

Network Working Group
Internet-Draft
Updates: 6698 (if approved)
Intended status: Standards Track
Expires: 24 October 2026

J. Preu Mattsson
G. Selander
Ericsson AB
S. Raza
University of Glasgow
J. Hglund
RISE AB
M. Furuhed
IN Groupe
L. Liao
NIO
22 April 2026

CBOR Encoded X.509 Certificates (C509 Certificates)
draft-ietf-cose-cbor-encoded-cert-18

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, common certificate profiles and is extensible.

Two types of C509 certificates are defined. One type is an invertible CBOR re-encoding of DER-encoded X.509 certificates with the signature field copied from the DER encoding. The other type is identical except that the signature is over the CBOR encoding instead of the DER encoding, avoiding the use of ASN.1. Both types of certificates have the same semantics as X.509 and the same reduced size compared to X.509.

The document also specifies CBOR encoded data structures for certificate (signing) requests and certification request templates, new COSE headers, as well as a TLS certificate type and a file format for C509. This document updates RFC 6698; the TLSA selectors registry is extended to include C509 certificates.

About This Document

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

Status information for this document may be found at
<https://datatracker.ietf.org/doc/draft-ietf-cose-cbor-encoded-cert/>.

Discussion of this document takes place on the CBOR Object Signing and Encryption Working Group mailing list (<mailto:cose@ietf.org>), which is archived at <https://mailarchive.ietf.org/arch/browse/cose/>. Subscribe at <https://www.ietf.org/mailman/listinfo/cose/>.

Source for this draft and an issue tracker can be found at <https://github.com/cose-wg/CBOR-certificates>.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 24 October 2026.

Copyright Notice

Copyright (c) 2026 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Revised BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Revised BSD License.

Table of Contents

1. Introduction	4
2. Notational Conventions	6
3. C509 Certificate	6
3.1. Message Fields	7
3.2. Encoding of subjectPublicKey and issuerSignatureValue . .	12
3.3. Encoding of Extensions	13
3.4. C509 COSE Header Parameters	20

3.5.	C509 COSE Header Algorithm Parameters	21
3.6.	Private Key Structures	22
3.7.	Deterministic Encoding	23
3.8.	C509 Name in TLS and DTLS	24
4.	C509 Certification Request	24
4.1.	Certification Request Types	25
4.2.	Subject Signature Algorithm	26
4.3.	Certification Request Attributes	27
4.4.	Certification Request Template	27
5.	C509 Processing and Certificate Issuance	29
6.	Operational Considerations	30
6.1.	Legacy Considerations	30
6.2.	Expected Certificate Sizes	31
7.	Security Considerations	32
8.	IANA Considerations	33
8.1.	Designated Expert Guidance	33
8.2.	C509 Certificate Types Registry	34
8.3.	C509 Certification Request Types Registry	34
8.4.	C509 Private Key Types Registry	35
8.5.	C509 Certification Request Templates Types Registry	35
8.6.	C509 RDN Attributes Registry	36
8.7.	C509 CR Attributes Registry	40
8.8.	C509 Extensions Registry	41
8.9.	C509 Certificate Policies Registry	45
8.10.	C509 Policies Qualifiers Registry	49
8.11.	C509 Information Access Registry	49
8.12.	C509 Extended Key Usages Registry	51
8.13.	C509 General Names Registry	53
8.14.	C509 Signature Algorithms Registry	55
8.15.	C509 Public Key Algorithms Registry	59
8.16.	COSE Header Parameters Registry	62
8.17.	COSE Header Algorithm Parameters Registry	62
8.18.	Media Type Application Registry	62
8.19.	CoAP Content-Formats Registry	69
8.20.	TLS Certificate Types Registry	70
8.21.	TLSA Selectors Registry	71
8.22.	EDHOC Authentication Credential Types Registry	71
8.23.	Relative Distinguished Name Attribute	71
9.	References	72
9.1.	Normative References	72
9.2.	Informative References	76
Appendix A.	C509 Certificate Examples	79
A.1.	Example: RFC 7925 profiled X.509 Certificate	79
A.2.	Example: IEEE 802.1AR profiled X.509 Certificate	85
A.3.	Example: CAB Baseline ECDSA HTTPS X.509 Certificate	89
A.4.	Example: CAB Baseline RSA HTTPS X.509 Certificate	91
A.5.	Example: Certificate with Extensions IPAddrBlocks and IPAddrBlocksV2	94

Acknowledgments	98
Authors' Addresses	98

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 [RFC9190] [RFC9191] where authenticators typically drop an EAP session after only 4050 round-trips, QUIC [RFC9000] where the latency increases significantly unless the server sends less than three times as many bytes as received prior to validating the client address, and Resource Public Key Infrastructure (RPKI) [RFC6487] where a single certificate can be very large. More compact certificate representations are, therefore, desirable in many use cases.

X.509 certificates are defined with Abstract Syntax Notation One (ASN.1) and encoded using the Distinguished Encoding Rules (DER) [X.690]. This document specifies an alternative encoding of X.509 certificates, using the Concise Binary Object Representation (CBOR) [RFC8949], initially proposed in [X.509-IoT]. The use of a more compact encoding reduces the certificate size, which has known performance benefits in terms of decreased communication overhead, power consumption, latency, storage, etc. The re-encoding of X.509 is called C509 and the resulting certificates are termed C509 certificates. C509 is not a general CBOR encoding for ASN.1 data structures.

CBOR is a data format designed for small code size and small message size to support systems with very limited memory, processor power, and instruction sets. 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, simplifying development and debugging. 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. For a complete specification and examples, see [RFC8949], [RFC8610], and [RFC8742]. Implementors can get familiar with CBOR by using the CBOR playground [CborMe].

The C509 encoding supports a large subset of [RFC5280] and all certificates compatible with the [RFC7925], IEEE 802.1AR (DevID) [IEEE-802.1AR], CAB Baseline [CAB-TLS], [CAB-Code], RPKI [RFC6487], Wi-SUN [Wi-SUN], and eUICC [GSMA-eUICC] profiled X.509 certificates,

and is designed to render a compact encoding of certificates used in constrained environments. This document does not specify a certificate profile.

CAB Baseline Requirements [CAB-TLS], [RFC7925], [IEEE-802.1AR], and CNSA 1.0 [RFC8603] specify certificate profiles which can be applied to certificate-based authentication with, e.g., TLS [RFC8446], QUIC [RFC9000], DTLS [RFC9147], COSE [RFC9052], EDHOC [RFC9528], or Compact TLS 1.3 [I-D.ietf-tls-ctls]. [RFC7925], RFC7925bis [I-D.ietf-uta-tls13-iot-profile], and IEEE 802.1AR [IEEE-802.1AR] specifically target IoT deployments.

At the time of publishing there are several implementations of C509 targeting, e.g., in-vehicle and vehicle-to-cloud communication, Uncrewed Aircraft Systems (UAS), and Global Navigation Satellite System (GNSS). When used to re-encode DER-encoded X.509 certificates, the CBOR encoding can reduce the size of [RFC7925]-profiled certificates by over 50%, see Appendix A.

C509 is designed to be extensible to additional features of X.509, for example, support for new algorithms, including new Post-Quantum (PQ) algorithms, which can be registered in the IANA registry as they become specified, see Section 8.14.

This document defines two types of C509 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. Due to the widespread deployment of X.509, it is necessary to allow backward compatibility.
2. Natively signed C509 certificates, where the signature is calculated over the CBOR encoding instead of over the DER encoding. 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 also specifies C509 Certification Requests, see Section 4; COSE headers for use of the C509 certificates with COSE, see Section 8.16; a TLS certificate type for use of the C509 certificates with TLS and QUIC (with or without additional TLS

certificate compression), see Section 8.20; and a C509 file format. The TLSA selectors registry is extended to include C509 certificates, thus this document updates [RFC6698].

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 [RFC2986], [RFC5280], [RFC7228], [RFC8610], and [RFC8949]. When referring to CBOR, this specification always refers to Deterministically Encoded CBOR as specified in Sections 4.2.1 and 4.2.2 of [RFC8949].

3. C509 Certificate

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], RPKI [RFC6487], GSMA eUICC [GSMA-eUICC], and CAB Baseline [CAB-TLS] [CAB-Code].

In the CBOR encoding, static fields are elided, elliptic curve points and time values are compressed, OID are replaced with short integers or complemented with CBOR OID encoding [RFC9090], and redundant encoding is removed. Combining these different components reduces the certificate size significantly, which is not possible with general purpose compression algorithms, see Figure 5.

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

3.1. Message Fields

The X.509 fields and their CBOR encodings are described in this section, and used in the definition of C509 certificates, see Figure 1. While much of [RFC5280] encodings used in practice is supported, there are a few instances indicated with "not supported" where no alternative is provided and hence no C509 encoding can be generated.

The following Concise Data Definition Language (CDDL) defines the CBOR array C509Certificate and the CBOR Sequence [RFC8742] TBSCertificate. The member names therefore only have documentary value. Applications not requiring a CBOR item MAY represent C509 certificates with the CBOR sequence ~C509Certificate (unwrapped C509Certificate). Examples are given in the appendices, e.g., Appendix A.1.

```

C509Certificate = [
    TBSCertificate,
    issuerSignatureValue : any,
]

; The elements of the following group are used in a CBOR Sequence:
TBSCertificate = (
    c509CertificateType: int,
    certificateSerialNumber: CertificateSerialNumber,
    issuerSignatureAlgorithm: AlgorithmIdentifier,
    issuer: Name / null,
    validityNotBefore: ~time,
    validityNotAfter: ~time / null,
    subject: Name,
    subjectPublicKeyAlgorithm: AlgorithmIdentifier,
    subjectPublicKey: Defined,
    extensions: Extensions,
)

CertificateSerialNumber = ~biguint

Name = [ * RDNAttribute ] / SpecialText

RDNAttribute = (
    ( attributeType: int, attributeValue: SpecialText ) //
    ( attributeType: ~oid, attributeValue: bytes )
)

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

Extensions = [ * Extension ] / int

Extension = (
    ( extensionID: int, extensionValue: Defined ) //
    ( extensionID: ~oid, extensionValue: bytes / [ bytes ] )
)

SpecialText = text / bytes / tag

Defined = any .ne undefined

tag = #6

```

Figure 1: CDDL for C509Certificate.

C509 certificates are defined in terms of DER-encoded X.509 certificates [RFC5280] as detailed in the following subsections.

3.1.1. version

The 'version' field is encoded in the 'c509CertificateType' CBOR int. The field 'c509CertificateType' also indicates the type of the C509 certificate. Two types are defined in this document: natively signed C509 certificates, following X.509 v3 (c509CertificateType = 2); and CBOR re-encoded X.509 v3 DER certificate (c509CertificateType = 3), see Section 8.2. The number of elements in TBSCertificate is fixed and determined by the type. Additional types may be added in the future.

3.1.2. 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.

3.1.3. signature

The 'signature' field, containing the signature algorithm including parameters, is encoded as a CBOR int (see Section 8.14) or as an array with an unwrapped CBOR OID tag [RFC9090] optionally followed by the parameters encoded as a CBOR byte string.

3.1.4. issuer

In the general case, the sequence of 'RDNAttribute' is encoded as a CBOR array consisting of RDNAttribute elements. RelativeDistinguishedName with more than one AttributeTypeAndValue is not supported. Each RDNAttribute is CBOR encoded as (type, value) either as a (int, SpecialText) pair, or a (~oid, bytes) tuple.

In the former case, the absolute value of the int encodes the attribute type (see Figure 11) and the sign is used to represent the character string type in the X.509 certificate; positive for utf8String, negative for printableString. Attribute values which are always of type IA5String are unambiguously represented using a non-negative int. Examples include emailAddress and domainComponent (see [RFC5280]). In CBOR, all text strings are UTF-8 encoded and in natively signed C509 certificates all CBOR ints SHALL be non-negative. Text strings SHALL still adhere to any [RFC5280] restrictions. serialNumber SHALL only contain the 74-character subset of ASCII allowed by printableString and countryName SHALL have length 2. CBOR encoding is allowed for IA5String (if this is the only allowed type, e.g., emailAddress), printableString and utf8String, whereas the string types teletexString, universalString, and bmpString are not supported.

The text strings are further optimized as follows:

- * If the text string has an even length 2 and contains only the symbols '0'-'9' or 'a'-'f', it is encoded as a CBOR byte string.
- * If the text string contains an EUI-64 of the form "HH-HH-HH-HH-HH-HH-HH-HH" where each 'H' is one of the symbols '0'-'9' or 'A'-'F', it is encoded as a CBOR tagged MAC address using the CBOR tag 48, see Section 2.4 of [RFC9542]. If of the form "HH-HH-HH-HH-HH-HH-HH-HH", it is encoded as a 48-bit MAC address, otherwise as a 64-bit MAC address. See example in Appendix A.1.
- * Otherwise, it is encoded as a CBOR text string.

The final encoding of the extension value may therefore be text, bytes, or tag, i.e., SpecialText. If Name contains a single 'common name' attribute with attributeType = +1, it is for compactness encoded as just the SpecialText containing the single attribute value.

In natively signed C509 certificates, bytes and tag 48 do not correspond to any predefined text string encoding and may also be used for other attribute types.

If the 'issuer' field is identical to the 'subject' field, e.g., in case of self-signed certificates, then the 'issuer' field MUST be encoded as the CBOR simple value null (0xf6).

3.1.5. 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 the CBOR simple value null.

3.1.6. subject

The 'subject' field is encoded exactly like issuer, except that the CBOR simple value is not a valid value.

3.1.7. subjectPublicKeyInfo

The 'AlgorithmIdentifier' field including parameters is encoded as the CBOR int 'subjectPublicKeyAlgorithm' (see Section 8.15) or as an array with an unwrapped CBOR OID tag [RFC9090] 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, but may be encoded as a CBOR item of any type except undefined (see Section 4.4). 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.

3.1.8. issuerUniqueID

Not supported.

3.1.9. subjectUniqueID

Not supported.

3.1.10. extensions

The 'extensions' field is encoded either as a CBOR array or as a CBOR int. An omitted 'extensions' field is encoded as an empty CBOR array.

Each 'extensionID' in the CBOR array is encoded either as a CBOR int (see Section 8.8) or as an unwrapped CBOR OID tag [RFC9090].

- * If 'extensionID' is encoded as a CBOR int, it is followed by a CBOR item of any type except undefined (see Section 4.4), and the sign of the int is used to encode if the extension is critical: Critical extensions are encoded with a negative sign and non-critical extensions are encoded with a positive sign. If the CBOR array contains exactly two ints and the absolute value of the first int is 2 (corresponding to keyUsage, see Section 3.3), the CBOR 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.
- * If extensionID is encoded as an unwrapped CBOR OID tag, it is followed by the DER-encoded extnValue encoded in the following way:
 - if the extension is non-critical, the extnValue OCTET STRING value field is encoded as a CBOR byte string;

- if the extension is critical, the extnValue OCTET STRING value field is encoded as a CBOR byte string and further wrapped in a CBOR array consisting of only this element.

The processing of critical and non-critical extensions is specified in Section 4.2 of [RFC5280].

The currently defined extension values for which there is CBOR int encoded 'extensionID' are specified in Section 3.3. The extensions mandated to be supported by [RFC7925] and [IEEE-802.1AR] are given special treatment.

More details about extensions in Section 3.3.

3.1.11. signatureAlgorithm

The 'signatureAlgorithm' field is always the same as the 'signature' field and therefore omitted from the CBOR encoding.

3.1.12. signatureValue

In general, the 'signatureValue' BIT STRING value field is encoded as the CBOR byte string issuerSignatureValue. This specification assumes that 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

3.2. Encoding of subjectPublicKey and issuerSignatureValue

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 are omitted and subjectPublicKey consists of only the modulus encoded as an unwrapped CBOR unsigned bignum (~biguint).

For elliptic curve public keys in Weierstrass form (`id-ecPublicKey`), keys may be point compressed as defined in Section 2.3.3 of [SECG]. Native C509 certificates with Weierstrass form keys use the octets 0x02, 0x03, and 0x04 as defined in [SECG]. If a DER-encoded certificate with an uncompressed public key of type `id-ecPublicKey` is CBOR encoded with point compression, then the octet 0xfe is used instead of 0x02 to represent an even y-coordinate, and the octet 0xfd is used instead of 0x03 to represent an odd y-coordinate.

3.2.2. Encoding of `issuerSignatureValue`

For ECDSA signatures, the SEQUENCE and INTEGER type and length fields as well as any leading 0x00 byte (to indicate that the number is not negative) are omitted. Each of the two INTEGER value fields are then padded with leading zeroes to the same fixed length, given by the number of bytes needed to represent the order *n* of the cyclic subgroup used with the algorithm. For example, for P-256, the number of bytes for each integer is 32. The resulting byte string is encoded as a CBOR byte string.

3.3. Encoding of Extensions

The 'extensions' field is encoded as specified in Section 3.1.10 with further details provided in this section.

For some extensions, the CBOR int encoded `extensionID` is only supported for commonly used values of the extension. In case of extension values for which the CBOR int encoded `extensionID` is not supported, the extension MUST be encoded using the unwrapped CBOR OID tag encoded `extensionID`.

A note on `extensionID` naming: in existing OID databases, most IDs can be found in versions with and without an 'id-pe' or 'id-ce' prefix. We have excluded the prefix for the commonly used extensions defined in [RFC5280] and included them for extensions defined elsewhere.

CBOR encoding of the following extension values is fully supported:

- * Subject Key Identifier (`subjectKeyIdentifier`). In natively signed certificates, `KeyIdentifier` can, for example, be composed of the leftmost 160-bits of the SHA-256 hash of the CBOR encoded `subjectPublicKey`. Other methods of generating unique numbers can be used. The `extensionValue` is encoded as follows:

```
KeyIdentifier = bytes
SubjectKeyIdentifier = KeyIdentifier
```

- * Key Usage (keyUsage). The 'KeyUsage' BIT STRING is interpreted as an unsigned integer in network byte order and encoded as a CBOR int. See Section 3.1.10 for special encoding in case keyUsage is the only extension present.

KeyUsage = uint

- * Policy Mappings (policyMappings). extensionValue is encoded as follows:

```
PolicyMappings = [  
  + (issuerDomainPolicy: int/~oid, subjectDomainPolicy: int/~oid)  
]
```

- * Basic Constraints (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.

BasicConstraints = int

- * Policy Constraints (policyConstraints). extensionValue is encoded as follows:

```
PolicyConstraints = [  
  requireExplicitPolicy: uint / null,  
  inhibitPolicyMapping: uint / null,  
]
```

- * Extended Key Usage (extKeyUsage). extensionValue is encoded as an array of CBOR ints (see Section 8.12), or unwrapped CBOR OID tags [RFC9090], where each int or OID encodes a key usage purpose. If the array contains a single KeyPurposeId, the array is omitted.

```
KeyPurposeId = int / ~oid  
ExtKeyUsageSyntax = [ 2* KeyPurposeId ] / KeyPurposeId
```

- * Inhibit anyPolicy (inhibitAnyPolicy). extensionValue is encoded as follows:

InhibitAnyPolicy = uint

CBOR encoding of the following extension values are partly supported:

- * Subject Alternative Name (subjectAltName). If the subject alternative name only contains general names registered in Section 8.13 the extension value can be CBOR encoded.

extensionValue is encoded as an array of (int, any) pairs where each pair encodes a general name (see Section 8.13). 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 otherName with type-id id-on-hardwareModuleName, id-on-SmtpUTF8Mailbox and id-on-MACAddress have been given their own ints; such otherName are encoded as follows:

- For id-on-hardwareModuleName, the value is a CBOR array [hwType: ~oid, hwSerialNum: bytes] as specified in [RFC4108].
- For id-on-SmtpUTF8Mailbox, the value is a CBOR text as specified in [RFC8398].
- For id-on-MACAddress, the value is a CBOR byte string containing 6 octets for EUI-48 and 8 octets for EUI-64 as specified in [I-D.ietf-lamps-macaddress-on].

GeneralName = (GeneralNameType : int, GeneralNameValue : any)

GeneralNames = [+ GeneralName]

SubjectAltName = GeneralNames / text

- * Issuer Alternative Name (issuerAltName). extensionValue is encoded exactly like subjectAltName.

IssuerAltName = GeneralNames / text

- * CRL Distribution Points (cRLDistributionPoints). If all DistributionPoint elements contain the distributionPoint with fullName choice of uniformResourceIdentifier, optional reasons, and optional cRLIssuer with one directoryName, the extension value can be CBOR encoded. The 'reasons' BIT STRING is interpreted as an unsigned integer in network byte order and encoded as a CBOR uint. If the cRLDistributionPoints consists of only one DistributionPointName, which in turn has only the fullName field of type CBOR text, it shall be encoded as CBOR text, otherwise as CBOR array.

DistributionPointName = [
 fullName [2 * text] / text,
 reasons uint / null,
 cRLIssuer Name / null,
]

cRLDistributionPoints = [+ DistributionPointName] / text

- * Freshest CRL (freshestCRL). extensionValue is encoded exactly like CRLDistributionPoints.

FreshestCRL = CRLDistributionPoints

- * Authority Information Access (authorityInfoAccess). If all the GeneralNames in authorityInfoAccess are of type uniformResourceIdentifier, the extension value can be CBOR encoded. Each accessMethod is encoded as a CBOR int (see Section 8.11) or an unwrapped CBOR OID tag [RFC9090]. The uniformResourceIdentifiers are encoded as CBOR text strings.

AccessDescription = (accessMethod: int / ~oid , uri: text)
AuthorityInfoAccessSyntax = [+ AccessDescription]

- * Subject Information Access (subjectInfoAccess). Encoded exactly like authorityInfoAccess.

SubjectInfoAccessSyntax = AuthorityInfoAccessSyntax

- * Authority Key Identifier (authorityKeyIdentifier). If the authority key identifier contains all of keyIdentifier, certIssuer, and certSerialNumber or if only keyIdentifier is present the extension value can be CBOR encoded. If all three are present a CBOR array is used, if only keyIdentifier is present, the array is omitted:

KeyIdentifierArray = [
 keyIdentifier: KeyIdentifier,
 authorityCertIssuer: GeneralNames,
 authorityCertSerialNumber: CertificateSerialNumber
]
AuthorityKeyIdentifier = KeyIdentifierArray / KeyIdentifier

- * Certificate Policies (certificatePolicies). If noticeRef is not used and any explicitText are encoded as UTF8String, the extension value can be CBOR encoded. OIDs registered in Section 8.9 are encoded as an int. The policyQualifierId is encoded as an CBOR int (see Section 8.10) or an unwrapped CBOR OID tag [RFC9090].

PolicyIdentifier = int / ~oid
PolicyQualifierInfo = (
 policyQualifierId: int / ~oid,
 qualifier: text,
)
CertificatePolicies = [
 + (PolicyIdentifier, [* PolicyQualifierInfo])
]

- * Name Constraints (nameConstraints). If the name constraints only contain general names registered in Section 8.13 the extension value can be CBOR encoded. C509 uses the same additions and restrictions as defined in Section 2.2 of [RFC9549]. Note that the minimum and maximum fields are not used and therefore omitted. For IPv4 addresses, the ipAddress field MUST contain five octets and for IPv6 addresses, the field MUST contain 17 octets, where the last octet indicates the number of bits in the prefix. As an example, the address block 192.0.2.0/24 is encoded as C0 00 02 00 18 instead of C0 00 02 00 FF FF FF 00 as in the DER encoding.

```
GeneralSubtrees = [ + GeneralName ]
NameConstraints = [
    permittedSubtrees: GeneralSubtrees / null,
    excludedSubtrees: GeneralSubtrees / null,
]
```

- * Subject Directory Attributes (subjectDirectoryAttributes). Encoded as attributes in issuer and subject with the difference that there can be more than one attributeValue.

```
RDNAttributes = (
    ( attributeType: int, attributeValue: [ + SpecialText ] ) //
    ( attributeType: ~oid, attributeValue: [+ bytes] )
)
SubjectDirectoryAttributes = [ + RDNAttributes ]
```

- * AS Identifiers (id-pe-autonomousSysIds). The X.509 extension AS Identifiers is specified in [RFC3779]. If rdi is not present, the extension value can be CBOR encoded. Each ASId is encoded as a CBOR uint. With the exception of the first ASId, the ASId is encoded as the difference to the previous ASId.

```
ASIdOrRange = uint / [min:uint, max:uint]
ASIdentifiers = [ + ASIdOrRange ] / null
```

- * AS Identifiers v2 (id-pe-autonomousSysIds-v2). The X.509 extension AS Identifiers v2 is specified in [RFC8360]. The extension value is encoded exactly like in the extension "AS Identifiers".

- * IPAddrBlocks (id-pe-ipAddrBlocks). The X.509 extension IPAddrBlocks is specified in [RFC3779]. The ASN.1 BIT STRING value of IPAddress is converted to a byte sequence defined as:

```
unusedBits || value
```

where `unusedBits` is a single octet indicating the number of unused bits in the final octet of the BIT STRING, and `value` is the sequence of octets containing the BIT STRING value. This byte sequence preserves the exact information contained in the ASN.1 BIT STRING.

For each `IPAddressFamily`, the representation is selected as follows:

- If `inherit` is present, `null` SHALL be used.
- Otherwise, if the byte sequence of any `IPAddress` (including `addressPrefix`, and the `min` and `max` fields of `addressRange`) exceeds 8 octets in length, the `IPAddressChoice` representation SHALL be used.
- Otherwise, the `IntIPAddressChoice` representation SHALL be used.

For `IntIPAddressChoice`, `IntAddressPrefix` and the `min` and `max` values of `IntAddressRange` SHALL be encoded as big-endian integers representing the following byte sequence:

`(unusedBits + 1) || value`

The first byte is encoded as `(unusedBits + 1)` instead of `unusedBits` in order to guarantee a non-zero value. With the exception of the first `IPAddress`, each subsequent `IPAddress` SHALL be encoded as a CBOR integer representing the difference from the previous `IPAddress`.

As specified in [RFC3779], the `IPAddressFamily` element contains an Address Family Identifier (AFI) and, optionally, a Subsequent Address Family Identifier (SAFI). AFIs and SAFIs are defined in [IANA-AFI] and [IANA-SAFI], respectively. The limitations specified in [RFC3779] apply here as well.

```

IntAddressPrefix = int
IntAddressRange  = [ min: int, max: int ]
IntIPAddressOrRange = IntAddressPrefix / IntAddressRange
IntIPAddressChoice = [ + IntIPAddressOrRange ]

AddressPrefix = bytes
AddressRange  = [ min: bytes, max: bytes ]
IPAddressOrRange = AddressPrefix / AddressRange
IPAddressChoice = [ + IPAddressOrRange ]

IPAddressFamily = (AFI: uint, SAFI: uint / null,
                  IntIPAddressChoice / IPAddressChoice / null)
IPAddrBlocks = [ + IPAddressFamily ]

```

- * IPAddrBlocks v2 (id-pe-ipAddrBlocks-v2). The X.509 extension IPAddrBlocks v2 is specified in [RFC8360]. The extension value is encoded exactly like in the extension "IPAddrBlocks".
- * OCSP No Check (id-pkix-ocsp-nocheck). If the extension value is NULL, it can be CBOR encoded. The CBOR encoded extensionValue is the value null.
- * Precertificate Signing Certificate. The CBOR encoded extensionValue is the value null.
- * TLS Features (id-pe-tlsfeature). The extensionValue is encoded as an array of integers, where each integer represents a TLS extension.

```
TLSFeatures = [* feature: uint]
```

3.3.1. Example Encoding of Extensions

The examples below use values from Section 8.8, Section 8.12, and Section 8.13:

- * A critical basicConstraints ('cA' = true) without pathLenConstraint is encoded as the two CBOR ints -4, -1.
- * A non-critical keyUsage with digitalSignature (0), nonRepudiation (1), keyEncipherment (2) and keyAgreement (4) asserted is encoded as the two CBOR ints 2, 23 ($2^0 + 2^1 + 2^2 + 2^4 = 23$).
- * A non-critical extKeyUsage containing id-kp-codeSigning and id-kp-OCSPSigning is encoded as the CBOR int 8 followed by the CBOR array [3, 9].

- * A non-critical subjectAltName containing only the dNSName example.com is encoded as the CBOR int 3 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 [-4, -1, 2, 23, 8, [3, 9], 3, "example.com"].

3.4. C509 COSE Header Parameters

The formatting and processing for c5b, c5c, c5t, and c5u, defined in Table 1 below, are similar to x5bag, x5chain, x5t, x5u defined in [RFC9360] except that the certificates are C509 instead of DER-encoded X.509 and use a COSE_C509 structure instead of COSE_X509.

The COSE_C509 structure used in c5b, c5c, and c5u is defined as:

```
COSE_C509 = C509CertData / [ 2* C509CertData ]  
C509CertData = bytes .cborseq C509Certificate
```

C509CertData thus includes the unwrapped CBOR sequence, ~C509Certificate. The byte string encoding includes the length of each certificate which simplifies parsing. See Appendix A.1.5 for an example.

The COSE_C509 item has media type application/cose-c509-cert, see Section 8.18.1. Different CoAP Content-Formats are defined depending on "usage" = "chain" or not, see Section 8.19. Stored file formats are defined for the cases with/without ("usage" = "chain") with "magic numbers" TBD8/TBD6 using the reserved CBOR tag 55799 and the corresponding Content-Formats TBD15/TBD3, enveloped as described in Section 2.2 of [RFC9277].

The value type of c5t is the COSE_CertHash structure defined in [RFC9360], which contains the hash value of the C509 certificate calculated over ~C509Certificate. Thus C509CertData contains all data necessary to calculate the thumbprint c5t.

c5u provides an alternative way to identify an untrusted certificate chain by reference with a URI [RFC3986], encoded as a CBOR text string (media type application/cbor and CoAP Content-Format 60). The referenced resource is a COSE_C509 item served with the application/cose-c509-cert media type ("usage" = "chain"), as described above.

As the contents of c5b, c5c, 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 appropriate authorization.

Name	Label	Value Type	Description
c5b	24	COSE_C509	An unordered bag of C509 certificates
c5c	25	COSE_C509	An ordered chain of C509 certificates
c5t	22	COSE_CertHash	Hash of a ~C509Certificate
c5u	23	uri	URI pointing to a COSE_C509 containing an ordered chain of certificates

Table 1: C509 COSE Header Parameters

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

3.5. C509 COSE Header Algorithm Parameters

This section defines the COSE header parameters used for identifying or transporting the sender's key for static-static key agreement algorithms corresponding to Section 3 of [RFC9360], see Table 2.

- * c5c-sender contains the chain of certificates starting with the sender's key exchange certificate. The structure is the same as 'c5c'.
- * c5t-sender contains the hash value for the sender's key exchange certificate. The structure is the same as 'c5t'.
- * c5u-sender contains a URI for the sender's key exchange certificate. The structure and processing are the same as 'c5u'.

Name	Algorithm	Label	Type	Description
c5c-sender	ECDH-SS+HKDF-256, ECDH-SS+HKDF-512, ECDH-SS+A128KW, ECDH-SS+A192KW, ECDH-SS+A256KW	-30 (suggested)	COSE_C509	An ordered chain of C509 certificates
c5t-sender	ECDH-SS+HKDF-256, ECDH-SS+HKDF-512, ECDH-SS+A128KW, ECDH-SS+A192KW, ECDH-SS+A256KW	-31 (suggested)	COSE_CertHash	Hash of a ~C509Certificate
c5u-sender	ECDH-SS+HKDF-256, ECDH-SS+HKDF-512, ECDH-SS+A128KW, ECDH-SS+A192KW, ECDH-SS+A256KW	-32 (suggested)	uri	URI pointing to a COSE_C509 containing an ordered chain of certificates

Table 2: Static ECDH Algorithm Values

3.6. Private Key Structures

Certificate management also makes use of data structures including private keys, see, e.g., [RFC7468]. This section defines the following CBOR encoded structures:

```
C509PrivateKey = [  
    C509PrivateKeyType: int,  
    subjectPrivateKeyAlgorithm: AlgorithmIdentifier,  
    subjectPrivateKey: any,  
]
```

The field 'C509PrivateKeyType' indicates the type of the C509 private key. Different types of C509 Private Key Structures can be defined, see Section 8.4. Currently, two types are defined. When C509PrivateKeyType = 0, the subjectPrivateKey is the CBOR byte string encoding of the PrivateKey OCTET STRING value field defined in [RFC5958]. When C509PrivateKeyType = 1, the subjectPrivateKey is a COSE_KEY structure containing a private key as defined in [RFC9052]. Note that COSE_KEY might not be possible to use with all algorithms that have a C509 AlgorithmIdentifier defined.

The C509PrivateKey item is served with the application/cose-c509-privkey media type, see Section 8.18.4, with corresponding CoAP Content-Format defined in Section 8.19. A stored file format is defined with "magic number" TBD12 using the reserved CBOR tag 55799 and the Content-Format TBD10, enveloped as described in Section 2.2 of [RFC9277].

```
C509PEM = [  
    C509PrivateKey,  
    COSE_C509 / null,  
]
```

The C509PEM item is served with the application/cose-c509-pem media type, see Section 8.18.5, with corresponding CoAP Content-Format defined in Section 8.19. A stored file format is defined with "magic number" TBD13 using the reserved CBOR tag 55799 and the Content-Format TBD11, enveloped as described in Section 2.2 of [RFC9277].

3.7. Deterministic Encoding

In some use cases it is desirable to be able to specify a unique C509 representation of a given X.509 certificate.

While this specification requires the use of Deterministically Encoded CBOR (see Section 2), it is still possible to represent certain X.509 certificate fields in different ways. This is a consequence of the extensibility of the C509 format where new encodings can be defined, for example to optimize extensions for which no special CBOR encoding have been previously defined.

Where there is support for a specific and a generic CBOR encoding, the specific CBOR encoding MUST be used. For example, when there is support for specific CBOR encoding of an extension, as specified in Section 3.3 and the C509 Extensions Registry, it MUST be used. In particular, when there is support for a specific otherName encoding (negative integer value in C509 General Names Registry) it MUST be used.

Native C509 certificates MUST only use specific CBOR encoded fields. However, when decoding a non-native C509 certificates, the decoder may need to support, for example, (extensionID: ~oid, extensionValue: bytes / [bytes])-encoding of an extension for which there is an (extensionID:int, extensionValue:Defined)-encoding. One reason is that the certificate was issued before the specific CBOR extension was registered.

3.8. C509 Name in TLS and DTLS

In TLS and DTLS, the subject of trusted authority may be sent to the peer to help it selecting the certificate chain, as in the CertificateAuthoritiesExtension in [RFC8446], in the certificate_authorities field of CertificateRequest in [RFC5246], or in the TrustedAuthorities in [RFC6066]. For such usage in the TLS and DTLS, the C509 name is wrapped in a distinguished name [X.501] with exactly one RelativeDistinguishedName, which in turn contains exactly one AttributeTypeAndValue with the attribute C509Name. The attribute value is the raw byte string of the encoded C509 Name as in Section 3.1.6.

The attribute for C509 Name has the following structure:

```
id-rdna-c509Name OBJECT IDENTIFIER ::= { 1 3 6 1 5 5 7 25 TBD30 }
```

```
c509Name ATTRIBUTE ::= {  
    WITH SYNTAX C509Name  
    SINGLE VALUE TRUE  
    ID id-rdna-c509Name }
```

```
C509Name ::= OCTET STRING
```

4. C509 Certification Request

This section defines the format of a C509 Certification Request based on [RFC2986]. It reuses the formatting of C509 certificates defined in Section 3. A Certification Request is commonly referred to as a Certificate Signing Request (CSR).

The CDDL for the C509 Certification Request is shown in Figure 2. The fields have the same encoding as the corresponding fields of the C509 Certificate, see Section 3.1.

```
C509CertificationRequest = [  
    TBSCertificationRequest,  
    subjectSignatureValue: any,  
]  
  
; The elements of the following group are used in a CBOR Sequence:  
TBSCertificationRequest = (  
    c509CertificationRequestType: int,  
    subjectSignatureAlgorithm: AlgorithmIdentifier,  
    subject: Name,  
    subjectPublicKeyAlgorithm: AlgorithmIdentifier,  
    subjectPublicKey: Defined,  
    attributes: CRAttributes,  
)  
  
CRAttributes = [ * CRAttribute ]  
  
CRAttribute = (( attributeType: int, attributeValue: Defined ) //  
    ( attributeType: ~oid, attributeValue: bytes ))
```

Figure 2: CDDL for C509CertificationRequest.

After verifying the subjectSignatureValue, the Certification Authority (CA) MAY transform the C509CertificationRequest into a [RFC2986] CertificationRequestInfo for compatibility with existing procedures and code.

The media type of C509CertificationRequest is application/cose-c509-pkcs10, see Section 8.18.2, with corresponding CoAP Content-Format defined in Section 8.19. The "magic number" TBD9 is defined using the reserved CBOR tag 55799 and the Content-Format TBD4, enveloped as described in Section 2.2 of [RFC9277].

4.1. Certification Request Types

Two types of C509 Certification Requests are defined, both using the same CBOR encoding and differing only in what is being signed, see Section 8.3. The C509 Certification Request can either be an invertible CBOR re-encoding of a DER-encoded certification request [RFC2986], or it can be natively signed where the signature is calculated over the CBOR encoding instead of the DER encoding.

- * `c509CertificationRequestType = 2`. This type indicates that the C509 Certification Request is natively signed, i.e., that `subjectSignatureValue` contains the signature over the CBOR Sequence `TBSCertificationRequest`, see Figure 2. This encoding removes the need for ASN.1 and DER parsing, and re-encoding in the requesting party.
- * `c509CertificationRequestType = 3`. This type indicates that the C509 Certification Request is a CBOR re-encoded [RFC2986] certification request, as defined in Section 4. This encoding is backwards compatible with legacy RFC 2986 certification requests, and enables a reduced transport overhead.

The type of certificate issued after the request is decided by the application. The default type of issued certificate in case of C509 is that `c509CertificateType = c509CertificationRequestType`.

An implementation MAY only support certain values of `c509CertificationRequestType`.

4.2. Subject Signature Algorithm

`subjectSignatureAlgorithm` can be a signature algorithm or a non-signature proof-of-possession algorithm, e.g., as defined in [RFC6955]. In the case of [RFC6955], the signature is replaced by a MAC and requires a public Diffie-Hellman key of the verifier distributed out-of-band. Both signature algorithms and non-signature proof-of-possession algorithms are listed in the C509 Signature Algorithms Registry, see Section 8.14. The non-signature proof-of-possession algorithms with SHA-2 and HMAC-SHA2 (see values 14-16 in Section 8.14) require a signature value with syntax `DhSigStatic` defined as follows:

`DhSigStatic = MessageDigest / DhSigStaticType`

`MessageDigest = bytes`

```
DhSigStaticType = [  
  issuer: Name,  
  serialNumber: CertificateSerialNumber  
  hashValue: MessageDigest  
]
```

Note that a key agreement key pair may be used with a signature algorithm in a certification request, see Appendix A.1.3.

4.3. Certification Request Attributes

The 'attributes' field specifies the attributes contained in a certification request. The 'attributes' field with no GeneralAttribute SHALL be encoded as an empty CBOR array.

The remainder of this section specifies CBOR encoded attributes for Certification Requests.

4.3.1. Extension Request

The X.509 attribute "Extension Request" is defined in [RFC2985]. The 'attributeValue' field has type Extensions as in Section 3.1. An empty CBOR array indicates no extensions.

4.3.2. Challenge Password

The X.509 attribute "Challenge Password" is defined in [RFC2985]. The 'attributeValue' field has type ChallengePassword. A UTF8 String is encoded as CBOR text, and a Printable String is tagged with number 121 (alternative 0 as defined in [IANA-CBOR-TAGS]). All other string types are not supported. For certification request type 2, only UTF8 String is allowed.

ChallengePassword = text / #6.121(text)

4.3.3. Private Key Possession Statement

The X.509 attribute "Statement of Possession of a Private Key" is defined in [RFC9883]. The 'attributeValue' field has type PrivateKeyPossessionStatement.

```
PrivateKeyPossessionStatement = [  
  issuer: Name,  
  serialNumber: CertificateSerialNumber,  
  cert: C509Certificate / null,  
]
```

4.4. Certification Request Template

Enrollment over Secure Transport (EST, [RFC7030]) defines, and [I-D.ietf-lamps-rfc7030-csrattrs] clarifies, how an EST server can specify what it expects the EST client to include in a subsequent Certification Request. Alternatively to the unstructured mechanism specified in [RFC7030], Appendix B of [RFC8295] describes an approach using a Certification Request Template in response to a GET /csrattrs request by the EST client. The EST server thus returns a Certification Request-like object with various fields filled out, and

other fields waiting to be filled in and a signature to be added by the EST client.

The approach of [RFC8295] is also followed for C509. The C509CertificationRequestTemplate is based on TBSCertificationRequest of the C509CertificationRequest, see Figure 2, but excludes the subjectSignatureValue field from the template since that needs no further specification.

The C509 Certification Request Template is shown in Figure 3.

```
C509CertificationRequestTemplate = [  
  c509CertificationRequestTemplateType: int,  
  c509CertificationRequestType: [+ int] / undefined,  
  subjectSignatureAlgorithm: [+ AlgorithmIdentifier] / undefined,  
  subject: NameTemplate / undefined,  
  subjectPublicKeyAlgorithm: [+ AlgorithmIdentifier] / undefined,  
  subjectPublicKey: undefined,  
  extensionsRequest: ExtensionsTemplate / undefined,  
]  
  
NameTemplate = [ * RDNAAttributeTemplate ]  
  
RDNAAttributeTemplate = (  
  ( attributeType: uint, minOccurs: uint, maxOccurs: uint,  
    attributeValue: SpecialText / undefined ) //  
  ( attributeType: ~oid, minOccurs: uint, maxOccurs: uint,  
    attributeValue: bytes / undefined )  
)  
  
ExtensionsTemplate = [ * ExtensionTemplate ]  
  
ExtensionTemplate = (  
  ( extensionID: uint, optional: bool, extensionValue: any ) //  
  ( extensionID: ~oid, optional: bool,  
    extensionValue: bytes / undefined )  
)
```

Figure 3: CDDL for C509CertificationRequestTemplate.

Except as specified in this section, the fields have the same encoding as the corresponding fields of the TBSCertificationRequest, see Figure 2. The specification of the template makes use of the CBOR simple value undefined (0xf7) to indicate fields to fill in. Consistent with this rule, note that the subjectPublicKey field always has the value undefined in the template.

Different types of Certification Request Templates can be defined (see Section 8.5), distinguished by the `c509CertificationRequestTemplateType` integer. Each type may have its own CDDL structure.

The presence of a Defined (non-undefined) value in a `C509CertificationRequestTemplate` indicates that the server expects the client to use that value in the certification request. If multiple `AlgorithmIdentifier` or `c509CertificationRequestType` values are present, the server expects the client to select one of them for use in the Certification Request. The presence of an undefined value indicates that the client is expected to provide an appropriate value for that field. For example, if the server includes a `subjectAltName` with a `GeneralNameType` `iPAddress` and a `GeneralNameValue` empty byte string, this means that the client SHOULD fill in a corresponding `GeneralNameValue`.

For `AttributeTemplate`, the `minOccurs` and `maxOccurs` fields specify the minimal and maximal occurrences of attributes of the given `attributeType`; maximal shall not be less than minimal, and maximal shall be positive. Negative `attributeType` is not allowed.

For `ExtensionTemplate`, the field "optional" specifies whether an extension of the given `extensionID` is optional. Negative `extensionID` is not allowed.

The media type of `C509CertificationRequestTemplate` is `application/cose-c509-crtemplate`, see Section 8.18.3, with corresponding CoAP Content-Format defined in Section 8.19. The "magic number" TBD18 is defined using the reserved CBOR tag 55799 and the Content-Format TBD19, enveloped as described in Section 2.2 of [RFC9277].

5. C509 Processing and Certificate Issuance

It is straightforward to integrate the C509 format into legacy X.509 processing during certificate issuance. C509 processing can be performed as an isolated function of the CA, or as a separate function trusted by the CA.

The Certification Request format defined in Section 4 follows the PKCS#10 format to enable a direct mapping to the certification request information, see Section 4.1 of [RFC2986]. The CA can make use of a Certification Request Template defined in Section 4.4, for simplified configuration.

When a certification request is received, the CA, or function trusted by the CA, needs to perform some limited C509 processing and verify the proof-of-possession corresponding to the public key, before normal certificate generation can take place.

In the reverse direction, in case `c509CertificateType = 3` was requested, a separate C509 processing function can perform the conversion from a generated X.509 certificate to C509 as a bump-in-the-wire. In case `c509CertificateType = 2` was requested, the C509 processing needs to be performed before signing the certificate, in which case a tighter integration with the CA may be needed.

6. Operational Considerations

6.1. Legacy Considerations

C509 certificates can be deployed with legacy X.509 certificates and CA infrastructure. An existing CA can continue to use its existing procedures and code for PKCS#10, and DER-encoded X.509 and only implement C509 as a thin processing layer on top. When receiving a C509 Certification Request, the CA transforms it into a DER-encoded `CertificationRequestInfo` [RFC2986] and uses that with existing processes and code to produce an RFC 5280 DER-encoded X.509 certificate. The DER-encoded X.509 is then transformed into a C509 certificate. At any later point, the C509 certificate can be used to recreate the original X.509 data structure needed to verify the signature.

For protocols like TLS/DTLS 1.2, where certificates are 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 constrained wireless links. The conversion to X.509 within a constrained 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.

6.2. Expected Certificate Sizes

The CBOR encoding of the sample certificate chains given in Appendix A results in the numbers shown in Figures 4 and 5. COSE_X509 is defined in [RFC9360] and COSE_C509 is defined in Section 8.16. 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 such as Brotli [RFC7932] will be small, mainly corresponding to making the ASN.1 encoding more compact. CBOR encoding can however significantly compress RFC 7925 profiled certificates. In the examples with HTTPS certificate chains (www.ietf.org (ECDSA) and cabforum.org (RSA)) both C509 and Brotli perform well complementing each other. C509 uses dedicated information to compress individual certificates, while Brotli can compress duplicate information in the entire chain. Note that C509 certificates of type 2 and 3 have the same size. For Brotli, the Rust crate Brotli 3.3.0 was used with compression level 11 and window size 22.

In the examples using FN-DSA and ML-DSA certificate chains, the largest portion of the certificate size consists of the public keys and signatures, which are essentially random. As a result, both Brotli and C509 achieve only very limited size reduction. However, C509 still performs slightly better.

Description (number of certs)	COSE_X509	COSE_C509
RFC 7925 profiled IoT Certificate (1)	319	142
RPKI Certificate (1)	20981	11523
ECDSA HTTPS Certificate Chain (2)	1644	1012
RSA HTTPS Certificate Chain (2)	2909	2240
FN-DSA-512 HTTPS Certificate Chain (2)	4417	3897
ML-DSA-65 HTTPS Certificate Chain (2)	11863	11318

Figure 4: Comparing Sizes of Certificate Chains in COSE. Number of bytes (length of certificate chain).

Description (number of certs)	X.509	X.509 + Brotli	C509	C509 + Brotli
RFC 7925 profiled IoT Certificate (1)	325	317	149	158
RPKI Certificate (1)	20987	9109	11529	7020
ECDSA HTTPS Certificate Chain (2)	1651	1181	1019	930
RSA HTTPS Certificate Chain (2)	2656	2195	2071	1913
FN-DSA-512 HTTPS Certificate Chain (2)	4437	4026	3917	3776
ML-DSA-65 HTTPS Certificate Chain (2)	11869	11420	11325	11148

Figure 5: Comparing Sizes of Certificate Chains with TLS 1.3. Number of bytes (length of certificate chain). X.509 and C509 are Certificate messages. X.509 + Brotli and C509 + Brotli are CompressedCertificate messages.

7. Security Considerations

The CBOR encoding 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 security considerations of [RFC5280] apply.

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 document does not reveal any additional information compared to X.509. Because of the difference in size, it will be possible to detect that this profile is used. The gateway solution described in Section 6.1 requires unencrypted certificates and is not recommended.

Any issues with decoding or parsing a C509 certificate should be handled exactly as how such errors would be handled for the corresponding X.509 certificate. For example, a non-critical extension MAY be ignored if it is not recognized, see Section 4.2 of [RFC5280].

As stated in Section 3.4, the contents of the COSE Header Parameters c5b, c5c, c5t, c5u is untrusted input that potentially may be verified using existing trust anchors or other trust establishment mechanism out of scope of this document. Similar security considerations as x5bag, x5chain, x5t and x5u applies, see [RFC9360]. Security considerations of the COSE protected and unprotected headers is discussed in [RFC9052].

8. IANA Considerations

This document creates several new registries in the new registry group "CBOR Encoded X.509 (C509) Parameters". For all items, the 'Reference' field points to this document.

Editor's note: Add informative reference to the newly created IANA registries and updated existing registries.

8.1. Designated Expert Guidance

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 an entry 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 encoding, other values in the interval [-256, 255] have a 2-byte encoding, and the remaining values in the interval [-65536, 65535] have a 3-byte encoding.

All assignments according to "IETF Review with Expert Review" are made on a "IETF Review" basis per Section 4.8 of [RFC8126] with "Expert Review" additionally required per Section 4.5 of [RFC8126]. The procedure for early IANA allocation of "standards track code points" defined in [RFC7120] also applies. When such a procedure is used, IANA will ask the designated expert(s) to approve the early allocation before registration. In addition, working group chairs are encouraged to consult the expert(s) early during the process outlined in Section 3.1 of [RFC7120].

8.2. C509 Certificate Types Registry

IANA has created a new registry titled "C509 Certificate Types" under the registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Description, and Reference, where Value is an integer, and the other columns are text strings. It is mandatory to specify content in all columns. For values in the interval [-24, 23], the registration procedure is "IETF Review with Expert Review". For all other values, the registration procedure is "Expert Review". The initial contents of the registry are (see Section 3.1.1):

Value	Description
0	Reserved
1	Reserved
2	Natively Signed C509 Certificate
3	CBOR Re-encoded X.509 v3 Certificate

Figure 6: C509 Certificate Types

8.3. C509 Certification Request Types Registry

IANA has created a new registry titled "C509 Certification Request Types" under the new registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Description, and Reference, where Value is an integer, and the other columns are text strings. All columns are mandatory. For values in the interval [-24, 23] the registration procedure is "IETF Review with Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Description
0	Reserved
1	Reserved
2	Natively Signed C509 Certification Request.
3	CBOR re-encoding of RFC 2986 certification request.

Figure 7: C509 Certification Request Types

8.4. C509 Private Key Types Registry

IANA has created a new registry titled "C509 Private Key Types" in the new registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Comments, and subjectPrivateKey, and Reference, where Value is an integer, and the other columns are text strings. All columns are mandatory. For values in the interval [-24, 23] the registration procedure is "IETF Review with Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Private Key Types
0	Comments: Asymmetric Key Package (RFC 5958) subjectPrivateKey: bytes
1	Comments: COSE Key Object (RFC 9052) subjectPrivateKey: COSE_Key

Figure 8: C509 Private Key Types

8.5. C509 Certification Request Templates Types Registry

IANA has created a new registry titled "C509 Certification Request Templates Types" under the new registry group "CBOR Encoded X.509 (C509) Parameters". The columns of the registry are Value, Description, and Reference, where Value is an integer, and the other columns are text strings. All columns are mandatory. 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	Simple C509 Certification Request Template

Figure 9: C509 Certification Request Templates Types

8.6. C509 RDN Attributes Registry

IANA has created a new registry titled "C509 RDN Attributes" in the new registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Name, Identifiers, OID, DER, Comments and Reference, where Value is a non-negative integer, and the other columns are text strings. Name and Identifiers are informal descriptions. The fields Name, OID, and DER are mandatory. For values in the interval [0, 23] the registration procedure is "IETF Review with Expert Review". Values 32768 are reserved for Private Use. For all other values the registration procedure is "Expert Review". Name and Identifiers are informal descriptions. If OID is present, the OID is given in dotted decimal representation, and the DER column contains the hex string of the DER-encoded OID [X.690].

The initial contents of the registry are:

Value	RDN Attribute
0	Name: Email Address Identifiers: emailAddress, e-mailAddress OID: 1.2.840.113549.1.9.1 DER: 06 09 2A 86 48 86 F7 0D 01 09 01 Comments: RFC 2985
1	Name: Common Name Identifiers: commonName, cn OID: 2.5.4.3 DER: 06 03 55 04 03 Comments: X.520
2	Name: Surname Identifiers: surname, sn OID: 2.5.4.4 DER: 06 03 55 04 04 Comments: X.520
3	Name: Serial Number

	Identifiers:	serialNumber
	OID:	2.5.4.5
	DER:	06 03 55 04 05
	Comments:	X.520
4	Name:	Country
	Identifiers:	countryName, c
	OID:	2.5.4.6
	DER:	06 03 55 04 06
	Comments:	X.520
5	Name:	Locality
	Identifiers:	localityName, locality, l
	OID:	2.5.4.7
	DER:	06 03 55 04 07
	Comments:	X.520
6	Name:	State or Province
	Identifiers:	stateOrProvinceName, st
	OID:	2.5.4.8
	DER:	06 03 55 04 08
	Comments:	X.520
7	Name:	Street Address
	Identifiers:	streetAddress, street
	OID:	2.5.4.9
	DER:	06 03 55 04 09
	Comments:	X.520
8	Name:	Organization
	Identifiers:	organizationName, o
	OID:	2.5.4.10
	DER:	06 03 55 04 0A
	Comments:	X.520
9	Name:	Organizational Unit
	Identifiers:	organizationalUnitName, ou
	OID:	2.5.4.11
	DER:	06 03 55 04 0B
	Comments:	X.520
10	Name:	Title
	Identifiers:	title
	OID:	2.5.4.12
	DER:	06 03 55 04 0C
	Comments:	X.520
11	Name:	Business Category

	Identifiers:	businessCategory
	OID:	2.5.4.15
	DER:	06 03 55 04 0F
	Comments:	X.520
12	Name:	Postal Code
	Identifiers:	postalCode
	OID:	2.5.4.17
	DER:	06 03 55 04 11
	Comments:	X.520
13	Name:	Given Name
	Identifiers:	givenName
	OID:	2.5.4.42
	DER:	06 03 55 04 2A
	Comments:	X.520
14	Name:	Initials
	Identifiers:	initials
	OID:	2.5.4.43
	DER:	06 03 55 04 2B
	Comments:	X.520
15	Name:	Generation Qualifier
	Identifiers:	generationQualifier
	OID:	2.5.4.44
	DER:	06 03 55 04 2C
	Comments:	X.520
16	Name:	DN Qualifier
	Identifiers:	dnQualifier
	OID:	2.5.4.46
	DER:	06 03 55 04 2E
	Comments:	X.520
17	Name:	Pseudonym
	Identifiers:	pseudonym
	OID:	2.5.4.65
	DER:	06 03 55 04 41
	Comments:	X.520
18	Name:	Organization Identifier
	Identifiers:	organizationIdentifier
	OID:	2.5.4.97
	DER:	06 03 55 04 61
	Comments:	X.520
19	Name:	Jurisdiction Locality Name

	Identifiers:	jurisdictionLocalityName
	OID:	1.3.6.1.4.1.311.60.2.1.1
	DER:	06 0B 2B 06 01 04 01 82 37 3C 02 01 01
	Comments:	Proprietary Microsoft Attribute
20	Name:	Jurisdiction State or Province
	Identifiers:	jurisdictionStateOrProvinceName
	OID:	1.3.6.1.4.1.311.60.2.1.2
	DER:	06 0B 2B 06 01 04 01 82 37 3C 02 01 02
	Comments:	Proprietary Microsoft Attribute
21	Name:	Jurisdiction Country Name
	Identifiers:	jurisdictionCountryName
	OID:	1.3.6.1.4.1.311.60.2.1.3
	DER:	06 0B 2B 06 01 04 01 82 37 3C 02 01 03
	Comments:	Proprietary Microsoft Attribute
22	Name:	Domain Component
	Identifiers:	domainComponent, dc
	OID:	0.9.2342.19200300.100.1.25
	DER:	06 0A 09 92 26 89 93 F2 2C 64 01 19
	Comments:	RFC 1274
25	Name:	Name
	Identifiers:	name
	OID:	2.5.4.41
	DER:	06 03 55 04 29
	Comments:	X.520
26	Name:	Telephone Number
	Identifiers:	telephoneNumber
	OID:	2.5.4.20
	DER:	06 03 55 04 14
	Comments:	X.520
27	Name:	Directory Management Domain Name
	Identifiers:	dmdName
	OID:	2.5.4.54
	DER:	06 03 55 04 36
	Comments:	X.520
28	Name:	userid
	Identifiers:	uid
	OID:	0.9.2342.19200300.100.1.1
	DER:	06 0A 09 92 26 89 93 F2 2C 64 01 01
	Comments:	RFC 1274
29	Name:	Unstructured Name

	Identifiers:	unstructuredName
	OID:	1.2.840.113549.1.9.2
	DER:	06 09 2A 86 48 86 F7 0D 01 09 02
	Comments:	RFC 2985
+-----+		
30	Name:	Unstructured Address
	Identifiers:	unstructuredAddress
	OID:	1.2.840.113549.1.9.8
	DER:	06 0A 2A 86 48 86 F7 0D 01 09 08 00
	Comments:	RFC 2985
+-----+		

Figure 10: C509 RDN Attributes

8.7. C509 CR Attributes Registry

IANA has created a new registry titled "C509 CR Attributes" under the registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Name, Identifiers, OID, DER, Comments, attributeValue, and Reference, where Value is an integer, and the other columns are text strings. Name and Identifiers are informal descriptions. The fields Name, OID, and DER are mandatory. For values in the interval [-24, 23] the registration procedure is "IETF Review with Expert Review". Values 32768 are reserved for Private Use. For all other values the registration procedure is "Expert Review". Name and Identifiers are informal descriptions. If OID is present, the OID is given in dotted decimal representation, and the DER column contains the hex string of the DER-encoded OID [X.690].

The initial contents of the registry are:

Value	CR Attribute
0	Name: Extension Request Identifiers: extensionRequest OID: 1.2.840.113549.1.9.14 DER: 06 09 2A 86 48 86 F7 0D 01 09 0E Comments: RFC 2985 attributeValue: Extensions
1	Name: Challenge Password Identifiers: challengePassword OID: 1.2.840.113549.1.9.7 DER: 06 09 2A 86 48 86 F7 0D 01 09 07 Comments: RFC 2985 attributeValue: ChallengePassword
2	Name: Private Key Possession Statement Identifiers: privateKeyPossessionStatement OID: 1.3.6.1.4.1.22112.2.1 DER: 06 0A 2B 06 01 04 01 81 AC 60 02 01 Comments: RFC 9883 attributeValue: PrivateKeyPossessionStatement

Figure 11: C509 CRAttributes

8.8. C509 Extensions Registry

IANA has created a new registry titled "C509 Extensions Registry" under the new registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Name, Identifiers, OID, DER, Comments, extensionValue, and Reference, where Value is a positive integer, and the other columns are text strings. The fields Name, OID, DER, and extensionValue are mandatory. For values in the interval [1, 23] the registration procedure is "IETF Review with Expert Review". Values 32768 are reserved for Private Use. For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Extension
1	Name: Subject Key Identifier Identifiers: subjectKeyIdentifier OID: 2.5.29.14 DER: 06 03 55 1D 0E Comments: RFC 5280

	extensionValue: SubjectKeyIdentifier
2	Name: Key Usage Identifiers: keyUsage OID: 2.5.29.15 DER: 06 03 55 1D 0F Comments: RFC 5280 AttributeValue: KeyUsage
3	Name: Subject Alternative Name Identifiers: subjectAltName OID: 2.5.29.17 DER: 06 03 55 1D 11 Comments: RFC 5280 extensionValue: SubjectAltName
4	Name: Basic Constraints Identifiers: basicConstraints OID: 2.5.29.19 DER: 06 03 55 1D 13 Comments: RFC 5280 extensionValue: BasicConstraints
5	Name: CRL Distribution Points Identifiers: cRLDistributionPoints OID: 2.5.29.31 DER: 06 03 55 1D 1F Comments: RFC 5280 extensionValue: CRLDistributionPoints
6	Name: Certificate Policies Identifiers: certificatePolicies OID: 2.5.29.32 DER: 06 03 55 1D 20 Comments: RFC 5280 extensionValue: CertificatePolicies
7	Name: Authority Key Identifier Identifiers: authorityKeyIdentifier OID: 2.5.29.35 DER: 06 03 55 1D 23 Comments: RFC 5280 extensionValue: AuthorityKeyIdentifier
8	Name: Extended Key Usage Identifiers: extKeyUsage OID: 2.5.29.37 DER: 06 03 55 1D 25

	Comments:	RFC 5280
	extensionValue:	ExtKeyUsageSyntax
9	Name:	Authority Information Access
	Identifiers:	authorityInfoAccess
	OID:	1.3.6.1.5.5.7.1.1
	DER:	06 08 2B 06 01 05 05 07 01 01
	Comments:	RFC 5280
	extensionValue:	AuthorityInfoAccessSyntax
24	Name:	Subject Directory Attributes
	Identifiers:	subjectDirectoryAttributes
	OID:	2.5.29.9
	DER:	06 03 55 1D 09
	Comments:	RFC 5280
	extensionValue:	SubjectDirectoryAttributes
25	Name:	Issuer Alternative Name
	Identifiers:	issuerAltName
	OID:	2.5.29.18
	DER:	06 03 55 1D 12
	Comments:	RFC 5280
	extensionValue:	IssuerAltName
26	Name:	Name Constraints
	Identifiers:	nameConstraints
	OID:	2.5.29.30
	DER:	06 03 55 1D 1E
	Comments:	RFC 9549
	extensionValue:	NameConstraints
27	Name:	Policy Mappings
	Identifiers:	policyMappings
	OID:	2.5.29.33
	DER:	06 03 55 1D 21
	Comments:	RFC 5280
	extensionValue:	PolicyMappings
28	Name:	Policy Constraints
	Identifiers:	policyConstraints
	OID:	2.5.29.36
	DER:	06 03 55 1D 24
	Comments:	RFC 5280
	extensionValue:	PolicyConstraints
29	Name:	Freshest CRL
	Identifiers:	freshestCRL
	OID:	2.5.29.46

	DER:	06 03 55 1D 2E
	Comments:	RFC 5280
	extensionValue:	FreshestCRL
30	Name:	Inhibit anyPolicy
	Identifiers:	inhibitAnyPolicy
	OID:	2.5.29.54
	DER:	06 03 55 1D 36
	Comments:	RFC 5280
	extensionValue:	InhibitAnyPolicy
31	Name:	Subject Information Access
	Identifiers:	subjectInfoAccess
	OID:	1.3.6.1.5.5.7.1.11
	DER:	06 08 2B 06 01 05 05 07 01 0B
	Comments:	RFC 5280
	extensionValue:	SubjectInfoAccessSyntax
32	Name:	IPAddrBlocks
	Identifiers:	id-pe-ipAddrBlocks
	OID:	1.3.6.1.5.5.7.1.7
	DER:	06 08 2B 06 01 05 05 07 01 07
	Comments:	RFC 3779
	extensionValue:	IPAddrBlocks
33	Name:	AS Identifiers
	Identifiers:	id-pe-autonomousSysIds
	OID:	1.3.6.1.5.5.7.1.8
	DER:	06 08 2B 06 01 05 05 07 01 08
	Comments:	RFC 3779
	extensionValue:	ASIdentifiers
34	Name:	IPAddrBlocks v2
	Identifiers:	id-pe-ipAddrBlocks-v2
	OID:	1.3.6.1.5.5.7.1.28
	DER:	06 08 2B 06 01 05 05 07 01 1C
	Comments:	RFC 8360
	extensionValue:	IPAddrBlocks
35	Name:	AS Identifiers v2
	Identifiers:	id-pe-autonomousSysIds-v2
	OID:	1.3.6.1.5.5.7.1.29
	DER:	06 08 2B 06 01 05 05 07 01 1D
	Comments:	RFC 8360
	extensionValue:	ASIdentifiers
36	Name:	OCSP No Check
	Identifiers:	id-pkix-ocsp-nocheck

	OID:	1.3.6.1.5.5.7.48.1.5
	DER:	06 09 2B 06 01 05 05 07 30 01 05
	Comments:	RFC 6960
	extensionValue:	null
37	Name:	Precertificate Signing Certificate
	Identifiers:	
	OID:	1.3.6.1.4.1.11129.2.4.3
	DER:	06 0A 2B 06 01 04 01 D6 79 02 04 03
	Comments:	RFC 6962
	extensionValue:	null
38	Name:	TLS Features
	Identifiers:	id-pe-tlsfeature
	OID:	1.3.6.1.5.5.7.1.24
	DER:	06 08 2B 06 01 05 05 07 01 18
	Comments:	RFC 7633
	extensionValue:	TLSFeatures

Figure 12: C509 Extensions

8.9. C509 Certificate Policies Registry

IANA has created a new registry titled "C509 Certificate Policies Registry" under the registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Name, Identifiers, OID, DER, Comments, and Reference, where Value is an integer, and the other columns are text strings. The fields Name, OID, and DER are mandatory. For values in the interval [-24, 23] the registration procedure is "IETF Review with Expert Review". Values 32768 are reserved for Private Use. For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Certificate Policy
0	Name: Any Policy Identifiers: anyPolicy OID: 2.5.29.32.0 DER: 06 04 55 1D 20 00 Comments: RFC 5280
1	Name: Domain Validation (DV) Identifiers: domain-validated OID: 2.23.140.1.2.1 DER: 06 06 67 81 0C 01 02 01

	Comments:	CA/Browser Forum
2	Name:	Organization Validation (OV)
	Identifiers:	organization-validated
	OID:	2.23.140.1.2.2
	DER:	06 06 67 81 0C 01 02 02
	Comments:	CA/Browser Forum
3	Name:	Individual Validation (IV)
	Identifiers:	individual-validated
	OID:	2.23.140.1.2.3
	DER:	06 06 67 81 0C 01 02 03
	Comments:	CA/Browser Forum
4	Name:	Extended Validation (EV)
	Identifiers:	ev-guidelines
	OID:	2.23.140.1.1
	DER:	06 05 67 81 0C 01 01
	Comments:	CA/Browser Forum
7	Name:	Resource PKI (RPKI)
	Identifiers:	id-cp-ipAddr-asNumber
	OID:	1.3.6.1.5.5.7.14.2
	DER:	06 08 2B 06 01 05 05 07 0E 02
	Comments:	RFC 3779
8	Name:	Resource PKI (RPKI) (Alternative)
	Identifiers:	id-cp-ipAddr-asNumber-v2
	OID:	1.3.6.1.5.5.7.14.3
	DER:	06 08 2B 06 01 05 05 07 0E 03
	Comments:	RFC 8360
24	Name:	Remote SIM Provisioning Role Certificate Issuer
	Identifiers:	id-rspRole-ci
	OID:	2.23.146.1.2.1.0
	DER:	06 07 67 81 12 01 02 01 00
	Comments:	GSMA SGP.22
25	Name:	Remote SIM Provisioning Role eUICC v2
	Identifiers:	id-rspRole-euicc-v2
	OID:	2.23.146.1.2.1.1
	DER:	06 07 67 81 12 01 02 01 01
	Comments:	GSMA SGP.22
26	Name:	Remote SIM Provisioning Role eUICC

	Identifiers:	id-rspRole-euicc
	OID:	2.23.146.1.2.1.0.0.0.0
	DER:	06 0B 67 81 12 01 02 01 00 00 00 00 00
	Comments:	GSMA SGP.22
27	Name:	Remote SIM Provisioning Role eUICC Manufacturer v2
	Identifiers:	id-rspRole-eum-v2
	OID:	2.23.146.1.2.1.2
	DER:	06 07 67 81 12 01 02 01 02
	Comments:	GSMA SGP.22
28	Name:	Remote SIM Provisioning Role eUICC Manufacturer
	Identifiers:	id-rspRole-eum
	OID:	2.23.146.1.2.1.0.0.0
	DER:	06 09 67 81 12 01 02 01 00 00 00
	Comments:	GSMA SGP.22
29	Name:	Remote SIM Provisioning Role SM-DP+ TLS v2
	Identifiers:	id-rspRole-dp-tls-v2
	OID:	2.23.146.1.2.1.3
	DER:	06 07 67 81 12 01 02 01 03
	Comments:	GSMA SGP.22
30	Name:	Remote SIM Provisioning Role SM-DP+ TLS
	Identifiers:	id-rspRole-dp-tls
	OID:	2.23.146.1.2.1.0.0.1.0
	DER:	06 0A 67 81 12 01 02 01 00 00 01 00
	Comments:	GSMA SGP.22
31	Name:	Remote SIM Provisioning Role SM-DP+ Authentication v2
	Identifiers:	id-rspRole-dp-auth-v2
	OID:	2.23.146.1.2.1.4
	DER:	06 07 67 81 12 01 02 01 04
	Comments:	GSMA SGP.22
32	Name:	Remote SIM Provisioning Role SM-DP+ Authentication
	Identifiers:	id-rspRole-dp-auth
	OID:	2.23.146.1.2.1.0.0.1.1
	DER:	06 0A 67 81 12 01 02 01 00 00 01 01
	Comments:	GSMA SGP.22
33	Name:	Remote SIM Provisioning Role

	Identifiers:	SM-DP+ Profile Binding v2 id-rspRole-dp-pb-v2
	OID:	2.23.146.1.2.1.5
	DER:	06 07 67 81 12 01 02 01 05
	Comments:	GSMA SGP.22
34	Name:	Remote SIM Provisioning Role SM-DP+ Profile Binding
	Identifiers:	id-rspRole-dp-pb
	OID:	2.23.146.1.2.1.0.0.1.2
	DER:	06 0A 67 81 12 01 02 01 00 00 01 02
	Comments:	GSMA SGP.22
35	Name:	Remote SIM Provisioning Role SM-DS TLS v2
	Identifiers:	id-rspRole-ds-tls-v2
	OID:	2.23.146.1.2.1.6
	DER:	06 07 67 81 12 01 02 01 06
	Comments:	GSMA SGP.22
36	Name:	Remote SIM Provisioning Role SM-DS TLS
	Identifiers:	id-rspRole-ds-tls
	OID:	2.23.146.1.2.1.0.0.2.0
	DER:	06 0A 67 81 12 01 02 01 00 00 02 00
	Comments:	GSMA SGP.22
37	Name:	Remote SIM Provisioning Role SM-DS Authentication v2
	Identifiers:	id-rspRole-ds-auth-v2
	OID:	2.23.146.1.2.1.7
	DER:	06 07 67 81 12 01 02 01 07
	Comments:	GSMA SGP.22
38	Name:	Remote SIM Provisioning Role SM-DS Authentication
	Identifiers:	id-rspRole-ds-auth
	OID:	2.23.146.1.2.1.0.0.2.1
	DER:	06 0A 67 81 12 01 02 01 00 00 02 01
	Comments:	GSMA SGP.22

Figure 13: C509 Certificate Policies

8.10. C509 Policies Qualifiers Registry

IANA has created a new registry titled "C509 Policies Qualifiers Registry" under the registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Name, Identifiers, OID, DER, Comments, and Reference, where Value is an integer, and the other columns are text strings. The fields Name, OID, and DER are mandatory. For values in the interval [-24, 23] the registration procedure is "IETF Review with Expert Review". Values 32768 are reserved for Private Use. For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Certificate Policy
1	Name: Certification Practice Statement Identifiers: id-qt-cps, cps OID: 1.3.6.1.5.5.7.2.1 DER: 06 08 2B 06 01 05 05 07 02 01 Comments: RFC 5280
2	Name: User Notice Identifiers: id-qt-unotice, unotice OID: 1.3.6.1.5.5.7.2.2 DER: 06 08 2B 06 01 05 05 07 02 02 Comments: RFC 5280

Figure 14: C509 Policies Qualifiers

8.11. C509 Information Access Registry

IANA has created a new registry titled "C509 Information Access Registry" under the registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Name, Identifiers, OID, DER, Comments, and Reference, where Value is an integer, and the other columns are text strings. The fields Name, OID, and DER are mandatory. For values in the interval [-24, 23] the registration procedure is "IETF Review with Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Information Access
1	Name: OCSF Identifiers: id-ad-ocsp, id-pkix-ocsp OID: 1.3.6.1.5.5.7.48.1 DER: 06 08 2B 06 01 05 05 07 30 01 Comments: RFC 5280
2	Name: CA Issuers Identifiers: id-ad-caIssuers, caIssuers OID: 1.3.6.1.5.5.7.48.2 DER: 06 08 2B 06 01 05 05 07 30 02 Comments: RFC 5280
3	Name: Time Stamping Identifiers: id-ad-timeStamping, timeStamping OID: 1.3.6.1.5.5.7.48.3 DER: 06 08 2B 06 01 05 05 07 30 03 Comments: RFC 3161
5	Name: CA Repository Identifiers: id-ad-caRepository OID: 1.3.6.1.5.5.7.48.5 DER: 06 08 2B 06 01 05 05 07 30 05 Comments: RFC 5280
10	Name: RPKI Manifest Identifiers: id-ad-rpkiManifest OID: 1.3.6.1.5.5.7.48.10 DER: 06 08 2B 06 01 05 05 07 30 0A Comments: RFC 6487
11	Name: Signed Object Identifiers: id-ad-signedObject OID: 1.3.6.1.5.5.7.48.11 DER: 06 08 2B 06 01 05 05 07 30 0B Comments: RFC 6487
13	Name: RPKI Notify Identifiers: id-ad-rpkiNotify OID: 1.3.6.1.5.5.7.48.13 DER: 06 08 2B 06 01 05 05 07 30 0D Comments: RFC 8182

Figure 15: C509 Information Accesses

8.12. C509 Extended Key Usages Registry

IANA has created a new registry titled "C509 Extended Key Usages Registry" under the registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Name, Identifiers, OID, DER, Comments, and Reference, where Value is an integer, and the other columns are text strings. The fields Name, OID, and DER are mandatory. For values in the interval [-24, 23] the registration procedure is "IETF Review with Expert Review". Values 32768 are reserved for Private Use. For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	Extended Key Usage
0	Name: Any Extended Key Usage Identifiers: anyExtendedKeyUsage OID: 2.5.29.37.0 DER: 06 04 55 1D 25 00 Comments: RFC 5280
1	Name: TLS Server authentication Identifiers: id-kp-serverAuth OID: 1.3.6.1.5.5.7.3.1 DER: 06 08 2B 06 01 05 05 07 03 01 Comments: RFC 5280
2	Name: TLS Client Authentication Identifiers: id-kp-clientAuth OID: 1.3.6.1.5.5.7.3.2 DER: 06 08 2B 06 01 05 05 07 03 02 Comments: RFC 5280
3	Name: Code Signing Identifiers: id-kp-codeSigning OID: 1.3.6.1.5.5.7.3.3 DER: 06 08 2B 06 01 05 05 07 03 03 Comments: RFC 5280
4	Name: Email protection (S/MIME) Identifiers: id-kp-emailProtection OID: 1.3.6.1.5.5.7.3.4 DER: 06 08 2B 06 01 05 05 07 03 04 Comments: RFC 5280
8	Name: Time Stamping Identifiers: id-kp-timeStamping, timestamping

	OID:	1.3.6.1.5.5.7.3.8
	DER:	06 08 2B 06 01 05 05 07 03 08
	Comments:	RFC 3161
+-----+		
9	Name:	OCSP Signing
	Identifiers:	id-kp-OCSPSigning
	OID:	1.3.6.1.5.5.7.3.9
	DER:	06 08 2B 06 01 05 05 07 03 09
	Comments:	RFC 5280
+-----+		
10	Name:	Kerberos PKINIT Client Auth
	Identifiers:	id-pkinit-KPClientAuth
	OID:	1.3.6.1.5.2.3.4
	DER:	06 07 2B 06 01 05 02 03 04
	Comments:	RFC 4556
+-----+		
11	Name:	Kerberos PKINIT KDC
	Identifiers:	id-pkinit-KPKdc
	OID:	1.3.6.1.5.2.3.5
	DER:	06 07 2B 06 01 05 02 03 05
	Comments:	RFC 4556
+-----+		
12	Name:	SSH Client
	Identifiers:	id-kp-secureShellClient
	OID:	1.3.6.1.5.5.7.3.21
	DER:	06 08 2B 06 01 05 05 07 03 15
	Comments:	RFC 6187
+-----+		
13	Name:	SSH Server
	Identifiers:	id-kp-secureShellServer
	OID:	1.3.6.1.5.5.7.3.22
	DER:	06 08 2B 06 01 05 05 07 03 16
	Comments:	RFC 6187
+-----+		
14	Name:	Bundle Security
	Identifiers:	id-kp-bundleSecurity
	OID:	1.3.6.1.5.5.7.3.35
	DER:	06 08 2B 06 01 05 05 07 03 23
	Comments:	RFC 9174
+-----+		
15	Name:	CMC Certification Authority
	Identifiers:	id-kp-cmcCA
	OID:	1.3.6.1.5.5.7.3.27
	DER:	06 08 2B 06 01 05 05 07 03 1B
	Comments:	RFC 6402
+-----+		
16	Name:	CMC Registration Authority
	Identifiers:	id-kp-cmcRA

	OID:	1.3.6.1.5.5.7.3.28
	DER:	06 08 2B 06 01 05 05 07 03 1C
	Comments:	RFC 6402
17	Name:	CMC Archive Server
	Identifiers:	id-kp-cmcArchive
	OID:	1.3.6.1.5.5.7.3.29
	DER:	06 08 2B 06 01 05 05 07 03 1D
	Comments:	RFC 6402
18	Name:	CMC Key Generation Authority
	Identifiers:	id-kp-cmKGA
	OID:	1.3.6.1.5.5.7.3.32
	DER:	06 08 2B 06 01 05 05 07 03 20
	Comments:	RFC 9480
19	Name:	Certificate Transparency
	Identifiers:	
	OID:	1.3.6.1.4.1.11129.2.4.4
	DER:	06 0A 2B 06 01 04 01 D6 79 02 04 04
	Comments:	RFC 6962
20	Name:	Wi-SUN FAN Device
	Identifiers:	id-kp-wisun-fan-device
	OID:	1.3.6.1.4.1.45605.1
	DER:	06 09 2B 06 01 04 01 82 E4 25 01
	Comments:	

Figure 16: C509 Extended Key Usages

8.13. C509 General Names Registry

IANA has created a new registry titled "C509 General Names Registry" under the registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Name, Comments, GeneralNameValue, and Reference, where Value is an integer, and the other columns are text strings. The fields Name and GeneralNameValue are mandatory. For values in the interval $[-24, 23]$ the registration procedure is "IETF Review with Expert Review". For all other values the registration procedure is "Expert Review". The initial contents of the registry are:

Value	General Names
-3	Name: otherName with MACAddress Comments: TBD92(Use RFC I-D-lamps-macaddress-on) id-on-MACAddress (1.3.6.1.5.5.7.8.12) 06 08 2B 06 01 05 05 07 08 0C GeneralNameValue: bytes
-2	Name: otherName with Smtputf8Mailbox Comments: RFC 8398 id-on-Smtputf8Mailbox (1.3.6.1.5.5.7.8.9) 06 08 2B 06 01 05 05 07 08 09 GeneralNameValue: text
-1	Name: otherName with hardwareModuleName Comments: RFC 4108 id-on-hardwareModuleName (1.3.6.1.5.5.7.8.4) 06 08 2B 06 01 05 05 07 08 04 GeneralNameValue: [~oid, bytes]
0	Name: otherName Comments: RFC 5280 GeneralNameValue: [~oid, bytes]
1	Name: rfc822Name Comments: RFC 5280 GeneralNameValue: text
2	Name: dNSName Comments: RFC 5280 GeneralNameValue: text
4	Name: directoryName Comments: RFC 5280 GeneralNameValue: Name
6	Name: uniformResourceIdentifier Comments: RFC 5280 GeneralNameValue: text
7	Name: iPAddress Comments: RFC 5280 GeneralNameValue: bytes

8	Name:	registeredID
	Comments	RFC 5280
	GeneralNameValue:	~oid

Figure 17: C509 General Names

8.14. C509 Signature Algorithms Registry

IANA has created a new registry titled "C509 Signature Algorithms" under the registry group "CBOR Encoded X.509 (C509) Parameters". The registry includes both signature algorithms and non-signature proof-of-possession algorithms. The fields of the registry are Value, Name, Identifiers, OID, Parameters, DER, Comments, and Reference, where Value is an integer, and the other columns are text strings. The fields Name, OID, Parameters, and DER are mandatory. Alignment with the value of public key algorithm MUST be considered, see instruction in Section 8.15. For values in the interval [-24, 23] the registration procedure is "IETF Review with 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 Identifiers: sha1-with-rsa-signature, sha1WithRSAEncryption, sha-1WithRSAEncryption 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 Identifiers: ecdsa-with-SHA1 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. See Section 3.2.2.
0	Name: ECDSA with SHA-256 Identifiers: ecdsa-with-SHA256 OID: 1.2.840.10045.4.3.2 Parameters: Absent DER: 30 0A 06 08 2A 86 48 CE 3D 04 03 02 Comments: See Section 3.2.2.

1	Name: ECDSA with SHA-384 Identifiers: ecdsa-with-SHA384 OID: 1.2.840.10045.4.3.3 Parameters: Absent DER: 30 0A 06 08 2A 86 48 CE 3D 04 03 03 Comments: See Section 3.2.2.
2	Name: ECDSA with SHA-512 Identifiers: ecdsa-with-SHA512 OID: 1.2.840.10045.4.3.4 Parameters: Absent DER: 30 0A 06 08 2A 86 48 CE 3D 04 03 04 Comments: See Section 3.2.2.
3	Name: ECDSA with SHAKE128 Identifiers: id-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: See Section 3.2.2.
4	Name: ECDSA with SHAKE256 Identifiers: id-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: See Section 3.2.2.
5	Name: Unsigned Identifiers: id-alg-unsigned OID: 1.3.6.1.5.5.7.6.36 Parameters: Absent DER: 30 0A 06 08 2B 06 01 05 05 07 06 24 Comments: bytes of size 0
8	Name: SM2 with SM3 Identifiers: sm2-with-sm3 OID: 1.2.156.10197.1.501 Parameters: Absent DER: 30 0A 06 08 2A 81 1C CF 55 01 83 75 Comments: See Section 3.2.2.
12	Name: Ed25519 Identifiers: id-Ed25519, id-EdDSA25519 OID: 1.3.101.112 Parameters: Absent DER: 30 05 06 03 2B 65 70 Comments:

13	Name: Ed448 Identifiers: id-Ed448, id-EdDSA448 OID: 1.3.101.113 Parameters: Absent DER: 30 05 06 03 2B 65 71 Comments:
14	Name: PoP with SHA-256 and HMAC-SHA256 Identifiers: sa-ecdhPop-sha256-hmac-sha256 OID: 1.3.6.1.5.5.7.6.26 Parameters: Absent DER: 30 0A 06 08 2B 06 01 05 05 07 06 1A Comments: Proof-of-possession algorithm, indexed with KDF and MAC, see RFC 6955. Requires recipient's public static Diffie-Hellman key
15	Name: PoP with SHA-384 and HMAC-SHA384 Identifiers: sa-ecdhPop-sha384-hmac-sha384 OID: 1.3.6.1.5.5.7.6.27 Parameters: Absent DER: 30 0A 06 08 2B 06 01 05 05 07 06 1B Comments: Proof-of-possession algorithm, indexed with KDF and MAC, see RFC 6955. Requires recipient's public static Diffie-Hellman key
16	Name: PoP with SHA-512 and HMAC-SHA512 Identifiers: sa-ecdhPop-sha512-hmac-sha512 OID: 1.3.6.1.5.5.7.6.28 Parameters: Absent DER: 30 0A 06 08 2B 06 01 05 05 07 06 1C Comments: Proof-of-possession algorithm, indexed with KDF and MAC, see RFC 6955. Requires recipient's public static Diffie-Hellman key
23	Name: RSASSA-PKCS1-v1_5 with SHA-256 Identifiers: sha256WithRSAEncryption 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 Identifiers: sha384WithRSAEncryption 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 Identifiers: sha512WithRSAEncryption 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 Identifiers: rsassa-pss, id-RSASSA-PSS 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 Identifiers: rsassa-pss, id-RSASSA-PSS 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 Identifiers: rsassa-pss, id-RSASSA-PSS 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 Identifiers: id-RSASSA-PSS-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
	Identifiers:	id-RSASSA-PSS-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:	

Figure 18: C509 Signature Algorithms

8.15. C509 Public Key Algorithms Registry

IANA has created a new registry titled "C509 Public Key Algorithms" under the registry group "CBOR Encoded X.509 (C509) Parameters". The fields of the registry are Value, Name, Identifiers, OID, Parameters, DER, Comments, and Reference, where Value is an integer, and the other columns are text strings. The fields Name, OID, Parameters, and DER are mandatory. If the public key can only be used with one signature algorithm and the OID of the public key algorithm is the same as the signature algorithm, then the value MUST be chosen equal to the value of signature algorithm, see Section 8.14. For values in the interval [-24, 23] the registration procedure is "IETF Review with 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 Identifiers: rsaEncryption 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 Identifiers: ecPublicKey, id-ecPublicKey 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: Compressed subjectPublicKey Also known as P-256, ansip256r1, prime256v1
2	Name: EC Public Key (Weierstrass) with secp384r1 Identifiers: ecPublicKey, id-ecPublicKey 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:	Compressed subjectPublicKey Also known as P-384, ansip384r1
3	Name:	EC Public Key (Weierstrass) with secp521r1
	Identifiers:	ecPublicKey, id-ecPublicKey
	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:	Compressed subjectPublicKey Also known as P-521, ansip521r1
6	Name:	EC Public Key (Weierstrass) with sm2p256v1
	Identifiers:	ecPublicKey, id-ecPublicKey
	OID:	1.2.840.10045.2.1
	Parameters:	namedCurve = sm2p256v1 (1.2.156.10197.1.301)
	DER:	30 13 06 07 2A 86 48 CE 3D 02 01 06 08 2A 81 1C CF 55 01 82 2D
	Comments:	Compressed subjectPublicKey
8	Name:	X25519 (Montgomery)
	Identifiers:	id-X25519
	OID:	1.3.101.110
	Parameters:	Absent
	DER:	30 05 06 03 2B 65 6E
	Comments:	
9	Name:	X448 (Montgomery)
	Identifiers:	id-X448
	OID:	1.3.101.111
	Parameters:	Absent
	DER:	30 05 06 03 2B 65 6F
	Comments:	
12	Name:	Ed25519 (Twisted Edwards)
	Identifiers:	id-Ed25519, id-EdDSA25519
	OID:	1.3.101.112
	Parameters:	Absent
	DER:	30 05 06 03 2B 65 70
	Comments:	
13	Name:	Ed448 (Edwards)
	Identifiers:	id-Ed448, id-EdDSA448
	OID:	1.3.101.113

	Parameters: Absent
	DER: 30 05 06 03 2B 65 71
	Comments:
24	Name: EC Public Key (Weierstrass) with brainpoolP256r1 Identifiers: ecPublicKey, id-ecPublicKey OID: 1.2.840.10045.2.1 Parameters: namedCurve = brainpoolP256r1 (1.3.36.3.3.2.8.1.1.7) DER: 30 14 06 07 2A 86 48 CE 3D 02 01 06 09 2B 24 03 03 02 08 01 01 07 Comments: Compressed subjectPublicKey
25	Name: EC Public Key (Weierstrass) with brainpoolP384r1 Identifiers: ecPublicKey, id-ecPublicKey OID: 1.2.840.10045.2.1 Parameters: namedCurve = brainpoolP384r1 (1.3.36.3.3.2.8.1.1.11) DER: 30 14 06 07 2A 86 48 CE 3D 02 01 06 09 2B 24 03 03 02 08 01 01 0B Comments: Compressed subjectPublicKey
26	Name: EC Public Key (Weierstrass) with brainpoolP512r1 Identifiers: ecPublicKey, id-ecPublicKey OID: 1.2.840.10045.2.1 Parameters: namedCurve = brainpoolP512r1 (1.3.36.3.3.2.8.1.1.13) DER: 30 14 06 07 2A 86 48 CE 3D 02 01 06 09 2B 24 03 03 02 08 01 01 0D Comments: Compressed subjectPublicKey
27	Name: EC Public Key (Weierstrass) with FRP256v1 Identifiers: ecPublicKey, id-ecPublicKey OID: 1.2.840.10045.2.1 Parameters: namedCurve = FRP256v1 (1.2.250.1.223.101.256.1) DER: 30 15 06 07 2A 86 48 CE 3D 02 01 06 0A 2A 81 7A 01 81 5F 65 82 00 01 Comments: Compressed subjectPublicKey

Figure 19: C509 Public Key Algorithms

8.15.1. Suitability of different public key algorithms for use within IoT scenarios

The public key algorithms registry Section 8.15 specifies a number of algorithms, not all which are suitable for usage with constrained devices. RSA requires large keys and large signature sizes compared to elliptic curve cryptography (ECC), which together with resource-efficient implementations of named elliptic curves (Montgomery, Edwards and Weierstrass curves) make them suitable candidates for IoT public key usage.

8.16. COSE Header Parameters Registry

IANA is requested to assign the entries in Table 1 to the "COSE Header Parameters" registry in the registry group "CBOR Object Signing and Encryption (COSE)" with this document as reference.

8.17. COSE Header Algorithm Parameters Registry

IANA is requested to assign the entries in Table 2 to the "COSE Header Algorithm Parameters" registry in the registry group "CBOR Object Signing and Encryption (COSE)" with this document as reference.

8.18. Media Type Application Registry

IANA is requested to assign the following entries in to the "application" registry in the registry group "Media Types" with this document as reference.

8.18.1. Media Type application/cose-c509-cert

When the application/cose-c509-cert media type is used, the data is a COSE_C509 structure. If the parameter "usage" is set to "chain", this sequence indicates a certificate chain.

Type name: application

Subtype name: cose-c509-cert

Required parameters: N/A

Optional parameters: usage

* Can be absent to provide no further information about the intended meaning of the order in the CBOR sequence of certificates.

- * Can be set to "chain" to indicate that the sequence of data items is to be interpreted as a certificate chain.

Encoding considerations: binary

Security considerations: See the Security Considerations section of [[this document]].

Interoperability considerations: N/A

Published specification: [[this document]]

Applications that use this media type: Applications that employ COSE and use C509 as a certificate type.

Fragment identifier considerations: N/A

Additional information:

- * Deprecated alias names for this type: N/A
- * Magic number(s): TBD8, TBD6
- * File extension(s): .c509
- * Macintosh file type code(s): N/A

Person & email address to contact for further information:
iesg@ietf.org

Intended usage: COMMON

Restrictions on usage: N/A

Author: COSE WG

Change controller: IETF

8.18.2. Media Type application/cose-c509-pkcs10

When the application/cose-c509-pkcs10 media type is used, the data is a C509CertificationRequest structure.

Type name: application

Subtype name: cose-c509-pkcs10

Required parameters: N/A

Optional parameters: N/A

Encoding considerations: binary

Security considerations: See the Security Considerations section of [[this document]].

Interoperability considerations: N/A

Published specification: [[this document]]

Applications that use this media type: Applications that employ COSE and C509 Certification Request.

Fragment identifier considerations: N/A

Additional information:

- * Deprecated alias names for this type: N/A

- * Magic number(s): TBD9

- * File extension(s): .c509

- * Macintosh file type code(s): N/A

Person & email address to contact for further information:
iesg@ietf.org

Intended usage: COMMON

Restrictions on usage: N/A

Author: COSE WG

Change controller: IETF

8.18.3. Media Type application/cose-c509-crtemplate

When the application/cose-c509-crtemplate media type is used, the data is a C509CertificationRequestTemplate structure.

Type name: application

Subtype name: cose-c509-crtemplate

Required parameters: N/A

Optional parameters: N/A

Encoding considerations: binary

Security considerations: See the Security Considerations section of [[this document]].

Interoperability considerations: N/A

Published specification: [[this document]]

Applications that use this media type: Applications that employ COSE and C509 Certification Request.

Fragment identifier considerations: N/A

Additional information:

- * Deprecated alias names for this type: N/A

- * Magic number(s): TBD18

- * File extension(s): .c509

- * Macintosh file type code(s): N/A

Person & email address to contact for further information:
iesg@ietf.org

Intended usage: COMMON

Restrictions on usage: N/A

Author: COSE WG

Change controller: IETF

8.18.4. Media Type application/cose-c509-privkey

When the application/cose-c509-privkey media type is used, the data is a C509PrivateKey structure.

Type name: application

Subtype name: cose-c509-privkey

Required parameters: N/A

Optional parameters: usage

Encoding considerations: binary

Security considerations: See the Security Considerations section of [[this document]].

Interoperability considerations: N/A

Published specification: [[this document]]

Applications that use this media type: Applications that employ COSE and use C509 as a certificate type.

Fragment identifier considerations: N/A

Additional information:

- * Deprecated alias names for this type: N/A

- * Magic number(s): TBD12

- * File extension(s): .c509

- * Macintosh file type code(s): N/A

Person & email address to contact for further information:
iesg@ietf.org

Intended usage: COMMON

Restrictions on usage: N/A

Author: COSE WG

Change controller: IETF

8.18.5. Media Type application/cose-c509-pem

When the application/cose-c509-pem media type is used, the data is a C509PEM structure.

Type name: application

Subtype name: cose-c509-pem

Required parameters: N/A

Optional parameters: usage

Encoding considerations: binary

Security considerations: See the Security Considerations section of [[this document]].

Interoperability considerations: N/A

Published specification: [[this document]]

Applications that use this media type: Applications that employ COSE and use C509 as a certificate type.

Fragment identifier considerations: N/A

Additional information:

- * Deprecated alias names for this type: N/A

- * Magic number(s): TBD13

- * File extension(s): .c509

- * Macintosh file type code(s): N/A

Person & email address to contact for further information:
iesg@ietf.org

Intended usage: COMMON

Restrictions on usage: N/A

Author: COSE WG

Change controller: IETF

8.18.6. Media Type application/cose-certhash

When the application/cose-certhash media type is used, the data is a COSE_CertHash structure, see [RFC9360].

Type name: application

Subtype name: cose-certhash

Required parameters: N/A

Optional parameters: usage

- * Can be absent to provide no further information about what the hash value is calculated over.
- * Can be set to "c509" to indicate that the hash value is calculated over a C509 certificate, see Section 3.4.

Encoding considerations: binary

Security considerations: See the Security Considerations section of [RFC9360].

Interoperability considerations: N/A

Published specification: [[this document]]

Applications that use this media type: Applications that employ COSE and use X.509 or C509 as certificate type.

Fragment identifier considerations: N/A

Additional information:

- * Deprecated alias names for this type: N/A
- * 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:
iesg@ietf.org

Intended usage: COMMON

Restrictions on usage: N/A

Author: COSE WG

Change controller: IETF

8.19. CoAP Content-Formats Registry

IANA is requested to add entries for "application/cose-c509-cert", "application/cose-c509-pkcs10", "application/cose-c509-crtemplate", "application/cose-c509-privkey" and "application/cose-c509-pem" to the "CoAP Content-Formats" registry in the registry group "Constrained RESTful Environments (CoRE) Parameters". A dedicated Content-Format ID is requested for the "application/cose-c509-cert" media type in the case when the parameter "usage" is set to "chain", see Section 8.18.1.

IANA is requested to add entries for "application/cose-certhash" to the "CoAP Content-Formats" registry in the registry group "Constrained RESTful Environments (CoRE) Parameters". A dedicated Content-Format ID is requested in the case when the parameter "usage" is set to "c509", see Section 8.18.6.

IANA is requested to add entries for "application/cbor" to the "CoAP Content-Formats" registry in the registry group "Constrained RESTful Environments (CoRE) Parameters", in the case when the encoding is a CBOR text string containing a URI, see [RFC3986].

Content Format	Content Coding	Media Type	ID	Reference
application/cose-c509-cert	-	[[link to 8.18]]	TBD3	[[this document]]
application/cose-c509-cert; usage = chain	-	[[link to 8.18]]	TBD15	[[this document]]
application/cose-c509-pkcs10	-	[[link to 8.18]]	TBD4	[[this document]]
application/cose-c509-crtemplate	-	[[link to 8.18]]	TBD19	[[this document]]
application/cose-c509-privkey	-	[[link to 8.18]]	TBD10	[[this document]]
application/cose-c509-pem	-	[[link to 8.18]]	TBD11	[[this document]]
application/cose-certhash	-	[[link to 8.18]]	TBD16	[[this document]]
application/cose-certhash; usage = c509	-	[[link to 8.18]]	TBD17	[[this document]]

Figure 20: CoAP Content-Format IDs

8.20. TLS Certificate Types Registry

This document registers the following entry in the "TLS Certificate Types" registry in the registry group "Transport Layer Security (TLS) Extensions". The new certificate type can be used with additional TLS certificate compression [RFC8879]. For TLS 1.3, the C509 certificate type is defined as a new case in the CertificateEntry struct specified in Section 4.4.2 of [RFC8446]:

```
case C509:
  opaque c509_data<1..2^24-1>;
```

where c509_data is the CBOR sequence ~C509Certificate (an unwrapped C509Certificate). For TLS 1.2 the same construction is applied with a similar union type defined for the Certificate struct in

Section 7.4.2 of [RFC5246]. Note that, similar to COSE_C509, the TLS handshake contains the length of each certificate. The TLS extensions `client_certificate_type` and `server_certificate_type` [RFC7250] are used to negotiate the use of C509.

Value	Name	Recommended	Comment
TBD5	C509 Certificate	N	

8.21. TLSA Selectors Registry

This document registers the following entry in the "TLSA Selectors" registry in the registry group "DNS-Based Authentication of Named Entities (DANE) Parameters". The C509 certificate data, `C509CertData`, is defined in Section 3.4.

Value	Acronym	Short Description	Reference
TBD7	C509	C509 certificate data	[[this document]]

The TLSA selectors registry defined in [RFC6698] originally only applied to PKIX [RFC5280] certificates in DER encoding. This specification updates [RFC6698] to accept the use of C509 certificates.

8.22. EDHOC Authentication Credential Types Registry

This document registers the following entry in the "EDHOC Authentication Credential Types" registry in the registry group "Ephemeral Diffie-Hellman Over COSE (EDHOC)". This is useful to identify C509 certificates as a supported authentication credential type to use with EDHOC [RFC9528], for example, during discovery of EDHOC resources, see [RFC9668].

Value	Description	Reference
3	C509 certificate	[[this document]]

8.23. Relative Distinguished Name Attribute

This document registers the following entry in the "SMI Security for PKIX Relative Distinguished Name Attribute" registry [RFC7299]:

Decimal	Description	Reference
TBD30	id-rdna-c509Name	[[this document]]

9. References

9.1. Normative References

- [I-D.ietf-lamps-macaddress-on]
Housley, R., Bonnell, C., Mandel, J., Okubo, T., and M. StJohns, "Media Access Control (MAC) Addresses in X.509 Certificates", Work in Progress, Internet-Draft, draft-ietf-lamps-macaddress-on-07, 12 March 2026, <<https://datatracker.ietf.org/doc/html/draft-ietf-lamps-macaddress-on-07>>.
- [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>>.
- [RFC2985] Nystrom, M. and B. Kaliski, "PKCS #9: Selected Object Classes and Attribute Types Version 2.0", RFC 2985, DOI 10.17487/RFC2985, November 2000, <<https://www.rfc-editor.org/rfc/rfc2985>>.
- [RFC2986] Nystrom, M. and B. Kaliski, "PKCS #10: Certification Request Syntax Specification Version 1.7", RFC 2986, DOI 10.17487/RFC2986, November 2000, <<https://www.rfc-editor.org/rfc/rfc2986>>.
- [RFC3779] Lynn, C., Kent, S., and K. Seo, "X.509 Extensions for IP Addresses and AS Identifiers", RFC 3779, DOI 10.17487/RFC3779, June 2004, <<https://www.rfc-editor.org/rfc/rfc3779>>.
- [RFC3986] Berners-Lee, T., Fielding, R., and L. Masinter, "Uniform Resource Identifier (URI): Generic Syntax", STD 66, RFC 3986, DOI 10.17487/RFC3986, January 2005, <<https://www.rfc-editor.org/rfc/rfc3986>>.
- [RFC4108] Housley, R., "Using Cryptographic Message Syntax (CMS) to Protect Firmware Packages", RFC 4108, DOI 10.17487/RFC4108, August 2005, <<https://www.rfc-editor.org/rfc/rfc4108>>.

- [RFC5246] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", RFC 5246, DOI 10.17487/RFC5246, August 2008, <<https://www.rfc-editor.org/rfc/rfc5246>>.
- [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>>.
- [RFC5958] Turner, S., "Asymmetric Key Packages", RFC 5958, DOI 10.17487/RFC5958, August 2010, <<https://www.rfc-editor.org/rfc/rfc5958>>.
- [RFC6066] Eastlake 3rd, D., "Transport Layer Security (TLS) Extensions: Extension Definitions", RFC 6066, DOI 10.17487/RFC6066, January 2011, <<https://www.rfc-editor.org/rfc/rfc6066>>.
- [RFC6698] Hoffman, P. and J. Schlyter, "The DNS-Based Authentication of Named Entities (DANE) Transport Layer Security (TLS) Protocol: TLSA", RFC 6698, DOI 10.17487/RFC6698, August 2012, <<https://www.rfc-editor.org/rfc/rfc6698>>.
- [RFC6962] Laurie, B., Langley, A., and E. Kasper, "Certificate Transparency", RFC 6962, DOI 10.17487/RFC6962, June 2013, <<https://www.rfc-editor.org/rfc/rfc6962>>.
- [RFC7030] Pritikin, M., Ed., Yee, P., Ed., and D. Harkins, Ed., "Enrollment over Secure Transport", RFC 7030, DOI 10.17487/RFC7030, October 2013, <<https://www.rfc-editor.org/rfc/rfc7030>>.
- [RFC7120] Cotton, M., "Early IANA Allocation of Standards Track Code Points", BCP 100, RFC 7120, DOI 10.17487/RFC7120, January 2014, <<https://www.rfc-editor.org/rfc/rfc7120>>.
- [RFC7250] Wouters, P., Ed., Tschofenig, H., Ed., Gilmore, J., Weiler, S., and T. Kivinen, "Using Raw Public Keys in Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS)", RFC 7250, DOI 10.17487/RFC7250, June 2014, <<https://www.rfc-editor.org/rfc/rfc7250>>.
- [RFC7299] Housley, R., "Object Identifier Registry for the PKIX Working Group", RFC 7299, DOI 10.17487/RFC7299, July 2014, <<https://www.rfc-editor.org/rfc/rfc7299>>.

- [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>>.
- [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>>.
- [RFC8295] Turner, S., "EST (Enrollment over Secure Transport) Extensions", RFC 8295, DOI 10.17487/RFC8295, January 2018, <<https://www.rfc-editor.org/rfc/rfc8295>>.
- [RFC8360] Huston, G., Michaelson, G., Martinez, C., Bruijnzeels, T., Newton, A., and D. Shaw, "Resource Public Key Infrastructure (RPKI) Validation Reconsidered", RFC 8360, DOI 10.17487/RFC8360, April 2018, <<https://www.rfc-editor.org/rfc/rfc8360>>.
- [RFC8398] Melnikov, A., Ed. and W. Chuang, Ed., "Internationalized Email Addresses in X.509 Certificates", RFC 8398, DOI 10.17487/RFC8398, May 2018, <<https://www.rfc-editor.org/rfc/rfc8398>>.
- [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>>.
- [RFC8742] Bormann, C., "Concise Binary Object Representation (CBOR) Sequences", RFC 8742, DOI 10.17487/RFC8742, February 2020, <<https://www.rfc-editor.org/rfc/rfc8742>>.
- [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>>.
- [RFC9090] Bormann, C., "Concise Binary Object Representation (CBOR) Tags for Object Identifiers", RFC 9090, DOI 10.17487/RFC9090, July 2021, <<https://www.rfc-editor.org/rfc/rfc9090>>.

- [RFC9277] Richardson, M. and C. Bormann, "On Stable Storage for Items in Concise Binary Object Representation (CBOR)", RFC 9277, DOI 10.17487/RFC9277, August 2022, <<https://www.rfc-editor.org/rfc/rfc9277>>.
- [RFC9360] Schaad, J., "CBOR Object Signing and Encryption (COSE): Header Parameters for Carrying and Referencing X.509 Certificates", RFC 9360, DOI 10.17487/RFC9360, February 2023, <<https://www.rfc-editor.org/rfc/rfc9360>>.
- [RFC9542] Eastlake 3rd, D., Abley, J., and Y. Li, "IANA Considerations and IETF Protocol and Documentation Usage for IEEE 802 Parameters", BCP 141, RFC 9542, DOI 10.17487/RFC9542, April 2024, <<https://www.rfc-editor.org/rfc/rfc9542>>.
- [RFC9549] Housley, R., "Internationalization Updates to RFC 5280", RFC 9549, DOI 10.17487/RFC9549, March 2024, <<https://www.rfc-editor.org/rfc/rfc9549>>.
- [RFC9668] Palombini, F., Tiloca, M., Hglund, R., Hristozov, S., and G. Selander, "Using Ephemeral Diffie-Hellman Over COSE (EDHOC) with the Constrained Application Protocol (CoAP) and Object Security for Constrained RESTful Environments (OSCORE)", RFC 9668, DOI 10.17487/RFC9668, November 2024, <<https://www.rfc-editor.org/rfc/rfc9668>>.
- [RFC9883] Housley, R., "An Attribute for Statement of Possession of a Private Key", RFC 9883, DOI 10.17487/RFC9883, October 2025, <<https://www.rfc-editor.org/rfc/rfc9883>>.
- [SECG] "Elliptic Curve Cryptography, Standards for Efficient Cryptography Group, ver. 2", 2009, <<https://secg.org/sec1-v2.pdf>>.
- [Wi-SUN] "Wi-SUN Alliance", n.d., <<https://wi-sun.org>>.
- [X.501] "Information Technology - Open Systems Interconnection - The Directory: Models, ITU-T X.501", December 2019, <<https://www.itu.int/rec/T-REC-X.501/en>>.
- [X.520] "Information Technology - Open Systems Interconnection - The Directory: Selected attribute types", October 2019, <<https://www.itu.int/rec/T-REC-X.520/en>>.

- [X.690] "ASN.1 encoding rules. Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)", n.d., <<https://www.itu.int/rec/T-REC-X.690>>.

9.2. Informative References

- [CAB-Code] CA/Browser Forum, "CA/Browser Forum, "Baseline Requirements for the Issuance and Management of Publicly-Trusted Code Signing Certificates Version 3.8.0"", August 2024, <<https://cabforum.org/baseline-requirements-code-signing/>>.
- [CAB-TLS] CA/Browser Forum, "CA/Browser Forum, "Baseline Requirements for the Issuance and Management of Publicly-Trusted Certificates Version 2.1.4"", March 2025, <<https://cabforum.org/baseline-requirements-documents/>>.
- [CborMe] Bormann, C., "CBOR Playground", May 2018, <<https://cbor.me/>>.
- [GSMA-eUICC] GSMA, "GSMA eUICC PKI Certificate Policy Version 2.2", January 2025, <<https://www.gsma.com/solutions-and-impact/technologies/esim/wp-content/uploads/2025/01/SGP.14-v2.2.pdf>>.
- [GSMA-SGP.22] "GSMA RSP Technial Specification Version 3.1 Final", December 2023, <<https://www.gsma.com/solutions-and-impact/technologies/esim/wp-content/uploads/2023/12/SGP.22-v3.1.pdf>>.
- [I-D.ietf-lamps-rfc7030-csrattrs] Richardson, M., Friel, O., von Oheimb, D., and D. Harkins, "Clarification and enhancement of RFC7030 CSR Attributes definition", Work in Progress, Internet-Draft, draft-ietf-lamps-rfc7030-csrattrs-23, 28 June 2025, <<https://datatracker.ietf.org/doc/html/draft-ietf-lamps-rfc7030-csrattrs-23>>.
- [I-D.ietf-tls-ctls] Rescorla, E., Barnes, R., Tschofenig, H., and B. M. Schwartz, "Compact TLS 1.3", Work in Progress, Internet-Draft, draft-ietf-tls-ctls-10, 17 April 2024, <<https://datatracker.ietf.org/doc/html/draft-ietf-tls-ctls-10>>.

- [I-D.ietf-uta-tls13-iot-profile]
Tschofenig, H., Fossati, T., Richardson, M., and D. Migault, "TLS/DTLS 1.3 Profiles for the Internet of Things", Work in Progress, Internet-Draft, draft-ietf-uta-tls13-iot-profile-19, 20 February 2026, <<https://datatracker.ietf.org/doc/html/draft-ietf-uta-tls13-iot-profile-19>>.
- [IANA-AFI] "Address Family Numbers", n.d., <<https://www.iana.org/assignments/address-family-numbers/address-family-numbers.xhtml>>.
- [IANA-CBOR-TAGS]
IANA, "Concise Binary Object Representation (CBOR) Tags", n.d., <<https://www.iana.org/assignments/cbor-tags/cbor-tags.xhtml>>.
- [IANA-SAFI]
"Subsequent Address Family Identifiers (SAFI) Parameters", n.d., <<https://www.iana.org/assignments/safi-namespace/safi-namespace.xhtml>>.
- [IEEE-802.1AR]
Institute of Electrical and Electronics Engineers, "IEEE Standard for Local and metropolitan area networks Secure Device Identity", IEEE Standard 802.1AR-2018 , August 2018, <https://standards.ieee.org/standard/802_1AR-2018.html>.
- [RFC1274] Barker, P. and S. Kille, "The COSINE and Internet X.500 Schema", RFC 1274, DOI 10.17487/RFC1274, November 1991, <<https://www.rfc-editor.org/rfc/rfc1274>>.
- [RFC2247] Kille, S., Wahl, M., Grimstad, A., Huber, R., and S. Sataluri, "Using Domains in LDAP/X.500 Distinguished Names", RFC 2247, DOI 10.17487/RFC2247, January 1998, <<https://www.rfc-editor.org/rfc/rfc2247>>.
- [RFC3161] Adams, C., Cain, P., Pinkas, D., and R. Zuccherato, "Internet X.509 Public Key Infrastructure Time-Stamp Protocol (TSP)", RFC 3161, DOI 10.17487/RFC3161, August 2001, <<https://www.rfc-editor.org/rfc/rfc3161>>.
- [RFC6487] Huston, G., Michaelson, G., and R. Loomans, "A Profile for X.509 PKIX Resource Certificates", RFC 6487, DOI 10.17487/RFC6487, February 2012, <<https://www.rfc-editor.org/rfc/rfc6487>>.

- [RFC6955] Schaad, J. and H. Prafullchandra, "Diffie-Hellman Proof-of-Possession Algorithms", RFC 6955, DOI 10.17487/RFC6955, May 2013, <<https://www.rfc-editor.org/rfc/rfc6955>>.
- [RFC6960] Santesson, S., Myers, M., Ankney, R., Malpani, A., Galperin, S., and C. Adams, "X.509 Internet Public Key Infrastructure Online Certificate Status Protocol - OCSP", RFC 6960, DOI 10.17487/RFC6960, June 2013, <<https://www.rfc-editor.org/rfc/rfc6960>>.
- [RFC7228] Bormann, C., Ersue, M., and A. Keranen, "Terminology for Constrained-Node Networks", RFC 7228, DOI 10.17487/RFC7228, May 2014, <<https://www.rfc-editor.org/rfc/rfc7228>>.
- [RFC7468] Josefsson, S. and S. Leonard, "Textual Encodings of PKIX, PKCS, and CMS Structures", RFC 7468, DOI 10.17487/RFC7468, April 2015, <<https://www.rfc-editor.org/rfc/rfc7468>>.
- [RFC7925] Tschofenig, H., Ed. and T. Fossati, "Transport Layer Security (TLS) / Datagram Transport Layer Security (DTLS) Profiles for the Internet of Things", RFC 7925, DOI 10.17487/RFC7925, July 2016, <<https://www.rfc-editor.org/rfc/rfc7925>>.
- [RFC7932] Alakuijala, J. and Z. Szabadka, "Brotli Compressed Data Format", RFC 7932, DOI 10.17487/RFC7932, July 2016, <<https://www.rfc-editor.org/rfc/rfc7932>>.
- [RFC8446] Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <<https://www.rfc-editor.org/rfc/rfc8446>>.
- [RFC8603] Jenkins, M. and L. Ziegler, "Commercial National Security Algorithm (CNSA) Suite Certificate and Certificate Revocation List (CRL) Profile", RFC 8603, DOI 10.17487/RFC8603, May 2019, <<https://www.rfc-editor.org/rfc/rfc8603>>.
- [RFC8879] Ghedini, A. and V. Vasiliev, "TLS Certificate Compression", RFC 8879, DOI 10.17487/RFC8879, December 2020, <<https://www.rfc-editor.org/rfc/rfc8879>>.
- [RFC9000] Iyengar, J., Ed. and M. Thomson, Ed., "QUIC: A UDP-Based Multiplexed and Secure Transport", RFC 9000, DOI 10.17487/RFC9000, May 2021, <<https://www.rfc-editor.org/rfc/rfc9000>>.

- [RFC9147] Rescorla, E., Tschofenig, H., and N. Modadugu, "The Datagram Transport Layer Security (DTLS) Protocol Version 1.3", RFC 9147, DOI 10.17487/RFC9147, April 2022, <<https://www.rfc-editor.org/rfc/rfc9147>>.
- [RFC9148] van der Stok, P., Kampanakis, P., Richardson, M., and S. Raza, "EST-coaps: Enrollment over Secure Transport with the Secure Constrained Application Protocol", RFC 9148, DOI 10.17487/RFC9148, April 2022, <<https://www.rfc-editor.org/rfc/rfc9148>>.
- [RFC9190] Preu Mattsson, J. and M. Sethi, "EAP-TLS 1.3: Using the Extensible Authentication Protocol with TLS 1.3", RFC 9190, DOI 10.17487/RFC9190, February 2022, <<https://www.rfc-editor.org/rfc/rfc9190>>.
- [RFC9191] Sethi, M., Preu Mattsson, J., and S. Turner, "Handling Large Certificates and Long Certificate Chains in TLS-Based EAP Methods", RFC 9191, DOI 10.17487/RFC9191, February 2022, <<https://www.rfc-editor.org/rfc/rfc9191>>.
- [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>>.
- [SP-800-56A] Barker, E., Chen, L., Roginsky, A., Vassilev, A., and R. Davis, "Recommendation for Pair-Wise Key-Establishment Schemes Using Discrete Logarithm Cryptography", NIST Special Publication 800-56A Revision 3, April 2018, <<https://doi.org/10.6028/NIST.SP.800-56Ar3>>.
- [X.509-IoT] Forsby, F., Furuheid, M., Papadimitratos, P., and S. Raza, "Lightweight X.509 Digital Certificates for the Internet of Things.", Springer, Cham. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 242., July 2018, <https://doi.org/10.1007/978-3-319-93797-7_14>.

Appendix A. C509 Certificate Examples

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 2023 GMT
  Not After : Jan  1 00:00:00 2026 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
30:46:02:21:00:d4:32:0b:1d:68:49:e3:09:21:9d:30:03:7e:
13:81:66:f2:50:82:47:dd:da:e7:6c:ce:ea:55:05:3c:10:8e:
90:02:21:00:d5:51:f6:d6:01:06:f1:ab:b4:84:cf:be:62:56:
c1:78:e4:ac:33:14:ea:19:19:1e:8b:60:7d:a5:ae:3b:da:16
```

The DER encoding of the above certificate is 316 bytes.

```
30 82 01 38 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 33 30 31 30 31 30 30 30 30 30 5a 30 22 31 20 30 1e 06
5a 17 0d 32 36 30 31 30 31 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 49 00 30 46 02 21 00 d4 32 0b 1d
68 49 e3 09 21 9d 30 03 7e 13 81 66 f2 50 82 47 dd da e7 6c ce ea 55
05 3c 10 8e 90 02 21 00 d5 51 f6 d6 01 06 f1 ab b4 84 cf be 62 56 c1
78 e4 ac 33 14 ea 19 19 1e 8b 60 7d a5 ae 3b da 16
```

A.1.1.1. Example: C509 Certificate Encoding

This section shows the C509 encoding of the X.509 certificate in the previous section. The point compressed public key is represented as described in Section 3.2.1.

Figure 21 shows the diagnostic notation of the unwrapped CBOR sequence, ~C509Certificate, see Section 3.1.

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

3,                / version and certificate type /
h'01f50d',        / serialNumber /
0,                / signatureAlgorithm /
"RFC test CA",    / issuer /
1672531200,       / notBefore /
1767225600,       / notAfter /
48(h'0123456789AB'), / subject, EUI-64 /
1,                / subjectPublicKeyAlgorithm /
h'FEB1216AB96E5B3B3340F5BDF02E693F16213A04525ED44450
  B1019C2DFD3838AB',
1,                / single extension:
                    non-critical keyUsage
                    digitalSignature /
h'D4320B1D6849E309219D30037E138166F2508247DDDAE76CCE
  EA55053C108E90D551F6D60106F1ABB484CFBE6256C178E4AC
  3314EA19191E8B607DA5AE3BDA16'
```

Figure 21: CBOR diagnostic notation of ~C509Certificate

Figure 22 shows the plain hex format of the unwrapped CBOR sequence, the size is 140 bytes.

```
03
43 01 F5 0D
00
6B 52 46 43 20 74 65 73 74 20 43 41
1A 63 B0 CD 00
1A 69 55 B9 00
D8 30 46 01 23 45 67 89 AB
01
58 21 FE 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
58 40 D4 32 0B 1D 68 49 E3 09 21 9D 30 03 7E 13 81 66 F2 50 82 47 DD
DA E7 6C CE EA 55 05 3C 10 8E 90 D5 51 F6 D6 01 06 F1 AB B4 84 CF BE
62 56 C1 78 E4 AC 33 14 EA 19 19 1E 8B 60 7D A5 AE 3B DA 16
```

Figure 22: CBOR plain hex format of ~C509Certificate.

A.1.2. Example: Natively Signed C509 Certificate

This section shows the natively signed C509 certificate corresponding to that of the previous section, which is identical except for `c509CertificateType`, encoding of point compression (see Section 3.2.1), and `signatureValue`.

Figure 23 shows the diagnostic notation of the natively signed unwrapped CBOR sequence, `~C509Certificate`.

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

```
2,
h'01f50d',
0,
"RFC test CA",
1672531200,
1767225600,
48(h'0123456789AB'),
1,
h'02B1216AB96E5B3B3340F5BDF02E693F16213A04525ED44450
  B1019C2DFD3838AB',
1,
h'EB0D472731F689BC00F5880B12C68B3F9FD38B23FADFCA2095
  0F3F241B60A202579CAC28CD3B7494D5FA5D8BBAB4600357E5
  50AB9FA9A65D9BA2B3B82E668CC6'
```

Figure 23: CBOR diagnostic notation of ~C509Certificate

Figure 24 shows the plain hex format of the natively signed unwrapped CBOR sequence, the size is 140 bytes.

```
02
43 01 F5 0D
00
6B 52 46 43 20 74 65 73 74 20 43 41
1A 63 B0 CD 00
1A 69 55 B9 00
D8 30 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
58 40 EB 0D 47 27 31 F6 89 BC 00 F5 88 0B 12 C6 8B 3F 9F D3 8B 23 FA
DF CA 20 95 0F 3F 24 1B 60 A2 02 57 9C AC 28 CD 3B 74 94 D5 FA 5D 8B
BA B4 60 03 57 E5 50 AB 9F A9 A6 5D 9B A2 B3 B8 2E 66 8C C6
```

Figure 24: CBOR plain hex format of ~C509Certificate.

A.1.3. C509 for Diffie-Hellman keys

The two previous examples illustrate keyUsage digitalSignature. A C509 certificate for a public Diffie-Hellman key would instead have key usage keyAgreement encoded according to Section 3.3 (in this case of single extension encoded as integer 16 instead of 1 for digital signature) but otherwise identical in format. Note that Section 5.6.3.2 of [SP-800-56A] allows a key agreement key pair to be used to sign a certification request.

A.1.4. Example: Additional 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 [RFC9052]. 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.1.5. Examples: C509Certificate and C509CertData

This section exemplifies other CBOR objects defined in this specification, based on the natively signed C509 certificate in Appendix A.1.2.

Figure 25 shows the encoding of the corresponding C509Certificate, i.e., the CBOR array wrapping of the CBOR sequence ~C509Certificate, see Section 3.1.

```

8B
02
43 01 F5 0D
00
6B 52 46 43 20 74 65 73 74 20 43 41
1A 63 B0 CD 00
1A 69 55 B9 00
D8 30 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
58 40 EB 0D 47 27 31 F6 89 BC 00 F5 88 0B 12 C6 8B 3F 9F D3 8B 23 FA
DF CA 20 95 0F 3F 24 1B 60 A2 02 57 9C AC 28 CD 3B 74 94 D5 FA 5D 8B
BA B4 60 03 57 E5 50 AB 9F A9 A6 5D 9B A2 B3 B8 2E 66 8C C6

```

Figure 25: C509Certificate: The CBOR array wrapping of
~C509Certificate

Note that C509Certificate is identical to ~C509Certificate in Appendix A.1.2 except for the prefix 8B (which indicates that it is a CBOR array with 11 elements).

Figure 26 shows the encoding of the corresponding C509CertData, i.e., the CBOR byte string wrapping of the CBOR sequence ~C509Certificate, see Section 3.4.

```

58 8C
02
43 01 F5 0D
00
6B 52 46 43 20 74 65 73 74 20 43 41
1A 63 B0 CD 00
1A 69 55 B9 00
D8 30 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
58 40 EB 0D 47 27 31 F6 89 BC 00 F5 88 0B 12 C6 8B 3F 9F D3 8B 23 FA
DF CA 20 95 0F 3F 24 1B 60 A2 02 57 9C AC 28 CD 3B 74 94 D5 FA 5D 8B
BA B4 60 03 57 E5 50 AB 9F A9 A6 5D 9B A2 B3 B8 2E 66 8C C6

```

Figure 26: C509CertData: CBOR byte string wrapping of
~C509Certificate.

Note that C509CertData is identical to ~C509Certificate in Appendix A.1.2 except for the prefix 58 8C (which indicates that it is a CBOR byte string of 140 bytes).

A.2. Example: IEEE 802.1AR profiled X.509 Certificate

An example of an IEEE 802.1AR profiled X.509 certificate (Secure Device Identifier, DevID) is provided in Appendix C.2 of [RFC9148]. The certificate is shown below including details of the hardwareModuleName type of otherName in subjectAltName, see Section 3.3.

Certificate:

Data:

Version: 3 (0x2)
Serial Number: 9112578475118446130 (0x7e7661d7b54e4632)
Signature Algorithm: ecdsa-with-SHA256
Issuer: C=US, ST=CA, O=Example Inc, OU=certification,
CN=802.1AR CA

Validity

Not Before: Jan 31 11:29:16 2019 GMT
Not After : Dec 31 23:59:59 9999 GMT
Subject: C=US, ST=CA, L=LA, O=example Inc,
OU=IoT/serialNumber=Wt1234

Subject Public Key Info:

Public Key Algorithm: id-ecPublicKey
Public-Key: (256 bit)

pub:

04:c8:b4:21:f1:1c:25:e4:7e:3a:c5:71:23:bf:2d:
9f:dc:49:4f:02:8b:c3:51:cc:80:c0:3f:15:0b:f5:
0c:ff:95:8d:75:41:9d:81:a6:a2:45:df:fa:e7:90:
be:95:cf:75:f6:02:f9:15:26:18:f8:16:a2:b2:3b:
56:38:e5:9f:d9

ASN1 OID: prime256v1

NIST CURVE: P-256

X509v3 extensions:

X509v3 Basic Constraints:

CA:FALSE

X509v3 Subject Key Identifier:

96:60:0D:87:16:BF:7F:D0:E7:52:D0:AC:76:07:77:AD:66:5D:02:A0

X509v3 Authority Key Identifier:

68:D1:65:51:F9:51:BF:C8:2A:43:1D:0D:9F:08:BC:2D:20:5B:11:60

X509v3 Key Usage: critical

Digital Signature, Key Encipherment

X509v3 Subject Alternative Name:

otherName:

type-id: 1.3.6.1.5.5.7.8.4 (id-on-hardwareModuleName)

value:

hwType: 1.3.6.1.4.1.6715.10.1

hwSerialNum: 01:02:03:04

Signature Algorithm: ecdsa-with-SHA256

Signature Value:

30:46:02:21:00:c0:d8:19:96:d2:50:7d:69:3f:3c:48:ea:a5:
ee:94:91:bd:a6:db:21:40:99:d9:81:17:c6:3b:36:13:74:cd:
86:02:21:00:a7:74:98:9f:4c:32:1a:5c:f2:5d:83:2a:4d:33:
6a:08:ad:67:df:20:f1:50:64:21:18:8a:0a:de:6d:34:92:36

The DER encoding of the certificate is 577 bytes:

```

30 82 02 3D 30 82 01 E2 A0 03 02 01 02 02 08 7E 76 61 D7 B5 4E 46 32
30 0A 06 08 2A 86 48 CE 3D 04 03 02 30 5D 31 0B 30 09 06 03 55 04 06
13 02 55 53 31 0B 30 09 06 03 55 04 08 0C 02 43 41 31 14 30 12 06 03
55 04 0A 0C 0B 45 78 61 6D 70 6C 65 20 49 6E 63 31 16 30 14 06 03 55
04 0B 0C 0D 63 65 72 74 69 66 69 63 61 74 69 6F 6E 31 13 30 11 06 03
55 04 03 0C 0A 38 30 32 2E 31 41 52 20 43 41 30 20 17 0D 31 39 30 31
33 31 31 31 32 39 31 36 5A 18 0F 39 39 39 39 31 32 33 31 32 33 35 39
35 39 5A 30 5C 31 0B 30 09 06 03 55 04 06 13 02 55 53 31 0B 30 09 06
03 55 04 08 0C 02 43 41 31 0B 30 09 06 03 55 04 07 0C 02 4C 41 31 14
30 12 06 03 55 04 0A 0C 0B 65 78 61 6D 70 6C 65 20 49 6E 63 31 0C 30
0A 06 03 55 04 0B 0C 03 49 6F 54 31 0F 30 0D 06 03 55 04 05 13 06 57
74 31 32 33 34 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 C8 B4 21 F1 1C 25 E4 7E 3A C5 71 23 BF 2D
9F DC 49 4F 02 8B C3 51 CC 80 C0 3F 15 0B F5 0C FF 95 8D 75 41 9D 81
A6 A2 45 DF FA E7 90 BE 95 CF 75 F6 02 F9 15 26 18 F8 16 A2 B2 3B 56
38 E5 9F D9 A3 81 8A 30 81 87 30 09 06 03 55 1D 13 04 02 30 00 30 1D
06 03 55 1D 0E 04 16 04 14 96 60 0D 87 16 BF 7F D0 E7 52 D0 AC 76 07
77 AD 66 5D 02 A0 30 1F 06 03 55 1D 23 04 18 30 16 80 14 68 D1 65 51
F9 51 BF C8 2A 43 1D 0D 9F 08 BC 2D 20 5B 11 60 30 0E 06 03 55 1D 0F
01 01 FF 04 04 03 02 05 A0 30 2A 06 03 55 1D 11 04 23 30 21 A0 1F 06
08 2B 06 01 05 05 07 08 04 A0 13 30 11 06 09 2B 06 01 04 01 B4 3B 0A
01 04 04 01 02 03 04 30 0A 06 08 2A 86 48 CE 3D 04 03 02 03 49 00 30
46 02 21 00 C0 D8 19 96 D2 50 7D 69 3F 3C 48 EA A5 EE 94 91 BD A6 DB
21 40 99 D9 81 17 C6 3B 36 13 74 CD 86 02 21 00 A7 74 98 9F 4C 32 1A
5C F2 5D 83 2A 4D 33 6A 08 AD 67 DF 20 F1 50 64 21 18 8A 0A DE 6D 34
92 36

```

A.2.1. Example: C509 Certificate Encoding

The CBOR encoding (~C509Certificate) of the same X.509 certificate is shown below in CBOR diagnostic format.

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

3,
h'7E7661D7B54E4632',
0,
[
  -4, "US",
  6, "CA",
  8, "Example Inc",
  9, "certification",
  1, "802.1AR CA"
],
1548934156,
null,
[
  -4, "US",
  6, "CA",
  5, "LA",
  8, "example Inc",
  9, "IoT",
  -3, "Wt1234"
],
1,
h'FDC8B421F11C25E47E3AC57123BF2D9FDC494F028BC351CC80C03F150BF50CFF
95',
[
  4, -2,
  1, h'96600D8716BF7FD0E752D0AC760777AD665D02A0',
  7, h'68D16551F951BFC82A431D0D9F08BC2D205B1160',
  -2, 5,
  3, [-1, [h'2B06010401B43B0A01', h'01020304']]
    / subjectAltName with hardwareModuleName /
],
h'C0D81996D2507D693F3C48EAA5EE9491BDA6DB214099D98117C63B361374CD86
A774989F4C321A5CF25D832A4D336A08AD67DF20F1506421188A0ADE6D349236'
```

The size of the CBOR encoding (CBOR sequence) is 275 bytes:

```
03 48 7E 76 61 D7 B5 4E 46 32 00 8A 23 62 55 53 06 62 43 41 08 6B 45
78 61 6D 70 6C 65 20 49 6E 63 09 6D 63 65 72 74 69 66 69 63 61 74 69
6F 6E 01 6A 38 30 32 2E 31 41 52 20 43 41 1A 5C 52 DC 0C F6 8C 23 62
55 53 06 62 43 41 05 62 4C 41 08 6B 65 78 61 6D 70 6C 65 20 49 6E 63
09 63 49 6F 54 22 66 57 74 31 32 33 34 01 58 21 FD C8 B4 21 F1 1C 25
E4 7E 3A C5 71 23 BF 2D 9F DC 49 4F 02 8B C3 51 CC 80 C0 3F 15 0B F5
0C FF 95 8A 04 21 01 54 96 60 0D 87 16 BF 7F D0 E7 52 D0 AC 76 07 77
AD 66 5D 02 A0 07 54 68 D1 65 51 F9 51 BF C8 2A 43 1D 0D 9F 08 BC 2D
20 5B 11 60 21 05 03 82 20 82 49 2B 06 01 04 01 B4 3B 0A 01 44 01 02
03 04 58 40 C0 D8 19 96 D2 50 7D 69 3F 3C 48 EA A5 EE 94 91 BD A6 DB
21 40 99 D9 81 17 C6 3B 36 13 74 CD 86 A7 74 98 9F 4C 32 1A 5C F2 5D
83 2A 4D 33 6A 08 AD 67 DF 20 F1 50 64 21 18 8A 0A DE 6D 34 92 36
```

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 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 (~C509Certificate) of the first X.509 certificate is shown below in CBOR diagnostic format.

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

```

3,
h'047FA1E31928EE403BA0B83A395673FC',
0,
[
  -4, "US",
  -8, "Cloudflare, Inc.",
  -1, "Cloudflare Inc ECC CA-3"
],
1595980800,
1627560000,
[
  -4, "US",
  -6, "CA",
  -5, "San Francisco",
  -8, "Cloudflare, Inc.",
  -1, "sni.cloudflaressl.com"
]

```

```

],
1,
h'FD963ECDD84DCD1B93A1CF432D1A7217D6C63BDE3355A02F8CFB5AD8994CD44E
 20',
[
 7, h'A5CE37EAE8B0750E946788B445FAD9241087961F',
 1, h'CC0B50E7D837DBF243F3853D4860F53B39BE9B2A',
 3, [2, "sni.cloudflaressl.com", 2, "www.ietf.org"],
-2, 1,
 8, [1, 2],
 5, [
    ["http://crl3.digicert.com/CloudflareIncECCCA-3.crl",
     null, null],
    ["http://crl4.digicert.com/CloudflareIncECCCA-3.crl",
     null, null]
  ],
 6, [h'6086480186FD6C0101', [1, "https://www.digicert.com/CPS"],
     2, []],
 9, [1, "http://ocsp.digicert.com",
     2, "http://cacerts.digicert.com/CloudflareIncECCCA-3.crt"],
-4, -2,
h'2B06010401D679020402',
h'0481F300F1007600F65C942FD1773022145418083094568EE34D131933BFDF0C
 2F200BCC4EF164E3000001739C835F8E0000040300473045022100F8D1B4A93D
 2F0D4C4176DFB488BCC73B86443D7DE00E6AC8174D8948A8843668022029FF5A
 34068A240C69502788E8EE25AB7ED2CBCF686ECE7B5F96B431A90702FA007700
 5CDC4392FEE6AB4544B15E9AD456E61037FBD5FA47DCA17394B25EE6F6C70ECA
 000001739C835FBE0000040300483046022100E891C197BFB0E3D30CB6CEE60D
 94C3C75FD1175336931108D89812D4D29D81D0022100A159D16C4647D1483757
 FCD6CE4E75EC7B5EF657EFE028F8E5CC4792682DAC43'
],
h'BD63CF4F7E5CFE6C29385EA71CFBFC1E3F7B1CD07251A221F77769C0F471DFEA
 B5C06CC45854FA30B28288B1D3BB9A6661ED5031725B1A8202E0DA5B59F95402'

```

The size of the CBOR encoding (CBOR sequence) is 835 bytes.

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 (~C509Certificate) of the first X.509 certificate is shown below in CBOR diagnostic format.

```

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

3,
h'A6A55C870E39B40E',
23,
[
  -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',
[
-4, -2,
8, [ 1, 2 ],
-2, 5,
5, "http://crl.starfieldtech.com/sfig2s1-242.crl",
6, [ h'6086480186FD6E01071701',
    [1, "http://certificates.starfieldtech.com/repository/"],
    1,
    []
  ],
9, [ 1, "http://ocsp.starfieldtech.com/", 2,
    "http://certificates.starfieldtech.com/repository/sfig2.crt"],
7, h'254581685026383D3B2D2CBECD6AD9B63DB36663',
3, [ 2, "*.tools.ietf.org", 2, "tools.ietf.org" ],
1, h'AD8AB41C0751D7928907B0B784622F36557A5F4D',
h'2B06010401D679020402',
h'0481F400F2007700F65C942FD1773022145418083094568EE34D131933BFDF0C
2F200BCC4EF164E300000174E5AC711300000403004830460221008CF54852CE
5635433911CF10CDB91F52B33639223AD138A41DECA6FEDE1FE90F022100BCA2
254366C19A2691C47A00B5B653ABBD44C2F8BAAEF4D2DAF2527CE64549950077
005CDC4392FEE6AB4544B15E9AD456E61037FBD5FA47DCA17394B25EE6F6C70E
CA00000174E5AC723C0000040300483046022100A5E0906E63E91D4FDDEFFFF03
52B91E50896007564B448A3828F596DC6B28726D022100FC91EAED0216886605
4EE18A2E5346C4CC51FEB3FA10A91D2EDBF99125F86CE6'
],
h'14043FA0BED2EE3FA86E3A1F788EA04C35530F11061FFF60A16D0B83E9D92ADB
B33F9DB3D7E0594C19A8E419A50CA770727763D5FE64510AD27AD650A58A9238
ECCB2F0F5AC064584D5C06B9736368278B8934DC79C71D3AFD345F8314415849
80682980398A867269CC7937CEE397F7DCF39588ED81032900D2A2C7BAABD63A
8ECA090BD9FB39264BFF03D88E2D3F6B21CA8A7DD85FFB94BA83DE9CFC158D61
FA672DB0C7DB3D250A414A85D37F4946373CF4B175D052F3DDC766F14BFDAA00
EDBFE47EED01EC7BE4F646FC31FD72FE03D2F265AF4D7EE2819B7AFD303CF552
F40534A08A3E194158C8A8E05171840915AECA57775FA18F7D577D531CCC72D'

```

The size of the CBOR encoding (CBOR sequence) is 1295 bytes.

A.5. Example: Certificate with Extensions IPAddrBlocks and IPAddrBlocksV2

An example X.509 certificate with extensions IPAddrBlocks and IPAddrBlocksV2.

Certificate:

SHA256 Fingerprint:

c4917e6e4belfe23eea1862fb57061aecead12b30db8f536cfe0da4a899bec75

Data:

Version: v3 (2)

Serial Number:

12:34

Issuer: CN=selfsign-brainpoolp384r1,SURNAME=my surname,
T=my title, GIVENNAME=my givenName,Name=my name

Validity:

Not Before: Thu Jan 02 01:00:00 CET 2025

Not After : Fri Jan 02 01:00:00 CET 2026

Subject: CN=selfsign-brainpoolp384r1,SURNAME=my surname,
T=my title ,GIVENNAME=my givenName,Name=my name

Subject Public Key Info:

Public Key Algorithm: EC/BRAINPOOLP384R1

Pub:

04:67:09:c9:92:91:9b:49:c4:8f:d9:31:d0:5c:49:7d:38:65:
e6:08:4c:91:df:3a:4c:7e:78:1f:41:85:43:b0:23:d5:9e:8b:
f2:5d:13:3f:b1:a0:94:e9:d4:2c:8f:a6:ed:3b:46:e9:88:3a:
35:ab:d4:b0:a9:d3:0a:ae:fd:9b:7e:88:ed:38:00:56:5d:1e:
7f:06:33:13:4d:65:19:29:2d:49:bd:55:ec:30:a1:67:19:7f:
ec:0f:74:29:82:2b:95

X509v3 extensions:

X509v3 keyUsage:

digitalSignature

X509v3 sbgp-ipAddrBlock:

IPv4:

22.82.0.0/16
23.83.112.0/20
23.106.104.0 - 23.106.119.255
23.109.0.0/16
23.111.16.0 - 23.111.63.255

IPv6:

2001:5::/32
2001:600:: - 2001:7f9:ffff:ffff:ffff:ffff:ffff:ffff
2001:7fb:: - 2001:bff:ffff:ffff:ffff:ffff:ffff:ffff
2001:1400::/22

X509v3 sbgp-ipAddrBlockV2:

IPv4 unicast:

22.82.0.0/16
23.83.112.0/20
23.106.104.0 - 23.106.119.255
23.109.0.0/16
23.111.16.0 - 23.111.63.255

IPv6 unicast:

2001:5::/32
2002:2::/72

```
2002:3:: - 2002:8:0:ffff:ffff:ffff:ffff:ffff
Signature Algorithm: SHA384WITHECDSA
Signature Value:
30:64:02:30:67:09:c9:92:91:9b:49:c4:8f:d9:31:d0:5c:49:
7d:38:65:e6:08:4c:91:df:3a:4c:7e:78:1f:41:85:43:b0:23:
d5:9e:8b:f2:5d:13:3f:b1:a0:94:e9:d4:2c:8f:a6:ed:02:30:
3f:7d:d0:c9:cf:50:86:29:85:29:f0:22:b8:2b:f6:32:f4:9d:
40:9a:2f:2e:70:0e:c2:b0:bd:24:a3:bb:09:41:85:da:7c:21:
af:47:9f:10:81:9a:41:04:c1:a4:b3:76
```

The DER encoding of the certificate is 791 bytes:

```
30 82 03 13 30 82 02 9a a0 03 02 01 02 02 02 12 34 30 0a 06 08 2a 86
48 ce 3d 04 03 03 30 74 31 21 30 1f 06 03 55 04 03 0c 18 73 65 6c 66
73 69 67 6e 2d 62 72 61 69 6e 70 6f 6f 6c 70 33 38 34 72 31 31 13 30
11 06 03 55 04 04 0c 0a 6d 79 20 73 75 72 6e 61 6d 65 31 11 30 0f 06
03 55 04 0c 0c 08 6d 79 20 74 69 74 6c 65 31 15 30 13 06 03 55 04 2a
0c 0c 6d 79 20 67 69 76 65 6e 4e 61 6d 65 31 10 30 0e 06 03 55 04 29
0c 07 6d 79 20 6e 61 6d 65 30 1e 17 0d 32 35 30 31 30 32 30 30 30
30 30 5a 17 0d 32 36 30 31 30 32 30 30 30 30 30 5a 30 74 31 21 30
1f 06 03 55 04 03 0c 18 73 65 6c 66 73 69 67 6e 2d 62 72 61 69 6e 70
6f 6f 6c 70 33 38 34 72 31 31 13 30 11 06 03 55 04 04 0c 0a 6d 79 20
73 75 72 6e 61 6d 65 31 11 30 0f 06 03 55 04 0c 0c 08 6d 79 20 74 69
74 6c 65 31 15 30 13 06 03 55 04 2a 0c 0c 6d 79 20 67 69 76 65 6e 4e
61 6d 65 31 10 30 0e 06 03 55 04 29 0c 07 6d 79 20 6e 61 6d 65 30 7a
30 14 06 07 2a 86 48 ce 3d 02 01 06 09 2b 24 03 03 02 08 01 01 0b 03
62 00 04 67 09 c9 92 91 9b 49 c4 8f d9 31 d0 5c 49 7d 38 65 e6 08 4c
91 df 3a 4c 7e 78 1f 41 85 43 b0 23 d5 9e 8b f2 5d 13 3f b1 a0 94 e9
d4 2c 8f a6 ed 3b 46 e9 88 3a 35 ab d4 b0 a9 d3 0a ae fd 9b 7e 88 ed
38 00 56 5d 1e 7f 06 33 13 4d 65 19 29 2d 49 bd 55 ec 30 a1 67 19 7f
ec 0f 74 29 82 2b 95 a3 81 fa 30 81 f7 30 0b 06 03 55 1d 0f 04 04 03
02 07 80 30 75 06 08 2b 06 01 05 05 07 01 07 04 69 30 67 30 32 04 02
00 01 30 2c 03 03 00 16 52 03 04 04 17 53 70 30 0c 03 04 00 17 6a 68
03 04 00 17 6a 77 03 03 00 17 6d 30 0c 03 04 00 17 6f 10 03 04 00 17
6f 3f 30 31 04 02 00 02 30 2b 03 05 00 20 01 00 05 30 0d 03 04 00 20
01 06 03 05 00 20 01 07 f9 30 0d 03 05 00 20 01 07 fb 03 04 00 20 01
0b 03 04 02 20 01 14 30 71 06 08 2b 06 01 05 05 07 01 1c 04 65 30 63
30 33 04 03 00 01 01 30 2c 03 03 00 16 52 03 04 04 17 53 70 30 0c 03
04 00 17 6a 68 03 04 00 17 6a 77 03 03 00 17 6d 30 0c 03 04 00 17 6f
10 03 04 00 17 6f 3f 30 2c 04 03 00 02 01 30 25 03 05 00 20 01 00 05
03 0a 00 20 02 00 02 00 00 00 00 00 30 10 03 05 00 20 02 00 03 03 07
00 20 02 00 08 00 00 30 0a 06 08 2a 86 48 ce 3d 04 03 03 03 67 00 30
64 02 30 67 09 c9 92 91 9b 49 c4 8f d9 31 d0 5c 49 7d 38 65 e6 08 4c
91 df 3a 4c 7e 78 1f 41 85 43 b0 23 d5 9e 8b f2 5d 13 3f b1 a0 94 e9
d4 2c 8f a6 ed 02 30 3f 7d d0 c9 cf 50 86 29 85 29 f0 22 b8 2b f6 32
f4 9d 40 9a 2f 2e 70 0e c2 b0 bd 24 a3 bb 09 41 85 da 7c 21 af 47 9f
10 81 9a 41 04 c1 a4 b3 76
```

A.5.1. Example: C509 Certificate Encoding

The CBOR encoding (~C509Certificate) of the X.509 certificate is shown below in CBOR diagnostic format.

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

3,
h'1234',
1,
null,
1735776000,
1767312000,
[
  1, "selfsign-brainpoolp384r1", 2, "my surname", 10, "my title",
  13, "my givenName", 25, "my name"
],
25,
h'046709C992919B49C48FD931D05C497D3865E6084C91DF3A4C7E781F418543B0
23D59E8BF25D133FB1A094E9D42C8FA6ED3B46E9883A35ABD4B0A9D30AAEFD9B
7E88ED3800565D1E7F0633134D6519292D49BD55EC30A167197FEC0F7429822B
95',
[
  2, 1,
  32, [ 1, null,
    [
      71250, 85343518, [-67102984, 15], -18240266,
      [18241443, 47]
    ],
    2, null,
    [
      4831903749, [-4813029119, 4813031155], [2, -4813031152],
      33554441]
    ],
  ],
  34, [ 1, 1,
    [
      71250, 85343518, [-67102984, 15], -18240266, [18241443, 47]
    ],
    2, 1,
    [
      h'0020010005', h'00200200020000000000',
      [h'0020020003', h'00200200080000']
    ]
  ],
],
h'6709C992919B49C48FD931D05C497D3865E6084C91DF3A4C7E781F418543B023
D59E8BF25D133FB1A094E9D42C8FA6ED3F7DD0C9CF5086298529F022B82BF632
F49D409A2F2E700EC2B0BD24A3BB094185DA7C21AF479F10819A4104C1A4B376'
```

Acknowledgments

The authors want to thank Henk Birkholz, Mohamed Boucadair, Corey Bonnell, Carsten Bormann, Viktor Dukhovni, Russ Housley, Paul Hoffmann, Christopher Inacio, Olle Johansson, Benjamin Kaduk, Ted Lemon, Ilari Liusvaara, Laurence Lundblade, Francesca Palombini, Thomas Peterson, Michael Richardson, Stefan Santesson, Jim Schaad, Brian Sipos, Rene Struik, Fraser Tweedale, Gunter Van de Velde, ric Vyncke, and Paul Wouters for reviewing and commenting on intermediate versions of the draft.

Authors' Addresses

John Preu Mattsson
Ericsson AB
Email: john.mattsson@ericsson.com

Gran Selander
Ericsson AB
Email: goran.selander@ericsson.com

Shahid Raza
University of Glasgow
Email: shahid.raza@glasgow.ac.uk

Joel Hglund
RISE AB
Email: joel.hoglund@ri.se

Martin Furuhed
IN Groupe
Email: martin.furuhed@ingroupe.com

Lijun Liao
NIO
Email: lijun.liao@nio.io