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Selective Disclosure CBOR Web Tokens (SD-CWT)
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Abstract

This specification describes a data minimization technique for use with CBOR Web Tokens (CWTs). The approach is inspired by the Selective Disclosure JSON Web Token (SD-JWT), with changes to align with CBOR Object Signing and Encryption (COSE) and CWTs.

About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at https://ietf-wg-spice.github.io/draft-ietf-spice-sd-cwt/draft-ietf-spice-sd-cwt.html. Status information for this document may be found at https://datatracker.ietf.org/doc/draft-ietf-spice-sd-cwt/.

Discussion of this document takes place on the Secure Patterns for Internet CrEdentials Working Group mailing list (mailto:spice@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/spice/. Subscribe at https://www.ietf.org/mailman/listinfo/spice/.

Source for this draft and an issue tracker can be found at https://github.com/ietf-wg-spice/draft-ietf-spice-sd-cwt.

Status of This Memo

This Internet-Draft will expire on 3 December 2026.

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1. Introduction

This specification creates a new format based on the CBOR Web Token (CWT) specification [RFC8392]. It enables the Holder of a CWT to disclose or withhold special claims marked as selectively disclosable by the Issuer of a CWT, when presenting those claims to a Verifier. The approach is inspired by SD-JWT [RFC9901], with changes to align with conventions from CBOR Object Signing and Encryption (COSE) [RFC9052] and CWT. Holders of SD-CWT credentials can prove the integrity and authenticity of Holder-chosen attributes asserted by an Issuer to a Verifier. The Holder also proves possession of the confirmation method (defined in [RFC8747]) to prevent copy and paste attacks.

This document defines a generic container format, not a specific credential type. For example, a license to operate a vehicle and a license to import a product will contain different attributes.

SD-CWT is unsuitable for use cases where preventing the Issuer from learning how credentials are used is a requirement. SD-CWTs provide privacy improvements compared to regular CWTs, which can be further improved by the use of one-time use and batch issuance.

1.1. High-Level Flow

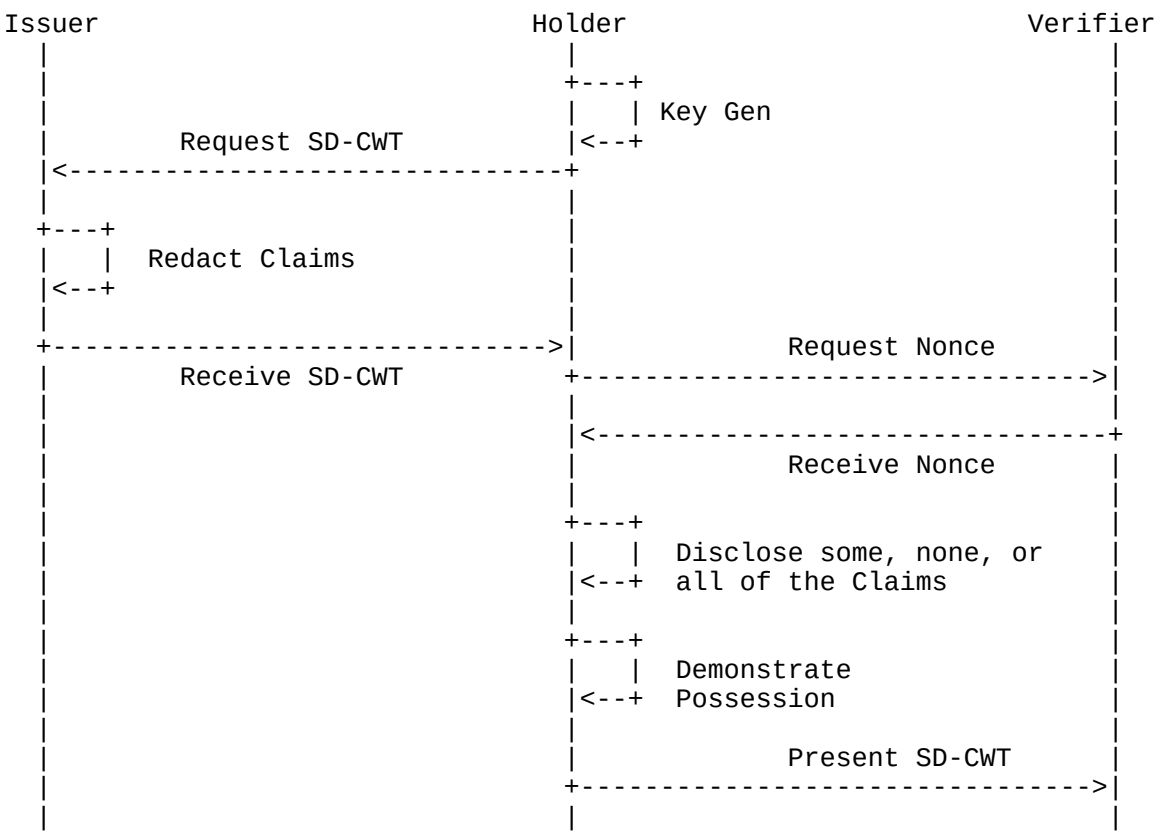


Figure 1: High-level SD-CWT Issuance and Presentation Flow

This diagram captures the flow to issue and present an SD-CWT.

The parameters necessary to support these processes can be obtained using transports or protocols that are out of scope for this specification.

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] [RFC8174] when, and only when, they appear in all capitals, as shown here.

The CBOR examples in this document are shown in CBOR Extended Diagnostic Notation (EDN) [I-D.ietf-cbor-edn-literals]. EDN resembles JSON, but it can contain comments, and it can represent all native CBOR types, including byte strings, tagged values, and CBOR simple values.

Data model constraints are described using the Concise Data Definition Language (CDDL) [RFC8610].

This specification uses terms from CWT [RFC8392], COSE [RFC9052] [RFC9053] and JWT [RFC7519].

The terms Claim Name, Claim Key, and Claim Value are defined in [RFC8392].

This specification defines the following new terms:

Selective Disclosure CBOR Web Token (SD-CWT): A CWT with claims enabling selective disclosure with key binding.

Key Binding Token (KBT): A CWT used to demonstrate possession of a confirmation method, associated with an SD-CWT.

Redact: In the context of this specification, to replace a Claim Value with its corresponding Redacted Claim Hash.

Disclose: In the context of this specification, to provide a Salted Disclosed Claim whose hash matches a Redacted Claim Hash in the same SD-CWT.

Selective Disclosure: In the context of this specification, the ability of the Holder to disclose a subset (all, some, or none) of the Redacted Claims in an SD-CWT.

Assertion Key: A key used by the Issuer to sign an SD-CWT, including the enclosed Claim Values.

Confirmation Key: A key used by the Holder to sign a KBT including the enclosed selected Salted Disclosed Claims.

Issuer: An entity that produces a SD-CWT, containing Claim Values, signed with an Assertion Key.

Holder: An entity that presents a KBT, containing an SD-CWT and selected Salted Disclosed Claims, signed with a Confirmation Key.

Verifier: An entity that validates a Partial or Full Disclosure by a Holder.

Salted Disclosed Claim: A salted claim included in the unprotected header of an SD-CWT.

Redacted Claim Hash: A hash digest of a Salted Disclosed Claim.

Redacted Claim: Any Redacted Claim Key or Redacted Claim Element that has been replaced in the CWT payload by a Redacted Claim Hash.

Non-redacted Claim: A claim that was not replaced by the Issuer with a Redacted Claim Hash in the SD-CWT.

Redacted Claim Key: The hash of a claim redacted from a map data structure.

Redacted Claim Element: The hash of an element redacted from an array data structure.

Presented Disclosed Claims Set: The CBOR map containing zero or more Redacted Claim Keys or Redacted Claim Elements.

Validated Disclosed Claims Set: The CBOR map containing all non-redacted claims that were signed by the Issuer and all selectively disclosed claims presented by the Holder; omitting all undisclosed instances of Redacted Claim Keys and Redacted Claim Element claims that are present in the original SD-CWT.

3. Overview of Selective Disclosure CWT

SD-CWT operates on CWT Claims Sets as described in [RFC8392]. CWT Claims Sets contain Claim Keys and Claim Values. Issuers choose which Claim Keys and Claim Values to redact or include in unredacted form. Holders choose to disclose none, some, or all of the Redacted Claim Keys and Claim Values, and whether to present an issued SD-CWT at all. Holders present an SD-CWT and any disclosures to Verifiers in a Key Binding Token (KBT) that proves the Holder’s control of the private key corresponding to the SD-CWT confirmation (public) key.

Selective Disclosure CBOR Web Tokens (SD-CWTs) can be deployed in environments that are already using CWTs with minor changes, even if the tokens contain no optional-to-disclose claims.

The following diagram explains the relationships between the three roles and the data each processes, using the terminology defined in this specification.

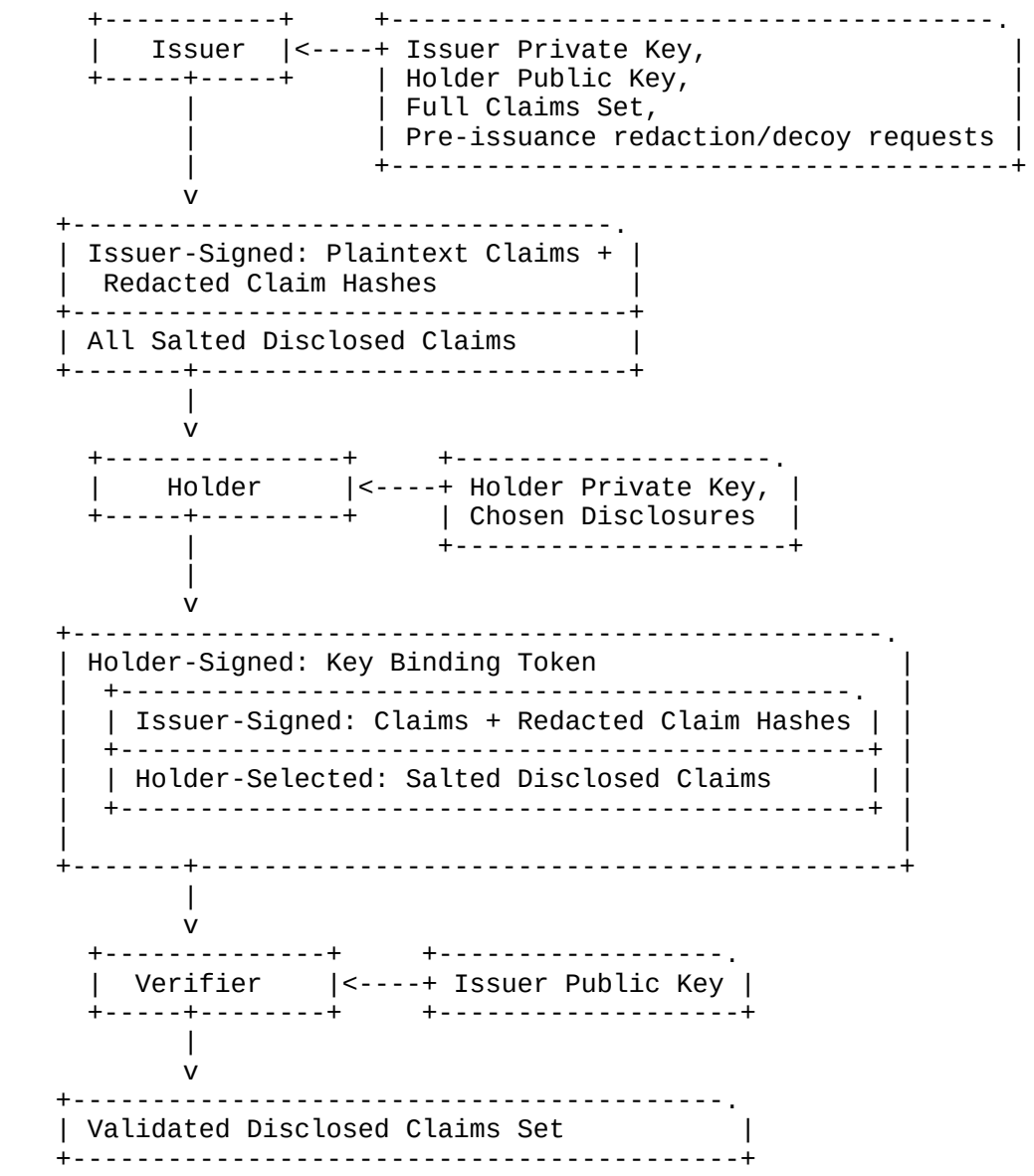
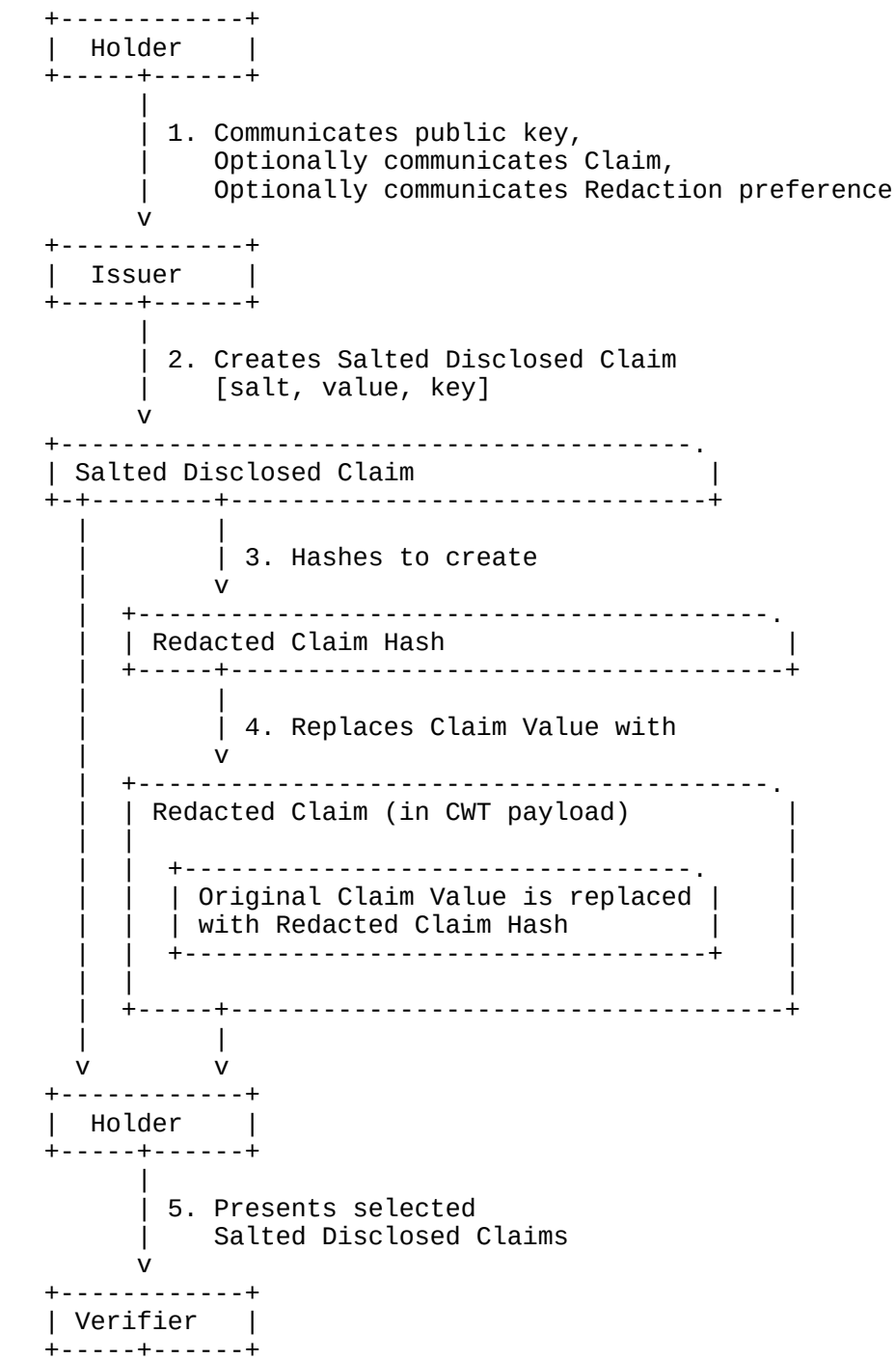


Figure 2: Inputs provided to each Role

The next diagram follows the steps of a specific Claim being redacted and then disclosed using the terminology specific to this document.


Holder
1. Communicates public key,
Optionally communicates Claim,
Optionally communicates Redaction preference
Issuer
2. Creates Salted Disclosed Claim
[salt, value, key]
Salted Disclosed Claim
3. Hashes to create
Redacted Claim Hash
4. Replaces Claim Value with
Redacted Claim (in CWT payload)
Original Claim Value is replaced
with Redacted Claim Hash
Holder
5. Presents selected
Salted Disclosed Claims
Verifier

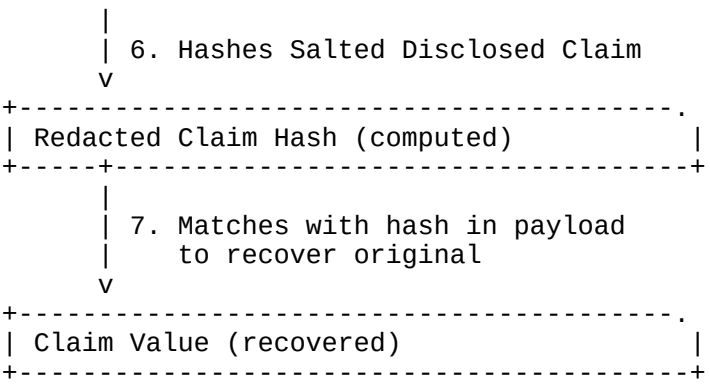


Figure 3: Round trip journey of a Redacted Claim

3.1. A CWT without Selective Disclosure

Below is the payload, or claims set, of a standard CWT not using selective disclosure. It consists of standard CWT claims, the Holder confirmation key, and five fictitious example claims. The payload is shown below in EDN [I-D.ietf-cbor-edn-literals]. Note that the fictitious map keys shown in the examples do not have IANA registered integer keys.

```
{
    / iss / 1  : "https://issuer.example",
    / sub / 2  : "https://holder.example",
    / exp / 4  : 1725330600, /2024-09-02T19:30:00Z/
    / nbf / 5  : 1725243840, /2024-09-01T19:25:00Z/
    / iat / 6  : 1725244200, /2024-09-01T19:30:00Z/
    / cnf / 8  : {
      / cose key / 1 : {
        / kty /  1: 2,  / EC2   /
        / crv / -1: 1,  / P-256 /
        / x /   -2: h'8554eb275dcd6fbd1c7ac641aa2c90d9
                     2022fd0d3024b5af18c7cc61ad527a2d',
        / y /   -3: h'4dc7ae2c677e96d0cc82597655ce92d5
                     503f54293d87875d1e79ce4770194343'
      }
    },
    /most_recent_inspection_passed/ 500: true,
    /inspector_license_number/ 501: "ABCD-123456",
    /inspection_dates/ 502 : [
        1549560720,   / 2019-02-07T17:32:00 /
        1612498440,   / 2021-02-04T20:14:00 /
        1674004740,   / 2023-01-17T17:19:00 /
    ],
    /inspection_location/ 503: {
        "country": "us",            / United States /
        "region": "ca",             / California /
        "postal_code": "94188"
    }
}
```

Figure 4: CWT Claims Set Without Selective Disclosure

The fictitious claims deal with attributes of an inspection of the subject: the pass/fail result, the inspection location, the license number of the inspector, and a list of dates when the subject was inspected.

3.2. Holder gets an SD-CWT from the Issuer

Alice would like to selectively disclose some of these claims to different Verifiers. Note that some of the claims may not be selectively disclosable. In our next example, the pass/fail status of the inspection, the most recent inspection date, and the country of the inspection will be claims that are always present in the SD-CWT. After the Holder requests an SD-CWT from the Issuer, the Issuer generates the following SD-CWT:

```
   / cose-sign1 / 18([  / issuer SD-CWT /
     / CWT protected / << {
       / alg /    1  : -35, / ES384 /
       / kid /    4  : 'https://issuer.example/cose-key3',
       / typ /    16 : 293, # application/sd-cwt
       / sd_alg / 170 : -16  / SHA256 /
     } >>,
     / CWT unprotected / {
       / sd_claims / 17 : [ / these are all the disclosures /
           <<[
               /salt/   h'bae611067bb823486797da1ebbb52f83',
               /value/  "ABCD-123456",
               /claim/  501   / inspector_license_number /
           ]>>,
           <<[
               /salt/   h'8de86a012b3043ae6e4457b9e1aaab80',
               /value/  1549560720   / inspected 7-Feb-2019 /
           ]>>,
           <<[
               /salt/   h'7af7084b50badeb57d49ea34627c7a52',
               /value/  1612560720   / inspected 4-Feb-2021 /
           ]>>,
           <<[
               /salt/   h'ec615c3035d5a4ff2f5ae29ded683c8e',
               /value/  "ca",
               /claim/  "region"   / region=California /
           ]>>,
           <<[
               /salt/   h'37c23d4ec4db0806601e6b6dc6670df9',
               /value/  "94188",
               /claim/  "postal_code"
           ]>>,
       ]
     },
     / CWT payload / << {
       / iss / 1   : "https://issuer.example",
       / sub / 2   : "https://holder.example",
       / exp / 4   : 1725330600,  /2024-09-03T02:30:00+00:00Z/
       / nbf / 5   : 1725243900,  /2024-09-02T02:25:00+00:00Z/
       / iat / 6   : 1725244200,  /2024-09-02T02:30:00+00:00Z/
       / cnf / 8   : {
         / cose key / 1 : {
           / kty /  1: 2,  / EC2   /
           / crv / -1: 1,  / P-256 /
           / x /   -2: h'8554eb275dcd6fbd1c7ac641aa2c90d9
                         2022fd0d3024b5af18c7cc61ad527a2d',
           / y /   -3: h'4dc7ae2c677e96d0cc82597655ce92d5
                         503f54293d87875d1e79ce4770194343'
```

```
        }
      },
      /most_recent_inspection_passed/ 500: true,
      /inspection_dates/ 502 : [
          / redacted inspection date 7-Feb-2019 /
          60(h'1b7fc8ecf4b1290712497d226c04b503
               b4aa126c603c83b75d2679c3c613f3fd'),
          / redacted inspection date 4-Feb-2021 /
          60(h'64afccd3ad52da405329ad935de1fb36
               814ec48fdfd79e3a108ef858e291e146'),
          1674004740,   / 2023-01-17T17:19:00 /
      ],
      / inspection_location / 503 : {
          "country" : "us",            / United States /
          / redacted_claim_keys / simple(59) : [
              / redacted region /
              h'0d4b8c6123f287a1698ff2db15764564
                a976fb742606e8fd00e2140656ba0df3'
              / redacted postal_code /
              h'c0b7747f960fc2e201c4d47c64fee141
                b78e3ab768ce941863dc8914e8f5815f'
        ]
      },
      / redacted_claim_keys / simple(59) : [
          / redacted inspector_license_number /
          h'af375dc3fba1d082448642c00be7b2f7
            bb05c9d8fb61cfc230ddfdfb4616a693'
      ]
    } >>,
    / CWT signature / h'12bdb0136ed93db0e3400660d5aee1ba
                        68ff24e743d613eea55d3bedff167ae4
                        d3c9c328ebfdc1793a178e754ce11432
                        f2e69a92eee6953d38d5a58830ece550
                        21951a83e4e30365828bb7918ceb187a
                        21da18c071ce2461ef642a9e7959299e'
])
```

Figure 5: Issued SD-CWT with all disclosures

Some of the claims are _redacted_ in the payload. The corresponding _disclosure_ is communicated in the unprotected header in the sd_claims header parameter. For example, the inspector_license_number claim is a Salted Disclosed Claim, consisting of a per-disclosure random salt, the Claim Value, and Claim Key.

```
          <<[
              /salt/   h'bae611067bb823486797da1ebbb52f83',
              /value/  "ABCD-123456",
              /claim/  501   / inspector_license_number /
          ]>>,
```

Figure 6: CBOR extended diagnostic notation representation of inspector_license_number disclosure

This is represented in CBOR pretty-printed format as follows (with end-of-line comments and spaces inserted for clarity):

```
83                                  # array(3)
   50                               # bytes(16)
      bae611067bb823486797da1ebbb52f83 # 16-byte salt
   6b                               # text(11)
      414243442d313233343536        # "ABCD-123456"
   19 01f5                          # unsigned(501)
```

Figure 7: CBOR encoding of inspector_license_number disclosure, pretty-printed in hexadecimal

The cryptographic hash, using the hash algorithm identified by the sd_alg header parameter in the protected headers, of that byte string is the Redacted Claim Hash (shown in hex). The digest value is included in the payload in a redacted_claim_keys field for a Redacted Claim Key (in this example), or in a named array for a Redacted Claim Element (for example, for the redacted claim element of inspection_dates).

```
d9df03da474fcb3c65771748e2e0608cf437504ecc24f450aaeacd40dd552b3f
```

Figure 8: SHA-256 hash of inspector_license_number disclosure, in hexadecimal

Finally, since this redacted claim is a map key and value, the Redacted Claim Hash is placed in a redacted_claim_keys array in the SD-CWT payload at the same level of hierarchy as the original claim.

```
  / redacted_claim_keys / simple(59) : [
      / redacted inspector_license_number /
      h'd9df03da474fcb3c65771748e2e0608c
        f437504ecc24f450aaeacd40dd552b3f',
      / ... next redacted claim at the same level would go here /  ],
```

Figure 9: redacted inspector_license_number claim in the issued CWT payload

Redacted claims that are array elements are handled slightly differently, as described in Section 4.1.

3.3. Holder prepares an SD-CWT for a Verifier

When the Holder wants to send an SD-CWT and disclose none, some, or all of the redacted values, it makes a list of the values to disclose and puts them in sd_claims header parameter in the unprotected header. If the Holder does not disclose any claims, it MUST omit the sd_claims header parameter.

For example, Alice decides to disclose to a Verifier the inspector_license_number claim (ABCD-123456), the region claim (California), and the earliest date element in the inspection_dates array (7-Feb-2019).

```
    / sd_claims / 17 : [ / these are the disclosures /
        <<[
            /salt/   h'bae611067bb823486797da1ebbb52f83',
            /value/  "ABCD-123456",
            /claim/  501   / inspector_license_number /
        ]>>,
        <<[
            /salt/   h'8de86a012b3043ae6e4457b9e1aaab80',
            /value/  1549560720   / inspected 7-Feb-2019 /
        ]>>,
        <<[
            /salt/   h'ec615c3035d5a4ff2f5ae29ded683c8e',
            /value/  "ca",
            /claim/  "region"   / region=California /
        ]>>,
    ]
```

Figure 10: The Holder's choice of the disclosures to present

When the Verifier requires freshness, it provides a nonce that the Holder signs in the KBT as the cnonce claim (Table 3).

Finally, the Holder generates a Key Binding Token (KBT) that ties together the SD-CWT generated by the Issuer (with the disclosures the Holder chose for the Verifier in its unprotected header), the Verifier target audience and optional nonces, and proof of possession of the Holder's private key.

As shown in the elided example below, the issued SD-CWT is placed in the kcwt (Confirmation Key CWT) protected header field (defined in [RFC9528]). For the full example, see Section 14.1.

```
/ cose-sign1 / 18( / sd_kbt / [
  / KBT protected / << {
    / alg /    1:  -7, / ES256 /
    / kcwt /  13:  ...
           /  *** SD-CWT from Issuer goes here      /
           /  with Holder's choice of disclosures   /
           /  in the SD-CWT unprotected header  *** /,
    / end of issuer SD-CWT /
    / typ /   16:  294   # application/kb+cwt,
  } >>,     / end of KBT protected header /
  / KBT unprotected / {},
  / KBT payload / << {
    / aud    /  3    : "https://verifier.example/app",
    / iat    /  6    : 1725244237, / 2024-09-02T02:30:37+00:00Z /
    / cnonce / 39    : h'8c0f5f523b95bea44a9a48c649240803'
  } >>,      / end of KBT payload /
  / KBT signature / h'ca38c411693201ceb418ab75217745cc
                      f1d52f76c934ce2910a9f4ccc4293711
                      f9ee18347b51f6f815d89b77d407e494
                      5551118df8f9b662e5250fb1c5f070c8'
])   / end of kbt /
```

Figure 11: Elided example of a Key Binding Token

The digests in protected parts of the issued SD-CWT and the disclosures hashed in unprotected header of the issuer_sd_cwt are used together by the Verifier to confirm the disclosed claims. Since the unprotected header of the included SD-CWT is covered by the signature in the KBT, the Verifier has assurance that the Holder included the sent list of disclosures.

4. SD-CWT Definition

SD-CWT is modeled after SD-JWT, with adjustments to align with conventions in CBOR, COSE, and CWT. An SD-CWT MUST declare its content type, by including the protected header parameter typ [RFC9596] with one of the following values:

* the unsigned integer Constrained Application Protocol (CoAP) [RFC7252] content-format value 293,

* the string content type value application/sd-cwt,

* or a value declaring that the object is a more specific kind of SD-CWT, such as a content type value using the +sd-cwt structured suffix.

The Issuer SHOULD use the value 293 instead of application/sd-cwt, as the CBOR representation is considerably smaller (3 bytes versus 19 bytes).

An SD-CWT is a format based on CWT, but it allows some additional types in maps to indicate values that were or should be redacted, and includes some additional constraints to improve robustness. Unlike CWT, SD-CWT requires key binding.

An SD-CWT can contain Redacted Claims (each expressed as a Redacted Claim Hash), at the root level or in any arrays or maps inside its Claims Set. An SD-CWT is not required to contain any Redacted Claims.

> An SD-CWT with no Redacted Claims is still valuable for its key binding properties.

Optionally the Salted Disclosed Claims (Claim Values and/or Claim Keys) for the corresponding Redacted Claim Hashes are disclosed in the sd_claims header parameter in the unprotected header of the CWT (the disclosures). If there are no disclosures (and when no Redacted Claims Hash is present in the payload) the sd_claims header parameter is not present in the unprotected header.

Any party with a Salted Disclosed Claim can generate its hash, find that hash in the CWT payload, and restore the original claim that was present before redaction. However, a Verifier with the hash cannot reconstruct the corresponding Redacted Claim without disclosure of the Salted Disclosed Claim.

4.1. Types of Redacted Claims

Salted Disclosed Claims for Claim Keys are structured as a 128-bit salt, the disclosed value, and the map key (the claim "name") of the redacted element. For Salted Disclosed Claims of Claim Values (items in an array), the "name" of the claim is omitted.

```
; an array of bstr-encoded Salted Disclosed Claims
salted-array = [ +bstr-encoded-salted ]

bstr-encoded-salted = bstr .cbor salted-entry
salted-entry = salted-claim / salted-element / decoy
salted-claim = [
  bstr .size 16,     ; 128-bit salt
  any,               ; Claim Value
  (int / text)       ; Claim Key
]
salted-element = [
  bstr .size 16,     ; 128-bit salt
  any                ; Claim Value
]
decoy = [
  bstr .size 16      ; 128-bit salt
]
```

Figure 12: CDDL of Salted Disclosed Claims

When a Redacted Claim is a key in a map, its Redacted Claim Hash is added to a redacted_claim_keys array claim in the CWT payload that is at the same level of hierarchy as the map key being redacted. The redacted_claim_keys key is the CBOR simple value 59 registered for that purpose. CBOR "simple values" Section 3.3 of [RFC8949] are values (like false or undefined) that do need any additional content. In this specification a simple value of 59 is used as the content of a map key to indicate that one or more map key/value pairs was redacted in this CBOR map. The simple value 59 is represented in examples using the syntax simple(59). The simple value 59 in CDDL is represented using the syntax #7.59.

When redacting an individual item in an array, the value of the item is replaced with the digested salted hash as a CBOR byte string, wrapped with the CBOR tag 60. CBOR tags Section 3.4 of [RFC8949] annotate other values. The tag 60 is represented in examples as 60(_tagged value_). The tag 60 is represented in CDDL as #6.60(_tagged value_).

```
; redacted_claim_keys is used as a map key. The corresponding value is
; an array of Redacted Claim Hashes whose corresponding unredacted map
; keys and values are in the same map.
redacted_claim_keys = #7.59  ; CBOR simple value 59

; CBOR tag for wrapping a redacted element in an array
REDACTED_ELEMENT_TAGNUM = 60

; redacted_claim_element is used in CDDL payloads that contain
; array elements that are meant to be redacted.
redacted_claim_element = #6.<REDACTED_ELEMENT_TAGNUM>( bstr )
```

Figure 13: CDDL of Redacted Claim Keys and Redacted Claim Elements

Redacted Claims can be nested. For example, both individual keys in the inspection_location claim, and the entire inspection_location element can be separately redacted. An example nested Claims Set is shown in Section 14.2.

Finally, an Issuer MAY create decoy digests, which look like Redacted Claim Hashes but have only a salt. Decoy digests are discussed in Section 10.

5. Differences from the CBOR Web Token Specification

The following subsections discuss differences between CWT and SD-CWT or clarify ambiguities in CWT. Some of these changes are necessary to enable the new functionality of SD-CWT, while some constraints were made in the interest of more robustness.

> Variability in serialization can also be exploited to impact privacy. See Section 16 for more details on the privacy impact of serialization and profiling.

5.1. Definite Length CBOR Required

Encoders of SD-CWT and KBT MUST NOT send indefinite length CBOR. Decoders of SD-CWT and KBT MUST reject any SD-CWT or KBT received containing indefinite length CBOR.

5.2. Finite values for standard date claims

The standard CWT claims exp, nbf, and iat MUST be finite numbers. For the avoidance of doubt, not a number (NaN) values and positive and negative infinity are not acceptable in those claims.

> In [RFC8392], these three claims are of type NumericDate. Section 2 of the same spec refers to NumericDate as a JWT NumericDate, "except that it is represented as [an untagged] CBOR numeric date (from Section 2.4.1 of [RFC7049]) instead of a JSON number". In CBOR, a NumericDate can be represented as an unsigned integer, a negative integer, or a floating point value. CBOR (both [RFC7049] and [RFC8949]) refer to floating-point values to include NaNs, and floating-point numbers that include finite and infinite numbers. Neither JSON [RFC8259] nor JWT [RFC7519] can represent infinite values.

As IEEE double-precision floating point numbers smaller than -(2^53) and larger than 2^53 are no longer as precise as CBOR integers, use of floating point numbers smaller than -(2^53) and larger than 2^53 is FORBIDDEN.

5.3. Allowed types of CBOR map keys

According to Section 1.1 of the CBOR Web Token Specification [RFC8392], "CBOR uses text strings, negative integers, and unsigned integers as map keys." Section 1.5 of CBOR Object Signing and Encryption (COSE): Structures and Process [RFC9052] states: "In COSE, we use text strings, negative integers, and unsigned integers as map keys." While a CBOR map key can contain any CBOR type, this statement implies that CWT map keys only contain those types.

An SD-CWT payload is typically its COSE payload. [RFC9597] also defines the CWT Claims COSE Header Parameter (value 15) that can appear in the protected headers; if it exists, it contains a CBOR map with additional claims that are treated as if they were in the SD-CWT payload. Both of these maps are described as SD-CWT Claims Maps.

> Note that CWT Claims is a separate CBOR map from the COSE payload and can contain the same Claim Keys as the COSE payload CBOR map.

The same valid CWT claim keys could be present in both SD-CWT Claims Maps, but if so, they MUST have the same unredacted value. Neither, one, or both could be redacted. If both are redacted they would have different disclosures, salts, and Redacted Claim Hashes.

In addition to map keys that are valid in CWT, SD-CWT Claims Maps MAY contain the CBOR simple value registered in this specification in Section 17.2. In SD-CWTs exchanged between the Holder and the Issuer prior to issuance, map keys MAY also consist of the To Be Redacted tag (defined in Section 11.1), containing an integer or text string; or a To Be Decoy tag (defined in Section 11.2), containing a positive integer. These two tags provide a way for the Holder to indicate specific claims to be redacted or decoys to be inserted.

The following list summarizes the map key constraints on SD-CWTs and KBTs:

* The KBT protected headers kcwt Header Parameter exclusively contains:
  - a single valid SD-CWT
* The KBT protected headers MUST NOT contain a CWT Claims Header Parameter.
* The KBT payload map; unprotected headers map; and protected headers map (excluding the kcwt Header Parameter) exclusively contain map keys (at any level of depth) with the following map key types:
  - unsigned integers
  - negative integers
  - text strings with a length no greater than 255 octets
* The SD-CWT unprotected headers map; and the protected headers map (excluding the CWT Claims Header Parameter) exclusively contain map keys (at any level of depth) with the following map key types:
  - unsigned integers
  - negative integers
  - text strings with a length no greater than 255 octets
* The SD-CWT Claims Maps at any level of depth, exclusively contain map keys with the following map key types:
  - unsigned integers;
  - negative integers;
  - text strings with a length no greater than 255 octets;
  - the simple value 59; or
  - when disclosable claims are communicated to the Issuer, prior to issuance:
    o the To Be Decoy tag 62 Section 11.2 containing a positive integer, or

- the To Be Redacted tag 58 Section 11.1 containing:
  - an unsigned integer,
  - a negative integer, or
  - a text strings with a length no greater than 255 octets.

In other words, there are exactly three places that can contain map keys (including values that might contain nested maps) with the SD-CWT values that are not allowed in a CWT:

* in the payload Claims Map of an SD-CWT
* in the CWT Claims Header Parameter Claims Map in the protected headers of an SD-CWT
* in the kcwt Header Parameter of a KBT (in one of the embedded SD-CWT Claims Maps).

All the other Header Parameters, and the KBT payload need to contain values valid in a CWT. These values are represented by the safe-value CDDL type.

```
; CWT claim legal values only
safe_map = { * label => safe_value }

safe_value =
  int / tstr / bstr /
  [ * safe_value ] /
  safe_map /
  #6.<safe_tag>(safe_value) / #7.<safe_simple> / float


; legal values in issued SD-CWT
issued_sd_cwt_map = {
    ? redacted_claim_keys ^ => [ * bstr ],
    * label => issued_sd_cwt_value
}

issued_array_element = redacted_claim_element / issued_sd_cwt_value

issued_sd_cwt_value =
  int / tstr / bstr /
  [ * issued_array_element ] /
  issued_sd_cwt_map /
  #6.<safe_tag>(issued_sd_cwt_value) / #7.<safe_simple> / float
```

```
; legal values in claim set sent to Issuer
preissuance_label = label /
                    #6.<TO_BE_REDACTED_TAGNUM>(label) /
                    #6.<TO_BE_DECOY_TAGNUM>(uint .gt 0)

preissuance_map = { * preissuance_label => preissuance_value }

preissuance_value =
  int / tstr / bstr /
  [ * preissuance_value ] /
  preissuance_map /
  #6.<safe_tag>(preissuance_value) / #7.<safe_simple> / float

; CBOR tag number for wrapping to-be-redacted keys or elements
TO_BE_REDACTED_TAGNUM = 58
; CBOR tag number for indicating a decoy value is to be inserted here
TO_BE_DECOY_TAGNUM = 62

label = int / tstr .size (1..255)
safe_tag = uint .ne (TO_BE_REDACTED_TAGNUM /
                     TO_BE_DECOY_TAGNUM /
                     REDACTED_ELEMENT_TAGNUM)

; exclude reserved simple values (24 through 31) from Table 4 of
; RFC 8949, and redacted keys array
safe_simple =  0..23 / 32..58 / 60..255
secs = int / float53
float53 = -9007199254740992.0..9007199254740992.0 ; from 2^53 to 2^53
```

Figure 14: CDDL of Safe Values in SD-CWTs

> Note that Holders presenting to a Verifier that does not support this specification would need to present a CWT without tagged map keys or simple value map keys.

Tagged map keys are not registered in the CBOR Web Token Claims IANA registry, since tags are not valid map keys in [RFC8392]. Instead, the tag provides additional information about the tagged Claim Key and the corresponding (untagged) value. Issuers MUST NOT nest multiple levels of tags in a map key. Holders and Verifiers MUST reject SD-CWTs that contain multiple levels of tags in a map key.

5.4. Duplicate map key detection

Implementations MUST NOT send multiple map keys inside the same CBOR map having the same CBOR Preferred Encoding (see Section 4.1 of [RFC8949]). This applies to any map anywhere in an SD-CWT or a KBT.

Note that it is not necessary to actually encode the map keys using Preferred Encoding to satisfy this requirement.

Likewise, a single SD-CWT Claims Set MUST NOT contain a map (at any level of depth) with both a map key k, and k tagged with the To Be Redacted tag (see Section 11.1). Map keys and their To Be Redacted tagged verison are considered duplicate map keys for the purposes of this specification.

For example, if the map below is contained inside a payload, it is invalid because the map key 500 and the map key 58(500) cannot both be present.

```
{
  500: "ABCD-123456",     # map key 500
  58(500): "DEFG-456789"  # to be redacted tag containing 500
}
```

Figure 15: EDN Example considered a duplicate map key

5.5. Level of Nesting of Claims

Selective disclosure of deeply nested structures could lead to resource exhaustion vulnerabilities. Issuers, Holders, and Verifiers MAY reject SD-CWT Claims Sets exceeding a depth of 16 levels.

The individual map key / value pairs in a Claims Set are defined as the "top level", or level 1. For each value that is an array, a map, or a tagged item, each of the elements of the array, each value corresponding to each map key in the map, and the tagged item are at the next level of depth.

For example, considering the following abbreviated document, the following table shows the level of depth of the corresponding values:

Level	Value
1	https://issuer.example
2	1549560720
3	DCBA-101777
4	us
5	27315

Table 1: Levels of Depth in Below Example

```
{                                  # contents are level 1
  1: "https://issuer.example",
  ...
  502: 1(1549560720),              # tagged value is level 2
  504: [                           # contents are level 2
    {                              # contents are level 3
      ...
      501: "DCBA-101777",
      503: {                       # contents are level 4
        1: "us",
        ...
      },
      505: 4(                      # decimal fraction tag
        [                          #   273.15
          -2,
          27315                    # level 5
        ]
      )
    },
    ...
  ]
}
```

Figure 16: EDN Example to demonstrate levels of depth

The contents of the top-level claims map are level 1. The contents of the array for map key 504 are level 2. The contents of the map inside that array are level 3 (ex: the value of map key 505). The value of tag 4 is at level 4. The values in the array inside tag 4 are at level 5.

5.6. Use of Structured Suffixes

Any type which contains the +sd-cwt structured suffix MUST be a legal SD-CWT. A type that is a legal CWT and does not contain any Redacted Claims SHOULD use the +cwt structure suffix instead, unless the CBOR map being secured contains claim keys with different semantics than those registered in the CBOR Web Token Claims IANA registry.

6. SD-CWT Issuance

How the Holder communicates to the Issuer to request a CWT or an SD-CWT is out of scope for this specification. Likewise, how the Holder determines which claims to redact or to disclose is a policy matter, which is not discussed in this specification. This specification defines the format of an SD-CWT communicated between an Issuer and a Holder in this section, and describes the format of a Key Binding Token containing that SD-CWT communicated between a Holder and a Verifier in Section 8.

The protected header MAY contain the sd_alg header parameter identifying the algorithm (from the COSE Algorithms registry) used to hash the Salted Disclosed Claims. If no sd_alg header parameter is present, the default hash function SHA-256 is used.

If any Salted Disclosed Claims or Decoys are present, the unprotected header MUST contain the sd_claims header parameter with a Salted Disclosed Claim for every Redacted Claim Hash present anywhere in the payload, and any decoys (see Section 10). If there are no disclosures, the sd_claims header parameter value is omitted. The payload also MUST include a key confirmation element (cnf) [RFC8747] for the Holder’s public key.

The Issuer SHOULD confirm the Holder controls all confirmation key material before issuing credentials using the cnf claim. If the Issuer does not, it may be communicating with an active attacker impersonating the Holder, instead of the actual Holder.

CWT [RFC8392] and JWT [RFC7519] register claims and leave their applicability to profiles. This document instead specifies claim requirements directly, because SD-CWT is a specific credential type whose selective-disclosure and key-binding semantics depend on a small set of claims being present, unredacted, and consistently interpreted across implementations. The requirements in Table 2 and Table 3 are the minimum needed for interoperable verification; profiles of this specification MAY add further constraints but MUST NOT relax these.

The following table describes the claim requirements for an SD-CWT:

Claim	Requirement	Never Redacted
iss / 1	MUST unless (see note)	Yes
sub / 2	MUST be present (disclosed or redacted)	No
aud / 3	OPTIONAL	Yes
exp / 4	OPTIONAL	Yes
nbf / 5	OPTIONAL	Yes
iat / 6	OPTIONAL	Yes
cti / 7	OPTIONAL	Yes
cnf / 8	MUST	Yes
cnonce / 39	OPTIONAL	Yes

Table 2: SD-CWT Claim Requirements

The iss claim MUST be present unless the protected header contains a certificate or certificate-like entity that fully identifies the Issuer.

Any claims not addressed in the tables above are OPTIONAL and MAY be redacted in an SD-CWT, unless specified differently by a profile or more specific media type.

To further reduce the size of the SD-CWT, a COSE Key Thumbprint (ckt) [RFC9679] MAY be used in the cnf claim, if the full public key is expected to be available to Verifiers out-of-band.

6.1. Issuer Generation

The Issuer follows all the requirements of generating a valid SD-CWT, largely a CWT extended by Section 5. The Issuer MUST implement COSE_Sign1 using an appropriate fully-specified asymmetric signature algorithm (for example, ESP256 or Ed25519).

The Issuer MUST generate a unique cryptographically random salt with at least 128-bits of entropy for each Salted Disclosed Claim. If the client communicates a client-generated nonce (cnonce) when requesting the SD-CWT, the Issuer MUST include it in the payload.

6.2. Holder Validation

Upon receiving an SD-CWT from the Issuer with the Holder as the subject, the Holder verifies the following:

* the issuer (iss) and subject (sub) are correct;
* if an audience (aud) is present, it is acceptable;
* the CWT is valid according to the nbf and exp claims, if present;
* a public key under the control of the Holder is present in the cnf claim;
* the hash algorithm identified by the sd_alg header parameter in the protected headers is supported by the Holder;
* if a cnonce is present, it was provided by the Holder to this Issuer and is still fresh;
* there are no non-redacted claims about the subject that violate its privacy policies;
* any place where the cardinality of claims needs to be protected have sufficient decoys (Section 10);
* every Redacted Claim Hash has a corresponding Salted Disclosed Claim, and vice versa; a Salted Disclosed Claim (disclosure) MAY contain additional Redacted Claim Keys nested inside the disclosure; if any of the Redacted Claim Hashes are nested, the Holder follows the procedure in Section 7 (see also Section 14.2 for a worked example);
* the values of the Salted Disclosed Claims when placed in their unredacted context in the payload are acceptable to the Holder.

  A Holder MAY choose to validate the appropriateness or correctness of some or all of the information in a token, should it have the ability to do so, and it MAY choose to not present information to a Verifier that it deems to be incorrect.

The following informative CDDL is provided to describe the syntax for SD-CWT issuance. A complete CDDL schema is in Appendix A.

```
sd-cwt-issued = #6.18([
   protected: bstr .cbor sd-protected,
   sd-unprotected,
   payload: bstr .cbor sd-payload,
   signature: bstr
])

sd-protected = {
   &(typ: 16) ^ => 293 / "application/sd-cwt",
   &(alg: 1) ^ => int,
   ? &(kid: 4) ^ => bstr,
   ? &(CWT_Claims: 15) ^ => issued_sd_cwt_map,
   ? &(sd_alg: 170) ^ => int,        ; -16 for sha-256
   ? &(sd_aead: 172) ^ => uint .size 2,
   * label => safe_value
}

sd-unprotected = {
   ? &(sd_claims: 17) ^ => salted-array,
   ? &(sd_aead_encrypted_claims: 171) ^ => aead-encrypted-array,
   * label => safe_value
}

sd-payload = {
    ; standard claims
      &(iss: 1) ^ => tstr, ; "https://issuer.example"
    ? &(sub: 2) ^ => tstr, ; "https://holder.example"
    ? &(aud: 3) ^ => tstr, ; "https://verifier.example/app"
    ? &(exp: 4) ^ => secs, ; 1883000000
    ? &(nbf: 5) ^ => secs, ; 1683000000
    ? &(iat: 6) ^ => secs, ; 1683000000
    ? &(cti: 7) ^ => bstr,
      &(cnf: 8) ^ => safe_map, ; key confirmation
    ? &(vct: 11) ^ => bstr,
    ? &(cnonce: 39) ^ => bstr,
    ;
    ? redacted_claim_keys ^ => [ * bstr ],
    * label => issued_sd_cwt_value
}
```

Figure 17: CDDL describing issued SD-CWT syntax

7. Nesting Validation

Both Holders and Verifiers validate the SD-CWTs they receive. The Holder needs a Salted Disclosed Claim for every Redacted Claim in the document (at any level). The Verifier just needs to match each Salted Disclosed Claim with a Redacted Claim (at any level of the document). In other words, both Holder and Verifier require a Redacted Claim for every Salted Disclosed Claim; for the Verifier there can be Redacted Claims that do not have matching Salted Disclosed Claims, but for the Holder there needs to be a one-to-one correspondance.

This matching becomes more involved when there are Redacted Claims inside disclosures. This "nesting" of Redacted Claims can occur at multiple levels of depth.

Typically the validating party (Holder or Verifier) would create a lookup table of Salted Disclosed Claims indexed by the Redacted Claim Hash.

The validating party looks for any Redacted Claim matching a Redacted Claim Hash of the disclosures it has received, and replaces the Redacted Claim with the corresponding disclosed value from the Salted Disclosed Claims. The validating party then removes the matching Salted Disclosed Claim. If there are any remaining Redacted Claims that were present before replacing the matching Redacted Claims with the corresponding disclosures, the extraneous claims at the current level are either deleted (in the case of Verifier validation), or the SD-CWT is considered invalid (in the case of Holder validation).

The newly disclosed claims are then examined for Redacted Claims, and the process repeats. When there are no Redacted Claims left anywhere in the document, and no Salted Disclosed Claims, the process is complete.

For a walkthrough of a nested example, see Section 14.2.

8. SD-CWT Presentation

When issuing an SD-CWT to a Holder, the Issuer includes all the Salted Disclosed Claims in the unprotected header.

By contrast, when a Holder presents an SD-CWT to a Verifier, it can disclose none, some, or all of its Redacted Claims. If the Holder wishes to disclose any Redacted Claims, it includes that subset of its Salted Disclosed Claims in the sd_claims header parameter of the unprotected header. If there is nothing to be disclosed, the sd_claims header parameter is omitted.

The Holder has flexibility in determining the order of disclosures when making presentations. The order can be sorted, randomized, or optimized for performance based on the Holder's needs.

An SD-CWT presentation to a Verifier has the same syntax as an SD-CWT issued to a Holder, except the Holder chooses the subset of disclosures included in the sd_claims header parameter.

> Since the unprotected header is not included in the Issuer's signature, the list of disclosed claims can differ without invalidating the corresponding signature.

Finally, the SD-CWT used for presentation to a Verifier is included in a Key Binding Token, as discussed in the next section.

8.1. Creating a Key Binding Token

Regardless if it discloses any claims, the Holder sends the Verifier a unique Holder Key Binding Token (KBT) for every presentation of an SD-CWT to a different Verifier.

A KBT is itself a type of CWT, signed using the private key corresponding to the key in the cnf claim in the presented SD-CWT. The KBT contains the SD-CWT, including the Holder's choice of presented disclosures, in the kcwt protected header field in the KBT.

The protected header of the KBT MUST include the typ header parameter with the unsigned integer value of 294, or the value application/kb+cwt. The Holder SHOULD use the value 294 instead of application/kb+cwt, as the CBOR representation is considerably smaller (3 bytes versus 19 bytes).

The Holder is conceptually both the subject and the Issuer of the Key Binding Token. Therefore, the sub and iss of a KBT are implied from the cnf claim in the included SD-CWT, and MUST NOT be present in the KBT. (Profiles of this specification MAY define additional semantics.)

The aud claim MUST be included and MUST correspond to the Verifier. The KBT payload MUST contain either the iat (issued at) claim, or the cti (CWT ID) claim. If the Holder has access to an accurate clock, use of the iat is preferred. The KBT MUST NOT be valid for any time period when its contained SD-CWT is invalid.

The KBT payload MAY include a cnonce claim. If included, the cnonce is a bstr provided by the Verifier and MUST be treated as opaque to the Holder.

The following table describes the claim requirements for a KBT:

Claim	Requirement
iss / 1	MUST NOT be present
sub / 2	MUST NOT be present
aud / 3	MUST
iat / 6	MUST (unless cti present)
cti / 7	MUST (unless iat present)
cnonce / 39	OPTIONAL

Table 3: KBT Claim Requirements

Any claims not addressed in the tables above are OPTIONAL in a KBT, unless specified differently by a profile or more specific media type.

The KBT provides the following assurances to the Verifier:

* the Holder of the SD-CWT controls the confirmation method chosen by the Issuer;

* the Holder’s disclosures have not been tampered with since confirmation occurred;

* the Holder intended to address the SD-CWT to the Verifier specified in the audience (aud) claim;

* if there are any time claims, the Holder’s disclosure is linked to the creation time (iat) of the key binding; otherwise the Holder’s disclosure is linked to a CWT ID (cti), which is expected to be unique per KBT.

The KBT prevents an attacker from copying and pasting disclosures, or from adding or removing disclosures without detection. Confirmation is established according to [RFC8747], using the cnf claim in the payload of the SD-CWT.

The Holder signs the KBT using the key specified in the cnf claim in the SD-CWT. This proves possession of the Holder’s private key.

The snippet of CDDL below corresponds to the rules above.

```
kbt-cwt = #6.18([
   protected: bstr .cbor kbt-protected,
   kbt-unprotected,
   payload: bstr .cbor kbt-payload,
   signature: bstr
])

kbt-protected = {
   &(typ: 16) ^ => 294 / "application/kb+cwt",
   &(alg: 1) ^ => int,
   &(kcwt: 13) ^ => sd-cwt-issued,
   * label => safe_value
}

kbt-unprotected = {
   * label => safe_value
}

kbt-payload = {
      &(aud: 3) ^ => tstr,  ; "https://verifier.example/app"
      time-or-cti-claims,
    ? &(cnonce: 39) ^ => bstr,
    * label => safe_value
}

time-or-cti-claims = (
  ; Requires either time claims that include an iat OR a cti claim.
  ; Note that in CDDL, the // operator has very low precedence (see
  ; Section 2.2.2 of RFC 8610)
  ;
  ; It is possible to have both a cti and time claims, but
  ; time-or-cti-claims insures at least cti or iat is present
  ? &(exp: 4) ^ => secs,
  ? &(nbf: 5) ^ => secs,
    &(iat: 6) ^ => secs  //
    &(cti: 7) ^ => bstr
)
```

Figure 18: CDDL describing KBT syntax

9. KBT and SD-CWT Verifier Validation

To protect against replay attacks, the Verifier SHOULD provide a nonce, and reject requests that do not include an acceptable nonce (cnonce) in the KBT. This guidance can be ignored in cases where replay attacks are mitigated at another layer.

The exact order of the following steps MAY be changed, as long as all checks are performed before deciding if an SD-CWT is valid.

1. First the Verifier must open the protected headers of the KBT and find the Issuer SD-CWT present in the kcwt field.

2. Next, the Verifier must validate the SD-CWT as described in Section 7.2 of [RFC8392]. Verifiers MUST treat an sd_claims or sd_aead_encrypted_claims unprotected Header Parameter with an empty array as invalid.

3. The Verifier checks the time claims in the SD-CWT as follows:

* nbf <= iat (if both exist)

* nbf < exp (if both exist)

* iat < exp (if both exist)

4. The Verifier extracts the confirmation key from the cnf claim in the SD-CWT payload.

5. Using the confirmation key, the Verifier validates the KBT as described in Section 7.2 of [RFC8392].

6. If a cnonce is present in the KBT it MUST be acceptable to the Verifier. A cnonce MAY be present in SD-CWT, but its validity is considered by the holder, and it MUST NOT be disclosed to the verifier.

7. The Verifier checks the time claims in the KBT to enforce the following logical constraints:

* if no cti claim is present in the KBT, there MUST be an iat in the KBT;

* if there is no iat claim in the KBT, there MUST NOT be an exp claim or an nbf claim in the KBT;

* nbf in the KBT <= iat in the KBT (if both exist)

* iat in the KBT < exp in the KBT (if both exist)

* nbf in the SD-CWT <= iat in the SD-CWT (if both exist)

* iat in the SD-CWT < exp in the SD-CWT (if both exist)

* nbf in the SD-CWT < exp in the SD-CWT (if both exist)

* exp in the KBT <= exp in the SD-CWT (if both exist)
* nbf in the KBT >= nbf in the SD-CWT (if both exist)
* iat in the KBT >= iat in the SD-CWT (if both exist)
* nbf in the KBT < exp in the SD-CWT (if both exist)
* iat in the KBT < exp in the SD-CWT (if both exist)
* iat in the KBT >= nbf in the SD-CWT (if both exist)

8. The Verifier MUST extract and decode the disclosed claims from the sd_claims header parameter in the unprotected header of the SD-CWT. Each decoded disclosure is treated as if it is a claim key or claim element at the location corresponding to its Redacted Claim Hash in the payload. If there are any disclosures that do not have a corresponding Redacted Claim Hash, the entire SD-CWT is invalid. If any decoded Redacted Claim Key duplicates another claim key in the same position, the entire SD-CWT is invalid.

   Note: A Verifier MUST be prepared to process disclosures in any order. A Salted Disclosed Claim (disclosure) MAY contain additional Redacted Claim Keys. If any Redacted Claim Hashes are nested inside a disclosure, the Verifier follows the procedure in Section 7 (see also Section 14.2 for a worked example). A disclosed value could appear before the disclosure of its parent.

9. A Verifier MUST reject the SD-CWT if the audience claim in either the SD-CWT or the KBT contains a value that does not correspond to the intended recipient.

10. Otherwise, the SD-CWT is considered valid. Once any remaining redacted elements (either redacted claims or decoys) are deleted, the Validated Disclosed Claims Set is now a CWT Claims Set with no claims marked for redaction.

    Note: Undisclosed Redacted Claim Elements will be removed from the Validated Disclosed Claims Set, changing the length of the containing array. If the semantics of the position of items in the array is important, the issuer should instead disclose or redact the entire array.

11. Further validation logic can be applied to the Validated Disclosed Claims Set, just as it might be applied to a validated CWT Claims Set.

By performing these steps, the recipient can cryptographically verify the integrity of the protected claims and verify they have not been tampered with.

10. Decoy Digests

An Issuer MAY add additional digests to the SD-CWT payload (including nested maps and arrays within the payload) that are not associated with any claim present in the original Claims Set. The purpose of such "decoy" digests is to make it more difficult for an adversarial Verifier to infer private information based on the number of Redacted Claim Keys or Redacted Claim Elements.

The list of disclosures sent by the Issuer to the Holder contains one disclosure for each decoy digest. Each disclosure contains a single element array with a per-decoy salt. Each salt MUST be unique.

```
<<[ h'C1069BC056E234D64F58BAFF8A7B776B' ]>>
```

Figure 19: EDN showing a sample decoy salt

The Redacted Claim Hash for each disclosure is calculated using the same algorithm for decoys as for Redacted Claim Keys and Redacted Claim Elements. An example issued SD-CWT containing decoy digests is shown below.

```
/ cose-sign1 / 18([  / issuer SD-CWT /
  / CWT protected / << {
    / alg /    1  : -35, / ES384 /
    / kid /    4  : 'https://issuer.example/cose-key3',
    / typ /    16 : 293, # application/sd-cwt
    / sd_alg / 170 : -16  / SHA256 /
  } >>,
  / CWT unprotected / {
    / sd_claims / 17 : [ / these are all the disclosures /
        <<[
            /salt/   h'2bfeab9315829fe0c82a15b2c57a47b2',
            /value/  "fr"   / France /
        ]>>,
        <<[
            /salt/   h'c1069bc056e234d64f58baff8a7b776b',
        ]>>,
        <<[
            /salt/   h'b0392772caefd08178218f86f3e2b3a9',
            /value/  true,
            /claim/  500   / inspection result /
        ]>>,
        <<[
```

```
              /salt/   h'89c41c270dd06cd3517d371c9ddf2bab',
          ]>>,
      ]
    },
    / CWT payload / << {
      / iss / 1   : "https://issuer.example",
      / sub / 2   : "https://holder.example",
      / exp / 4   : 1725330600,  /2024-09-03T02:30:00+00:00Z/
      / nbf / 5   : 1725243900,  /2024-09-02T02:25:00+00:00Z/
      / iat / 6   : 1725244200,  /2024-09-02T02:30:00+00:00Z/
      / cnf / 8   : {
        / cose key / 1 : {
          / kty /  1: 2,  / EC2   /
          / crv / -1: 1,  / P-256 /
          / x /   -2: h'8554eb275dcd6fbd1c7ac641aa2c90d9
                        2022fd0d3024b5af18c7cc61ad527a2d',
          / y /   -3: h'4dc7ae2c677e96d0cc82597655ce92d5
                        503f54293d87875d1e79ce4770194343'
        }
      },
      /countries array/ 98: [
          /redacted country == "fr" /
          60(h'dc5f753b66acd89d78481039934a86cc
               14f9959c64c4037dea3f872b9a8453f1')
          /decoy country #1 /
          60(h'3f80963a1246b412d6567f2a5ca446fd
               19a01dd8cfc291bed69e8c575c5abfb8')
      ],
      / redacted_claim_keys / simple(59) : [
          / redacted claim 500 (== true) /
          h'bd0fd88127b3071ff5433eef59a5e3c5
            f18341f25c5bd119c41fd34802a9797b'
          / decoy claim #2 /
          h'eeec970897a5b9108f24f44751baedab
            b53a1f3d241ab6b60c9f309f114ecf88'
      ]
    } >>,
    / CWT signature / h'a96d92f340e37ab56586c74f237a50ef
                       bf176f7326a88a5429084a283b82a514
                       27753805febd98987c13f8a41586feda
                       df507e98d6d26af6f09eb01d0f4a5644
                       fdd05e7bac083338c7a8770a68896df3
                       c2f79e5450fd19f5dbbd1868898e984b'
  ])
```

Figure 20: EDN showing a SD-CWT containing decoys

As with regular Redacted Claims, the Holder needs to receive the disclosure for every decoy so it can be sure the Issuer is not communicating unwanted information to Verifiers (see Section 16.3).

11. Tags Used Before SD-CWT Issuance

This section describes the semantics of two CBOR tags that are (optionally) only used to convey information to the Issuer about disclosures to create.

11.1. To Be Redacted Tag Definition

In order to indicate specific claims that the Holder would like to be redacted in a Claims Set, this specification defines a new CBOR tag "To Be Redacted". The tag can be used by a library to automatically convert a Claims Set with "To Be Redacted" tags into a) a new Claims Set containing Redacted Claim Keys and Redacted Claim Elements replacing the tagged claim keys or claim elements, and b) a set of corresponding Salted Disclosed Claims.

When used on an element in an array, the value to be redacted is present inside the tag. When used on a map key and value, the tag is placed around the map key, while the map value remains.

Examples in this draft use the To Be Redacted tag in order to distinguish their pre-issued, post-issued, and post-presented representations in EDN and CDDL. The snippet of EDN shown below shows one mechanism to communicate to the Issuer to redact the inspector license number claim, and two of the inspection dates in our primary example.

```
{
  ...
  58(501): "ABCD-123456",   # redact inspector license number claim
  /inspection dates/ 502: [
    58(1549560720),         # redact 07-Feb-2019
    58(1612560720),         # redact 04-Feb-2021
    1674004740              # don’t redact 17-Jan-2023
  ]
  ...
}
```

Figure 21: EDN example requesting redaction of license number and two inspection dates

As discussed in Section 5.4, a map key k and a map key 58 containing the value k are considered duplicate map keys. An Issuer MUST NOT issue an SD-CWT if the pre-issued Claims Set contains duplicate map keys.

11.2. To Be Decoy

In order to indicate a location that should contain a decoy digest Section 10 in the issued SD-CWT, this specification defines a new CBOR tag "To Be Decoy". This tag can be used by a library to automatically a) add a decoy digest at a particular location in an array, or at a particular level in a map; and b) create the corresponding Salted Disclosed Claims. The value inside is a positive integer that MUST be unique for each decoy location within the SD-CWT. The integer could be used to look up the salt for the decoy deterministically, but does not impose any ordering. When a decoy digest is requested in a map, the map _value_ is always null.

> Note: Requiring an integer that is unique per decoy within the entire CWT ensures that there are no duplicate map keys in the Claims Set (see Section 5.6 of [RFC8949]).

An Issuer MUST NOT issue an SD-CWT if the pre-issued Claims Set contains duplicate map keys.

In the example fragment below, the transit countries claim contains an array of countries. The Claim Elements array contains Germany (de) and the Philippines (ph). The Holder wants to redact each country, but add decoys to obfuscate the number of component origin countries. The example fragment also shows two decoy digests in the same map.

```
{
  ...
  /component origin countries/ 607: [
    58("de"),
    58("ph"),
    62(1),      # add two decoys in this array
    62(2)
  ],
  62(3): null,  # add a decoy in this map
  62(4): null,  # add a second decoy in the same map
  ...
}
```

Figure 22: EDN example requesting two decoys

12. Encrypted Disclosures

The RATS architecture [RFC9334] defines a model where the Verifier is split into separate entities, with an initial verifier called an Attester, and a target entity called a Relying Party. Other protocols have a similar type of internal structure for the Verifier.

In some of these use cases, there is existing usage of AES-128 GCM and other Authenticated Encryption with Additional Data (AEAD) [RFC5116] algorithms.

This section describes how to use AEADs to encrypt disclosures to a target entity, while enabling a initial verifier to confirm the authenticity of the presentation from the Holder.

In these systems, an appropriate symmetric key and its context are provided completely out-of-band.

The entire SD-CWT is included in the protected header of the KBT, which secures the entire Issuer-signed SD-CWT including its unprotected headers that include its disclosures.

The Issuer MUST make the plaintext Salted Disclosed Claims of all Redacted Claims available to the Holder by placing them in the unprotected header in the sd_claims header parameter. The Holder MAY then chose to encrypt some of these Salted Disclosed Claims, omit the plaintext versions from the sd_claims unprotected header field, and add the corresponding encrypted disclosures to the sd_aead_encrypted_claims unprotected header field. The Holder finally signs the KBT containing all intended disclosures of either type.

The initial Verifier of the KBT might not be able to decrypt encrypted disclosures and MAY decide to forward them to an inner Verifier that can decrypt them.

12.1. AEAD Encrypted Disclosures Mechanism

This section defines two new COSE Header Parameters. If present in the protected headers, the first header parameter (sd_aead) specifies an Authenticated Encryption with Additional Data (AEAD) algorithm [RFC5116] registered in the IANA AEAD Algorithms registry (https://www.iana.org/assignments/aead-parameters/aead-parameters.xhtml) . (Guidance on specific algorithms is discussed in Section 16.9.) The second header parameter (sd_aead_encrypted_claims), if present, contains a non-empty list of AEAD encrypted disclosures. Taking the first example disclosure from Figure 6:

```
        <<[
            /salt/   h'bae611067bb823486797da1ebbb52f83',
            /value/  "ABCD-123456",
            /claim/  501   / inspector_license_number /
        ]>>,
```

Figure 23: EDN example of plaintext disclosure

The corresponding bstr is encrypted with an AEAD algorithm [RFC5116]. If present, the algorithm of the sd_aead protected header field is used, or AEAD_AES_128_GCM if no algorithm was specified. The bstr is encrypted with a unique, random nonce of N_MIN octets. The associated (authenticated) data A is zero-length. The AEAD ciphertext consists of its encryption algorithm's ciphertext and its authentication tag. (For example, in AEAD_AES_128_GCM the authentication tag is 16 octets.) The nonce (nonce), the encryption algorithm's ciphertext (ciphertext) and authentication tag (tag) are put in an array.

Optionally an AEAD key context MAY be added to the array. The key context can be an unsigned integer, a text string, or a byte string of the COSE Key Thumbprint ([RFC9679]) of the decryption key.

The resulting array is placed in the sd_aead_encrypted_claims header parameter in the unprotected headers of the SD-CWT.

Given the AEAD encryption key (in hexadecimal):

a061c27a3273721e210d031863ad81b6

A valid AEAD encrypted disclosure for that first disclosure is:

```
/ sd_aead_encrypted_claims / 171 : [ / AEAD encrypted disclosures /
[
    / nonce /      h'95d0040fe650e5baf51c907c',
    / ciphertext / h'563a7d9f0f65d40b751fbc3fcc408e8f
                    e27c375b60a4727b1f1e9572c07992eb
                    5ec5a9',
    / tag /        h'9f4d37da32187528416ed7ee95e0625f'
],
    ...
]
```

Figure 24: EDN Example of an AEAD Encrypted Disclosure

The Redacted Claim Hash is still over the unencrypted disclosure. The receiver of an AEAD encrypted disclosure determines the appropriate decryption key by local configuration, using the aead-key-context if present, or by looking up the authentication tag.

> Which key determination mechanism to use is the responsibility of the relevant profile or enclosing protocol.

If the Verifier is able to decrypt and verify an encrypted disclosure, the decrypted disclosure is then processed as if it were in the sd_claims header parameter in the unprotected headers of the SD-CWT.

Details of key management are left to profiles of the specific protocols that make use of AEAD encrypted disclosures.

The CDDL for AEAD encrypted disclosures is below.

```
aead-encrypted-array = [ +aead-encrypted ]
aead-encrypted = [
  bstr,              ; nonce of N_MIN octets
  bstr,              ; the encryption ciphertext output of a
                     ;   bstr-encoded-salted
  bstr,              ; the corresponding authentication tag
  ?aead-key-context  ; optional context to select the correct key
]
aead-key-context = uint / tstr / thumbprint
thumbprint = bstr    ; a COSE key thumprint
```

Figure 25: CDDL describing syntax of AEAD Encrypted disclosures

> Note: Because the encryption algorithm is in a registry that contains only AEAD algorithms, an attacker cannot replace the algorithm or the message, without a decryption verification failure.

13. Credential Types

This specification defines the CWT claim vct (for Verifiable Credential Type). The vct value is an identifier for the type of the SD-CWT Claims Set. Like the typ header parameter [RFC9596], its value can be either a string or an integer. For size reasons, it is RECOMMENDED that the numeric representation be used.

If its value is a string, it is a case-sensitive StringOrURI, as defined in [RFC7519]. In this case, the vct string MUST either be registered in the IANA "Verifiable Credential Type Identifiers" registry established in Section 17.8, or be a Collision-Resistant Name, as defined in Section 2 of [RFC7515].

If its value is an integer, it is either a value in the range 0-64999 registered in the IANA "Verifiable Credential Type Identifiers" registry established in Section 17.8 or an Experimental Use value in the range 65000-65535, which is not to be used in operational deployments.

This claim is defined for COSE-based verifiable credentials, similar to the JOSE-based verifiable credentials claim (vct) described in Section 3.2.2.1.1 of [I-D.draft-ietf-oauth-sd-jwt-vc].

14. Examples

14.1. Minimal Spanning Example

The following example contains claims needed to demonstrate redaction of key-value pairs and array elements.

```
/ cose-sign1 / 18( / sd_kbt / [
  / KBT protected / << {
    / alg /    1:  -7, / ES256 /
    / kcwt /  13:  18([  / issuer SD-CWT /
      / CWT protected / << {
        / alg /    1  : -35, / ES384 /
        / kid /    4  : 'https://issuer.example/cose-key3',
        / typ /    16 : 293, # application/sd-cwt
        / sd_alg / 170 : -16  / SHA256 /
      } >>,
      / CWT unprotected / {
        / sd_claims / 17 : [ / these are the disclosures /
            <<[
                /salt/   h'bae611067bb823486797da1ebbb52f83',
                /value/  "ABCD-123456",
                /claim/  501   / inspector_license_number /
            ]>>,
            <<[
                /salt/   h'8de86a012b3043ae6e4457b9e1aaab80',
                /value/  1549560720   / inspected 7-Feb-2019 /
            ]>>,
            <<[
                /salt/   h'ec615c3035d5a4ff2f5ae29ded683c8e',
                /value/  "ca",
                /claim/  "region"   / region=California /
```

```
            ]>>,
        ]
      },
      / CWT payload / << {
        / iss / 1   : "https://issuer.example",
        / sub / 2   : "https://holder.example",
        / exp / 4   : 1725330600,  /2024-09-03T02:30:00+00:00Z/
        / nbf / 5   : 1725243900,  /2024-09-02T02:25:00+00:00Z/
        / iat / 6   : 1725244200,  /2024-09-02T02:30:00+00:00Z/
        / cnf / 8   : {
          / cose key / 1 : {
            / kty /  1: 2,  / EC2   /
            / crv / -1: 1,  / P-256 /
            / x /   -2: h'8554eb275dcd6fbd1c7ac641aa2c90d9
                          2022fd0d3024b5af18c7cc61ad527a2d',
            / y /   -3: h'4dc7ae2c677e96d0cc82597655ce92d5
                          503f54293d87875d1e79ce4770194343'
          }
        },
        /most_recent_inspection_passed/ 500: true,
        /inspection_dates/ 502 : [
            / redacted inspection date 7-Feb-2019 /
            60(h'1b7fc8ecf4b1290712497d226c04b503
                 b4aa126c603c83b75d2679c3c613f3fd'),
            / redacted inspection date 4-Feb-2021 /
            60(h'64afccd3ad52da405329ad935de1fb36
                 814ec48fdfd79e3a108ef858e291e146'),
            1674004740,   / 2023-01-17T17:19:00 /
        ],
        / inspection_location / 503 : {
            "country" : "us",            / United States /
            / redacted_claim_keys / simple(59) : [
                / redacted region /
                h'0d4b8c6123f287a1698ff2db15764564
                  a976fb742606e8fd00e2140656ba0df3'
                / redacted postal_code /
                h'c0b7747f960fc2e201c4d47c64fee141
                  b78e3ab768ce941863dc8914e8f5815f'
          ]
        },
        / redacted_claim_keys / simple(59) : [
            / redacted inspector_license_number /
            h'af375dc3fba1d082448642c00be7b2f7
              bb05c9d8fb61cfc230ddfdfb4616a693'
        ]
      } >>,
      / CWT signature / h'12bdb0136ed93db0e3400660d5aee1ba
                          68ff24e743d613eea55d3bedff167ae4
```

```
                            d3c9c328ebfdc1793a178e754ce11432
                            f2e69a92eee6953d38d5a58830ece550
                            21951a83e4e30365828bb7918ceb187a
                            21da18c071ce2461ef642a9e7959299e'
        ]),
        / end of issuer SD-CWT /
        / typ /   16:  294   # application/kb+cwt,
      } >>,     / end of KBT protected header /
      / KBT unprotected / {},
      / KBT payload / << {
        / aud    /  3    : "https://verifier.example/app",
        / iat    /  6    : 1725244237, / 2024-09-02T02:30:37+00:00Z /
        / cnonce / 39    : h'8c0f5f523b95bea44a9a48c649240803'
      } >>,      / end of KBT payload /
      / KBT signature / h'ca38c411693201ceb418ab75217745cc
                          f1d52f76c934ce2910a9f4ccc4293711
                          f9ee18347b51f6f815d89b77d407e494
                          5551118df8f9b662e5250fb1c5f070c8'
   ])   / end of kbt /
```

Figure 26: A minimal, full EDN Example

14.2. Nested Example

Instead of the structure from the previous example, imagine that the payload contains an inspection history log with the following structure. It could be redacted at multiple levels of the claims set hierarchy.

```
{
    / iss / 1  : "https://issuer.example",
    / sub / 2  : "https://holder.example",
    / exp / 4  : 1725330600, /2024-09-02T19:30:00Z/
    / nbf / 5  : 1725243840, /2024-09-01T19:25:00Z/
    / iat / 6  : 1725244200, /2024-09-01T19:30:00Z/
    / cnf / 8  : { ... },
    504: [                      / inspection history log /
        {
            500: true,          / inspection passed /
            502: 1549560720,    / 2019-02-07T17:32:00 /
            501: "DCBA-101777", / inspector license /
            503: {
                1: "us",        / United States /
                2: "co",        / region=Colorado /
                3: "80302"      / postcode /
            }
        },
        {
            500: true,          / inspection passed /
            502: 1612560720,    / 2021-02-04T20:14:00 /
            501: "EFGH-789012", / inspector license /
            503: {
                1: "us",        / United States /
                2: "nv",        / region=Nevada /
                3: "89155"      / postcode /
            }
        },
        {
            500: true,          / inspection passed /
            502: 17183928,      / 2023-01-17T17:19:00 /
            501: "ABCD-123456", / inspector license /
            503: {
                1: "us",        / United States /
                2: "ca",        / region=California /
                3: "94188"      / postcode /
            }
        }
    ]
}
```

Figure 27: EDN example of Nested Claims Set before redaction

For example, looking at the nested disclosures below, the first disclosure reveals the entire January 2023 inspection record. However, when the record is disclosed, the inspector license number and inspection location are still redacted inside the record. The fifth disclosure reveals the inspector_license_number, and the fourth

disclosure reveals the inspection location record, but the region and postcode claims inside the location record are also individually redacted. The second disclosure reveals the inspection region.

The last disclosure reveals the earliest inspection record, and the sixth disclosure reveals the inspector_license_number for that record.

Verifiers start replacing each Redacted Claim Hash whose hash matches a Salted Disclosed Claim, with the unredacted Claim Key or Claim Value from that Salted Disclosed Claim. They continue descending until there are no Redacted Claim Hashes at any level of the hierarchy for which they have a corresponding disclosure. A walkthrough of processing an example with nested disclosures is in Appendix D.

```
    / sd_claims / 17 : [ / these are the disclosures /
        <<[
            /salt/   h'cd99b3858f1d659f9d16039abf8c5fba',
            /value/  {
                         500: true,
                         502: 1674004740,
                         simple(59): [
                         h'af375dc3fba1d082448642c00be7b2f7
                           bb05c9d8fb61cfc230ddfdfb4616a693',
                         h'9d151abeb800adcc11ff10ff61fbd3d7
                           5944c134b40a24abef1787d3ae6583aa'
                     ]
                     }   / inspection 17-Jan-2023 /
        ]>>,         / Redacted Claim Hash begins 20d9bb11 /
        <<[
            /salt/   h'52da9de5dc61b33775f9348b991d3d78',
            /value/  "ca",
            /claim/  2   / region=California /
        ]>>,         / Redacted Claim Hash begins 2470fb91 /
        <<[
            /salt/   h'591eb2081b05be2dcbb6f8459cc0fe51',
            /value/  "DCBA-101777",
            /claim/  501   / inspector_license_number /
        ]>>,         / Redacted Claim Hash begins 7257a869 /
        <<[
            /salt/   h'483e4b3c194df6073a9c41ca9f274067',
            /value/  {
                         1: "us",
                         simple(59): [
                         h'2470fb9175b062c347ab3c3a19776d02
                           476112a17cd7cfc9416664bc058c220b',
                         h'cf397a08917528624ca3b332c9edcc54
```

```
                            a72c9411dd5983f68017ce160f709f52'
                    ]
                    },
        /claim/  503   / San Francisco location /
    ]>>,         / Redacted Claim Hash begins 9d151abe /
    <<[
        /salt/   h'bae611067bb823486797da1ebbb52f83',
        /value/  "ABCD-123456",
        /claim/  501   / inspector_license_number /
    ]>>,         / Redacted Claim Hash begins af375dc3 /
    <<[
        /salt/   h'c23a4d192be75dbd583be570482de8dd',
        /value/  {
                    1: "us",
                    simple(59): [
                    h'1b89717167f39d51eec08b13baeda570
                      eff5d0aedaa1d7d0821185c33634a5a0',
                    h'49412884fa1e3787c17d1320bdd48f6e
                      0e5365da010cde0571d4a7effd13cc2a'
                    ]
                    },
        /claim/  503   / Denver location /
    ]>>,         / Redacted Claim Hash begins c24c646b /
    <<[
        /salt/   h'2df7d2c105b5bf3acf9c698f3658552f',
        /value/  {
                    500: true,
                    502: 1549560720,
                    simple(59): [
                    h'7257a8697dfa40221079b00fb65fe587
                      c310e6ca3da1aa33b090335de66ec810',
                    h'c24c646b52fecd773c6ea01c6caa5a73
                      422b85d3afa5900fa998336d83a88025'
                    ]
                    }   / inspection 7-Feb-2019 /
    ]>>,         / Redacted Claim Hash begins ca6b8516 /
]
```

Figure 28: EDN Example of SD-CWT with Nested Redacted Claims

After applying the disclosures of the nested structure above, the disclosed Claims Set visible to the Verifier would look like the following:

```
{
    / iss / 1  : "https://issuer.example",
    / sub / 2  : "https://holder.example",
    / exp / 4  : 1725330600, /2024-09-02T19:30:00Z/
    / nbf / 5  : 1725243840, /2024-09-01T19:25:00Z/
    / iat / 6  : 1725244200, /2024-09-01T19:30:00Z/
    / cnf / 8  : { ... },
    504: [                      / inspection history log /
        {
            500: true,          / inspection passed /
            501: "DCBA-101777", / inspector license /
            502: 1549560720,    / 2019-02-07T17:32:00 /
            503: {
                1: "us"         / United States /
            }
        },
        {
            500: true,          / inspection passed /
            501: "ABCD-123456", / inspector license /
            502: 17183928,      / 2023-01-17T17:19:00 /
            503: {
                1: "us",        / United States /
                2: "ca"         / region=California /
            }
        }
    ]
}
```

Figure 29: EDN of validated nested claims

15. Privacy Considerations

This section describes the privacy considerations in accordance with the recommendations from [RFC6973]. Many of the topics discussed in [RFC6973] apply to SD-CWT, but are not repeated here.

15.1. Correlation and Linkability

The term linkability or unlinkability applies to presentations of SD-CWT in the same ways that it applies to SD-JWT as described in Section 10.1 of [RFC9901].

SD-CWT cannot prevent Issuer-Verifier linkability. Any presentation of an SD-CWT can be correlated with its issuance if an Issuer and Verifier cooperate. In cases where the Issuer is part of the privacy threat model, a different mechanism than SD-CWT is needed.

Presentations of the same SD-CWT to multiple Verifiers can be correlated by matching on the signature component of the COSE_Sign1. That is, SD-CWT does not naturally provide Verifier-Verifier unlinkability. Verifier-Verifier unlinkability can be achieved by requesting a fresh, uncorrelated copy of the credential for each presentation, at a credential management complexity cost. This assumes that the revealed claims do not contain information that could enable Verifiers to correlate presentations. If the claims, or the timing or structure of their presentation, leak correlatable information, then fresh copies of credentials may be insufficient. SD-CWT is designed to mitigate such leakage; however, implementers must ensure that no leakage occurs (for example, by appropriately using decoy digests, see Section 10).

Any Claim Value that pertains to a sufficiently small set of subjects can be used to facilitate tracking the subject. For example, a high precision issuance time might match the issuance of only a few credentials for a given Issuer, and as such, any presentation of a credential issued at that time can be determined to be associated with the set of credentials issued at that time, for those subjects.

15.2. Determinism

It is possible for the Issuer to encode additional information through the choices made during the serialization stage of producing an SD-CWT, for example, by adjusting the order of CBOR map keys, by choosing different numeric encodings for certain data elements, or by incorporating fewer or more decoys (see Section 10). Likewise the Holder can encode information in the KBT. Appendix B of [I-D.ietf-cbor-serialization] provides guidance for constructing application profiles that further constrain CBOR encoding. The construction of such profiles has a significant impact on the privacy properties of a credential type.

15.3. Audience

If the audience claim is present in both the SD-CWT and the KBT, they are not required to be the same. SD-CWTs with audience claims that do not correspond to the intended recipients MUST be rejected, to protect against accidental disclosure of sensitive data.

15.4. Credential Types

The privacy implications of selective disclosure vary significantly across different credential types due to their inherent characteristics and intended use cases. The non-redacted and optional-to-disclose data elements in an SD-CWT must be carefully chosen based on the specific privacy risks associated with each credential type.

For example, a passport credential contains highly sensitive personal information where even disclosure of a subset of its claims can have significant privacy implications:

* Revealing citizenship status may expose an individual to discrimination
* Date of birth combined with any other attribute enables age-based profiling
* Biometric data, even if selectively disclosed, presents irreversible privacy risks
* The mere possession of a passport from certain countries can be sensitive information

In contrast, a legal entity certificate has fundamentally different privacy considerations:

* The entity’s legal name and registration number are often public information
* Business addresses and contact details may already be in public registries
* Authorized signatories’ names might be required for legal validity
* The primary concern is often business confidentiality rather than personal privacy

These differences mean that:

* Passport credentials should minimize non-redacted claims and maximize holder control over optional elements
* Legal entity certificates might reasonably require disclosure of more fields to establish business legitimacy

* The granularity of selective disclosure should match the credential type’s privacy sensitivity

* Default disclosure sets must be carefully calibrated to each credential’s risk profile

Several distinct credential types might be applicable to a given use case, each with unique privacy trade-offs. Issuers MUST perform a comprehensive privacy and confidentiality assessment for each credential type they intend to issue, considering:

* The sensitivity spectrum of contained attributes

* Likely disclosure scenarios and their privacy impacts

* Correlation risks when attributes are combined

* Long-term privacy implications of disclosed information

* Cultural and jurisdictional privacy expectations

16. Security Considerations

Security considerations from COSE [RFC9052] and CWT [RFC8392] apply to this specification.

16.1. Issuer Key Compromise

Verification of an SD-CWT requires that the Verifier have access to a verification key (public key) associated with the Issuer. Compromise of the Issuer’s signing key would enable an attacker to forge credentials for any subject, potentially undermining the entire trust model of the credential system. Beyond key compromise, an attacker might seek to attack the process by which a Verifier obtains the public keys of Issuers. An attacker who can manipulate the process by which a Verifier obtains information about Issuer public keys could substitute their own keys, enabling credential forgery while appearing to be a trusted Issuer.

16.2. Disclosure Coercion and Over-identification

The Security Considerations from Section 10.2 of [RFC9901] apply, with additional attention to disclosure coercion risks. Holders can be pressured to disclose more claims than are necessary for a given transaction. This risk is heightened when a Verifier does not provide adequate data protection practices, when disclosed attributes derive from highly trusted authorities (for example, government-issued credentials), and because disclosure is effectively

irreversible once data has been shared.

Mitigations include mechanisms by which Verifiers demonstrate eligibility to receive sensitive claims, Holder-side evaluation of Verifier compliance posture and certifications, and use of trust lists curated by trusted parties to identify responsible Verifiers. In the absence of such safeguards, including Verifier trust lists, Holders remain exposed to over-identification and long-term misuse of disclosed information.

Implementers deploying SD-CWT in credential systems should review [W3CTAG-Credential-Abuse], which discusses broader risks of credential abuse including surveillance, exclusion, and overuse.

16.3. Disclosure of Decoys

Issuers control the claimset and may include decoy digests to obscure the number of claims in a credential. Unless all decoy disclosures are made available to Holders, an Issuer could use this mechanism to hide claims from Holders without their knowledge. A Holder receiving a credential with undisclosed decoys cannot distinguish between a digest that conceals a real claim and one that is genuinely a decoy. This creates a severe privacy risk: an Issuer could embed hidden claims — such as behavioral flags, risk scores, or sensitive attributes — that Verifiers can later be given selective access to, without the Holder’s awareness or consent.

16.4. Random Numbers

Each salt used to protect disclosed claims MUST be generated independently. Identical salt values, or values that can be correlated, might allow a Verifier to recover redacted values that were not disclosed.

The salts MUST be generated using fresh randomness or from a source that has outputs cannot be predicted by any potential Verifier. Poor choice of salts can lead to brute force attacks that can reveal redacted claims.

16.5. Binding the KBT and the CWT

The "iss" claim in the SD-CWT is self-asserted by the Issuer.

Because confirmation is mandatory, the subject claim of an SD-CWT, when present, is always related directly to the confirmation claim. There might be many subject claims and many confirmation keys that identify the same entity or that are controlled by the same entity, while the identifiers and keys are distinct values. Reusing an

identifier or key enables correlation, but needs to be evaluated in terms of the confidential and privacy constraints associated with the credential type. Conceptually, the Holder is both the Issuer and subject of the KBT, and the subject of the SD-CWT. Presence of an "iss" or "sub" claim in the KBT would be superfluous, so they MUST NOT be present.

As with any self-assigned identifiers, Verifiers need to take care to verify that the KBT "iss" and "sub" claims match the subject in the KBT, and are a valid representation of the Holder and correspond to the Holder’s confirmation key. Extra care should be taken in case the SD-CWT subject claim is redacted.

Likewise, Holders and Verifiers need to verify that the "iss" claim of the SD-CWT corresponds to the Issuer and the key described in the protected header of the SD-CWT. If the Holder does not verify the "iss" claim in the SD-CWT, an active attacker could be inserted between the Issuer and the Holder. If the Verifier does not verify the "iss" claim in the SD-CWT, there is no assurance that the Holder is authentic.

Finally, the Verifier needs to verify that the time claims in both the SD-CWT and KBT are self-consistent and that the KBT is not valid for any period of time when the SD-CWT is not. Specific tests for time claims are described in steps 3 and 6 of Section 9.

16.6. Revocation and Status Lists

Currently, CWTs do not have a standard notion of revocation in the same way that [RFC5280] has Certificate Revocation Lists to invalidate X.509 certificates. CWTs and JWTs do have a notion of status lists [I-D.ietf-oauth-status-list]. If an SD-CWT is using [I-D.ietf-oauth-status-list], the status check should be confirmed after the KBT is verified, to protect the verifier from accessing network resources specified in forged tokens. It does not make sense to apply status lists to KBTs.

16.7. Covert Channels

Any data element that is supplied by the Issuer, and that appears random to the Holder might be used to produce a covert channel between the Issuer and the Verifier. The ordering of claims, and precision of timestamps can also be used to produce a covert channel. This is more of a concern for SD-CWT than typical CWTs, because the Holder is usually considered to be aware of the Issuer claims they are disclosing to a Verifier.

16.8. Use of authenticated encryption for encrypted disclosures

This section provides justification of the choice of AEAD (or generally authenticated) algorithms for encrypted disclosures in SD-CWT versus unauthenticated encryption.

1. AEAD algorithms (especially AES_GCM) are among the most widely available cryptographic algorithms. Implementations of these algorithms are generally well tested and documented across a wide range of environments and programming environments, and often benefit from hardware accelleration. Unauthenticated algorithms are less widely available and are often only available in "subtle" cryptographic interfaces. Use of a mainstream AEAD algorithm is less likely to trigger false alarms in security audits than unauthenticated encryption algorithms.

2. Since SD-CWTs support nested disclosures, a Verifier may need to decrypt and process disclosures from an honest Holder at multiple depths to find the Salted Disclosed Claim and Redacted Claim Hash associated with a specific Redacted Claim. Using an authenticated algorithm allows the Verifier to determine immediately if a specific decryption succeeded or failed. It also prevents the Verifier from keeping state for encrypted disclosures that were not correctly decrypted. Knowing exactly when decryption fails makes troubleshooting easier, and error handling more straightforward to implement.

3. The amount of time

4. In the target environments (ex: RATS), the performance penalty of using authenticated encryption is minor compared the other cryptographic operations already in use in those environments. Reuse of cryptographic algorithms compatible with existing profiles and cipher suites was considered more important than the performance gain of using unauthenticated encryption.

5. If desired by the community, it is possible to add an unauthenticated encryption mode (with appropriate guidance) as a future extension.

16.9. Choice of AEAD algorithms

The AEAD encrypted disclosures mechanism discussed in Section 12.1 can refer to any AEAD alogithm in the IANA AEAD Algorithms registry (https://www.iana.org/assignments/aead-parameters/aead-parameters.xhtml) .

When choosing an AEAD algorithm, the tag length is relevant to the integrity of encrypted disclosures in SD-CWT before the corresponding plaintext can be hashed and matched to a Redacted Claim. As such, implementations MUST NOT use any AEAD algorithm with a tag length less than 16 octets.

Algorithms using AES-CCM are NOT RECOMMENDED.

As of this writing, implementations MUST NOT use algorithms 3 through 14, 18, 19, 21, 22, 24, 25, 27, or 28. Implementations using the AEGIS algorithms containing an X MUST only use the 256-bit tag variant.

17. IANA Considerations

17.1. COSE Header Parameters

IANA is requested to add the following entries to the IANA "COSE Header Parameters" registry (https://www.iana.org/assignments/cose/cose.xhtml#header-parameters):

17.1.1. sd_claims

The following completed registration template per RFC8152 is provided:

* Name: sd_claims
* Label: 17
* Value Type: [+bstr]
* Value Registry: (empty)
* Description: A list of selectively disclosed claims, which were originally redacted, then later disclosed at the discretion of the sender.
* Reference: Section 3.3 of this specification

17.1.2. sd_alg

The following completed registration template per RFC8152 is provided:

* Name: sd_alg
* Label: 170

* Value Type: int

* Value Registry: IANA COSE Algorithms

* Description: The hash algorithm used for redacting disclosures.

* Reference: Section 6 of this specification

17.1.3. sd_aead_encrypted_claims

The following completed registration template per RFC8152 is provided:

* Name: sd_aead_encrypted_claims

* Label: 171

* Value Type: [+[bstr,bstr,bstr]]

* Value Registry: (empty)

* Description: A list of AEAD encrypted selectively disclosed claims, which were originally redacted, then later disclosed at the discretion of the sender.

* Reference: Section 12.1 of this specification

17.1.4. sd_aead

The following completed registration template per RFC8152 is provided:

* Name: sd_aead

* Label: 172

* Value Type: uint .size 2

* Value Registry: IANA AEAD Algorithm number

* Description: The AEAD algorithm used for encrypting disclosures.

* Reference: Section 12.1 of this specification

17.2. CBOR Simple Values

IANA is requested to add the following entry to the IANA "CBOR Simple Values" registry (https://www.iana.org/assignments/cbor-simple-values#simple):

* Value: 59
* Semantics: This value as a map key indicates that the Claim Value is an array of redacted Claim Keys at the same level as the map key.
* Specification Document(s): Section 4.1 of this specification

17.3. CBOR Tags

IANA is requested to add the following entries to the IANA "CBOR Tags" registry (https://www.iana.org/assignments/cbor-tags/cbor-tags.xhtml#tags):

17.3.1. To Be Redacted Tag

The array claim element, or map key and value inside the "To be redacted" tag is intended to be redacted using selective disclosure.

* Tag: 58
* Data Item: (any)
* Semantics: An array claim element intended to be redacted, or a map key whose key and value are intended to be redacted.
* Specification Document(s): Section 11.1 of this specification

17.3.2. Redacted Claim Element Tag

The byte string inside the tag is a selective disclosure redacted claim element of an array.

* Tag: 60
* Data Item: byte string
* Semantics: A selective disclosure redacted (array) claim element.
* Specification Document(s): Section 4.1 of this specification

17.3.3. To Be Decoy Tag

The positive integer inside the tag is a unique number to indicate a specific decoy instance among all the instances in the document.

* Tag: 62 (requested)
* Data Item: uint .gt 0
* Semantics: A marker of a location in a map or an array where a decoy is intended to be inserted.
* Specification Document(s): Section 11.2 of this specification

17.4. CBOR Web Token (CWT) Claims

IANA is requested to add the following entry to the IANA "CWT Claims" registry (https://www.iana.org/assignments/cwt/cwt.xhtml#claims-registry):

17.4.1. vct

The following completed registration template per RFC8392 is provided:

* Claim Name: vct
* Claim Description: Verifiable credential type
* JWT Claim Name: vct
* Claim Key: 11
* Claim Value Type(s): bstr
* Change Controller: IETF
* Specification Document(s): Section 13 of this specification

17.5. Media Types

IANA is requested to add the following entries to the IANA "Media Types" registry (https://www.iana.org/assignments/media-types/media-types.xhtml#application):

17.5.1. application/sd-cwt

The following completed registration template is provided:

* Type name: application
* Subtype name: sd-cwt
* Required parameters: n/a
* Optional parameters: n/a
* Encoding considerations: binary
* Security considerations: Section 16 of this specification and [RFC8392]
* Interoperability considerations: n/a
* Published specification: Section 4 of this specification
* Applications that use this media type: TBD
* Fragment identifier considerations: n/a
* 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: SPICE WG mailing list (spice@ietf.org) or IETF Security Area (saag@ietf.org)
* Intended usage: COMMON
* Restrictions on usage: none
* Author: See Author’s Addresses section
* Change controller: IETF
* Provisional registration? No

17.5.2. application/kb+cwt

The following completed registration template is provided:

* Type name: application
* Subtype name: kb+cwt
* Required parameters: n/a
* Optional parameters: n/a
* Encoding considerations: binary
* Security considerations: Section 16 of this specification and [RFC8392]
* Interoperability considerations: n/a
* Published specification: Section 8.1 of this specification
* Applications that use this media type: TBD
* Fragment identifier considerations: n/a
* 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: SPICE WG mailing list (spice@ietf.org) or IETF Security Area (saag@ietf.org)
* Intended usage: COMMON
* Restrictions on usage: none
* Author: See Author’s Addresses section
* Change controller: IETF
* Provisional registration? No

17.6. Structured Syntax Suffix

IANA is requested to add the following entry to the IANA "Structured Syntax Suffix" registry (https://www.iana.org/assignments/media-type-structured-suffix/media-type-structured-suffix.xhtml#structured-syntax-suffix):

* Name: SD-CWT
* +suffix: +sd-cwt
* References: Section 4 of this specification
* Encoding considerations: binary
* Interoperability considerations: n/a
* Fragment identifier considerations: n/a
* Security considerations: Section 16 of this specification
* Contact: See Author’s Addresses section
* Author/Change controller: IETF

17.7. Content-Formats

IANA is requested to register the following entries in the IANA "CoAP Content-Formats" registry (https://www.iana.org/assignments/core-parameters/core-parameters.xhtml#content-formats):

Content-Type	Content Coding	ID	Reference
application/sd-cwt	-	293	Section 4 of this specification
application/kb+cwt	-	294	Section 8.1 of this specification

Table 4: New CoAP Content Formats

17.8. Verifiable Credential Type Identifiers

This specification establishes the Verifiable Credential Type Identifiers registry, under the IANA "CBOR Web Token (CWT) Claims" group registry heading (https://www.iana.org/assignments/cwt/cwt.xhtml). It registers identifiers for the type of the SD-CWT Claims Set.

It enables short integers in the range 0-65535 to be used as vct Claim Values, similarly to how CoAP Content-Formats (Section 12.3 of [RFC7252]) enable short integers to be used as typ header parameter [RFC9596] values.

The registration procedures for numbers in specific ranges are as described below:

Range	Registration Procedure from RFC8126
0-9999	Specification Required
10000-64999	First Come First Served
65000-65535	Experimental Use (no operational use)

Table 5

Values in the Specification Required [RFC8126] range are registered after a two-week review period on the spice-ext-review@ietf.org mailing list, on the advice of one or more Designated Experts. To allow for the allocation of values prior to publication of the final version of a specification, the Designated Experts may approve registration once they are satisfied that the specification will be completed and published. However, if the specification is not completed and published in a timely manner, as determined by the Designated Experts, the Designated Experts may request that IANA withdraw the registration.

Registration requests sent to the mailing list for review should use an appropriate subject (e.g., "Request to register VCT value").

Within the review period, the Designated Experts 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. The IANA escalation process can be initiated by the party requesting registration when the Designated Experts are not responsive within 14 days.

Criteria that should be applied by the Designated Experts includes determining whether the proposed registration duplicates existing functionality, determining whether it is likely to be of general applicability or whether it is useful only for a single application, and whether the registration makes sense.

IANA must only accept registry updates from the Designated Experts and should direct all requests for registration in the Specification Required range to the review mailing list.

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.

17.8.1. Registration Template

Verifiable Credential Type Identifier String: String identifier for use as a JWT vct or CWT vct Claim Value. It is a StringOrURI value.

Verifiable Credential Type Identifier Number: Integer in the range 0-64999 for use as a CWT vct Claim Value. (Integers in the range 65000-65535 are not to be registered.)

Description: Brief description of the verifiable credential type

Change Controller: For IETF stream RFCs, use "IETF". For others, give the name of the responsible party. Other details (e.g., postal address, e-mail address, home page URI) may also be included.

Specification Document(s): Reference to the document or documents that specify the values to be registered, preferably including URLs that can be used to retrieve the documents. An indication of the relevant sections may also be included, but is not required.

17.8.2. Initial Registry Contents

No initial values are provided for the registry.

18. References

18.1. Normative References

[BCP205] Best Current Practice 205, <https://www.rfc-editor.org/info/bcp205>. At the time of writing, this BCP comprises the following:

Sheffer, Y. and A. Farrel, "Improving Awareness of Running Code: The Implementation Status Section", BCP 205, RFC 7942, DOI 10.17487/RFC7942, July 2016, <https://www.rfc-editor.org/info/rfc7942>.

[I-D.ietf-cbor-edn-literals] Bormann, C., "Concise Diagnostic Notation (CDN)", Work in Progress, Internet-Draft, draft-ietf-cbor-edn-literals-25, 18 May 2026, <https://datatracker.ietf.org/doc/html/draft-ietf-cbor-edn-literals-25>.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/rfc/rfc2119>.

[RFC5116] McGrew, D., "An Interface and Algorithms for Authenticated Encryption", RFC 5116, DOI 10.17487/RFC5116, January 2008, <https://www.rfc-editor.org/rfc/rfc5116>.

[RFC7515] Jones, M., Bradley, J., and N. Sakimura, "JSON Web Signature (JWS)", RFC 7515, DOI 10.17487/RFC7515, May 2015, <https://www.rfc-editor.org/rfc/rfc7515>.

[RFC7519] Jones, M., Bradley, J., and N. Sakimura, "JSON Web Token (JWT)", RFC 7519, DOI 10.17487/RFC7519, May 2015, <https://www.rfc-editor.org/rfc/rfc7519>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/rfc/rfc8174>.

[RFC8392] Jones, M., Wahlstroem, E., Erdtman, S., and H. Tschofenig, "CBOR Web Token (CWT)", RFC 8392, DOI 10.17487/RFC8392, May 2018, <https://www.rfc-editor.org/rfc/rfc8392>.

[RFC8610] Birkholz, H., Vigano, C., and C. Bormann, "Concise Data Definition Language (CDDL): A Notational Convention to Express Concise Binary Object Representation (CBOR) and JSON Data Structures", RFC 8610, DOI 10.17487/RFC8610, June 2019, <https://www.rfc-editor.org/rfc/rfc8610>.

[RFC8747] Jones, M., Seitz, L., Selander, G., Erdtman, S., and H. Tschofenig, "Proof-of-Possession Key Semantics for CBOR Web Tokens (CWTs)", RFC 8747, DOI 10.17487/RFC8747, March 2020, <https://www.rfc-editor.org/rfc/rfc8747>.

[RFC8949] Bormann, C. and P. Hoffman, "Concise Binary Object Representation (CBOR)", STD 94, RFC 8949, DOI 10.17487/RFC8949, December 2020, <https://www.rfc-editor.org/rfc/rfc8949>.

[RFC9052] Schaad, J., "CBOR Object Signing and Encryption (COSE): Structures and Process", STD 96, RFC 9052, DOI 10.17487/RFC9052, August 2022, <https://www.rfc-editor.org/rfc/rfc9052>.

[RFC9053] Schaad, J., "CBOR Object Signing and Encryption (COSE): Initial Algorithms", RFC 9053, DOI 10.17487/RFC9053, August 2022, <https://www.rfc-editor.org/rfc/rfc9053>.

[RFC9528] Selander, G., Preu Mattsson, J., and F. Palombini, "Ephemeral Diffie-Hellman Over COSE (EDHOC)", RFC 9528, DOI 10.17487/RFC9528, March 2024, <https://www.rfc-editor.org/rfc/rfc9528>.

[RFC9596] Jones, M.B. and O. Steele, "CBOR Object Signing and Encryption (COSE) "typ" (type) Header Parameter", RFC 9596, DOI 10.17487/RFC9596, June 2024, <https://www.rfc-editor.org/rfc/rfc9596>.

[RFC9679] Isobe, K., Tschofenig, H., and O. Steele, "CBOR Object Signing and Encryption (COSE) Key Thumbprint", RFC 9679, DOI 10.17487/RFC9679, December 2024, <https://www.rfc-editor.org/rfc/rfc9679>.

18.2. Informative References

[I-D.draft-ietf-keytrans-protocol] McMillion, B. and F. Linker, "Key Transparency Protocol", Work in Progress, Internet-Draft, draft-ietf-keytrans-protocol-04, 16 April 2026, <https://datatracker.ietf.org/doc/html/draft-ietf-keytrans-protocol-04>.

[I-D.draft-ietf-oauth-sd-jwt-vc]
Terbu, O., Fett, D., and B. Campbell, "SD-JWT-based Verifiable Digital Credentials (SD-JWT VC)", Work in Progress, Internet-Draft, draft-ietf-oauth-sd-jwt-vc-16, 24 April 2026, <https://datatracker.ietf.org/doc/html/draft-ietf-oauth-sd-jwt-vc-16>.

[I-D.ietf-cbor-serialization]
Lundblade, L., "CBOR Serialization and Determinism", Work in Progress, Internet-Draft, draft-ietf-cbor-serialization-06, 23 April 2026, <https://datatracker.ietf.org/doc/html/draft-ietf-cbor-serialization-06>.

[I-D.ietf-oauth-status-list]
Looker, T., Bastian, P., and C. Bormann, "Token Status List (TSL)", Work in Progress, Internet-Draft, draft-ietf-oauth-status-list-20, 20 April 2026, <https://datatracker.ietf.org/doc/html/draft-ietf-oauth-status-list-20>.

[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, DOI 10.17487/RFC5280, May 2008, <https://www.rfc-editor.org/rfc/rfc5280>.

[RFC6973] Cooper, A., Tschofenig, H., Aboba, B., Peterson, J., Morris, J., Hansen, M., and R. Smith, "Privacy Considerations for Internet Protocols", RFC 6973, DOI 10.17487/RFC6973, July 2013, <https://www.rfc-editor.org/rfc/rfc6973>.

[RFC7049] Bormann, C. and P. Hoffman, "Concise Binary Object Representation (CBOR)", RFC 7049, DOI 10.17487/RFC7049, October 2013, <https://www.rfc-editor.org/rfc/rfc7049>.

[RFC7252] Shelby, Z., Hartke, K., and C. Bormann, "The Constrained Application Protocol (CoAP)", RFC 7252, DOI 10.17487/RFC7252, June 2014, <https://www.rfc-editor.org/rfc/rfc7252>.

[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, <https://www.rfc-editor.org/rfc/rfc8126>.

[RFC8259] Bray, T., Ed., "The JavaScript Object Notation (JSON) Data Interchange Format", STD 90, RFC 8259, DOI 10.17487/RFC8259, December 2017, <https://www.rfc-editor.org/rfc/rfc8259>.

[RFC9162] Laurie, B., Messeri, E., and R. Stradling, "Certificate Transparency Version 2.0", RFC 9162, DOI 10.17487/RFC9162, December 2021, <https://www.rfc-editor.org/rfc/rfc9162>.

[RFC9334] Birkholz, H., Thaler, D., Richardson, M., Smith, N., and W. Pan, "Remote ATtestation procedureS (RATS) Architecture", RFC 9334, DOI 10.17487/RFC9334, January 2023, <https://www.rfc-editor.org/rfc/rfc9334>.

[RFC9597] Looker, T. and M.B. Jones, "CBOR Web Token (CWT) Claims in COSE Headers", RFC 9597, DOI 10.17487/RFC9597, June 2024, <https://www.rfc-editor.org/rfc/rfc9597>.

[RFC9901] Fett, D., Yasuda, K., and B. Campbell, "Selective Disclosure for JSON Web Tokens", RFC 9901, DOI 10.17487/RFC9901, November 2025, <https://www.rfc-editor.org/rfc/rfc9901>.

[t-Closeness] "t-Closeness: Privacy Beyond k-Anonymity and l-Diversity", 4 June 2007, <https://ieeexplore.ieee.org/document/4221659>.

[W3CTAG-Credential-Abuse] W3C Technical Architecture Group, "Preventing the Abuse of Digital Credentials", n.d., <https://w3ctag.github.io/prevent-credential-abuse/>.

Appendix A. Complete CDDL Schema

```
sd-cwt-types = sd-cwt-issued / kbt-cwt / sd-cwt-preissued

sd-cwt-issued = #6.18([
   protected: bstr .cbor sd-protected,
   sd-unprotected,
   payload: bstr .cbor sd-payload,
   signature: bstr
])

sd-protected = {
   &(typ: 16) ^ => 293 / "application/sd-cwt",
   &(alg: 1) ^ => int,
   ? &(kid: 4) ^ => bstr,
```

```
      ? &(CWT_Claims: 15) ^ => issued_sd_cwt_map,
      ? &(sd_alg: 170) ^ => int,        ; -16 for sha-256
      ? &(sd_aead: 172) ^ => uint .size 2,
      * label => safe_value
   }

   sd-unprotected = {
      ? &(sd_claims: 17) ^ => salted-array,
      ? &(sd_aead_encrypted_claims: 171) ^ => aead-encrypted-array,
      * label => safe_value
   }

   sd-payload = {
       ; standard claims
         &(iss: 1) ^ => tstr, ; "https://issuer.example"
       ? &(sub: 2) ^ => tstr, ; "https://holder.example"
       ? &(aud: 3) ^ => tstr, ; "https://verifier.example/app"
       ? &(exp: 4) ^ => secs, ; 1883000000
       ? &(nbf: 5) ^ => secs, ; 1683000000
       ? &(iat: 6) ^ => secs, ; 1683000000
       ? &(cti: 7) ^ => bstr,
         &(cnf: 8) ^ => safe_map, ; key confirmation
       ? &(vct: 11) ^ => bstr,
       ? &(cnonce: 39) ^ => bstr,
       ;
       ? redacted_claim_keys ^ => [ * bstr ],
       * label => issued_sd_cwt_value
   }

   kbt-cwt = #6.18([
      protected: bstr .cbor kbt-protected,
      kbt-unprotected,
      payload: bstr .cbor kbt-payload,
      signature: bstr
   ])

   kbt-protected = {
      &(typ: 16) ^ => 294 / "application/kb+cwt",
      &(alg: 1) ^ => int,
      &(kcwt: 13) ^ => sd-cwt-issued,
      * label => safe_value
   }

   kbt-unprotected = {
      * label => safe_value
   }

   kbt-payload = {
```

```
        &(aud: 3) ^ => tstr,  ; "https://verifier.example/app"
        time-or-cti-claims,
      ? &(cnonce: 39) ^ => bstr,
      * label => safe_value
  }

  time-or-cti-claims = (
    ; Requires either time claims that include an iat OR a cti claim.
    ; Note that in CDDL, the // operator has very low precedence (see
    ; Section 2.2.2 of RFC 8610)
    ;
    ; It is possible to have both a cti and time claims, but
    ; time-or-cti-claims insures at least cti or iat is present
    ? &(exp: 4) ^ => secs,
    ? &(nbf: 5) ^ => secs,
      &(iat: 6) ^ => secs  //
      &(cti: 7) ^ => bstr
  )
  sd-cwt-preissued = #6.18([
     protected: bstr .cbor sd-protected,
     sd-unprotected,
     payload: bstr .cbor preissuance_map,
     signature: bstr
  ])

  ; CWT claim legal values only
  safe_map = { * label => safe_value }

  safe_value =
    int / tstr / bstr /
    [ * safe_value ] /
    safe_map /
    #6.<safe_tag>(safe_value) / #7.<safe_simple> / float


  ; legal values in issued SD-CWT
  issued_sd_cwt_map = {
      ? redacted_claim_keys ^ => [ * bstr ],
      * label => issued_sd_cwt_value
  }

  issued_array_element = redacted_claim_element / issued_sd_cwt_value

  issued_sd_cwt_value =
    int / tstr / bstr /
    [ * issued_array_element ] /
    issued_sd_cwt_map /
    #6.<safe_tag>(issued_sd_cwt_value) / #7.<safe_simple> / float
```

```
   ; legal values in claim set sent to Issuer
   preissuance_label = label /
                       #6.<TO_BE_REDACTED_TAGNUM>(label) /
                       #6.<TO_BE_DECOY_TAGNUM>(uint .gt 0)

   preissuance_map = { * preissuance_label => preissuance_value }

   preissuance_value =
     int / tstr / bstr /
     [ * preissuance_value ] /
     preissuance_map /
     #6.<safe_tag>(preissuance_value) / #7.<safe_simple> / float

   ; CBOR tag number for wrapping to-be-redacted keys or elements
   TO_BE_REDACTED_TAGNUM = 58
   ; CBOR tag number for indicating a decoy value is to be inserted here
   TO_BE_DECOY_TAGNUM = 62

   label = int / tstr .size (1..255)
   safe_tag = uint .ne (TO_BE_REDACTED_TAGNUM /
                        TO_BE_DECOY_TAGNUM /
                        REDACTED_ELEMENT_TAGNUM)

   ; exclude reserved simple values (24 through 31) from Table 4 of
   ; RFC 8949, and redacted keys array
   safe_simple =  0..23 / 32..58 / 60..255
   secs = int / float53
   float53 = -9007199254740992.0..9007199254740992.0 ; from 2^53 to 2^53

   salted-array = [ +bstr-encoded-salted ]

   bstr-encoded-salted = bstr .cbor salted-entry
   salted-entry = salted-claim / salted-element / decoy
   salted-claim = [
     bstr .size 16,     ; 128-bit salt
     any,               ; Claim Value
     (int / text)       ; Claim Key
   ]
   salted-element = [
     bstr .size 16,     ; 128-bit salt
     any                ; Claim Value
   ]
   decoy = [
     bstr .size 16      ; 128-bit salt
   ]

   aead-encrypted-array = [ +aead-encrypted ]
   aead-encrypted = [
```

```
    bstr,              ; nonce of N_MIN octets
    bstr,              ; the encryption ciphertext output of a
                       ;   bstr-encoded-salted
    bstr,              ; the corresponding authentication tag
    ?aead-key-context  ; optional context to select the correct key
  ]
  aead-key-context = uint / tstr / thumbprint
  thumbprint = bstr    ; a COSE key thumprint
  ; redacted_claim_keys is used as a map key. The corresponding value is
  ; an array of Redacted Claim Hashes whose corresponding unredacted map
  ; keys and values are in the same map.
  redacted_claim_keys = #7.59  ; CBOR simple value 59

  ; CBOR tag for wrapping a redacted element in an array
  REDACTED_ELEMENT_TAGNUM = 60

  ; redacted_claim_element is used in CDDL payloads that contain
  ; array elements that are meant to be redacted.
  redacted_claim_element = #6.<REDACTED_ELEMENT_TAGNUM>( bstr )
```

Figure 30: A complete CDDL description of SD-CWT

Appendix B. Comparison to SD-JWT

SD-CWT is modeled after SD-JWT, with adjustments to align with conventions in CBOR, COSE, and CWT.

B.1. Media Types

The COSE equivalent of application/sd-jwt is application/sd-cwt.

The COSE equivalent of application/kb+jwt is application/kb+cwt.

The COSE equivalent of the +sd-jwt structured suffix is +sd-cwt.

B.2. Redaction Claims

The COSE equivalent of _sd is a CBOR Simple Value (requested assignment 59). The following value is an array of the redacted Claim Keys.

The COSE equivalent of ... is a CBOR tag (requested assignment 60) of the digested salted claim.

In SD-CWT, the order of the fields in a disclosure is salt, value, key. In SD-JWT the order of fields in a disclosure is salt, key, value. This choice ensures that the second element in the CBOR array is always the value, which makes parsing faster and more efficient in strongly-typed programming languages.

In SD-CWT, all decoy digests are disclosed between the Issuer and the Holder. In SD-JWT, no disclosure is sent for a decoy digest.

B.3. Issuance

The issuance process for SD-CWT is similar to SD-JWT, with the exception that a confirmation claim is REQUIRED.

B.4. Presentation

The presentation process for SD-CWT is similar to SD-JWT, except that a Key Binding Token is REQUIRED. The KBT then includes the issued SD-CWT, including the Holder-selected disclosures. Because the entire SD-CWT is included as a claim in the KBT, the disclosures are covered by the Holder's signature in the KBT, but not by the Issuer's signature in the SD-CWT.

B.5. Validation

The validation process for SD-CWT is similar to SD-JWT, however, JSON Objects are replaced with CBOR Maps, which can contain integer keys and CBOR Tags.

Appendix C. Keys Used in the Examples

C.1. Subject / Holder

Holder COSE key pair in EDN format:

```
{
  /kty/  1 : 2, /EC/
  /alg/  3 : -7, /ES256/
  /crv/ -1 : 1, /P-256/
  /x/   -2 : h'8554eb275dcd6fbd1c7ac641aa2c90d9
               2022fd0d3024b5af18c7cc61ad527a2d',
  /y/   -3 : h'4dc7ae2c677e96d0cc82597655ce92d5
               503f54293d87875d1e79ce4770194343',
  /d/   -4 : h'5759a86e59bb3b002dde467da4b52f3d
               06e6c2cd439456cf0485b9b864294ce5'
}
```

The fields necessary for the COSE Key Thumbprint [RFC9679] in EDN format:

```
{
  /kty/  1 : 2, /EC/
  /crv/ -1 : 1, /P-256/
  /x/   -2 : h'8554eb275dcd6fbd1c7ac641aa2c90d9
              2022fd0d3024b5af18c7cc61ad527a2d',
  /y/   -3 : h'4dc7ae2c677e96d0cc82597655ce92d5
              503f54293d87875d1e79ce4770194343'
}
```

The same map in CBOR pretty printing:

```
A4                                      # map(4)
   01                                   # unsigned(1)
   02                                   # unsigned(2)
   20                                   # negative(0)
   01                                   # unsigned(1)
   21                                   # negative(1)
   58 20                                # bytes(32)
      8554EB275DCD6FBD1C7AC641AA2C90D92022FD0D3024B5AF18C7CC61AD527A2D
   22                                   # negative(2)
   58 20                                # bytes(32)
      4DC7AE2C677E96D0CC82597655CE92D5503F54293D87875D1E79CE4770194343
```

The COSE Key Thumbprint (in hexadecimal)--SHA256 hash of the thumbprint fields:

```
8343d73cdfcb81f2c7cd11a5f317be8eb34e4807ec8c9ceb282495cffdf037e0
```

The COSE Key Thumbprint URI:

```
urn:ietf:params:oauth:ckt:g0PXPN_LgfLHzRGl8xe-jrNOSAfsjJzrKCSVz_3wN-A
```

Holder key pair in JWK format:

```
{
  "kty": "EC",
  "alg": "ES256",
  "kid": "WRQ2RbY5RYJCIxfDQL9agl9fFSCYVu4Xocqb6zerc1M",
  "crv": "P-256",
  "x": "hVTrJ13Nb70cesZBqiyQ2SAi_Q0wJLWvGMfMYa1Sei0",
  "y": "TceuLGd-ltDMgll2Vc6S1VA_VCk9h4ddHnnOR3AZQ0M",
  "d": "V1moblm7OwAt3kZ9pLUvPQbmws1DlFbPBIW5uGQpTOU"
}
```

Input to Holder public JWK thumbprint (ignore line breaks):

{"crv":"P-256","kty":"EC","x":"hVTrJ13Nb70cesZBqiyQ2SAi_Q0wJLWvGMfMYa1S
ei0","y":"TceuLGd-ltDMgll2Vc6S1VA_VCk9h4ddHnnOR3AZQ0M"}

SHA-256 of the Holder public JWK input string (in hex):

59143645b6394582422317c340bf5a825f5f15209856ee17a1ca9beb37ab7353

Holder public JWK thumbprint:

WRQ2RbY5RYJCIxfDQL9agl9fFSCYVu4Xocqb6zerc1M

Holder public key in PEM format:

```
-----BEGIN PUBLIC KEY-----
MFkwEwYHKoZIzj0CAQYIKoZIzj0DAQcDQgAEhVTrJ13Nb70cesZBqiyQ2SAi/Q0w
JLWvGMfMYa1Sei1Nx64sZ36W0MyCWXZVzpLVUD9UKT2Hh10eec5HcBlDQw==
-----END PUBLIC KEY-----
```

Holder private key in PEM format:

```
-----BEGIN PRIVATE KEY-----
MIGHAgEAMBMGByqGSM49AgEGCCqGSM49AwEHBG0wawIBAQQgV1moblm7OwAt3kZ9
pLUvPQbmws1DlFbPBIW5uGQpTOWhRANCAASFVOsnXc1vvRx6xkGqLJDZICL9DTAk
ta8Yx8xhrVJ6LU3HrixnfpbQzIJZdlXOktVQP1QpPYeHXR55zkdwGUND
-----END PRIVATE KEY-----
```

C.2. Issuer

Issuer COSE key pair in Extended Diagnostic Notation (EDN):

```
{
  /kty/  1 : 2, /EC/
  /kid/  2 : "https://issuer.example/cwk3.cbor",
  /alg/  3 : -51, /ESP384/
  /crv/ -1 : 2, /P-384/
  /x/   -2 : h'c31798b0c7885fa3528fbf877e5b4c3a6dc67a5a5dc6b307
               b728c3725926f2abe5fb4964cd91e3948a5493f6ebb6cbbf',
  /y/   -3 : h'8f6c7ec761691cad374c4daa9387453f18058ece58eb0a8e
               84a055a31fb7f9214b27509522c159e764f8711e11609554',
  /d/   -4 : h'71c54d2221937ea612db1221f0d3ddf771c9381c4e3be41d
               5aa0a89d685f09cfef74c4bbf104783fd57e87ab227d074c'
}
```

The fields necessary for the COSE Key Thumbprint [RFC9679] in EDN format:

```
{
  /kty/  1 : 2, /EC/
  /crv/ -1 : 2, /P-384/
  /x/   -2 : h'c31798b0c7885fa3528fbf877e5b4c3a6dc67a5a5dc6b307
                b728c3725926f2abe5fb4964cd91e3948a5493f6ebb6cbbf',
  /y/   -3 : h'8f6c7ec761691cad374c4daa9387453f18058ece58eb0a8e
                84a055a31fb7f9214b27509522c159e764f8711e11609554'
}
```

The same map in CBOR pretty printing:

```
A4                                      # map(5)
   01                                   # unsigned(1)
   02                                   # unsigned(2)
   20                                   # negative(0)
   02                                   # unsigned(2)
   21                                   # negative(1)
   58 30                                # bytes(48)
      C31798B0C7885FA3528FBF877E5B4C3A6DC67A5A5DC6B307
      B728C3725926F2ABE5FB4964CD91E3948A5493F6EBB6CBBF
   22                                   # negative(2)
   58 30                                # bytes(48)
      8F6C7EC761691CAD374C4DAA9387453F18058ECE58EB0A8E
      84A055A31FB7F9214B27509522C159E764F8711E11609554
```

The COSE Key Thumbprint (in hexadecimal)--SHA256 hash of the thumbprint fields:

```
554550a611c9807b3462cfec4a690a1119bc43b571da1219782133f5fd6dbcb0
```

The COSE Key Thumbprint URI:

```
urn:ietf:params:oauth:ckt:VUVQphHJgHs0Ys_sSmkKERm8Q7Vx2hIZeCEz9f1tvLA
```

Issuer key pair in JWK format:

```
{
"kty": "EC",
"alg": "ES384",
"kid": "https://issuer.example/cwk3.cbor",
"crv": "P-384",
"x":"wxeYsMeIX6NSj7-HfltMOm3GelpdxrMHtyjDclkm8qvl-0lkzZHjlIpUk_brtsu_",
"y":"j2x-x2FpHK03TE2qk4dFPxgFjs5Y6wqOhKBVox-3-SFLJ1CVIsFZ52T4cR4RYJVU",
"d":"ccVNIiGTfqYS2xIh8NPd93HJOBxOO-QdWqConWhfCc_vdMS78QR4P9V-h6sifQdM"
}
```

Input to Issuer JWK thumbprint (ignore line breaks):

{"crv":"P-384","kty":"EC","x":"wxeYsMeIX6NSj7-HfltMOm3GelpdxrMHtyjDclkm
8qvl-0lkzZHjlIpUk_brtsu_","y":"j2x-x2FpHK03TE2qk4dFPxgFjs5Y6wqOhKBVox-3
-SFLJ1CVIsFZ52T4cR4RYJVU"}

SHA-256 of the Issuer JWK input string (in hex):

18d4ddb7065d945357e3972dee76af4eddc7c285fb42efcfa900c6a4f8437850

Issuer JWK thumbprint:

GNTdtwZdlFNX45ct7navTt3HwoX7Qu_PqQDGpPhDeFA

Issuer public key in PEM format:

```
-----BEGIN PUBLIC KEY-----
MHYwEAYHKoZIzj0CAQYFK4EEACIDYgAEwxeYsMeIX6NSj7+HfltMOm3GelpdxrMH
tyjDclkm8qvl+0lkzZHjlIpUk/brtsu/j2x+x2FpHK03TE2qk4dFPxgFjs5Y6wqO
hKBVox+3+SFLJ1CVIsFZ52T4cR4RYJVU
-----END PUBLIC KEY-----
```

Issuer private key in PEM format:

```
-----BEGIN PRIVATE KEY-----
MIG2AgEAMBAGByqGSM49AgEGBSuBBAAiBIGeMIGbAgEBBDBxxU0iIZN+phLbEiHw
0933cck4HE475B1aoKidaF8Jz+90xLvxBHg/1X6HqyJ9B0yhZANiAATDF5iwx4hf
o1KPv4d+W0w6bcZ6Wl3Gswe3KMNyWSbyq+X7SWTNkeOUilST9uu2y7+PbH7HYWkc
rTdMTaqTh0U/GAWOzljrCo6EoFWjH7f5IUsnUJUiwVnnZPhxHhFglVQ=
-----END PRIVATE KEY-----
```

Appendix D. Nesting Example Walkthrough

D.1. Issuer

How the Issuer decides which claims to include in an SD-CWT Claims Set, and which claims in a Claims Set to redact is a local policy matter outside of the scope of this specification.

Here we will start with the example Claims Set from Figure 27.

The Holder or the administrator of the Issuer could use the To Be Redacted tag (see Section 11.1) and the To Be Decoy tag (see Section 11.2) as a hint to the Issuer to indicate claims to be redacted or locations for decoys. The examples in this document were produced using this method.

Below is the nested Claims Set example from Figure 27 with To Be Redacted tags wrapping the claims that are actually redacted in our nested example.

```
{
    / iss / 1  : "https://issuer.example",
    / sub / 2  : "https://holder.example",
    / exp / 4  : 1725330600, /2024-09-02T19:30:00Z/
    / nbf / 5  : 1725243840, /2024-09-01T19:25:00Z/
    / iat / 6  : 1725244200, /2024-09-01T19:30:00Z/
    / cnf / 8  : { ... },
    504: [                          / inspection history log /
        58({                        / REDACT /
            500: true,              / inspection passed /
            502: 1549560720,        / 2019-02-07T17:32:00 /
            58(501): "DCBA-101777", / inspector license ; REDACT /
            58(503): {              / REDACT /
                1: "us",            / United States /
                58(2): "co",        / region=Colorado ; REDACT /
                58(3): "80302"      / postcode ; REDACT /
            }
        }),
        58({                        / REDACT /
            500: true,              / inspection passed /
            502: 1612560720,        / 2021-02-04T20:14:00 /
            58(501): "EFGH-789012", / inspector license ; REDACT /
            58(503): {              / REDACT /
                1: "us",            / United States /
                58(2): "nv",        / region=Nevada ; REDACT /
                58(3): "89155"      / postcode ; REDACT /
            }
        }),
        58({                        / REDACT /
            500: true,              / inspection passed /
            502: 17183928,          / 2023-01-17T17:19:00 /
            58(501): "ABCD-123456", / inspector license ; REDACT /
            58(503): {              / REDACT /
                1: "us",            / United States /
                58(2): "ca",        / region=California ; REDACT /
                58(3): "94188"      / postcode ; REDACT /
            }
        })
    ]
}
```

Figure 31: EDN example of Nested Claims Set tagged with desired redactions

The Issuer in our example respects the hints and produces the following issued SD-CWT. The Issuer has generated 15 disclosures.

Note that the Issuer can list the issued disclosures (if any) in any order.

```
/ cose-sign1 / 18([  / issuer SD-CWT /
  / CWT protected / << {
    / alg /    1  : -35, / ES384 /
    / kid /    4  : 'https://issuer.example/cose-key3',
    / typ /    16 : 293, # application/sd-cwt
    / sd_alg / 170 : -16  / SHA256 /
  } >>,
  / CWT unprotected / {
    / sd_claims / 17 : [ / these are all the disclosures /
        <<[
            /salt/   h'591eb2081b05be2dcbb6f8459cc0fe51',
            /value/  "DCBA-101777",
            /claim/  501   / inspector_license_number /
        ]>>,         / Redacted Claim Hash begins 7257a869 /
        <<[
            /salt/   h'e70e23e77176fa59beb0b2559943a079',
            /value/  "co",
            /claim/  2   / region=Colorado /
        ]>>,         / Redacted Claim Hash begins 1b897171 /
        <<[
            /salt/   h'cbbf1cd3d1a5da83e1d92c08d566a481',
            /value/  "80302",
            /claim/  3   / postcode=80302 /
        ]>>,         / Redacted Claim Hash begins 49412884 /
        <<[
            /salt/   h'c23a4d192be75dbd583be570482de8dd',
            /value/  {
                         1: "us",
                         simple(59): [
                         h'1b89717167f39d51eec08b13baeda570
                           eff5d0aedaa1d7d0821185c33634a5a0',
                         h'49412884fa1e3787c17d1320bdd48f6e
                           0e5365da010cde0571d4a7effd13cc2a'
                       ]
                       },
            /claim/  503   / Denver location /
        ]>>,         / Redacted Claim Hash begins c24c646b /
        <<[
            /salt/   h'2df7d2c105b5bf3acf9c698f3658552f',
            /value/  {
                         500: true,
                         502: 1549560720,
                         simple(59): [
                         h'7257a8697dfa40221079b00fb65fe587
                           c310e6ca3da1aa33b090335de66ec810',
```

```
                    h'c24c646b52fecd773c6ea01c6caa5a73
                      422b85d3afa5900fa998336d83a88025'
                ]
                }   / inspection 7-Feb-2019 /
        ]>>,        / Redacted Claim Hash begins ca6b8516 /
        <<[
            /salt/   h'9a3bc899090435650b377199450c1fa1',
            /value/  "EFGH-789012",
            /claim/  501   / inspector_license_number /
        ]>>,        / Redacted Claim Hash begins 98d15f82 /
        <<[
            /salt/   h'5e852d2eef59c0ebeab8c08fca252cc5',
            /value/  "nv",
            /claim/  2   / region=Nevada /
        ]>>,        / Redacted Claim Hash begins da268d9b /
        <<[
            /salt/   h'3dd46bd7dea09c9ee7dfe4e0d510129b',
            /value/  "89155",
            /claim/  3   / postcode=89155 /
        ]>>,        / Redacted Claim Hash begins 61dcdb8c /
        <<[
            /salt/   h'c225607427e01072bbafcce7e48049e3',
            /value/  {
                        1: "us",
                        simple(59): [
                        h'da268d9b81c19c02fcea7c4cadc2e23f
                          0454a4550a380cde8b0842463ed034da',
                        h'61dcdb8cbae7b66c3e36b2510daf61ba
                          9168a50f20f4cad4213ed231e33d5b7b'
                ]
                },
            /claim/  503   / Las Vegas location /
        ]>>,        / Redacted Claim Hash begins 5dec8f26 /
        <<[
            /salt/   h'1b248d469cf00b8dfa896f069f04697b',
            /value/  {
                        500: true,
                        502: 1612560720,
                        simple(59): [
                        h'98d15f82dfadc18f5700582ff47b286c
                          d7ca047bb1e0529a5374c59d6dc5057d',
                        h'5dec8f268d3b9735936740c91b9baf00
                          43de8ee42357a414e3e8d4ab098fae5d'
                ]
                }   / inspection 4-Feb-2021 /
        ]>>,        / Redacted Claim Hash begins 0dfdc69d /
        <<[
            /salt/   h'bae611067bb823486797da1ebbb52f83',
```

```
            /value/  "ABCD-123456",
            /claim/  501   / inspector_license_number /
        ]>>,         / Redacted Claim Hash begins af375dc3 /
        <<[
            /salt/   h'52da9de5dc61b33775f9348b991d3d78',
            /value/  "ca",
            /claim/  2   / region=California /
        ]>>,         / Redacted Claim Hash begins 2470fb91 /
        <<[
            /salt/   h'a965de35aa599d603fe1b7aa89490eb0',
            /value/  "94188",
            /claim/  3   / postcode=94188 /
        ]>>,         / Redacted Claim Hash begins cf397a08 /
        <<[
            /salt/   h'483e4b3c194df6073a9c41ca9f274067',
            /value/  {
                         1: "us",
                         simple(59): [
                         h'2470fb9175b062c347ab3c3a19776d02
                           476112a17cd7cfc9416664bc058c220b',
                         h'cf397a08917528624ca3b332c9edcc54
                           a72c9411dd5983f68017ce160f709f52'
                       ]
                       },
            /claim/  503   / San Francisco location /
        ]>>,         / Redacted Claim Hash begins 9d151abe /
        <<[
            /salt/   h'cd99b3858f1d659f9d16039abf8c5fba',
            /value/  {
                         500: true,
                         502: 1674004740,
                         simple(59): [
                         h'af375dc3fba1d082448642c00be7b2f7
                           bb05c9d8fb61cfc230ddfdfb4616a693',
                         h'9d151abeb800adcc11ff10ff61fbd3d7
                           5944c134b40a24abef1787d3ae6583aa'
                       ]
                       }   / inspection 17-Jan-2023 /
        ]>>,         / Redacted Claim Hash begins 20d9bb11 /
    ]
  },
  / CWT payload / << {
    / iss / 1   : "https://issuer.example",
    / sub / 2   : "https://holder.example",
    / exp / 4   : 1725330600,  /2024-09-03T02:30:00+00:00Z/
    / nbf / 5   : 1725243900,  /2024-09-02T02:25:00+00:00Z/
    / iat / 6   : 1725244200,  /2024-09-02T02:30:00+00:00Z/
    / cnf / 8   : {
```

```
        / cose key / 1 : {
          / kty /  1: 2,  / EC2   /
          / crv / -1: 1,  / P-256 /
          / x /   -2: h'8554eb275dcd6fbd1c7ac641aa2c90d9
                       2022fd0d3024b5af18c7cc61ad527a2d',
          / y /   -3: h'4dc7ae2c677e96d0cc82597655ce92d5
                       503f54293d87875d1e79ce4770194343'
        }
      },
      /inspection history log/ 504: [
        / inspection 7-Feb-2019 /
        60(h'ca6b851688236744ff0cf0814508e4f1
             81d3811bfec4ed5bb8ace7823132dbc0'),
        / inspection 4-Feb-2021 /
        60(h'0dfdc69d0efb65eec14bf28af78cd8f0
             6cabfe8e2b1a0611ef8bca869ce35b61'),
        / inspection 17-Jan-2023 /
        60(h'20d9bb11363bae49851cfd4a3f166539
             d0aa00433c30aede18380bfa98d781dc')
      ]
    } >>,
    / CWT signature / h'8c1e9957b573191c47a9f4244abc4be2
                        7c9944c2a992e015a86e19c24b041195
                        51ee920061066edb22823114f96dac2a
                        1bfa9c7a503e3033a0cd5aad6d9165f7
                        5483e9a79eb31f9bfdfb07df5fb7b8e5
                        0da8acbabad974999d12096f4ae8b420'
])
```

Figure 32: The Issued CWT containing nested redacted claims

Now the issued SD-CWT is provided to the Holder for processing.

D.2. Holder

Once it receives an issued SD-CWT from the Issuer, the Holder validates all of the disclosures as described in Section 6.2. The Holder needs to unwrap all nested claims starting with the top level and proceeding deeper, to insure that there are no unmatched Redacted Claim Hashes anywhere in the document, and no unmatched disclosures.

Once the issued CWT is validated, the Holder can create multiple presentations, generating different KBTs (as described in Section 8.1) for each presentation by changing, for example, the audience and the choice of disclosures. The privacy issues in Section 15 apply.

In our example, the Holder chooses to disclose two of the inspections (from 2019 and 2023), the inspector license numbers and partially redacted location maps from both of these inspections, and the region (California) in the location map of the 2023 inspection. In our example, the Holder sorts these disclosures in ascending order of the Redacted Claim Hash corresponding to each disclosure. (It could have used _any_ order.)

```
    / sd_claims / 17 : [ / these are the disclosures /
        <<[
            /salt/   h'cd99b3858f1d659f9d16039abf8c5fba',
            /value/  {
                         500: true,
                         502: 1674004740,
                         simple(59): [
                         h'af375dc3fba1d082448642c00be7b2f7
                           bb05c9d8fb61cfc230ddfdfb4616a693',
                         h'9d151abeb800adcc11ff10ff61fbd3d7
                           5944c134b40a24abef1787d3ae6583aa'
                     ]
                     }   / inspection 17-Jan-2023 /
        ]>>,         / Redacted Claim Hash begins 20d9bb11 /
        <<[
            /salt/   h'52da9de5dc61b33775f9348b991d3d78',
            /value/  "ca",
            /claim/  2   / region=California /
        ]>>,         / Redacted Claim Hash begins 2470fb91 /
        <<[
            /salt/   h'591eb2081b05be2dcbb6f8459cc0fe51',
            /value/  "DCBA-101777",
            /claim/  501   / inspector_license_number /
        ]>>,         / Redacted Claim Hash begins 7257a869 /
        <<[
            /salt/   h'483e4b3c194df6073a9c41ca9f274067',
            /value/  {
                         1: "us",
                         simple(59): [
                         h'2470fb9175b062c347ab3c3a19776d02
                           476112a17cd7cfc9416664bc058c220b',
                         h'cf397a08917528624ca3b332c9edcc54
                           a72c9411dd5983f68017ce160f709f52'
                     ]
                     },
            /claim/  503   / San Francisco location /
        ]>>,         / Redacted Claim Hash begins 9d151abe /
        <<[
            /salt/   h'bae611067bb823486797da1ebbb52f83',
            /value/  "ABCD-123456",
```

```
            /claim/  501   / inspector_license_number /
        ]>>,         / Redacted Claim Hash begins af375dc3 /
        <<[
            /salt/   h'c23a4d192be75dbd583be570482de8dd',
            /value/  {
                         1: "us",
                         simple(59): [
                         h'1b89717167f39d51eec08b13baeda570
                           eff5d0aedaa1d7d0821185c33634a5a0',
                         h'49412884fa1e3787c17d1320bdd48f6e
                           0e5365da010cde0571d4a7effd13cc2a'
                     ]
                     },
            /claim/  503   / Denver location /
        ]>>,         / Redacted Claim Hash begins c24c646b /
        <<[
            /salt/   h'2df7d2c105b5bf3acf9c698f3658552f',
            /value/  {
                         500: true,
                         502: 1549560720,
                         simple(59): [
                         h'7257a8697dfa40221079b00fb65fe587
                           c310e6ca3da1aa33b090335de66ec810',
                         h'c24c646b52fecd773c6ea01c6caa5a73
                           422b85d3afa5900fa998336d83a88025'
                     ]
                     }   / inspection 7-Feb-2019 /
        ]>>,         / Redacted Claim Hash begins ca6b8516 /
    ]
```

Figure 33: The Holder's choice of nested disclosures, sorted

Due to the way the claims are nested, disclosing the region of the 2023 inspection would not have been useful without disclosing the enclosing location map and its enclosing 2023 inspection array element. In other words, the Holder needs to make sure that any intermediate levels of nested claims it wishes to disclose are also disclosed, otherwise the Verifier will not be able to validate them. At best, such "orphaned" disclosures will be discarded by the Verifier, and at worst, the Verifier could reject the entire SD-CWT.

The Holder then presents its KBT to the Verifier.

D.3. Verifier

The Verifier receives the Holder's KBT, which contains an SD-CWT with the Holder's choice of (nested) disclosures. The example does not show the KBT for brevity; it is always used in an actual presentation. In the example the disclosures are sorted in the order of the Redacted Claim Hash corresponding to each disclosure. (The Holder can present its disclosures in any order.)

The Verifier needs to match the disclosures to their corresponding Redacted Claims in the Claims Set in the payload of our example SD-CWT. The Verifier needs to calculate the Redacted Claim Hash for each of the disclosures it receives.

Typically the Verifier would create a lookup table of disclosures indexed by the Redacted Claim Hash. Comments in all the examples show the first 4 bytes of the Redacted Claim Hash of each disclosure. The comments are only present in the diagnostic (text) notation to make it easier for the reader; comments are not included in CWTs or in SD-CWT in their native form.

Our example document only contains three Redacted Claims that are currently visible.

```
...
/inspection history log/ 504: [
  / inspection 7-Feb-2019 /
  60(h'ca6b851688236744ff0cf0814508e4f1
       81d3811bfec4ed5bb8ace7823132dbc0'),
  / inspection 4-Feb-2021 /
  60(h'0dfdc69d0efb65eec14bf28af78cd8f0
       6cabfe8e2b1a0611ef8bca869ce35b61'),
  / inspection 17-Jan-2023 /
  60(h'20d9bb11363bae49851cfd4a3f166539
       d0aa00433c30aede18380bfa98d781dc')
]
...
```

Figure 34: Redacted Claims at Level 1

The Verifier looks for matching Redacted Claim Hashes among the disclosures it has received. In this example it finds two matching hashes (the first and last hash in the inspection history log claim array). The Verifier replaces the two matching Redacted Claim Hashes with their disclosed values (in this case, the last and first disclosures, which are both replacing Redacted Claim Elements) and removes the second Redacted Claim Hash. The Verifier no longer considers the matched disclosures; each disclosure cannot match more than one Redacted Claim Hash.

```
...
/inspection history log/ 504: [
  {
    500: true,
    502: 1549560720,
    simple(59): [
      h'7257a8697dfa40221079b00fb65fe587
        c310e6ca3da1aa33b090335de66ec810',
      h'c24c646b52fecd773c6ea01c6caa5a73
        422b85d3afa5900fa998336d83a88025'
    ]
  }   / inspection 7-Feb-2019 /,
  {
    500: true,
    502: 1674004740,
    simple(59): [
      h'af375dc3fba1d082448642c00be7b2f7
        bb05c9d8fb61cfc230ddfdfb4616a693',
      h'9d151abeb800adcc11ff10ff61fbd3d7
        5944c134b40a24abef1787d3ae6583aa'
    ]
  }   / inspection 17-Jan-2023 /
]
...
```

Figure 35: Claims after revealing disclosures at Level 1

The Verifier then repeats the process again at the next "level" of nesting. In this example, all the visible Redacted Claims happen to be Redacted Claim Keys. The second, third, fourth, and sixth disclosures match. The Verifier replaces these Redacted Claims with the corresponding Claim Keys from the disclosures.

```
...
/inspection history log/ 504: [
  {
    500: true,
    502: 1549560720,
    501: "DCBA-101777",
    503: {
      1: "us",
      simple(59): [
        h'1b89717167f39d51eec08b13baeda570
          eff5d0aedaa1d7d0821185c33634a5a0',
        h'49412884fa1e3787c17d1320bdd48f6e
          0e5365da010cde0571d4a7effd13cc2a'
      ]
    }
  }   / inspection 7-Feb-2019 /,
  {
    500: true,
    502: 1674004740,
    501: "ABCD-123456",
    503: {
      1: "us",
      simple(59): [
        h'2470fb9175b062c347ab3c3a19776d02
          476112a17cd7cfc9416664bc058c220b',
        h'cf397a08917528624ca3b332c9edcc54
          a72c9411dd5983f68017ce160f709f52'
      ]
    }
  }   / inspection 17-Jan-2023 /
]
...
```

Figure 36: Claims after revealing disclosures at Level 2

The Verifier then repeats the process again at the next "level" of nesting. The Verifier finds a single matching disclosure (the second disclosure). The Verifier replaces the matching Redacted Claim Hash and removes the others.

```
...
/inspection history log/ 504: [
  {
    500: true,
    502: 1549560720,
    501: "DCBA-101777",
    503: {
      1: "us"
    }
  }   / inspection 7-Feb-2019 /,
  {
    500: true,
    502: 1674004740,
    501: "ABCD-123456",
    503: {
      1: "us",
      2: "ca" / region=California /
    }
  }   / inspection 17-Jan-2023 /
]
...
```

Figure 37: Claims after revealing disclosures at Level 3

The Verifier has no more Redacted Claim Hashes to process. Assuming the other validation steps pass, the Verifier can pass the Validated Claims Set on to the application.

If there were remaining disclosures, the SD-CWT is invalid. The Verifier could decide to ignore the extra disclosures, or to reject the entire SD-CWT depending on its local policy. Extra disclosures cannot be verified and indicate incorrect behavior by the Holder.

Appendix E. Implementation Status

Note to the RFC Editor: Please remove this section as well as references to [BCP205] before AUTH48.

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [BCP205]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been made to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to [BCP205], "This will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit".

E.1. Transmute Prototype

Organization: Transmute Industries Inc

Name: github.com/transmute-industries/sd-cwt (https://github.com/transmute-industries/sd-cwt)

Description: An open-source implementation of this specification.

Maturity: Prototype

Coverage: The current version (’main’) implements functionality similar to that described in this specification, and will be revised, with breaking changes to support the generation of example data to support this specification.

License: Apache-2.0

Implementation Experience: No interop testing has been done yet. The code works as a proof of concept, but is not yet production ready.

Contact: Orie Steele (orie.steele@tradeverifyd.com)

E.2. Rust Prototype

Organization: SimpleLogin

Name: github.com/beltram/esdicawt (https://github.com/beltram/esdicawt)

Description: An open-source Rust implementation of this specification in Rust.

Maturity: Prototype

Coverage: The current version is close to the spec with the exception of redacted_claim_keys using a CBOR SimpleValue as label instead of a tagged key. Not all of the verifications have been implemented yet.

License: Apache-2.0

Implementation Experience: No interop testing has been done yet. The code works as a proof of concept, but is not yet production ready.

Contact: Beltram Maldant (beltram.ietf.spice@pm.me)

E.3. Python Prototype

Organization: Tradeverifyd

Name: github.com/tradeverifyd/sd-cwt (https://github.com/tradeverifyd/sd-cwt)

Description: An open-source Python implementation of this specification.

Maturity: Prototype

Coverage: The current version does not implement decoys, but does verify the test vectors in draft-ietf-spice-sd-cwt-05.

License: Apache-2.0

Implementation Experience: No interop testing has been done yet. The code works as a proof of concept, but is not yet production ready.

Contact: Orie Steele (orie.steele@tradeverifyd.com)

Appendix F. Relationship between RATS Architecture and Verifiable Credentials

This appendix describes the relationship between the Remote ATtestation procedureS (RATS) architecture defined in [RFC9334] and the three-party model used in verifiable credentials.

F.1. Three-Party Verifiable Credentials Model

The verifiable credentials model involves three distinct parties:

* *Issuer*: Creates and signs credentials containing claims about a subject

* *Holder*: Controls the credential and presents it to verifiers (the holder is typically the subject of the credential)

* *Verifier*: Receives and validates presented credentials to make authorization or access decisions. In this appendix we refer to this role as a *Credential Verifier*

In SD-CWT, these roles are explicitly represented: the Issuer signs claims using an Assertion Key (Section 2), the Holder controls the credential and creates presentations using a Confirmation Key, and the Verifier validates both the Issuer’s signature over the credential and the Holder’s signature over the presentation (Key Binding Token).

F.2. RATS Architecture Roles

The RATS architecture defines the following key roles:

* *Attester*: Produces Evidence about its own trustworthiness and operational state

* *Endorser*: Provides Endorsements about an Attester (typically a manufacturer)

* *Reference Value Provider*: Supplies Reference Values used by Verifiers to evaluate Evidence

* *Verifier*: Appraises Evidence and produces Attestation Results. In this appendix we refer to this role as a *RATS Verifier*

* *Relying Party*: Consumes Attestation Results to make authorization decisions

F.3. Role Mappings in the Three-Party Model

The mapping between RATS roles and verifiable credential roles can be understood as follows:

F.3.1. Verifiable Credential Issuer as RATS Endorser

A verifiable credential Issuer functions as a RATS Endorser. The Endorser role in RATS produces Endorsements - secure statements about an Attester's capabilities, identity, or trustworthiness. Similarly, a credential Issuer produces signed credentials containing claims about a subject (the Holder). Both roles:

* Make authoritative statements about another party's attributes or capabilities
* Use cryptographic signatures to ensure integrity and authenticity
* Are typically trusted third parties in their respective ecosystems
* Provide information that enables downstream authorization decisions

The credential issued by the Issuer serves the same function as an Endorsement in RATS: it is a signed assertion about the Holder's attributes that can be used by Credential Verifiers to make trust decisions.

F.3.2. Verifiable Credential Holder as RATS Verifier

A verifiable credential Holder functions as a RATS Verifier. The RATS Verifier appraises Evidence and Endorsements and produces Attestation Results. In the credentials model, the Holder:

* Receives credentials (analogous to Endorsements) from Issuers
* Evaluates which credentials to present and which claims to disclose
* Produces presentations (analogous to Attestation Results) that are sent to Credential Verifiers
* Uses their Confirmation Key to create key binding tokens that prove control

The Holder's presentation, which includes the Issuer's credential plus the Holder's signature over selected disclosures, functions as an Attestation Result - a processed, signed assertion derived from the original credential (Endorsement).

F.3.3. Verifiable Credential Verifier as RATS Relying Party

A verifiable credential Credential Verifier functions as a RATS Relying Party. The Relying Party:

* Consumes Attestation Results (credential presentations) to make authorization decisions
* Validates the cryptographic integrity of received assertions
* Makes access control or authorization decisions based on the claims received
* Does not directly interact with the original Endorsement source (the Issuer)

The Credential Verifier appraises the Holder's presentation in the same way a Relying Party appraises Attestation Results from a RATS Verifier.

F.3.4. All Parties Can Be Attesters

Importantly, any of these parties - Issuer, Holder, or Credential Verifier - can simultaneously function as a RATS Attester. The Attester role in RATS is about producing Evidence about one's own trustworthiness:

* An *Issuer* may be an Attester when it needs to prove its own integrity, platform state, or authorization to issue certain credential types. For example, an Issuer might provide Evidence about its secure enclave or certified infrastructure when establishing trust with Holders or during credential issuance.
* A *Holder* may be an Attester when presenting credentials, particularly when the presentation itself requires proof of the Holder's platform integrity. For example, a Holder might provide Evidence about their device's secure boot state, firmware version, or trusted execution environment alongside their credential presentation.
* A *Credential Verifier* may be an Attester when it needs to prove its own trustworthiness to Holders or to upstream systems. For example, a Credential Verifier might provide Evidence about its data protection capabilities, compliance certifications, or secure processing environment before Holders agree to disclose sensitive claims.

The Attester role is orthogonal to the three primary roles - it represents the ability to produce evidence about one's own state, while the Issuer/Holder/Credential Verifier roles represent the flow of credentials and claims about subjects.

F.4. Comparison with RATS Interaction Models

RATS defines two interaction models:

Passport Model: The Attester sends Evidence to a RATS Verifier, receives Attestation Results, and presents these results to Relying Parties. This maps to the three-party credentials model where the Holder obtains credentials from Issuers and presents them to Credential Verifiers.

Background-Check Model: The Attester sends Evidence to a Relying Party, which forwards it to a RATS Verifier. The RATS Verifier returns results directly to the Relying Party. This is a two-party model from the Attester's perspective and does not map well to the three-party credentials model, as it lacks Holder mediation and control over presentations.

F.5. Roles That Don't Map to the Three-Party Model

The *Reference Value Provider* role from RATS does not have a direct equivalent in the three-party verifiable credentials model. This role supplies reference values (known-good measurements or configurations) that RATS Verifiers use to appraise Endorsements and Evidence. In credentials systems, equivalent functionality might be provided through:

* Trust registries that list authorized Issuers
* Schema registries, or lists of valid claims that define credential formats
* Governance frameworks that specify validation rules
* Revocation registries

However, these are typically considered part of the trust infrastructure rather than a distinct party in the presentation protocol. The Reference Value Provider role is primarily relevant in scenarios where raw Evidence must be evaluated against known-good values - a pattern more common in the two-party background-check model than in the three-party credentials model where Issuers have already performed evaluation and produced credentials.

F.6. Application to SD-CWT

When applying RATS concepts to SD-CWT:

* SD-CWT credentials function as Endorsements about the Holder (subject)

* The Holder’s key binding token and selective disclosure act as the RATS Verifier’s appraisal and production of Attestation Results

* The Credential Verifier consumes these presentations as a Relying Party consumes Attestation Results

* Any party can additionally provide Evidence about their own platform or operational state (act as an Attester)

* The three-party model with selective disclosure maps naturally to the RATS passport model

* Reference Value Provider functionality is addressed through trust infrastructure and out-of-band mechanisms rather than protocol-level roles

Appendix G. Sample Disclosure Matching Algorithm for Verifier

The Verifier of an SD-CWT needs to decode disclosed claims match them with their redacted versions. The following example algorithm describes a way to accomplish this.

1. The decoded sd_claims are converted to an intermediate data structure called a Digest To Disclosed Claim Map that is used to transform the Presented Disclosed Claims Set into a Validated Disclosed Claims Set.

2. The Verifier MUST compute the hash of each Salted Disclosed Claim (salted), in order to match each disclosed value to each entry of the Presented Disclosed Claims Set.

   One possible concrete representation of the intermediate data structure for the Digest To Disclosed Claim Map is a CBOR map with the hash of the bstr-encoded-salted data structure (from the CDDL) as the map key and its value as the contents of the corresponding salted-entry data structure.

3. The Verifier constructs an empty CBOR map called the Validated Disclosed Claims Set, and initializes it with all non-redacted claims from the verified Presented Disclosed Claims Set.

4. Next, the Verifier performs a depth-first traversal of the Presented Disclosed Claims Set and Validated Disclosed Claims Set, using the Digest To Disclosed Claim Map to insert claims into the Validated Disclosed Claims Set when they appear in the Presented Disclosed Claims Set.

5. The Verifier repeats the fourth step if the previous iteration resulted in any new Presented Disclosed Claims.

6. If there remain unused claims in the Digest To Disclosed Claim Map at the end of this procedure the SD-CWT MUST be considered invalid. Likewise, if this algorithm results in any duplicate CBOR map keys, the entire SD-CWT MUST be considered invalid.

   Note: If there are remaining digests without corresponding disclosures, this means that either the holder intentionally did not disclose a claim, or that the digest is a decoy digest Section 10.

Appendix H. Document History

Note: RFC Editor, please remove this entire section on publication.

H.1. draft-ietf-spice-sd-cwt-08

Normative changes:

* Add more text about nesting validation in new section after Section 6.2 on Holder Validation (PR#292).

* Add optional key context to AEAD encrypted disclosures (PR#285).

* Use clearer normative language around CBOR tags and nesting (PR#262).

* Fix AEAD nonce length and mention that AAD is empty (PR#260).

Non-normative changes:

* PR#290 / Issue #284

  - Clarify cnonce in SD-CWT is intended for 2-party model.

  - Clarify Verifier behavior when extra disclosures are present.

  - In elided KBT description point to fully worked example

  - Remove incorrect compatibility discussion

* Rename device.example to holder.example (PR#289).

* Globally use KBT instead of KBT (PR#288).

* Add Appendix walking through nested disclosure handling (PR#286).

* Clean up AEAD encrypted disclosures section and justify used of AEAD (PR#285).

* Heavy editing pass (PR#283).

  - Renumber Section 4 to Section 3.3 as it is part of the Overview.

  - Move normative statement from Section 3 to Section 6.

  - Improve Figures 2 and 3

  - Remove unused terms or terms used only once.

  - Rearrange order of discussion in Section 7.1

  - Clarify use of cnonce

  - Remind about special definition of duplicate map keys in To Be Redacted section

  - Miscellaneous typo, minor rewordings, cleanups, and clarifications

* Update references (PR#280 and PR#281).

* Add change log for -07 and -08 (PR#279).

* Add COSE key thumbprint URIs to Appendix C (PR#278).

* Explain why SD-CWT specifies claim requirements (PR#276).

* Reframe nonce/freshness text (PR#275).

* Reword discussion of Verifier use of Issuer keys (PR#274).

* Justify linkage between KBT and CWT; move revocation discussion to its own section (PR#273).

* Replace blind with redact and unblind with disclose or reveal (PR#272).

* Remove redundant Section 16.7 (PR#271).

* Explain why Issuer should verify Holder key (PR#266).

* Reword applicability and linkability discussions (PR#265).

* Reword disclosure threats and mitigations (PR#264).

* Improve Determinism section (PR#261).

* Better explain To Be Decoy integer uniqueness requirements (PR#259).

* Temporarily remove Rust CDDL tool from cargo.txt to solve a CI issue (PR#267).

* Remove Mike Jones from Acknowledgments (except in list of SD-JWT contributors) since he is already listed as a Contributor.

* Allowed then Reverted that media types can omit application/ (PR#283 then PR#287).

H.2. draft-ietf-spice-sd-cwt-07

* Replace claim requirements with tables (PR#258).

* Explain To Be Decoy integer uniqueness requirements (PR#257).

* Note that Holder needs to verify disclosure of all decoys (PR#256).

* Discuss security considerations of decoys to Holders (PR#254).

* Remove discussion of Certificate and Key Transparency (PR#253).

* Remove Threat Model section and add reference to W3C TAG credential doc (PR#252).

* Address several issues in PR#251:

  - Modify introduction to remove "mandatory to disclose";

  - Note the confirmation keys are mandatory early;

  - Replace "based on" with "inspired by" SD-JWT;

  - Move text from the Introduction into the Overview;

  - Move Figures 2 and 3 into the Overview;
  - Use rounded corners in Figure 3;
  - Clarify opening sections;
  - Add "generic container format, not a specific credential type" language;
  - Move normative language out of Introduction;
  - Represent no disclosure by omitting sd_claims;
  - Reword discussion of typ protected header;
  - Clarify language about claim "name";
  - Replace a lowercase must.

* Allow Holder to use cti instead of iat (PR#250).
* Add Figure descriptions throughout (PR#246).
* Improve Figures 2 and 3 (PR#245).
* Remove the description of "custom" claims (PR#244).
* Add note about Holder choice of order in relevant section (PR#243).
* Explain CBOR-specific terms and concepts: EDN, CDDL, tags, simple values (PR#242).
* Add Holder check for sufficient number of decoys (PR#241).
* Explain why legal CBOR simple values have a gap (PR#240).
* Clarify legal range of floating-point dates (PR#239).
* Make CDDL consistent with IANA section: use uint for To Be Decoy value (PR#238).
* Split the CDDL into individual fragments; add sd-cwt-preissued type (PR#235).
* Rewrite the Makefile to automatically run validation against the combined CDDL (PR#185).

* Move note about redacted array elements (PR#196).

* Expand discussion of random numbers (PR#231).

* Fix a few places where lists missed an initial blank line (PR#225).

* Remove assumption of claim keys being used often (PR#200).

* Remove extraneous trailing dot in references Section (PR#228).

* Distinguish Verifier-Verifier and Verifier-Issuer unlinkability (PR#223).

H.3. draft-ietf-spice-sd-cwt-06

* Refactored deterministic draft generation code (PR#152).

* Added pointer to a Python implementation (PR#155).

* Added decoy digests (PR#157).

* Addressed early IANA feedback about the escalation process (PR#160).

* Used the CoAP Content Type in the examples instead of the text strings "application/sd-cwt" and "application/kb+cwt" (PR#162).

* Added a section on specific CBOR encoding and data model considerations (PR#163).

* Swapped the order of Sections 5 and 6 (PR#167).

* Split the CDDL definitions for payload maps in Issued CWT and pre-issued (PR#168).

* Used the IANA early assigned values in the draft (PR#169).

* Defined the To Be Decoy tag (PR#171).

* Made use of the CoAP Content Type a SHOULD (PR#172).

* Made the draft generation code agnostic to hash algorithm (PR#173)

* Added time claim verification rules and security considerations (PR#175)

* Instead of an empty array, sd_claims is now omitted if empty (PR#176)

* Update the COSE header values to use their newly assigned values (also PR#176)

* Fix some kramdown-xml bracket errors (PR#177)

* Add IANA Considerations for To Be Decoy tag (PR#180)

* Clarify that remaining redacted claims are removed in validated claim set (PR#181)

* Restrict floating point dates to -2^53 to 2^53 (PR#182)

* Rename CDDL production using a standard prelude name (PR#183)

H.4. draft-ietf-spice-sd-cwt-05

* Added this change log (PR#150)

* Moved non-normative validation algorithm to an appendix (PR#149)

* Added appendix describing mapping to RATS concepts (#147)

* Provided guidance on choice of AEAD algorithm (#148)

* Fixed algorithm in COSE key examples (#145)

* Updated contact information (PR#142, PR #150)

* Removed SPICE from the title of the document (PR#139)

* Made clear extent to which verifiers cannot process unknown claims (PR#138)

* Sorted CBOR map keys in examples to facilitate use as test vectors (PR#135)

* Consistently use term "tag" in context of AEAD algorithms (PR#134)

* Improved AASVG diagram in Terminology section (PR#129)

H.5. draft-ietf-spice-sd-cwt-04

* Place value before claim name in disclosures

* Use CBOR simple value 59 for the redacted_key_claims

* Greatly improved text around AEAD encrypted disclosures

* Applied clarifications and corrections suggested by Mike Jones.

* Do not update CWT [RFC8392].

* Use application/sd-cwt media type and define +sd-cwt structured suffix.

* Made SHA-256 be the default sd_alg value.

* Created Verifiable Credential Type Identifiers registry.

* Corrected places where Claim Name was used when what was meant was Claim Key.

* Defined the To Be Redacted CBOR tag

* In the SD-KBT, iss and sub are now forbidden

* Clarified text about aud

* Described Trust Lists

* EDN Examples are now in deterministic order

* Expressed some validation steps as a list

* Clarified handling of nested claims

* Fixed the handling of the to be registered items in the CDDL; made CDDL self consistent

* Fixed some references

H.6. draft-ietf-spice-sd-cwt-03

* remove bstr encoding from sd_claims array (but not the individual disclosures)

* clarify which claims are optional/mandatory

* correct that an SD-CWT may have zero redacted claims

* improve the walkthrough of computing a disclosure

* clarify that duplicate map keys are not allowed, and how tagged keys are represented.

* added security considerations section (#42) and text about privacy and linkability risks (#43)

* register SD-CWT and SD-KBT as content formats in CoAP registry (#39)

* updated media types registrations to have more useful contacts (#44)

* build most of the values (signatures/salts/hashes/dates) in the examples automatically using a script that implements SD-CWT

* regenerate all examples with correct signatures

* add nested example

* add optional encrypted disclosures

H.7. draft-ietf-spice-sd-cwt-02

* KBT now includes the entire SD-CWT in the Confirmation Key CWT (kcwt) existing COSE protected header. Has algorithm now specified in new sd_alg COSE protected header. No more sd_hash claim. (PR #34, 32)

* Introduced tags for redacted and to-be-redacted claim keys and elements. (PR#31, 28)

* Updated example to be a generic inspection certificate. (PR#33)

* Add section saying SD-CWT updates the CWT spec (RFC8392). (PR#29)

H.8. draft-ietf-spice-sd-cwt-01

* Added Overview section

* Rewritten the main normative section

* Made redacted_claim_keys use an unlikely to collide claim key integer

* Make cnonce optional (it now says SHOULD)

* Made most standard claims optional.

* Consistently avoid use of bare term "key" - to make crypto keys and map keys clear

* Make clear issued SD-CWT can contain zero or more redactions; presented SD-CWT can disclose zero, some, or all redacted claims.

* Clarified use of sd_hash for issuer to holder case.

* Lots of editorial cleanup

* Added Rohan as an author and Brian Campbell to Acknowledgements

* Updated implementation status section to be BCP205-compatible

* Updated draft metadata

H.9. draft-ietf-spice-sd-cwt-00

* Initial working group version based on draft-prorock-spice-cose-sd-cwt-01.

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