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Use of Edwards-Curve Digital Signature Algorithm (EdDSA) Signatures in the Cryptographic Message Syntax (CMS)

Abstract

This document specifies the conventions for using the Edwards-curve Digital Signature Algorithm (EdDSA) for curve25519 and curve448 in the Cryptographic Message Syntax (CMS). For each curve, EdDSA defines the PureEdDSA and HashEdDSA modes. However, the HashEdDSA mode is not used with the CMS. In addition, no context string is used with the CMS.

Status of This Memo

This is an Internet Standards Track document.

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Table of Contents

1. Introduction 2
   1.1. Terminology 2
   1.2. ASN.1 2
2. EdDSA Signature Algorithm 3
   2.1. Algorithm Identifiers 3
   2.2. EdDSA Algorithm Identifiers 3
   2.3. Message Digest Algorithm Identifiers 4
   2.4. EdDSA Signatures 4
3. Signed-data Conventions 5
   3.1. Signed-data Conventions with Signed Attributes 5
   3.2. Signed-data Conventions without Signed Attributes 6
4. Implementation Considerations 6
5. Security Considerations 6
6. IANA Considerations 7
7. References 7
   7.1. Normative References 7
   7.2. Informative References 8
Acknowledgments 9
Author's Address 9

1. Introduction

This document specifies the conventions for using the Edwards-curve Digital Signature Algorithm (EdDSA) [RFC8032] for curve25519 [CURVE25519] and curve448 [CURVE448] with the Cryptographic Message Syntax (CMS) [RFC5652] signed-data content type. For each curve, [RFC8032] defines the PureEdDSA and HashEdDSA modes; however, the HashEdDSA mode is not used with the CMS. In addition, no context string is used with CMS. EdDSA with curve25519 is referred to as "Ed25519", and EdDSA with curve448 is referred to as "Ed448". The CMS conventions for PureEdDSA with Ed25519 and Ed448 are described in this document.

1.1. Terminology

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

1.2. ASN.1

CMS values are generated using ASN.1 [X680], which uses the Basic Encoding Rules (BER) and the Distinguished Encoding Rules (DER) [X690].

2. EdDSA Signature Algorithm

The Edwards-curve Digital Signature Algorithm (EdDSA) [RFC8032] is a variant of Schnorr's signature system with (possibly twisted) Edwards curves. Ed25519 is intended to operate at around the 128-bit security level; Ed448 is intended to operate at around the 224-bit security level.

One of the parameters of the EdDSA algorithm is the "prehash" function. This may be the identity function, resulting in an algorithm called "PureEdDSA", or a collision-resistant hash function, resulting in an algorithm called "HashEdDSA". In most situations, the CMS SignedData includes signed attributes, including the message digest of the content. Since HashEdDSA offers no benefit when signed attributes are present, only PureEdDSA is used with the CMS.

2.1. Algorithm Identifiers

Each algorithm is identified by an object identifier, and the algorithm identifier may contain parameters if needed.

The ALGORITHM definition is repeated here for convenience:

```
ALGORITHM ::= CLASS {
    &id    OBJECT IDENTIFIER UNIQUE,
    &Type  OPTIONAL }
  WITH SYNTAX {
    OID &id [PARMS &Type] }
```

2.2. EdDSA Algorithm Identifiers

The EdDSA signature algorithm is defined in [RFC8032], and the conventions for encoding the public key are defined in [RFC8410].

The id-Ed25519 and id-Ed448 object identifiers are used to identify EdDSA public keys in certificates. The object identifiers are specified in [RFC8410], and they are repeated here for convenience:

```
sigAlg-Ed25519  ALGORITHM  ::=  { OID id-Ed25519 }

sigAlg-Ed448    ALGORITHM  ::=  { OID id-Ed448 }

id-Ed25519  OBJECT IDENTIFIER  ::=  { 1 3 101 112 }

id-Ed448    OBJECT IDENTIFIER  ::=  { 1 3 101 113 }
```

2.3. Message Digest Algorithm Identifiers

When the signer includes signed attributes, a message digest algorithm is used to compute the message digest on the eContent value. When signing with Ed25519, the message digest algorithm MUST be SHA-512 [FIPS180]. Additional information on SHA-512 is available in [RFC6234]. When signing with Ed448, the message digest algorithm MUST be SHAKE256 [FIPS202] with a 512-bit output value.

Signing with Ed25519 uses SHA-512 as part of the signing operation, and signing with Ed448 uses SHAKE256 as part of the signing operation.

For convenience, the object identifiers and parameter syntax for these algorithms are repeated here:

```
hashAlg-SHA-512  ALGORITHM  ::=  { OID id-sha512 }

hashAlg-SHAKE256  ALGORITHM  ::=  { OID id-shake256 }
hashAlg-SHAKE256-LEN  ALGORITHM  ::=  { OID id-shake256-len
                        PARMS ShakeOutputLen }

hashalgs  OBJECT IDENTIFIER  ::=  { joint-iso-itu-t(2)
                        country(16) us(840) organization(1)
                        gov(101) csor(3) nistalgorithm(4) 2 }

id-sha512  OBJECT IDENTIFIER  ::=  { hashAlgs 3 }

id-shake256  OBJECT IDENTIFIER  ::=  { hashAlgs 12 }

id-shake256-len  OBJECT IDENTIFIER  ::=  { hashAlgs 18 }

ShakeOutputLen  ::=  INTEGER  -- Output length in bits
```

When using the id-sha512 or id-shake256 algorithm identifier, the parameters MUST be absent.

When using the id-shake256-len algorithm identifier, the parameters MUST be present, and the parameter MUST contain 512, encoded as a positive integer value.

2.4. EdDSA Signatures

The id-Ed25519 and id-Ed448 object identifiers are also used for signature values. When used to identify signature algorithms, the AlgorithmIdentifier parameters field MUST be absent.

The data to be signed is processed using PureEdDSA, and then a private key operation generates the signature value. As described in Section 3.3 of [RFC8032], the signature value is the opaque value ENC(R) || ENC(S), where || represents concatenation. As described in Section 5.3 of [RFC5652], the signature value is ASN.1 encoded as an OCTET STRING and included in the signature field of SignerInfo.

3. Signed-data Conventions

The processing depends on whether the signer includes signed attributes.

The inclusion of signed attributes is preferred, but the conventions for signed-data without signed attributes are provided for completeness.

3.1. Signed-data Conventions with Signed Attributes

The SignedData digestAlgorithms field includes the identifiers of the message digest algorithms used by one or more signer. There MAY be any number of elements in the collection, including zero. When signing with Ed25519, the digestAlgorithm SHOULD include id-sha512, and if present, the algorithm parameters field MUST be absent. When signing with Ed448, the digestAlgorithm SHOULD include id-shake256-len, and if present, the algorithm parameters field MUST also be present, and the parameter MUST contain 512, encoded as a positive integer value.

The SignerInfo digestAlgorithm field includes the identifier of the message digest algorithms used by the signer. When signing with Ed25519, the digestAlgorithm MUST be id-sha512, and the algorithm parameters field MUST be absent. When signing with Ed448, the digestAlgorithm MUST be id-shake256-len, the algorithm parameters field MUST be present, and the parameter MUST contain 512, encoded as a positive integer value.

The SignerInfo signedAttributes MUST include the message-digest attribute as specified in Section 11.2 of [RFC5652]. When signing with Ed25519, the message-digest attribute MUST contain the message digest computed over the eContent value using SHA-512. When signing with Ed448, the message-digest attribute MUST contain the message digest computed over the eContent value using SHAKE256 with an output length of 512 bits.

The SignerInfo signatureAlgorithm field MUST contain either id-Ed25519 or id-Ed448, depending on the elliptic curve that was used by the signer. The algorithm parameters field MUST be absent.

The SignerInfo signature field contains the octet string resulting from the EdDSA private key signing operation.

3.2. Signed-data Conventions without Signed Attributes

The SignedData digestAlgorithms field includes the identifiers of the message digest algorithms used by one or more signer. There MAY be any number of elements in the collection, including zero. When signing with Ed25519, the list of identifiers MAY include id-sha512, and if present, the algorithm parameters field MUST be absent. When signing with Ed448, the list of identifiers MAY include id-shake256, and if present, the algorithm parameters field MUST be absent.

The SignerInfo digestAlgorithm field includes the identifier of the message digest algorithms used by the signer. When signing with Ed25519, the digestAlgorithm MUST be id-sha512, and the algorithm parameters field MUST be absent. When signing with Ed448, the digestAlgorithm MUST be id-shake256, and the algorithm parameters field MUST be absent.

> NOTE: Either id-sha512 or id-shake256 is used as part to the private key signing operation. However, the private key signing operation does not take a message digest computed with one of these algorithms as an input.

The SignerInfo signatureAlgorithm field MUST contain either id-Ed25519 or id-Ed448, depending on the elliptic curve that was used by the signer. The algorithm parameters field MUST be absent.

The SignerInfo signature field contains the octet string resulting from the EdDSA private key signing operation.

4. Implementation Considerations

The EdDSA specification [RFC8032] includes the following warning. It deserves highlighting, especially when signed-data is used without signed attributes and the content to be signed might be quite large:

> PureEdDSA requires two passes over the input. Many existing APIs, protocols, and environments assume digital signature algorithms only need one pass over the input and may have API or bandwidth concerns supporting anything else.

5. Security Considerations

Implementations must protect the EdDSA private key. Compromise of the EdDSA private key may result in the ability to forge signatures.

The generation of EdDSA private key relies on random numbers. The use of inadequate pseudo-random number generators (PRNGs) to generate these values can result in little or no security. An attacker may find it much easier to reproduce the PRNG environment that produced the keys, searching the resulting small set of possibilities, rather than brute-force searching the whole key space. The generation of quality random numbers is difficult. RFC 4086 [RANDOM] offers important guidance in this area.

Unlike DSA and Elliptic Curve Digital Signature Algorithm (ECDSA), EdDSA does not require the generation of a random value for each signature operation.

Using the same private key with different algorithms has the potential to leak extra information about the private key to an attacker. For this reason, the same private key SHOULD NOT be used with more than one set of EdDSA parameters, although it appears that there are no security concerns when using the same private key with PureEdDSA and HashEdDSA [RFC8032].

When computing signatures, the same hash function SHOULD be used for all operations. This reduces the number of failure points in the signature process.

6. IANA Considerations

This document has no IANA actions.

7. References

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