Abstract

This specification describes how to declare in a CBOR Web Token (CWT) that the presenter of the CWT possesses a particular proof-of-possession key. Being able to prove possession of a key is also sometimes described as being the holder-of-key. This specification provides equivalent functionality to "Proof-of-Possession Key Semantics for JSON Web Tokens (JWTs)" (RFC 7800) but using CBOR and CWTs rather than JSON and JWTs.
1. Introduction

This specification describes how a CBOR Web Token (CWT) [RFC8392] can declare that the presenter of the CWT possesses a particular proof-of-possession (PoP) key. Proof of possession of a key is also sometimes described as being the holder-of-key. This specification provides equivalent functionality to "Proof-of-Possession Key Semantics for JSON Web Tokens (JWTs)" [RFC7800] but using CBOR [RFC7049] and CWTs [RFC8392] rather than JSON [RFC8259] and JWTs [JWT].
2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] and [RFC8174] when, and only when, they appear in all capitals, as shown here.

This specification uses terms defined in the CBOR Web Token (CWT) [RFC8392], CBOR Object Signing and Encryption (COSE) [RFC8152], and Concise Binary Object Representation (CBOR) [RFC7049] specifications.

These terms are defined by this specification:

**Issuer**
- Party that creates the CWT and binds the claims about the subject to the proof-of-possession key.

**Presenter**
- Party that proves possession of a private key (for asymmetric key cryptography) or secret key (for symmetric key cryptography) to a recipient of a CWT.
  
  In the context of OAuth, this party is also called the OAuth Client.

**Recipient**
- Party that receives the CWT containing the proof-of-possession key information from the presenter.
  
  In the context of OAuth, this party is also called the OAuth Resource Server.

This specification provides examples in CBOR extended diagnostic notation, as defined in Appendix G of [RFC8610]. The examples include line breaks for readability.

3. Representations for Proof-of-Possession Keys

By including a "cnf" (confirmation) claim in a CWT, the issuer of the CWT declares that the presenter possesses a particular key and that the recipient can cryptographically confirm that the presenter has possession of that key. The value of the "cnf" claim is a CBOR map and the members of that map identify the proof-of-possession key.

The presenter can be identified in one of several ways by the CWT, depending upon the application requirements. For instance, some applications may use the CWT "sub" (subject) claim [RFC8392], to identify the presenter. Other applications may use the "iss" claim to identify the presenter. In some applications, the subject
identifier might be relative to the issuer identified by the "iss" (issuer) claim [RFC8392]. The actual mechanism used is dependent upon the application. The case in which the presenter is the subject of the CWT is analogous to Security Assertion Markup Language (SAML) 2.0 [OASIS.saml-core-2.0-os] SubjectConfirmation usage.

3.1. Confirmation Claim

The "cnf" claim in the CWT is used to carry confirmation methods. Some of them use proof-of-possession keys while others do not. This design is analogous to the SAML 2.0 [OASIS.saml-core-2.0-os] SubjectConfirmation element in which a number of different subject confirmation methods can be included (including proof-of-possession key information).

The set of confirmation members that a CWT must contain to be considered valid is context dependent and is outside the scope of this specification. Specific applications of CWTs will require implementations to understand and process some confirmation members in particular ways. However, in the absence of such requirements, all confirmation members that are not understood by implementations MUST be ignored.

This specification establishes the IANA "CWT Confirmation Methods" registry for these members in Section 7.2 and registers the members defined by this specification. Other specifications can register other members used for confirmation, including other members for conveying proof-of-possession keys using different key representations.

The "cnf" claim value MUST represent only a single proof-of-possession key. At most one of the "COSE_Key" and "Encrypted_COSE_Key" confirmation values defined in Figure 1 may be present. Note that if an application needs to represent multiple proof-of-possession keys in the same CWT, one way for it to achieve this is to use other claim names, in addition to "cnf", to hold the additional proof-of-possession key information. These claims could use the same syntax and semantics as the "cnf" claim. Those claims would be defined by applications or other specifications and could be registered in the IANA "CBOR Web Token Claims" registry [IANA.CWT.Claims].
3.2. Representation of an Asymmetric Proof-of-Possession Key

When the key held by the presenter is an asymmetric private key, the "COSE_Key" member is a COSE_Key [RFC8152] representing the corresponding asymmetric public key. The following example demonstrates such a declaration in the CWT Claims Set of a CWT:

```
{
  /iss/ 1 : "coaps://server.example.com",
  /aud/ 3 : "coaps://client.example.org",
  /exp/ 4 : 1879067471,
  /cnf/ 8 :{
    /COSE_Key/ 1 :{
      /kty/ 1 : /EC2/ 2,
      /crv/ -1 : /P-256/ 1,
      /x/ -2 : h’d7cc072de2205bdc1537a543d60a6acb62eccd8907fa27c9
             e354089bbe13’,
      /y/ -3 : h’f95e1d4b851a2cc80ff87d8e23f22af7b725d535e515d020731e
             79a3b4e47120’
    };
  }
}
```

The COSE_Key MUST contain the required key members for a COSE_Key of that key type and MAY contain other COSE_Key members, including the "kid" (Key ID) member.

The "COSE_Key" member MAY also be used for a COSE_Key representing a symmetric key, provided that the CWT is encrypted so that the key is not revealed to unintended parties. The means of encrypting a CWT is explained in [RFC8392]. If the CWT is not encrypted, the symmetric key MUST be encrypted as described in Section 3.3.

3.3. Representation of an Encrypted Symmetric Proof-of-Possession Key

When the key held by the presenter is a symmetric key, the "Encrypted_COSE_Key" member is an encrypted COSE_Key [RFC8152]
representing the symmetric key encrypted to a key known to the recipient using COSE_Encrypt or COSE_Encrypt0.

The following example illustrates a symmetric key that could subsequently be encrypted for use in the "Encrypted_COSE_Key" member:

```
{
  /kty/ 1 : /Symmetric/ 4,
  /alg/ 3 : /HMAC256//256/ 5,
  /k/ -1 : h'6684523ab17337f173500e5728c628547cb37df68449c65f885d1b73b49eae1'
}
```

The COSE_Key representation is used as the plaintext when encrypting the key.

The following example CWT Claims Set of a CWT illustrates the use of an encrypted symmetric key as the "Encrypted_COSE_Key" member value:

```
{
  /iss/ 1 : "coaps://server.example.com",
  /sub/ 2 : "24400320",
  /aud/ 3: "s6BhdRkqt3",
  /exp/ 4 : 1311281970,
  /iat/ 5 : 1311280970,
  /cnf/ 8 : { 
    /Encrypted_COSE_Key/ 2 : [
      /protected header/ h'A1010A' /{ /alg\ 1:10 \AES-CCM-16-64-128\}/, 
      /unprotected header/ { / iv / 5: h'636898994FF0EC7BF CF6D3F95B' }, 
      /ciphertext/ h'0573318A3573EB983E55A7C2F06CA7D0796C9E584F1D0E3E
        A8C5B052592A8B2694BE9654F0431F38D5B8C8049FA7F13F'
    ]
  }
}
```

The example above was generated with the key:

```
h'6162630405060708090a0b0c0d0e0f10'
```

### 3.4. Representation of a Key ID for a Proof-of-Possession Key

The proof-of-possession key can also be identified using a Key ID instead of communicating the actual key, provided the recipient is able to obtain the identified key using the Key ID. In this case, the issuer of a CWT declares that the presenter possesses a particular key and that the recipient can cryptographically confirm proof of possession of the key by the presenter by including a "cnf"
claim in the CWT whose value is a CBOR map with the CBOR map containing a "kid" member identifying the key.

The following example demonstrates such a declaration in the CWT Claims Set of a CWT:

```
{
  /iss/ 1 : "coaps://as.example.com",
  /aud/ 3 : "coaps://resource.example.org",
  /exp/ 4 : 1361398824,
  /cnf/ 8 : {
    /kid/ 3 : h’dfd1aa976d8d4575a0fe34b96de2bfad’
  }
}
```

The content of the "kid" value is application specific. For instance, some applications may choose to use a cryptographic hash of the public key value as the "kid" value.

Note that the use of a Key ID to identify a proof-of-possession key needs to be carefully circumscribed, as described below and in Section 6. In cases where the Key ID is not a cryptographic value derived from the key or where not all of the parties involved are validating the cryptographic derivation, implementers should expect collisions, where different keys are assigned the same Key ID. Recipients of a CWT with a PoP key linked through only a Key ID should be prepared to handle such situations.

In the world of constrained Internet of Things (IoT) devices, there is frequently a restriction on the size of Key IDs, either because of table constraints or a desire to keep message sizes small.

3.5. Specifics Intentionally Not Specified

Proof of possession is often demonstrated by having the presenter sign a value determined by the recipient using the key possessed by the presenter. This value is sometimes called a "nonce" or a "challenge". There are, however, also other means to demonstrate freshness of the exchange and to link the proof-of-possession key to the participating parties, as demonstrated by various authentication and key exchange protocols.

The means of communicating the nonce and the nature of its contents are intentionally not described in this specification, as different protocols will communicate this information in different ways. Likewise, the means of communicating the signed nonce is also not specified, as this is also protocol specific.
Note that other means of proving possession of the key exist, which could be used in conjunction with a CWT’s confirmation key. Applications making use of such alternate means are encouraged to register them in the IANA "CWT Confirmation Methods" registry established in Section 7.2.

4. Security Considerations

All the security considerations that are discussed in [RFC8392] also apply here. In addition, proof of possession introduces its own unique security issues. Possessing a key is only valuable if it is kept secret. Appropriate means must be used to ensure that unintended parties do not learn private key or symmetric key values.

Applications utilizing proof of possession SHOULD also utilize audience restriction, as described in Section 4.1.3 of [JWT], as it provides additional protections. Audience restriction can be used by recipients to reject messages intended for different recipients.

A recipient might not understand the "cnf" claim. Applications that use proof-of-possession keys in CWTs with the "cnf" claim MUST ensure that the parts of this specification that they use are implemented by the intended recipient.

CBOR Web Tokens with proof-of-possession keys are used in context of an architecture, such as the ACE OAuth Framework [I-D.ietf-ace-oauth-authz], in which protocols are used by a presenter to request these tokens and to subsequently use them with recipients. Proof of possession only provides the intended security gains when the proof is known to be current and not subject to replay attacks; security protocols using mechanisms such as nonces and timestamps can be used to avoid the risk of replay when performing proof of possession for a token. Note that a discussion of the architecture or specific protocols that CWT proof-of-possession tokens are used with is beyond the scope of this specification.

As is the case with other information included in a CWT, it is necessary to apply data origin authentication and integrity protection (via a keyed message digest or a digital signature). Data origin authentication ensures that the recipient of the CWT learns about the entity that created the CWT since this will be important for any policy decisions. Integrity protection prevents an adversary from changing any elements conveyed within the CWT payload. Special care has to be applied when carrying symmetric keys inside the CWT since those not only require integrity protection but also confidentiality protection (e.g., either by encrypting the "cnf" element, as specified in Section 3.3, or by encrypting the whole CWT, as specified in [RFC8392]).
As described in Section 6 (Key Identification) and Appendix D (Notes on Key Selection) of [JWS], it is important to make explicit trust decisions about the keys. Proof-of-possession signatures made with keys not meeting the application’s trust criteria MUST NOT be relied upon.

5. Privacy Considerations

A proof-of-possession key can be used as a correlation handle if the same key is used on multiple occasions. Thus, for privacy reasons, it is recommended that different proof-of-possession keys be used when interacting with different parties.

6. Operational Considerations

The use of CWTs with proof-of-possession keys requires additional information to be shared between the involved parties in order to ensure correct processing. The recipient needs to be able to use credentials to verify the authenticity and integrity of the CWT. Furthermore, the recipient may need to be able to decrypt either the whole CWT or the encrypted parts thereof (see Section 3.3). This requires the recipient to know information about the issuer. Likewise, there needs to be agreement between the issuer and the recipient about the claims being used (which is also true of CWTs in general).

When an issuer creates a CWT containing a Key ID claim, it needs to make sure that it does not issue another CWT with different claims containing the same Key ID within the lifetime of the CWTs, unless intentionally desired. Failure to do so may allow one party to impersonate another party, with the potential to gain additional privileges. A case where such reuse of a Key ID would be intentional is when a presenter obtains a CWT with different claims (e.g., extended scope) for the same recipient, but wants to continue using an existing security association (e.g., a DTLS session) bound to the key identified by the Key ID. Likewise, if PoP keys are used for multiple different kinds of CWTs in an application and the PoP keys are identified by Key IDs, care must be taken to keep the keys for the different kinds of CWTs segregated so that an attacker cannot cause the wrong PoP key to be used by using a valid Key ID for the wrong kind of CWT. Using an audience restriction for the CWT would be one strategy to mitigate this risk.

7. IANA Considerations

The following registration procedure is used for all the registries established by this specification.
Values are registered on a Specification Required [RFC8126] basis after a three-week review period on the cwt-reg-review@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 Experts may approve registration once they are satisfied that such a specification will be published. [[ Note to the RFC Editor: The name of the mailing list should be determined in consultation with the IESG and IANA. Suggested name: cwt-reg-review@ietf.org. ]]

Registration requests sent to the mailing list for review should use an appropriate subject (e.g., "Request to Register CWT Confirmation Method: example"). Registration requests that are undetermined for a period longer than 21 days can be brought to the IESG’s attention (using the iesg@ietf.org mailing list) for resolution.

Designated Experts should determine whether a registration request contains enough information for the registry to be populated with the new values and whether the proposed new functionality already exists. In the case of an incomplete registration or an attempt to register already existing functionality, the Designated Experts should ask for corrections or reject the registration.

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

7.1. CBOR Web Token Claims Registration

This specification registers the "cnf" claim in the IANA "CBOR Web Token Claims" registry [IANA.CWT.Claims] established by [RFC8392].

7.1.1. Registry Contents

- Claim Name: "cnf"
- Claim Description: Confirmation
- JWT Claim Name: "cnf"
- Claim Key: TBD (maybe 8)
- Claim Value Type(s): map
- Change Controller: IESG
- Specification Document(s): Section 3.1 of [[ this document ]]
7.2. CWT Confirmation Methods Registry

This specification establishes the IANA "CWT Confirmation Methods" registry for CWT "cnf" member values. The registry records the confirmation method member and a reference to the specification that defines it.

7.2.1. Registration Template

Confirmation Method Name:
   The human-readable name requested (e.g., "kid").

Confirmation Method Description:
   Brief description of the confirmation method (e.g., "Key Identifier").

JWT Confirmation Method Name:
   Claim Name of the equivalent JWT confirmation method value, as registered in [IANA.JWT.Claims]. CWT claims should normally have a corresponding JWT claim. If a corresponding JWT claim would not make sense, the Designated Experts can choose to accept registrations for which the JWT Claim Name is listed as "N/A".

Confirmation Key:
   CBOR map key value for the confirmation method.

Confirmation Value Type(s):
   CBOR types that can be used for the confirmation method value.

Change Controller:
   For Standards Track RFCs, list the "IESG". For others, give the name of the responsible party.

Specification Document(s):
   Reference to the document or documents that specify the parameter, preferably including URIs that can be used to retrieve copies of the documents. An indication of the relevant sections may also be included but is not required. Note that the Designated Experts and IANA must be able to obtain copies of the specification document(s) to perform their work.

7.2.2. Initial Registry Contents

- Confirmation Method Name: "COSE_Key"
- Confirmation Method Description: COSE_Key Representing Public Key
- JWT Confirmation Method Name: "jwk"
- Confirmation Key: 1
- Confirmation Value Type(s): COSE_Key structure
8. References

8.1. Normative References

[IANA.CWT.Claims]
IANA, "CBOR Web Token Claims",
<http://www.iana.org/assignments/cwt>.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119,
DOI 10.17487/RFC2119, March 1997,

[RFC7049] Bormann, C. and P. Hoffman, "Concise Binary Object Representation (CBOR)", RFC 7049,
DOI 10.17487/RFC7049, October 2013,

[RFC8126] Cotton, M., Leiba, B., and T. Narten, "Guidelines for Writing an IANA Considerations Section in RFCs",
BCP 26, RFC 8126, DOI 10.17487/RFC8126, June 2017,

[RFC8152] Schaad, J., "CBOR Object Signing and Encryption (COSE)", RFC 8152,
DOI 10.17487/RFC8152, July 2017,
<https://www.rfc-editor.org/info/rfc8152>.
8.2. Informative References


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Document History

[[ to be removed by the RFC Editor before publication as an RFC ]]
-07
  o Addressed Area Director review by Benjamin Kaduk.
-06
  o Corrected nits identified by Roman Danyliw.
-05
  o Added text suggested by Jim Schaad describing considerations when using the Key ID confirmation method.
-04
  o Addressed additional WGLC comments by Jim Schaad and Roman Danyliw.
-03
  o Addressed review comments by Jim Schaad, see https://www.ietf.org/mail-archive/web/ace/current/msg02798.html
  o Removed unnecessary sentence in the introduction regarding the use any strings that could be case-sensitive.
  o Clarified the terms Presenter and Recipient.
  o Clarified text about the confirmation claim.
-02

- Changed "typically" to "often" when describing ways of performing proof of possession.

- Changed b64 to hex encoding in an example.

- Changed to using the RFC 8174 boilerplate instead of the RFC 2119 boilerplate.

-01

- Now uses CBOR diagnostic notation for the examples.

- Added a table summarizing the "cnf" names, keys, and value types.

- Addressed some of Jim Schaad’s feedback on -00.

-00

- Created the initial working group draft from draft-jones-ace-cwt-proof-of-possession-01.

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