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**Use of the SHAKE One-way Hash Functions in the Cryptographic Message
Syntax (CMS)
draft-ietf-lamps-cms-shakes-18**

Abstract

This document updates the "Cryptographic Message Syntax Algorithms" ([RFC3370](#)) 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 and ECDSA signature algorithms. The conventions for the associated signer public keys in CMS are also described.

Status of This Memo

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[1.](#) Change Log

[EDNOTE: Remove this section before publication.]

[o \[draft-ietf-lamps-cms-shake-18\]\(#\):](#)

- * Minor ASN.1 changes.

[o \[draft-ietf-lamps-cms-shake-17\]\(#\):](#)

- * Minor updates for EDNOTE accuracy.

[o \[draft-ietf-lamps-cms-shake-16\]\(#\):](#)

- * Minor nits.
- * Using bytes instead of bits for consistency.

[o \[draft-ietf-lamps-cms-shake-15\]\(#\):](#)

- * Minor editorial nits.

- o [draft-ietf-lamps-cms-shake-14](#):
 - * Fixing error with incorrect preimage resistance bits for SHA128 and SHA256.
- o [draft-ietf-lamps-cms-shake-13](#):
 - * Addressing comments from Dan M.'s secdir review.
 - * Addressing comment from Scott B.'s opsdireview about references in the abstract.
- o [draft-ietf-lamps-cms-shake-12](#):
 - * Nits identified by Roman, Barry L. in ballot position review.
- o [draft-ietf-lamps-cms-shake-11](#):
 - * Minor nits.
 - * Nits identified by Roman in AD Review.
- o [draft-ietf-lamps-cms-shake-10](#):
 - * Updated IANA considerations section to request for OID assignments.
- o [draft-ietf-lamps-cms-shake-09](#):
 - * Fixed minor text nit.
 - * Updates in Sec Considerations section.
- o [draft-ietf-lamps-cms-shake-08](#):
 - * id-shake128-len and id-shake256-len were replaced with id-sha128 with 32 bytes output length and id-shake256 with 64 bytes output length.
 - * Fixed a discrepancy between [section 3](#) and 4.4 about the KMAC OIDs that have parameters as optional.
- o [draft-ietf-lamps-cms-shake-07](#):
 - * Small nit from Russ while in WGLC.
- o [draft-ietf-lamps-cms-shake-06](#):

- * Incorporated Eric's suggestion from WGLC.
- o [draft-ietf-lamps-cms-shake-05](#):
 - * Added informative references.
 - * Updated ASN.1 so it compiles.
 - * Updated IANA considerations.
- o [draft-ietf-lamps-cms-shake-04](#):
 - * Added [RFC8174](#) reference and text.
 - * Explicitly explained why RSASSA-PSS-params are omitted in [section 4.2.1](#).
 - * Simplified Public Keys section by removing redundant info from RFCs.
- o [draft-ietf-lamps-cms-shake-03](#):
 - * Removed paragraph suggesting KMAC to be used in generating k in Deterministic ECDSA. That should be [RFC6979](#)-bis.
 - * Removed paragraph from Security Considerations that talks about randomness of k because we are using deterministic ECDSA.
 - * Completed ASN.1 module and fixed KMAC ASN.1 based on Jim's feedback.
 - * Text fixes.
- o [draft-ietf-lamps-cms-shake-02](#):
 - * Updates based on suggestions and clarifications by Jim.
 - * Started ASN.1 module.
- o [draft-ietf-lamps-cms-shake-01](#):
 - * Significant reorganization of the sections to simplify the introduction, the new OIDs and their use in CMS.
 - * Added new OIDs for RSASSA-PSS that hardcodes hash, salt and MGF, according the WG consensus.

- * Updated Public Key section to use the new RSASSA-PSS OIDs and clarify the algorithm identifier usage.
- * Removed the no longer used SHAKE OIDs from [section 3.1](#).
- o [draft-ietf-lamps-cms-shake-00](#):
 - * Various updates to title and section names.
 - * Content changes filling in text and references.
- o [draft-dang-lamps-cms-shakes-hash-00](#):
 - * Initial version

2. Introduction

The "Cryptographic Message Syntax (CMS)" [[RFC5652](#)] is 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 [RFC3370](#) 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 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 $\text{SHAKE}(M, d)$ where the output is a d -bits-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 (Appendix A.1 [[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, 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 meaning.

2.1. 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.

3. 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.

[I-D.ietf-lamps-pkix-shake] [EDNOTE: Update reference with the RFC when it is published.] 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.

[I-D.ietf-lamps-pkix-shake] [EDNOTE: Update reference with the RFC when it is published.] 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.

Two object identifiers for KMACs using SHAKE128 and SHAKE256 as defined in by the National Institute of Standards and Technology (NIST) in [[shake-nist-oids](#)] 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.

[Section 4.1](#), [Section 4.2.1](#), [Section 4.2.2](#) and [Section 4.4](#) specify the required output length for each use of SHAKE128 or SHAKE256 in message digests, RSASSA-PSS, ECDSA and KMAC.

4. Use in CMS

4.1. Message Digests

The id-shake128 and id-shake256 OIDs ([Section 3](#)) 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 signerInfo. In addition, digest values are input to signature algorithms. The digest algorithm MUST be the same as the message hash algorithms used in signatures.

4.2. Signatures

In CMS, signature algorithm identifiers are located in the `SignerInfo` `signatureAlgorithm` field of `SignedData` content type and `countersignature` attribute. Signature values are located in the `SignerInfo` `signature` field of `SignedData` 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 3](#).

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 6](#) for more details.

4.2.1. RSASSA-PSS Signatures

The RSASSA-PSS algorithm is defined in [\[RFC8017\]](#). When `id-RSASSA-PSS-SHAKE128` or `id-RSASSA-PSS-SHAKE256` specified in [Section 3](#) 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 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 which 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 function, instead of the MGF1 algorithm that uses the hash function in multiple iterations as specified in Section 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 the seed from which mask is generated, an octet string [\[RFC8017\]](#). As explained in Step 9 of [section 9.1.1 of \[RFC8017\]](#), the output length of the MGF is $\text{emLen} - \text{hLen} - 1$ bytes. `emLen` is the maximum message length $\text{ceil}((n-1)/8)$, 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 $(8 * \text{emLen} - 264)$ or $(8 * \text{emLen} - 520)$ 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].

4.2.2. 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 3) 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, 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 CA implementations that generate ECDSA with SHAKE signatures in certificates or CRLs SHOULD generate such signatures with a deterministically generated, non-random 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.

4.3. 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 3](#) 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 3](#).

Conforming implementations MUST specify and process the algorithms explicitly by using the OIDs specified in [Section 3](#) when encoding ECDSA with SHAKE public keys in CMS messages.

The identifier parameters, as explained in [Section 3](#), MUST be absent.

4.4. Message Authentication Codes

KMAC 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.

5. IANA Considerations

One object identifier for the ASN.1 module in [Appendix A](#) was requested for the SMI Security for S/MIME Module Identifiers (1.2.840.113549.1.9.16.0) registry:

Decimal	Description	References
70	CMSAlgsForSHAKE-2019	[EDNOTE: THIS RFC]

6. 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 output length of 32 bytes offers 128-bits of collision and preimage resistance. Thus, SHAKE128 OIDs in this specification are RECOMMENDED with 2048 (112-bit security) or 3072-bit (128-bit security) RSA modulus or curves with group order of 256-bits (128-bit security). SHAKE256 with 64 bytes 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 4096-bit RSA because we would need 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.

7. Acknowledgements

This document is based on Russ Housley's draft [[I-D.housley-lamps-cms-sha3-hash](#)]. 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.

8. References

8.1. 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, U.S. Department of Commerce, "SHA-3 Standard - Permutation-Based Hash and Extendable-Output Functions", FIPS PUB 202, August 2015.
- [SP800-185] National Institute of Standards and Technology, "SHA-3 Derived Functions: cSHAKE, KMAC, TupleHash and ParallelHash. NIST SP 800-185", December 2016, <<http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-185.pdf>>.

8.2. Informative References

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[I-D.ietf-lamps-pkix-shake]

Kampanakis, P. and Q. Dang, "Internet X.509 Public Key Infrastructure: Additional Algorithm Identifiers for RSASSA-PSS and ECDSA using SHAKEs", [draft-ietf-lamps-pkix-shake-15](#) (work in progress), July 2019.

[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>>.

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[shake-nist-oids]

National Institute of Standards and Technology, "Computer Security Objects Register", October 2017, <<https://csrc.nist.gov/Projects/Computer-Security-Objects-Register/Algorithm-Registration>>.

[SP800-107]

National Institute of Standards and Technology (NIST),
 "SP800-107: Recommendation for Applications Using Approved
 Hash Algorithms", May 2014,
[<https://csrc.nist.gov/csrc/media/publications/sp/800-107/rev-1/final/documents/draft_revised_sp800-107.pdf>](https://csrc.nist.gov/csrc/media/publications/sp/800-107/rev-1/final/documents/draft_revised_sp800-107.pdf) .

[SP800-78-4]

National Institute of Standards and Technology (NIST),
 "SP800-78-4: Cryptographic Algorithms and Key Sizes for
 Personal Identity Verification", May 2014,
[<https://csrc.nist.gov/csrc/media/publications/sp/800-78/4/final/documents/sp800_78-4_revised_draft.pdf>](https://csrc.nist.gov/csrc/media/publications/sp/800-78/4/final/documents/sp800_78-4_revised_draft.pdf) .

[X9.62]

American National Standard for Financial Services (ANSI),
 "X9.62-2005 Public Key Cryptography for the Financial
 Services Industry: The Elliptic Curve Digital Signature
 Standard (ECDSA)", 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-rsaspssWithSHAKE128, sa-rsaspssWithSHAKE256,
```



```
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 SignedData content
-- type and countersignature attribute in CMS.
--
-- From RFC5280, 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 outout length, respectively. The mask generation
-- function MUST be SHAKE128 or SHAKE256 with an output length
-- of  $(8 \cdot \text{ceil}((n-1)/8) - 264)$  or  $(8 \cdot \text{ceil}((n-1)/8) - 520)$  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 RFC4055, 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 outout
-- length, respectively. In both cases, the ECDSA public key,
-- MUST be encoded using the id-ecPublicKey type.
```



```
-- From RFC5480, 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 SignatureAlgorithms from [RFC5912]
--
-- SignatureAlgs SIGNATURE-ALGORITHM ::= {
--   sa-rsassaPssWithSHAKE128 |
--   sa-rsassaPssWithSHAKE256 |
--   sa-ecdsaWithSHAKE128 |
--   sa-ecdsaWithSHAKE256,
--   ...
-- }

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

-- This expands SMimeCaps from [RFC5911]
--
SMimeCaps SMIME-CAPS ::= {
  -- sa-rsassaPssWithSHAKE128.&smimeCaps |
  -- sa-rsassaPssWithSHAKE256.&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
```

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