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JSON Web Signature (JWS) draft-ietf-jose-json-web-signature-01

Abstract

JSON Web Signature (JWS) is a means of representing content secured with digital signatures or Hash-based Message Authentication Codes (HMACs) using JSON data structures. Cryptographic algorithms and identifiers used with this specification are enumerated in the separate JSON Web Algorithms (JWA) specification. Related encryption capabilities are described in the separate JSON Web Encryption (JWE) specification.

Requirements Language

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 **RFC 2119** [RFC2119].

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Table of Contents

- 1. Introduction**
- 2. Terminology**
- 3. JSON Web Signature (JWS) Overview**
 - 3.1. Example JWS**

- 4. JWS Header**
 - 4.1. Reserved Header Parameter Names**
 - 4.2. Public Header Parameter Names**
 - 4.3. Private Header Parameter Names**
- 5. Rules for Creating and Validating a JWS**
- 6. Securing JWSs with Cryptographic Algorithms**
- 7. IANA Considerations**
- 8. Security Considerations**
 - 8.1. Unicode Comparison Security Issues**
- 9. Open Issues and Things To Be Done (TBD)**
- 10. References**
 - 10.1. Normative References**
 - 10.2. Informative References**
- Appendix A. JWS Examples**
 - A.1. JWS using HMAC SHA-256**
 - A.1.1. Encoding**
 - A.1.2. Decoding**
 - A.1.3. Validating**
 - A.2. JWS using RSA SHA-256**
 - A.2.1. Encoding**
 - A.2.2. Decoding**
 - A.2.3. Validating**
 - A.3. JWS using ECDSA P-256 SHA-256**
 - A.3.1. Encoding**
 - A.3.2. Decoding**
 - A.3.3. Validating**
 - A.4. Example Plaintext JWS**
- Appendix B. Notes on implementing base64url encoding without padding**
- Appendix C. Acknowledgements**
- Appendix D. Document History**
- § Authors' Addresses**

1. Introduction

TOC

JSON Web Signature (JWS) is a compact format for representing content secured with digital signatures or Hash-based Message Authentication Codes (HMACs) intended for space constrained environments such as HTTP Authorization headers and URI query parameters. It represents this content using JSON **[RFC4627]** data structures. The JWS digital signature and HMAC mechanisms are independent of the type of content being secured, allowing arbitrary content to be secured. Cryptographic algorithms and identifiers used with this specification are enumerated in the separate JSON Web Algorithms (JWA) **[JWA]** specification. Related encryption capabilities are described in the separate JSON Web Encryption (JWE) **[JWE]** specification.

2. Terminology

TOC

- JSON Web Signature (JWS)
 - A data structure cryptographically securing a JWS Header and a JWS Payload with a JWS Signature value.
- JWS Header
 - A string representing a JSON object that describes the digital signature or HMAC applied to the JWS Header and the JWS Payload to create the JWS Signature value.
- JWS Payload
 - The bytes to be secured - a.k.a., the message.
- JWS Signature
 - A byte array containing the cryptographic material that secures the contents of the JWS Header and the JWS Payload.
- Encoded JWS Header
 - Base64url encoding of the bytes of the UTF-8 **RFC 3629** [RFC3629] representation of the JWS Header.
- Encoded JWS Payload

Base64url encoding of the JWS Payload.
Encoded JWS Signature
Base64url encoding of the JWS Signature.
JWS Secured Input
The concatenation of the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload.
Header Parameter Names
The names of the members within the JSON object represented in a JWS Header.
Header Parameter Values
The values of the members within the JSON object represented in a 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 period ('.') characters.
Base64url Encoding
For the purposes of this specification, this term always refers to 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 B** for notes on implementing base64url encoding without padding.)

3. JSON Web Signature (JWS) Overview

TOC

JWS represents digitally signed or HMACed content using JSON data structures and base64url encoding. The representation consists of three parts: the JWS Header, the JWS Payload, and the JWS Signature. In the Compact Serialization, the three parts are base64url-encoded for transmission, and represented as the concatenation of the encoded strings in that order, with the three strings being separated by period ('.') characters. (A JSON Serialization for this information is defined in the separate JSON Web Signature JSON Serialization (JWS-JS) **[JWS-JS]** specification.)

The JWS Header describes the signature or HMAC 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 bytes 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 bytes of the UTF-8 representation of the JSON object yields the following Encoded JWS Payload (with line breaks for display purposes only):

```
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFTcGx1LmNvbS9pc19yb290Ijp0cnVlfQ
```

Computing the HMAC of the UTF-8 representation of the JWS Secured Input (the concatenation of the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload) with the HMAC SHA-256 algorithm and base64url encoding the result, as per **Appendix A.1**, yields this Encoded JWS Signature value:

```
dBjftJeZ4CVP-mB92K27uhbUJU1p1r_wW1gFwF0EjXk
```

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

```
eyJ0eXAiOiJKV1QiLA0KICJhbGciOiJIUzI1NiJ9
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFTcGx1LmNvbS9pc19yb290Ijp0cnVlfQ
.
dBjftJeZ4CVP-mB92K27uhbUJU1p1r_wW1gFwF0EjXk
```

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 HMAC 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. Implementations MUST understand the entire contents of the header; otherwise, the JWS MUST be rejected.

The JWS Header MUST contain an `alg` (algorithm) parameter, the value of which is a string that unambiguously identifies the algorithm used to secure the JWS Header and the JWS Payload to produce the JWS Signature.

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. All the names are short because a core goal of JWSs is for the representations to be compact.

Header Parameter Name	JSON Value Type	Header Parameter Syntax	Header Parameter Semantics
<code>alg</code>	string	StringOrURI	The <code>alg</code> (algorithm) header parameter identifies the cryptographic algorithm used to secure the JWS. A list of defined <code>alg</code> values is presented in Section 3, Table 1 of the JSON Web Algorithms (JWA) [JWA] specification. The processing of the <code>alg</code> header parameter requires that the value MUST be one that is

			both supported and for which there exists a key for use with that algorithm associated with the party that digitally signed or HMACed the content. The <code>alg</code> parameter value is case sensitive. This header parameter is REQUIRED.
<code>jku</code>	string	URL	The <code>jku</code> (JSON Web Key URL) header parameter is an absolute URL that refers to a resource for a set of JSON-encoded public keys, one of which corresponds to the key that was used to digitally sign the JWS. The keys MUST be encoded as described in the JSON Web Key (JWK) [JWK] specification. The protocol used to acquire the resource MUST provide integrity protection. An HTTP GET request to retrieve the certificate MUST use TLS RFC 2818 [RFC2818] RFC 5246 [RFC5246] with server authentication RFC 6125 [RFC6125]. This header parameter is OPTIONAL.
<code>kid</code>	string	String	The <code>kid</code> (key ID) header parameter is a hint indicating which specific key owned by the signer should be used to validate the digital signature. This allows signers to explicitly signal a change of key to recipients. The interpretation of the contents of the <code>kid</code> parameter is unspecified. This header parameter is OPTIONAL.
<code>jpk</code>	object	JWK Key Object	The <code>jpk</code> (JSON Public Key) header parameter is a public key that corresponds to the key that was used to digitally sign the JWS. This key is represented in the same manner as a JSON Web Key [JWK] JWK Key Object value. This header parameter is OPTIONAL.
<code>x5u</code>	string	URL	The <code>x5u</code> (X.509 URL) header parameter is an absolute URL that refers to a resource for the X.509 public key certificate or certificate chain 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 RFC 1421 [RFC1421]. The certificate containing the public key of the entity signing 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 RFC 2818 [RFC2818] RFC 5246 [RFC5246] with server authentication RFC 6125 [RFC6125]. This header parameter is OPTIONAL.
<code>x5t</code>	string	String	The <code>x5t</code> (x.509 certificate thumbprint) header parameter provides a base64url encoded SHA-1 thumbprint (a.k.a. digest) of the DER encoding of an X.509 certificate that can be used to match the certificate. This header parameter is OPTIONAL.
<code>x5c</code>	array	ArrayOfStrings	The <code>x5c</code> (x.509 certificate chain) header parameter contains the X.509 public key certificate or certificate chain corresponding to the key used to digitally sign the JWS. The certificate or certificate chain is represented as an array of certificate values. Each value is a base64-encoded (not base64url encoded) DER/BER PKIX certificate value. The certificate containing the public key of the entity signing 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. This header parameter is OPTIONAL.
<code>typ</code>	string	String	The <code>typ</code> (type) header parameter is used to declare the type of the secured content. The <code>typ</code> value is case sensitive. This header parameter is OPTIONAL.

Table 1: Reserved Header Parameter Definitions

Additional reserved header parameter names MAY be defined via the IANA JSON Web Signature Header Parameters registry, as per **Section 7**. The syntax values used above are defined as follows:

Syntax Name	Syntax Definition
IntDate	The number of seconds from 1970-01-01T0:0:0Z as measured in UTC until the desired date/time. See RFC 3339 [RFC3339] for details regarding date/times in general and UTC in particular.
String	Any string value MAY be used.
StringOrURI	Any string value MAY be used but a value containing a ":" character MUST be a URI as defined in RFC 3986 [RFC3986].
URL	A URL as defined in RFC 1738 [RFC1738].
ArrayOfStrings	An array of string values.

Table 2: Header Parameter Syntax Definitions

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 or algorithm value SHOULD either be defined in the IANA JSON Web Signature Header Parameters registry or be defined as a URI 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 since an implementation that does not understand a parameter MUST reject the JWS.

4.3. Private Header Parameter Names

TOC

A producer and consumer of a JWS may agree to any header parameter name that is not a Reserved Name **Section 4.1** or a Public Name **Section 4.2**. Unlike Public Names, these private names are subject to collision and should be used with caution.

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

5. Rules for Creating and Validating a JWS

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 bytes 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 bytes 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. The JWS Secured Input is always the concatenation of the Encoded JWS Header, a period ('.') character, and the Encoded JWS Payload. (Note that if the JWS represents a JWT, this corresponds to the portion of the JWT representation preceding the second period character.) The `alg` (algorithm) header parameter MUST be present in the JSON 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, taken together, are the result. The 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 period ('.') characters.

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 three parts of the input (which are separated by period characters when using the JWS Compact Serialization) into the Encoded JWS Header, the Encoded JWS Payload, and the Encoded JWS Signature.
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 JWS Header **MUST** be completely valid JSON syntax conforming to **RFC 4627** [RFC4627].
4. The JWS Header **MUST** be validated to only include parameters and values whose syntax and semantics are both understood and supported.
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 Secured 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.

Processing a JWS inevitably requires comparing known strings to values in the header. 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 applied escaping to produce an array of Unicode code points.
2. **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.
3. Comparisons between the two strings **MUST** be performed as a Unicode code point to code point equality comparison.

6. Securing JWSs with Cryptographic Algorithms

TOC

JWS uses cryptographic algorithms to digitally sign or HMAC the contents of the JWS Header and the JWS Payload. The JSON Web Algorithms (JWA) **[JWA]** specification enumerates a set of cryptographic algorithms and identifiers to be used with this specification. Specifically, Section 3, Table 1 enumerates 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 and algorithm families.

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. IANA Considerations

TOC

This specification calls for:

- A new IANA registry entitled "JSON Web Signature Header Parameters" for reserved header parameter names is defined in **Section 4.1**. Inclusion in the registry is RFC Required in the **RFC 5226** [RFC5226] sense for reserved JWS

header parameter names that are intended to be interoperable between implementations. The registry will just record the reserved header parameter name and a pointer to the RFC that defines it. This specification defines inclusion of the header parameter names defined in **Table 1**.

8. Security Considerations

TOC

TBD: Lots of work to do here. We need to remember to look into any issues relating to security and JSON parsing. One wonders just how secure most JSON parsing libraries are. Were they ever hardened for security scenarios? If not, what kind of holes does that open up? Also, we need to walk through the JSON standard and see what kind of issues we have especially around comparison of names. For instance, comparisons of header parameter names and other parameters must occur after they are unescaped. Need to also put in text about: Importance of keeping secrets secret. Rotating keys. Strengths and weaknesses of the different algorithms.

TBD: Need to put in text about why strict JSON validation is necessary. Basically, that if malformed JSON is received then the intent of the sender is impossible to reliably discern. One example of malformed JSON that MUST be rejected is an object in which the same member name occurs multiple times.

TBD: Write security considerations about the implications of using a SHA-1 hash (for compatibility reasons) for the `x5t` (x.509 certificate thumbprint).

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

8.1. Unicode Comparison Security Issues

TOC

Header parameter names in JWSs 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`", "`s\u0047`").

JSON strings MAY 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.

9. Open Issues and Things To Be Done (TBD)

TOC

The following items remain to be done in this draft:

- EDITORIAL: Give each header parameter definition its own section. This will let them appear in the index, will give space for examples when needed, and will get rid of the way-too-cramped tables.
- Describe the relationship between the JWS, JWE, and JWT header parameters. In particular, point out that the set of `alg` values defined by each must be compatible and non-overlapping.
- Combine the JWS and JWE `alg` parameter registries and possibly also the header parameter registries.
- Clarify the intended use of the `typ` Header Parameter across the JWS, JWE, and JWT specifications. Decide whether a registry of `typ` values is appropriate.
- Add normative text that requires rejecting headers in which member names occur multiple times, as apparently this is legal JSON.

- Clarify the semantics of the `kid` (key ID) header parameter. Open issues include: What happens if a `kid` header is received with an unrecognized value? Is that an error? Should it be treated as if it's empty? What happens if the header has a recognized value but the value doesn't match the key associated with that value, but it does match another key that is associated with the issuer? Is that an error?
- Consider whether a key type parameter should also be introduced.
- It would be good to have a confirmation method element so it could be used with holder-of-key.
- EDITORIAL: Think about how to best describe the concept currently described as "the bytes of the UTF-8 representation of". Possible terms to use instead of "bytes of" include "byte sequence", "octet series", and "octet sequence". Also consider whether we want to add an overall clarifying statement somewhere in each spec something like "every place we say 'the UTF-8 representation of X', we mean 'the bytes of the UTF-8 representation of X'". That would potentially allow us to omit the "the bytes of" part everywhere else.
- Write a note in the Security Considerations section about how `x5t` (x.509 certificate thumbprint) should be deprecated because of known problems with SHA-1.
- Add Security Considerations text on timing attacks.
- Finish the Security Considerations section.
- EDITORIAL: Add an example in which the payload is not a base64url encoded JSON object.

10. References

TOC

10.1. Normative References

TOC

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10.2. Informative References

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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. 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 Secured Input is secured using the HMAC SHA-256 algorithm.

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

The following byte array contains the UTF-8 characters for 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 this UTF-8 representation yields this Encoded JWS Header value:

```
eyJ0eXAiOiJKV1QiLA0KICJhbGciOiJIUzI1NiJ9
```

The JWS Payload used in this example follows. (Note that the payload can be any base64url encoded content, and need not be a base64url encoded JSON object.)

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

The following byte array contains the UTF-8 characters for 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):

```
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFt
cGx1LmNvbS9pc19yb290IjpcnV1fQ
```

Concatenating the Encoded JWS Header, a period character, and the Encoded JWS Payload

yields this JWS Secured Input value (with line breaks for display purposes only):

```
eyJ0eXAiOiJKV1QiLA0KICJhbGciOiJIUzI1NiJ9
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFt
cGx1LmNvbS9pc19yb290Ijpb0cnV1fQ
```

The UTF-8 representation of the JWS Secured Input is the following byte array:

```
[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 byte array:

```
[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 UTF-8 representation of the JWS Secured Input with this key yields the following byte array:

```
[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_wW1gFwF0EjXk
```

A.1.2. Decoding

TOC

Decoding the JWS first requires removing the base64url encoding from the Encoded JWS Header, the Encoded JWS Payload, and the Encoded JWS Signature. We base64url decode the inputs and turn them into the corresponding byte arrays. We translate the header input byte array containing UTF-8 encoded characters 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 UTF-8 representation of the JWS Secured Input as input to a SHA-256 HMAC 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. JWS using RSA SHA-256

TOC

A.2.1. Encoding

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 byte array contains the UTF-8 characters for the JWS Header:

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

Base64url encoding this UTF-8 representation 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 Secured Input value (with line breaks for display purposes only):

```
eyJhbGciOiJSUzI1NiJ9
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFt
cGxlLmNvbS9pc19yb290Ijpb0cnVlfnQ
```

The UTF-8 representation of the JWS Secured Input is the following byte array:

```
[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 (n, e), and a private exponent d. The values of the RSA key used in this example, presented as the byte arrays representing big endian integers are:

Parameter Name	Value
n	[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,

e	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]
	[1, 0, 1]
d	[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 (n, d) is then passed to the RSA signing function, which also takes the hash type, SHA-256, and the UTF-8 representation of the JWS Secured Input as inputs. The result of the digital signature is a byte array S, which represents a big endian integer. In this example, S is:

Result Name	Value
S	[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-e0kHWesqtFZESc6BfI7noOPqv
hJ1phCnvWh6IeYI2w9Q0YEUipUTI8np6LbgGY9Fs98rqVt5AXLIhWkWyw1VmtVrB
p0igcN_IoypGLUPQGe77Rw
```

A.2.2. Decoding

TOC

Decoding the JWS from this example requires processing the Encoded JWS Header and Encoded JWS Payload exactly as done in the first example.

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 UTF-8 representation of the JWS Secured Input to an RSA signature verifier that has been configured to use the SHA-256 hash function.

A.3. 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 byte array contains the UTF-8 characters for the JWS Header:

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

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

```
eyJhbGciOiJIJFUiI1NiJ9
```

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 Secured Input value (with line breaks for display purposes only):

```
eyJhbGciOiJIJFUiI1NiJ9  
.  
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFt  
cGx1LmNvbS9pc19yb290Ijpb0cnV1fQ
```

The UTF-8 representation of the JWS Secured Input is the following byte array:

```
[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 byte arrays representing 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 UTF-8 representation of the JWS Secured 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 byte arrays 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
```

A.3.2. Decoding

TOC

Decoding the JWS from this example requires processing the Encoded JWS Header and Encoded JWS Payload exactly as done in the first example.

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 byte array that must result into two 32 byte arrays, the first R and the second S. We then pass (x, y), (R, S) and the UTF-8 representation of the JWS Secured 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 3.3 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 Plaintext JWS

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

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

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

```
eyJhbGciOiJub25lIn0
```

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}
```

The Encoded JWS Signature is the empty string.

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

```
eyJhbGciOiJub25lIn0
.
eyJpc3MiOiJqb2UiLA0KICJleHAiOjEzMDA4MTkzODAsDQogImh0dHA6Ly9leGFT
cGxlLmNvbS9pc19yb290IjpcnV1fQ
.
```

Appendix B. Notes on implementing base64url encoding without padding

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); // Standard 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 byte sequence below encodes into the string below, which when decoded, reproduces the byte sequence.

```
3 236 255 224 193
```

```
A-z_4ME
```

Appendix C. 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. Dirk Balfanz, Yaron Y. Goland, John Panzer, and Paul Tarjan all made significant contributions to the design of this specification.

Appendix D. Document History

TOC

-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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