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JSON Web Key (JWK) draft-ietf-jose-json-web-key-15

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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1. Introduction

TOC

A JSON Web Key (JWK) is a JavaScript Object Notation (JSON) **[RFC4627]** 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

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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]**.

2. Terminology

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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.

Base64url Encoding

Base64 encoding using the URL- and filename-safe character set defined in Section 5 of **RFC 4648** [RFC4648], with all trailing '=' characters omitted (as permitted by Section 3.2). (See Appendix C of **[JWS]** for notes on implementing

base64url encoding without padding.)

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. 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.

3. JSON Web Key (JWK) Format TOC

A JSON Web Key (JWK) is a JSON object containing specific members, as specified below. Those members that are common to multiple key types are defined below.

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 5 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 **MAY** 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 kinds of keys need not be distinct. Any new member name **SHOULD** either be registered in the IANA JSON Web Key Parameters registry [Section 7.1](#) or be a value that contains a Collision Resistant Namespace.

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 [\[JWA\]](#) or be a value that contains a Collision Resistant Namespace. The `kty` value is a case sensitive string. Use of this member is **REQUIRED**.

A list of defined `kty` values can be found in the IANA JSON Web Key Types registry [\[JWA\]](#); the initial contents of this registry are the values defined in Section 5.1 of the JSON Web Algorithms (JWA) [\[JWA\]](#) specification.

Additional members used with these `kty` values can be found in the IANA JSON Web Key Parameters registry [Section 7.1](#); the initial contents of this registry are the values defined in Sections 5.2 and 5.3 of the JSON Web Algorithms (JWA) [\[JWA\]](#) specification.

3.2. "use" (Key Use) Parameter TOC

The `use` (key use) member identifies the intended use of the key. Values defined by this specification are:

- `sig` (signature or MAC operation)
- `enc` (encryption)

Other values **MAY** be used. The `use` value is a case sensitive string. Use of this member is **OPTIONAL**.

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3.3. "alg" (Algorithm) Parameter

[TOC](#)

The `alg` (algorithm) member identifies the algorithm intended for use with the key. The values used in this field are the same as those used in the JWS `[JWS]` and JWE `[JWE]` `alg` and `enc` header parameters; these values can be found in the JSON Web Signature and Encryption Algorithms registry `[JWA]`. Use of this member is OPTIONAL.

3.4. "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 interpretation 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. The `kid` value is a case sensitive string. Use of this member is OPTIONAL.

When used with JWS or JWE, the `kid` value can be used to match a JWS or JWE `kid` header parameter value.

3.5. "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 bare 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.

3.6. "x5t" (X.509 Certificate Thumbprint) Parameter

[TOC](#)

The `x5t` (X.509 Certificate 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 bare public key represented by other members of the JWK. Use of this member is OPTIONAL.

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 bare public key represented by other members of the JWK. Use of this member is OPTIONAL.

4. JSON Web Key Set (JWK Set) Format

[TOC](#)

A JSON Web Key Set (JWK Set) is a JSON object that contains an array of JSON Web Key values as the value of its `keys` member.

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 MAY 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 **Section 7.2** or be a value that contains a Collision Resistant Namespace.

4.1. "keys" (JSON Web Key Set) Parameter TOC

The value of the `keys` (JSON Web Key Set) member is an array of JSON Web Key (JWK) values. Use of this member is REQUIRED.

5. String Comparison Rules TOC

Processing a JWK inevitably requires comparing known strings to values in JSON objects. For example, in checking what the key type is, the Unicode string encoding `key` will be checked against the member names in the JWK to see if there is a matching 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. 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 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 `cty` (content type) header parameter value of `JWK` can be used to indicate that the content of the JWE is a JWK in contexts where this is useful.

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 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 `JWK-SET` can be used to indicate that the content of the JWE is a JWK Set in contexts where this is useful.

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 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.

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

7.1. JSON Web Key Parameters Registry

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This specification establishes the IANA JSON Web Key Parameters registry for reserved JWK parameter names. The registry records the reserved parameter name 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 algorithm-specific JWK parameters; in this case, the meaning of the duplicate parameter name is disambiguated by the `key` value of the JWK containing it.

7.1.1. Registration Template

TOC

Parameter Name:

The name requested (e.g., "example"). This name is case sensitive. Names that match other registered names in a case insensitive manner SHOULD NOT be accepted.

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 "IETF". 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 Information Class: Public
- Change Controller: IETF
- Specification Document(s): **Section 3.1** of [[this document]]

- Parameter Name: `use`
- Parameter Information Class: Public
- Change Controller: IETF
- Specification Document(s): **Section 3.2** of [[this document]]

- Parameter Name: `alg`
- Parameter Information Class: Public
- Change Controller: IETF
- Specification Document(s): **Section 3.3** of [[this document]]

- Parameter Name: `kid`
- Parameter Information Class: Public
- Change Controller: IETF
- Specification Document(s): **Section 3.4** of [[this document]]

- Parameter Name: `x5u`
- Parameter Information Class: Public
- Change Controller: IETF
- Specification Document(s): **Section 3.5** of [[this document]]

- Parameter Name: `x5t`

- Parameter Information Class: Public
- Change Controller: IETF
- Specification Document(s): **Section 3.6** of [[this document]]
- Parameter Name: [x5c](#)
- Parameter Information Class: Public
- Change Controller: IETF
- Specification Document(s): **Section 3.7** of [[this document]]

7.2. JSON Web Key Set Parameters Registry TOC

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

7.2.1. Registration Template TOC

Parameter Name:

The name requested (e.g., "example"). This name is case sensitive. Names that match other registered names in a case insensitive manner SHOULD NOT be accepted.

Change Controller:

For Standards Track RFCs, state "IETF". 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

- Parameter Name: [keys](#)
- Change Controller: IETF
- Specification Document(s): **Section 4.1** of [[this document]]

7.3. JSON Web Signature and Encryption Type Values Registration TOC

7.3.1. Registry Contents TOC

This specification registers the [JWK](#) and [JWK-SET](#) type values in the IANA JSON Web Signature and Encryption Type Values registry [[JWS](#)], which can be used to indicate, respectively, that the content is a JWK or a JWK Set.

- "typ" Header Parameter Value: [JWK](#)
- Abbreviation for MIME Type: application/jwk+json
- Change Controller: IETF
- Specification Document(s): **Section 3** of [[this document]]
- "typ" Header Parameter Value: [JWK-SET](#)
- Abbreviation for MIME Type: application/jwk-set+json
- Change Controller: IETF
- Specification Document(s): **Section 4** of [[this document]]

7.4.1. Registry Contents

This specification registers the `application/jwk+json` and `application/jwk-set+json` Media Types **[RFC2046]** in the MIME Media Type registry **[RFC4288]**, 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: 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: IETF
-
- Type Name: application
 - Subtype Name: jwk-set+json
 - Required Parameters: n/a
 - Optional Parameters: n/a
 - Encoding considerations: 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: IETF

8. Security Considerations

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.

A key is no more trustworthy than the method by which it was received.

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 also apply to this specification.

The security considerations in **XML DSIG 2.0** [W3C.CR-xmldsig-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. References

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9.1. Normative References

TOC

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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](#)).
- [RFC4122]** [Leach, P.](#), [Mealling, M.](#), and [R. Salz](#), "[A Universally Unique Identifier \(UUID\) URN Namespace](#)," RFC 4122, July 2005 ([TXT](#), [HTML](#), [XML](#)).
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Appendix A. Example JSON Web Key Sets

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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": "0vx7agoebGcQSuuPiLJXZptN9nndrQmbXEps2aiAFbWhM78Lhwx4cbbfAAAtVT86zWu1RK7aPFFxuhDR1L6tSoc_BJECPEbWKRXjBZCiFV4n3oknjhMstn64tZ_2W-5JsGY4Hc5n9yBXArwl93lqt7_RN5w6Cf0h4QyQ5v-65YGjQR0_FDW2QvzqY368QQMicAtaSqzs8KJZgnYb9c7d0zgdAZHzu6qMQvRL5hajrn1n91Cb0pbISD08qNLyrdkt-bFTwhAI4vMQFh6WeZu0fM4lFd2NcRwr3XPksINHaQ-G_xBniIqbw0Ls1jF44-csFCur-kEgU8awapJzKnqDKgw",
      "e": "AQAB",
      "alg": "RS256",
      "kid": "2011-04-29"
    }
  ]
}
```

A.2. Example Private Keys

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": "870MB6gfuTJ4HtUnUvYMyJpr5eUZNP4Bk43bVdj3eAE",
      "use": "enc",
      "kid": "1"
    },
    {
      "kty": "RSA",
      "n": "0vx7agoebGcQSuuPiLJXZptN9nndrQmbXEps2aiAFbWhM78Lhwx4cbbfAAAtVT86zWu1RK7aPFFxuhDR1L6tSoc_BJECPEbWKRXjBZCiFV4n3oknjhMstn64tZ_2W-5JsGY4Hc5n9yBXArwl93lqt7_RN5w6Cf0h4QyQ5v-65YGjQR0_FDW2QvzqY368QQMicAtaSqzs8KJZgnYb9c7d0zgdAZHzu6qMQvRL5hajrn1n91Cb0pbISD08qNLyrdkt-bFTwhAI4vMQFh6WeZu0fM4lFd2NcRwr3XPksINHaQ-G_xBniIqbw0Ls1jF44-csFCur-kEgU8awapJzKnqDKgw",
      "e": "AQAB",
      "d": "X4cTteJY_gn4FYPsXB8rdXix5vwsg1FLN5E3EaG6RJoVH-HLLKD9M7dx5oo7GURknchnrRweUkC7hT5fJLM0WbFAKNLWY2vv7B6NqXSzUvxT0_YSfqijwp3RTz1BaCwP4doFk5N2o8Gy_nHNKroADiKj46pRUohsXywbReAdYaMwFs9tv8d"
    }
  ]
}
```

```

_cPVY3i07a3t8MN6TNwm0dSawm9v47UiCl3Sk5ZiG7xojPLu4sbg1U2jx4IBTNBz
nbJSzFHK66jT8bgkuqsk0GjskDJK19Z4qwjwbsnn4j2WBii3RL-Us2lGVkY8fkFz
me1z0HbIkfz0Y6mqn0Ytqc0X4jfcKoAC8Q",
  "p": "83i-7IvMGXoMXCskv73TKr8637Fi07Z27zv8oj6pbWUQyLPQBQxtPV
nwd20R-60eTDmD2ujnMt5PoqMrm8RfmNhVWDtjjMmCMjOpSXicFHj7X0uVIYQyqV
WlWEh6dN36GVZYk93N8Bc9vY41xy8B9Rzz0GVQzXvNEvn700nVbfs",
  "q": "3dfOR9cuYq-0S-mkFLzgItgMEffzB2q3hWehMuG0oCuqnb3vobLyum
qjVZQ01dIrdwgTnCdpYzBcOfw5r370AFXjiWft_NGEiovonizhKpo9VVS78TzFgx
kIdrecRezsZ-1kYd_s1qDbxtkDEgfAITAG9LUnADun4vIcb6yelxk",
  "dp": "G4sPXkc6Ya9y8oJW9_ILj4xuppu0lzi_H7VTkS8xj5SdX3coE0oim
YwxIi2emTAue0U0a5dpgFGyBJ4c8tQ2VF402XRugKDTP8akYhFo5tAA77Qe_Nmtu
YZc3C3m3I24G2GvR5sSDxUyAN2zq8Lfn9EUms6rY30b8YeiKkTiBj0",
  "dq": "s9lAH9fggBsoFR80ac2R_E2gw282rT2kG0AhvIlLETE1efrA6huUU
vMfBcMpn8lqeW6vzznYY5SSQF7pMdC_agI3nG8Ibp1BUb0JUiraRNqUfLhcQb_d9
GF4Dh7e74WbRsobRonujTYN1xCaP6T061jvWrX-L18txXw494Q_cgk",
  "qi": "GyM_p6JrXySiz1toFgKbWV-JdI3jQ4ypu9rbMMwx3rQJBfmt0FoYzg
UIZEVFec0qwemRN81zoDAaa-Bk0KWNdGjJHZZdDmFhw3AN7lI-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 a bare public key and as an X.509 certificate using the `x5c` parameter:

```

{"kty": "RSA",
 "use": "sig",
 "kid": "1b94c",
 "n": "vrj0fz9Ccdgx5nQudyhdoR17V-IubWMe0ZCWx_jj0hgAsz2J_pqYW08
PLbK_PdiVGKPrqzmDI7sA25VEnHU1uCLNwBuUiC011_-7dYbsr4iJmG0Q
u2j8DsVyT1azpJC_NG84Ty5KKthuCaPod7iI7w0LK9orSMhBEwwZDCxTWq4a
YWAchc8t-emd9q0vWtVMDC2BXksRngh6X5bUYLy6AyHKvj-nUy1wgzjYQDwH
MTp1CoLtU-o-8SNnZ1tmRoGE9uJkBLdh5gFENabWnU5m1ZqZPdW-s-qo-meMv
VfJb6jJVWRp12SutCnYG2C32qvbWbjZ_jBPD5eunqsIo1vQ",
 "e": "AQAB",
 "x5c":
  ["MIIDQjCCAiqqAwIBAgIGATz/FuLiMA0GCSqGSIb3DQEBBQUAMGIXCzAJB
gNVBAYTAlVTMQswCQYDVQQIEwJDTzEPMA0GA1UEBxMGRGVudmVYMRwwGgYD

```

```
VQKExNQaw5nIElkZW50aXR5IENvcnAuMRcwFQYDVQDEw5Ccm1hbiBDYW1wYmVsbDAeFw0xMzAyMjEyMzI5MTVaFw0xODA4MTQyMjI5MTVaMGIXCzAJBgNVBAYTA1VTRQswCQYDVQIQIEdwJDTzEPMA0GA1UEBxMGRGVudmVyMRwwGgYDVQKExNQaw5nIElkZW50aXR5IENvcnAuMRcwFQYDVQDEw5Ccm1hbiBDYW1wYmVsbDCCASIwDQYJKoZIhvcNAQEBBQADggEPADCCAQoCggEBAL64zn8/QnHYMeZ0Lnc0XaEde1fiLm1jHjmQsF/449IYALM9if6amFtPDy2yvz3YlRij66s5gyLCy07ANuVRJx1NbgizcAblIgjtdf/u3WG7K+IiZhtELto/A7Fck9Ws6SQvzRv0E8uSirYbgmj6He4i08NCyvaK0jIQRMMGQwsU1quGmFgHIXPLfnpnfajr1rVTAwtgV5LEZ4Ie1+W1GC8ugMhyr4/p1MtcIM42EA8BzE6ZQqC7VPqPvEjZ2dbZkaBhPbiZAS3YeYBRDwm1p10ZtWamT3cEvqqPpnjL1XyW+oyVVkaZdklLQp2Btgt9qr21m42f4wTw+Xrp6rCKNb0CAwEAATANBgkqhkiG9w0BAQUFAAOCAQEAh8zGlfSlcI0o3rYDPBB07aXNswb4ECNIKG0CETTUXmXl9KUL+9gGlqCz5iWL0gWsnrcKcY0vXPG9J1r9AqBNTqNgHq2G03X09266X5Cp0e1zFo+0wb1zxtP3PehFdfQJ610CDLEaS9V9Rqp17hCyybEp0GVve8fnk+fbEL2Bo3UPGrpsHzUoaGpDftmWssZkhpBJKVMJyf/RuP2SmmaIzmnw9JiSlYhzo4tpzd5rFXhjRbg4zW9C+2qok+2+qDM1iJ684gPHMIY8aLWrdgQTxkumGmTqgawR+N5MDtdPTEQ0XfIBc2cJEUyMTY5MPvACWpkA6SdS4xSvdXK3IVfOWA==" ]
```

}

Appendix C. 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 D. Document History

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

-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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