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RFC 10082
Composite Module-Lattice-Based Digital Signature Algorithm (ML-DSA) for Use in the Cryptographic Message Syntax (CMS)

Abstract

The Composite Module-Lattice-Based Digital Signature Algorithm (ML-DSA) defines combinations of ML-DSA with RSA, ECDSA, and EdDSA. This document specifies the conventions for using Composite ML-DSA algorithms within the Cryptographic Message Syntax (CMS).

Status of This Memo

This is an Internet Standards Track document.

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Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc10082.

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1. Introduction

[RFC10073] defines a collection of signature algorithms, referred to as Composite ML-DSA, which combine ML-DSA [FIPS.204] with RSASSA-PKCS1-v1.5 [RFC8017], RSASSA-PSS [RFC8017], ECDSA (Section 6 of [FIPS.186-5]), Ed25519 [RFC8410], and Ed448 [RFC8410]. This document acts as a companion to [RFC10073] by providing conventions for using Composite ML-DSA algorithms within the Cryptographic Message Syntax (CMS) [RFC5652].

1.1. ASN.1

CMS values are generated using ASN.1 [X.680], using the Basic Encoding Rules (BER) and the Distinguished Encoding Rules (DER) [X.690].

1.2. 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.

2. Composite ML-DSA Algorithm Identifiers

The same AlgorithmIdentifier is used to identify a Composite ML-DSA public key and signature algorithm. The object identifiers (OIDs) for Composite ML-DSA algorithms are defined in [RFC10073] and are reproduced here for convenience. The parameters field of the AlgorithmIdentifier for the Composite ML-DSA public key and signature algorithm **MUST** be absent.

```
id-MLDSA44-RSA2048-PSS-SHA256 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 37 }
id-MLDSA44-RSA2048-PKCS15-SHA256 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 38 }
id-MLDSA44-Ed25519-SHA512 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 39 }
id-MLDSA44-ECDSA-P256-SHA256 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 40 }
id-MLDSA65-RSA3072-PSS-SHA512 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 41 }
id-MLDSA65-RSA3072-PKCS15-SHA512 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 42 }
id-MLDSA65-RSA4096-PSS-SHA512 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 43 }
id-MLDSA65-RSA4096-PKCS15-SHA512 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 44 }
id-MLDSA65-ECDSA-P256-SHA512 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 45 }
id-MLDSA65-ECDSA-P384-SHA512 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 46 }
id-MLDSA65-ECDSA-brainpoolP256r1-SHA512 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 47 }
id-MLDSA65-Ed25519-SHA512 OBJECT IDENTIFIER ::= {
   iso(1) identified-organization(3) dod(6) internet(1) security(5)
   mechanisms(5) pkix(7) alg(6) 48 }
id-MLDSA87-ECDSA-P384-SHA512 OBJECT IDENTIFIER ::= {
```

```
    iso(1) identified-organization(3) dod(6) internet(1) security(5)
    mechanisms(5) pkix(7) alg(6) 49 }
id-MLDSA87-ECDSA-brainpoolP384r1-SHA512 OBJECT IDENTIFIER ::= {
    iso(1) identified-organization(3) dod(6) internet(1) security(5)
    mechanisms(5) pkix(7) alg(6) 50 }
id-MLDSA87-Ed448-SHAKE256 OBJECT IDENTIFIER ::= {
    iso(1) identified-organization(3) dod(6) internet(1) security(5)
    mechanisms(5) pkix(7) alg(6) 51 }
id-MLDSA87-RSA3072-PSS-SHA512 OBJECT IDENTIFIER ::= {
    iso(1) identified-organization(3) dod(6) internet(1) security(5)
    mechanisms(5) pkix(7) alg(6) 52 }
id-MLDSA87-RSA4096-PSS-SHA512 OBJECT IDENTIFIER ::= {
    iso(1) identified-organization(3) dod(6) internet(1) security(5)
    mechanisms(5) pkix(7) alg(6) 53 }
id-MLDSA87-ECDSA-P521-SHA512 OBJECT IDENTIFIER ::= {
    iso(1) identified-organization(3) dod(6) internet(1) security(5)
    mechanisms(5) pkix(7) alg(6) 54 }
```

3. Signed-Data Conventions

3.1. Pre-Hashing

[RFC5652] specifies that digital signatures for CMS are produced using a digest of the message to be signed and the signer's private key. At the time [RFC5652] was published, all signature algorithms supported in the CMS required a message digest to be calculated externally to that algorithm, which would then be supplied to the algorithm implementation when calculating and verifying signatures. Since then, EdDSA [RFC8032] and ML-DSA [FIPS.204] have also been standardized, and these algorithms support both a "pure" and a "pre-hash" mode, although their use in CMS has only been defined for "pure" mode.

Composite ML-DSA only provides a "pre-hash" mode. Unlike RSA and ECDSA, each Composite ML-DSA algorithm is defined to be used with a single digest algorithm, which is identified in the Composite ML-DSA algorithm name. For example, id-MLDSA87-ECDSA-P521-SHA512 uses SHA-512 as its pre-hash digest algorithm.

When Composite ML-DSA is used in CMS, the digest algorithm used by CMS **SHALL** be the same pre-hash digest algorithm used by the Composite ML-DSA algorithm. A Composite ML-DSA algorithm might use additional digest algorithms internally, e.g., in the case of id-MLDSA87-ECDSA-P384-SHA512, the ECDSA component uses SHA-384. These internal digest algorithms are irrelevant to Composite ML-DSA's use in CMS.

3.2. SignedData digestAlgorithms

The SignedData digestAlgorithms field includes the identifiers of the message digest algorithms used by one or more signers. When signing with a Composite ML-DSA algorithm, this list of identifiers **SHOULD** include the corresponding digest algorithm from Table 1. The field is intended to list the message digest algorithms employed by all of the signers, to facilitate one-pass signature verification. If the corresponding digest algorithm from Table 1 is not listed, a one-pass verifier might not successfully verify the Composite ML-DSA signature.

3.3. Signature Generation and Verification

[RFC5652] describes the two methods that are used to calculate and verify signatures in the CMS. One method is used when signed attributes are present in the signedAttrs field of the relevant SignerInfo, and another is used when signed attributes are absent. Use of signed attributes is preferred, but the conventions for the signed-data content type without signed attributes are also described below for completeness.

When signed attributes are absent, Composite ML-DSA signatures are computed over the content of the signed-data. As described in Section 5.4 of [RFC5652], the "content" of a signed-data is the value of the encapContentInfo eContent OCTET STRING. The tag and length octets are not included.

When signed attributes are included, Composite ML-DSA signatures are computed over the complete DER encoding of the SignedAttrs value contained in the SignerInfo's signedAttrs field. As described in Section 5.4 of [RFC5652], this encoding includes the tag and length octets, but an EXPLICIT SET OF tag is used rather than the IMPLICIT [0] tag that appears in the final message. At a minimum, the signedAttrs field **MUST** include a content-type attribute and a message-digest attribute. The message-digest attribute contains a hash of the content of the signed-data, where the content is as described for the case with absent signed attributes above. Recalculation of the hash value by the recipient is an important step in signature verification.

Composite ML-DSA has a context string input that can be used to ensure that different signatures are generated for different application contexts. When using Composite ML-DSA as specified in this document, the context string is set to the empty string.

3.4. SignerInfo Content

When using Composite ML-DSA, the fields of a SignerInfo are used as follows:

digestAlgorithm: Per Section 5.3 of [RFC5652], the digestAlgorithm field identifies the message digest algorithm used by the signer and any associated parameters. This **MUST** be the same digest algorithm used by the Composite ML-DSA algorithm. Per [RFC8933], if the signedAttrs field is present in the SignerInfo, then the same digest algorithm **MUST** be used to compute both the digest of the SignedData encapContentInfo eContent, which is carried in the message-digest attribute, and the digest of the DER-encoded signedAttrs, which is passed to the signature algorithm. See Table 1 for exact algorithm mappings.

[RFC5754] defines the use of SHA-256 [FIPS.180] (id-sha256) and SHA-512 [FIPS.180] (id-sha512) in CMS. [RFC8702] defines the use of SHAKE256 [FIPS.202] (id-shake256) in CMS. When id-sha256 or id-sha512 is used, the parameters field **MUST** be omitted. When id-shake256 is used, the parameters field **MUST** be omitted, and the digest length **MUST** be 64 bytes.

Signature Algorithm	Digest Algorithm
id-MLDSA44-RSA2048-PSS-SHA256	id-sha256
id-MLDSA44-RSA2048-PKCS15-SHA256	id-sha256
id-MLDSA44-Ed25519-SHA512	id-sha512
id-MLDSA44-ECDSA-P256-SHA256	id-sha256
id-MLDSA65-RSA3072-PSS-SHA512	id-sha512
id-MLDSA65-RSA3072-PKCS15-SHA512	id-sha512
id-MLDSA65-RSA4096-PSS-SHA512	id-sha512
id-MLDSA65-RSA4096-PKCS15-SHA512	id-sha512
id-MLDSA65-ECDSA-P256-SHA512	id-sha512
id-MLDSA65-ECDSA-P384-SHA512	id-sha512
id-MLDSA65-ECDSA-brainpoolP256r1-SHA512	id-sha512
id-MLDSA65-Ed25519-SHA512	id-sha512
id-MLDSA87-ECDSA-P384-SHA512	id-sha512
id-MLDSA87-ECDSA-brainpoolP384r1-SHA512	id-sha512
id-MLDSA87-Ed448-SHAKE256	id-shake256
id-MLDSA87-RSA3072-PSS-SHA512	id-sha512
id-MLDSA87-RSA4096-PSS-SHA512	id-sha512
id-MLDSA87-ECDSA-P521-SHA512	id-sha512

Table 1: Digest Algorithms for Composite ML-DSA

signatureAlgorithm: The signatureAlgorithm field **MUST** contain one of the Composite ML-DSA signature algorithm OIDs, and the parameters field **MUST** be absent. The algorithm OID **MUST** be one of the OIDs described in Section 2.

signature: The signature field contains the signature value resulting from the use of the Composite ML-DSA signature algorithm identified by the signatureAlgorithm field. The Composite ML-DSA signature-generation operation is specified in Section 3.2 of [RFC10073], and the signature-verification operation is specified in Section 3.3 of [RFC10073]. Note that Section 5.6 of [RFC5652] places further requirements on the successful verification of a signature.

4. IANA Considerations

For the ASN.1 module defined in this document, IANA has made the following assignment in the "SMI Security for S/MIME Module Identifier (1.2.840.113549.1.9.16.0)" registry.

Decimal	Description	Reference
88	id-mod-composite-mldsa-cms-2026	RFC 10082

Table 2: ASN.1 Module Assignment

5. Security Considerations

All security considerations from [RFC10073] apply.

Security of the Composite ML-DSA private key is critical. Compromise of the private key will enable an adversary to forge arbitrary signatures.

Composite ML-DSA depends on high-quality random numbers that are suitable for use in cryptography. The use of inadequate pseudorandom number generators (PRNGs) to generate such values can significantly undermine the security properties offered by a cryptographic algorithm. For instance, an attacker may find it much easier to reproduce the PRNG environment that produced any private keys, searching the resulting small set of possibilities, rather than brute-force searching the whole key space. The generation of random numbers of a sufficient level of quality for use in cryptography is difficult; see Section 3.6.1 of [FIPS.204] for some additional information.

To avoid algorithm substitution attacks, the CMSAlgorithmProtection attribute defined in [RFC6211] **SHOULD** be included in signed attributes.

Section 3.4 specifies that the SignerInfo digestAlgorithm field **MUST** contain the Composite ML-DSA algorithm's pre-hash algorithm. If the digestAlgorithm and pre-hash algorithm don't match, the verifier **SHOULD** reject the message as invalid CMS, but for backwards compatibility or interoperability reasons, it **MAY** verify the signature using the pre-hash algorithm. If these algorithms don't match, this implies that the signer may have passed an incorrect digest value to the Composite ML-DSA signing algorithm and the resulting signature would not be valid for the data being signed. This is a general issue with CMS, where a SignerInfo's digestAlgorithm field might not correspond to the digest required by the SignerInfo's signatureAlgorithm field.

ECDSA, EdDSA, and RSA signatures are relatively small compared to ML-DSA signatures, and thus compared to Composite ML-DSA signatures as well. On the other hand, Composite ML-DSA signatures are not that much larger than ML-DSA signatures. When moving from ECDSA, EdDSA, or RSA to Composite ML-DSA (or ML-DSA), the resulting increased message sizes could stress size-constrained processing pipelines.

ECDSA (with curve secp256r1) and Ed25519 have very fast signing operations compared to ML-DSA (and thus Composite ML-DSA). Implementations that rely on this fast signing should be aware of potential denial-of-service issues arising from the slower signing times.

6. References

6.1. Normative References

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Appendix A. ASN.1 Module

This appendix includes the ASN.1 module [X.680] for the use of Composite ML-DSA in the CMS. This module imports objects from [RFC5911].

```
<CODE BEGINS>
Composite-MLDSA-CMS-2026
  { iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1) pkcs9(9)
        id-smime(16) id-mod(0)
        id-mod-composite-mldsa-cms-2026(88) }

DEFINITIONS IMPLICIT TAGS ::= BEGIN

EXPORTS ALL;

IMPORTS
  SIGNATURE-ALGORITHM, SMIME-CAPS
    FROM AlgorithmInformation-2009  -- RFC 5911
      { iso(1) identified-organization(3) dod(6) internet(1)
        security(5) mechanisms(5) pkix(7) id-mod(0)
        id-mod-algorithmInformation-02(58) }

  sa-MLDSA44-RSA2048-PSS-SHA256, sa-MLDSA44-RSA2048-PKCS15-SHA256,
  sa-MLDSA44-Ed25519-SHA512, sa-MLDSA44-ECDSA-P256-SHA256,
  sa-MLDSA65-RSA3072-PSS-SHA512, sa-MLDSA65-RSA3072-PKCS15-SHA512,
  sa-MLDSA65-RSA4096-PSS-SHA512, sa-MLDSA65-RSA4096-PKCS15-SHA512,
  sa-MLDSA65-ECDSA-P256-SHA512, sa-MLDSA65-ECDSA-P384-SHA512,
  sa-MLDSA65-ECDSA-brainpoolP256r1-SHA512, sa-MLDSA65-Ed25519-SHA512,
  sa-MLDSA87-ECDSA-P384-SHA512,
  sa-MLDSA87-ECDSA-brainpoolP384r1-SHA512, sa-MLDSA87-Ed448-SHAKE256,
  sa-MLDSA87-RSA3072-PSS-SHA512, sa-MLDSA87-RSA4096-PSS-SHA512,
  sa-MLDSA87-ECDSA-P521-SHA512
   FROM Composite-MLDSA-2025
      { iso(1) identified-organization(3) dod(6) internet(1)
        security(5) mechanisms(5) pkix(7) id-mod(0)
        id-mod-composite-mldsa-2025(127) }
;

--
-- Expand the signature algorithm set used by CMS (RFC 5911)
--

SignatureAlgorithmSet SIGNATURE-ALGORITHM ::= {
  sa-MLDSA44-RSA2048-PSS-SHA256 |
  sa-MLDSA44-RSA2048-PKCS15-SHA256 |
  sa-MLDSA44-Ed25519-SHA512 |
  sa-MLDSA44-ECDSA-P256-SHA256 |
  sa-MLDSA65-RSA3072-PSS-SHA512 |
  sa-MLDSA65-RSA3072-PKCS15-SHA512 |
  sa-MLDSA65-RSA4096-PSS-SHA512 |
  sa-MLDSA65-RSA4096-PKCS15-SHA512 |
  sa-MLDSA65-ECDSA-P256-SHA512 |
  sa-MLDSA65-ECDSA-P384-SHA512 |
  sa-MLDSA65-ECDSA-brainpoolP256r1-SHA512 |
  sa-MLDSA65-Ed25519-SHA512 |
  sa-MLDSA87-ECDSA-P384-SHA512 |
  sa-MLDSA87-ECDSA-brainpoolP384r1-SHA512 |
  sa-MLDSA87-Ed448-SHAKE256 |
  sa-MLDSA87-RSA3072-PSS-SHA512 |
  sa-MLDSA87-RSA4096-PSS-SHA512 |
  sa-MLDSA87-ECDSA-P521-SHA512,
  ... }
```

```
--
-- Expand the S/MIME capabilities set used by CMS (RFC 5911)
--

SMimeCaps SMIME-CAPS ::= {
  sa-MLDSA44-RSA2048-PSS-SHA256.&smimeCaps |
  sa-MLDSA44-RSA2048-PKCS15-SHA256.&smimeCaps |
  sa-MLDSA44-Ed25519-SHA512.&smimeCaps |
  sa-MLDSA44-ECDSA-P256-SHA256.&smimeCaps |
  sa-MLDSA65-RSA3072-PSS-SHA512.&smimeCaps |
  sa-MLDSA65-RSA3072-PKCS15-SHA512.&smimeCaps |
  sa-MLDSA65-RSA4096-PSS-SHA512.&smimeCaps |
  sa-MLDSA65-RSA4096-PKCS15-SHA512.&smimeCaps |
  sa-MLDSA65-ECDSA-P256-SHA512.&smimeCaps |
  sa-MLDSA65-ECDSA-P384-SHA512.&smimeCaps |
  sa-MLDSA65-ECDSA-brainpoolP256r1-SHA512.&smimeCaps |
  sa-MLDSA65-Ed25519-SHA512.&smimeCaps |
  sa-MLDSA87-ECDSA-P384-SHA512.&smimeCaps |
  sa-MLDSA87-ECDSA-brainpoolP384r1-SHA512.&smimeCaps |
  sa-MLDSA87-Ed448-SHAKE256.&smimeCaps |
  sa-MLDSA87-RSA3072-PSS-SHA512.&smimeCaps |
  sa-MLDSA87-RSA4096-PSS-SHA512.&smimeCaps |
  sa-MLDSA87-ECDSA-P521-SHA512.&smimeCaps,
  ... }

END
<CODE ENDS>
```

Appendix B. Examples

This appendix contains an example signed-data encoding with the id-MLDSA65-ECDSA-P256-SHA512 signature algorithm.

It can be verified using the example public keys and certificates specified in Appendix E of [RFC10073], specifically, the following example:

- tcId: id-MLDSA65-ECDSA-P256-SHA512
- x5c: Base64 of the DER encoding of the certificate. Wrap this in Privacy-Enhanced Mail (PEM) headers and footers to get a PEM certificate.

To keep the size of the example down, the signing certificate is not included in the CMS encoding. The example certificate from [RFC10073] used to sign the CMS content is self-signed.

The following is an example of a signed-data with a single id-MLDSA65-ECDSA-P256-SHA512 signer, with signed attributes included:

```
-----BEGIN CMS-----
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```

```
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```

```
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-----END CMS-----
```

```
SEQUENCE {
  # signedData
  OBJECT_IDENTIFIER { 1.2.840.113549.1.7.2 }
  [0] {
    SEQUENCE {
      INTEGER { 1 }
      SET {
        SEQUENCE {
          # sha512
          OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.2.3 }
        }
      }
      SEQUENCE {
        # data
        OBJECT_IDENTIFIER { 1.2.840.113549.1.7.1 }
        [0] {
          OCTET_STRING { "id-MLDSA65-ECDSA-P256-SHA512 signed-da
ta example with signed attributes" }
        }
      }
      SET {
        SEQUENCE {
          INTEGER { 1 }
          SEQUENCE {
            SEQUENCE {
              SET {
                SEQUENCE {
                  # organizationName
                  OBJECT_IDENTIFIER { 2.5.4.10 }
                  UTF8String { "IETF" }
                }
              }
              SET {
                SEQUENCE {
                  # organizationUnitName
                  OBJECT_IDENTIFIER { 2.5.4.11 }
                  UTF8String { "LAMPS" }
```

```
                }
              }
              SET {
                SEQUENCE {
                  # commonName
                  OBJECT_IDENTIFIER { 2.5.4.3 }
                  UTF8String { "id-MLDSA65-ECDSA-P256-SHA512" }
                }
              }
            }
            INTEGER { `5b43282ced27a7bfc2874f667c3231026f701f70`
 }
          }
          SEQUENCE {
            # sha512
            OBJECT_IDENTIFIER { 2.16.840.1.101.3.4.2.3 }
          }
          [0] {
            SEQUENCE {
              # contentType
              OBJECT_IDENTIFIER { 1.2.840.113549.1.9.3 }
              SET {
                # data
                OBJECT_IDENTIFIER { 1.2.840.113549.1.7.1 }
              }
            }
            SEQUENCE {
              # signingTime
              OBJECT_IDENTIFIER { 1.2.840.113549.1.9.5 }
              SET {
                UTCTime { "260121203920Z" }
              }
            }
            SEQUENCE {
              # messageDigest
              OBJECT_IDENTIFIER { 1.2.840.113549.1.9.4 }
              SET {
                OCTET_STRING { `88d87347f688afe2febdf4f37a2e1115
e14074925ee9611fcb7a8e22d252530ae846d6e71345b2744b6d523d3d874ebe
154ba8a6a8a1506b6d5bf18993c85f4d` }
              }
            }
          }
          SEQUENCE {
            OBJECT_IDENTIFIER { 1.3.6.1.5.5.7.6.45 }
          }
          OCTET_STRING { `12441c14b2fd180879fbaccd044403af8c4f26
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```

```
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```

```
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b6` }
        }
      }
    }
  }
}
```

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