

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.

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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 `algorithmParameters` field MUST be absent. When signing with Ed448, the `digestAlgorithm` SHOULD include `id-shake256-len`, and if present, the `algorithmParameters` 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 `algorithmParameters` field MUST be absent. When signing with Ed448, the `digestAlgorithm` MUST be `id-shake256-len`, the `algorithmParameters` 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 `algorithmParameters` 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

7.1. Normative References

- [FIPS180] National Institute of Standards and Technology, "Secure Hash Standard (SHS)", FIPS PUB 180-4, DOI 10.6028/NIST.FIPS.180-4, August 2015.
- [FIPS202] National Institute of Standards and Technology, "SHA-3 Standard: Permutation-Based Hash and Extendable-Output Functions", FIPS PUB 202, DOI 10.6028/NIST.FIPS.202, August 2015.
- [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/info/rfc2119>>.

- [RFC5652] Housley, R., "Cryptographic Message Syntax (CMS)", STD 70, RFC 5652, DOI 10.17487/RFC5652, September 2009, <<https://www.rfc-editor.org/info/rfc5652>>.
- [RFC8032] Josefsson, S. and I. Liusvaara, "Edwards-Curve Digital Signature Algorithm (EdDSA)", RFC 8032, DOI 10.17487/RFC8032, January 2017, <<https://www.rfc-editor.org/info/rfc8032>>.
- [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/info/rfc8174>>.
- [RFC8410] Josefsson, S. and J. Schaad, "Algorithm Identifiers for Ed25519, Ed448, X25519, and X448 for Use in the Internet X.509 Public Key Infrastructure", RFC 8410, DOI 10.17487/RFC8410, August 2018, <<https://www.rfc-editor.org/info/rfc8410>>.
- [X680] ITU-T, "Information technology -- Abstract Syntax Notation One (ASN.1): Specification of basic notation", ITU-T Recommendation X.680, ISO/IEC 8824-1, August 2015, <<https://www.itu.int/rec/T-REC-X.680/en>>.
- [X690] ITU-T, "Information technology -- ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)", ITU-T Recommendation X.690, ISO/IEC 8825-1, August 2015, <<https://www.itu.int/rec/T-REC-X.690/en>>.

7.2. Informative References

- [CURVE25519] Bernstein, D., "Curve25519: new Diffie-Hellman speed records", DOI 10.1007/11745853_14, February 2006, <<http://cr.yp.to/ecdh.html>>.
- [CURVE448] Hamburg, M., "Ed448-Goldilocks, a new elliptic curve", June 2015, <<http://eprint.iacr.org/2015/625>>.
- [RANDOM] Eastlake 3rd, D., Schiller, J., and S. Crocker, "Randomness Requirements for Security", BCP 106, RFC 4086, DOI 10.17487/RFC4086, June 2005, <<https://www.rfc-editor.org/info/rfc4086>>.
- [RFC6234] Eastlake 3rd, D. and T. Hansen, "US Secure Hash Algorithms (SHA and SHA-based HMAC and HKDF)", RFC 6234, DOI 10.17487/RFC6234, May 2011, <<https://www.rfc-editor.org/info/rfc6234>>.

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