

Internet-Draft  
Intended status: Standards Track  
Expires: 10 October 2017

R. Housley  
Vigil Security  
10 April 2017

**Use of the Elliptic Curve Diffie-Hellman Key Agreement Algorithm  
with X25519 and X448 in the Cryptographic Message Syntax (CMS)**

[<draft-ietf-curdle-cms-ecdh-new-curves-03.txt>](mailto:ietf-curdle-cms-ecdh-new-curves-03.txt)

**Abstract**

This document describes the conventions for using Elliptic Curve Diffie-Hellman (ECDH) key agreement algorithm using curve25519 and curve448 in the Cryptographic Message Syntax (CMS).

**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 <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 10 October 2017.

**Copyright Notice**

Copyright (c) 2017 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 (<http://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.

## **1. Introduction**

This document describes the conventions for using Elliptic Curve Diffie-Hellman (ECDH) key agreement using curve25519 and curve448 [[CURVES](#)] in the Cryptographic Message Syntax (CMS) [[CMS](#)]. Key agreement is supported in three CMS content types: the enveloped-data content type [[CMS](#)], authenticated-data content type [[CMS](#)], and the authenticated-enveloped-data content type [[AUTHENV](#)].

The conventions for using some Elliptic Curve Cryptography (ECC) algorithms in CMS are described in [[CMSECC](#)]. These conventions cover the use of ECDH with some curves other than curve25519 and curve448 [[CURVES](#)]. Those other curves are not deprecated, but support for curve25519 and curve448 is encouraged.

Using curve25519 with Diffie-Hellman key agreement is referred to as X25519. Using curve448 with Diffie-Hellman key agreement is referred to as X448.

### **1.1. Terminology**

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[STDWORDS](#)].

### **1.2. ASN.1**

CMS values are generated using ASN.1 [[X680](#)], which uses the Basic Encoding Rules (BER) and the Distinguished Encoding Rules (DER) [[X690](#)].

## **2. Key Agreement**

In 1976, Diffie and Hellman described a means for two parties to agree upon a shared secret value in manner that prevents eavesdroppers from learning the shared secret value [[DH1976](#)]. This secret may then be converted into pairwise symmetric keying material for use with other cryptographic algorithms. Over the years, many variants of this fundamental technique have been developed. This document describes the conventions for using Ephemeral-Static Elliptic Curve Diffie-Hellman (ECDH) key agreement using X25519 and X448 [[CURVES](#)].

The originator uses an ephemeral public/private key pair that is generated on the same elliptic curve as the public key of the recipient. The ephemeral key pair is used for a single CMS protected content type, and then it is discarded. The originator obtains the



recipient's static public key from the recipient's certificate [\[PROFILE\]](#).

X25519 is described in Section 6.1 of [\[CURVES\]](#), and X448 is described in Section 6.2 of [\[CURVES\]](#). Since curve25519 and curve448 have cofactors of 8 and 4, respectively, an input point of small order will eliminate any contribution from the other party's private key. As described in Section 7 of [\[CURVES\]](#), implementations MAY detect this situation by checking for the all-zero output.

In [\[CURVES\]](#), the shared secret value that is produced by ECDH is called K. (In some other specifications, the shared secret value is called Z.) A key derivation function (KDF) is used to produce a pairwise key-encryption key from the shared secret value (K), the length of the key-encryption key, and the DER-encoded ECC-CMS-SharedInfo structure [\[CMSECC\]](#).

The ECC-CMS-SharedInfo definition from [\[CMSECC\]](#) is repeated here for convenience.

```
ECC-CMS-SharedInfo ::= SEQUENCE {  
    keyInfo          AlgorithmIdentifier,  
    entityUInfo [0] EXPLICIT OCTET STRING OPTIONAL,  
    suppPubInfo [2] EXPLICIT OCTET STRING }
```

The ECC-CMS-SharedInfo keyInfo field contains the object identifier of the key-encryption algorithm and associated parameters. This algorithm will be used to wrap the content-encryption key. For example, the AES Key Wrap algorithm [\[AESKW\]](#) does not need parameters, so the algorithm identifier parameters are absent.

The ECC-CMS-SharedInfo entityUInfo field optionally contains additional keying material supplied by the sending agent. Note that [\[CMS\]](#) requires implementations to accept a KeyAgreeRecipientInfo SEQUENCE that includes the ukm field. If the ukm field is present, the ukm is placed in the entityUInfo field. The ukm value need not be longer than the key-encryption key that will be produced by the KDF. When present, the ukm ensures that a different key-encryption key is generated, even when the originator ephemeral private key is improperly used more than once.

The ECC-CMS-SharedInfo suppPubInfo field contains the length of the generated key-encryption key, in bits, represented as a 32-bit number. For example, the key length for AES-256 [\[AES\]](#) would be 0x00000100.



### **2.1. ANSI-X9.63-KDF**

The ANSI-X9.63-KDF key derivation function is a simple construct based on a one-way hash function described in ANS X9.63 [[X963](#)]. This KDF is also described in Section 3.6.1 of [[SEC1](#)].

Three values are concatenated to produce the input string to the KDF:

1. The shared secret value generated by ECDH, K.
2. The iteration counter, starting with one, as described below.
3. The DER-encoded ECC-CMS-SharedInfo structure.

To generate a key-encryption key (KEK), the KDF generates one or more KM blocks, with the counter starting at 0x00000001, and incrementing the counter for each subsequent KM block until enough material has been generated. The 32-bit counter is represented in network byte order. The KM blocks are concatenated left to right to produce the pairwise key-encryption key, KEK:

$$\text{KM}(i) = \text{Hash}(K \parallel \text{INT32}(\text{counter}=i) \parallel \text{DER}(\text{ECC-CMS-SharedInfo}))$$
$$\text{KEK} = \text{KM}(\text{counter}=1) \parallel \text{KM}(\text{counter}=2) \dots$$

### **2.2. HKDF**

The HMAC-based Extract-and-Expand Key Derivation Function (HKDF) is a robust construct based on a one-way hash function described in [RFC 5869](#) [[HKDF](#)]. HKDF is comprised of two steps: HKDF-Extract followed by HKDF-Expand.

Three values are used as inputs to the HKDF:

1. The shared secret value generated by ECDH, K.
2. The length in octets of the keying data to be generated.
3. The DER-encoded ECC-CMS-SharedInfo structure.

The ECC-CMS-SharedInfo structure optionally includes the ukm. If the ukm is present, the ukm is also used as the HKDF salt.

The length of the generated key-encryption key is used two places, once in bits, and once in octets. The ECC-CMS-SharedInfo structure includes the length of the generated key-encryption key in bits. The HKDF-Expand function takes an argument for the length of the generated key-encryption key in octets.



In summary, to produce the pairwise key-encryption key, KEK:

```
if ukm is provided, then salt = ukm, else salt = zero
PRK = HKDF-Extract(salt, K)
```

```
KEK = HKDF-Expand(PRK, DER(ECC-CMS-SharedInfo), SizeInOctets(KEK))
```

### **3. Enveloped-data Conventions**

The CMS enveloped-data content type [CMS] consists of an encrypted content and wrapped content-encryption keys for one or more recipients. The ECDH key agreement algorithm is used to generate a pairwise key-encryption key between the originator and a particular recipient. Then, the key-encryption key is used to wrap the content-encryption key for that recipient. When there is more than one recipient, the same content-encryption key MUST be wrapped for each of them.

A compliant implementation MUST meet the requirements for constructing an enveloped-data content type in Section 6 of [CMS].

A content-encryption key MUST be randomly generated for each instance of an enveloped-data content type. The content-encryption key is used to encrypt the content.

#### **3.1. EnvelopedData Fields**

The enveloped-data content type is ASN.1 encoded using the EnvelopedData syntax. The fields of the EnvelopedData syntax MUST be populated as described in [CMS]; for the recipients that use X25519 or X448 the RecipientInfo kari choice MUST be used.

#### **3.2. KeyAgreeRecipientInfo Fields**

The fields of the KeyAgreeRecipientInfo syntax MUST be populated as described in this section when X25519 or X448 is employed for one or more recipients.

The KeyAgreeRecipientInfo version MUST be 3.

The KeyAgreeRecipientInfo originator provides three alternatives for identifying the originator's public key, and the originatorKey alternative MUST be used. The originatorKey MUST contain an ephemeral key for the originator. The originatorKey algorithm field MUST contain the id-ecPublicKey object identifier along with ECPParameters as specified in [PKIXECC]. The originator's ephemeral public key MUST be encoded using the type ECPoint as specified in



[[CMSECC](#)]. As a convenience, the definitions are repeated here:

```
id-ecPublicKey OBJECT IDENTIFIER ::= {
    iso(1) member-body(2) us(840) ansi-X9-62(10045) keyType(2) 1 }

ECPoint ::= OCTET STRING

ECParameters ::= CHOICE {
    namedCurve          OBJECT IDENTIFIER
    -- implicitCurve     NULL --
    -- specifiedCurve     SpecifiedECDomain -- }
```

The object identifiers for X25519 and X448 have been assigned in [[ID.curdle-pkix](#)]. They are repeated below for convenience.

When using X25519, the ECPoint contains exactly 32 octets, and the ECParameters namedCurve MUST contain the following object identifier:

```
id-X25519 OBJECT IDENTIFIER ::= { 1 3 101 110 }
```

When using X448, the ECPoint contains exactly 56 octets, and the ECParameters namedCurve MUST contain the following object identifier:

```
id-X448 OBJECT IDENTIFIER ::= { 1 3 101 111 }
```

KeyAgreeRecipientInfo ukm is optional. Note that [[CMS](#)] requires implementations to accept a KeyAgreeRecipientInfo SEQUENCE that includes the ukm field. If present, the ukm is placed in the entityUIInfo field of the ECC-CMS-SharedInfo as input to the KDF. The ukm value need not be longer than the key-encryption key produced by the KDF.

KeyAgreeRecipientInfo keyEncryptionAlgorithm MUST contain the object identifier of the key-encryption algorithm that will be used to wrap the content-encryption key. The conventions for using AES-128, AES-192, and AES-256 in the key wrap mode are specified in [[CMSAES](#)].

KeyAgreeRecipientInfo recipientEncryptedKeys includes a recipient identifier and encrypted key for one or more recipients. The RecipientEncryptedKey KeyAgreeRecipientIdentifier MUST contain either the issuerAndSerialNumber identifying the recipient's certificate or the RecipientKeyIdentifier containing the subject key identifier from the recipient's certificate. In both cases, the recipient's certificate contains the recipient's static X25519 or X448 public key. RecipientEncryptedKey EncryptedKey MUST contain the content-encryption key encrypted with the pairwise key-encryption key using the algorithm specified by the KeyWrapAlgorithm.



#### **4. Authenticated-data Conventions**

The CMS authenticated-data content type [[CMS](#)] consists an authenticated content, a message authentication code (MAC), and encrypted authentication keys for one or more recipients. The ECDH key agreement algorithm is used to generate a pairwise key-encryption key between the originator and a particular recipient. Then, the key-encryption key is used to wrap the authentication key for that recipient. When there is more than one recipient, the same authentication key **MUST** be wrapped for each of them.

A compliant implementation **MUST** meet the requirements for constructing an authenticated-data content type in Section 9 of [[CMS](#)].

A authentication key **MUST** be randomly generated for each instance of an authenticated-data content type. The authentication key is used to compute the MAC over the content.

##### **4.1. AuthenticatedData Fields**

The authenticated-data content type is ASN.1 encoded using the AuthenticatedData syntax. The fields of the AuthenticatedData syntax **MUST** be populated as described in [[CMS](#)]; for the recipients that use X25519 or X448 the RecipientInfo kari choice **MUST** be used.

##### **4.2. KeyAgreeRecipientInfo Fields**

The fields of the KeyAgreeRecipientInfo syntax **MUST** be populated as described in [Section 3.2](#) of this document.

#### **5. Authenticated-Enveloped-data Conventions**

The CMS authenticated-enveloped-data content type [[AUTHENV](#)] consists of an authenticated and encrypted content and encrypted content-authenticated-encryption keys for one or more recipients. The ECDH key agreement algorithm is used to generate a pairwise key-encryption key between the originator and a particular recipient. Then, the key-encryption key is used to wrap the content-authenticated-encryption key for that recipient. When there is more than one recipient, the same content-authenticated-encryption key **MUST** be wrapped for each of them.

A compliant implementation **MUST** meet the requirements for constructing an authenticated-data content type in Section 2 of [[AUTHENV](#)].

A content-authenticated-encryption key **MUST** be randomly generated for



each instance of an authenticated-enveloped-data content type. The content-authenticated-encryption key key is used to authenticate and encrypt the content.

### **5.1. AuthEnvelopedData Fields**

The authenticated-enveloped-data content type is ASN.1 encoded using the AuthEnvelopedData syntax. The fields of the AuthEnvelopedData syntax MUST be populated as described in [\[AUTHENV\]](#); for the recipients that use X25519 or X448 the RecipientInfo kari choice MUST be used.

### **5.2. KeyAgreeRecipientInfo Fields**

The fields of the KeyAgreeRecipientInfo syntax MUST be populated as described in [Section 3.2](#) of this document.

## **6. Certificate Conventions**

[RFC 5280](#) [\[PROFILE\]](#) specifies the profile for using X.509 Certificates in Internet applications. A recipient static public key is needed for X25519 or X448, and the originator obtains that public key from the recipient's certificate. The conventions for carrying X25519 and X448 public keys are specified in [\[ID.curdle-pkix\]](#).

## **7. Key Agreement Algorithm Identifiers**

The following object identifiers are assigned in [\[CMSECC\]](#) to indicate ECDH with ANSI-X9.63-KDF using various one-way hash functions. These are expected to be used as AlgorithmIdentifiers with a parameter that specifies the key-encryption algorithm. These are repeated here for convenience.

```
secg-scheme OBJECT IDENTIFIER ::= {
  iso(1) identified-organization(3) certicom(132) schemes(1) }

dhSinglePass-stdDH-sha256kdf-scheme OBJECT IDENTIFIER ::= {
  secg-scheme 11 1 }

dhSinglePass-stdDH-sha384kdf-scheme OBJECT IDENTIFIER ::= {
  secg-scheme 11 2 }

dhSinglePass-stdDH-sha512kdf-scheme OBJECT IDENTIFIER ::= {
  secg-scheme 11 3 }
```

The following object identifiers are assigned to indicate ECDH with HKDF using various one-way hash functions. These are expected to be used as AlgorithmIdentifiers with a parameter that specifies the



key-encryption algorithm.

```
smime-alg OBJECT IDENTIFIER ::= {  
    iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1)  
    pkcs-9(9) smime(16) alg(3) }  
  
dhSinglePass-stdDH-hkdf-sha256-scheme OBJECT IDENTIFIER ::= {  
    smime-alg TBD1 }  
  
dhSinglePass-stdDH-hkdf-sha384-scheme OBJECT IDENTIFIER ::= {  
    smime-alg TBD2 }  
  
dhSinglePass-stdDH-hkdf-sha512-scheme OBJECT IDENTIFIER ::= {  
    smime-alg TBD3 }
```

## 8. SMIMECapabilities Attribute Conventions

A sending agent MAY announce to other agents that it supports ECDH key agreement using the SMIMECapabilities signed attribute in a signed message [[SMIME](#)] or a certificate [[CERTCAP](#)]. Following the pattern established in [[CMSECC](#)], the SMIMECapabilities associated with ECDH carries a DER-encoded object identifier that identifies support for ECDH in conjunction with a particular KDF, and it includes a parameter that names the key wrap algorithm.

The following SMIMECapabilities values (in hexadecimal) from [[CMSECC](#)] might be of interest to implementations that support X25519 and X448:

ECDH with ANSI-X9.63-KDF using SHA-256; uses AES-128 key wrap:  
30 15 06 06 2B 81 04 01 0B 01 30 0B 06 09 60 86 48 01 65 03 04  
01 05

ECDH with ANSI-X9.63-KDF using SHA-384; uses AES-128 key wrap:  
30 15 06 06 2B 81 04 01 0B 02 30 0B 06 09 60 86 48 01 65 03 04  
01 05

ECDH with ANSI-X9.63-KDF using SHA-512; uses AES-128 key wrap:  
30 15 06 06 2B 81 04 01 0B 03 30 0B 06 09 60 86 48 01 65 03 04  
01 05

ECDH with ANSI-X9.63-KDF using SHA-256; uses AES-256 key wrap:  
30 15 06 06 2B 81 04 01 0B 01 30 0B 06 09 60 86 48 01 65 03 04  
01 2D

ECDH with ANSI-X9.63-KDF using SHA-384; uses AES-256 key wrap:  
30 15 06 06 2B 81 04 01 0B 02 30 0B 06 09 60 86 48 01 65 03 04  
01 2D



ECDH with ANSI-X9.63-KDF using SHA-512; uses AES-256 key wrap:

30 15 06 06 2B 81 04 01 0B 03 30 0B 06 09 60 86 48 01 65 03 04  
01 2D

The following SMIMECapabilities values (in hexadecimal) based on the algorithm identifiers in [Section 7](#) of this document might be of interest to implementations that support X25519 and X448:

ECDH with HKDF using SHA-256; uses AES-128 key wrap:

TBD

ECDH with HKDF using SHA-384; uses AES-128 key wrap:

TBD

ECDH with HKDF using SHA-512; uses AES-128 key wrap:

TBD

ECDH with HKDF using SHA-256; uses AES-256 key wrap:

TBD

ECDH with HKDF using SHA-384; uses AES-256 key wrap:

TBD

ECDH with HKDF using SHA-512; uses AES-256 key wrap:

TBD

## 9. Security Considerations

Please consult the security considerations of [\[CMS\]](#) for security considerations related to the enveloped-data content type and the authenticated-data content type.

Please consult the security considerations of [\[AUTHENV\]](#) for security considerations related to the authenticated-enveloped-data content type.

Please consult the security considerations of [\[CURVES\]](#) for security considerations related to the use of X25519 and X448.

The originator uses an ephemeral public/private key pair that is generated on the same elliptic curve as the public key of the recipient. The ephemeral key pair is used for a single CMS protected content type, and then it is discarded. If the originator wants to be able to decrypt the content (for enveloped-data and authenticated-enveloped-data) or check the authentication (for authenticated-data), then the originator needs to treat themselves as a recipient.

As specified in [\[CMS\]](#), implementations MUST support processing of the



KeyAgreeRecipientInfo ukm field; this ensures that interoperability is not a concern whether the ukm is present or absent. The ukm is placed in the entityUInfo field of the ECC-CMS-SharedInfo structure. When present, the ukm ensures that a different key-encryption key is generated, even when the originator ephemeral private key is improperly used more than once.

## **10. IANA Considerations**

One object identifier for the ASN.1 module in the Appendix needs to be assigned in the SMI Security for S/MIME Module Identifiers (1.2.840.113549.1.9.16.0) [[IANA-MOD](#)] registry:

```
id-mod-cms-ecdh-alg-2017 OBJECT IDENTIFIER ::= {
    iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1)
    pkcs-9(9) smime(16) mod(0) TBD0 }
```

Three object identifiers for the Key Agreement Algorithm Identifiers in Sections 7 need to be assigned in the SMI Security for S/MIME Algorithms (1.2.840.113549.1.9.16.3) [[IANA-ALG](#)] registry:

```
smime-alg OBJECT IDENTIFIER ::= {
    iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1)
    pkcs-9(9) smime(16) alg(3) }

dhSinglePass-stdDH-hkdf-sha256-scheme OBJECT IDENTIFIER ::= {
    smime-alg TBD1 }

dhSinglePass-stdDH-hkdf-sha384-scheme OBJECT IDENTIFIER ::= {
    smime-alg TBD2 }

dhSinglePass-stdDH-hkdf-sha512-scheme OBJECT IDENTIFIER ::= {
    smime-alg TBD3 }
```

## **11. Normative References**

- [AUTHENV] Housley, R., "Cryptographic Message Syntax (CMS) Authenticated-Enveloped-Data Content Type", [RFC 5083](#), November 2007.
- [CERTCAP] Santesson, S., "X.509 Certificate Extension for Secure/Multipurpose Internet Mail Extensions (S/MIME) Capabilities", [RFC 4262](#), December 2005.
- [CMS] Housley, R., "Cryptographic Message Syntax (CMS)", [RFC 5652](#), September 2009.



- [CMSASN1] Hoffman, P., and J. Schaad, "New ASN.1 Modules for Cryptographic Message Syntax (CMS) and S/MIME", [RFC 5911](#), June 2010.
- [CMSECC] Turner, S., and D. Brown, "Use of Elliptic Curve Cryptography (ECC) Algorithms in Cryptographic Message Syntax (CMS)", [RFC 5753](#), January 2010.
- [CURVES] Langley, A., Hamburg, M., and S. Turner, "Elliptic Curves for Security", [RFC 7748](#), January 2016.
- [HKDF] Krawczyk, H., and P. Eronen, "HMAC-based Extract-and-Expand Key Derivation Function (HKDF)", [RFC 5869](#), May 2010.
- [ID.curdle-pkix] Josefsson, S., and J. Schaad, "Algorithm Identifiers for Ed25519, Ed25519ph, Ed448, Ed448ph, X25519 and X448 for use in the Internet X.509 Public Key Infrastructure", 15 August 2016, Work-in-progress.
- [PKIXALG] 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](#), April 2002.
- [PKIXECC] Turner, S., Brown, D., Yiu, K., Housley, R., and T. Polk, "Elliptic Curve Cryptography Subject Public Key Information", [RFC 5480](#), March 2009.
- [PROFILE] Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", [RFC 5280](#), May 2008.
- [SEC1] Standards for Efficient Cryptography Group, "SEC 1: Elliptic Curve Cryptography", version 2.0, May 2009, <<http://www.secg.org/sec1-v2.pdf>>.
- [SMIME] Ramsdell, B. and S. Turner, "Secure/Multipurpose Internet Mail Extensions (S/MIME) Version 3.2 Message Specification", [RFC 5751](#), January 2010.
- [STDWORDS] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), March 1997.



- [X680] ITU-T, "Information technology -- Abstract Syntax Notation One (ASN.1): Specification of basic notation", ITU-T Recommendation X.680, 2015.
- [X690] ITU-T, "Information technology -- ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)", ITU-T Recommendation X.690, 2015.

## **12. Informative References**

- [AES] National Institute of Standards and Technology. FIPS Pub 197: Advanced Encryption Standard (AES). 26 November 2001.
- [AESKW] Schaad, J., and R. Housley, "Advanced Encryption Standard (AES) Key Wrap Algorithm", [RFC 3394](#), September 2002.
- [CMSAES] Schaad, J., "Use of the Advanced Encryption Standard (AES) Encryption Algorithm in Cryptographic Message Syntax (CMS)", [RFC 3565](#), July 2003.
- [DH1976] Diffie, W., and M. E. Hellman, "New Directions in Cryptography", IEEE Trans. on Info. Theory, Vol. IT-22, Nov. 1976, pp. 644-654.
- [IANA-ALG] <https://www.iana.org/assignments/smi-numbers/smi-numbers.xhtml#security-smime-3>.
- [IANA-MOD] <https://www.iana.org/assignments/smi-numbers/smi-numbers.xhtml#security-smime-0>.
- [X963] "Public-Key Cryptography for the Financial Services Industry: Key Agreement and Key Transport Using Elliptic Curve Cryptography", American National Standard X9.63-2001, 2001.



## Appendix: ASN.1 Module

```
CMSECDHAlgs-2017
{ iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1) pkcs-9(9)
  smime(16) modules(0) id-mod-cms-ecdh-alg-2017(TBD0) }

DEFINITIONS IMPLICIT TAGS ::=
BEGIN

-- EXPORTS ALL

IMPORTS

KeyWrapAlgorithm
FROM CryptographicMessageSyntaxAlgorithms-2009 -- in [CMSASN1]
{ iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1)
  pkcs-9(9) smime(16) modules(0) id-mod-cmsalg-2001-02(37) }

KEY-AGREE, SMIME-CAPS
FROM AlgorithmInformation-2009 -- in [CMSASN1]
{ iso(1) identified-organization(3) dod(6) internet(1)
  security(5) mechanisms(5) pkix(7) id-mod(0)
  id-mod-algorithmInformation-02(58) }

dhSinglePass-stdDH-sha256kdf-scheme,
dhSinglePass-stdDH-sha384kdf-scheme,
dhSinglePass-stdDH-sha512kdf-scheme,
kaa-dhSinglePass-stdDH-sha256kdf-scheme,
kaa-dhSinglePass-stdDH-sha384kdf-scheme,
kaa-dhSinglePass-stdDH-sha512kdf-scheme,
cap-kaa-dhSinglePass-stdDH-sha256kdf-scheme,
cap-kaa-dhSinglePass-stdDH-sha384kdf-scheme,
cap-kaa-dhSinglePass-stdDH-sha512kdf-scheme
FROM CMSECCAlgs-2009-02 -- in [CMSECC]
{ iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1)
  pkcs-9(9) smime(16) modules(0)
  id-mod-cms-ecc-alg-2009-02(46) }
;
```



```
--
-- Object Identifiers
--

smime-alg OBJECT IDENTIFIER ::= {
    iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1)
    pkcs-9(9) smime(16) alg(3) }

dhSinglePass-stdDH-hkdf-sha256-scheme OBJECT IDENTIFIER ::= {
    smime-alg TBD1 }

dhSinglePass-stdDH-hkdf-sha384-scheme OBJECT IDENTIFIER ::= {
    smime-alg TBD2 }

dhSinglePass-stdDH-hkdf-sha512-scheme OBJECT IDENTIFIER ::= {
    smime-alg TBD3 }

--
-- Extend the Key Agreement Algorithms in [CMSECC]
--

KeyAgreementAlgs KEY-AGREE ::= { ...,
    kaa-dhSinglePass-stdDH-sha256kdf-scheme |
    kaa-dhSinglePass-stdDH-sha384kdf-scheme |
    kaa-dhSinglePass-stdDH-sha512kdf-scheme |
    kaa-dhSinglePass-stdDH-hkdf-sha256-scheme |
    kaa-dhSinglePass-stdDH-hkdf-sha384-scheme |
    kaa-dhSinglePass-stdDH-hkdf-sha512-scheme }

kaa-dhSinglePass-stdDH-hkdf-sha256-scheme KEY-AGREE ::= {
    IDENTIFIER dhSinglePass-stdDH-hkdf-sha256-scheme
    PARAMS TYPE KeyWrapAlgorithm ARE required
    UKM -- TYPE unencoded data -- ARE preferredPresent
    SMIME-CAPS cap-kaa-dhSinglePass-stdDH-hkdf-sha256-scheme }

kaa-dhSinglePass-stdDH-hkdf-sha384-scheme KEY-AGREE ::= {
    IDENTIFIER dhSinglePass-stdDH-hkdf-sha384-scheme
    PARAMS TYPE KeyWrapAlgorithm ARE required
    UKM -- TYPE unencoded data -- ARE preferredPresent
    SMIME-CAPS cap-kaa-dhSinglePass-stdDH-hkdf-sha384-scheme }

kaa-dhSinglePass-stdDH-hkdf-sha512-scheme KEY-AGREE ::= {
    IDENTIFIER dhSinglePass-stdDH-hkdf-sha512-scheme
    PARAMS TYPE KeyWrapAlgorithm ARE required
    UKM -- TYPE unencoded data -- ARE preferredPresent
    SMIME-CAPS cap-kaa-dhSinglePass-stdDH-hkdf-sha512-scheme }
```



```
--
-- Extend the S/MIME CAPS in [CMSECC]
--

SMimeCAPS SMIME-CAPS ::= { ...,
    kaa-dhSinglePass-stdDH-sha256kdf-scheme.&smimeCaps |
    kaa-dhSinglePass-stdDH-sha384kdf-scheme.&smimeCaps |
    kaa-dhSinglePass-stdDH-sha512kdf-scheme.&smimeCaps |
    kaa-dhSinglePass-stdDH-hkdf-sha256-scheme.&smimeCaps |
    kaa-dhSinglePass-stdDH-hkdf-sha384-scheme.&smimeCaps |
    kaa-dhSinglePass-stdDH-hkdf-sha512-scheme.&smimeCaps }

cap-kaa-dhSinglePass-stdDH-hkdf-sha256-scheme SMIME-CAPS ::= {
    TYPE KeyWrapAlgorithm
    IDENTIFIED BY dhSinglePass-stdDH-hkdf-sha256-scheme }

cap-kaa-dhSinglePass-stdDH-hkdf-sha384-scheme SMIME-CAPS ::= {
    TYPE KeyWrapAlgorithm
    IDENTIFIED BY dhSinglePass-stdDH-hkdf-sha384-scheme}

cap-kaa-dhSinglePass-stdDH-hkdf-sha512-scheme SMIME-CAPS ::= {
    TYPE KeyWrapAlgorithm
    IDENTIFIED BY dhSinglePass-stdDH-hkdf-sha512-scheme }

END
```

#### Acknowledgements

Many thanks to Daniel Migault, Jim Schaad, Stefan Santesson, and Sean Turner for their review and insightful suggestions.

#### Author's Address

Russ Housley  
918 Spring Knoll Drive  
Herndon, VA 20170  
USA  
housley@vigilsec.com

