Registration](#)
 - [7.5.1. Registry Contents](#)
- [8. Security Considerations](#)
- [9. References](#)
 - [9.1. Normative References](#)
 - [9.2. Informative References](#)
- [Appendix A. Example JSON Web Key Sets](#)
 - [A.1. Example Public Keys](#)
 - [A.2. Example Private Keys](#)
 - [A.3. Example Symmetric Keys](#)
- [Appendix B. Example Use of "x5c" \(X.509 Certificate Chain\) Parameter](#)
- [Appendix C. Example Encrypted RSA Private Key](#)
 - [C.1. Plaintext RSA Private Key](#)
 - [C.2. JWE Header](#)
 - [C.3. Content Encryption Key \(CEK\)](#)
 - [C.4. Key Derivation](#)
 - [C.5. Key Encryption](#)
 - [C.6. Initialization Vector](#)
 - [C.7. Additional Authenticated Data](#)
 - [C.8. Content Encryption](#)
 - [C.9. Complete Representation](#)
- [Appendix D. Acknowledgements](#)
- [Appendix E. Document History](#)
- [§ Author's Address](#)

1. Introduction

TOC

A JSON Web Key (JWK) is a JavaScript Object Notation (JSON) [\[I-D.ietf-json-rfc4627bis\]](#) data structure that represents a cryptographic key. This specification also defines a JSON Web Key Set (JWK Set) JSON data structure for representing a set of JWKs. Cryptographic algorithms and identifiers for use with this specification are described in the separate JSON Web Algorithms (JWA) [\[JWA\]](#) specification and IANA registries defined by that specification.

Goals for this specification do not include representing certificate chains, representing certified keys, and replacing X.509 certificates.

JWKs and JWK Sets are used in the JSON Web Signature (JWS) [\[JWS\]](#) and JSON Web Encryption (JWE) [\[JWE\]](#) specifications.

Names defined by this specification are short because a core goal is for the resulting representations to be compact.

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]**. If these words are used without being spelled in uppercase then they are to be interpreted with their normal natural language meanings.

BASE64URL(OCTETS) denotes the base64url encoding of OCTETS, per **Section 2**.

UTF8(STRING) denotes the octets of the UTF-8 **[RFC3629]** representation of STRING.

ASCII(STRING) denotes the octets of the ASCII **[USASCII]** representation of STRING.

The concatenation of two values A and B is denoted as A || B.

2. Terminology

TOC

These terms defined by the JSON Web Signature (JWS) **[JWS]** specification are incorporated into this specification: "Base64url Encoding" and "Collision-Resistant Name".

These terms are defined for use by this specification:

JSON Web Key (JWK)

A JSON object that represents a cryptographic key.

JSON Web Key Set (JWK Set)

A JSON object that contains an array of JWKs as the value of its `keys` member.

3. JSON Web Key (JWK) Format

TOC

A JSON Web Key (JWK) is a JSON object. The members of the object represent properties of the key, including its value. This document defines the key parameters that are not algorithm specific, and thus common to many keys.

In addition to the common parameters, each JWK will have members that are specific to the kind of key being represented. These members represent the parameters of the key. Section 6 of the JSON Web Algorithms (JWA) **[JWA]** specification defines multiple kinds of cryptographic keys and their associated members.

The member names within a JWK **MUST** be unique; recipients **MUST** either reject JWKs with duplicate member names or use a JSON parser that returns only the lexically last duplicate member name, as specified in Section 15.12 (The JSON Object) of ECMAScript 5.1 **[ECMAScript]**.

Additional members can be present in the JWK; if not understood by implementations encountering them, they **MUST** be ignored. Member names used for representing key parameters for different keys types need not be distinct. Any new member name should either be registered in the IANA JSON Web Key Parameters registry defined in **Section 7.1** or be a value that contains a Collision-Resistant Name.

3.1. "kty" (Key Type) Parameter

TOC

The `kty` (key type) member identifies the cryptographic algorithm family used with the key. `kty` values should either be registered in the IANA JSON Web Key Types registry defined in **[JWA]** or be a value that contains a Collision-Resistant Name. The `kty` value is a case-sensitive string. This member **MUST** be present in a JWK.

A list of defined `kty` values can be found in the IANA JSON Web Key Types registry defined in **[JWA]**; the initial contents of this registry are the values defined in Section 6.1 of the JSON Web Algorithms (JWA) **[JWA]** specification.

The key type definitions include specification of the members to be used for those key types. Additional members used with `kty` values can also be found in the IANA JSON Web Key Parameters registry defined in **Section 7.1**.

3.2. "use" (Public Key Use) Parameter

The `use` (public key use) member identifies the intended use of the public key. The `use` parameter is intended for use cases in which it is useful to distinguish between public signing keys and public encryption keys. It is not intended for use cases in which private or symmetric keys may also be present.

Values defined by this specification are:

- `sig` (signature)
- `enc` (encryption)

Other values MAY be used. Public Key Use values can be registered in the IANA JSON Web Key Use registry defined in [Section 7.2](#). The `use` value is a case-sensitive string. Use of the `use` member is OPTIONAL, unless the application requires its presence.

When a key is used to wrap another key and a key use designation for the first key is desired, the `enc` (encryption) key use value SHOULD be used, since key wrapping is a kind of encryption. The `enc` value SHOULD also be used for public keys used for key agreement operations. (The `alg` member can be used to specify the particular cryptographic operation to be performed, when desired.)

3.3. "key_ops" (Key Operations) Parameter

The `key_ops` (key operations) member identifies the operations(s) that the key is intended to be used for. The `key_ops` parameter is intended for use cases in which public, private, or symmetric keys may be present.

Its value is an array of key operation values. Values defined by this specification are:

- `sign` (compute signature or MAC)
- `verify` (verify signature or MAC)
- `encrypt` (encrypt content)
- `decrypt` (decrypt content and validate decryption, if applicable)
- `wrapKey` (encrypt key)
- `unwrapKey` (decrypt key and validate decryption, if applicable)
- `deriveKey` (derive key)
- `deriveBits` (derive bits not to be used as a key)

(Note that the `key_ops` values intentionally match the `KeyUsage` values defined in the [Web Cryptography API](#) [WebCrypto] specification.)

Other values MAY be used. Key operation values can be registered in the IANA JSON Web Key Operations registry defined in [Section 7.3](#). The key operation values are case-sensitive strings. Duplicate key operation values MUST NOT be present in the array.

Use of the `key_ops` member is OPTIONAL, unless the application requires its presence.

Multiple unrelated key operations SHOULD NOT be specified for a key because of the potential vulnerabilities associated with using the same key with multiple algorithms. Thus, the combinations `sign` with `verify`, `encrypt` with `decrypt`, and `wrapKey` with `unwrapKey` are permitted, but other combinations SHOULD NOT be used.

The `use` and `key_ops` JWK members SHOULD NOT be used together. Applications should specify which of these members they use, if either is to be used by the application.

3.4. "alg" (Algorithm) Parameter

The `alg` (algorithm) member identifies the algorithm intended for use with the key. The values used should either be registered in the IANA JSON Web Signature and Encryption Algorithms registry defined in [\[JWA\]](#) or be a value that contains a Collision-Resistant Name. Use of this member is OPTIONAL.

3.5. "kid" (Key ID) Parameter

TOC

The `kid` (key ID) member can be used to match a specific key. This can be used, for instance, to choose among a set of keys within a JWK Set during key rollover. The structure of the `kid` value is unspecified. When `kid` values are used within a JWK Set, different keys within the JWK Set SHOULD use distinct `kid` values. (One example in which different keys might use the same `kid` value is if they have different `key type` values but are considered to be equivalent alternatives by the application using them.) The `kid` value is a case-sensitive string. Use of this member is OPTIONAL.

When used with JWS or JWE, the `kid` value is used to match a JWS or JWE `kid` Header Parameter value.

3.6. "x5u" (X.509 URL) Parameter

TOC

The `x5u` (X.509 URL) member is a URI [\[RFC3986\]](#) that refers to a resource for an X.509 public key certificate or certificate chain [\[RFC5280\]](#). 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 key in the first certificate MUST match the public key represented by other members of the 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 member is OPTIONAL.

While there is no requirement that members other than those representing the public key be populated when an `x5u` member is present, doing so may improve interoperability for applications that do not handle PKIX certificates. If other members are present, the contents of those members MUST be semantically consistent with the related fields in the first certificate. For instance, if the `use` member is present, then it needs to allow for only a subset of the usages that are permitted by the certificate. Similarly, if the `alg` member is present, it should represent an algorithm that the certificate allows.

3.7. "x5c" (X.509 Certificate Chain) Parameter

TOC

The `x5c` (X.509 Certificate Chain) member contains a chain of one or more PKIX certificates [\[RFC5280\]](#). The certificate chain is represented as a JSON array of certificate value strings. Each string in the array is a base64 encoded ([\[RFC4648\]](#) Section 4 -- not base64url encoded) DER [\[ITU.X690.1994\]](#) PKIX certificate value. The PKIX certificate containing the key value 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 key in the first certificate MUST match the public key represented by other members of the JWK. Use of this member is OPTIONAL.

As with the `x5u` member, members other than those representing the public key may also be populated when an `x5c` member is present. If other members are present, the contents of those members MUST be semantically consistent with the related fields in the first certificate. See the last paragraph of [Section 3.6](#) for additional guidance on this.

3.8. "x5t" (X.509 Certificate SHA-1 Thumbprint) Parameter

TOC

The `x5t` (X.509 Certificate SHA-1 Thumbprint) member is a base64url encoded SHA-1 thumbprint (a.k.a. digest) of the DER encoding of an X.509 certificate [RFC5280]. The key in the certificate MUST match the public key represented by other members of the JWK. Use of this member 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 JWK parameters be defined for that purpose. For example, it is suggested that a new `x5t#S256` (X.509 Certificate Thumbprint using SHA-256) JWK parameter could be defined by registering it in the IANA JSON Web Key Parameters registry defined in Section 7.1.

As with the `x5u` member, members other than those representing the public key may also be populated when an `x5t` member is present. If other members are present, the contents of those members MUST be semantically consistent with the related fields in the referenced certificate. See the last paragraph of Section 3.6 for additional guidance on this.

4. JSON Web Key Set (JWK Set) Format

TOC

A JSON Web Key Set (JWK Set) is a JSON object representing a set of JWKs. The JSON object MUST have a `keys` member, which is an array of JWK objects.

The member names within a JWK Set MUST be unique; recipients MUST either reject JWK Sets with duplicate member names or use a JSON parser that returns only the lexically last duplicate member name, as specified in Section 15.12 (The JSON Object) of ECMA Script 5.1 [ECMAScript].

Additional members can be present in the JWK Set; if not understood by implementations encountering them, they MUST be ignored. Parameters for representing additional properties of JWK Sets should either be registered in the IANA JSON Web Key Set Parameters registry defined in Section 7.4 or be a value that contains a Collision-Resistant Name.

Implementations SHOULD ignore JWKs within a JWK Set that use `key` (key type) values that are not understood by them, are missing required members, or for which values are out of the supported ranges.

4.1. "keys" Parameter

TOC

The value of the `keys` member is an array of JWK values. By default, the order of the JWK values within the array does not imply an order of preference among them, although applications of JWK Sets can choose to assign a meaning to the order for their purposes, if desired. This member MUST be present in a JWK Set.

5. String Comparison Rules

TOC

The string comparison rules for this specification are the same as those defined in Section 5.3 of [JWS].

6. Encrypted JWK and Encrypted JWK Set Formats

TOC

JWKs containing non-public key material will need to be encrypted in some contexts to prevent the disclosure of private or symmetric key values to unintended parties. The use of an Encrypted JWK, which is a JWE with the UTF-8 encoding of a JWK as its plaintext value, is recommended for this purpose. The processing of Encrypted JWKs is identical to the processing of other JWEs. A `content` (content type) Header Parameter value of `jwt+jwk` MUST be used to indicate that the content of the JWE is a JWK, unless the application knows that the encrypted content is a JWK by another means or convention.

JWK Sets containing non-public key material will similarly need to be encrypted. The use of an Encrypted JWK Set, which is a JWE with the UTF-8 encoding of a JWK Set as its plaintext value, is recommended for this purpose. The processing of Encrypted JWK Sets is identical to the processing of other JWEs. A `cty` (content type) Header Parameter value of `jwt-set+jwk` MUST be used to indicate that the content of the JWE is a JWK Set, unless the application knows that the encrypted content is a JWK Set by another means or convention.

See **Appendix C** for an example encrypted JWK.

7. IANA Considerations

TOC

The following registration procedure is used for all the registries established by this specification.

Values are registered with a Specification Required **[RFC5226]** after a two-week review period on the `[TBD]@ietf.org` mailing list, on the advice of one or more Designated Experts. However, to allow for the allocation of values prior to publication, the Designated Expert(s) may approve registration once they are satisfied that such a specification will be published.

Registration requests must be sent to the `[TBD]@ietf.org` mailing list for review and comment, with an appropriate subject (e.g., "Request for access token type: example"). [[Note to the RFC Editor: The name of the mailing list should be determined in consultation with the IESG and IANA. Suggested name: `jose-reg-review`.]]

Within the review period, the Designated Expert(s) will either approve or deny the registration request, communicating this decision to the review list and IANA. Denials should include an explanation and, if applicable, suggestions as to how to make the request successful. Registration requests that are undetermined for a period longer than 21 days can be brought to the IESG's attention (using the `iesg@iesg.org` mailing list) for resolution.

Criteria that should be applied by the Designated Expert(s) includes determining whether the proposed registration duplicates existing functionality, determining whether it is likely to be of general applicability or whether it is useful only for a single application, and whether the registration makes sense.

IANA must only accept registry updates from the Designated Expert(s) and should direct all requests for registration to the review mailing list.

It is suggested that multiple Designated Experts be appointed who are able to represent the perspectives of different applications using this specification, in order to enable broadly-informed review of registration decisions. In cases where a registration decision could be perceived as creating a conflict of interest for a particular Expert, that Expert should defer to the judgment of the other Expert(s).

7.1. JSON Web Key Parameters Registry

TOC

This specification establishes the IANA JSON Web Key Parameters registry for JWK parameter names. The registry records the parameter name, the key type(s) that the parameter is used with, and a reference to the specification that defines it. It also records whether the parameter conveys public or private information. This specification registers the parameter names defined in **Section 3**. The same JWK parameter name may be registered multiple times, provided that duplicate parameter registrations are only for key type specific JWK parameters; in this case, the meaning of the duplicate parameter name is disambiguated by the `kt` value of the JWK containing it.

7.1.1. Registration Template

TOC

Parameter Name:

The name requested (e.g., "example"). Because a core goal of this specification is for the resulting representations to be compact, it is RECOMMENDED that the

name be short -- not to exceed 8 characters without a compelling reason to do so. This name is case-sensitive. Names may not match other registered names in a case-insensitive manner unless the Designated Expert(s) state that there is a compelling reason to allow an exception in this particular case. However, matching names may be registered, provided that the accompanying sets of *key* values that the Parameter Name is used with are disjoint; for the purposes of matching *key* values, "*" matches all values.

Parameter Description:

Brief description of the parameter (e.g., "Example description").

Used with "key" Value(s):

The key type parameter value(s) that the parameter name is to be used with, or the value "*" if the parameter value is used with all key types. Values may not match other registered *key* values in a case-insensitive manner when the registered Parameter Name is the same (including when the Parameter Name matches in a case-insensitive manner) unless the Designated Expert(s) state that there is a compelling reason to allow an exception in this particular case.

Parameter Information Class:

Registers whether the parameter conveys public or private information. Its value must be one of the words Public or Private.

Change Controller:

For Standards Track RFCs, state "IESG". For others, give the name of the responsible party. Other details (e.g., postal address, email address, home page URI) may also be included.

Specification Document(s):

Reference to the document(s) that specify the parameter, preferably including URI(s) that can be used to retrieve copies of the document(s). An indication of the relevant sections may also be included but is not required.

7.1.2. Initial Registry Contents

TOC

- Parameter Name: *key*
- Parameter Description: Key Type
- Used with "key" Value(s): *
- Parameter Information Class: Public
- Change Controller: IESG
- Specification Document(s): **Section 3.1** of [[this document]]

- Parameter Name: *use*
- Parameter Description: Public Key Use
- Used with "key" Value(s): *
- Parameter Information Class: Public
- Change Controller: IESG
- Specification Document(s): **Section 3.2** of [[this document]]

- Parameter Name: *key_ops*
- Parameter Description: Key Operations
- Used with "key" Value(s): *
- Parameter Information Class: Public
- Change Controller: IESG
- Specification Document(s): **Section 3.3** of [[this document]]

- Parameter Name: *alg*
- Parameter Description: Algorithm
- Used with "key" Value(s): *
- Parameter Information Class: Public
- Change Controller: IESG
- Specification Document(s): **Section 3.4** of [[this document]]

- Parameter Name: *kid*
- Parameter Description: Key ID
- Used with "key" Value(s): *
- Parameter Information Class: Public
- Change Controller: IESG
- Specification Document(s): **Section 3.5** of [[this document]]

- Parameter Name: [x5u](#)
 - Parameter Description: X.509 URL
 - Used with "kty" Value(s): *
 - Parameter Information Class: Public
 - Change Controller: IESG
 - Specification Document(s): **Section 3.6** of [[this document]]
- Parameter Name: [x5c](#)
 - Parameter Description: X.509 Certificate Chain
 - Used with "kty" Value(s): *
 - Parameter Information Class: Public
 - Change Controller: IESG
 - Specification Document(s): **Section 3.7** of [[this document]]
- Parameter Name: [x5t](#)
 - Parameter Description: X.509 Certificate SHA-1 Thumbprint
 - Used with "kty" Value(s): *
 - Parameter Information Class: Public
 - Change Controller: IESG
 - Specification Document(s): **Section 3.8** of [[this document]]

7.2. JSON Web Key Use Registry

TOC

This specification establishes the IANA JSON Web Key Use registry for JWK use (public key use) member values. The registry records the public key use value and a reference to the specification that defines it. This specification registers the parameter names defined in **Section 3.2**.

7.2.1. Registration Template

TOC

Use Member Value:

The name requested (e.g., "example"). Because a core goal of this specification is for the resulting representations to be compact, it is RECOMMENDED that the name be short -- not to exceed 8 characters without a compelling reason to do so. This name is case-sensitive. Names may not match other registered names in a case-insensitive manner unless the Designated Expert(s) state that there is a compelling reason to allow an exception in this particular case.

Use Description:

Brief description of the use (e.g., "Example description").

Change Controller:

For Standards Track RFCs, state "IESG". For others, give the name of the responsible party. Other details (e.g., postal address, email address, home page URI) may also be included.

Specification Document(s):

Reference to the document(s) that specify the parameter, preferably including URI(s) that can be used to retrieve copies of the document(s). An indication of the relevant sections may also be included but is not required.

7.2.2. Initial Registry Contents

TOC

- Use Member Value: [sig](#)
 - Use Description: Signature or MAC
 - Change Controller: IESG
 - Specification Document(s): **Section 3.2** of [[this document]]
- Use Member Value: [enc](#)
 - Use Description: Encryption
 - Change Controller: IESG
 - Specification Document(s): **Section 3.2** of [[this document]]

7.3. JSON Web Key Operations Registry

This specification establishes the IANA JSON Web Key Operations registry for values of JWK `key_ops` array elements. The registry records the key operation value and a reference to the specification that defines it. This specification registers the parameter names defined in [Section 3.3](#).

7.3.1. Registration Template

Key Operation Value:

The name requested (e.g., "example"). Because a core goal of this specification is for the resulting representations to be compact, it is RECOMMENDED that the name be short -- not to exceed 8 characters without a compelling reason to do so. This name is case-sensitive. Names may not match other registered names in a case-insensitive manner unless the Designated Expert(s) state that there is a compelling reason to allow an exception in this particular case.

Key Operation Description:

Brief description of the key operation (e.g., "Example description").

Change Controller:

For Standards Track RFCs, state "IESG". For others, give the name of the responsible party. Other details (e.g., postal address, email address, home page URI) may also be included.

Specification Document(s):

Reference to the document(s) that specify the parameter, preferably including URI(s) that can be used to retrieve copies of the document(s). An indication of the relevant sections may also be included but is not required.

7.3.2. Initial Registry Contents

- Key Operation Value: `sign`
- Key Operation Description: Compute signature or MAC
- Change Controller: IESG
- Specification Document(s): [Section 3.3](#) of [[this document]]

- Key Operation Value: `verify`
- Key Operation Description: Verify signature or MAC
- Change Controller: IESG
- Specification Document(s): [Section 3.3](#) of [[this document]]

- Key Operation Value: `encrypt`
- Key Operation Description: Encrypt content
- Change Controller: IESG
- Specification Document(s): [Section 3.3](#) of [[this document]]

- Key Operation Value: `decrypt`
- Key Operation Description: Decrypt content and validate decryption, if applicable
- Change Controller: IESG
- Specification Document(s): [Section 3.3](#) of [[this document]]

- Key Operation Value: `wrapKey`
- Key Operation Description: Encrypt key
- Change Controller: IESG
- Specification Document(s): [Section 3.3](#) of [[this document]]

- Key Operation Value: `unwrapKey`
- Key Operation Description: Decrypt key and validate decryption, if applicable
- Change Controller: IESG
- Specification Document(s): [Section 3.3](#) of [[this document]]

- Key Operation Value: [deriveKey](#)
- Key Operation Description: Derive key
- Change Controller: IESG
- Specification Document(s): **Section 3.3** of [[this document]]
- Key Operation Value: [deriveBits](#)
- Key Operation Description: Derive bits not to be used as a key
- Change Controller: IESG
- Specification Document(s): **Section 3.3** of [[this document]]

7.4. JSON Web Key Set Parameters Registry TOC

This specification establishes the IANA JSON Web Key Set Parameters registry for JWK Set parameter names. The registry records the parameter name and a reference to the specification that defines it. This specification registers the parameter names defined in **Section 4**.

7.4.1. Registration Template TOC

Parameter Name:

The name requested (e.g., "example"). Because a core goal of this specification is for the resulting representations to be compact, it is RECOMMENDED that the name be short -- not to exceed 8 characters without a compelling reason to do so. This name is case-sensitive. Names may not match other registered names in a case-insensitive manner unless the Designated Expert(s) state that there is a compelling reason to allow an exception in this particular case.

Parameter Description:

Brief description of the parameter (e.g., "Example description").

Change Controller:

For Standards Track RFCs, state "IESG". For others, give the name of the responsible party. Other details (e.g., postal address, email address, home page URI) may also be included.

Specification Document(s):

Reference to the document(s) that specify the parameter, preferably including URI(s) that can be used to retrieve copies of the document(s). An indication of the relevant sections may also be included but is not required.

7.4.2. Initial Registry Contents TOC

- Parameter Name: [keys](#)
- Parameter Description: Array of JWK values
- Change Controller: IESG
- Specification Document(s): **Section 4.1** of [[this document]]

7.5. Media Type Registration TOC

7.5.1. Registry Contents TOC

This specification registers the [application/jwk+json](#) and [application/jwk-set+json](#) Media Types [**RFC2046**] in the MIME Media Types registry [**IANA.MediaTypes**], which can be used to indicate, respectively, that the content is a JWK or a JWK Set.

- Type Name: [application](#)
- Subtype Name: [jwk+json](#)

- Required Parameters: n/a
 - Optional Parameters: n/a
 - Encoding considerations: 8bit; application/jwk+json values are represented as 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: IESG
-
- Type Name: application
 - Subtype Name: jwk-set+json
 - Required Parameters: n/a
 - Optional Parameters: n/a
 - Encoding considerations: 8bit; application/jwk-set+json 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: IESG

8. 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, but some significant considerations are listed here.

One should place no more trust in the data associated with a key than in the method by which it was obtained and in the trustworthiness of the entity asserting an association with the key. Any data associated with a key that is obtained in an untrusted manner should be treated with skepticism.

Private and symmetric keys MUST be protected from disclosure to unintended parties. One recommended means of doing so is to encrypt JWKS or JWK Sets containing them by using the JWK or JWK Set value as the plaintext of a JWE.

The security considerations in **RFC 3447** [RFC3447] and **RFC 6030** [RFC6030] about protecting private and symmetric keys, key usage, and information leakage also apply to this specification.

The security considerations in **XML DSIG 2.0** [W3C.CR-xmlsig-core2-20120124], about key representations also apply to this specification, other than those that are XML specific.

The TLS Requirements in **[JWS]** also apply to this specification.

9.1. Normative References

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9.2. Informative References

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- [**RFC3447**] Jonsson, J. and B. Kaliski, "[Public-Key Cryptography Standards \(PKCS\) #1: RSA Cryptography Specifications Version 2.1](#)," RFC 3447, February 2003 ([TXT](#)).
- [**RFC5226**] Narten, T. and H. Alvestrand, "[Guidelines for Writing an IANA Considerations Section in RFCs](#)," BCP 26, RFC 5226, May 2008 ([TXT](#)).
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Appendix A. Example JSON Web Key Sets

A.1. Example Public Keys

The following example JWK Set contains two public keys represented as JWKs: one using an Elliptic Curve algorithm and a second one using an RSA algorithm. The first specifies that the key is to be used for encryption. The second specifies that the key is to be used with the RS256 algorithm. Both provide a Key ID for key matching purposes. In both cases, integers

are represented using the base64url encoding of their big endian representations. (Long lines are broken are for display purposes only.)

```
{ "keys":
  [
    { "kty": "EC",
      "crv": "P-256",
      "x": "MKBCTNIcKUSDii11ySs3526iDZ8AiTo7Tu6KPAqv7D4",
      "y": "4Et16SRW2YiLUrN5vfVHUhp7x8Px1tmWW1bbM4IFyM",
      "use": "enc",
      "kid": "1" },

    { "kty": "RSA",
      "n": "0vx7agoebGcQSuuPiLJXZptN9nndrQmbXEps2aiAFbWhM78LhWx
4cbbfAAAtVT86zWu1RK7aPFFxuhDR1L6tSoc_BJECPEbWKRXjBZCiFV4n3oknjhMs
tn64tZ_2W-5JsGY4Hc5n9yBXArwl93lqt7_RN5w6Cf0h4QyQ5v-65YGjQR0_FDW2
QvzqY368QQMicAtaSqzs8KJZgnYb9c7d0zgdAZHzu6qMQvRL5hajrn1n91Cb0pbI
SD08qNLyrdkt-bFTwhAI4vMQFh6WeZu0fM4lFd2NcRwr3XPksINHaQ-G_xBniIqb
w0Ls1jF44-csFCur-kEgU8awapJzKnqDKgw",
      "e": "AQAB",
      "alg": "RS256",
      "kid": "2011-04-29" }
  ]
}
```

A.2. Example Private Keys

TOC

The following example JWK Set contains two keys represented as JWKs containing both public and private key values: one using an Elliptic Curve algorithm and a second one using an RSA algorithm. This example extends the example in the previous section, adding private key values. (Line breaks are for display purposes only.)

```
{ "keys":
  [
    { "kty": "EC",
      "crv": "P-256",
      "x": "MKBCTNIcKUSDii11ySs3526iDZ8AiTo7Tu6KPAqv7D4",
      "y": "4Et16SRW2YiLUrN5vfVHUhp7x8Px1tmWW1bbM4IFyM",
      "d": "870MB6gfU TJ4HtUnUvYMyJpr5eUZNP4Bk43bVdj3eAE",
      "use": "enc",
      "kid": "1" },

    { "kty": "RSA",
      "n": "0vx7agoebGcQSuuPiLJXZptN9nndrQmbXEps2aiAFbWhM78LhWx4
cbbfAAAtVT86zWu1RK7aPFFxuhDR1L6tSoc_BJECPEbWKRXjBZCiFV4n3oknjhMst
n64tZ_2W-5JsGY4Hc5n9yBXArwl93lqt7_RN5w6Cf0h4QyQ5v-65YGjQR0_FDW2Q
vzqY368QQMicAtaSqzs8KJZgnYb9c7d0zgdAZHzu6qMQvRL5hajrn1n91Cb0pbIS
D08qNLyrdkt-bFTwhAI4vMQFh6WeZu0fM4lFd2NcRwr3XPksINHaQ-G_xBniIqbw
0Ls1jF44-csFCur-kEgU8awapJzKnqDKgw",
      "e": "AQAB",
      "d": "X4cTteJY_gn4FYPsXB8rdXix5vwsG1FLN5E3EaG6RJoVH-HLLKD9
M7dx5oo7GURknchnrRweUkC7hT5fJLM0WbFAKNLWY2vv7B6NqXSzUvxT0_YSfqij
wp3RTz1BaCwP4doFk5N2o8Gy_nHNKroADiKJ46pRUohsXywbReAdYaMwFs9tv8d
_cPVY3i07a3t8MN6TNwm0dSawm9v47UiCl3Sk5ZiG7xojPLu4sbg1U2jx4IBTNBz
nbJSzFHK66jT8bgkuqsk0GjskDJk19Z4qwjwsnn4j2WBii3RL-Us2lGVkY8fkFz
me1z0HbIkfz0Y6mqn0Ytqc0X4jfcKoAC8Q",
      "p": "83i-7IvMGXoMXCskv73TKr8637Fi07Z27zv8oj6pbWUQyLPQBQxtPV
nwd20R-60eTDMd2ujnMt5PqMrm8RfmNhVWdtjjMmCMjOpSXicFhj7X0uVIYQyqV
WlWEh6dN36GVZYk93N8Bc9vY41xy8B9Rzz0GVQzXvNEvn700nVbfs",
      "q": "3df0R9cuYq-0S-mkFLzGItgMEffzB2q3hWehMuG0oCuqnb3vobLyum
qjVZQ01dIrdwgTncdpYzBc0fW5r370AFXjiWft_NGEiovonizhKpo9VVS78TzFgx
kIdrecRezsZ-1kYd_s1qDbxtkDEgfAITAG9LUnADun4vIcb6yelxk",
      "dp": "G4sPXkc6Ya9y8oJW9_ILj4xuppu0lzi_H7VTkS8xj5SdX3coE0oim
```

```

YwxIi2emTAue0U0a5dpgFGyBJ4c8tQ2VF402XRugKDTP8akYhFo5tAA77Qe_Nmtu
YZc3C3m3I24G2GvR5sSDxUyAN2zq8Lfn9EUms6rY30b8YeiKkTiBj0",
  "dq": "s9lAH9fggBsoFR80ac2R_E2gw282rT2kG0AhvI1lETE1efrA6huUU
vMfBcMpn8lqew6vzznYY5SSQF7pMdc_agI3nG8Ibp1BUb0JUiraRNqUfLhcQb_d9
GF4Dh7e74WbRsobRonujTYN1xCaP6T061jvWrX-L18txXw494Q_cgk",
  "qi": "GyM_p6JrXySiz1toFgKbWV-JdI3jQ4ypu9rbMWx3rQJBfmt0FoYzg
UIZEVFecOqwemRN81zoDAaa-Bk0KWNdgJHZZDdDmFhw3AN71I-puxk_mHZGJ11rx
yR8055XLSe3SPmRfKwZI6yU24ZxvQKFYItldldUKGz06Ia6zTKhAVRU",
  "alg": "RS256",
  "kid": "2011-04-29"}
]
}

```

A.3. Example Symmetric Keys

TOC

The following example JWK Set contains two symmetric keys represented as JWKs: one designated as being for use with the AES Key Wrap algorithm and a second one that is an HMAC key. (Line breaks are for display purposes only.)

```

{"keys":
  [
    {"kty": "oct",
     "alg": "A128KW",
     "k": "GawggguFyGrWKav7AX4VKUg"},

    {"kty": "oct",
     "k": "AyM1SysPpbyDfgZld3umj1qzK0bwVMkoqQ-EstJQLr_T-1qS0gZH75
akTMN3Yj0iPS4hcgUuTwjAzZr1Z9CAow",
     "kid": "HMAC key used in JWS A.1 example"}
  ]
}

```

Appendix B. Example Use of "x5c" (X.509 Certificate Chain) Parameter

TOC

The following is an example of a JWK with a RSA signing key represented both as an RSA public key and as an X.509 certificate using the `x5c` parameter:

```

{"kty": "RSA",
 "use": "sig",
 "kid": "1b94c",
 "n": "vrj0fz9Ccdgx5nQudyhdoR17V-IubWMe0ZCwX_jj0hgAsz2J_pqYW08
PLbK_PdiVGKPrqzmDIslI7sA25VENHU1uCLNwBuUiC011_-7dYbsr4iJmG0Q
u2j8DsVyT1azpJC_NG84Ty5KKthuCaPod7iI7w0LK9orSMhBEwwZDCxTWq4a
YWAchc8t-emd9q0vWtVMDc2BXksRngh6X5bUYLy6AyHKvj-nUy1wgzjYQDwH
MTplCoLtU-o-8SNnZ1tmRoGE9uJkBLdh5gFENabWnU5m1ZqZPdW-s-qo-meMv
VfJb6jJVWRpl2SutCnYG2C32qvbWbjZ_jBPD5eunqsIo1vQ",
 "e": "AQAB",
 "x5c":
  ["MIIDQjCCAiqqAwIBAgIGATz/FuLiMa0GCSqGSIb3DQEBBQUAMGIXCzAJB
gNVBAYTAlVTMQswCQYDVQQIEwJDTzEPMA0GA1UEBxMGRGVudmVyMRwwGgYD
VQQKEsXNqaW5nIElkZW50aXR5IENvcnAuMRcwFQYDVQQDEw5CcmlhbiBDYW1
wYmVsbDAeFw0xMzAyMjE5MTVaFw0xODA4MTQyMjE5MTVaMGIXCzAJBg
NVBAYTAlVTMQswCQYDVQQIEwJDTzEPMA0GA1UEBxMGRGVudmVyMRwwGgYD
VQQKEsXNqaW5nIElkZW50aXR5IENvcnAuMRcwFQYDVQQDEw5CcmlhbiBDYW1w
YmVsbDCCASiWdQYJKoZIhvcNAQEBBQADggEPADCCAQoCggEBAL64zn8/QnH
YMeZ0Lnc0XaEde1fiLm1jHjmQsF/449IYALM9if6amFtPDy2yvz3Y1Rij66
s5gyLCy07ANuVRJx1NbgizcAblIgjtdf/u3WG7K+IiZhtELto/A7Fck9Ws6
SQvzRv0E8uSirYbgmj6He4i08NCyvaK0jIQRMMGQwsU1quGmFgHIXPLfnpn
fajr1rVTawtgV5LEZ4Iel+W1GC8ugMhyr4/p1MtcIM42EA8BzE6ZQqC7VPq
PvEjZ2dbZkaBhPbiZAS3YeYBRDwm1p10ZtWamT3cEvqqPpnjL1XyW+oyVvK

```

```

aZdk1LQp2Btgt9qr21m42f4wTw+Xrp6rCKNb0CAwEAATANBgkqhkiG9w0BA
QUFAAOCAQEAh8zGlfsLcI0o3rYDPBB07aXNswb4ECNIKG0CETTUmXl9KUL
+9gGlqCz5iWLOgWsnrcKcY0vXPG9J1r9AqBNTqNgHq2G03X09266X5Cp0e1
zFo+Owb1zxtP3PehFdfQJ610CDLEaS9V9Rqp17hCyybEp0GVwe8fnk+fbEL
2Bo3UPGrpsHzUoaGpDftmWssZkhpBJKVMJyf/RuP2SmmaIzmnw9JiSlYhzo
4tpzd5rFXhjRbg4zW9C+2qok+2+qDM1iJ684gPHMIY8aLWrdgQTxkumGmTq
gawR+N5MDtdPTEQ0XfIBc2cJEUyMTY5MPvACWpkA6SdS4xSvdXK3IVfOWA==" ]
}

```

Appendix C. Example Encrypted RSA Private Key

TOC

This example encrypts an RSA private key to the recipient using PBES2-HS256+A128KW for key encryption and A128CBC+HS256 for content encryption.

NOTE: Unless otherwise indicated, all line breaks are included solely for readability.

C.1. Plaintext RSA Private Key

TOC

The following RSA key is the plaintext for the encryption operation, formatted as a JWK object:

```

{
  "kty": "RSA",
  "kid": "juliet@capulet.lit",
  "use": "enc",
  "n": "t6Q8PWSi1dkJj9hTP8hNYFlvadM7DflW9mWep0JhJ66w7nyoK1gPNqFMSQRy
0125Gp-TEkodhWr0iujjHVx7BcV0l1S4w5ACGgPrcAd6ZcSR0-Iqom-QFcNP
8Sjg086MwoqQU_LYywLAGZ21WSdS_PERyGFiNnj3QQl08Yns5jCtLCRWLHL0
Pb1fEv45AuRIuUfVcPySBWYnDyGxvYJGDsm-AqWS9zIQ2ZilgT-GqUmipg0X
0C0Cc20rgLe2ymLHjpHciCKVAbY5-L32-lSeZ0-0s6U15_aXrk9Gw8cPUaX1
_I8sLGuSiVdt3C_Fn2PZ3Z8i744FPFGGcG1qs2Wz-Q",
  "e": "AQAB",
  "d": "GRtbIQmh0ZtyszfgKdg4u_N-R_mZGU_9k7JQ_jn1DnfTuMdsNprTeaSTyWfS
NkuaAwn0EbIQVy1IQbWV25NY3ybc_IhUJtfri7bAXYERewaCl3hd1PKXy9U
vqPYGR0kIXTQRqns-dVJ7jah1I7LyckrpTmrM8dWBo4_PMaenNnPiQg00xnu
ToxutRZJfJvG40x4ka3GORQd9CsCZ2vsUDmsX0fUEN0yMqADC6p1M3h33tsu
rY15k9qMSPg90X_IJAXmxzAh_tWiZowk2K4yxH9tS3Lq1yX8C1EwmeRDkK2a
hecG85-oLKQt5VEpWHKmj0i_gJSdSgqcN96X52esAQ",
  "p": "2rnSOV4hKSN8sS4CgcQHFbs08XboFDqKum3sc4h3GRxrTmQd11ZK9uw-PIHF
QP0FkxXVrx-WE-ZEbrqivH_2iCLUS7wAl6XvArt1KkIaUxPPSYB9yk31s0Q8
UK96E3_OrADAYtAJs-M3JxCLfNgqh56HDnETTQhH3rCT5T3yJws",
  "q": "1u_RiFDP7LBYh3N4GXLT90pSKYP0uQZyiaZwBt0CBNJgQxaj10RWjsZu0c6I
edis4S7B_coSKB0Kj9PaPaBzg-IySRvvcQuPamQu66riMhjVtG6T1V8CLCYK
rY152ziqK0E_ym2QnkwsUX7eYTB7LbAHRK9GqocDE5B0f808I4s",
  "dp": "KkMTWqBUefVwZ2_Dbj1pPQqyHSHjj90L5x_M0zqYAJMcLMZtbUtWkqvVDq3
tbEo3ZiCohbDtt6SbfmWzggabpQxNxuBpo00f_a_HgMXK_lhqigI4y_kqS1w
Y52IwjUn5rgRrJ-yYo1h41KR-vz2pYhEAeYrhttwTxVqLCRviD6c",
  "dq": "AvfS0-gRxvn0bwJoMSnFxCk1WnuEjQFluMGfwGitQBwtfZ1Er7t1xDkbN9
GQTB9yqpDoYaN06H7CFtrkxhJIBQaj6nkF5KKS3TQtQ5qCzk0kmxIe3KRbBy
mXxkb5qwUpX5ELD5xFc6FeiafWYY63TmmEAu_lRFC0J3xDea-ots",
  "qi": "1sQi-w9CpyURemErP1RsBLk7wNtOvs5EQpPqmuMvqW57NBUCzScEoPwmUqq
abu9V0-Py4dQ57_bapoKRu1R90bvFnU63SHWEFglZQvJDMeAvmj4sm-Fp0o
Yu_neotgQ0hzbI5gry7ajdYy9-2lNx_76aBZo0Uu9HCJ-Ufs0I8"
}

```

The octets representing the Plaintext are:

[123, 34, 107, 116, 121, 34, 58, 34, 82, 83, 65, 34, 44, 34, 107, 105, 100, 34, 58, 34, 106, 117, 108, 105, 101, 116, 64, 99, 97, 112, 117, 108, 101, 116, 46, 108, 105, 116, 34, 44, 34, 117, 115, 101, 34, 58, 34, 101, 110, 99, 34, 44, 34, 110, 34, 58, 34, 116, 54, 81, 56, 80, 87, 83, 105, 49, 100, 107, 74, 106, 57, 104, 84, 80, 56, 104, 78, 89, 70, 108, 118, 97, 100, 77, 55,

68, 102, 108, 87, 57, 109, 87, 101, 112, 79, 74, 104, 74, 54, 54, 119, 55, 110, 121, 111, 75, 49, 103, 80, 78, 113, 70, 77, 83, 81, 82, 121, 79, 49, 50, 53, 71, 112, 45, 84, 69, 107, 111, 100, 104, 87, 114, 48, 105, 117, 106, 106, 72, 86, 120, 55, 66, 99, 86, 48, 108, 108, 83, 52, 119, 53, 65, 67, 71, 103, 80, 114, 99, 65, 100, 54, 90, 99, 83, 82, 48, 45, 73, 113, 111, 109, 45, 81, 70, 99, 78, 80, 56, 83, 106, 103, 48, 56, 54, 77, 119, 111, 113, 81, 85, 95, 76, 89, 121, 119, 108, 65, 71, 90, 50, 49, 87, 83, 100, 83, 95, 80, 69, 82, 121, 71, 70, 105, 78, 110, 106, 51, 81, 81, 108, 79, 56, 89, 110, 115, 53, 106, 67, 116, 76, 67, 82, 119, 76, 72, 76, 48, 80, 98, 49, 102, 69, 118, 52, 53, 65, 117, 82, 73, 117, 85, 102, 86, 99, 80, 121, 83, 66, 87, 89, 110, 68, 121, 71, 120, 118, 106, 89, 71, 68, 83, 77, 45, 65, 113, 87, 83, 57, 122, 73, 81, 50, 90, 105, 108, 103, 84, 45, 71, 113, 85, 109, 105, 112, 103, 48, 88, 79, 67, 48, 67, 99, 50, 48, 114, 103, 76, 101, 50, 121, 109, 76, 72, 106, 112, 72, 99, 105, 67, 75, 86, 65, 98, 89, 53, 45, 76, 51, 50, 45, 108, 83, 101, 90, 79, 45, 79, 115, 54, 85, 49, 53, 95, 97, 88, 114, 107, 57, 71, 119, 56, 99, 80, 85, 97, 88, 49, 95, 73, 56, 115, 76, 71, 117, 83, 105, 86, 100, 116, 51, 67, 95, 70, 110, 50, 80, 90, 51, 90, 56, 105, 55, 52, 52, 70, 80, 70, 71, 71, 99, 71, 49, 113, 115, 50, 87, 122, 45, 81, 34, 44, 34, 101, 34, 58, 34, 65, 81, 65, 66, 34, 44, 34, 100, 34, 58, 34, 71, 82, 116, 98, 73, 81, 109, 104, 79, 90, 116, 121, 115, 122, 102, 103, 75, 100, 103, 52, 117, 95, 78, 45, 82, 95, 109, 90, 71, 85, 95, 57, 107, 55, 74, 81, 95, 106, 110, 49, 68, 110, 102, 84, 117, 77, 100, 83, 78, 112, 114, 84, 101, 97, 83, 84, 121, 87, 102, 83, 78, 107, 117, 97, 65, 119, 110, 79, 69, 98, 73, 81, 86, 121, 49, 73, 81, 98, 87, 86, 86, 50, 53, 78, 89, 51, 121, 98, 99, 95, 73, 104, 85, 74, 116, 102, 114, 105, 55, 98, 65, 88, 89, 69, 82, 101, 87, 97, 67, 108, 51, 104, 100, 108, 80, 75, 88, 121, 57, 85, 118, 113, 80, 89, 71, 82, 48, 107, 73, 88, 84, 81, 82, 113, 110, 115, 45, 100, 86, 74, 55, 106, 97, 104, 108, 73, 55, 76, 121, 99, 107, 114, 112, 84, 109, 114, 77, 56, 100, 87, 66, 111, 52, 95, 80, 77, 97, 101, 110, 78, 110, 80, 105, 81, 103, 79, 48, 120, 110, 117, 84, 111, 120, 117, 116, 82, 90, 74, 102, 74, 118, 71, 52, 79, 120, 52, 107, 97, 51, 71, 79, 82, 81, 100, 57, 67, 115, 67, 90, 50, 118, 115, 85, 68, 109, 115, 88, 79, 102, 85, 69, 78, 79, 121, 77, 113, 65, 68, 67, 54, 112, 49, 77, 51, 104, 51, 51, 116, 115, 117, 114, 89, 49, 53, 107, 57, 113, 77, 83, 112, 71, 57, 79, 88, 95, 73, 74, 65, 88, 109, 120, 122, 65, 104, 95, 116, 87, 105, 90, 79, 119, 107, 50, 75, 52, 121, 120, 72, 57, 116, 83, 51, 76, 113, 49, 121, 88, 56, 67, 49, 69, 87, 109, 101, 82, 68, 107, 75, 50, 97, 104, 101, 99, 71, 56, 53, 45, 111, 76, 75, 81, 116, 53, 86, 69, 112, 87, 72, 75, 109, 106, 79, 105, 95, 103, 74, 83, 100, 83, 103, 113, 99, 78, 57, 54, 88, 53, 50, 101, 115, 65, 81, 34, 44, 34, 112, 34, 58, 34, 50, 114, 110, 83, 79, 86, 52, 104, 75, 83, 78, 56, 115, 83, 52, 67, 103, 99, 81, 72, 70, 98, 115, 48, 56, 88, 98, 111, 70, 68, 113, 75, 117, 109, 51, 115, 99, 52, 104, 51, 71, 82, 120, 114, 84, 109, 81, 100, 108, 49, 90, 75, 57, 117, 119, 45, 80, 73, 72, 102, 81, 80, 48, 70, 107, 120, 88, 86, 114, 120, 45, 87, 69, 45, 90, 69, 98, 114, 113, 105, 118, 72, 95, 50, 105, 67, 76, 85, 83, 55, 119, 65, 108, 54, 88, 118, 65, 82, 116, 49, 75, 107, 73, 97, 85, 120, 80, 80, 83, 89, 66, 57, 121, 107, 51, 49, 115, 48, 81, 56, 85, 75, 57, 54, 69, 51, 95, 79, 114, 65, 68, 65, 89, 116, 65, 74, 115, 45, 77, 51, 74, 120, 67, 76, 102, 78, 103, 113, 104, 53, 54, 72, 68, 110, 69, 84, 84, 81, 104, 72, 51, 114, 67, 84, 53, 84, 51, 121, 74, 119, 115, 34, 44, 34, 113, 34, 58, 34, 49, 117, 95, 82, 105, 70, 68, 80, 55, 76, 66, 89, 104, 51, 78, 52, 71, 88, 76, 84, 57, 79, 112, 83, 75, 89, 80, 48, 117, 81, 90, 121, 105, 97, 90, 119, 66, 116, 79, 67, 66, 78, 74, 103, 81, 120, 97, 106, 49, 48, 82, 87, 106, 115, 90, 117, 48, 99, 54, 73, 101, 100, 105, 115, 52, 83, 55, 66, 95, 99, 111, 83, 75, 66, 48, 75, 106, 57, 80, 97, 80, 97, 66, 122, 103, 45, 73, 121, 83, 82, 118, 118, 99, 81, 117, 80, 97, 109, 81, 117, 54, 54, 114, 105, 77, 104, 106, 86, 116, 71, 54, 84, 108, 86, 56, 67, 76, 67, 89, 75, 114, 89, 108, 53, 50, 122, 105, 113, 75, 48, 69, 95, 121, 109, 50, 81, 110, 107, 119, 115, 85, 88, 55, 101, 89, 84, 66, 55, 76, 98, 65, 72, 82, 75, 57, 71, 113, 111, 99, 68, 69, 53, 66, 48, 102, 56, 48, 56, 73, 52, 115, 34, 44, 34, 100, 112, 34, 58, 34, 75, 107, 77, 84, 87, 113, 66, 85, 101, 102, 86, 119, 90, 50, 95, 68, 98, 106, 49, 112, 80, 81, 113, 121, 72, 83, 72, 106, 106, 57, 48, 76, 53, 120, 95, 77, 79, 122, 113, 89, 65, 74, 77, 99, 76, 77, 90, 116, 98, 85, 116, 119, 75, 113, 118, 86, 68, 113, 51, 116, 98, 69, 111, 51, 90, 73, 99, 111, 104, 98, 68, 116, 116, 54, 83, 98, 102, 109, 87, 122, 103, 103, 97, 98, 112, 81, 120, 78, 120, 117, 66, 112, 111, 79, 79, 102, 95, 97, 95, 72, 103, 77, 88, 75, 95, 108, 104, 113, 105, 103, 73, 52, 121, 95, 107, 113, 83, 49, 119, 89, 53, 50, 73, 119, 106, 85, 110, 53, 114, 103, 82, 114, 74, 45, 121, 89, 111, 49, 104, 52, 49, 75, 82, 45, 118, 122, 50, 112, 89, 104, 69, 65, 101, 89, 114, 104, 116, 116, 87, 116, 120, 86, 113, 76, 67, 82, 86, 105, 68, 54, 99, 34, 44, 34, 100, 113, 34, 58, 34, 65, 118, 102, 83, 48, 45, 103, 82, 120, 118, 110, 48, 98, 119, 74, 111, 77, 83, 110, 70, 120, 89, 99, 75, 49, 87, 110, 117, 69, 106, 81, 70, 108, 117, 77, 71, 102, 119, 71, 105, 116, 81, 66, 87, 116, 102, 90, 49, 69, 114, 55, 116, 49, 120, 68, 107, 98, 78, 57, 71, 81, 84, 66, 57, 121, 113, 112, 68, 111, 89, 97, 78, 48, 54, 72, 55, 67, 70, 116, 114, 107, 120, 104, 74, 73, 66, 81, 97, 106, 54, 110, 107, 70, 53, 75, 75, 83, 51, 84, 81, 116, 81, 53, 113, 67, 122, 107, 79, 107, 109, 120, 73, 101, 51, 75, 82, 98, 66, 121, 109, 88, 120, 107, 98, 53, 113, 119, 85, 112, 88, 53, 69, 76, 68, 53, 120, 70, 99, 54, 70, 101, 105, 97, 102, 87, 89, 89, 54, 51, 84, 109, 109, 69, 65, 117, 95, 108, 82, 70, 67, 79, 74, 51, 120, 68, 101, 97, 45, 111, 116, 115, 34, 44, 34, 113, 105, 34, 58, 34, 108, 83, 81, 105, 45, 119, 57, 67, 112, 121, 85, 82, 101, 77, 69, 114, 80, 49, 82, 115, 66, 76, 107, 55, 119, 78, 116, 79, 118, 115, 53, 69, 81, 112, 80, 113, 109, 117, 77, 118, 113, 87, 53, 55, 78, 66, 85, 99, 122, 83, 99, 69, 111, 80, 119, 109, 85, 113, 113, 97, 98, 117, 57, 86, 48, 45, 80, 121, 52, 100, 81, 53, 55, 95, 98, 97, 112, 111, 75, 82, 117, 49, 82, 57, 48, 98, 118, 117, 70, 110, 85, 54, 51, 83, 72, 87, 69, 70, 103, 108, 90, 81, 118, 74, 68, 77,

The Salt value (UTF8(Alg) || 0x00 || Salt Input) is:

[80, 66, 69, 83, 50, 45, 72, 83, 50, 53, 54, 43, 65, 49, 50, 56, 75, 87, 0, 217, 96, 147, 112, 150, 117, 70, 247, 127, 8, 155, 137, 174, 42, 80, 215].

The resulting PBKDF2 Derived Key value is:

[110, 171, 169, 92, 129, 92, 109, 117, 233, 242, 116, 233, 170, 14, 24, 75]

C.5. Key Encryption

TOC

Encrypt the CEK with the `A128KW` algorithm using the PBKDF2 Derived Key. The resulting JWE Encrypted Key value is:

[78, 186, 151, 59, 11, 141, 81, 240, 213, 245, 83, 211, 53, 188, 134, 188, 66, 125, 36, 200, 222, 124, 5, 103, 249, 52, 117, 184, 140, 81, 246, 158, 161, 177, 20, 33, 245, 57, 59, 4]

Encoding this JWE Encrypted Key as `BASE64URL(JWE Encrypted Key)` gives this value:

```
TrqX0wuNUfDV9VPTNbyGvEJ9JMjefAVn-TR1uIxR9p6hsRQh9Tk7BA
```

C.6. Initialization Vector

TOC

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

[97, 239, 99, 214, 171, 54, 216, 57, 145, 72, 7, 93, 34, 31, 149, 156]

Encoding this JWE Initialization Vector as `BASE64URL(JWE Initialization Vector)` gives this value:

```
Ye9j1qs22DmRSAddIh-VnA
```

C.7. Additional Authenticated Data

TOC

Let the Additional Authenticated Data encryption parameter be `ASCII(BASE64URL(UTF8(JWE Protected Header)))`. This value is:

[123, 34, 97, 108, 103, 34, 58, 34, 80, 66, 69, 83, 50, 45, 72, 83, 50, 53, 54, 43, 65, 49, 50, 56, 75, 87, 34, 44, 34, 112, 50, 115, 34, 58, 34, 50, 87, 67, 84, 99, 74, 90, 49, 82, 118, 100, 95, 67, 74, 117, 74, 114, 105, 112, 81, 49, 119, 34, 44, 34, 112, 50, 99, 34, 58, 52, 48, 57, 54, 44, 34, 101, 110, 99, 34, 58, 34, 65, 49, 50, 56, 67, 66, 67, 45, 72, 83, 50, 53, 54, 34, 44, 34, 99, 116, 121, 34, 58, 34, 106, 119, 107, 43, 106, 115, 111, 110, 34, 125]

C.8. Content 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 resulting Ciphertext is:

[3, 8, 65, 242, 92, 107, 148, 168, 197, 159, 77, 139, 25, 97, 42, 131, 110, 199, 225, 56, 61, 127, 38, 64, 108, 91, 247, 167, 150, 98, 112, 122, 99, 235, 132, 50, 28, 46, 56, 170, 169, 89, 220, 145, 38, 157, 148, 224, 66, 140, 8, 169, 146, 117, 222, 54, 242, 28, 31, 11, 129, 227, 226, 169, 66, 117, 133, 254, 140, 216, 115, 203, 131, 60, 60, 47, 233, 132, 121, 13, 35, 188, 53, 19, 172, 77, 59, 54, 211, 158, 172, 25, 60, 111, 0, 80, 201, 158, 160, 210, 68, 55, 12, 67, 136, 130, 87, 216, 197, 95, 62, 20, 155, 205, 5, 140, 27, 168, 221, 65, 114, 78, 157, 254, 46,

206, 182, 52, 135, 87, 239, 3, 34, 186, 126, 220, 151, 17, 33, 237, 57, 96, 172, 183, 58, 45, 248, 103, 241, 142, 136, 7, 53, 16, 173, 181, 7, 93, 92, 252, 1, 53, 212, 242, 8, 255, 11, 239, 181, 24, 148, 136, 111, 24, 161, 244, 23, 106, 69, 157, 215, 243, 189, 240, 166, 169, 249, 72, 38, 201, 99, 223, 173, 229, 9, 222, 82, 79, 157, 176, 248, 85, 239, 121, 163, 1, 31, 48, 98, 206, 61, 249, 104, 216, 201, 227, 105, 48, 194, 193, 10, 36, 160, 159, 241, 166, 84, 54, 188, 211, 243, 242, 40, 46, 45, 193, 193, 160, 169, 101, 201, 1, 73, 47, 105, 142, 88, 28, 42, 132, 26, 61, 58, 63, 142, 243, 77, 26, 179, 153, 166, 46, 203, 208, 49, 55, 229, 34, 178, 4, 109, 180, 204, 204, 115, 1, 103, 193, 5, 91, 215, 214, 195, 1, 110, 208, 53, 144, 36, 105, 12, 54, 25, 129, 101, 15, 183, 150, 250, 147, 115, 227, 58, 250, 5, 128, 232, 63, 15, 14, 19, 141, 124, 253, 142, 137, 189, 135, 26, 44, 240, 27, 88, 132, 105, 127, 6, 71, 37, 41, 124, 187, 165, 140, 34, 200, 123, 80, 228, 24, 231, 176, 132, 171, 138, 145, 152, 116, 224, 50, 141, 51, 147, 91, 186, 7, 246, 106, 217, 148, 244, 227, 244, 45, 220, 121, 165, 224, 148, 181, 17, 181, 128, 197, 101, 237, 11, 169, 229, 149, 199, 78, 56, 15, 14, 190, 91, 216, 222, 247, 213, 74, 40, 8, 96, 20, 168, 119, 96, 26, 24, 52, 37, 82, 127, 57, 176, 147, 118, 59, 7, 224, 33, 117, 72, 155, 29, 82, 26, 215, 189, 140, 119, 28, 152, 118, 93, 222, 194, 192, 148, 115, 83, 253, 216, 212, 108, 88, 83, 175, 172, 220, 97, 79, 110, 42, 223, 170, 161, 34, 164, 144, 193, 76, 122, 92, 160, 41, 178, 175, 6, 35, 96, 113, 96, 158, 90, 129, 101, 26, 45, 70, 180, 189, 230, 15, 5, 247, 150, 209, 94, 171, 26, 13, 142, 212, 129, 1, 176, 5, 0, 112, 203, 174, 185, 119, 76, 233, 189, 54, 172, 189, 245, 223, 253, 205, 12, 88, 9, 126, 157, 225, 90, 40, 229, 191, 63, 30, 160, 224, 69, 3, 140, 109, 70, 89, 37, 213, 245, 194, 210, 180, 188, 63, 210, 139, 221, 2, 144, 200, 20, 177, 216, 29, 227, 242, 106, 12, 135, 142, 139, 144, 82, 225, 162, 171, 176, 108, 99, 6, 43, 193, 161, 116, 234, 216, 1, 242, 21, 124, 162, 98, 205, 124, 193, 38, 12, 242, 90, 101, 76, 204, 184, 124, 58, 180, 16, 240, 26, 76, 195, 250, 212, 191, 185, 191, 97, 198, 186, 73, 225, 75, 14, 90, 123, 121, 172, 101, 50, 160, 221, 141, 253, 205, 126, 77, 9, 87, 198, 110, 104, 182, 141, 120, 51, 25, 232, 3, 32, 80, 6, 156, 8, 18, 4, 135, 221, 142, 25, 135, 2, 129, 132, 115, 227, 74, 141, 28, 119, 11, 141, 117, 134, 198, 62, 150, 254, 97, 75, 197, 251, 99, 89, 204, 224, 226, 67, 83, 175, 89, 0, 81, 29, 38, 207, 89, 140, 255, 197, 177, 164, 128, 62, 116, 224, 180, 109, 169, 28, 2, 59, 176, 130, 252, 44, 178, 81, 24, 181, 176, 75, 44, 61, 91, 12, 37, 21, 255, 83, 130, 197, 16, 231, 60, 217, 56, 131, 118, 168, 202, 58, 52, 84, 124, 162, 185, 174, 162, 226, 242, 112, 68, 246, 202, 16, 208, 52, 154, 58, 129, 80, 102, 33, 171, 6, 186, 177, 14, 195, 88, 136, 6, 0, 155, 28, 100, 162, 207, 162, 222, 117, 248, 170, 208, 114, 87, 31, 57, 176, 33, 57, 83, 253, 12, 168, 110, 194, 59, 22, 86, 48, 227, 196, 22, 176, 218, 122, 149, 21, 249, 195, 178, 174, 250, 20, 34, 120, 60, 139, 201, 99, 40, 18, 177, 17, 54, 54, 6, 3, 222, 128, 160, 88, 11, 27, 0, 81, 192, 36, 41, 169, 146, 8, 47, 64, 136, 28, 64, 209, 67, 135, 202, 20, 234, 182, 91, 204, 146, 195, 187, 0, 72, 77, 11, 111, 152, 204, 252, 177, 212, 89, 33, 50, 132, 184, 44, 183, 186, 19, 250, 69, 176, 201, 102, 140, 14, 143, 212, 212, 160, 123, 208, 185, 27, 155, 68, 77, 133, 198, 2, 126, 155, 215, 22, 91, 30, 217, 176, 172, 244, 156, 174, 143, 75, 90, 21, 102, 1, 160, 59, 253, 188, 88, 57, 185, 197, 83, 24, 22, 180, 174, 47, 207, 52, 1, 141, 146, 119, 233, 68, 228, 224, 228, 193, 248, 155, 202, 90, 7, 213, 88, 33, 108, 107, 14, 86, 8, 120, 250, 58, 142, 35, 164, 238, 221, 219, 35, 123, 88, 199, 192, 143, 104, 83, 17, 166, 243, 247, 11, 166, 67, 68, 204, 132, 23, 110, 103, 228, 14, 55, 122, 88, 57, 180, 178, 237, 52, 130, 214, 245, 102, 123, 67, 73, 175, 1, 127, 112, 148, 94, 132, 164, 197, 153, 217, 87, 25, 89, 93, 63, 22, 66, 166, 90, 251, 101, 10, 145, 66, 17, 124, 36, 255, 165, 226, 97, 16, 86, 112, 154, 88, 105, 253, 56, 209, 229, 122, 103, 51, 24, 228, 190, 3, 236, 48, 182, 121, 176, 140, 128, 117, 87, 251, 224, 37, 23, 248, 21, 218, 85, 251, 136, 84, 147, 143, 144, 46, 155, 183, 251, 89, 86, 23, 26, 237, 100, 167, 32, 130, 173, 237, 89, 55, 110, 70, 142, 127, 65, 230, 208, 109, 69, 19, 253, 84, 130, 130, 193, 92, 58, 108, 150, 42, 136, 249, 234, 86, 241, 182, 19, 117, 246, 26, 181, 92, 101, 155, 44, 103, 235, 173, 30, 140, 90, 29, 183, 190, 77, 53, 206, 127, 5, 87, 8, 187, 184, 92, 4, 157, 22, 18, 105, 251, 39, 88, 182, 181, 103, 148, 233, 6, 63, 70, 188, 7, 101, 216, 127, 77, 31, 12, 233, 7, 147, 106, 30, 150, 77, 145, 13, 205, 48, 56, 245, 220, 89, 252, 127, 51, 180, 36, 31, 55, 18, 214, 230, 254, 217, 197, 65, 247, 27, 215, 117, 247, 108, 157, 121, 11, 63, 150, 195, 83, 6, 134, 242, 41, 24, 105, 204, 5, 63, 192, 14, 159, 113, 72, 140, 128, 51, 215, 80, 215, 39, 149, 94, 79, 128, 34, 5, 129, 82, 83, 121, 187, 37, 146, 27, 32, 177, 167, 71, 9, 195, 30, 199, 196, 205, 252, 207, 69, 8, 120, 27, 190, 51, 43, 75, 249, 234, 167, 116, 206, 203, 199, 43, 108, 87, 48, 155, 140, 228, 210, 85, 25, 161, 96, 67, 8, 205, 64, 39, 75, 88, 44, 238, 227, 16, 0, 100, 93, 129, 18, 4, 149, 50, 68, 72, 99, 35, 111, 254, 27, 102, 175, 108, 233, 87, 181, 44, 169, 18, 139, 79, 208, 14, 202, 192, 5, 162, 222, 231, 149, 24, 211, 49, 120, 101, 39, 206, 87, 147, 204, 200, 251, 104, 115, 5, 127, 117, 195, 79, 151, 18, 224, 52, 0, 245, 4, 85, 255, 103, 217, 0, 116, 198, 80, 91, 167, 192, 154, 199, 197, 149, 237, 51, 2, 131, 30, 226, 95, 105, 48, 68, 135, 208, 144, 120, 176, 145, 157, 8, 171, 80, 94, 61, 92, 92, 220, 157, 13, 138, 51, 23, 185, 124, 31, 77, 1, 87, 241, 43, 239, 55, 122, 86, 210, 48, 208, 204, 112, 144, 80, 147, 106, 219, 47, 253, 31, 134, 176, 16, 135, 219, 95, 17, 129, 83, 236, 125, 136, 112, 86, 228, 252, 71, 129, 218, 174, 156, 236, 12, 27, 159, 11, 138, 252, 253, 207, 31, 115, 214, 118, 239, 203, 16, 211, 205, 99, 22, 51, 163, 107, 162, 246, 199, 67, 127, 34, 108, 197, 53, 117, 58, 199, 3, 190, 74, 70, 190, 65, 235, 175, 97, 157, 215, 252, 189, 245, 100, 229, 248, 46, 90, 126, 237, 4, 159, 128, 58, 7, 156, 236, 69, 191, 85, 240, 179, 224, 249, 152, 49, 195, 223, 60, 78, 186, 157, 155, 217, 58, 105, 116, 164, 217, 111, 215, 150, 218, 252, 84, 86, 248, 140, 240, 226, 61, 106, 208, 95, 60, 163, 6, 0, 235, 253, 162, 96,

62, 234, 251, 249, 35, 21, 7, 211, 233, 86, 50, 33, 203, 67, 248, 60, 190, 123, 48, 167, 226, 90, 191, 71, 56, 183, 165, 17, 85, 76, 238, 140, 211, 168, 53, 223, 194, 4, 97, 149, 156, 120, 137, 76, 33, 229, 243, 194, 208, 198, 202, 139, 28, 114, 46, 224, 92, 254, 83, 100, 134, 158, 92, 70, 78, 61, 62, 138, 24, 173, 216, 66, 198, 70, 254, 47, 59, 193, 53, 6, 139, 19, 153, 253, 28, 199, 122, 160, 27, 67, 234, 209, 227, 139, 4, 50, 7, 178, 183, 89, 252, 32, 128, 137, 55, 52, 29, 89, 12, 111, 42, 181, 51, 170, 132, 132, 207, 170, 228, 254, 178, 213, 0, 136, 175, 8]

The resulting Authentication Tag value is:

[125, 249, 143, 191, 240, 4, 204, 132, 62, 241, 113, 178, 91, 88, 254, 19]

Encoding this JWE Ciphertext as BASE64URL(JWE Ciphertext) gives this value:

```
AwhB81xr1KjFn02LGEWegq27H4Tg9fyZAbFv3p5ZicHpj64QyHC44qq1Z3JEmnZTgQo
wIqZJ13jbyHB8LgePiqUJ1hf6M2HPLgzw8L-mEeQ0jvDUTrE07Nt0erBk8bwBQyZ6g
0kQ3DE0IglfYxv8-FJvNBYwbqN1Bck6d_i70tjSHV-8DIrp-3JcRIe05Yky30i34Z_
G0iAc1EK21B11c_AE11PII_wvvtRiUiG8YofQXakwd1_098Kap-UgmyWPfreUJ31JP
nbD4Ve95owEfMGL0Pflo2MnjaTDCwQokoJ_xplQ2vNPz8iguLcHBoKllyQFJL2m0WB
wqhBo90j-0800as5mmLsvQMTf1IrIEbbTMzHMBZ8EFW9fWwwFu0DWQJGkMnHmBZQ-3
lvqTc-M6-gWA6D8PDh0NfP20ib2HGizwG1iEaX8GRyUpfLuljCLIE1DkGOewhKuKkZ
h04DKNM5Nbugf2atmU90P0Ldx5peCUtRG1gMV17Qup5ZXHTjgPDr5b2N731UooCGAU
qHdgGhg0JVJ_0bCTdjsH4CF1SJsduhrXvYx3HJh2Xd7CwJRzU_3Y1GxYU6-s3GFPbi
rfqqEipJDBTHpcoCmyrwYjYHFgnlqBZRotRrS95g8F95bRXqsaDY7UgQGwBQWby665
d0zpvTasvfXf_c0MWA1-neFaKOW_Px6g4EUDjG1GWSXV9cLStLw_0ovdApDIFLHYHe
PyagyHjouQUuGiQ7BsYwYrwaF06tgB8hV8omLNFMEmpDPJaZUZMuHw6tBDwGkzD-tS_
ub9hxrPJ4Us0Wnt5rGUyoN2N_c1-TQlXxm5oto14MxnoAyBQBpwIEgSH3Y4ZhwKBhH
PjSo0cdwuNdYbGppb-YUvF-2NZzODiQ10vWQBRHSbPWyz_xbGkgD504LRtqRwC07CC
_CyyURi1sEssPVsMJRX_U4LFE0c82TiDdqjK0jRUfKK5rqLi8nBE9soQ0DSa0oFQZi
GrBrqxDsNYiAYAmxxkos-i3nX4qtByVx85sCE5U_0MqG7C0xZWM0PEFrDaepUV-c0y
rvoUIng8i8ljKBKxETY2BgPegKBYCxsAUcAkKamSCC9AiBxA0U0HyhTqt1vMks07AE
hNC2-YzPyx1FkhMoS4LLe6E_pFsMlMjA6P1NSge9C5G5tETYXGAN6b1xZbHtmwrPSc
ro9LWhVmAaA7_bxY0bnFUxgWtK4vzzQBjZJ36UTk40TB-JvKWgfVwCFsaw5WCHj60o
4jp07d2yN7WMfAj2hTEabz9wumQ0TMhBduZ-QON3pY0bSy7TSC1vVme0NjRwF_cJRe
hKTFmdlXGVldPxZCplr7ZQqRQhF8JP-14mEQVnCaWgn90NH1emczGOS-A-wwtnmwjI
B1V_vgJRF4FdpV-4hUk4-QLpu3-1lWFxrtZKcggq3tWTduRo5_QebQbUUT_VSCgsFc
OmyWkoj561bxtHn19hq1XGwbLGfrrR6MWh23vk01zn8FVwi7uFwEnRYSafsnWLa1Z5
TpBj9GvAdl2H9NHwzpB5NqHpZnkQ3NMDj13Fn8fz00JB83Etbm_tnFQfcb13X3bJ15
Cz-Ww1MGhvIpGGnMBT_Adp9xSIyAM9dQ1yeVXk-AIgwBULN5uyWSGyCxp0cJwx7HxM
38z0UIeBu-MytL-eqndM7LxytsVzCbj0TSVRmHYEMIZUANs1gs7uMQAGRdgRIE1TJE
SGMjb_4bZq9s6Ve1LkKSi0_QDsrABaLe55UY0zF4ZSf0V5PMYPt0cwV_dcNP1xLgNA
D1BFX_Z9kAdMzQW6fAmsfFle0zAoMe4l9pMESH0JB4sJGdCKtQXj1cXNydDYozF7l8
H00BV_Er7zd6VtIw0MxwkFCTatsv_R-GsBCH218RgVPsfYhwVuT8R4HarpzsDBufC4
r8_c8fc9Z278sQ081jFj0ja6L2x0N_ImzFNXU6xw0-Ska-QeuvYZ3X_L31ZOX4Llp-
7QSfgDoHn0xFv1Xws-D5mDHD3zx0up2b2TppdKTZb9eW2vxUVviM80I9atBfPKMGA0
v9omA-6vv5IxUH0-lWmiHLQ_g8vnsWP-Jav0c4t6URVUzujN0oNd_CBGgVnHiJTCH1
88LQxsqlHHIu4Fz-U2SGnlxGTj0-ihit2ELGRv4v08E1BosTmf0cx3qgG0Pq0e0LBD
IHSrdZ_CCAiTC0HVkMbyq1M6qEHM-q5P6y1QCIrwg
```

Encoding this JWE Authentication Tag as BASE64URL(JWE Authentication Tag) gives this value:

```
ffmPv_AEzIQ-8XGyW1j-Ew
```

C.9. Complete Representation

TOC

Assemble the final representation: The Compact Serialization of this result is the string
BASE64URL(UTF8(JWE Protected Header)) || '.' || BASE64URL(JWE Encrypted Key) || '.' ||
BASE64URL(JWE Initialization Vector) || '.' || BASE64URL(JWE Ciphertext) || '.' ||
BASE64URL(JWE Authentication Tag).

The final result in this example is:

eyJhbGciOiJQVkVMTi1IuzI1NitBMTI4S1ciLCJwMnMiOiIyV0NUY0paMVJ2ZF9DSn
VKcmlwUTF3IiwicDjIjo0MDk2L2JlbnMiOiJBMTI4Q0JDLUhmTjU2IiwieY3R5Ijo1
andrK2pzb24ifQ.
TrqX0WuNUFDV9VPTNbyGvEJ9JMjefAVn-TR1uIxR9p6hsRQh9Tk7BA.
Ye9j1qs22DmRSAddIh-VnA.
AwhB81xrlKjFn02LGEqg27H4Tg9fyZAbFv3p5ZicHpj64QyHC44qq1Z3JEmnZTgQo
wIQZJ13jbyHB8LgePiqUJ1hf6M2HPLgzW8L-mEeQ0jvDUTrE07NtOerBk8bwBQyZ6g
0kQ3DE0IglfYxv8-FJvNBYwbqN1Bck6d_i70tjSHV-8DIrp-3JcRIe05YKy30i34Z_
G0iAc1EK21B11c_AE11PII_wvvtRiUiG8YofQXakWd1_098Kap-UgmyWPfreUJ31JP
nbD4Ve95owEfMGLOPflo2MnjaTDCwQokoJ_xplQ2vNPz8iguLcHBoKllyQFJL2m0WB
wqhBo90j-0800as5mmLsvQMTf1rIEbbTMzHMBZ8EFW9fWwFu0DWQJGkMNhMBZQ-3
lvqTc-M6-gWA6D8PDh0NfP20ib2HGizwG1iEaX8GRyUpfLuljCLIE1DkGOewhKuKkZ
h04DKNM5Nbugf2atmU90P0Ldx5peCUtRG1gMV17Qup5ZXHTjgPDr5b2N731UooCGAU
qHdgGhg0JVJ_0bCTdjsH4CF1SJsduhrXvYx3HJh2Xd7CwJRzU_3Y1GxYU6-s3GFPbi
rfqqEipJDBTHpcoCmyrwYjYHFgnlqBZRotRrS95g8F95bRXqsaDY7UgQGwBQBwy665
d0zpvTasvxf_c0MWA1-neFaKOW_Px6g4EUDjG1GWSXV9cLStLw_0ovdApDIFLHYHe
PyagyHjouQUuGiQ7BsYwYrwaF06tgB8hV8omLNFMEmpJaZuzMuHw6tBDwGkzD-ts_
ub9hxrPJ4Us0Wnt5rGUyoN2N_c1-TQLXxm5oto14MxnoAyBQBpwIEgSH3Y4ZhwKBhH
PjSo0cdwuNdYbGppb-YUvF-2NZzODiQ10vWQBRHSbPWYz_xbGkgD504LRtqrWc07CC
_CyyURI1sEssPVsMJRX_U4LFE0c82TiDdqjK0jRufKK5rqLi8nBE9soQ0DSa0oFQZi
GrBrqxDsNYiAYAmxxkos-i3nX4qtByVx85sCE5U_0MqG7C0xZWMOPeFrDaepUV-c0y
rvoUIng8i8ljKBKxETY2BgPegKBYCxsAUcAkKamSCC9AiBxA0U0HyhTqt1vMks07AE
hNC2-YzPyx1FkhMoS4LLe6E_pFsMlMjA6P1NSge9C5G5tETYXGAn6b1xZbHtmwrPSc
ro9LWhVmAaA7_bxY0bnFUxgWtK4vzzQBjZJ36UtK40TB-JvKwgfVWCFsaw5Wchwj60o
4jp07d2yN7WMfAj2hTEabz9wumQ0TMhBduZ-QON3pY0bSy7TSC1vVme0NjRwF_cJRe
hKTFmdlXGVldPxZCplr7ZQqRQhF8JP-14mEQVnCaWgn90NHlenczGOS-A-wwtnmwjI
B1V_vgJRF4FdpV-4hUk4-QLpu3-1lWFxrtZKcggq3tWtduRo5_QebQbUUT_VSCgsFc
OmyWkoj561bXtHn19hq1XGwbLGfrrR6MWh23vk01zn8FVwi7uFwEnRYSafsnWLa1Z5
TpBj9GvAd12H9NHwzPB5NqHpZnkQ3NMDj13Fn8fz00JB83Etbm_tnFQfcb13X3bJ15
Cz-ww1MGhvIpGGnMBT_ADp9xSIyAM9dQ1yeVXk-AIgwBUlN5uyWSGyCxp0cJwx7HxM
38z0UIeBu-MytL-eqndM7LxytsVzCbjoTSVRmhYEMIZUANs1gs7uMQAGRdgrIE1TJE
SGMjb_4bZq9s6Ve1LkKSi0_QDsRABaLe55UY0zF4ZSf0V5PMYPt0cW_dcNP1xLgNA
D1BFX_Z9kAdMZQW6fAmsfFle0zAoMe4l9pMESH0JB4sJGdCKtQXj1cXNydyozF7l8
H00BV_Er7zd6VtIw0MxwkFCTatsv_R-GsBCH218RgVPsfYhwVuT8R4HarpzsDBufC4
r8_c8fc9Z278sQ081jFj0ja6L2x0N_ImzFNXU6xw0-Ska-QeuvYZ3X_L31ZOX4Llp-
7QSfgDoHn0xVf1Xws-D5mDHD3zx0up2b2TppdKTZb9eW2vxUVviM80I9atBfPKMGAO
v9omA-6vv5IxUH0-lWmiHLQ_g8vnsWp-Jav0c4t6URVUzujN0oNd_CBGgVnHiJTCH1
88LQxsqLHHIu4Fz-U2SGnlxGTj0-ihit2ELGRv4v08E1BosTmf0cx3qgG0Pq0e0LBD
IHsrDZ_CCAiTC0HVkMbyq1M6qEhM-q5P6y1QCIrwg.
ffmPv_AEzIQ-8XGyW1j-Ew

Appendix D. Acknowledgements

TOC

A JSON representation for RSA public keys was previously introduced by John Panzer, Ben Laurie, and Dirk Balfanz in **Magic Signatures** [MagicSignatures].

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:

Dirk Balfanz, Richard Barnes, John Bradley, Brian Campbell, Breno de Medeiros, Joe Hildebrand, Edmund Jay, Ben Laurie, James Manger, Matt Miller, Tony Nadalin, Axel Nennker, John Panzer, Eric Rescorla, Nat Sakimura, Jim Schaad, Paul Tarjan, 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]]

-21

- Replaced the `key_ops` values `wrap` and `unwrap` with `wrapKey` and `unwrapKey` to match the `KeyUsage` values defined in the current **Web Cryptography API** [WebCrypto] editor's draft.
- Compute the PBES2 salt parameter as (UTF8(Alg) || 0x00 || Salt Input), where the `p2s` Header Parameter encodes the Salt Input value and `alg` is the `alg` Header Parameter value.
- Changed some references from being normative to informative, addressing issue #90.

-20

- Renamed `use_details` to `key_ops` (key operations).
- Clarified that `use` is meant for public key use cases, `key_ops` is meant for use cases in which public, private, or symmetric keys may be present, and that `use` and `key_ops` should not be used together.
- Replaced references to RFC 4627 with draft-ietf-json-rfc4627bis, addressing issue #90.

-19

- Added optional `use_details` (key use details) JWK member.
- Reordered the key selection parameters.

-18

- Changes to address editorial and minor issues #68, #69, #73, #74, #76, #77, #78, #79, #82, #85, #89, and #135.
- Added and used Description registry fields.

-17

- Refined the `typ` and `cty` definitions to always be MIME Media Types, with the omission of "application/" prefixes recommended for brevity, addressing issue #50.
- Added an example encrypting an RSA private key with `PBES2-HS256+A128KW` and `A128CBC-HS256`. Thanks to Matt Miller for producing this!
- Processing rules occurring in both JWS and JWK are now referenced in JWS by JWK, rather than duplicated, addressing issue #57.
- Terms used in multiple documents are now defined in one place and incorporated by reference. Some lightly used or obvious terms were also removed. This addresses issue #58.

-16

- Changes to address editorial and minor issues #41, #42, #43, #47, #51, #67, #71, #76, #80, #83, #84, #85, #86, #87, and #88.

-15

- Changes to address editorial issues #48, #64, #65, #66, and #91.

-14

- Relaxed language introducing key parameters since some parameters are applicable to multiple, but not all, key types.

-13

- Applied spelling and grammar corrections.

-12

- Stated that recipients **MUST** either reject JWKs and JWK Sets with duplicate member names or use a JSON parser that returns only the lexically last duplicate member name.

-11

- Stated that when `kid` values are used within a JWK Set, different keys within the JWK Set SHOULD use distinct `kid` values.
- Added optional `x5u` (X.509 URL), `x5t` (X.509 Certificate Thumbprint), and `x5c` (X.509 Certificate Chain) JWK parameters.
- Added section on Encrypted JWK and Encrypted JWK Set Formats.
- Added a Parameter Information Class value to the JSON Web Key Parameters registry, which registers whether the parameter conveys public or private information.
- Registered `application/jwk+json` and `application/jwk-set+json` MIME types and `JWK` and `JWK-SET` typ header parameter values, addressing issue #21.

-10

- No changes were made, other than to the version number and date.

-09

- Expanded the scope of the JWK specification to include private and symmetric key representations, as specified by draft-jones-jose-json-private-and-symmetric-key-00.
- Defined that members that are not understood must be ignored.

-08

- Changed the name of the JWK key type parameter from `alg` to `kt` to enable use of `alg` to indicate the particular algorithm that the key is intended to be used with.
- Clarified statements of the form "This member is OPTIONAL" to "Use of this member is OPTIONAL".
- Referenced String Comparison Rules in JWS.
- Added seriesInfo information to Internet Draft references.

-07

- Changed the name of the JWK RSA modulus parameter from `mod` to `n` and the name of the JWK RSA exponent parameter from `xpo` to `e`, so that the identifiers are the same as those used in RFC 3447.

-06

- Changed the name of the JWK RSA exponent parameter from `exp` to `xpo` so as to allow the potential use of the name `exp` for a future extension that might define an expiration parameter for keys. (The `exp` name is already used for this purpose in the JWT specification.)
- Clarify that the `alg` (algorithm family) member is REQUIRED.
- Correct an instance of "JWK" that should have been "JWK Set".
- Applied changes made by the RFC Editor to RFC 6749's registry language to this specification.

-05

- 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 DSIG 2.0** [W3C.CR-xmlsig-core2-20120124] for its security considerations.
- Added this language to Registration Templates: "This name is case sensitive. Names that match other registered names in a case insensitive manner SHOULD NOT be accepted."
- Described additional open issues.
- Applied editorial suggestions.

-03

- Clarified that `kid` values need not be unique within a JWK Set.
- Moved JSON Web Key Parameters registry to the JWK specification.
- Added "Collision Resistant Namespace" to the terminology section.
- Changed registration requirements from RFC Required to Specification Required with Expert Review.
- Added Registration Template sections for defined registries.
- Added Registry Contents sections to populate registry values.
- Numerous editorial improvements.

-02

- 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 top-level member name for a set of keys was changed from `jwk` to `keys`.
- Clarified that values with duplicate member names MUST be rejected.
- Established JSON Web Key Set Parameters registry.
- Explicitly listed non-goals in the introduction.
- Moved algorithm-specific definitions from JWK to JWA.
- Reformatted to give each member definition its own section heading.

-01

- Corrected the Magic Signatures reference.

-00

- Created the initial IETF draft based upon draft-jones-json-web-key-03 with no normative changes.

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TOC

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