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CBOR Encoded X.509 Certificates (C509 Certificates)
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Abstract

This document specifies a CBOR encoding of X.509 certificates. The resulting certificates are called C509 Certificates. The CBOR encoding supports a large subset of [RFC 5280](#) and significantly reduces the size of certificates compatible with e.g. [RFC 7925](#), IEEE 802.1AR (DevID), CNSA, and CA/Browser Forum Baseline Requirements. When used to re-encode DER encoded X.509 certificates, the CBOR encoding can in many cases reduce the size of [RFC 7925](#) profiled certificates with over 50%. The CBOR encoded structure can alternatively be signed directly ("natively signed"), which does not require re-encoding for the signature to be verified. The document also specifies COSE headers as well as a TLS certificate type for C509 certificates.

NOTE: "C509" is a placeholder, name to be decided by the COSE WG.

Status of This Memo

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1. Introduction

One of the challenges with deploying a Public Key Infrastructure (PKI) for the Internet of Things (IoT) is the size and parsing of X.509 public key certificates [RFC5280], since those are not optimized for constrained environments [RFC7228]. Large certificate chains are also problematic in non-constrained protocols such as EAP-TLS [I-D.ietf-emu-eap-tls13] [I-D.ietf-emu-eap-tls-cert] where authenticators typically drop an EAP session after only 40 - 50 round-trips and QUIC [I-D.ietf-quic-transport] where the latency increases significantly unless the server only send less than three times as many bytes as received prior to validating the client address. More compact certificate representations are therefore desirable in many use cases. Due to the current PKI usage of DER encoded X.509 certificates, keeping compatibility with DER encoded X.509 is necessary at least for a transition period. However, the use of a more compact encoding with the Concise Binary Object Representation (CBOR) [RFC8949] reduces the certificate size significantly which has known performance benefits in terms of decreased communication overhead, power consumption, latency, storage, etc.

CBOR is a data format designed for small code size and small message size. CBOR builds on the JSON data model but extends it by e.g. encoding binary data directly without base64 conversion. In addition to the binary CBOR encoding, CBOR also has a diagnostic notation that is readable and editable by humans. The Concise Data Definition Language (CDDL) [RFC8610] provides a way to express structures for protocol messages and APIs that use CBOR. [RFC8610] also extends the diagnostic notation.

CBOR data items are encoded to or decoded from byte strings using a type-length-value encoding scheme, where the three highest order bits of the initial byte contain information about the major type. CBOR supports several different types of data items, in addition to integers (int, uint), simple values (e.g. null), byte strings (bstr), and text strings (tstr), CBOR also supports arrays [] of data items, maps {} of pairs of data items, and sequences of data items. For a complete specification and examples, see [RFC8949], [RFC8610], and [RFC8742].

CAB Baseline Requirements [CAB-Baseline], RFC 7925 [RFC7925], IEEE 802.1AR [IEEE-802.1AR], and CNSA [RFC8603] specify certificate profiles which can be applied to certificate based authentication with, e.g., TLS [RFC8446], QUIC [I-D.ietf-quic-transport], DTLS [I-D.ietf-tls-dtls13], COSE [RFC8152], EDHOC [I-D.ietf-lake-edhoc], or Compact TLS 1.3 [I-D.ietf-tls-ctls]. RFC 7925 [RFC7925], RFC7925bis [I-D.ietf-uta-tls13-iot-profile], and IEEE 802.1AR

[IEEE-802.1AR] specifically target Internet of Things deployments. This document specifies a CBOR encoding based on [X.509-IoT], which can support large parts of [RFC5280]. The encoding support all [RFC7925] and IEEE 802.1AR [IEEE-802.1AR] and CAB Baseline [CAB-Baseline] profiled X.509 certificates. The resulting certificates are called C509 Certificates. Two variants are defined using the same CBOR encoding and differing only in what is being signed:

1. An invertible CBOR re-encoding of DER encoded X.509 certificates [RFC5280], which can be reversed to obtain the original DER encoded X.509 certificate.
2. Natively signed C509 certificates, where the signature is calculated over the CBOR encoding instead of over the DER encoding as in 1. This removes the need for ASN.1 and DER parsing and the associated complexity but they are not backwards compatible with implementations requiring DER encoded X.509.

Natively signed C509 certificates can be applied in devices that are only required to authenticate to natively signed C509 certificate compatible servers, which is not a major restriction for many IoT deployments where the parties issuing and verifying certificates can be a restricted ecosystem.

This document specifies COSE headers for use of the C509 certificates with COSE, see [Section 8.8](#). The document also specifies a TLS certificate type for use of the C509 certificates with TLS and QUIC (with or without additional TLS certificate compression), see [Section 8.9](#).

2. Notational Conventions

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.

This specification makes use of the terminology in [RFC5280], [RFC7228], [RFC8610], and [RFC8949].

3. CBOR Encoding

This section specifies the content and encoding for C509 certificates, with the overall objective to produce a very compact representation supporting large parts of [RFC5280], and everything in [RFC7925], [IEEE-802.1AR], and CAB Baseline [CAB-Baseline]. In the

CBOR encoding, static fields are elided, elliptic curve points and time values are compressed, OID are replaced with short integers, and redundant encoding is removed. Combining these different components reduces the certificate size significantly, which is not possible with general purpose compressions algorithms, see Figure 2.

The C509 certificate can be either a CBOR re-encoding of a DER encoded X.509 certificate, in which case the signature is calculated on the DER encoded ASN.1 data in the X.509 certificate, or a natively signed C509 certificate, in which case the signature is calculated directly on the CBOR encoded data. In both cases the certificate content is adhering to the restrictions given by [\[RFC5280\]](#). The re-encoding is known to work with DER encoded certificates but might work with other canonical encodings. The re-encoding does not work for BER encoded certificates.

In the encoding described below, the order of elements in arrays are always encoded in the same order as the elements or the corresponding SEQUENCE or SET in the DER encoding.

[3.1.](#) Message Fields

The X.509 fields and their CBOR encodings are listed below, and used in the definition of C509 certificates, see Figure 1.

C509 certificates are defined in terms of DER encoded [\[RFC5280\]](#) X.509 certificates:

- o version. The 'version' field is encoded in the 'cborCertificateType' CBOR int. The field 'cborCertificateType' also indicates the type of the C509 certificate. Currently, the type can be a natively signed C509 certificate following X.509 v3 (cborCertificateType = 0) or a CBOR re-encoded X.509 v3 DER certificate (cborCertificateType = 1), see [Section 8.1](#).
- o serialNumber. The 'serialNumber' INTEGER value field is encoded as the unwrapped CBOR unsigned bignum (~biguint) 'certificateSerialNumber'. Any leading 0x00 byte (to indicate that the number is not negative) is therefore omitted.
- o signature. The 'signature' field is always the same as the 'signatureAlgorithm' field and therefore omitted from the CBOR encoding.
- o issuer. In the general case, the sequence of 'RelativeDistinguishedName' is encoded as a CBOR array of CBOR arrays of Attributes. Typically each RelativeDistinguishedName only contains a single attribute and the sequence is then encoded

as a CBOR array of Attributes. Each Attribute is encoded as a (CBOR int, CBOR text string) pair or as a (unwrapped CBOR OID, CBOR bytes) pair. The absolute value of the CBOR int (see Figure 4) encodes the attribute type and the sign is used to represent the character string type; positive for Utf8String, negative for PrintableString. In natively signed C509 certificates all text strings are UTF-8 encoded and all attributes SHALL have a positive sign. Text strings SHALL still adhere to any X.509 restrictions, i.e. serialNumber SHALL only contain the 74 character subset of ASCII allowed by PrintableString and countryName SHALL have length 2. The string types teletexString, universalString, and bmpString are not supported. If Name contains a single Attribute containing an utf8String encoded 'common name' it is encoded as a CBOR text string. If the text string contains an EUI-64 of the form "HH-HH-HH-HH-HH-HH-HH-HH" where 'H' is one of the symbol '0'-'9' or 'A'-'F' it is encoded as a CBOR byte string of length 8 instead. EUI-64 mapped from a 48-bit MAC address (i.e. of the form "HH-HH-HH-HH-HH-HH-HH-HH") is encoded as a CBOR byte string of length 6.

- o validity. The 'notBefore' and 'notAfter' fields are encoded as unwrapped CBOR epoch-based date/time (~time) where the tag content is an unsigned integer. In POSIX time, leap seconds are ignored, with a leap second having the same POSIX time as the second before it. Compression of X.509 certificates with the time 23:59:60 UTC is therefore not supported. Note that [RFC 5280](#) mandates encoding of dates through the year 2049 as UTCTime, and later dates as GeneralizedTime. The value "99991231235959Z" (no expiration date) is encoded as CBOR null.
- o subject. The 'subject' is encoded exactly like issuer.
- o subjectPublicKeyInfo. The 'AlgorithmIdentifier' field including parameters is encoded as the CBOR int 'subjectPublicKeyAlgorithm' (see [Section 8.7](#)) or as an array with an unwrapped CBOR OID tag [[I-D.ietf-cbor-tags-oid](#)] optionally followed by the parameters encoded as a CBOR byte string. In general, the 'subjectPublicKey' BIT STRING value field is encoded as a CBOR byte string. This specification assumes the BIT STRING has zero unused bits and the unused bits byte is omitted. For rsaEncryption and id-ecPublicKey, the encoding of subjectPublicKey is further optimized as described in [Section 3.2](#).
- o issuerUniqueID. Not supported.
- o subjectUniqueID. Not supported.

- o extensions. The 'extensions' field is encoded as a CBOR array where each extension is encoded as either a CBOR int (see [Section 8.3](#)) followed by an optional CBOR item of any type or an unwrapped CBOR OID tag [[I-D.ietf-cbor-tags-oid](#)] followed by a CBOR bool encoding 'critical' and the DER encoded value of the 'extnValue' encoded as a CBOR byte string. If the array contains exactly two ints and the absolute value of the first int is 2, the array is omitted and the extensions is encoded as a single CBOR int with the absolute value of the second int and the sign of the first int. Extensions are encoded as specified in [Section 3.3](#). The extensions mandated to be supported by [[RFC7925](#)] and [[IEEE-802.1AR](#)] are given special treatment. An omitted 'extensions' field is encoded as an empty CBOR array.
- o signatureAlgorithm. The 'signatureAlgorithm' field including parameters is encoded as a CBOR int (see [Section 8.6](#)) or as an array with an unwrapped CBOR OID tag [[I-D.ietf-cbor-tags-oid](#)] optionally followed by the parameters encoded as a CBOR byte string.
- o signatureValue. In general, the 'signatureValue' BIT STRING value field is encoded as the CBOR byte string issuerSignatureValue. This specification assumes the BIT STRING has zero unused bits and the unused bits byte is omitted. For natively signed C509 certificates the signatureValue is calculated over the CBOR sequence TBSCertificate. For ECDSA, the encoding of issuerSignatureValue is further optimized as described in [Section 3.2](#).

The following Concise Data Definition Language (CDDL) defines CBORCertificate and TBSCertificate, which are encoded as CBOR Sequences [[RFC8742](#)]. The member names therefore only have documentary value.

; The elements of the following group are to be used in a CBOR Sequence:

```
CBORCertificate = (
    TBSCertificate,
    issuerSignatureValue : any,
)

TBSCertificate = (
    cborCertificateType: int,
    certificateSerialNumber: CertificateSerialNumber,
    issuer: Name,
    validityNotBefore: Time,
    validityNotAfter: Time,
    subject: Name,
    subjectPublicKeyAlgorithm: AlgorithmIdentifier,
    subjectPublicKey: any,
    extensions: Extensions,
    issuerSignatureAlgorithm: AlgorithmIdentifier,
)

CertificateSerialNumber = ~biguint

Name = [ * RelativeDistinguishedName ] / text / bytes

RelativeDistinguishedName = Attribute / [ 2* Attribute ]

Attribute = ( attributeType: int, attributeValue: text ) //
            ( attributeType: ~oid, attributeValue: bytes )

Time = ~time / null

AlgorithmIdentifier = int / [ algorithm: ~oid, ? parameters: bytes ]

Extensions = [ * Extension ] / int

Extension = ( extensionID: int, extensionValue: any ) //
            ( extensionID: ~oid, critical: bool, extensionValue: bytes )
```

Figure 1: CDDL for CBORCertificate.

3.2. Encoding of subjectPublicKey and issuerSingatureValue

3.2.1. Encoding of subjectPublicKey

For RSA public keys (rsaEncryption), the SEQUENCE and INTEGER type and length fields are omitted and the two INTEGER value fields (modulus, exponent) are encoded as an array of two unwrapped CBOR unsigned bignum (~biguint), i.e. [modulus : ~biguint, exponent :

~biguint]. If the exponent is 65537, the array and the exponent is omitted and subjectPublicKey consist of only the modulus encoded as an unwrapped CBOR unsigned bignum (~biguint).

For elliptic curve public keys in Weirstrass form (id-ecPublicKey), uncompressed keys are point compressed as defined in Section 2.3.3 of [SECG]. If a DER encoded certificate with a point compressed public key of type id-ecPublicKey is CBOR encoded, the octets 0xfe and 0xfd are used instead of 0x02 and 0x03 in the CBOR encoding to represent even and odd y-coordinate, respectively.

3.2.2. Encoding of issuerSingatureValue

For ECDSA signatures, the SEQUENCE and INTEGER type and length fields as well as the any leading 0x00 byte (to indicate that the number is not negative) are omitted. If the two INTEGER value fields have different lengths, the shortest INTEGER value field is padded with zeroes so that the two fields have the same length. The resulting byte string is encoded as a CBOR byte string.

3.3. Encoding of Extensions

This section details the encoding of the 'extensions' field. The 'extensions' field is encoded as a CBOR array where each extensionID is encoded as either a CBOR int or a CBOR OID tag. If 'extensionID' is encoded an int (see [Section 8.3](#)), the sign is used to encode if the extension is critical and the 'critical' field is omitted. Critical extensions are encoded with a positive sign and non-critical extensions are encoded with a negative sign.

The 'extnValue' OCTET STREAM value field is encoded as the CBOR byte string 'extensionValue' except for the extensions specified below. The 'extensionValue' for the extensions mandated to be supported by [RFC7925], [IEEE-802.1AR], and [CAB-Baseline] are encoded as follows:

- o keyUsage. The 'KeyUsage' BIT STRING is interpreted as an unsigned integer *n* in network byte order and encoded as a CBOR int.
- o subjectAltName. extensionValue is encoded as an array of (int, any) pairs where each pair encodes a general name (see [Section 8.5](#)). If subjectAltName contains exactly one *dnsName*, the array and the int are omitted and extensionValue is the *dnsName* encoded as a CBOR text string. In addition to the general names defined in [RFC5280], the hardwareModuleName type of otherName has been given its own int due to its mandatory use in IEEE 802.1AR. When 'otherName + hardwareModuleName' is used, then [oid, bytes] is used to identify the pair (hwType, hwSerialEntries) directly as specified in [RFC4108].


```
GeneralNames = [ + GeneralName ] / text
```

```
GeneralName = ( GeneralNameType : int, GeneralNameValue : any )
```

- o basicConstraints. If 'cA' = false then extensionValue = -2, if 'cA' = true and 'pathLenConstraint' is not present then extensionValue = -1, and if 'cA' = true and 'pathLenConstraint' is present then extensionValue = pathLenConstraint.
- o extKeyUsage. extensionValue is encoded as an array of CBOR ints (see [Section 8.4](#)) or unwrapped CBOR OID tags [[I-D.ietf-cbor-tags-oid](#)] where each int or OID tag encodes a key usage purpose. If the array contains a single int, the array is omitted.

```
ExtValueEKU = [ + int / ~oid ] / int
```

- o subjectKeyIdentifier. extensionValue is the value of the 'keyIdentifier' field encoded as a CBOR byte string.
- o authorityKeyIdentifier. extensionValue is encoded as an array where the value of the 'keyIdentifier' is encoded as a CBOR byte string, 'GeneralNames' is encoded like in subjectAltName, and 'AuthorityCertSerialNumber' is encoded as ~biguint exactly like certificateSerialNumber. Omitted values are encoded as CBOR null.

```
ExtValueAKI = [ keyIdentifier: bytes / null,
                 certIssuer: GeneralNames / null,
                 certSerialNumber: CertificateSerialNumber / null ]
               / bytes
```

- o cRLDistributionPoints. If the cRLDistributionPoints is a sequence of DistributionPointName, it is encoded like subjectAltName, with the difference that if cRLDistributionPoints contains exactly one uniformResourceIdentifier, the array and the int are omitted and extensionValue is the uniformResourceIdentifier encoded as a CBOR text string.
- o authorityInfoAccess. If authorityInfoAccess consist of only uniformResourceIdentifiers it is encoded as an array of uris.

```
ExtValueAIA = [ + ( ocspr : 1 // caIssuers : 2 , uri : text ) ]
```

3.3.1. Example Encoding of Extensions

The examples below use values from [Section 8.3](#), [Section 8.4](#), and [Section 8.5](#):

- o A critical basicConstraints ('cA' = true) without pathLenConstraint is encoded as the two CBOR ints -1, -1.
- o A non-critical keyUsage with digitalSignature and keyAgreement asserted is encoded as the two CBOR ints 2, 17 ($2^0 + 2^4 = 17$).
- o A non-critical extKeyUsage containing id-kp-codeSigning and id-kp-OCSPSigning is encoded as the CBOR int 3 followed by the CBOR array [3, 6].
- o A non-critical subjectAltName containing only the dNSName example.com is encoded as the CBOR int 4 followed by the CBOR text string "example.com".

Thus, the extension field of a certificate containing all of the above extensions in the given order would be encoded as the CBOR array [-1, -1, 2, 17, 3, [3, 6], 4, "example.com"].

4. Compliance Requirements for Constrained IoT

For general purpose applications, the normative requirements of [\[RFC5280\]](#) applies. This section describes the mandatory to implement algorithms and OIDs for constrained IoT application; the values of the OIDs including certificate fields and extensions, time format, attributes in distinguished names, etc.

TODO: Write this section

5. Legacy Considerations

C509 certificates can be deployed with legacy X.509 certificates and CA infrastructure. In order to verify the signature, the C509 certificate is used to recreate the original X.509 data structure to be able to verify the signature.

For protocols like TLS/DTLS 1.2, where the handshake is sent unencrypted, the actual encoding and compression can be done at different locations depending on the deployment setting. For example, the mapping between C509 certificate and standard X.509 certificate can take place in a 6LoWPAN border gateway which allows the server side to stay unmodified. This case gives the advantage of the low overhead of a C509 certificate over a constrained wireless links. The conversion to X.509 within an IoT device will incur a computational overhead, however, measured in energy this is likely to be negligible compared to the reduced communication overhead.

For the setting with constrained server and server-only authentication, the server only needs to be provisioned with the C509

certificate and does not perform the conversion to X.509. This option is viable when client authentication can be asserted by other means.

For protocols like IKEv2, TLS/DTLS 1.3, and EDHOC, where certificates are encrypted, the proposed encoding needs to be done fully end-to-end, through adding the encoding/decoding functionality to the server.

6. Expected Certificate Sizes

The CBOR encoding of the sample certificate given in [Appendix A](#) results in the numbers shown in Figure 2. After [[RFC7925](#)] profiling, most duplicated information has been removed, and the remaining text strings are minimal in size. Therefore, the further size reduction reached with general compression mechanisms will be small, mainly corresponding to making the ASN.1 encoding more compact. For Brtoli [[RFC7932](#)], the brotli command line tool 1.09 was used with the default best compression level.

+-----+-----+-----+-----+				
	RFC 7925	Brotli	C509 Certificate	
+-----+-----+-----+-----+				
Certificate Size	314	303	138	
+-----+-----+-----+-----+				

Figure 2: Comparing Sizes of Certificates (bytes)

7. Security Considerations

The CBOR profiling of X.509 certificates does not change the security assumptions needed when deploying standard X.509 certificates but decreases the number of fields transmitted, which reduces the risk for implementation errors.

The use of natively signed C509 certificates removes the need for ASN.1 encoding, which is a rich source of security vulnerabilities.

Conversion between the certificate formats can be made in constant time to reduce risk of information leakage through side channels.

The mechanism in this draft does not reveal any additional information compared to X.509. Because of difference in size, it will be possible to detect that this profile is used. The gateway solution described in [Section 5](#) requires unencrypted certificates and is not recommended.

8. IANA Considerations

This document creates several new registries under the new heading "C509 Certificate". For all items, the 'Reference' field points to this document.

The expert reviewers for the registries defined in this document are expected to ensure that the usage solves a valid use case that could not be solved better in a different way, that it is not going to duplicate one that is already registered, and that the registered point is likely to be used in deployments. They are furthermore expected to check the clarity of purpose and use of the requested code points. Experts should take into account the expected usage of entries when approving point assignment, and the length of the encoded value should be weighed against the number of code points left that encode to that size and how constrained the systems it will be used on are. Values in the interval $[-24, 23]$ have a 1 byte encodings, other values in the interval $[-256, 255]$ have a 2 byte encodings, and the remaining values in the interval $[-65536, 65535]$ have 3 byte encodings.

8.1. C509 Certificate Types Registry

IANA has created a new registry titled "C509 Certificate Types" under the new heading "C509 Certificate". The columns of the registry are Value, Description, and Reference, where Value is an integer, and the other columns are text strings. For values in the interval $[-24, 23]$ the registration procedure is "IETF Review" and "Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Description
0	Natively Signed C509 Certificate following X.509 v3
1	CBOR re-encoding of X.509 v3 Certificate

Figure 3: C509 Certificate Types

8.2. C509 Certificate Attributes Registry

IANA has created a new registry titled "C509 Certificate Attributes" under the new heading "C509 Certificate". The columns of the registry are Value, Name, OID, DER, Comments, and Reference, where Value is an integer, and the other columns are text strings. Only non-negative values can be registered. For values in the interval

[0, 23] the registration procedure is "IETF Review" and "Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Attribute
1	Name: Common Name OID: 2.5.4.3 DER: 06 03 55 04 03 Comments:
2	Name: Surname OID: 2.5.4.4 DER: 06 03 55 04 04 Comments:
3	Name: Serial Number OID: 2.5.4.5 DER: 06 03 55 04 05 Comments:
4	Name: Country OID: 2.5.4.6 DER: 06 03 55 04 06 Comments:
5	Name: Locality OID: 2.5.4.7 DER: 06 03 55 04 07 Comments:
6	Name: State or Province OID: 2.5.4.8 DER: 06 03 55 04 08 Comments:
7	Name: Street Address OID: 2.5.4.9 DER: 06 03 55 04 09 Comments:
8	Name: Organization OID: 2.5.4.10 DER: 06 03 55 04 0A Comments:
9	Name: Organizational Unit

	OID:	2.5.4.11	
	DER:	06 03 55 04 0B	
	Comments:		
+-----+			
10	Name:	Title	
	OID:	2.5.4.12	
	DER:	06 03 55 04 0C	
	Comments:		
+-----+			
11	Name:	Postal Code	
	OID:	2.5.4.17	
	DER:	06 03 55 04 11	
	Comments:		
+-----+			
12	Name:	Given Name	
	OID:	2.5.4.42	
	DER:	06 03 55 04 2A	
	Comments:		
+-----+			
13	Name:	Initials	
	OID:	2.5.4.43	
	DER:	06 03 55 04 2B	
	Comments:		
+-----+			
14	Name:	Generation Qualifier	
	OID:	2.5.4.44	
	DER:	06 03 55 04 2C	
	Comments:		
+-----+			
15	Name:	DN Qualifier	
	OID:	2.5.4.46	
	DER:	06 03 55 04 2E	
	Comments:		
+-----+			
16	Name:	Pseudonym	
	OID:	2.5.4.65	
	DER:	06 03 55 04 41	
	Comments:		
+-----+			
17	Name:	Organization Identifier	
	OID:	2.5.4.97	
	DER:	06 03 55 04 61	
	Comments:		
+-----+			

Figure 4: C509 Certificate Attributes

8.3. C509 Certificate Extensions Registry

IANA has created a new registry titled "C509 Certificate Extensions" under the new heading "C509 Certificate". The columns of the registry are Value, Name, OID, DER, Comments, extensionValue, and Reference, where Value is an integer, and the other columns are text strings. Only non-negative values can be registered. For values in the interval [0, 23] the registration procedure is "IETF Review" and "Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Extension
0	Name: Subject Key Identifier OID: 2.5.29.14 DER: 06 03 55 1D 0E Comments: extensionValue: bytes
1	Name: Key Usage OID: 2.5.29.15 DER: 06 03 55 1D 0F Comments: AttributeValue: int
2	Name: Subject Alternative Name OID: 2.5.29.17 DER: 06 03 55 1D 11 Comments: extensionValue: [+ (int, any)] / text
3	Name: Basic Constraints OID: 2.5.29.19 DER: 06 03 55 1D 13 Comments: extensionValue: int
4	Name: CRL Distribution Points OID: 2.5.29.31 DER: 06 03 55 1D 1F Comments: extensionValue: [+ (int, any)] / text
5	Name: Certificate Policies OID: 2.5.29.32 DER: 06 03 55 1D 20 Comments:

		extensionValue:	[+ (oid, ? text)]
6	Name:	Authority Key Identifier	
	OID:	2.5.29.35	
	DER:	06 03 55 1D 23	
	Comments:		
	extensionValue:	bytes	
7	Name:	Extended Key Usage	
	OID:	2.5.29.37	
	DER:	06 03 55 1D 25	
	Comments:		
	extensionValue:	int	
8	Name:	Authority Information Access	
	OID:	1.3.6.1.5.5.7.1.1	
	DER:	06 08 2B 06 01 05 05 07 01 01	
	Comments:		
	extensionValue:	[+ (1 / 2 , text)]	
9	Name:	Signed Certificate Timestamp List	
	OID:	1.3.6.1.4.1.11129.2.4.2	
	DER:	06 0A 2B 06 01 04 01 D6 79 02 04 02	
	Comments:		
	extensionValue:	[bytes, ~biguint, AlgorithmIdentifier, bytes]	
24	Name:	Subject Directory Attributes	
	OID:	2.5.29.9	
	DER:	06 03 55 1D 09	
	Comments:		
	extensionValue:	bytes	
25	Name:	Issuer Alternative Name	
	OID:	2.5.29.18	
	DER:	06 03 55 1D 12	
	Comments:		
	extensionValue:	bytes	
26	Name:	Name Constraints	
	OID:	2.5.29.30	
	DER:	06 03 55 1D 1E	
	Comments:		
	extensionValue:	bytes	
27	Name:	Policy Mappings	
	OID:	2.5.29.33	
	DER:	06 03 55 1D 21	

	Comments:	
	extensionValue:	bytes
+-----+		
28	Name:	Policy Constraints
	OID:	2.5.29.36
	DER:	06 03 55 1D 24
	Comments:	
	extensionValue:	bytes
+-----+		
29	Name:	Freshest CRL
	OID:	2.5.29.46
	DER:	06 03 55 1D 2E
	Comments:	
	extensionValue:	bytes
+-----+		
30	Name:	Inhibit anyPolicy
	OID:	2.5.29.54
	DER:	06 03 55 1D 36
	Comments:	
	extensionValue:	bytes
+-----+		
31	Name:	Subject Information Access
	OID:	1.3.6.1.5.5.7.1.11
	DER:	06 08 2B 06 01 05 05 07 01 0B
	Comments:	
	extensionValue:	bytes
+-----+		

Figure 5: C509 Certificate Extensions

8.4. C509 Certificate Extended Key Usages Registry

IANA has created a new registry titled "C509 Certificate Extended Key Usages" under the new heading "C509 Certificate". The columns of the registry are Value, Name, OID, DER, Comments, and Reference, where Value is an integer, and the other columns are text strings. For values in the interval [-24, 23] the registration procedure is "IETF Review" and "Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Extended Key Usage
1	Name: TLS Server authentication OID: 1.3.6.1.5.5.7.3.1 DER: 06 08 2B 06 01 05 05 07 03 01 Comments:
2	Name: TLS Client Authentication OID: 1.3.6.1.5.5.7.3.2 DER: 06 08 2B 06 01 05 05 07 03 02 Comments:
3	Name: Code Signing OID: 1.3.6.1.5.5.7.3.3 DER: 06 08 2B 06 01 05 05 07 03 03 Comments:
4	Name: Email protection (S/MIME) OID: 1.3.6.1.5.5.7.3.4 DER: 06 08 2B 06 01 05 05 07 03 04 Comments:
8	Name: Time Stamping OID: 1.3.6.1.5.5.7.3.8 DER: 06 08 2B 06 01 05 05 07 03 08 Comments:
9	Name: OCSP Signing OID: 1.3.6.1.5.5.7.3.9 DER: 06 08 2B 06 01 05 05 07 03 09 Comments:

Figure 6: C509 Certificate Extended Key Usages

8.5. C509 Certificate General Names Registry

IANA has created a new registry titled "C509 Certificate General Names" under the new heading "C509 Certificate". The columns of the registry are Value, General Name, and Reference, where Value is an integer, and the other columns are text strings. For values in the interval $[-24, 23]$ the registration procedure is "IETF Review" and "Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	General Names
-1	Name: otherName with hardwareModuleName Comments: Value: [~oid, bytes]
0	Name: otherName Comments: Value: [~oid, bytes]
1	Name: rfc822Name Comments: Value: text
2	Name: dNSName Comments: Value: text
4	Name: directoryName Comments: Value: Name
6	Name: uniformResourceIdentifier Comments: Value: text
7	Name: iPAddress Comments: Value: bytes
8	Name: registeredID Comments: Value: ~oid

Figure 7: C509 Certificate General Names

8.6. C509 Certificate Signature Algorithms Registry

IANA has created a new registry titled "C509 Certificate Signature Algorithms" under the new heading "C509 Certificate". The columns of the registry are Value, Name, OID, Parameters, DER, Comments, and Reference, where Value is an integer, and the other columns are text strings. For values in the interval [-24, 23] the registration procedure is "IETF Review" and "Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value		X.509 Signature Algorithms	
-256	Name:	RSASSA-PKCS1-v1_5 with SHA-1	
	OID:	1.2.840.113549.1.1.5	
	Parameters:	NULL	
	DER:	30 0D 06 09 2A 86 48 86 F7 0D 01 01 05 05 00	
	Comments:	Don't use	
-255	Name:	ECDSA with SHA-1	
	OID:	1.2.840.10045.4.1	
	Parameters:	Absent	
	DER:	30 09 06 07 2A 86 48 CE 3D 04 01	
	Comments:	Don't use. Compressed signature value	
0	Name:	ECDSA with SHA-256	
	OID:	1.2.840.10045.4.3.2	
	Parameters:	Absent	
	DER:	30 0A 06 08 2A 86 48 CE 3D 04 03 02	
	Comments:	Compressed signature value	
1	Name:	ECDSA with SHA-384	
	OID:	1.2.840.10045.4.3.3	
	Parameters:	Absent	
	DER:	30 0A 06 08 2A 86 48 CE 3D 04 03 03	
	Comments:	Compressed signature value	
2	Name:	ECDSA with SHA-512	
	OID:	1.2.840.10045.4.3.4	
	Parameters:	Absent	
	DER:	30 0A 06 08 2A 86 48 CE 3D 04 03 04	
	Comments:	Compressed signature value	
3	Name:	ECDSA with SHAKE128	
	OID:	1.3.6.1.5.5.7.6.32	
	Parameters:	Absent	
	DER:	30 0A 06 08 2B 06 01 05 05 07 06 20	
	Comments:	Compressed signature value	
4	Name:	ECDSA with SHAKE256	
	OID:	1.3.6.1.5.5.7.6.33	
	Parameters:	Absent	
	DER:	30 0A 06 08 2B 06 01 05 05 07 06 21	
	Comments:	Compressed signature value	
12	Name:	Ed25519	
	OID:	1.3.101.112	
	Parameters:	Absent	

	DER:	30 05 06 03 2B 65 70	
	Comments:		
+-----+			
13	Name:	Ed448	
	OID:	1.3.101.113	
	Parameters:	Absent	
	DER:	30 05 06 03 2B 65 71	
	Comments:		
+-----+			
23	Name:	RSASSA-PKCS1-v1_5 with SHA-256	
	OID:	1.2.840.113549.1.1.11	
	Parameters:	NULL	
	DER:	30 0B 06 09 2A 86 48 86 F7 0D 01 01 0B 05 00	
	Comments:		
+-----+			
24	Name:	RSASSA-PKCS1-v1_5 with SHA-384	
	OID:	1.2.840.113549.1.1.12	
	Parameters:	NULL	
	DER:	30 0B 06 09 2A 86 48 86 F7 0D 01 01 0C 05 00	
	Comments:		
+-----+			
25	Name:	RSASSA-PKCS1-v1_5 with SHA-512	
	OID:	1.2.840.113549.1.1.13	
	Parameters:	NULL	
	DER:	30 0B 06 09 2A 86 48 86 F7 0D 01 01 0D 05 00	
	Comments:		
+-----+			
26	Name:	RSASSA-PSS with SHA-256	
	OID:	1.2.840.113549.1.1.10	
	Parameters:	SHA-256, MGF-1 with SHA-256, saltLength = 32	
	DER:	30 41 06 09 2A 86 48 86 F7 0D 01 01 0A 30 34 A0 0F 30 0D 06 09 60 86 48 01 65 03 04 02 01 05 00 A1 1C 30 1A 06 09 2A 86 48 86 F7 0D 01 01 08 30 0D 06 09 60 86 48 01 65 03 04 02 01 05 00 a2 03 02 01 20	
	Comments:		
+-----+			
27	Name:	RSASSA-PSS with SHA-384	
	OID:	1.2.840.113549.1.1.10	
	Parameters:	SHA-384, MGF-1 with SHA-384, saltLength = 48	
	DER:	30 41 06 09 2A 86 48 86 F7 0D 01 01 0A 30 34 A0 0F 30 0D 06 09 60 86 48 01 65 03 04 02 02 05 00 A1 1C 30 1A 06 09 2A 86 48 86 F7 0D 01 01 08 30 0D 06 09 60 86 48 01 65 03 04 02 02 05 00 A2 03 02 01 30	
	Comments:		
+-----+			
28	Name:	RSASSA-PSS with SHA-512	

	OID:	1.2.840.113549.1.1.10
	Parameters:	SHA-512, MGF-1 with SHA-512, saltLength = 64
	DER:	30 41 06 09 2A 86 48 86 F7 0D 01 01 0A 30 34 A0 0F 30 0D 06 09 60 86 48 01 65 03 04 02 03 05 00 A1 1C 30 1A 06 09 2A 86 48 86 F7 0D 01 01 08 30 0D 06 09 60 86 48 01 65 03 04 02 03 05 00 A2 03 02 01 40
	Comments:	
29	Name:	RSASSA-PSS with SHAKE128
	OID:	1.3.6.1.5.5.7.6.30
	Parameters:	Absent
	DER:	30 0A 06 08 2B 06 01 05 05 07 06 1E
	Comments:	
30	Name:	RSASSA-PSS with SHAKE256
	OID:	1.3.6.1.5.5.7.6.31
	Parameters:	Absent
	DER:	30 0A 06 08 2B 06 01 05 05 07 06 1F
	Comments:	
42	Name:	HSS / LMS
	OID:	1.2.840.113549.1.9.16.3.17
	Parameters:	Absent
	DER:	30 0D 06 0B 2A 86 48 86 F7 0D 01 09 10 03 11
	Comments:	
43	Name:	XMSS
	OID:	0.4.0.127.0.15.1.1.13.0
	Parameters:	Absent
	DER:	30 0B 06 09 04 00 7F 00 0F 01 01 0D 00
	Comments:	
44	Name:	XMSS^MT
	OID:	0.4.0.127.0.15.1.1.14.0
	Parameters:	Absent
	DER:	30 0B 06 09 04 00 7F 00 0F 01 01 0E 00
	Comments:	

Figure 8: C509 Certificate Signature Algorithms

8.7. C509 Certificate Public Key Algorithms Registry

IANA has created a new registry titled "C509 Certificate Public Key Algorithms" under the new heading "C509 Certificate". The columns of the registry are Value, Name, OID, Parameters, DER, Comments, and Reference, where Value is an integer, and the other columns are text

strings. For values in the interval [-24, 23] the registration procedure is "IETF Review" and "Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	X.509 Public Key Algorithms
0	Name: RSA OID: 1.2.840.113549.1.1.1 Parameters: NULL DER: 30 0d 06 09 2a 86 48 86 f7 0d 01 01 01 05 00 Comments: Compressed subjectPublicKey
1	Name: EC Public Key (Weierstrass) with secp256r1 OID: 1.2.840.10045.2.1 Parameters: namedCurve = secp256r1 (1.2.840.10045.3.1.7) DER: 30 13 06 07 2A 86 48 CE 3D 02 01 06 08 2A 86 48 CE 3D 03 01 07 Comments: Point compressed subjectPublicKey
2	Name: EC Public Key (Weierstrass) with secp384r1 OID: 1.2.840.10045.2.1 Parameters: namedCurve = secp384r1 (1.3.132.0.34) DER: 30 10 06 07 2A 86 48 CE 3D 02 01 06 05 2B 81 04 00 22 Comments: Point compressed subjectPublicKey
3	Name: EC Public Key (Weierstrass) with secp521r1 OID: 1.2.840.10045.2.1 Parameters: namedCurve = secp521r1 (1.3.132.0.35) DER: 30 10 06 07 2A 86 48 CE 3D 02 01 06 05 2B 81 04 00 23 Comments: Point compressed subjectPublicKey
8	Name: X25519 (Montgomery) OID: 1.3.101.110 Parameters: Absent DER: 30 05 06 03 2B 65 6E Comments:
9	Name: X448 (Montgomery) OID: 1.3.101.111 Parameters: Absent DER: 30 05 06 03 2B 65 6F Comments:
10	Name: Ed25519 (Twisted Edwards)

	OID:	1.3.101.112
	Parameters:	Absent
	DER:	30 05 06 03 2B 65 70
	Comments:	
+-----+		
11	Name:	Ed448 (Edwards)
	OID:	1.3.101.113
	Parameters:	Absent
	DER:	30 05 06 03 2B 65 71
	Comments:	
+-----+		
16	Name:	HSS / LMS
	OID:	1.2.840.113549.1.9.16.3.17
	Parameters:	Absent
	DER:	30 0D 06 0B 2A 86 48 86 F7 0D 01 09 10 03 11
	Comments:	
+-----+		
17	Name:	XMSS
	OID:	0.4.0.127.0.15.1.1.13.0
	Parameters:	Absent
	DER:	30 0B 06 09 04 00 7F 00 0F 01 01 0D 00
	Comments:	
+-----+		
18	Name:	XMSS^MT
	OID:	0.4.0.127.0.15.1.1.14.0
	Parameters:	Absent
	DER:	30 0B 06 09 04 00 7F 00 0F 01 01 0E 00
	Comments:	
+-----+		

Figure 9: C509 Certificate Public Key Algorithms

8.8. COSE Header Parameters Registry

EDITORS NOTE: Should x5u refer to a bag or a chain? The text should be moved a section and not be in the IANA Section.

This document registers the following entries in the "COSE Header Parameters" registry under the "CBOR Object Signing and Encryption (COSE)" heading. The formatting and processing for c5b, c5c, and c5t, and c5u are similar to x5bag, x5chain, x5t, x5u defined in [\[I-D.ietf-cose-x509\]](#) except that the certificates are CBOR encoded instead of DER encoded, uses a COSE_C5 structure instead of COSE_X509, and that c5t MUST refer to an end-entity certificate. c5u provides an alternative way to identify an untrusted certificate bag/chain by reference with a URI. The content is a COSE_C5 item served with the application/cbor content format. The COSE_C5 structure used in c5b, c5c, and c5u is defined as:


```
COSE_C5 = [ + CBORCertificate ]
```

As the contents of c5bag, c5chain, c5t, and c5u are untrusted input, the header parameters can be in either the protected or unprotected header bucket. The trust mechanism MUST process any certificates in the c5b, c5c, and c5u parameters as untrusted input. The presence of a self-signed certificate in the parameter MUST NOT cause the update of the set of trust anchors without some out-of-band confirmation.

Note that certificates can also be identified with a 'kid' header parameter by storing 'kid' and the associated bag or chain in a dictionary.

Name	Label	Value Type	Description
c5b	TBD1	COSE_C5	An unordered bag of C509 certificates
c5c	TBD2	COSE_C5	An ordered chain of C509 certificates
c5t	TBD3	COSE_CertHash	Hash of a C509 certificate
c5u	TBD4	uri	URI pointing to a COSE_C5 containing a ordered chain of certificates

8.9. TLS Certificate Types Registry

This document registers the following entry in the "TLS Certificate Types" registry under the "Transport Layer Security (TLS) Extensions" heading. The new certificate type can be used with additional TLS certificate compression [[RFC8879](#)].

EDITOR'S NOTE: The TLS registrations should be discussed and approved by the TLS WG at a later stage. When COSE WG has adopted work on C509 certificates, it could perhaps be presented in the TLS WG. The TLS WG might e.g. want a separate draft in the TLS WG.

Value	Name	Recommended	Comment
TBD5	C509 Certificate	Y	

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- [SECG] "Elliptic Curve Cryptography, Standards for Efficient Cryptography Group, ver. 2", 2009, <<https://secg.org/sec1-v2.pdf>>.

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[I-D.ietf-quic-transport]

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[Appendix A](#). Example C509 Certificates

[A.1](#). Example [RFC 7925](#) profiled X.509 Certificate

Example of [[RFC7925](#)] profiled X.509 certificate parsed with OpenSSL.

Certificate:

Data:

```
Version: 3 (0x2)
Serial Number: 128269 (0x1f50d)
Signature Algorithm: ecdsa-with-SHA256
Issuer: CN=RFC test CA
Validity
  Not Before: Jan  1 00:00:00 2020 GMT
  Not After : Feb  2 00:00:00 2021 GMT
Subject: CN=01-23-45-FF-FE-67-89-AB
Subject Public Key Info:
  Public Key Algorithm: id-ecPublicKey
  Public-Key: (256 bit)
  pub:
    04:b1:21:6a:b9:6e:5b:3b:33:40:f5:bd:f0:2e:69:
    3f:16:21:3a:04:52:5e:d4:44:50:b1:01:9c:2d:fd:
    38:38:ab:ac:4e:14:d8:6c:09:83:ed:5e:9e:ef:24:
    48:c6:86:1c:c4:06:54:71:77:e6:02:60:30:d0:51:
    f7:79:2a:c2:06
  ASN1 OID: prime256v1
  NIST CURVE: P-256
X509v3 extensions:
  X509v3 Key Usage:
    Digital Signature
Signature Algorithm: ecdsa-with-SHA256
  30:44:02:20:44:5d:79:8c:90:e7:f5:00:dc:74:7a:65:4c:ec:
  6c:fa:6f:03:72:76:e1:4e:52:ed:07:fc:16:29:4c:84:66:0d:
  02:20:5a:33:98:5d:fb:d4:bf:dd:6d:4a:cf:38:04:c3:d4:6e:
  bf:3b:7f:a6:26:40:67:4f:c0:35:4f:a0:56:db:ae:a6
```

The DER encoding of the above certificate is 314 bytes.

```
30 82 01 36 30 81 DE A0 03 02 01 02 02 03 01 F5 0D 30 0A 06 08 2A 86
48 CE 3D 04 03 02 30 16 31 14 30 12 06 03 55 04 03 0C 0B 52 46 43 20
74 65 73 74 20 43 41 30 1E 17 0D 32 30 30 31 30 31 30 30 30 30 30
5A 17 0D 32 31 30 32 30 32 30 30 30 30 30 30 5A 30 22 31 20 30 1E 06
03 55 04 03 0C 17 30 31 2D 32 33 2D 34 35 2D 46 46 2D 46 45 2D 36 37
2D 38 39 2D 41 42 30 59 30 13 06 07 2A 86 48 CE 3D 02 01 06 08 2A 86
48 CE 3D 03 01 07 03 42 00 04 B1 21 6A B9 6E 5B 3B 33 40 F5 BD F0 2E
69 3F 16 21 3A 04 52 5E D4 44 50 B1 01 9C 2D FD 38 38 AB AC 4E 14 D8
6C 09 83 ED 5E 9E EF 24 48 C6 86 1C C4 06 54 71 77 E6 02 60 30 D0 51
F7 79 2A C2 06 A3 0F 30 0D 30 0B 06 03 55 1D 0F 04 04 03 02 07 80 30
0A 06 08 2A 86 48 CE 3D 04 03 02 03 47 00 30 44 02 20 44 5D 79 8C 90
E7 F5 00 DC 74 7A 65 4C EC 6C FA 6F 03 72 76 E1 4E 52 ED 07 FC 16 29
4C 84 66 0D 02 20 5A 33 98 5D FB D4 BF DD 6D 4A CF 38 04 C3 D4 6E BF
3B 7F A6 26 40 67 4F C0 35 4F A0 56 DB AE A6
```


A.1.1. Example C509 Certificate Encoding

The CBOR encoding of the same X.509 certificate is shown below in CBOR diagnostic format.

```
/This defines a CBOR Sequence (RFC 8742):/

1,
h'01f50d',
"RFC test CA",
1577836800,
1612224000,
h'0123456789AB',
1,
h'02B1216AB96E5B3B3340F5BDF02E693F16213A04525ED44450
  B1019C2DFD3838AB',
1,
0,
h'445D798C90E7F500DC747A654CEC6CFA6F037276E14E52ED07
  FC16294C84660D5A33985DFBD4BFDD6D4ACF3804C3D46EBF3B
  7FA62640674FC0354FA056DBAEA6
```

The size of the CBOR encoding (CBOR sequence) is 138 bytes.

```
01
43 01 F5 0D
6B 52 46 43 20 74 65 73 74 20 43 41
1A 5E 0B E1 00
1A 60 18 96 00
46 01 23 45 67 89 AB
01
58 21 02 B1 21 6A B9 6E 5B 3B 33 40 F5 BD F0 2E 69 3F 16 21 3A 04 52
5E D4 44 50 B1 01 9C 2D FD 38 38 AB
01
00
58 40 44 5D 79 8C 90 E7 F5 00 DC 74 7A 65 4C EC 6C FA 6F 03 72 76 E1
4E 52 ED 07 FC 16 29 4C 84 66 0D 5A 33 98 5D FB D4 BF DD 6D 4A CF 38
04 C3 D4 6E BF 3B 7F A6 26 40 67 4F C0 35 4F A0 56 DB AE A6
```

A.1.2. Example: Natively Signed C509 Certificate

The corresponding natively signed C509 certificate in CBOR diagnostic format is identical, except for `cborCertificateType` and `signatureValue`.

/This defines a CBOR Sequence ([RFC 8742](#)):/

```

0,
h'01f50d',
"RFC test CA",
1577836800,
1612224000,
h'0123456789AB',
1,
h'02B1216AB96E5B3B3340F5BDF02E693F16213A04525ED44450
  B1019C2DFD3838AB',
1,
6,
h'B27A0B781455F71B68290F6C2EC9A897F18FDE9B6C59575953
  BC67268AB0E4DDE99D273E04E4715383AB2257C6AAA35284E5
  ED18BDB91247E9F2C433136480B9'
```

The size of the CBOR encoding (CBOR sequence) is 138 bytes.

```

00
43 01 F5 0D
6B 52 46 43 20 74 65 73 74 20 43 41
1A 5E 0B E1 00
1A 60 18 96 00
46 01 23 45 67 89 AB
01
58 21 02 B1 21 6A B9 6E 5B 3B 33 40 F5 BD F0 2E 69 3F 16 21 3A 04 52
5E D4 44 50 B1 01 9C 2D FD 38 38 AB
01
00
58 40 B2 7A 0B 78 14 55 F7 1B 68 29 0F 6C 2E C9 A8 97 F1 8F DE 9B 6C
59 57 59 53 BC 67 26 8A B0 E4 DD E9 9D 27 3E 04 E4 71 53 83 AB 22 57
C6 AA A3 52 84 E5 ED 18 BD B9 12 47 E9 F2 C4 33 13 64 80 B9
```

[A.1.3.](#) Example: Additonal Keys for the Example Certificates

Below are the issuer key pair and the subject private key belonging to the above example certificates. The private keys are encoded as in COSE [[RFC8152](#)]. These issuer key pair can be used to sign or verify the example certificates and the subject private key allows the example certificates to be used in test vectors for other protocols like EDHOC.


```
issuerPublicKeyAlgorithm :  
1 (EC Public Key (Weierstrass) with secp256r1)  
  
issuerPublicKey :  
h'02AE4CDB01F614DEFC7121285FDC7F5C6D1D42C95647F061BA0080DF678867845E'  
  
issuerPrivateKey :  
h'DC66B3415456D649429B53223DF7532B942D6B0E0842C30BCA4C0ACF91547BB2'  
  
subjectPrivateKey :  
h'D718111F3F9BD91B92FF6877F386BDBFCEA7154268FD7F2FB56EE17D99EA16D4'
```

[A.2.](#) Example IEEE 802.1AR profiled X.509 Certificate

EDITOR'S NOTE: To do

[A.3.](#) Example CAB Baseline ECDSA HTTPS X.509 Certificate

The www.ietf.org HTTPS server replies with a certificate message with 2 certificates. The DER encoding of the first certificate is 1209 bytes.

```
30 82 04 b5 30 82 04 5a a0 03 02 01 02 02 10 04 7f a1 e3 19 28 ee 40  
3b a0 b8 3a 39 56 73 fc 30 0a 06 08 2a 86 48 ce 3d 04 03 02 30 4a 31  
0b 30 09 06 03 55 04 06 13 02 55 53 31 19 30 17 06 03 55 04 0a 13 10  
43 6c 6f 75 64 66 6c 61 72 65 2c 20 49 6e 63 2e 31 20 30 1e 06 03 55  
04 03 13 17 43 6c 6f 75 64 66 6c 61 72 65 20 49 6e 63 20 45 43 43 20  
43 41 2d 33 30 1e 17 0d 32 30 30 37 32 39 30 30 30 30 30 30 5a 17 0d  
32 31 30 37 32 39 31 32 30 30 30 30 5a 30 6d 31 0b 30 09 06 03 55 04  
06 13 02 55 53 31 0b 30 09 06 03 55 04 08 13 02 43 41 31 16 30 14 06  
03 55 04 07 13 0d 53 61 6e 20 46 72 61 6e 63 69 73 63 6f 31 19 30 17  
06 03 55 04 0a 13 10 43 6c 6f 75 64 66 6c 61 72 65 2c 20 49 6e 63 2e  
31 1e 30 1c 06 03 55 04 03 13 15 73 6e 69 2e 63 6c 6f 75 64 66 6c 61  
72 65 73 73 6c 2e 63 6f 6d 30 59 30 13 06 07 2a 86 48 ce 3d 02 01 06  
08 2a 86 48 ce 3d 03 01 07 03 42 00 04 96 3e cd d8 4d cd 1b 93 a1 cf  
43 2d 1a 72 17 d6 c6 3b de 33 55 a0 2f 8c fb 5a d8 99 4c d4 4e 20 5f  
15 f6 e3 d2 3b 38 2b a6 49 9b b1 7f 34 1f a5 92 fa 21 86 1f 16 d3 12  
06 63 24 05 fd 70 42 bd a3 82 02 fd 30 82 02 f9 30 1f 06 03 55 1d 23  
04 18 30 16 80 14 a5 ce 37 ea eb b0 75 0e 94 67 88 b4 45 fa d9 24 10  
87 96 1f 30 1d 06 03 55 1d 0e 04 16 04 14 cc 0b 50 e7 d8 37 db f2 43  
f3 85 3d 48 60 f5 3b 39 be 9b 2a 30 2e 06 03 55 1d 11 04 27 30 25 82  
15 73 6e 69 2e 63 6c 6f 75 64 66 6c 61 72 65 73 73 6c 2e 63 6f 6d 82  
0c 77 77 77 2e 69 65 74 66 2e 6f 72 67 30 0e 06 03 55 1d 0f 01 01 ff  
04 04 03 02 07 80 30 1d 06 03 55 1d 25 04 16 30 14 06 08 2b 06 01 05  
05 07 03 01 06 08 2b 06 01 05 05 07 03 02 30 7b 06 03 55 1d 1f 04 74  
30 72 30 37 a0 35 a0 33 86 31 68 74 74 70 3a 2f 2f 63 72 6c 33 2e 64  
69 67 69 63 65 72 74 2e 63 6f 6d 2f 43 6c 6f 75 64 66 6c 61 72 65 49  
6e 63 45 43 43 43 41 2d 33 2e 63 72 6c 30 37 a0 35 a0 33 86 31 68 74
```



```

74 70 3a 2f 2f 63 72 6c 34 2e 64 69 67 69 63 65 72 74 2e 63 6f 6d 2f
43 6c 6f 75 64 66 6c 61 72 65 49 6e 63 45 43 43 43 41 2d 33 2e 63 72
6c 30 4c 06 03 55 1d 20 04 45 30 43 30 37 06 09 60 86 48 01 86 fd 6c
01 01 30 2a 30 28 06 08 2b 06 01 05 05 07 02 01 16 1c 68 74 74 70 73
3a 2f 2f 77 77 77 2e 64 69 67 69 63 65 72 74 2e 63 6f 6d 2f 43 50 53
30 08 06 06 67 81 0c 01 02 02 30 76 06 08 2b 06 01 05 05 07 01 01 04
6a 30 68 30 24 06 08 2b 06 01 05 05 07 30 01 86 18 68 74 74 70 3a 2f
2f 6f 63 73 70 2e 64 69 67 69 63 65 72 74 2e 63 6f 6d 30 40 06 08 2b
06 01 05 05 07 30 02 86 34 68 74 74 70 3a 2f 2f 63 61 63 65 72 74 73
2e 64 69 67 69 63 65 72 74 2e 63 6f 6d 2f 43 6c 6f 75 64 66 6c 61 72
65 49 6e 63 45 43 43 43 41 2d 33 2e 63 72 74 30 0c 06 03 55 1d 13 01
01 ff 04 02 30 00 30 82 01 05 06 0a 2b 06 01 04 01 d6 79 02 04 02 04
81 f6 04 81 f3 00 f1 00 76 00 f6 5c 94 2f d1 77 30 22 14 54 18 08 30
94 56 8e e3 4d 13 19 33 bf df 0c 2f 20 0b cc 4e f1 64 e3 00 00 01 73
9c 83 5f 8e 00 00 04 03 00 47 30 45 02 21 00 f8 d1 b4 a9 3d 2f 0d 4c
41 76 df b4 88 bc c7 3b 86 44 3d 7d e0 0e 6a c8 17 4d 89 48 a8 84 36
68 02 20 29 ff 5a 34 06 8a 24 0c 69 50 27 88 e8 ee 25 ab 7e d2 cb cf
68 6e ce 7b 5f 96 b4 31 a9 07 02 fa 00 77 00 5c dc 43 92 fe e6 ab 45
44 b1 5e 9a d4 56 e6 10 37 fb d5 fa 47 dc a1 73 94 b2 5e e6 f6 c7 0e
ca 00 00 01 73 9c 83 5f be 00 00 04 03 00 48 30 46 02 21 00 e8 91 c1
97 bf b0 e3 d3 0c b6 ce e6 0d 94 c3 c7 5f d1 17 53 36 93 11 08 d8 98
12 d4 d2 9d 81 d0 02 21 00 a1 59 d1 6c 46 47 d1 48 37 57 fc d6 ce 4e
75 ec 7b 5e f6 57 ef e0 28 f8 e5 cc 47 92 68 2d ac 43 30 0a 06 08 2a
86 48 ce 3d 04 03 02 03 49 00 30 46 02 21 00 bd 63 cf 4f 7e 5c fe 6c
29 38 5e a7 1c fb fc 1e 3f 7b 1c d0 72 51 a2 21 f7 77 69 c0 f4 71 df
ea 02 21 00 b5 c0 6c c4 58 54 fa 30 b2 82 88 b1 d3 bb 9a 66 61 ed 50
31 72 5b 1a 82 02 e0 da 5b 59 f9 54 02

```

[A.3.1.](#) Example C509 Certificate Encoding

The CBOR encoding of the first X.509 certificate is shown below in CBOR diagnostic format.

/This defines a CBOR Sequence ([RFC 8742](#)):/

```

1,
h'047FA1E31928EE403BA0B83A395673FC',
[
  -4, "IE",
  -8, "Baltimore",
  -9, "CyberTrust",
  -1, "Baltimore CyberTrust Root"
],
1595980800,
1627560000,
[
  -4, "US",
  -6, "CA",
  -5, "San Francisco",
  -8, "Cloudflare, Inc.",
  -1, "sni.cloudflaressl.com"
],
1,
h'03963ECDD84DCD1B93A1CF432D1A7217D6C63BDE3355A02F8CFB5AD8994CD44E20',
[
  6, h'A5CE37EAE8B0750E946788B445FAD9241087961F',
  0, h'CC0B50E7D837DBF243F3853D4860F53B39BE9B2A',
  2, [2, "sni.cloudflaressl.com", 2, "www.ietf.org"],
  -1, 1,
  7, [1, 2],
  4, ["http://crl3.digicert.com/CloudflareIncECCCA-3.crl",
      "http://crl4.digicert.com/CloudflareIncECCCA-3.crl"],
  5, [h'6086480186FD6C0101', "https://www.digicert.com/CPS", 2],
  8, [1, "http://ocsp.digicert.com",
      2, "http://cacerts.digicert.com/CloudflareIncECCCA-3.crt"],
  -3, -2,
  9, ...
],
0,
h'BD63CF4F7E5CFE6C29385EA71CFBFC1E3F7B1CD07251A221F77769C0F471DFEA
B5C06CC45854FA30B28288B1D3BB9A6661ED5031725B1A8202E0DA5B59F95402'

```

[A.4.](#) Example CAB Baseline RSA HTTPS X.509 Certificate

The tools.ietf.org HTTPS server replies with a certificate message with 4 certificates. The DER encoding of the first certificate is 1647 bytes.

```

30 82 06 6b 30 82 05 53 a0 03 02 01 02 02 09 00 a6 a5 5c 87 0e 39 b4
0e 30 0d 06 09 2a 86 48 86 f7 0d 01 01 0b 05 00 30 81 c6 31 0b 30 09
06 03 55 04 06 13 02 55 53 31 10 30 0e 06 03 55 04 08 13 07 41 72 69

```


7a 6f 6e 61 31 13 30 11 06 03 55 04 07 13 0a 53 63 6f 74 74 73 64 61
6c 65 31 25 30 23 06 03 55 04 0a 13 1c 53 74 61 72 66 69 65 6c 64 20
54 65 63 68 6e 6f 6c 6f 67 69 65 73 2c 20 49 6e 63 2e 31 33 30 31 06
03 55 04 0b 13 2a 68 74 74 70 3a 2f 2f 63 65 72 74 73 2e 73 74 61 72
66 69 65 6c 64 74 65 63 68 2e 63 6f 6d 2f 72 65 70 6f 73 69 74 6f 72
79 2f 31 34 30 32 06 03 55 04 03 13 2b 53 74 61 72 66 69 65 6c 64 20
53 65 63 75 72 65 20 43 65 72 74 69 66 69 63 61 74 65 20 41 75 74 68
6f 72 69 74 79 20 2d 20 47 32 30 1e 17 0d 32 30 31 30 30 31 31 39 33
38 33 36 5a 17 0d 32 31 31 31 30 32 31 39 33 38 33 36 5a 30 3e 31 21
30 1f 06 03 55 04 0b 13 18 44 6f 6d 61 69 6e 20 43 6f 6e 74 72 6f 6c
20 56 61 6c 69 64 61 74 65 64 31 19 30 17 06 03 55 04 03 0c 10 2a 2e
74 6f 6f 6c 73 2e 69 65 74 66 2e 6f 72 67 30 82 01 22 30 0d 06 09 2a
86 48 86 f7 0d 01 01 01 05 00 03 82 01 0f 00 30 82 01 0a 02 82 01 01
00 b1 e1 37 e8 eb 82 d6 89 fa db f5 c2 4b 77 f0 2c 4a de 72 6e 3e 13
60 d1 a8 66 1e c4 ad 3d 32 60 e5 f0 99 b5 f4 7a 7a 48 55 21 ee 0e 39
12 f9 ce 0d ca f5 69 61 c7 04 ed 6e 0f 1d 3b 1e 50 88 79 3a 0e 31 41
16 f1 b1 02 64 68 a5 cd f5 4a 0a ca 99 96 35 08 c3 7e 27 5d d0 a9 cf
f3 e7 28 af 37 d8 b6 7b dd f3 7e ae 6e 97 7f f7 ca 69 4e cc d0 06 df
5d 27 9b 3b 12 e7 e6 fe 08 6b 52 7b 82 11 7c 72 b3 46 eb c1 e8 78 b8
0f cb e1 eb bd 06 44 58 dc 83 50 b2 a0 62 5b dc 81 b8 36 e3 9e 7c 79
b2 a9 53 8a e0 0b c9 4a 2a 13 39 31 13 bd 2c cf a8 70 cf 8c 8d 3d 01
a3 88 ae 12 00 36 1d 1e 24 2b dd 79 d8 53 01 26 ed 28 4f c9 86 94 83
4e c8 e1 14 2e 85 b3 af d4 6e dd 69 46 af 41 25 0e 7a ad 8b f2 92 ca
79 d9 7b 32 4f f7 77 e8 f9 b4 4f 23 5c d4 5c 03 ae d8 ab 3a ca 13 5f
5d 5d 5d a1 02 03 01 00 01 a3 82 02 e1 30 82 02 dd 30 0c 06 03 55 1d
13 01 01 ff 04 02 30 00 30 1d 06 03 55 1d 25 04 16 30 14 06 08 2b 06
01 05 05 07 03 01 06 08 2b 06 01 05 05 07 03 02 30 0e 06 03 55 1d 0f
01 01 ff 04 04 03 02 05 a0 30 3d 06 03 55 1d 1f 04 36 30 34 30 32 a0
30 a0 2e 86 2c 68 74 74 70 3a 2f 2f 63 72 6c 2e 73 74 61 72 66 69 65
6c 64 74 65 63 68 2e 63 6f 6d 2f 73 66 69 67 32 73 31 2d 32 34 32 2e
63 72 6c 30 63 06 03 55 1d 20 04 5c 30 5a 30 4e 06 0b 60 86 48 01 86
fd 6e 01 07 17 01 30 3f 30 3d 06 08 2b 06 01 05 05 07 02 01 16 31 68
74 74 70 3a 2f 2f 63 65 72 74 69 66 69 63 61 74 65 73 2e 73 74 61 72
66 69 65 6c 64 74 65 63 68 2e 63 6f 6d 2f 72 65 70 6f 73 69 74 6f 72
79 2f 30 08 06 06 67 81 0c 01 02 01 30 81 82 06 08 2b 06 01 05 05 07
01 01 04 76 30 74 30 2a 06 08 2b 06 01 05 05 07 30 01 86 1e 68 74 74
70 3a 2f 2f 6f 63 73 70 2e 73 74 61 72 66 69 65 6c 64 74 65 63 68 2e
63 6f 6d 2f 30 46 06 08 2b 06 01 05 05 07 30 02 86 3a 68 74 74 70 3a
2f 2f 63 65 72 74 69 66 69 63 61 74 65 73 2e 73 74 61 72 66 69 65 6c
64 74 65 63 68 2e 63 6f 6d 2f 72 65 70 6f 73 69 74 6f 72 79 2f 73 66
69 67 32 2e 63 72 74 30 1f 06 03 55 1d 23 04 18 30 16 80 14 25 45 81
68 50 26 38 3d 3b 2d 2c be cd 6a d9 b6 3d b3 66 63 30 2b 06 03 55 1d
11 04 24 30 22 82 10 2a 2e 74 6f 6f 6c 73 2e 69 65 74 66 2e 6f 72 67
82 0e 74 6f 6f 6c 73 2e 69 65 74 66 2e 6f 72 67 30 1d 06 03 55 1d 0e
04 16 04 14 ad 8a b4 1c 07 51 d7 92 89 07 b0 b7 84 62 2f 36 55 7a 5f
4d 30 82 01 06 06 0a 2b 06 01 04 01 d6 79 02 04 02 04 81 f7 04 81 f4
00 f2 00 77 00 f6 5c 94 2f d1 77 30 22 14 54 18 08 30 94 56 8e e3 4d
13 19 33 bf df 0c 2f 20 0b cc 4e f1 64 e3 00 00 01 74 e5 ac 71 13 00


```

00 04 03 00 48 30 46 02 21 00 8c f5 48 52 ce 56 35 43 39 11 cf 10 cd
b9 1f 52 b3 36 39 22 3a d1 38 a4 1d ec a6 fe de 1f e9 0f 02 21 00 bc
a2 25 43 66 c1 9a 26 91 c4 7a 00 b5 b6 53 ab bd 44 c2 f8 ba ae f4 d2
da f2 52 7c e6 45 49 95 00 77 00 5c dc 43 92 fe e6 ab 45 44 b1 5e 9a
d4 56 e6 10 37 fb d5 fa 47 dc a1 73 94 b2 5e e6 f6 c7 0e ca 00 00 01
74 e5 ac 72 3c 00 00 04 03 00 48 30 46 02 21 00 a5 e0 90 6e 63 e9 1d
4f dd ef ff 03 52 b9 1e 50 89 60 07 56 4b 44 8a 38 28 f5 96 dc 6b 28
72 6d 02 21 00 fc 91 ea ed 02 16 88 66 05 4e e1 8a 2e 53 46 c4 cc 51
fe b3 fa 10 a9 1d 2e db f9 91 25 f8 6c e6 30 0d 06 09 2a 86 48 86 f7
0d 01 01 0b 05 00 03 82 01 01 00 14 04 3f a0 be d2 ee 3f a8 6e 3a 1f
78 8e a0 4c 35 53 0f 11 06 1f ff 60 a1 6d 0b 83 e9 d9 2a db b3 3f 9d
b3 d7 e0 59 4c 19 a8 e4 19 a5 0c a7 70 72 77 63 d5 fe 64 51 0a d2 7a
d6 50 a5 8a 92 38 ec cb 2f 0f 5a c0 64 58 4d 5c 06 b9 73 63 68 27 8b
89 34 dc 79 c7 1d 3a fd 34 5f 83 14 41 58 49 80 68 29 80 39 8a 86 72
69 cc 79 37 ce e3 97 f7 dc f3 95 88 ed 81 03 29 00 d2 a2 c7 ba ab d6
3a 8e ca 09 0b d9 fb 39 26 4b ff 03 d8 8e 2d 3f 6b 21 ca 8a 7d d8 5f
fb 94 ba 83 de 9c fc 15 8d 61 fa 67 2d b0 c7 db 3d 25 0a 41 4a 85 d3
7f 49 46 37 3c f4 b1 75 d0 52 f3 dd c7 66 f1 4b fd aa 00 ed bf e4 7e
ed 01 ec 7b e4 f6 46 fc 31 fd 72 fe 03 d2 f2 65 af 4d 7e e2 81 9b 7a
fd 30 3c f5 52 f4 05 34 a0 8a 3e 19 41 58 c8 a8 e0 51 71 84 09 15 ae
ec a5 77 75 fa 18 f7 d5 77 d5 31 cc c7 2d

```

A.4.1. Example C509 Certificate Encoding

The CBOR encoding of the first X.509 certificate is shown below in CBOR diagnostic format.

/This defines a CBOR Sequence ([RFC 8742](#)):/

```

1,
h'A6A55C870E39B40E',
[
  -4, "US",
  -6, "Arizona",
  -5, "Scottsdale",
  -8, "Starfield Technologies, Inc.",
  -9, "http://certs.starfieldtech.com/repository/",
  -1, "Starfield Secure Certificate Authority - G2"
],
1601581116,
1635881916,
[
  -9, "Domain Control Validated",
  1, "/*.tools.ietf.org"
],
0,
h'B1E137E8EB82D689FADBF5C24B77F02C4ADE726E3E1360D1A8661EC4AD3D3260
E5F099B5F47A7A485521EE0E3912F9CE0DCAF56961C704ED6E0F1D3B1E508879

```



```

3A0E314116F1B1026468A5CDF54A0ACA99963508C37E275DD0A9CFF3E728AF37
D8B67BDDF37EAE6E977FF7CA694ECCD006DF5D279B3B12E7E6FE086B527B8211
7C72B346EBC1E878B80FCBE1EBBD064458DC8350B2A0625BDC81B836E39E7C79
B2A9538AE00BC94A2A13393113BD2CCFA870CF8C8D3D01A388AE1200361D1E24
2BDD79D8530126ED284FC98694834EC8E1142E85B3AFD46EDD6946AF41250E7A
AD8BF292CA79D97B324FF777E8F9B44F235CD45C03AED8AB3ACA135F5D5D5DA1',
[
-3, -2,
 7, [ 1, 2 ],
-1, 5,
 4, "http://crl.starfieldtech.com/sfig2s1-242.crl",
 5, [ h'6086480186fd6e01071701',
      "http://certificates.starfieldtech.com/repository/", 1 ],
 8, [1, "http://ocsp.starfieldtech.com/",
      2, "http://certificates.starfieldtech.com/repository/sfig2.crt"],
 6, h'254581685026383D3B2D2CBECD6AD9B63DB36663',
 2, [ 2, "*.tools.ietf.org", 2, "tools.ietf.org" ],
 0, h'AD8AB41C0751D7928907B0B784622F36557A5F4D',
 9, [
    h'F65C942FD1773022145418083094568EE34D131933BFDF0C2F200BCC4EF164
      E3',
    1715,
    1,
    h'8CF54852CE5635433911CF10CDB91F52B33639223AD138A41DECA6FEDE1FE9
      0FBCA2254366C19A2691C47A00B5B653ABBD44C2F8BAAEF4D2DAF2527CE645
      4995',
    h'5CDC4392FEE6AB4544B15E9AD456E61037FBD5FA47DCA17394B25EE6F6C70E
      CA',
    2012,
    1,
    h'A5E0906E63E91D4FDDEFFF0352B91E50896007564B448A3828F596DC6B2872
      6DFC91EAED02168866054EE18A2E5346C4CC51FEB3FA10A91D2EDBF99125F8
      6CE6'
  ]
],
23,
h'14043FA0BED2EE3FA86E3A1F788EA04C35530F11061FFF60A16D0B83E9D92ADB
B33F9DB3D7E0594C19A8E419A50CA770727763D5FE64510AD27AD650A58A9238
ECCB2F0F5AC064584D5C06B9736368278B8934DC79C71D3AFD345F8314415849
80682980398A867269CC7937CEE397F7DCF39588ED81032900D2A2C7BAABD63A
8ECA090BD9FB39264BFF03D88E2D3F6B21CA8A7DD85FFB94BA83DE9CFC158D61
FA672DB0C7DB3D250A414A85D37F4946373CF4B175D052F3DDC766F14BFDAA00
EDBFE47EED01EC7BE4F646FC31FD72FE03D2F265AF4D7EE2819B7AFD303CF552
F40534A08A3E194158C8A8E05171840915AECA57775FA18F7D577D531CCC72D'

```

The size of the CBOR encoding (CBOR sequence) is 1242 bytes.

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