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Composite Module-Lattice-Based Digital Signature Algorithm (ML-DSA) for use in Cryptographic Message Syntax (CMS)
draft-ietf-lamps-cms-composite-sigs-05

Abstract

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).

About This Document

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

The latest revision of this draft can be found at https://lamps-wg.github.io/cms-composite-sigs/draft-ietf-lamps-cms-composite-sigs.html. Status information for this document may be found at https://datatracker.ietf.org/doc/draft-ietf-lamps-cms-composite-sigs/.

Discussion of this document takes place on the LAMPS Working Group mailing list (mailto:spams@ietf.org), which is archived at https://datatracker.ietf.org/wg/lamps/about/. Subscribe at https://www.ietf.org/mailman/listinfo/spams/.

Source for this draft and an issue tracker can be found at https://github.com/lamps-wg/cms-composite-sigs.

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/.

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1. Introduction

[I-D.ietf-lamps-pq-composite-sigs] 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 [I-D.ietf-lamps-pq-composite-sigs] 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 [X680], using the Basic Encoding Rules (BER) and the Distinguished Encoding Rules (DER) [X690].

1.2. Conventions and 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. These words may also appear in this document in lower case as plain English words, absent their normative meanings.

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 for Composite ML-DSA algorithms are defined in [I-D.ietf-lamps-pq-composite-sigs], 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 "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 signer. 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 signed-data without signed attributes is 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 absent signed attributes case 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 Algorithms
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 4.2 of [I-D.ietf-lamps-pq-composite-sigs], and the signature-verification operation is specified in Section 4.3 of [I-D.ietf-lamps-pq-composite-sigs]. Note that Section 5.6 of [RFC5652] places further requirements on the successful verification of a signature.

4. IANA Considerations

IANA is requested to allocate a value from the "SMI Security for S/MIME Module Identifier (1.2.840.113549.1.9.16.0)" registry for the included ASN.1 module.

* Decimal: IANA Assigned - *Replace TBDMOD*

* Description: Composite-MLDSA-CMS-2026 - id-mod-composite-mldsa-cms-2026

* References: This Document

5. Security Considerations

All security considerations from [I-D.ietf-lamps-pq-composite-sigs] 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 pseudo-random 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 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 which 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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[RFC8933] Housley, R., "Update to the Cryptographic Message Syntax (CMS) for Algorithm Identifier Protection", RFC 8933, DOI 10.17487/RFC8933, October 2020, <https://www.rfc-editor.org/rfc/rfc8933>.

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6.2. Informative References

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[RFC9882] Salter, B., Raine, A., and D. Van Geest, "Use of the ML-DSA Signature Algorithm in the Cryptographic Message Syntax (CMS)", RFC 9882, DOI 10.17487/RFC9882, October 2025, <https://www.rfc-editor.org/rfc/rfc9882>.

[RFC8411] Schaad, J. and R. Andrews, "IANA Registration for the Cryptographic Algorithm Object Identifier Range", RFC 8411, DOI 10.17487/RFC8411, August 2018, <https://www.rfc-editor.org/rfc/rfc8411>.

Appendix A. ASN.1 Module

This appendix includes the ASN.1 module [X680] for the use of ML-KEM 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(TBDMOD) }

DEFINITIONS IMPLICIT TAGS ::= BEGIN

EXPORTS ALL;

IMPORTS
  SIGNATURE-ALGORITHM, SMIME-CAPS
    FROM AlgorithmInformation-2009  -- [RFC5911]
      { 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(TBDCompositeMOD) }
;

--
-- Expand the signature algorithm set used by CMS [RFC5911]
--

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 [RFC5911]
--

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 [I-D.ietf-lamps-pq-composite-sigs]. Specifically, the following example:

* tcId: id-MLDSA65-ECDSA-P256-SHA512

* x5c: Base64 of the DER encoding of the certificate. Wrap this in PEM headers and footers to get a PEM certificate.

To keep example size down, the signing certificate is not included in the CMS encoding. The example certificate from [I-D.ietf-lamps-pq-composite-sigs] 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-----
MIIOxQYJKoZIhvcNAQcCoIIOtjCCDrICAQExDTALBglghkgBZQMEAgMwVgYJKoZI
hvcNAQcBoEkER2lkLU1MRFNBNjUtRUNEU0EtUDI1Ni1TSEE1MTIgc2lnbmVkLWRh
dGEgZXhhbXBsZSB3aXRoIHNpZ25lZCBhdHRyaWJ1dGVzMYIORDCCDkACAQEwXjBG
MQ0wCwYDVQQKDARJRVRGMQ4wDAYDVQQLDAVMQU1QUzElMCMGA1UEAwwcaWQtTUxE
U0E2NS1FQ0RTQS1QMjU2LVNIQTUxMgIUW0MoLO0np7/Ch09mfDIxAm9wH3AwCwYJ
YIZIAWUDBAIDoIGJMBgGCSqGSIb3DQEJAzELBgkqhkiG9w0BBwEwHAYJKoZIhvcN
AQkFMQ8XDTI2MDEyMTIwMzkyMFowTwYJKoZIhvcNAQkEMUIEQIjYc0f2iK/i/r30
83ouERXhQHSSXulhH8t6jiLSUlMK6EbW5xNFsnRLbVI9PYdOvhVLqKaooVBrbVvx
iZPIX00wCgYIKwYBBQUHBi0Egg00EkQcFLL9GAh5+6zNBEQDr4xPJjTZjEgwgf0E
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j2ec7W7w1fmsXzF0ltk2wDwxIZF8g0qAiH3SOx7Gs2hfQnb0V9zhbjPt2NHiTM7r
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BkBCVoJbqWYaHFY1wS+qFB9dIdOXK6rvqx1PO3yaAn8Yy1Sg3Wogie5m23hqysB+
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```
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```

```
   pWoMuOAdkAIgXpG9PLXn/nqA6YMPvNnIi7zQDA3ucqzgF7pkjMN+CrY=
   -----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
   34d98c483081fd04e645e234bb733c9d06333acbfdc509cfc2cc844126d4732d
   2c359cdc93b0487e6ce56c8544d4abf6385b0dcc331c50dd7593b798014189b4
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   fc421ab92c63a0bb6697acc72eb9bea9e44ca99cd8517c0fded8f95b3249e002
   63edd9cd30d9d631080294f3aaa4e22b2e662e91de274d366f8b5d4ed55d5dae
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   33268c721d1fb3eba6c5ed48b60159ddf279a48ed2862c3e8f679ced6ef0d5f9
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```

```
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```

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```

```
   b6' }
           }
         }
       }
     }
   }
```

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