

Internet Engineering Task Force (IETF)
Request for Comments: 8702
Updates: 3370
Category: Standards Track
ISSN: 2070-1721

P. Kampanakis
Cisco Systems
Q. Dang
NIST
January 2020

Use of the SHAKE One-Way Hash Functions in the Cryptographic Message
Syntax (CMS)

Abstract

This document updates the "Cryptographic Message Syntax (CMS) Algorithms" (RFC 3370) and describes the conventions for using the SHAKE family of hash functions in the Cryptographic Message Syntax as one-way hash functions with the RSA Probabilistic Signature Scheme (RSASSA-PSS) and Elliptic Curve Digital Signature Algorithm (ECDSA). The conventions for the associated signer public keys in CMS are also described.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

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/rfc8702>.

Copyright Notice

Copyright (c) 2020 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction
 - 1.1. Terminology
 2. Identifiers
 3. Use in CMS
 - 3.1. Message Digests
 - 3.2. Signatures
 - 3.2.1. RSASSA-PSS Signatures
 - 3.2.2. ECDSA Signatures
 - 3.3. Public Keys
 - 3.4. Message Authentication Codes
 4. IANA Considerations
 5. Security Considerations
 6. References
 - 6.1. Normative References
 - 6.2. Informative References
- Appendix A. ASN.1 Module

1. Introduction

"Cryptographic Message Syntax (CMS)" [RFC5652] describes syntax used to digitally sign, digest, authenticate, or encrypt arbitrary message contents. "Cryptographic Message Syntax (CMS) Algorithms" [RFC3370] defines the use of common cryptographic algorithms with CMS. This specification updates RFC 3370 and describes the use of the SHAKE128 and SHAKE256 specified in [SHA3] as new hash functions in CMS. In addition, it describes the use of these functions with the RSA Probabilistic Signature Scheme (RSASSA-PSS) signature algorithm [RFC8017] and the Elliptic Curve Digital Signature Algorithm (ECDSA) [X9.62] with the CMS signed-data content type.

In the SHA-3 family, two extendable-output functions (SHAKEs), SHAKE128 and SHAKE256, are defined. Four other hash function instances (SHA3-224, SHA3-256, SHA3-384, and SHA3-512) are also defined but are out of scope for this document. A SHAKE is a variable-length hash function defined as SHAKE(M, d) where the output is a d-bit-long digest of message M. The corresponding collision and second-preimage-resistance strengths for SHAKE128 are $\min(d/2, 128)$ and $\min(d, 128)$ bits, respectively (see Appendix A.1 of [SHA3]). And the corresponding collision and second-preimage-resistance strengths for SHAKE256 are $\min(d/2, 256)$ and $\min(d, 256)$ bits, respectively. In this specification, we use $d=256$ (for SHAKE128) and $d=512$ (for SHAKE256).

A SHAKE can be used in CMS as the message digest function (to hash the message to be signed) in RSASSA-PSS and ECDSA, as the message authentication code, and as the mask generation function (MGF) in RSASSA-PSS. This specification describes the identifiers for SHAKEs to be used in CMS and their meanings.

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.

2. Identifiers

This section identifies eight new object identifiers (OIDs) for using SHAKE128 and SHAKE256 in CMS.

Two object identifiers for SHAKE128 and SHAKE256 hash functions are defined in [shake-nist-oids], and we include them here for convenience.

```
id-shake128 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
  country(16) us(840) organization(1) gov(101) csor(3)
  nistAlgorithm(4) 2 11 }
```

```
id-shake256 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
  country(16) us(840) organization(1) gov(101) csor(3)
  nistAlgorithm(4) 2 12 }
```

In this specification, when using the id-shake128 or id-shake256 algorithm identifiers, the parameters MUST be absent. That is, the identifier SHALL be a SEQUENCE of one component, the OID.

[RFC8692] defines two identifiers for RSASSA-PSS signatures using SHAKEs, which we include here for convenience.

```
id-RSASSA-PSS-SHAKE128 OBJECT IDENTIFIER ::= { iso(1)
  identified-organization(3) dod(6) internet(1)
  security(5) mechanisms(5) pkix(7) algorithms(6) 30 }
```

```
id-RSASSA-PSS-SHAKE256 OBJECT IDENTIFIER ::= { iso(1)
    identified-organization(3) dod(6) internet(1)
    security(5) mechanisms(5) pkix(7) algorithms(6) 31 }
```

The same RSASSA-PSS algorithm identifiers can be used for identifying public keys and signatures.

[RFC8692] also defines two algorithm identifiers of ECDSA signatures using SHAKEs, which we include here for convenience.

```
id-ecdsa-with-shake128 OBJECT IDENTIFIER ::= { iso(1)
    identified-organization(3) dod(6) internet(1)
    security(5) mechanisms(5) pkix(7) algorithms(6) 32 }
```

```
id-ecdsa-with-shake256 OBJECT IDENTIFIER ::= { iso(1)
    identified-organization(3) dod(6) internet(1)
    security(5) mechanisms(5) pkix(7) algorithms(6) 33 }
```

The parameters for the four RSASSA-PSS and ECDSA identifiers MUST be absent. That is, each identifier SHALL be a SEQUENCE of one component, the OID.

In [shake-nist-oids], the National Institute of Standards and Technology (NIST) defines two object identifiers for Keccak message authentication codes (KMACs) using SHAKE128 and SHAKE256, and we include them here for convenience.

```
id-KmacWithSHAKE128 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
    country(16) us(840) organization(1) gov(101) csor(3)
    nistAlgorithm(4) 2 19 }
```

```
id-KmacWithSHAKE256 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
    country(16) us(840) organization(1) gov(101) csor(3)
    nistAlgorithm(4) 2 20 }
```

The parameters for id-KmacWithSHAKE128 and id-KmacWithSHAKE256 are OPTIONAL.

Sections 3.1, 3.2.1, 3.2.2, and 3.4 specify the required output length for each use of SHAKE128 or SHAKE256 in message digests, RSASSA-PSS, ECDSA, and KMAC.

3. Use in CMS

3.1. Message Digests

The id-shake128 and id-shake256 OIDs (see Section 2) can be used as the digest algorithm identifiers located in the SignedData, SignerInfo, DigestedData, and the AuthenticatedData digestAlgorithm fields in CMS [RFC5652]. The OID encoding MUST omit the parameters field and the output length of SHAKE128 or SHAKE256 as the message digest MUST be 32 or 64 bytes, respectively.

The digest values are located in the DigestedData field and the Message Digest authenticated attribute included in the signedAttributes of the SignedData signerInfos. In addition, digest values are input to signature algorithms. The digest algorithm MUST be the same as the message hash algorithms used in signatures.

3.2. Signatures

In CMS, signature algorithm identifiers are located in the SignerInfo signatureAlgorithm field of signed-data content type and countersignature attribute. Signature values are located in the SignerInfo signature field of signed-data content type and countersignature attribute.

Conforming implementations that process RSASSA-PSS and ECDSA with SHAKE signatures when processing CMS data MUST recognize the corresponding OIDs specified in Section 2.

When using RSASSA-PSS or ECDSA with SHAKEs, the RSA modulus or ECDSA curve order SHOULD be chosen in line with the SHAKE output length. Refer to Section 5 for more details.

3.2.1. RSASSA-PSS Signatures

The RSASSA-PSS algorithm is defined in [RFC8017]. When id-RSASSA-PSS-SHAKE128 or id-RSASSA-PSS-SHAKE256 (specified in Section 2) is used, the encoding MUST omit the parameters field. That is, the AlgorithmIdentifier SHALL be a SEQUENCE of one component: id-RSASSA-PSS-SHAKE128 or id-RSASSA-PSS-SHAKE256. [RFC4055] defines RSASSA-PSS-params that are used to define the algorithms and inputs to the algorithm. This specification does not use parameters because the hash, mask generation algorithm, trailer, and salt are embedded in the OID definition.

The hash algorithm used to hash a message being signed and the hash algorithm as the mask generation function used in RSASSA-PSS MUST be the same: both SHAKE128 or both SHAKE256. The output length of the hash algorithm that hashes the message SHALL be 32 (for SHAKE128) or 64 bytes (for SHAKE256).

The mask generation function takes an octet string of variable length and a desired output length as input, and outputs an octet string of the desired length. In RSASSA-PSS with SHAKEs, the SHAKEs MUST be used natively as the MGF, instead of the MGF1 algorithm that uses the hash function in multiple iterations, as specified in Appendix B.2.1 of [RFC8017]. In other words, the MGF is defined as the SHAKE128 or SHAKE256 with input being the mgfSeed for id-RSASSA-PSS-SHAKE128 and id-RSASSA-PSS-SHAKE256, respectively. The mgfSeed is an octet string used as the seed to generate the mask [RFC8017]. As explained in Step 9 of Section 9.1.1 of [RFC8017], the output length of the MGF is $emLen - hLen - 1$ bytes. $emLen$ is the maximum message length $\lceil (n-1)/8 \rceil$, where n is the RSA modulus in bits. $hLen$ is 32 and 64 bytes for id-RSASSA-PSS-SHAKE128 and id-RSASSA-PSS-SHAKE256, respectively. Thus, when SHAKE is used as the MGF, the SHAKE output length $maskLen$ is $(8 * emLen - 264)$ or $(8 * emLen - 520)$ bits, respectively. For example, when RSA modulus n is 2048, the output length of SHAKE128 or SHAKE256 as the MGF will be 1784 or 1528 bits when id-RSASSA-PSS-SHAKE128 or id-RSASSA-PSS-SHAKE256 is used, respectively.

The RSASSA-PSS saltLength MUST be 32 bytes for id-RSASSA-PSS-SHAKE128 or 64 bytes for id-RSASSA-PSS-SHAKE256. Finally, the trailerField MUST be 1, which represents the trailer field with hexadecimal value 0xBC [RFC8017].

3.2.2. ECDSA Signatures

The Elliptic Curve Digital Signature Algorithm (ECDSA) is defined in [X9.62]. When the id-ecdsa-with-shake128 or id-ecdsa-with-shake256 (specified in Section 2) algorithm identifier appears, the respective SHAKE function is used as the hash. The encoding MUST omit the parameters field. That is, the AlgorithmIdentifier SHALL be a SEQUENCE of one component, the OID id-ecdsa-with-shake128 or id-ecdsa-with-shake256.

For simplicity and compliance with the ECDSA standard specification [X9.62], the output length of the hash function must be explicitly determined. The output length for SHAKE128 or SHAKE256 used in ECDSA MUST be 32 or 64 bytes, respectively.

Conforming Certification Authority (CA) implementations that generate ECDSA with SHAKE signatures in certificates or Certificate Revocation Lists (CRLs) SHOULD generate such signatures with a deterministically generated, nonrandom k in accordance with all the requirements specified in [RFC6979]. They MAY also generate such signatures in accordance with all other recommendations in [X9.62] or [SEC1] if they have a stated policy that requires conformance to those standards. Those standards have not specified SHAKE128 and SHAKE256 as hash algorithm options. However, SHAKE128 and SHAKE256 with

output length being 32 and 64 octets, respectively, can be used instead of 256 and 512-bit output hash algorithms, such as SHA256 and SHA512.

3.3. Public Keys

In CMS, the signer's public key algorithm identifiers are located in the OriginatorPublicKey's algorithm attribute. The conventions and encoding for RSASSA-PSS and ECDSA public keys algorithm identifiers are as specified in Section 2.3 of [RFC3279], Section 3.1 of [RFC4055], and Section 2.1 of [RFC5480].

Traditionally, the rsaEncryption object identifier is used to identify RSA public keys. The rsaEncryption object identifier continues to identify the public key when the RSA private key owner does not wish to limit the use of the public key exclusively to RSASSA-PSS with SHAKEs. When the RSA private key owner wishes to limit the use of the public key exclusively to RSASSA-PSS, the AlgorithmIdentifier for RSASSA-PSS defined in Section 2 SHOULD be used as the algorithm attribute in the OriginatorPublicKey sequence. Conforming client implementations that process RSASSA-PSS with SHAKE public keys in CMS message MUST recognize the corresponding OIDs in Section 2.

Conforming implementations MUST specify and process the algorithms explicitly by using the OIDs specified in Section 2 when encoding ECDSA with SHAKE public keys in CMS messages.

The identifier parameters, as explained in Section 2, MUST be absent.

3.4. Message Authentication Codes

Keccak message authentication code (KMAC) is specified in [SP800-185]. In CMS, KMAC algorithm identifiers are located in the AuthenticatedData macAlgorithm field. The KMAC values are located in the AuthenticatedData mac field.

When the id-KmacWithSHAKE128 or id-KmacWithSHAKE256 OID is used as the MAC algorithm identifier, the parameters field is optional (absent or present). If absent, the SHAKE256 output length used in KMAC is 32 or 64 bytes, respectively, and the customization string is an empty string by default.

Conforming implementations that process KMACs with the SHAKEs when processing CMS data MUST recognize these identifiers.

When calculating the KMAC output, the variable N is 0xD2B282C2, S is an empty string, and L (the integer representing the requested output length in bits) is 256 or 512 for KmacWithSHAKE128 or KmacWithSHAKE256, respectively, in this specification.

4. IANA Considerations

One object identifier for the ASN.1 module in Appendix A was updated in the "Structure of Management Information (SMI) Security for S/MIME Module Identifier (1.2.840.113549.1.9.16.0)" registry:

Decimal	Description	References
70	CMSAlgsForSHAKE-2019	RFC 8702

Table 1

5. Security Considerations

This document updates [RFC3370]. The security considerations section of that document applies to this specification as well.

NIST has defined appropriate use of the hash functions in terms of

the algorithm strengths and expected time frames for secure use in Special Publications (SPs) [SP800-78-4] and [SP800-107]. These documents can be used as guides to choose appropriate key sizes for various security scenarios.

SHAKE128 with an output length of 32 bytes offers 128 bits of collision and preimage resistance. Thus, SHAKE128 OIDs in this specification are RECOMMENDED with a 2048- (112-bit security) or 3072-bit (128-bit security) RSA modulus or curves with a group order of 256 bits (128-bit security). SHAKE256 with a 64-byte output length offers 256 bits of collision and preimage resistance. Thus, the SHAKE256 OIDs in this specification are RECOMMENDED with 4096-bit RSA modulus or higher or curves with group order of at least 512 bits, such as NIST curve P-521 (256-bit security). Note that we recommended a 4096-bit RSA because we would need a 15360-bit modulus for 256 bits of security, which is impractical for today's technology.

When more than two parties share the same message-authentication key, data origin authentication is not provided. Any party that knows the message-authentication key can compute a valid MAC; therefore, the content could originate from any one of the parties.

6. References

6.1. Normative References

- [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>>.
- [RFC3370] Housley, R., "Cryptographic Message Syntax (CMS) Algorithms", RFC 3370, DOI 10.17487/RFC3370, August 2002, <<https://www.rfc-editor.org/info/rfc3370>>.
- [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, DOI 10.17487/RFC4055, June 2005, <<https://www.rfc-editor.org/info/rfc4055>>.
- [RFC5480] Turner, S., Brown, D., Yiu, K., Housley, R., and T. Polk, "Elliptic Curve Cryptography Subject Public Key Information", RFC 5480, DOI 10.17487/RFC5480, March 2009, <<https://www.rfc-editor.org/info/rfc5480>>.
- [RFC5652] Housley, R., "Cryptographic Message Syntax (CMS)", STD 70, RFC 5652, DOI 10.17487/RFC5652, September 2009, <<https://www.rfc-editor.org/info/rfc5652>>.
- [RFC8017] Moriarty, K., Ed., Kaliski, B., Jonsson, J., and A. Rusch, "PKCS #1: RSA Cryptography Specifications Version 2.2", RFC 8017, DOI 10.17487/RFC8017, November 2016, <<https://www.rfc-editor.org/info/rfc8017>>.
- [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>>.
- [SHA3] National Institute of Standards and Technology (NIST), "SHA-3 Standard: Permutation-Based Hash and Extendable-Output Functions", FIPS PUB 202, DOI 10.6028/NIST.FIPS.202, August 2015, <<https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.202.pdf>>.
- [SP800-185] National Institute of Standards and Technology (NIST), "SHA-3 Derived Functions: cSHAKE, KMAC, TupleHash and

ParallelHash", NIST Special Publication 800-185,
DOI 10.6028/NIST.SP.800-185, December 2016,
<[http://nvlpubs.nist.gov/nistpubs/SpecialPublications/
NIST.SP.800-185.pdf](http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-185.pdf)>.

6.2. Informative References

- [CMS-SHA3] Housley, R., "Use of the SHA3 One-way Hash Functions in the Cryptographic Message Syntax (CMS)", Work in Progress, Internet-Draft, draft-housley-lamps-cms-sha3-hash-00, 27 March 2017, <<https://tools.ietf.org/html/draft-housley-lamps-cms-sha3-hash-00>>.
- [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, DOI 10.17487/RFC3279, April 2002, <<https://www.rfc-editor.org/info/rfc3279>>.
- [RFC5753] Turner, S. and D. Brown, "Use of Elliptic Curve Cryptography (ECC) Algorithms in Cryptographic Message Syntax (CMS)", RFC 5753, DOI 10.17487/RFC5753, January 2010, <<https://www.rfc-editor.org/info/rfc5753>>.
- [RFC5911] Hoffman, P. and J. Schaad, "New ASN.1 Modules for Cryptographic Message Syntax (CMS) and S/MIME", RFC 5911, DOI 10.17487/RFC5911, June 2010, <<https://www.rfc-editor.org/info/rfc5911>>.
- [RFC6268] Schaad, J. and S. Turner, "Additional New ASN.1 Modules for the Cryptographic Message Syntax (CMS) and the Public Key Infrastructure Using X.509 (PKIX)", RFC 6268, DOI 10.17487/RFC6268, July 2011, <<https://www.rfc-editor.org/info/rfc6268>>.
- [RFC6979] Pornin, T., "Deterministic Usage of the Digital Signature Algorithm (DSA) and Elliptic Curve Digital Signature Algorithm (ECDSA)", RFC 6979, DOI 10.17487/RFC6979, August 2013, <<https://www.rfc-editor.org/info/rfc6979>>.
- [RFC8692] Kampanakis, P. and Q. Dang, "Internet X.509 Public Key Infrastructure: Additional Algorithm Identifiers for RSASSA-PSS and ECDSA Using SHAKEs", RFC 8692, DOI 10.17487/RFC8692, December 2019, <<https://www.rfc-editor.org/info/rfc8692>>.
- [SEC1] Standards for Efficient Cryptography Group, "SEC 1: Elliptic Curve Cryptography", May 2009, <<http://www.secg.org/sec1-v2.pdf>>.
- [shake-nist-oids]
National Institute of Standards and Technology (NIST),
"Computer Security Objects Register", October 2019,
<<https://csrc.nist.gov/Projects/Computer-Security-Objects-Register/Algorithm-Registration>>.
- [SP800-107]
National Institute of Standards and Technology (NIST),
"Recommendation for Applications Using Approved Hash Algorithms", Draft NIST Special Publication 800-107 Revised, August 2012,
<[https://nvlpubs.nist.gov/nistpubs/Legacy/SP/
nistspecialpublication800-107r1.pdf](https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-107r1.pdf)>.
- [SP800-78-4]
National Institute of Standards and Technology (NIST),
"Cryptographic Algorithms and Key Sizes for Personal Identity Verification", NIST Special Publication 800-78-4, DOI 10.6028/NIST.SP.800-78-4, May 2015,
<[https://nvlpubs.nist.gov/nistpubs/SpecialPublications/
NIST.SP.800-78-4.pdf](https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-78-4.pdf)>.

[X9.62] American National Standard for Financial Services (ANSI),
"Public Key Cryptography for the Financial Services
Industry: the Elliptic Curve Digital Signature Algorithm
(ECDSA)", ANSI X9.62, November 2005.

Appendix A. ASN.1 Module

This appendix includes the ASN.1 modules for SHAKEs in CMS. This module includes some ASN.1 from other standards for reference.

```
CMSAlgsForSHAKE-2019 { iso(1) member-body(2) us(840)
  rsadsi(113549) pkcs(1) pkcs-9(9) smime(16) modules(0)
  id-mod-cms-shakes-2019(70) }
```

```
DEFINITIONS EXPLICIT TAGS ::=
```

```
BEGIN
```

```
-- EXPORTS ALL;
```

```
IMPORTS
```

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

```
RSAPublicKey, rsaEncryption, id-ecPublicKey
FROM PKIXAlgs-2009 { iso(1) identified-organization(3) dod(6)
  internet(1) security(5) mechanisms(5) pkix(7) id-mod(0)
  id-mod-pkix1-algorithms2008-02(56) }
```

```
sa-rsassaPssWithSHAKE128, sa-rsassaPssWithSHAKE256,
sa-ecdsaWithSHAKE128, sa-ecdsaWithSHAKE256
FROM PKIXAlgsForSHAKE-2019 {
  iso(1) identified-organization(3) dod(6)
  internet(1) security(5) mechanisms(5) pkix(7) id-mod(0)
  id-mod-pkix1-shakes-2019(94) } ;
```

```
-- Message digest Algorithms (mda-)
-- used in SignedData, SignerInfo, DigestedData,
-- and the AuthenticatedData digestAlgorithm
-- fields in CMS
```

```
-- This expands MessageAuthAlgs from [RFC5652] and
-- MessageDigestAlgs in [RFC5753]
```

```
-- MessageDigestAlgs DIGEST-ALGORITHM ::= {
--   mda-shake128 |
--   mda-shake256,
--   ...
-- }
```

```
--
-- One-Way Hash Functions
-- SHAKE128
```

```
mda-shake128 DIGEST-ALGORITHM ::= {
  IDENTIFIER id-shake128 -- with output length 32 bytes.
}
```

```
id-shake128 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2) country(16)
  us(840) organization(1) gov(101)
  csor(3) nistAlgorithm(4)
  hashAlgs(2) 11 }
```

```
-- SHAKE256
```

```
mda-shake256 DIGEST-ALGORITHM ::= {
  IDENTIFIER id-shake256 -- with output length 64 bytes.
}
```

```
id-shake256 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2) country(16)
```

```

                                us(840) organization(1) gov(101)
                                csor(3) nistAlgorithm(4)
                                hashAlgs(2) 12 }

--
-- Public key algorithm identifiers located in the
-- OriginatorPublicKey's algorithm attribute in CMS.
-- And Signature identifiers used in SignerInfo
-- signatureAlgorithm field of signed-data content
-- type and countersignature attribute in CMS.
--
-- From RFC 5280, for reference:
-- rsaEncryption OBJECT IDENTIFIER ::= { pkcs-1 1 }
-- When the rsaEncryption algorithm identifier is used
-- for a public key, the AlgorithmIdentifier parameters
-- field MUST contain NULL.
--
id-RSASSA-PSS-SHAKE128 OBJECT IDENTIFIER ::= { iso(1)
    identified-organization(3) dod(6) internet(1)
    security(5) mechanisms(5) pkix(7) algorithms(6) 30 }

id-RSASSA-PSS-SHAKE256 OBJECT IDENTIFIER ::= { iso(1)
    identified-organization(3) dod(6) internet(1)
    security(5) mechanisms(5) pkix(7) algorithms(6) 31 }

-- When the id-RSASSA-PSS-* algorithm identifiers are used
-- for a public key or signature in CMS, the AlgorithmIdentifier
-- parameters field MUST be absent. The message digest algorithm
-- used in RSASSA-PSS MUST be SHAKE128 or SHAKE256 with a 32- or
-- 64-byte output length, respectively. The mask generation
-- function MUST be SHAKE128 or SHAKE256 with an output length
-- of (8*ceil((n-1)/8) - 264) or (8*ceil((n-1)/8) - 520) bits,
-- respectively, where n is the RSA modulus in bits.
-- The RSASSA-PSS saltLength MUST be 32 or 64 bytes, respectively.
-- The trailerField MUST be 1, which represents the trailer
-- field with hexadecimal value 0xBC. Regardless of
-- id-RSASSA-PSS-* or rsaEncryption being used as the
-- AlgorithmIdentifier of the OriginatorPublicKey, the RSA
-- public key MUST be encoded using the RSAPublicKey type.

-- From RFC 4055, for reference:
-- RSAPublicKey ::= SEQUENCE {
--     modulus INTEGER, -- -- n
--     publicExponent INTEGER } -- -- e

id-ecdsa-with-shake128 OBJECT IDENTIFIER ::= { iso(1)
    identified-organization(3) dod(6) internet(1)
    security(5) mechanisms(5) pkix(7) algorithms(6) 32 }

id-ecdsa-with-shake256 OBJECT IDENTIFIER ::= { iso(1)
    identified-organization(3) dod(6) internet(1)
    security(5) mechanisms(5) pkix(7) algorithms(6) 33 }

-- When the id-ecdsa-with-shake* algorithm identifiers are
-- used in CMS, the AlgorithmIdentifier parameters field
-- MUST be absent and the signature algorithm should be
-- deterministic ECDSA [RFC6979]. The message digest MUST
-- be SHAKE128 or SHAKE256 with a 32- or 64-byte output
-- length, respectively. In both cases, the ECDSA public key,
-- MUST be encoded using the id-ecPublicKey type.

-- From RFC 5480, for reference:
-- id-ecPublicKey OBJECT IDENTIFIER ::= {
--     iso(1) member-body(2) us(840) ansi-X9-62(10045) keyType(2) 1 }
-- The id-ecPublicKey parameters must be absent or present
-- and are defined as:
-- ECPParameters ::= CHOICE {
--     namedCurve          OBJECT IDENTIFIER
--     -- -- implicitCurve  NULL
--     -- -- specifiedCurve SpecifiedECDomain
-- }

```

```

-- This expands SignatureAlgs from [RFC5912]
--
-- SignatureAlgs SIGNATURE-ALGORITHM ::= {
--   sa-rsaspssWithSHAKE128 |
--   sa-rsaspssWithSHAKE256 |
--   sa-ecdsaWithSHAKE128 |
--   sa-ecdsaWithSHAKE256,
--   ...
-- }

-- This expands MessageAuthAlgs from [RFC5652] and [RFC6268]
--
-- Message Authentication (maca-) Algorithms
-- used in AuthenticatedData macAlgorithm in CMS
--
MessageAuthAlgs MAC-ALGORITHM ::= {
    maca-KMACwithSHAKE128 |
    maca-KMACwithSHAKE256,
    ...
}

-- This expands SMimeCaps from [RFC5911]
--
SMimeCaps SMIME-CAPS ::= {
    -- sa-rsaspssWithSHAKE128.&smimeCaps |
    -- sa-rsaspssWithSHAKE256.&smimeCaps |
    -- sa-ecdsaWithSHAKE128.&smimeCaps |
    -- sa-ecdsaWithSHAKE256.&smimeCaps,
    maca-KMACwithSHAKE128.&smimeCaps |
    maca-KMACwithSHAKE256.&smimeCaps,
    ...
}

--
-- KMAC with SHAKE128
maca-KMACwithSHAKE128 MAC-ALGORITHM ::= {
    IDENTIFIER id-KMACwithSHAKE128
    PARAMS TYPE KMACwithSHAKE128-params ARE optional
        -- If KMACwithSHAKE128-params parameters are absent,
        -- the SHAKE128 output length used in KMAC is 256 bits
        -- and the customization string is an empty string.
    IS-KEYED-MAC TRUE
    SMIME-CAPS {IDENTIFIED BY id-KMACwithSHAKE128}
}
id-KMACwithSHAKE128 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
    country(16) us(840) organization(1)
    gov(101) csor(3) nistAlgorithm(4)
    hashAlgs(2) 19 }
KMACwithSHAKE128-params ::= SEQUENCE {
    kMACOutputLength INTEGER DEFAULT 256, -- Output length in bits
    customizationString OCTET STRING DEFAULT ''H
}

-- KMAC with SHAKE256
maca-KMACwithSHAKE256 MAC-ALGORITHM ::= {
    IDENTIFIER id-KMACwithSHAKE256
    PARAMS TYPE KMACwithSHAKE256-params ARE optional
        -- If KMACwithSHAKE256-params parameters are absent,
        -- the SHAKE256 output length used in KMAC is 512 bits
        -- and the customization string is an empty string.
    IS-KEYED-MAC TRUE
    SMIME-CAPS {IDENTIFIED BY id-KMACwithSHAKE256}
}
id-KMACwithSHAKE256 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
    country(16) us(840) organization(1)
    gov(101) csor(3) nistAlgorithm(4)
    hashAlgs(2) 20 }
KMACwithSHAKE256-params ::= SEQUENCE {
    kMACOutputLength INTEGER DEFAULT 512, -- Output length in bits
    customizationString OCTET STRING DEFAULT ''H
}

```

}

END

Acknowledgements

This document is based on Russ Housley's document [CMS-SHA3]. It replaces SHA3 hash functions by SHAKE128 and SHAKE256, as the LAMPS WG agreed.

The authors would like to thank Russ Housley for his guidance and very valuable contributions with the ASN.1 module. Valuable feedback was also provided by Eric Rescorla.

Authors' Addresses

Panos Kampanakis
Cisco Systems

Email: pkampana@cisco.com

Quynh Dang
NIST
100 Bureau Drive
Gaithersburg, MD 20899
United States of America

Email: quynh.Dang@nist.gov