            EdDSA, Ed25519, Ed448, Curve25519 and Curve448 for X.509
                        draft-ietf-curdle-pkix-00

Abstract

   This document specify algorithm identifiers and ASN.1 encoding
   formats for EdDSA digital signatures, subject public keys, and a
   "named curve" object identifier, used in the Internet X.509 Public
   Key Infrastructure. Parameters for Ed25519, Ed25519ph, Ed448,
   Ed448ph, Curve25519 and Curve448 are defined.

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1. Introduction

   In [RFC7748], the elliptic curves Curve25519 and Curve448 are
   described. They are designed with performance and security in mind.
   The curves may be used for Diffie-Hellman and Digital Signature
   operations. In [I-D.irtf-cfrg-eddsa] the elliptic curve signature
   system EdDSA is described and the recommended choice of curves
   Ed25519/Ed448 are chosen. For each curve, two modes are defined, the
   PureEdDSA mode without pre-hashing (Ed25519 and Ed448), and the
   HashEdDSA mode with pre-hashing (Ed25519ph and Ed448ph).

   This RFC defines ASN.1 object identifiers for EdDSA for use in the
   Internet X.509 PKI [RFC5280], and parameters for Ed25519, Ed25519ph,
   Ed448 and Ed448ph. This document serves a similar role as [RFC3279]
   does for RSA (and more), [RFC4055] for RSA-OAEP/PSS, and [RFC5758]
   for SHA2-based (EC)DSA. This document also specify ASN.1 "named
   curve" object identifiers for Curve25519 and Curve448, similar to
   what is done in [RFC5639]. This allows the curves to be used and
   referenced in PKIX standards and software, in particular enabling re-
   use of existing constructs already defined for ECDSA/ECDH but for the
   new curves. Similar to [RFC5639], this document does not describe
   the cryptographic algorithms to be used with the specified parameters
   nor their application in other standards.

2. Requirements Terminology

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in [RFC2119].

3. Curve25519 and Curve448 Named Curve Identifier

   Certificates conforming to [RFC5280] may convey a public key for any
   public key algorithm. The certificate indicates the algorithm
   through an algorithm identifier. This algorithm identifier is an OID
   and optionally associated parameters. Section 2.3.5 of [RFC3279]
   describe ECDSA/ECDH public keys, specifying the id-ecPublicKey OID.
   This OID has the associated EcpkParameters parameters structure,
   which contains the namedCurve CHOICE. Here we introduce two new OIDs
   for use in the namedCurve field.

```
    id-Curve25519   OBJECT IDENTIFIER ::= { 1.3.101.110 }
    id-Curve448     OBJECT IDENTIFIER ::= { 1.3.101.111 }
    id-Curve25519ph OBJECT IDENTIFIER ::= { 1.3.101.112 }
    id-Curve448ph   OBJECT IDENTIFIER ::= { 1.3.101.113 }
```

   The OID id-Curve25519 refers to Curve25519. The OID id-Curve448
   refers to Curve448. Both curves are described in [RFC7748]. The
   OIDs id-Curve25519ph and id-Curve448ph refers to Curve25519 and
   Curve448 when used with pre-hashing as Ed25519ph and Ed448ph
   described in [I-D.irtf-cfrg-eddsa].

   The public key value encoded into the ECPoint value is the raw binary
   values described in [RFC7748].

4. Subject Public Key Information Fields

   In the X.509 certificate, the subjectPublicKeyInfo field has the
   SubjectPublicKeyInfo type, which has the following ASN.1 syntax:

```
    SubjectPublicKeyInfo  ::=  SEQUENCE  {
      algorithm         AlgorithmIdentifier,
      subjectPublicKey  BIT STRING
     }
```

   The fields in SubjectPublicKeyInfo have the following meanings:

   o algorithm is the algorithm identifier and parameters for the
      public key (see below).

   o subjectPublicKey is the EdDSA public key.

The AlgorithmIdentifier type, which is included for convenience, is
defined as follows:

```
    AlgorithmIdentifier  ::=  SEQUENCE  {
      algorithm   OBJECT IDENTIFIER,
      parameters  ANY DEFINED BY algorithm OPTIONAL
    }
```

The fields in AlgorithmIdentifier have the following meanings:

o   algorithm identifies the cryptographic algorithm with an object
    identifier. This is the EdDSA OID defined below.

o   parameters, which are optional, are the associated parameters for
    the algorithm identifier in the algorithm field.

5. EdDSA Public Keys

Certificates conforming to [RFC5280] may convey a public key for any
public key algorithm. The certificate indicates the algorithm
through an algorithm identifier. This algorithm identifier is an OID
and optionally associated parameters.

This section identify the OID and parameters for the EdDSA algorithm.
Conforming CAs MUST use the identified OIDs when issuing certificates
containing EdDSA public keys. Conforming applications supporting
EdDSA MUST, at a minimum, recognize the OID identified in this
section.

The id-EdDSAPublicKey OID is used for identifying EdDSA public keys.

```
      id-EdDSAPublicKey OBJECT IDENTIFIER ::= { 1 3 101 100 }
```

The id-EdDSAPublicKey OID is intended to be used in the algorithm
field of a value of type AlgorithmIdentifier.

EdDSA public keys use the parameter field to specify the particular
instantiation of EdDSA parameters. The parameters field have the
ASN.1 type EdDSAParameters as follows.

```
    EdDSAParameters ::= ENUMERATED { ed25519   (1),
                                     ed25519ph (2) }
                                     ed448     (3) }
                                     ed448ph   (4) }
```

The EdDSAParameters enumeration may be extended in the future.

The "ed25519" and "ed448" values correspond to the PureEdDSA
variants, and the "ed25519ph" and "ed448ph" values correspond to the
HashEdDSA variants, as discussed in [I-D.irtf-cfrg-eddsa].

The raw binary EdDSA public key is encoded directly in the
subjectPublicKey BIT STRING object. Note that unlike some other
schemes, there is no additional OCTET STRING encoding step.

6. Key Usage Bits

The intended application for the key MAY be indicated in the keyUsage
certificate extension.

If the keyUsage extension is present in an end-entity certificate
that conveys an EdDSA public key with the id-EdDSAPublicKey object
identifier, then the keyUsage extension MUST contain one or both of
the following values:

        nonRepudiation; and
        digitalSignature.

If the keyUsage extension is present in a certification authority
certificate that conveys an EdDSA public key with the id-
EdDSAPublicKey object identifier, then the keyUsage extension MUST
contain one or more of the following values:

        nonRepudiation;
        digitalSignature;
        keyCertSign; and
        cRLSign.

7. EdDSA Signatures

Certificates and CRLs conforming to [RFC5280] may be signed with any
public key signature algorithm. The certificate or CRL indicates the
algorithm through an algorithm identifier which appears in the
signatureAlgorithm field within the Certificate or CertificateList.
This algorithm identifier is an OID and has optionally associated
parameters. For illustration the Certificate structure is reproduced
here:

```
   Certificate  ::=  SEQUENCE  {
        tbsCertificate       TBSCertificate,
        signatureAlgorithm   AlgorithmIdentifier,
        signatureValue       BIT STRING  }
```

Recall the definition of the AlgorithmIdentifier type:

```
      AlgorithmIdentifier  ::=  SEQUENCE  {
        algorithm   OBJECT IDENTIFIER,
        parameters  ANY DEFINED BY algorithm OPTIONAL
      }
```

This document identify an AlgorithmIdentifier OID for EdDSA
signatures. No parameters are defined. The EdDSA parameters follow
from the public-key parameters.

The data to be signed is prepared for EdDSA. Then, a private key
operation is performed to generate the signature value. This value
is the opaque value ENC(R) || ENC(S) described in section 3.3 of
[I-D.irtf-cfrg-eddsa]. This signature value is then ASN.1 encoded as
a BIT STRING and included in the Certificate or CertificateList in
the signatureValue field.

The id-EdDSASignature OID is used for identifying EdDSA signatures.

```
       id-EdDSASignature OBJECT IDENTIFIER ::= { 1 3 101 101 }
```

The id-EdDSASignature OID is intended to be used in the algorithm
field of a value of type AlgorithmIdentifier. The parameters field
MUST be absent. To further clarify how to encode the parameters
field, due to historical misunderstandings in this area, it MUST NOT
have an ASN.1 type NULL.

8. Private Key Format

In Elliptic Curve Private Key Structure [RFC5915] it is described how
to encode elliptic curve private keys. Unfortunately, that format is
specific to how traditional elliptic curve cryptography works so in
order to re-use the format some details has to be modified for EdDSA,
Curve25519 and Curve448. In particular, [RFC5915] assumes that EC
private keys are unsigned integers, but for EdDSA, Curve25519 and
Curve448 private keys are opaque binary byte sequences.

For illustration, the ASN.1 structure ECPrivateKey as defined by
[RFC5915] is repeated here.

```
   ECPrivateKey ::= SEQUENCE {
     version        INTEGER { ecPrivkeyVer1(1) } (ecPrivkeyVer1),
     privateKey     OCTET STRING,
     parameters [0] ECParameters {{ NamedCurve }} OPTIONAL,
     publicKey  [1] BIT STRING OPTIONAL
   }
```

To encode a EdDSA, Curve25519 or Curve448 private key, the
"privateKey" field will hold the raw binary private key rather than

any I2OSP-converted data as described by [RFC5915]. The ECParameters
field "parameters" will hold one of the NamedCurve OIDs described
earlier in this document. If present, the "publicKey" field will
hold the raw public key. Note that these requirements normatively
updates [RFC5915] on how these fields are interpreted, for the OIDs
defined in this document.

9. Human Readable Algorithm Names

For the purpose of consistent cross-implementation naming this
section establish human readable names for the algorithms specified
in this document. Implementations SHOULD use these names when
referring to the algorithms. If there is a strong reason to deviate
from these names -- for example, if the implementation has a
different naming convention and wants to maintain internal
consistency -- it is encouraged to deviate as little as possible from
the names given here.

Use the string "EdDSA" when referring to a public key or signature
when the parameter set is not known or relevant.

When the EdDSAParameters value is known, use a more specific string.
For the ed25519(1) value use the string "Ed25519". For the
ed25519ph(2) value use the string "Ed25519ph". For ed448(3) use
"Ed448". For ed448ph(4) use "Ed448ph".

10. ASN.1 Module

For reference purposes, the ASN.1 syntax is presented as an ASN.1
module here.

```
-- ASN.1 Module

safecurves-pkix-0 {1 3 101 120}

DEFINITIONS ::= BEGIN

id-EdDSAPublicKey OBJECT IDENTIFIER ::= { 1 3 101 100 }
id-EdDSASignature OBJECT IDENTIFIER ::= { 1 3 101 101 }

id-Curve25519   OBJECT IDENTIFIER ::= { 1.3.101.110 }
id-Curve448     OBJECT IDENTIFIER ::= { 1.3.101.111 }
id-Curve25519ph OBJECT IDENTIFIER ::= { 1.3.101.112 }
id-Curve448ph   OBJECT IDENTIFIER ::= { 1.3.101.113 }

EdDSAParameters ::= ENUMERATED { ed25519   (1),
                                 ed25519ph (2) }
                                 ed448     (3) }
                                 ed448ph   (4) }

END
```

11. Examples

This section contains illustrations of EdDSA public keys and
certificates, illustrating parameter choices.

11.1. Example Ed25519ph Public Key

An example of a Ed25519ph public key:

```
    Public Key Information:
        Public Key Algorithm: EdDSA
        Algorithm Security Level: High
        Parameters: Ed25519ph

    Public Key Usage:

    Public Key ID: 9b1f5eeded043385e4f7bc623c5975b90bc8bb3b

    -----BEGIN PUBLIC KEY-----
    MC0wCAYDK2VkCgECAyEAGb9ECWmEzf6FQbrBZ9w7lshQhqowtrbLDFw4rXAxZuE=
    -----END PUBLIC KEY-----
```

11.2. Example Ed25519ph Certificate

An example of a PKIX certificate using Ed25519ph would be:

```
    X.509 Certificate Information:
```

```
        Version: 3
        Serial Number (hex): 5601474a2a8dc326
        Issuer: CN=Test Ed25519ph certificate
        Validity:
            Not Before: Tue Sep 22 12:19:24 UTC 2015
            Not After: Fri Dec 31 23:59:59 UTC 9999
        Subject: CN=Test Ed25519ph certificate
        Subject Public Key Algorithm: Ed25519ph
        Algorithm Security Level: High
        Extensions:
            Basic Constraints (critical):
                Certificate Authority (CA): FALSE
            Key Usage (critical):
                Digital signature.
            Subject Key Identifier (not critical):
                9b1f5eeded043385e4f7bc623c5975b90bc8bb3b
        Signature Algorithm: Ed25519ph
        Signature:
            be:9d:f8:b4:19:07:99:c9:04:12:21:e7:85:33:55:76
            b0:5f:29:70:77:bd:69:7a:a6:db:33:fe:c4:f5:3d:79
            d2:ba:77:6d:68:9b:a3:e9:53:bc:a6:56:54:3f:fa:f4
            1c:37:89:4e:c7:43:c0:3b:77:68:5d:98:f6:19:9d:05
    Other Information:
        SHA1 fingerprint:
            a3b75d83a56e127d0728ed8563233cadf943757e
        SHA256 fingerprint:
            cab1d7df29bdf82270d2192997c81f1b333dc37e670d7e88068fbe9dd747da3a
        Public Key ID:
            9b1f5eeded043385e4f7bc623c5975b90bc8bb3b
        Public key's random art:
            +---[Ed25519ph]---+
            |               . |
            |              o ..|
            |               o.=|
            |          . .  +=|
            |       S  o .+oo|
            |         o  o.++o|
            |        o ...*.o.|
            |         o Eo.oo |
            |          ooo ..o|
            +-----------------+

        -----BEGIN CERTIFICATE-----
        MIIBUTCCAQKgAwIBAgIIVgFHSiqNwyYwBgYEK2VkATAqMSgwJgYDVQQDEx9UZXN0
        IEVkMjU1MTktU0hBNTEyIGNlcnRpZmljYXRlMCAXDTE1MDkyMjEyMTkyNFoYDzk5
        OTkxMjMxMjM1OTU5WjAqMSgwJgYDVQQDEx9UZXN0IEVkMjU1MTktU0hBNTEyIGNl
        cnRpZmljYXRlMC0wCAYDK2VkCgECAyEAGb9ECWmEzf6FQbrBZ9w7lshQhqowtrbL
        DFw4rXAxZuGjQDA+MAwGA1UdEwEB/wQCMAAwDwYDVR0PAQH/BAUDAweAADAdBgNV
```

```
HQ4EFgQUmx9e7e0EM4Xk97xiPFl1uQvIuzswBgYEK2VkAQNBAL6d+LQZB5nJBBIh
54UzVXawXylwd71peqbbM/7E9T150rp3bWibo+lTvKZWVD/69Bw3iU7HQ8A7d2hd
mPYZnQU=
-----END CERTIFICATE-----
```

11.3. Example Ed25519ph Private Key

An example of a Ed25519ph private key:

```
Public Key Info:
    Public Key Algorithm: EdDSA
    Key Security Level: High

parameters:    Ed25519ph
private key:
    d4:ee:72:db:f9:13:58:4a:d5:b6:d8:f1:f7:69:f8:ad
    3a:fe:7c:28:cb:f1:d4:fb:e0:97:a8:8f:44:75:58:42

x:
    19:bf:44:09:69:84:cd:fe:85:41:ba:c1:67:dc:3b:96
    c8:50:86:aa:30:b6:b6:cb:0c:5c:38:ad:70:31:66:e1


Public Key ID: 9B:1F:5E:ED:ED:04:33:85:E4:F7:BC:62:3C:59:75:B9:0B:C8:BB:
```
3B
```
Public key's random art:
+---[Ed25519ph]---+
|             .   |
|            o ..|
|             o.=|
|          . .  +=|
|         S  o .+oo|
|          o  o.++o|
|          o ...*.o.|
|           o Eo.oo |
|            ooo ..o|
+-----------------+

-----BEGIN EDDSA PRIVATE KEY-----
MCUKAQEEINTuctv5E1hK1bbY8fdp+K06/nwoy/HU++CXqI9EdVhC
-----END EdDSA PRIVATE KEY-----
```

12. Acknowledgements

Text and/or inspiration were drawn from [RFC5280], [RFC3279],
[RFC4055], [RFC5480], and [RFC5639].

Several people suggested the utility of specifying NamedCurve OIDs
for encoding Curve25519/Curve448 public keys into PKIX certificates.
The editor of this document cannot take credit for this idea.

The following people discussed the document and provided feedback:
Klaus Hartke, Ilari Liusvaara, Erwann Abalea, Rick Andrews, Rob
Stradling, James Manger, Nikos Mavrogiannopoulos, Russ Housley, Jim
Schaad.

A big thank you to Symantec for kindly donating the OIDs used in this
draft.

13. IANA Considerations

None.

14. Security Considerations

The security considerations of [RFC5280], [RFC7748], and
[I-D.irtf-cfrg-eddsa] apply accordingly.

A common misconception may be that a Ed25519 public key can be used
to create Ed25519ph signatures, or vice versa. This leads to cross-
key attacks, and is not permitted.

15. References

15.1. Normative References

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

[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, May 2008.

[RFC5480] Turner, S., Brown, D., Yiu, K., Housley, R., and T. Polk,
           "Elliptic Curve Cryptography Subject Public Key
           Information", RFC 5480, March 2009.

[RFC5915] Turner, S. and D. Brown, "Elliptic Curve Private Key
           Structure", RFC 5915, DOI 10.17487/RFC5915, June 2010,
           <http://www.rfc-editor.org/info/rfc5915>.

[RFC7748] Langley, A., Hamburg, M., and S. Turner, "Elliptic Curves
           for Security", RFC 7748, DOI 10.17487/RFC7748, January
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               Josefsson, S. and I. Liusvaara, "Edwards-curve Digital
               Signature Algorithm (EdDSA)", draft-irtf-cfrg-eddsa-00
               (work in progress), October 2015.

15.2. Informative References

    [RFC3279] Bassham, L., Polk, W., and R. Housley, "Algorithms and
               Identifiers for the Internet X.509 Public Key
               Infrastructure Certificate and Certificate Revocation List
               (CRL) Profile", RFC 3279, April 2002.

    [RFC4055] Schaad, J., Kaliski, B., and R. Housley, "Additional
               Algorithms and Identifiers for RSA Cryptography for use in
               the Internet X.509 Public Key Infrastructure Certificate
               and Certificate Revocation List (CRL) Profile", RFC 4055,
               June 2005.

    [RFC5639] Lochter, M. and J. Merkle, "Elliptic Curve Cryptography
               (ECC) Brainpool Standard Curves and Curve Generation", RFC
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    [RFC5758] Dang, Q., Santesson, S., Moriarty, K., Brown, D., and T.
               Polk, "Internet X.509 Public Key Infrastructure:
               Additional Algorithms and Identifiers for DSA and ECDSA",
               RFC 5758, January 2010.

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