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JSON Web Signature (JWS)

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Abstract

JSON Web Signature (JWS) is a means of representing content secured with digital signatures or Message Authentication Codes (MACs) using JavaScript Object Notation (JSON) data structures. Cryptographic algorithms and identifiers for use with this specification are described in the separate JSON Web Algorithms (JWA) specification. Related encryption capabilities are described in the separate JSON Web Encryption (JWE) specification.

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Table of Contents

- 1. Introduction**
 - 1.1. Notational Conventions**
- 2. Terminology**
- 3. JSON Web Signature (JWS) Overview**
 - 3.1. Example JWS**
- 4. JWS Header**
 - 4.1. Reserved Header Parameter Names**
 - 4.1.1. "alg" (Algorithm) Header Parameter**
 - 4.1.2. "jku" (JWK Set URL) Header Parameter**
 - 4.1.3. "jwk" (JSON Web Key) Header Parameter**

- [4.1.4. "x5u" \(X.509 URL\) Header Parameter](#)
 - [4.1.5. "x5t" \(X.509 Certificate Thumbprint\) Header Parameter](#)
 - [4.1.6. "x5c" \(X.509 Certificate Chain\) Header Parameter](#)
 - [4.1.7. "kid" \(Key ID\) Header Parameter](#)
 - [4.1.8. "typ" \(Type\) Header Parameter](#)
 - [4.1.9. "cty" \(Content Type\) Header Parameter](#)
 - [4.1.10. "crit" \(Critical\) Header Parameter](#)
 - [4.2. Public Header Parameter Names](#)
 - [4.3. Private Header Parameter Names](#)
 - [5. Producing and Consuming JWSs](#)
 - [5.1. Message Signing or MACing](#)
 - [5.2. Message Signature or MAC Validation](#)
 - [5.3. String Comparison Rules](#)
 - [6. Securing JWSs with Cryptographic Algorithms](#)
 - [7. JSON Serialization](#)
 - [7.1. Example JWS-JS](#)
 - [8. Implementation Considerations](#)
 - [9. IANA Considerations](#)
 - [9.1. JSON Web Signature and Encryption Header Parameters Registry](#)
 - [9.1.1. Registration Template](#)
 - [9.1.2. Initial Registry Contents](#)
 - [9.2. JSON Web Signature and Encryption Type Values Registry](#)
 - [9.2.1. Registration Template](#)
 - [9.2.2. Initial Registry Contents](#)
 - [9.3. Media Type Registration](#)
 - [9.3.1. Registry Contents](#)
 - [10. Security Considerations](#)
 - [10.1. Cryptographic Security Considerations](#)
 - [10.2. JSON Security Considerations](#)
 - [10.3. Unicode Comparison Security Considerations](#)
 - [11. References](#)
 - [11.1. Normative References](#)
 - [11.2. Informative References](#)
- [Appendix A. JWS Examples](#)
 - [A.1. Example JWS using HMAC SHA-256](#)
 - [A.1.1. Encoding](#)
 - [A.1.2. Decoding](#)
 - [A.1.3. Validating](#)
 - [A.2. Example JWS using RSA SHA-256](#)
 - [A.2.1. Encoding](#)
 - [A.2.2. Decoding](#)
 - [A.2.3. Validating](#)
 - [A.3. Example JWS using ECDSA P-256 SHA-256](#)
 - [A.3.1. Encoding](#)
 - [A.3.2. Decoding](#)
 - [A.3.3. Validating](#)
 - [A.4. Example JWS using ECDSA P-521 SHA-512](#)
 - [A.4.1. Encoding](#)
 - [A.4.2. Decoding](#)
 - [A.4.3. Validating](#)
 - [A.5. Example Plaintext JWS](#)
- [Appendix B. "x5c" \(X.509 Certificate Chain\) Example](#)
- [Appendix C. Notes on implementing base64url encoding without padding](#)
- [Appendix D. Acknowledgements](#)
- [Appendix E. Document History](#)
- [§ Authors' Addresses](#)

JSON Web Signature (JWS) is a compact format for representing content secured with digital signatures or Message Authentication Codes (MACs) intended for space constrained environments such as HTTP Authorization headers and URI query parameters. It represents this content using JavaScript Object Notation (JSON) [\[RFC4627\]](#) based data structures. The JWS cryptographic mechanisms provide integrity protection for arbitrary sequences of octets.

Cryptographic algorithms and identifiers for use with this specification are described in the separate JSON Web Algorithms (JWA) **[JWA]** specification. Related encryption capabilities are described in the separate JSON Web Encryption (JWE) **[JWE]** specification.

TOC

1.1. Notational Conventions

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

TOC

JSON Web Signature (JWS)

A data structure representing a digitally signed or MACed message. The structure represents three values: the JWS Header, the JWS Payload, and the JWS Signature.

JSON Text Object

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

JWS Header

A JSON Text Object that describes the digital signature or MAC operation applied to create the JWS Signature value.

JWS Payload

The sequence of octets to be secured -- a.k.a., the message. The payload can contain an arbitrary sequence of octets.

JWS Signature

A sequence of octets containing the cryptographic material that ensures the integrity of the JWS Header and the JWS Payload. The JWS Signature value is a digital signature or MAC value calculated over the JWS Signing Input using the parameters specified in the JWS Header.

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** for notes on implementing base64url encoding without padding.)

Encoded JWS Header

Base64url encoding of the JWS Header.

Encoded JWS Payload

Base64url encoding of the JWS Payload.

Encoded JWS Signature

Base64url encoding of the JWS Signature.

JWS Signing Input

The concatenation of the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload.

Header Parameter Name

The name of a member of the JWS Header.

Header Parameter Value

The value of a member of the JWS Header.

JWS Compact Serialization

A representation of the JWS as the concatenation of the Encoded JWS Header, the Encoded JWS Payload, and the Encoded JWS Signature in that order, with the three strings being separated by two period ('.') characters. This results in a compact, URL-safe representation.

JWS JSON Serialization

A representation of the JWS as a JSON structure containing Encoded JWS Header, Encoded JWS Payload, and Encoded JWS Signature values. Unlike the JWS Compact Serialization, the JWS JSON Serialization enables multiple digital signatures and/or MACs to be applied to the same content. This representation is neither compact nor URL-safe.

Collision Resistant Namespace

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

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

StringOrURI

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

3. JSON Web Signature (JWS) Overview

TOC

JWS represents digitally signed or MACed content using JSON data structures and base64url encoding. Three values are represented in a JWS: the JWS Header, the JWS Payload, and the JWS Signature. In the Compact Serialization, the three values are base64url-encoded for transmission, and represented as the concatenation of the encoded strings in that order, with the three strings being separated by two period ('.') characters. A JSON Serialization for this information is also defined in **Section 7**.

The JWS Header describes the signature or MAC method and parameters employed. The JWS Payload is the message content to be secured. The JWS Signature ensures the integrity of both the JWS Header and the JWS Payload.

3.1. Example JWS

TOC

The following example JWS Header declares that the encoded object is a JSON Web Token (JWT) [JWT] and the JWS Header and the JWS Payload are secured using the HMAC SHA-256 algorithm:

```
{"typ": "JWT",  
  "alg": "HS256"}
```

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

```
eyJ0eXAiOiJKV1QiLA0KICJhbGciOiJIUzI1NiJ9
```

The following is an example of a JSON object that can be used as a JWS Payload. (Note that the payload can be any content, and need not be a representation of a JSON object.)

```
{"iss": "joe",  
  "exp": 1300819380,  
  "http://example.com/is_root": true}
```

Base64url encoding the octets of the UTF-8 representation of the JSON object yields the following Encoded JWS Payload (with line breaks for display purposes only):

```
eyJpc3MiOiJqb2UiLA0KICJleHAiOiJleZMDA4MTkzODAsDQogImh0dHA6Ly9leGFt  
cGx1LmNvbS9pc19yb290Ijp0cnV1fQ
```

Computing the HMAC of the octets of the ASCII **[USASCII]** representation of the JWS Signing Input (the concatenation of the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload) with the HMAC SHA-256 algorithm using the key specified in **Appendix A.1** and base64url encoding the result yields this Encoded JWS Signature value:

```
dBjftJeZ4CVP-mB92K27uhbUJU1p1r_wW1gFWFOEjXk
```

Concatenating these values in the order Header.Payload.Signature with period ('.') characters between the parts yields this complete JWS representation using the JWS Compact Serialization (with line breaks for display purposes only):

```
eyJ0eXAiOiJKV1QiLA0KICJhbGciOiJIUzI1NiJ9
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGZt
cGx1LmNvbS9pc19yb290Ijpb0cnV1fQ
.
dBjftJeZ4CVP-mB92K27uhbUJU1p1r_wW1gFWFOEjXk
```

This computation is illustrated in more detail in **Appendix A.1**.

4. JWS Header

TOC

The members of the JSON object represented by the JWS Header describe the digital signature or MAC applied to the Encoded JWS Header and the Encoded JWS Payload and optionally additional properties of the JWS. The Header Parameter Names within this object **MUST** be unique; JWSs with duplicate Header Parameter Names **MUST** be rejected.

Implementations are required to understand the specific header parameters defined by this specification that are designated as "MUST be understood" and process them in the manner defined in this specification. All other header parameters defined by this specification that are not so designated **MUST** be ignored when not understood. Unless listed as a critical header parameter, per **Section 4.1.10**, all other header parameters **MUST** be ignored when not understood.

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

4.1. Reserved Header Parameter Names

TOC

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

Additional reserved Header Parameter Names **MAY** be defined via the IANA JSON Web Signature and Encryption Header Parameters registry **Section 9.1**. As indicated by the common registry, JWSs and JWEs share a common header parameter space; when a parameter is used by both specifications, its usage must be compatible between the specifications.

4.1.1. "alg" (Algorithm) Header Parameter

TOC

The **alg** (algorithm) header parameter identifies the cryptographic algorithm used to secure the JWS. The algorithm specified by the **alg** value **MUST** be supported by the implementation and there **MUST** be a key for use with that algorithm associated with the party that digitally signed or MACed the content or the JWS **MUST** be rejected. **alg** values **SHOULD** either be registered in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]** or be a

value that contains a Collision Resistant Namespace. The `alg` value is a case sensitive string containing a StringOrURI value. Use of this header parameter is REQUIRED. This header parameter MUST be understood by implementations.

A list of defined `alg` values can be found in the IANA JSON Web Signature and Encryption Algorithms registry [\[JWA\]](#); the initial contents of this registry are the values defined in Section 3.1 of the JSON Web Algorithms (JWA) [\[JWA\]](#) specification.

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

TOC

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

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

TOC

The `jwk` (JSON Web Key) header parameter is the public key that corresponds to the key used to digitally sign the JWS. This key is represented as a JSON Web Key [\[JWK\]](#). Use of this header parameter is OPTIONAL.

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

TOC

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

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

TOC

The `x5t` (X.509 Certificate Thumbprint) header parameter provides a base64url encoded SHA-1 thumbprint (a.k.a. digest) of the DER encoding of the X.509 certificate [\[RFC5280\]](#) corresponding to the key used to digitally sign the JWS. Use of this header parameter is OPTIONAL.

If, in the future, certificate thumbprints need to be computed using hash functions other than SHA-1, it is suggested that additional related header parameters be defined for that purpose. For example, it is suggested that a new `x5t#S256` (X.509 Certificate Thumbprint using SHA-256) header parameter could be defined by registering it in the IANA JSON Web Signature and Encryption Header Parameters registry [Section 9.1](#).

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

TOC

The `x5c` (X.509 Certificate Chain) header parameter contains the X.509 public key certificate

or certificate chain [\[RFC5280\]](#) corresponding to the key used to digitally sign the JWS. The certificate or certificate chain is represented as an array of certificate value strings. Each string is a base64 encoded ([\[RFC4648\]](#) Section 4 -- not base64url encoded) DER [\[ITU.X690.1994\]](#) PKIX certificate value. The certificate containing the public key corresponding to the key used to digitally sign the JWS 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 recipient MUST verify the certificate chain according to [\[RFC5280\]](#) and reject the JWS if any validation failure occurs. Use of this header parameter is OPTIONAL.

See [Appendix B](#) for an example `x5c` value.

4.1.7. "kid" (Key ID) Header Parameter

TOC

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

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

4.1.8. "typ" (Type) Header Parameter

TOC

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

MIME Media Type [\[RFC2046\]](#) values MAY be used as `typ` values.

`typ` values SHOULD either be registered in the IANA JSON Web Signature and Encryption Type Values registry [Section 9.2](#) or be a value that contains a Collision Resistant Namespace.

4.1.9. "cty" (Content Type) Header Parameter

TOC

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

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

4.1.10. "crit" (Critical) Header Parameter

TOC

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

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

```
{ "alg": "ES256",  
  "crit": [ "exp" ],  
  "exp": 1363284000  
}
```

4.2. Public Header Parameter Names

TOC

Additional Header Parameter Names can be defined by those using JWSs. However, in order to prevent collisions, any new Header Parameter Name SHOULD either be registered in the IANA JSON Web Signature and Encryption Header Parameters registry [Section 9.1](#) or be a Public Name: a value that contains a Collision Resistant Namespace. In each case, the definer of the name or value needs to take reasonable precautions to make sure they are in control of the part of the namespace they use to define the Header Parameter Name.

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

4.3. Private Header Parameter Names

TOC

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

5. Producing and Consuming JWSs

TOC

5.1. Message Signing or MACing

TOC

To create a JWS, one MUST perform these steps. The order of the steps is not significant in cases where there are no dependencies between the inputs and outputs of the steps.

1. Create the content to be used as the JWS Payload.
2. Base64url encode the octets of the JWS Payload. This encoding becomes the Encoded JWS Payload.
3. Create a JWS Header containing the desired set of header parameters. Note that white space is explicitly allowed in the representation and no canonicalization need be performed before encoding.
4. Base64url encode the octets of the UTF-8 representation of the JWS Header to create the Encoded JWS Header.
5. Compute the JWS Signature in the manner defined for the particular algorithm being used over the JWS Signing Input (the concatenation of the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload). The `alg` (algorithm) header parameter MUST be present in the JWS Header, with the algorithm value accurately representing the algorithm used to construct the JWS Signature.
6. Base64url encode the representation of the JWS Signature to create the Encoded JWS Signature.
7. The three encoded parts are the result values used in both the JWS Compact Serialization and the JWS JSON Serialization representations.
8. If the JWS JSON Serialization is being used, repeat this process for each digital signature or MAC value being applied.
9. Create the desired serialized output. The JWS Compact Serialization of this result is the concatenation of the Encoded JWS Header, the Encoded JWS Payload, and the Encoded JWS Signature in that order, with the three strings being separated by two period ('.') characters. The JWS JSON Serialization is described in [Section 7](#).

5.2. Message Signature or MAC Validation

When validating a JWS, the following steps **MUST** be taken. The order of the steps is not significant in cases where there are no dependencies between the inputs and outputs of the steps. If any of the listed steps fails, then the JWS **MUST** be rejected.

1. Parse the serialized input to determine the values of the Encoded JWS Header, the Encoded JWS Payload, and the Encoded JWS Signature. When using the JWS Compact Serialization, these three values are represented as text strings in that order, separated by two period ('.') characters. The JWS JSON Serialization is described in **Section 7**.
2. The Encoded JWS Header **MUST** be successfully base64url decoded following the restriction given in this specification that no padding characters have been used.
3. The resulting JWS Header **MUST** be completely valid JSON syntax conforming to **RFC 4627** [RFC4627].
4. The resulting JWS Header **MUST** be validated to only include parameters and values whose syntax and semantics are both understood and supported or that are specified as being ignored when not understood.
5. The Encoded JWS Payload **MUST** be successfully base64url decoded following the restriction given in this specification that no padding characters have been used.
6. The Encoded JWS Signature **MUST** be successfully base64url decoded following the restriction given in this specification that no padding characters have been used.
7. The JWS Signature **MUST** be successfully validated against the JWS Signing Input (the concatenation of the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload) in the manner defined for the algorithm being used, which **MUST** be accurately represented by the value of the `alg` (algorithm) header parameter, which **MUST** be present.
8. If the JWS JSON Serialization is being used, repeat this process for each digital signature or MAC value contained in the representation.

5.3. String Comparison Rules

Processing a JWS inevitably requires comparing known strings to values in JSON objects. For example, in checking what the algorithm is, the Unicode string encoding `alg` will be checked against the member names in the JWS Header to see if there is a matching Header Parameter Name. A similar process occurs when determining if the value of the `alg` header parameter represents a supported algorithm.

Comparisons between JSON strings and other Unicode strings **MUST** be performed as specified below:

1. Remove any JSON escaping from the input JSON string and convert the string into a sequence of Unicode code points.
2. Likewise, convert the string to be compared against into a sequence of Unicode code points.
3. Unicode Normalization **[USA15]** **MUST NOT** be applied at any point to either the JSON string or to the string it is to be compared against.
4. Comparisons between the two strings **MUST** be performed as a Unicode code point to code point equality comparison. (Note that values that originally used different Unicode encodings (UTF-8, UTF-16, etc.) may result in the same code point values.)

Also, see the JSON security considerations in **Section 10.2** and the Unicode security considerations in **Section 10.3**.

6. Securing JWSs with Cryptographic Algorithms

JWS uses cryptographic algorithms to digitally sign or MAC the JWS Header and the JWS Payload. The JSON Web Algorithms (JWA) **[JWA]** specification describes a set of cryptographic

algorithms and identifiers to be used with this specification. Specifically, Section 3.1 specifies a set of `alg` (algorithm) header parameter values intended for use this specification. It also describes the semantics and operations that are specific to these algorithms.

Public keys employed for digital signing can be identified using the Header Parameter methods described in [Section 4.1](#) or can be distributed using methods that are outside the scope of this specification.

7. JSON Serialization

TOC

The JWS JSON Serialization represents digitally signed or MACed content as a JSON object with a `signatures` member containing an array of per-signature information and a `payload` member containing a shared Encoded JWS Payload value. Each member of the `signatures` array is a JSON object with a `header` member containing an Encoded JWS Header value and a `signature` member containing an Encoded JWS Signature value.

Unlike the JWS Compact Serialization, content using the JWS JSON Serialization MAY be secured with more than one digital signature and/or MAC value. Each is represented as an Encoded JWS Signature value in the `signature` member of an object in the `signatures` array. For each signature, there is an Encoded JWS Encoded Header value in the `header` member of the same object in the `signatures` array. This specifies the digital signature or MAC applied to the Encoded JWS Header value and the shared Encoded JWS Payload value to create the JWS Signature value. Therefore, the syntax is:

```
{
  "signatures": [
    {
      "header": "<header 1 contents>",
      "signature": "<signature 1 contents>",
      ...
    },
    {
      "header": "<header N contents>",
      "signature": "<signature N contents>"
    }
  ],
  "payload": "<payload contents>"
}
```

The contents of the Encoded JWS Header, Encoded JWS Payload, and Encoded JWS Signature values are exactly as specified in the rest of this specification. They are interpreted and validated in the same manner, with each corresponding `header` and `signature` value being created and validated together.

Each JWS Signature value is computed on the JWS Signing Input corresponding to the concatenation of the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload in the same manner as for the JWS Compact Serialization. This has the desirable result that each Encoded JWS Signature value in the `signatures` array is identical to the value that would be used for the same parameter in the JWS Compact Serialization, as is the shared JWS Payload value.

7.1. Example JWS-JS

TOC

This section contains an example using the JWS JSON Serialization. This example demonstrates the capability for conveying multiple digital signatures and/or MACs for the same payload.

The Encoded JWS Payload used in this example is the same as used in the examples in [Appendix A](#) (with line breaks for display purposes only):

```
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzZDA4MTkzODAsDQogImh0dHA6Ly9leGFTcGx1LmNvbS9pc19yb290Ijpb0cnV1fQ
```

Two digital signatures are used in this example: an RSA SHA-256 signature, for which the

header and signature values are the same as in **Appendix A.2**, and an ECDSA P-256 SHA-256 signature, for which the header and signature values are the same as in **Appendix A.3**. The two Decoded JWS Header Segments used are:

```
{"alg": "RS256"}
```

and:

```
{"alg": "ES256"}
```

Since the computations of the JWS Header and JWS Signature values are the same as in **Appendix A.2** and **Appendix A.3**, they are not repeated here.

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

```
{
  "signatures": [
    {
      "header": "eyJhbGciOiJSUzI1NiJ9",
      "signature": "cC4hiUPoj9Eetdgtv3hF80EGrhuB__dzERat0XF9g2VtQgr9PJbu3X0iZj5RZmh7AAuHIm4Bh-0Qc_lF5YKt_08W2Fp5jujGbds9uJdbF9CUAr7t1dnZcAcQjbKBYNX4BAynRFdiuB--f_nZLgrnbyTyWz075vRK5h6xBARLIARNPvkSjtQBMH1b1L07Qe7K0GarZRmB_eSN9383Lc0Ln6_d0--xi12jzDwusC-e0kHWesqtFZESc6BfI7no0PqvhJ1phCnvWh6IeYI2w9Q0YEUipUTI8np6LbgGY9Fs98rqVt5AXLIhWkWyw1VmtVrBp0igcN_IoypG1UPQGe77Rw"},
    {
      "header": "eyJhbGciOiJFUzI1NiJ9",
      "signature": "DtEhU31jbEg8L38VWAFUAqOyKAM6-Xx-F4GawxaepmXFCgfTjDxw5djxLa8ISlSApmWQxfKTUJqPP3-Kg6NU1Q"}],
  "payload": "eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFtcGx1LmNvbS9pc19yb290Ijpb0cnVlfQ"
}
```

8. Implementation Considerations

TOC

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

9. 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.

9.1. JSON Web Signature and Encryption Header Parameters Registry

TOC

This specification establishes the IANA JSON Web Signature and Encryption Header Parameters registry for reserved JWS and JWE Header Parameter Names. The registry records the reserved Header Parameter Name and a reference to the specification that defines it. The same Header Parameter Name MAY be registered multiple times, provided that the parameter usage is compatible between the specifications. Different registrations of the same Header Parameter Name will typically use different Header Parameter Usage Location(s) values.

9.1.1. Registration Template

TOC

Header 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.

Header Parameter Usage Location(s):

The header parameter usage locations, which should be one or more of the values [JWS](#) or [JWE](#).

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.

9.1.2. Initial Registry Contents

TOC

This specification registers the Header Parameter Names defined in **Section 4.1** in this registry.

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

- Header Parameter Name: [jku](#)
- Header Parameter Usage Location(s): [JWS](#)
- Change Controller: IETF
- Specification Document(s): **Section 4.1.2** of [[this document]]

- Header Parameter Name: [jwk](#)
- Header Parameter Usage Location(s): [JWS](#)
- Change Controller: IETF
- Specification document(s): **Section 4.1.3** of [[this document]]

- Header Parameter Name: [x5u](#)
- Header Parameter Usage Location(s): [JWS](#)
- Change Controller: IETF
- Specification Document(s): **Section 4.1.4** of [[this document]]

- Header Parameter Name: [x5t](#)
- Header Parameter Usage Location(s): [JWS](#)
- Change Controller: IETF
- Specification Document(s): **Section 4.1.5** of [[this document]]

- Header Parameter Name: `x5c`
- Header Parameter Usage Location(s): `JWS`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.6** of [[this document]]
- Header Parameter Name: `kid`
- Header Parameter Usage Location(s): `JWS`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.7** of [[this document]]
- Header Parameter Name: `typ`
- Header Parameter Usage Location(s): `JWS`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.8** of [[this document]]
- Header Parameter Name: `cty`
- Header Parameter Usage Location(s): `JWS`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.9** of [[this document]]
- Header Parameter Name: `crit`
- Header Parameter Usage Location(s): `JWS`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.10** of [[this document]]

9.2. JSON Web Signature and Encryption Type Values Registry

TOC

This specification establishes the IANA JSON Web Signature and Encryption Type Values registry for values of the `JWS` and `JWE typ` (type) header parameter. It is RECOMMENDED that all registered `typ` values also include a MIME Media Type **[RFC2046]** value that the registered value is a short name for. The registry records the `typ` value, the MIME type value that it is an abbreviation for (if any), and a reference to the specification that defines it.

MIME Media Type **[RFC2046]** values MUST NOT be directly registered as new `typ` values; rather, new `typ` values MAY be registered as short names for MIME types.

9.2.1. Registration Template

TOC

"typ" Header Parameter Value:

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.

Abbreviation for MIME Type:

The MIME type that this name is an abbreviation for (e.g., "application/example").

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.

9.2.2. Initial Registry Contents

TOC

This specification registers the `JWS` and `JWS-JS` type values in this registry:

- "typ" Header Parameter Value: `JWS`
- Abbreviation for MIME type: `application/jws`

- Change Controller: IETF
- Specification Document(s): **Section 4.1.8** of [[this document]]
- "typ" Header Parameter Value: JWS-JS
- Abbreviation for MIME type: application/jws-js
- Change Controller: IETF
- Specification Document(s): **Section 4.1.8** of [[this document]]

9.3. Media Type Registration

TOC

9.3.1. Registry Contents

TOC

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

- Type name: application
- Subtype name: jws
- Required parameters: n/a
- Optional parameters: n/a
- Encoding considerations: JWS values are encoded as a series of base64url encoded values (some of which may be the empty string) separated by period ('.') characters
- Security considerations: See the Security Considerations section of [[this document]]
- Interoperability considerations: n/a
- Published specification: [[this document]]
- Applications that use this media type: OpenID Connect, Mozilla Persona, Salesforce, Google, numerous others that use signed JWTs
- Additional information: Magic number(s): n/a, File extension(s): n/a, Macintosh file type code(s): n/a
- Person & email address to contact for further information: Michael B. Jones, mbj@microsoft.com
- Intended usage: COMMON
- Restrictions on usage: none
- Author: Michael B. Jones, mbj@microsoft.com
- Change Controller: IETF

- Type name: application
- Subtype name: jws-js
- Required parameters: n/a
- Optional parameters: n/a
- Encoding considerations: JWS-JS values are represented as a JSON Object; UTF-8 encoding SHOULD be employed for the JSON object.
- Security considerations: See the Security Considerations section of [[this document]]
- Interoperability considerations: n/a
- Published specification: [[this document]]
- Applications that use this media type: TBD
- Additional information: Magic number(s): n/a, File extension(s): n/a, Macintosh file type code(s): n/a
- Person & email address to contact for further information: Michael B. Jones, mbj@microsoft.com
- Intended usage: COMMON
- Restrictions on usage: none
- Author: Michael B. Jones, mbj@microsoft.com
- Change Controller: IETF

10. Security Considerations

TOC

10.1. Cryptographic 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 concerns are listed here.

All the security considerations in **XML DSIG 2.0** [W3C.CR-xmlsig-core2-20120124], also apply to this specification, other than those that are XML specific. Likewise, many of the best practices documented in **XML Signature Best Practices** [W3C.WD-xmlsig-bestpractices-20110809] also apply to this specification, other than those that are XML specific.

Keys are only as strong as the amount of entropy used to generate them. A minimum of 128 bits of entropy should be used for all keys, and depending upon the application context, more may be required. In particular, it may be difficult to generate sufficiently random values in some browsers and application environments.

Creators of JWSs should not allow third parties to insert arbitrary content into the message without adding entropy not controlled by the third party.

When utilizing TLS to retrieve information, the authority providing the resource **MUST** be authenticated and the information retrieved **MUST** be free from modification.

When cryptographic algorithms are implemented in such a way that successful operations take a different amount of time than unsuccessful operations, attackers may be able to use the time difference to obtain information about the keys employed. Therefore, such timing differences must be avoided.

A SHA-1 hash is used when computing `x5t` (x.509 certificate thumbprint) values, for compatibility reasons. Should an effective means of producing SHA-1 hash collisions be developed, and should an attacker wish to interfere with the use of a known certificate on a given system, this could be accomplished by creating another certificate whose SHA-1 hash value is the same and adding it to the certificate store used by the intended victim. A prerequisite to this attack succeeding is the attacker having write access to the intended victim's certificate store.

If, in the future, certificate thumbprints need to be computed using hash functions other than SHA-1, it is suggested that additional related header parameters be defined for that purpose. For example, it is suggested that a new `x5t#S256` (X.509 Certificate Thumbprint using SHA-256) header parameter could be defined and used.

10.2. JSON Security Considerations

Strict JSON validation is a security requirement. If malformed JSON is received, then the intent of the sender is impossible to reliably discern. Ambiguous and potentially exploitable situations could arise if the JSON parser used does not reject malformed JSON syntax.

Section 2.2 of the JavaScript Object Notation (JSON) specification [**RFC4627**] states "The names within an object **SHOULD** be unique", whereas this specification states that "Header Parameter Names within this object **MUST** be unique; JWSs with duplicate Header Parameter Names **MUST** be rejected". Thus, this specification requires that the Section 2.2 "SHOULD" be treated as a "MUST". Ambiguous and potentially exploitable situations could arise if the JSON parser used does not enforce the uniqueness of member names.

Some JSON parsers might not reject input that contains extra significant characters after a valid input. For instance, the input `{"tag": "value"}ABCD` contains a valid JSON object followed by the extra characters `ABCD`. Such input **MUST** be rejected in its entirety.

Header Parameter Names and algorithm names are Unicode strings. For security reasons, the representations of these names must be compared verbatim after performing any escape processing (as per [RFC 4627](#) [RFC4627], Section 2.5). This means, for instance, that these JSON strings must compare as being equal ("sig", "\u0073ig"), whereas these must all compare as being not equal to the first set or to each other ("SIG", "Sig", "si\u0047").

JSON strings can contain characters outside the Unicode Basic Multilingual Plane. For instance, the G clef character (U+1D11E) may be represented in a JSON string as "\uD834\uDD1E". Ideally, JWS implementations SHOULD ensure that characters outside the Basic Multilingual Plane are preserved and compared correctly; alternatively, if this is not possible due to these characters exercising limitations present in the underlying JSON implementation, then input containing them MUST be rejected.

11. References

11.1. Normative References

- [ITU.X690.1994] International Telecommunications Union, "Information Technology - ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)," ITU-T Recommendation X.690, 1994.
- [JWA] [Jones, M., "JSON Web Algorithms \(JWA\),"](#) draft-ietf-jose-json-web-algorithms (work in progress), April 2013 ([HTML](#)).
- [JWK] [Jones, M., "JSON Web Key \(JWK\),"](#) draft-ietf-jose-json-web-key (work in progress), April 2013 ([HTML](#)).
- [RFC1421] [Linn, J., "Privacy Enhancement for Internet Electronic Mail: Part I: Message Encryption and Authentication Procedures,"](#) RFC 1421, February 1993 ([TXT](#)).
- [RFC2046] [Freed, N. and N. Borenstein, "Multipurpose Internet Mail Extensions \(MIME\) Part Two: Media Types,"](#) RFC 2046, November 1996 ([TXT](#)).
- [RFC2119] [Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels,"](#) BCP 14, RFC 2119, March 1997 ([TXT](#), [HTML](#), [XML](#)).
- [RFC2818] [Rescorla, E., "HTTP Over TLS,"](#) RFC 2818, May 2000 ([TXT](#)).
- [RFC3629] [Yergeau, F., "UTF-8, a transformation format of ISO 10646,"](#) STD 63, RFC 3629, November 2003 ([TXT](#)).
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- [RFC4288] [Freed, N. and J. Klensin, "Media Type Specifications and Registration Procedures,"](#) RFC 4288, December 2005 ([TXT](#)).
- [RFC4627] [Crockford, D., "The application/json Media Type for JavaScript Object Notation \(JSON\),"](#) RFC 4627, July 2006 ([TXT](#)).
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- [RFC5246] [Dierks, T. and E. Rescorla, "The Transport Layer Security \(TLS\) Protocol Version 1.2,"](#) RFC 5246, August 2008 ([TXT](#)).
- [RFC5280] [Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List \(CRL\) Profile,"](#) RFC 5280, May 2008 ([TXT](#)).
- [USA15] [Davis, M., Whistler, K., and M. Dürst, "Unicode Normalization Forms,"](#) Unicode Standard Annex 15, 09 2009.
- [USASCII] American National Standards Institute, "Coded Character Set -- 7-bit American Standard Code for Information Interchange," ANSI X3.4, 1986.
- [W3C.WD-xmldsig-bestpractices-20110809] [Datta, P. and F. Hirsch, "XML Signature Best Practices,"](#) World Wide Web Consortium WD WD-xmldsig-bestpractices-20110809, August 2011 ([HTML](#)).

11.2. Informative References

- [CanvasApp] Facebook, "[Canvas Applications](#)," 2010.
- [JSS] Bradley, J. and N. Sakimura (editor), "[JSON Simple Sign](#)," September 2010.
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- [JWT] [Jones, M., Bradley, J., and N. Sakimura, "JSON Web Token \(JWT\)," draft-ietf-oauth-json-web-token \(work in progress\), April 2013 \(HTML\).](#)
- [MagicSignatures] Panzer (editor), J., Laurie, B., and D. Balfanz, "[Magic Signatures](#)," January 2011.
- [RFC4122] [Leach, P., Mealling, M., and R. Salz, "A Universally Unique Identifier \(UUID\) URN Namespace," RFC 4122, July 2005 \(TXT, HTML, XML\).](#)
- [W3C.CR-xmlsig-core2-20120124] Eastlake, D., Reagle, J., Yiu, K., Solo, D., Datta, P., Hirsch, F., Cantor, S., and T. Roessler, "[XML Signature Syntax and Processing Version 2.0](#)," World Wide Web Consortium CR CR-xmlsig-core2-20120124, January 2012 (HTML).

Appendix A. JWS Examples

TOC

This section provides several examples of JWSs. While these examples all represent JSON Web Tokens (JWTs) [JWT], the payload can be any base64url encoded content.

A.1. Example JWS using HMAC SHA-256

TOC

A.1.1. Encoding

TOC

The following example JWS Header declares that the data structure is a JSON Web Token (JWT) [JWT] and the JWS Signing Input is secured using the HMAC SHA-256 algorithm.

```
{ "typ": "JWT",  
  "alg": "HS256" }
```

The following octet sequence contains the UTF-8 representation of the JWS Header:

```
[123, 34, 116, 121, 112, 34, 58, 34, 74, 87, 84, 34, 44, 13, 10, 32, 34, 97, 108, 103, 34, 58,  
34, 72, 83, 50, 53, 54, 34, 125]
```

Base64url encoding these octets yields this Encoded JWS Header value:

```
eyJ0eXAiOiJKV1QiLA0KICJhbGciOiJIUzI1NiJ9
```

The JWS Payload used in this example is the octets of the UTF-8 representation of the JSON object below. (Note that the payload can be any base64url encoded octet sequence, and need not be a base64url encoded JSON object.)

```
{ "iss": "joe",  
  "exp": 1300819380,  
  "http://example.com/is_root": true }
```

The following octet sequence, which is the UTF-8 representation of the JSON object above, is the JWS Payload:

```
[123, 34, 105, 115, 115, 34, 58, 34, 106, 111, 101, 34, 44, 13, 10, 32, 34, 101, 120, 112, 34,  
58, 49, 51, 48, 48, 56, 49, 57, 51, 56, 48, 44, 13, 10, 32, 34, 104, 116, 116, 112, 58, 47, 47,  
101, 120, 97, 109, 112, 108, 101, 46, 99, 111, 109, 47, 105, 115, 95, 114, 111, 111, 116, 34,  
58, 116, 114, 117, 101, 125]
```

Base64url encoding the above yields the Encoded JWS Payload value (with line breaks for display purposes only):

```
eyJpc3MiOiJqb2UiLA0KICJleHAiOiJlZjZMDA4MTkzODAsDQogImh0dHA6Ly9leGFt  
cGx1LmNvbS9pc19yb290Ijp0cnVlfQ
```

Concatenating the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload yields this JWS Signing Input value (with line breaks for display purposes only):

```
eyJ0eXAiOiJKV1QiLA0KICJhbGciOiJIUzI1NiJ9
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGZt
cGx1LmNvbS9pc19yb290Ijp0cnVlfQ
```

The ASCII representation of the JWS Signing Input is the following octet sequence:

```
[101, 121, 74, 48, 101, 88, 65, 105, 79, 105, 74, 75, 86, 49, 81, 105, 76, 65, 48, 75, 73, 67,
74, 104, 98, 71, 99, 105, 79, 105, 74, 73, 85, 122, 73, 49, 78, 105, 74, 57, 46, 101, 121, 74,
112, 99, 51, 77, 105, 79, 105, 74, 113, 98, 50, 85, 105, 76, 65, 48, 75, 73, 67, 74, 108, 101,
72, 65, 105, 79, 106, 69, 122, 77, 68, 65, 52, 77, 84, 107, 122, 79, 68, 65, 115, 68, 81, 111,
103, 73, 109, 104, 48, 100, 72, 65, 54, 76, 121, 57, 108, 101, 71, 70, 116, 99, 71, 120, 108,
76, 109, 78, 118, 98, 83, 57, 112, 99, 49, 57, 121, 98, 50, 57, 48, 73, 106, 112, 48, 99, 110,
86, 108, 102, 81]
```

HMACs are generated using keys. This example uses the key represented by the following octet sequence:

```
[3, 35, 53, 75, 43, 15, 165, 188, 131, 126, 6, 101, 119, 123, 166, 143, 90, 179, 40, 230, 240,
84, 201, 40, 169, 15, 132, 178, 210, 80, 46, 191, 211, 251, 90, 146, 210, 6, 71, 239, 150, 138,
180, 195, 119, 98, 61, 34, 61, 46, 33, 114, 5, 46, 79, 8, 192, 205, 154, 245, 103, 208, 128,
163]
```

Running the HMAC SHA-256 algorithm on the octets of the ASCII representation of the JWS Signing Input with this key yields the following octet sequence:

```
[116, 24, 223, 180, 151, 153, 224, 37, 79, 250, 96, 125, 216, 173, 187, 186, 22, 212, 37, 77,
105, 214, 191, 240, 91, 88, 5, 88, 83, 132, 141, 121]
```

Base64url encoding the above HMAC output yields the Encoded JWS Signature value:

```
dBjftJeZ4CVP-mB92K27uhbUJU1p1r_wW1gFWFOEjXk
```

Concatenating these values in the order Header.Payload.Signature with period ('.') characters between the parts yields this complete JWS representation using the JWS Compact Serialization (with line breaks for display purposes only):

```
eyJ0eXAiOiJKV1QiLA0KICJhbGciOiJIUzI1NiJ9
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGZt
cGx1LmNvbS9pc19yb290Ijp0cnVlfQ
.
dBjftJeZ4CVP-mB92K27uhbUJU1p1r_wW1gFWFOEjXk
```

A.1.2. Decoding

TOC

Decoding the JWS requires base64url decoding the Encoded JWS Header, Encoded JWS Payload, and Encoded JWS Signature to produce the JWS Header, JWS Payload, and JWS Signature octet sequences. The octet sequence containing the UTF-8 representation of the JWS Header is decoded into the JWS Header string.

A.1.3. Validating

TOC

Next we validate the decoded results. Since the `alg` parameter in the header is "HS256", we

validate the HMAC SHA-256 value contained in the JWS Signature. If any of the validation steps fail, the JWS MUST be rejected.

First, we validate that the JWS Header string is legal JSON.

To validate the HMAC value, we repeat the previous process of using the correct key and the ASCII representation of the JWS Signing Input as input to the HMAC SHA-256 function and then taking the output and determining if it matches the JWS Signature. If it matches exactly, the HMAC has been validated.

A.2. Example JWS using RSA SHA-256

TOC

A.2.1. Encoding

TOC

The JWS Header in this example is different from the previous example in two ways: First, because a different algorithm is being used, the `alg` value is different. Second, for illustration purposes only, the optional `typ` parameter is not used. (This difference is not related to the algorithm employed.) The JWS Header used is:

```
{"alg": "RS256"}
```

The following octet sequence contains the UTF-8 representation of the JWS Header:

```
[123, 34, 97, 108, 103, 34, 58, 34, 82, 83, 50, 53, 54, 34, 125]
```

Base64url encoding these octets yields this Encoded JWS Header value:

```
eyJhbGciOiJSUzI1NiJ9
```

The JWS Payload used in this example, which follows, is the same as in the previous example. Since the Encoded JWS Payload will therefore be the same, its computation is not repeated here.

```
{"iss": "joe",  
 "exp": 1300819380,  
 "http://example.com/is_root": true}
```

Concatenating the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload yields this JWS Signing Input value (with line breaks for display purposes only):

```
eyJhbGciOiJSUzI1NiJ9  
.  
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFt  
cGx1LmNvbS9pc19yb290Ijp0cnVlfQ
```

The ASCII representation of the JWS Signing Input is the following octet sequence:

```
[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 83, 85, 122, 73, 49, 78, 105, 74, 57, 46, 101,  
121, 74, 112, 99, 51, 77, 105, 79, 105, 74, 113, 98, 50, 85, 105, 76, 65, 48, 75, 73, 67, 74,  
108, 101, 72, 65, 105, 79, 106, 69, 122, 77, 68, 65, 52, 77, 84, 107, 122, 79, 68, 65, 115, 68,  
81, 111, 103, 73, 109, 104, 48, 100, 72, 65, 54, 76, 121, 57, 108, 101, 71, 70, 116, 99, 71,  
120, 108, 76, 109, 78, 118, 98, 83, 57, 112, 99, 49, 57, 121, 98, 50, 57, 48, 73, 106, 112, 48,  
99, 110, 86, 108, 102, 81]
```

The RSA key consists of a public part (Modulus, Exponent), and a Private Exponent. The

values of the RSA key used in this example, presented as the octet sequences representing big endian integers are:

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

The RSA private key (Modulus, Private Exponent) is then passed to the RSA signing function, which also takes the hash type, SHA-256, and the octets of the ASCII representation of the JWS Signing Input as inputs. The result of the digital signature is an octet sequence, which represents a big endian integer. In this example, it is:

```
[112, 46, 33, 137, 67, 232, 143, 209, 30, 181, 216, 45, 191, 120, 69, 243, 65, 6, 174, 27, 129, 255, 247, 115, 17, 22, 173, 209, 113, 125, 131, 101, 109, 66, 10, 253, 60, 150, 238, 221, 115, 162, 102, 62, 81, 102, 104, 123, 0, 11, 135, 34, 110, 1, 135, 237, 16, 115, 249, 69, 229, 130, 173, 252, 239, 22, 216, 90, 121, 142, 232, 198, 109, 219, 61, 184, 151, 91, 23, 208, 148, 2, 190, 237, 213, 217, 217, 112, 7, 16, 141, 178, 129, 96, 213, 248, 4, 12, 167, 68, 87, 98, 184, 31, 190, 127, 249, 217, 46, 10, 231, 111, 36, 242, 91, 51, 187, 230, 244, 74, 230, 30, 177, 4, 10, 203, 32, 4, 77, 62, 249, 18, 142, 212, 1, 48, 121, 91, 212, 189, 59, 65, 238, 202, 208, 102, 171, 101, 25, 129, 253, 228, 141, 247, 127, 55, 45, 195, 139, 159, 175, 221, 59, 239, 177, 139, 93, 163, 204, 60, 46, 176, 47, 158, 58, 65, 214, 18, 202, 173, 21, 145, 18, 115, 160, 95, 35, 185, 232, 56, 250, 175, 132, 157, 105, 132, 41, 239, 90, 30, 136, 121, 130, 54, 195, 212, 14, 96, 69, 34, 165, 68, 200, 242, 122, 122, 45, 184, 6, 99, 209, 108, 247, 202, 234, 86, 222, 64, 92, 178, 33, 90, 69, 178, 194, 85, 102, 181, 90, 193, 167, 72, 160, 112, 223, 200, 163, 42, 70, 149, 67, 208, 25, 238, 251, 71]
```

Base64url encoding the digital signature produces this value for the Encoded JWS Signature (with line breaks for display purposes only):

```
cC4hiUPoj9Eetdgtv3hF80EGrhuB__dzERat0XF9g2VtQgr9PJbu3X0iZj5RZmh7
AAuHIm4Bh-0Qc_lF5YKt_08W2Fp5jujGbds9uJdbF9CUAr7t1dnZcAcQjbKBYNX4
BAynRFdiuB--f_nZLgrnbyTyWz075vRK5h6xBarLIARNPvkSjtQBMH1b1L07Qe7K
0GarZRMb_eSN9383Lc0Ln6_d0--xi12jzDwusC-e0kHWEsqfZESc6BfI7no0Pqv
hJ1phCnvWh6IeYI2w9Q0YEUipUTI8np6LbgGY9Fs98rqVt5AXLIhWkWywlvmtVrB
p0igcN_IoypG1UPQGe77Rw
```

Concatenating these values in the order Header.Payload.Signature with period ('.') characters between the parts yields this complete JWS representation using the JWS Compact Serialization (with line breaks for display purposes only):

```
eyJhbGciOiJSUzI1NiJ9
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOiJleMDA4MTkzODAsDQogImh0dHA6Ly9leGFT
cGx1LmNvbS9pc19yb290IjppcnV1fQ
.
cC4hiUPoj9Eetdgtv3hF80EGrhuB__dzERat0XF9g2VtQgr9PJbu3X0iZj5RZmh7
AAuHIm4Bh-0Qc_lF5Ykt_08W2Fp5jujGbds9uJdbF9CUAr7t1dnZcAcQjbKBYNX4
BAynRFdiuB--f_nZLgrnbyTyWz075vRK5h6xBarLIARNPvkSjtQBMH1b1L07Qe7K
0GarZRmB_eSN9383Lc0Ln6_d0--xi12jzDwusC-e0kHWesqtFZEsc6BfI7no0Pqv
hJ1phCnvWh6IeYI2w9Q0YEUIpUTI8np6LbgGY9Fs98rqVt5AXLIhWkWyw1VmtVrB
p0igcN_IoypGlUPQGe77Rw
```

A.2.2. Decoding

TOC

Decoding the JWS requires base64url decoding the Encoded JWS Header, Encoded JWS Payload, and Encoded JWS Signature to produce the JWS Header, JWS Payload, and JWS Signature octet sequences. The octet sequence containing the UTF-8 representation of the JWS Header is decoded into the JWS Header string.

A.2.3. Validating

TOC

Since the `alg` parameter in the header is "RS256", we validate the RSA SHA-256 digital signature contained in the JWS Signature. If any of the validation steps fail, the JWS MUST be rejected.

First, we validate that the JWS Header string is legal JSON.

Validating the JWS Signature is a little different from the previous example. First, we base64url decode the Encoded JWS Signature to produce a digital signature `S` to check. We then pass `(n, e)`, `S` and the octets of the ASCII representation of the JWS Signing Input to an RSA signature verifier that has been configured to use the SHA-256 hash function.

A.3. Example JWS using ECDSA P-256 SHA-256

TOC

A.3.1. Encoding

TOC

The JWS Header for this example differs from the previous example because a different algorithm is being used. The JWS Header used is:

```
{"alg": "ES256"}
```

The following octet sequence contains the UTF-8 representation of the JWS Header:

```
[123, 34, 97, 108, 103, 34, 58, 34, 69, 83, 50, 53, 54, 125]
```

Base64url encoding these octets yields this Encoded JWS Header value:

```
eyJhbGciOiJFUzI1NiJ9
```

The JWS Payload used in this example, which follows, is the same as in the previous examples. Since the Encoded JWS Payload will therefore be the same, its computation is not repeated here.

```
{ "iss": "joe",  
  "exp": 1300819380,  
  "http://example.com/is_root": true }
```

Concatenating the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload yields this JWS Signing Input value (with line breaks for display purposes only):

```
eyJhbGciOiJIJFZ1I1NiJ9  
.  
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFt  
cGx1LmNvbS9pc19yb290Ijpb0cnV1fQ
```

The ASCII representation of the JWS Signing Input is the following octet sequence:

```
[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 70, 85, 122, 73, 49, 78, 105, 74, 57, 46, 101,  
121, 74, 112, 99, 51, 77, 105, 79, 105, 74, 113, 98, 50, 85, 105, 76, 65, 48, 75, 73, 67, 74,  
108, 101, 72, 65, 105, 79, 106, 69, 122, 77, 68, 65, 52, 77, 84, 107, 122, 79, 68, 65, 115, 68,  
81, 111, 103, 73, 109, 104, 48, 100, 72, 65, 54, 76, 121, 57, 108, 101, 71, 70, 116, 99, 71,  
120, 108, 76, 109, 78, 118, 98, 83, 57, 112, 99, 49, 57, 121, 98, 50, 57, 48, 73, 106, 112, 48,  
99, 110, 86, 108, 102, 81]
```

The ECDSA key consists of a public part, the EC point (x, y), and a private part d. The values of the ECDSA key used in this example, presented as the octet sequences representing three 256 bit big endian integers are:

Parameter Name	Value
x	[127, 205, 206, 39, 112, 246, 196, 93, 65, 131, 203, 238, 111, 219, 75, 123, 88, 7, 51, 53, 123, 233, 239, 19, 186, 207, 110, 60, 123, 209, 84, 69]
y	[199, 241, 68, 205, 27, 189, 155, 126, 135, 44, 223, 237, 185, 238, 185, 244, 179, 105, 93, 110, 169, 11, 36, 173, 138, 70, 35, 40, 133, 136, 229, 173]
d	[142, 155, 16, 158, 113, 144, 152, 191, 152, 4, 135, 223, 31, 93, 119, 233, 203, 41, 96, 110, 190, 210, 38, 59, 95, 87, 194, 19, 223, 132, 244, 178]

The ECDSA private part d is then passed to an ECDSA signing function, which also takes the curve type, P-256, the hash type, SHA-256, and the octets of the ASCII representation of the JWS Signing Input as inputs. The result of the digital signature is the EC point (R, S), where R and S are unsigned integers. In this example, the R and S values, given as octet sequences representing big endian integers are:

Result Name	Value
R	[14, 209, 33, 83, 121, 99, 108, 72, 60, 47, 127, 21, 88, 7, 212, 2, 163, 178, 40, 3, 58, 249, 124, 126, 23, 129, 154, 195, 22, 158, 166, 101]
S	[197, 10, 7, 211, 140, 60, 112, 229, 216, 241, 45, 175, 8, 74, 84, 128, 166, 101, 144, 197, 242, 147, 80, 154, 143, 63, 127, 138, 131, 163, 84, 213]

Concatenating the S array to the end of the R array and base64url encoding the result produces this value for the Encoded JWS Signature (with line breaks for display purposes only):

```
DtEhU31jBEG8L38VwAFUAQ0yKAM6-Xx-F4GawxaepmXFCgfTjDxw5djxLa8ISlSA  
pmWQxfKTUJqPP3-Kg6NU1Q
```

Concatenating these values in the order Header.Payload.Signature with period ('.') characters between the parts yields this complete JWS representation using the JWS Compact Serialization (with line breaks for display purposes only):

```
eyJhbGciOiJIUzI1NiJ9
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGZt
cGx1LmNvbS9pc19yb290Ijpp0cnV1fQ
.
DtEhU31jbEg8L38VWAFUAq0yKAM6 - Xx - F4GawxaepmXFCgfTjDxw5djxLa8IS1SA
pmWQxfKTUJqPP3 - Kg6NU1Q
```

A.3.2. Decoding

TOC

Decoding the JWS requires base64url decoding the Encoded JWS Header, Encoded JWS Payload, and Encoded JWS Signature to produce the JWS Header, JWS Payload, and JWS Signature octet sequences. The octet sequence containing the UTF-8 representation of the JWS Header is decoded into the JWS Header string.

A.3.3. Validating

TOC

Since the `alg` parameter in the header is "ES256", we validate the ECDSA P-256 SHA-256 digital signature contained in the JWS Signature. If any of the validation steps fail, the JWS MUST be rejected.

First, we validate that the JWS Header string is legal JSON.

Validating the JWS Signature is a little different from the first example. First, we base64url decode the Encoded JWS Signature as in the previous examples but we then need to split the 64 member octet sequence that must result into two 32 octet sequences, the first R and the second S. We then pass (x, y), (R, S) and the octets of the ASCII representation of the JWS Signing Input to an ECDSA signature verifier that has been configured to use the P-256 curve with the SHA-256 hash function.

As explained in Section 3.4 of the JSON Web Algorithms (JWA) **[JWA]** specification, the use of the K value in ECDSA means that we cannot validate the correctness of the digital signature in the same way we validated the correctness of the HMAC. Instead, implementations MUST use an ECDSA validator to validate the digital signature.

A.4. Example JWS using ECDSA P-521 SHA-512

TOC

A.4.1. Encoding

TOC

The JWS Header for this example differs from the previous example because a different ECDSA curve and hash function are used. The JWS Header used is:

```
{"alg": "ES512"}
```

The following octet sequence contains the UTF-8 representation of the JWS Header:

```
[123, 34, 97, 108, 103, 34, 58, 34, 69, 83, 53, 49, 50, 34, 125]
```

Base64url encoding these octets yields this Encoded JWS Header value:

eyJhbGciOiJIJFuzUxMiJ9

The JWS Payload used in this example, is the ASCII string "Payload". The representation of this string is the octet sequence:

[80, 97, 121, 108, 111, 97, 100]

Base64url encoding these octets yields the Encoded JWS Payload value:

UGF5bG9hZA

Concatenating the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload yields this JWS Signing Input value:

eyJhbGciOiJIJFuzUxMiJ9.UGF5bG9hZA

The ASCII representation of the JWS Signing Input is the following octet sequence:

[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 70, 85, 122, 85, 120, 77, 105, 74, 57, 46, 85, 71, 70, 53, 98, 71, 57, 104, 90, 65]

The ECDSA key consists of a public part, the EC point (x, y), and a private part d. The values of the ECDSA key used in this example, presented as the octet sequences representing three 521 bit big endian integers are:

Parameter Name	Value
x	[1, 233, 41, 5, 15, 18, 79, 198, 188, 85, 199, 213, 57, 51, 101, 223, 157, 239, 74, 176, 194, 44, 178, 87, 152, 249, 52, 235, 4, 227, 198, 186, 227, 112, 26, 87, 167, 145, 14, 157, 129, 191, 54, 49, 89, 232, 235, 203, 21, 93, 99, 73, 244, 189, 182, 204, 248, 169, 76, 92, 89, 199, 170, 193, 1, 164]
y	[0, 52, 166, 68, 14, 55, 103, 80, 210, 55, 31, 209, 189, 194, 200, 243, 183, 29, 47, 78, 229, 234, 52, 50, 200, 21, 204, 163, 21, 96, 254, 93, 147, 135, 236, 119, 75, 85, 131, 134, 48, 229, 203, 191, 90, 140, 190, 10, 145, 221, 0, 100, 198, 153, 154, 31, 110, 110, 103, 250, 221, 237, 228, 200, 200, 246]
d	[1, 142, 105, 111, 176, 52, 80, 88, 129, 221, 17, 11, 72, 62, 184, 125, 50, 206, 73, 95, 227, 107, 55, 69, 237, 242, 216, 202, 228, 240, 242, 83, 159, 70, 21, 160, 233, 142, 171, 82, 179, 192, 197, 234, 196, 206, 7, 81, 133, 168, 231, 187, 71, 222, 172, 29, 29, 231, 123, 204, 246, 97, 53, 230, 61, 130]

The ECDSA private part d is then passed to an ECDSA signing function, which also takes the curve type, P-521, the hash type, SHA-512, and the octets of the ASCII representation of the JWS Signing Input as inputs. The result of the digital signature is the EC point (R, S), where R and S are unsigned integers. In this example, the R and S values, given as octet sequences representing big endian integers are:

Result Name	Value
R	[1, 220, 12, 129, 231, 171, 194, 209, 232, 135, 233, 117, 247, 105, 122, 210, 26, 125, 192, 1, 217, 21, 82, 91, 45, 240, 255, 83, 19, 34, 239, 71, 48, 157, 147, 152, 105, 18, 53, 108, 163, 214, 68, 231, 62, 153, 150, 106, 194, 164, 246, 72, 143, 138, 24, 50, 129, 223, 133, 206, 209, 172, 63, 237, 119, 109]
S	[0, 111, 6, 105, 44, 5, 41, 208, 128, 61, 152, 40, 92, 61, 152, 4, 150, 66, 60, 69, 247, 196, 170, 81, 193, 199, 78, 59, 194, 169, 16, 124, 9, 143, 42, 142, 131, 48, 206, 238, 34, 175, 83, 203, 220, 159, 3, 107, 155, 22, 27, 73, 111, 68, 68, 21, 238, 144, 229, 232, 148, 188, 222, 59, 242, 103]

Concatenating the S array to the end of the R array and base64url encoding the result

produces this value for the Encoded JWS Signature (with line breaks for display purposes only):

```
AdwMgeerwtHoh-1192160hp9wAHZfVJbLFD_UxMi70cwnZ0YaRI1bKPWR0c-mZZq
wqT2SI-KGDKB34X00aw_7XdtAG8GaSwFKdCAPZgoXD2YBJZCPEX3xKpRwcd008Kp
EHwJjyqOgzD07iKvU8vcnwNrmxYbSW9ERBXuk0Xo1Lze0_Jn
```

Concatenating these values in the order Header.Payload.Signature with period ('.') characters between the parts yields this complete JWS representation using the JWS Compact Serialization (with line breaks for display purposes only):

```
eyJhbGciOiJIJFuzUxMiJ9
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGft
cGx1LmNvbS9pc19yb290Ijpb0cnV1fQ
.
AdwMgeerwtHoh-1192160hp9wAHZfVJbLFD_UxMi70cwnZ0YaRI1bKPWR0c-mZZq
wqT2SI-KGDKB34X00aw_7XdtAG8GaSwFKdCAPZgoXD2YBJZCPEX3xKpRwcd008Kp
EHwJjyqOgzD07iKvU8vcnwNrmxYbSW9ERBXuk0Xo1Lze0_Jn
```

A.4.2. Decoding

TOC

Decoding the JWS requires base64url decoding the Encoded JWS Header, Encoded JWS Payload, and Encoded JWS Signature to produce the JWS Header, JWS Payload, and JWS Signature octet sequences. The octet sequence containing the UTF-8 representation of the JWS Header is decoded into the JWS Header string.

A.4.3. Validating

TOC

Since the `alg` parameter in the header is "ES512", we validate the ECDSA P-521 SHA-512 digital signature contained in the JWS Signature. If any of the validation steps fail, the JWS MUST be rejected.

First, we validate that the JWS Header string is legal JSON.

Validating the JWS Signature is similar to the previous example. First, we base64url decode the Encoded JWS Signature as in the previous examples but we then need to split the 132 member octet sequence that must result into two 66 octet sequences, the first R and the second S. We then pass (x, y), (R, S) and the octets of the ASCII representation of the JWS Signing Input to an ECDSA signature verifier that has been configured to use the P-521 curve with the SHA-512 hash function.

As explained in Section 3.4 of the JSON Web Algorithms (JWA) **[JWA]** specification, the use of the K value in ECDSA means that we cannot validate the correctness of the digital signature in the same way we validated the correctness of the HMAC. Instead, implementations MUST use an ECDSA validator to validate the digital signature.

A.5. Example Plaintext JWS

TOC

The following example JWS Header declares that the encoded object is a Plaintext JWS:

```
{"alg": "none"}
```

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


```
24gQXV0aG9yaXR5MSEwHwYDVQQDEExodHRwOi8vd3d3LnZhbG1jZXJ0LmNvbS8x
IDAeBkgqhkig9w0BCQEWELuZm9AdmFsaWNlcnQuY29tMB4XDTA0MDYyOTE3MDY
yMFoXDTI0MDYyOTE3MDYyMFowYzELMAkGA1UEBhMCMVVMxITAFBgNVBAoTGFROZS
BHbyBEYWRkeSBHcm91cCwgSW5jLjExMC8GA1UECXMOR28gRGFKZHKgQ2xhc3MgM
iBDZXJ0aWZpY2F0aW9uIEF1dGhvcml0eTCCASAwDQYJKoZIhvcNAQEBBQADggEN
ADCCAQgCggEBAN6d1+pXGEmhw+vXX0iG6r7d/+TvZxz0ZWizV3GgXne77ZtJ6XC
APVYYYwhv2vLM0D9/AlQiVBDYsoHUWU9S3/Hd8M+eKsaA7Ugay9qk7HFih7Eux
6wwdhFJ2+qN1j3hybX2C32qRe3H3I2TqYXP2WYktsqbl2i/ojgC95/5Y0V4evL0
tXiEqITLdiOr18SPaAIBQi2XKVLOARFmR6jYGB0xUGlcmIbYsUfb18aQr4CUWwo
riMYavx4A6lNf4DD+qta/KFApMoZfV6yy09ecw3ud72a9nmYvLEHZ6IVDd2gWMZ
Eewo+YihfukEHU1jPEX44dMX4/7Vpki+Ed0qXG68CAQ0jggHhMIIB3TAdBgNVHQ
4EFgQU0sSw0pHUTBFxs2HLPaH+3ahq10MwgdIGA1UdIwSByjCBx6GBwaSBvjCBu
zEkMCIGA1UEBxMbVmFsaUNlcnQgVmFsaWRhdGlvbiB0ZXR3b3JrMRcwFQYDVQQK
Ew5WYwXpQ2VydcCwgSW5jLjE1MDMGA1UECXMsVmFsaUNlcnQgQ2xhc3MgMiBQb2x
pY3kgVmFsaWRhdGlvbiBBdXR0b3JpdHkxITAFBgNVBAMTGg0dHA6Ly93d3cudm
FsaWNlcnQuY29tLzEgMB4GCSqGSIb3DQEJARYRaw5mb0B2YwXpY2Vydc5jb22CA
QEwDwYDVR0TAQH/BAUwAwEB/zAzBggrBgEFBQcBAQQnMCUwIwYIKwYBBQUHMAGG
F2h0dHA6Ly9vY3NwLmdvZGFkZHKuY29tMEQGA1UdHwQ9MDsw0aA3oDWGM2h0dHA
6Ly9jZXJ0aWZpY2F0ZXMuZ29kYWRkeS5jb20vcmlvbmV3NpdG9yeS9yb290LmNybd
BLBgNVHSAERDBCMEAGBFUdIAAwODA2BggrBgEFBQcCARYqaHR0cDovL2NlcnRpZ
mljYXRlcY5nb2RhZGR5LmNvbS9yZXBvc2l0b3J5MA4GA1UdDwEB/wQEAwIBBjAN
Bkgqhkig9w0BAQUFAA0BgQC1QPmnHfbq/qQaQlpE9xXUuUaJwL6e4+PrxeNYiY+
Sn1eocSxI0YgyeR+sBjUZsE40WBSUs5iB0QQeyAfJg594RAoYC5jcdnplDQ1tgM
QLARzLrUc+cb53S8wGd9D0VmsfSx0aFIqII6hR8INMqzW/Rn453HWkrugp++85j
09VZw==",
```

```
"MIIC5zCCAlACAQEwDQYJKoZIhvcNAQEFBQAwwgsxJDAiBgNVBACGTG1ZhbG1DZXJ
0IFZhbG1kYXRpb24gTmV0d29yazEXMBUGA1UEChM0VmFsaUNlcnQsIEluYy4xNT
AzBgNVBAsTFLZhbG1DZXJ0IENsYXNzIDIgUG9saWN5IFZhbG1kYXRpb24gQXV0a
G9yaXR5MSEwHwYDVQQDEExodHRwOi8vd3d3LnZhbG1jZXJ0LmNvbS8xIDAeBkgq
hkig9w0BCQEWELuZm9AdmFsaWNlcnQuY29tMB4XDTk5MDYyNjAwMTk1NFoXDTI0
5MDYyNjAwMTk1NFowgbsxJDAiBgNVBACGTG1ZhbG1DZXJ0IFZhbG1kYXRpb24gTm
V0d29yazEXMBUGA1UEChM0VmFsaUNlcnQsIEluYy4xNTAzBgNVBAsTFLZhbG1DZ
XJ0IENsYXNzIDIgUG9saWN5IFZhbG1kYXRpb24gQXV0aG9yaXR5MSEwHwYDVQQD
ExodHRwOi8vd3d3LnZhbG1jZXJ0LmNvbS8xIDAeBkgqhkig9w0BCQEWELuZm9
AdmFsaWNlcnQuY29tMIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQD00nHK5a
vIWZJV16vYdA757tn2VUdZZUcOBVXc65g2PFxTXdMwzzj svUGJ7SVCCSRrC16zf
N1SLUzm1NZ9WlmpZdRJEy0kTRxQb7XBhVQ7/nHk01xC+YDgkRoKwzk2Z/M/VXwb
P7RfZHM047Qsv4dk+NoS/zcnwbNDu+97bi5p9wIDAQABMA0GCSqGSIb3DQEBBQU
AA4GBADt/UG9vUJSZSWI40B9L+KXIPqeCgfYrx+jFzug6EILLGAC0Tb2oWH+heQ
C1u+mNr0HZDzTuIYEZodJJKPTEjlbVUjP9UNV+mWwD5M1M/Mtsq2azSiGM5bUMM
j4QssxsodyamEwCW/POuZ6lcg5Ktz885hZo+L7tdEy8W9ViH0Pd"]
```

Appendix C. Notes on implementing base64url encoding without padding

TOC

This appendix describes how to implement base64url encoding and decoding functions without padding based upon standard base64 encoding and decoding functions that do use padding.

To be concrete, example C# code implementing these functions is shown below. Similar code could be used in other languages.

```
static string base64urlencode(byte [] arg)
{
    string s = Convert.ToBase64String(arg); // Regular base64 encoder
    s = s.Split('=')[0]; // Remove any trailing '='s
    s = s.Replace('+', '-'); // 62nd char of encoding
    s = s.Replace('/', '_'); // 63rd char of encoding
    return s;
}

static byte [] base64urldecode(string arg)
{
    string s = arg;
    s = s.Replace('-', '+'); // 62nd char of encoding
```

```
s = s.Replace('_', '/'); // 63rd char of encoding
switch (s.Length % 4) // Pad with trailing '='s
{
    case 0: break; // No pad chars in this case
    case 2: s += "=="; break; // Two pad chars
    case 3: s += "="; break; // One pad char
    default: throw new System.Exception(
        "Illegal base64url string!");
}
return Convert.FromBase64String(s); // Standard base64 decoder
}
```

As per the example code above, the number of '=' padding characters that needs to be added to the end of a base64url encoded string without padding to turn it into one with padding is a deterministic function of the length of the encoded string. Specifically, if the length mod 4 is 0, no padding is added; if the length mod 4 is 2, two '=' padding characters are added; if the length mod 4 is 3, one '=' padding character is added; if the length mod 4 is 1, the input is malformed.

An example correspondence between unencoded and encoded values follows. The octet sequence below encodes into the string below, which when decoded, reproduces the octet sequence.

```
3 236 255 224 193
```

```
A-z_4ME
```

Appendix D. Acknowledgements

TOC

Solutions for signing JSON content were previously explored by **Magic Signatures** [MagicSignatures], **JSON Simple Sign** [JSS], and **Canvas Applications** [CanvasApp], all of which influenced this draft.

Thanks to Axel Nennker for his early implementation and feedback on the JWS and JWE specifications.

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, Brian Campbell, Breno de Medeiros, Dick Hardt, Joe Hildebrand, Jeff Hodges, Edmund Jay, Yaron Y. Goland, Ben Laurie, James Manger, Tony Nadalin, Axel Nennker, John Panzer, Emmanuel Raviart, Eric Rescorla, 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]]

-09

- Added JWS JSON Serialization, as specified by draft-jones-jose-jws-json-serialization-04.
- Registered `application/jws-js` MIME type and `JWS-JS` typ header parameter value.
- Defined that the default action for header parameters that are not understood is to ignore them unless specifically designated as "MUST be understood" or

included in the new `crit` (critical) header parameter list. This addressed issue #6.

- Changed term "JWS Secured Input" to "JWS Signing Input".
- Changed from using the term "byte" to "octet" when referring to 8 bit values.
- Changed member name from `recipients` to `signatures` in the JWS JSON Serialization.
- Added complete values using the JWS Compact Serialization for all examples.

-08

- Applied editorial improvements suggested by Jeff Hodges and Hannes Tschofenig. Many of these simplified the terminology used.
- Clarified statements of the form "This header parameter is OPTIONAL" to "Use of this header parameter is OPTIONAL".
- Added a Header Parameter Usage Location(s) field to the IANA JSON Web Signature and Encryption Header Parameters registry.
- Added seriesInfo information to Internet Draft references.

-07

- Updated references.

-06

- Changed `x5c` (X.509 Certificate Chain) representation from being a single string to being an array of strings, each containing a single base64 encoded DER certificate value, representing elements of the certificate chain.
- Applied changes made by the RFC Editor to RFC 6749's registry language to this specification.

-05

- Added statement that "StringOrURI values are compared as case-sensitive strings with no transformations or canonicalizations applied".
- Indented artwork elements to better distinguish them from the body text.

-04

- Completed JSON Security Considerations section, including considerations about rejecting input with duplicate member names.
- Completed security considerations on the use of a SHA-1 hash when computing `x5t` (x.509 certificate thumbprint) values.
- 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."
- Reference draft-jones-jose-jws-json-serialization instead of draft-jones-json-web-signature-json-serialization.
- Described additional open issues.
- Applied editorial suggestions.

-03

- Added the `cty` (content type) header parameter for declaring type information about the secured content, as opposed to the `typ` (type) header parameter, which declares type information about this object.
- Added "Collision Resistant Namespace" to the terminology section.
- Reference ITU.X690.1994 for DER encoding.
- Added an example JWS using ECDSA P-521 SHA-512. This has particular illustrative value because of the use of the 521 bit integers in the key and signature values. This is also an example in which the payload is not a base64url encoded JSON object.
- Added an example `x5c` value.
- No longer say "the UTF-8 representation of the JWS Secured Input (which is the same as the ASCII representation)". Just call it "the ASCII representation of the JWS Secured Input".

- Added Registration Template sections for defined registries.
- Added Registry Contents sections to populate registry values.
- Changed name of the JSON Web Signature and Encryption "typ" Values registry to be the JSON Web Signature and Encryption Type Values registry, since it is used for more than just values of the `typ` parameter.
- Moved registries JSON Web Signature and Encryption Header Parameters and JSON Web Signature and Encryption Type Values to the JWS specification.
- Numerous editorial improvements.

-02

- Clarified that it is an error when a `kid` value is included and no matching key is found.
- Removed assumption that `kid` (key ID) can only refer to an asymmetric key.
- Clarified that JWSs with duplicate Header Parameter Names MUST be rejected.
- Clarified the relationship between `typ` header parameter values and MIME types.
- Registered application/jws MIME type and "JWS" `typ` header parameter value.
- Simplified JWK terminology to get replace the "JWK Key Object" and "JWK Container Object" terms with simply "JSON Web Key (JWK)" and "JSON Web Key Set (JWK Set)" and to eliminate potential confusion between single keys and sets of keys. As part of this change, the Header Parameter Name for a public key value was changed from `jpk` (JSON Public Key) to `jwk` (JSON Web Key).
- Added suggestion on defining additional header parameters such as `x5t#S256` in the future for certificate thumbprints using hash algorithms other than SHA-1.
- Specify RFC 2818 server identity validation, rather than RFC 6125 (paralleling the same decision in the OAuth specs).
- Generalized language to refer to Message Authentication Codes (MACs) rather than Hash-based Message Authentication Codes (HMACs) unless in a context specific to HMAC algorithms.
- Reformatted to give each header parameter its own section heading.

-01

- Moved definition of Plaintext JWSs (using "alg":"none") here from the JWT specification since this functionality is likely to be useful in more contexts that just for JWTs.
- Added `jpk` and `x5c` header parameters for including JWK public keys and X.509 certificate chains directly in the header.
- Clarified that this specification is defining the JWS Compact Serialization. Referenced the new JWS-JS spec, which defines the JWS JSON Serialization.
- Added text "New header parameters should be introduced sparingly since an implementation that does not understand a parameter MUST reject the JWS".
- Clarified that the order of the creation and validation steps is not significant in cases where there are no dependencies between the inputs and outputs of the steps.
- Changed "no canonicalization is performed" to "no canonicalization need be performed".
- Corrected the Magic Signatures reference.
- Made other editorial improvements suggested by JOSE working group participants.

-00

- Created the initial IETF draft based upon draft-jones-json-web-signature-04 with no normative changes.
- Changed terminology to no longer call both digital signatures and HMACs "signatures".

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