JOSE Working Group	M. Jones
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JSON Web Key (JWK)
draft-ietf-jose-json-web-key-14

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.

Status of this Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on January 30, 2014.

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1. Introduction

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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.

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.

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]**.

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

Collision Resistant Namespace
: A namespace that allows names to be allocated in a manner such that they are highly unlikely to collide with other names. For instance, collision resistance can be

achieved through administrative delegation of portions of the namespace or through use of collision-resistant name allocation functions. Examples of Collision Resistant Namespaces include: Domain Names, Object Identifiers (OIDs) as defined in the ITU-T X.660 and X.670 Recommendation series, and Universally Unique IDentifiers (UUIDs) **[RFC4122]**. When using an administratively delegated namespace, the definer of a name needs to take reasonable precautions to ensure they are in control of the portion of the namespace they use to define the name.

Encrypted JWK
: A JWE with a JWK as its plaintext value.

Encrypted JWK Set
: A JWE with a JWK Set as its plaintext value.

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3. JSON Web Key (JWK) Format

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.

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3.1. "kty" (Key Type) Parameter

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.

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3.2. "use" (Key Use) Parameter

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.

3.3. "alg" (Algorithm) Parameter

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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

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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) Header Parameter

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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) Header Parameter

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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

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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

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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 ECMAScript 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

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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.

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5. String Comparison Rules

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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 `kty` 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]**.

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6. Encrypted JWK and Encrypted JWK Set Formats

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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 RECOMMENED 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 RECOMMENED 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.

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7. IANA Considerations

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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 `kty` value of the JWK containing it.

7.1.1. Registration Template

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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 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

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- Parameter Name: `kty`
- 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]]

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7.2. JSON Web Key Set Parameters Registry

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**.

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7.2.1. Registration Template

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.

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7.2.2. Initial Registry Contents

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

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7.3. JSON Web Signature and Encryption Type Values Registration

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7.3.1. Registry Contents

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. Media Type Registration

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7.4.1. Registry Contents

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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

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8. Security Considerations

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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

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9.2. Informative References

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Appendix A. Example JSON Web Key Sets

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A.1. Example Public Keys

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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":"4Etl6SRW2YiLUrN5vfvVHuhp7x8PxltmWWlbbM4IFyM",
     "use":"enc",
     "kid":"1"},

    {"kty":"RSA",
     "n": "0vx7agoebGcQSuuPiLJXZptN9nndrQmbXEps2aiAFbWhM78LhWx
4cbbfAAtVT86zwu1RK7aPFFxuhDR1L6tSoc_BJECPebWKRXjBZCiFV4n3oknjhMs
tn64tZ_2W-5JsGY4Hc5n9yBXArwl93lqt7_RN5w6Cf0h4QyQ5v-65YGjQR0_FDW2
QvzqY368QQMicAtaSqzs8KJZgnYb9c7d0zgdAZHzu6qMQvRL5hajrn1n91CbOpbI
SD08qNLyrdkt-bFTWhAI4vMQFh6WeZu0fM4lFd2NcRwr3XPksINHaQ-G_xBniIqb
w0Ls1jF44-csFCur-kEgU8awapJzKnqDKgw",
     "e":"AQAB",
     "alg":"RS256",
     "kid":"2011-04-29"}
  ]
}
```

A.2. Example Private Keys

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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":"4Etl6SRW2YiLUrN5vfvVHuhp7x8PxltmWWlbbM4IFyM",
     "d":"870MB6gfuTJ4HtUnUvYMyJpr5eUZNP4Bk43bVdj3eAE",
     "use":"enc",
     "kid":"1"},

    {"kty":"RSA",
     "n":"0vx7agoebGcQSuuPiLJXZptN9nndrQmbXEps2aiAFbWhM78LhWx4
cbbfAAtVT86zwu1RK7aPFFxuhDR1L6tSoc_BJECPebWKRXjBZCiFV4n3oknjhMst
n64tZ_2W-5JsGY4Hc5n9yBXArwl93lqt7_RN5w6Cf0h4QyQ5v-65YGjQR0_FDW2Q
vzqY368QQMicAtaSqzs8KJZgnYb9c7d0zgdAZHzu6qMQvRL5hajrn1n91CbOpbIS
D08qNLyrdkt-bFTWhAI4vMQFh6WeZu0fM4lFd2NcRwr3XPksINHaQ-G_xBniIqbw
0Ls1jF44-csFCur-kEgU8awapJzKnqDKgw",
     "e":"AQAB",
     "d":"X4cTteJY_gn4FYPsXB8rdXix5vwsg1FLN5E3EaG6RJoVH-HLLKD9
```

```
M7dx5oo7GURknchnrRweUkC7hT5fJLM0WbFAKNLWY2vv7B6NqXSzUvxT0_YSfqij
wp3RTzlBaCxWp4doFk5N2o8Gy_nHNKroADIkJ46pRUohsXywbReAdYaMwFs9tv8d
_cPVY3i07a3t8MN6TNwm0dSawm9v47UiCl3Sk5ZiG7xojPLu4sbg1U2jx4IBTNBz
nbJSzFHK66jT8bgkuqsk0GjskDJk19Z4qwjwbsnn4j2WBii3RL-Us2lGVkY8fkFz
me1z0HbIkfz0Y6mqnOYtqc0X4jfcKoAC8Q",
     "p":"83i-7IvMGXoMXCskv73TKr8637FiO7Z27zv8oj6pbWUQyLPQBQxtPV
nwD20R-60eTDmD2ujnMt5PoqMrm8RfmNhVWDtjjMmCMjOpSXicFHj7XOuVIYQyqV
WlWEh6dN36GVZYk93N8Bc9vY41xy8B9RzzOGVQzXvNEvn7O0nVbfs",
     "q":"3dfOR9cuYq-0S-mkFLzgItgMEfFzB2q3hWehMuG0oCuqnb3vobLyum
qjVZQO1dIrdwgTnCdpYzBcOfW5r370AFXjiWft_NGEiovonizhKpo9VVS78TzFgx
kIdrecRezsZ-1kYd_s1qDbxtkDEgfAITAG9LUnADun4vIcb6yelxk",
     "dp":"G4sPXkc6Ya9y8oJW9_ILj4xuppu0lzi_H7VTkS8xj5SdX3coE0oim
YwxIi2emTAue0UOa5dpgFGyBJ4c8tQ2VF402XRugKDTP8akYhFo5tAA77Qe_Nmtu
YZc3C3m3I24G2GvR5sSDxUyAN2zq8Lfn9EUms6rY3Ob8YeiKkTiBj0",
     "dq":"s9lAH9fggBsoFR8Oac2R_E2gw282rT2kGOAhvIllETE1efrA6huUU
vMfBcMpn8lqeW6vzznYY5SSQF7pMdC_agI3nG8Ibp1BUb0JUiraRNqUfLhcQb_d9
GF4Dh7e74WbRsobRonujTYN1xCaP6TO61jvWrX-L18txXw494Q_cgk",
     "qi":"GyM_p6JrXySiz1toFgKbWV-JdI3jQ4ypu9rbMWx3rQJBfmt0FoYzg
UIZEVFEcOqwemRN81zoDAaa-Bk0KWNGDjJHZDdDmFhW3AN7lI-puxk_mHZGJ11rx
yR8O55XLSe3SPmRfKwZI6yU24ZxvQKFYItdldUKGzO6Ia6zTKhAVRU",
     "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":"GawgguFyGrWKav7AX4VKUg"},

    {"kty":"oct",
     "k":"AyM1SysPpbyDfgZld3umj1qzKObwVMkoqQ-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 a non-normative 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":"vrjOfz9Ccdgx5nQudyhdoR17V-IubWMeOZCwX_jj0hgAsz2J_pqYW08
 PLbK_PdiVGKPrqzmDIsLI7sA25VEnHU1uCLNwBuUiCO11_-7dYbsr4iJmG0Q
 u2j8DsVyT1azpJC_NG84Ty5KKthuCaPod7iI7w0LK9orSMhBEwwZDCxTWq4a
 YWAchc8t-emd9qOvWtVMDC2BXksRngh6X5bUYLy6AyHKvj-nUy1wgzjYQDwH
 MTplCoLtU-o-8SNnZ1tmRoGE9uJkBLdh5gFENabWnU5m1ZqZPdwS-qo-meMv
 VfJb6jJVWRpl2SUtCnYG2C32qvbWbjZ_jBPD5eunqsIo1vQ",
 "e":"AQAB",
 "x5c":
```

```
    ["MIIDQjCCAiqgAwIBAgIGATz/FuLiMA0GCSqGSIb3DQEBBQUAMGIxCzAJB
    gNVBAYTAlVTMQswCQYDVQQIEwJDTzEPMA0GA1UEBxMGRGVudmVyMRwwGgYD
    VQQKExNQaW5nIElkZW50aXR5IENvcnAuMRcwFQYDVQQDEw5CcmlhbiBDYW1
    wYmVsbDAeFw0xMzAyMjEyMzI5MTVaFw0xODA4MTQyMjI5MTVaMGIxCzAJBg
    NVBAYTAlVTMQswCQYDVQQIEwJDTzEPMA0GA1UEBxMGRGVudmVyMRwwGgYDV
    QQKExNQaW5nIElkZW50aXR5IENvcnAuMRcwFQYDVQQDEw5CcmlhbiBDYW1w
    YmVsbDCCASIwDQYJKoZIhvcNAQEBBQADggEPADCCAQoCggEBAL64zn8/QnH
    YMeZ0LncoXaEde1fiLm1jHjmQsF/449IYALM9if6amFtPDy2yvz3YlRij66
    s5gyLCyO7ANuVRJx1NbgizcAblIgjtdf/u3WG7K+IiZhtELto/A7Fck9Ws6
    SQvzRvOE8uSirYbgmj6He4iO8NCyvaK0jIQRMMGQwsU1quGmFgHIXPLfnpn
    fajr1rVTAwtgV5LEZ4Iel+W1GC8ugMhyr4/p1MtcIM42EA8BzE6ZQqC7VPq
    PvEjZ2dbZkaBhPbiZAS3YeYBRDWm1p1OZtWamT3cEvqqPpnjL1XyW+oyVVk
    aZdklLQp2Btgt9qr21m42f4wTw+Xrp6rCKNb0CAwEAATANBgkqhkiG9w0BA
    QUFAAOCAQEAh8zGlfSlcI0o3rYDPBB07aXNswb4ECNIKG0CETTUxmXl9KUL
    +9gGlqCz5iWLOgWsnrcKcY0vXPG9J1r9AqBNTqNgHq2G03X09266X5CpOe1
    zFo+Owb1zxtp3PehFdfQJ610CDLEaS9V9Rqp17hCyybEpOGVwe8fnk+fbEL
    2Bo3UPGrpsHzUoaGpDftmWssZkhpBJKVMJyf/RuP2SmmaIzmnw9JiSlYhzo
    4tpzd5rFXhjRbg4zW9C+2qok+2+qDM1iJ684gPHMIY8aLWrdgQTxkumGmTq
    gawR+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

TOC

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

-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 `kty` 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-xmldsig-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.

Author's Address

Michael B. Jones
Microsoft
Email: mbj@microsoft.com
URI: http://self-issued.info/