      Using Authenticated Encryption Algorithms with the Encrypted Payload
           of the Internet Key Exchange version 2 (IKEv2) Protocol

Status of This Memo

   This document specifies an Internet standards track protocol for the
   Internet community, and requests discussion and suggestions for
   improvements.  Please refer to the current edition of the "Internet
   Official Protocol Standards" (STD 1) for the standardization state
   and status of this protocol.  Distribution of this memo is unlimited.

Abstract

   An authenticated encryption algorithm combines encryption and
   integrity into a single operation; such algorithms may also be
   referred to as combined modes of an encryption cipher or as combined
   mode algorithms.  This document describes the use of authenticated
   encryption algorithms with the Encrypted Payload of the Internet Key
   Exchange version 2 (IKEv2) protocol.

   The use of two specific authenticated encryption algorithms with the
   IKEv2 Encrypted Payload is also described; these two algorithms are
   the Advanced Encryption Standard (AES) in Galois/Counter Mode (AES
   GCM) and AES in Counter with CBC-MAC Mode (AES CCM).  Additional
   documents may describe the use of other authenticated encryption
   algorithms with the IKEv2 Encrypted Payload.

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1.  Introduction

   An authenticated encryption algorithm combines encryption and
   integrity into a single operation on plaintext data to produce
   ciphertext that includes an integrity check [RFC5116].  The integrity
   check may be an Integrity Check Value (ICV) that is logically
   distinct from the encrypted data, or the integrity check may be
   incorporated into the encrypted data that is produced.  Authenticated
   encryption algorithms may also be referred to as combined modes of
   operation of a block cipher or as combined mode algorithms.

   An Authenticated Encryption with Associated Data (AEAD) algorithm
   also provides integrity protection for additional data that is
   associated with the plaintext, but which is left unencrypted.  This
   document describes the use of AEAD algorithms with the Encrypted
   Payload of the Internet Key Exchange version 2 (IKEv2) protocol.  The
   use of two specific AEAD algorithms with the IKEv2 Encrypted Payload
   is also described; the two algorithms are the Advanced Encryption
   Standard (AES) in Galois/Counter Mode (AES GCM) [GCM] and AES in
   Counter with CBC-MAC Mode (AES CCM) [CCM].

   Version 1 of the Internet Key Exchange protocol (IKEv1) [RFC2409] is
   based on the Internet Security Association and Key Management
   Protocol (ISAKMP) [RFC2408].  The E (Encryption) bit in the ISAKMP
   header specifies that all payloads following the header are
   encrypted, but any data integrity verification of those payloads is
   handled by a separate Hash Payload or Signature Payload (see Sections
   3.1, 3.11, and 3.12 of [RFC2408]).  This separation of encryption
   from data integrity protection prevents the use of authenticated
   encryption with IKEv1, thus limiting initial specifications of AES
   combined mode usage for IPsec to the Encapsulating Security Payload
   (ESP) [RFC2406].  The current version of ESP is version 3, ESPv3
   [RFC4303].

   Version 2 of the Internet Key Exchange Protocol (IKEv2) [RFC4306]
   employs an Encrypted Payload that is based on the design of ESP.  The
   IKEv2 Encrypted Payload associates encryption and data integrity
   protection in a fashion that makes it possible to use AEAD
   algorithms.

1.1.  Conventions Used in This Document

   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 [RFC2119].

   The symbols or variables that designate authenticated encryption and
   decryption operation inputs and outputs (K, N, P, A, and C) are

defined in [RFC5116].  The SK_* symbols or variables that designate
specific IKEv2 keys are defined in [RFC4306].

2.  Structure of this Document

   This document is based on the RFCs that describe the usage of AES GCM
   [RFC4106] and AES CCM [RFC4309] with ESP; hence, the introductory
   material and specification of the modes in those documents are not
   repeated here.  The structure of this document follows the structure
   of those documents; many sections of this document indicate which
   sections of those two documents correspond, and call out any
   significant differences that implementers should be aware of.
   Significant portions of the text of this document have been adapted
   from those two documents.

   This document is based on the authenticated encryption interfaces,
   notation, and terminology described in [RFC5116].  An important
   departure from [RFC4106] and [RFC4309] is that these two RFCs
   describe separate ciphertext and integrity check outputs of the
   encryption operation, whereas [RFC5116] specifies a single ciphertext
   (C) output that includes an integrity check.  The latter more general
   approach encompasses authenticated encryption algorithms that produce
   a single, expanded ciphertext output into which the integrity check
   is incorporated, rather than producing separate ciphertext and
   integrity check outputs.

   For AES GCM and AES CCM, the [RFC5116] ciphertext (C) output of
   authenticated encryption consists of the [RFC4106] or [RFC4309]
   ciphertext output concatenated with the [RFC4106] or [RFC4309]
   Integrity Check Value (ICV) output.  This document does not modify
   the AES GCM or AES CCM authenticated encryption algorithms specified
   in [RFC4106] and [RFC4309].

3.  IKEv2 Encrypted Payload Data

   This section is based on [RFC5116] and Section 3.14 of [RFC4306].

   For the use of authenticated encryption algorithms with the IKEv2
   Encrypted Payload, this section updates Section 3.14 of [RFC4306] by
   replacing Figure 21 and the text that follows it (through the end of
   that section) with the contents of this section.  In addition,
   Section 3.14 of [RFC4306] is also updated to allow the use of a
   single authenticated encryption algorithm instead of a block cipher
   and a separate integrity check algorithm.  In contrast, Sections 3.1
   and 3.2 of this document are specific to the AES GCM and AES CCM
   algorithms and hence do not update [RFC4306].  The updates to
   [RFC4306] made by this document have no effect when authenticated
   encryption algorithms are neither proposed nor used.

The IKEv2 Encrypted Payload Data structure applies to all
authenticated encryption algorithms, and it is the same structure
that is used with ESP.  When an authenticated encryption algorithm is
used, the IKEv2 Encrypted Payload is composed of the payload header
fields, followed by an Initialization Vector (IV) field and a
Ciphertext (C) field that includes an integrity check as shown in
Figure 1.

```
                          1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ! Next Payload  !C!  RESERVED   !         Payload Length        !
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     !                        Initialization Vector                 !
     !  (length is specified by authenticated encryption algorithm) !
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ~                           Ciphertext                         ~
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
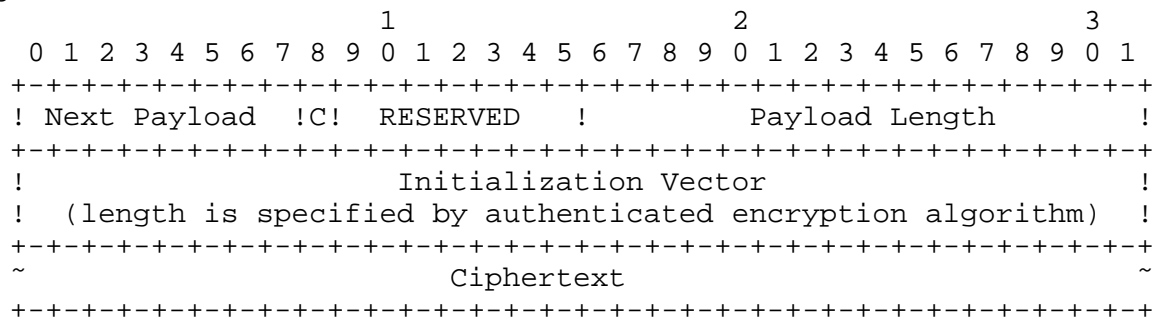
   Figure 1. IKEv2 Encrypted Payload Data for Authenticated Encryption

The Next Payload, C bit, and Payload Length fields are unchanged from
[RFC4306].

The contents of the Initialization Vector (IV) field are specified by
the authenticated encryption algorithm; see Sections 3.1 and 4
(below) for AES GCM and AES CCM.

The Ciphertext field is the output of an authenticated encryption
operation (see Section 2.1 of [RFC5116]) on the following inputs:

o   The secret key (K) is the cipher key obtained from the SK_ei or
    SK_er key, whichever is appropriate, see [RFC4306].  The
    authenticated encryption algorithm describes how to obtain the
    cipher key from SK_ei or SK_er; for AES GCM and AES CCM, see
    Section 7.1 (below).

o   The nonce (N) is specified by the authenticated encryption
    algorithm; for AES GCM and AES CCM, see Section 4 (below).  When
    decrypting an Encrypted Payload, a receiver constructs the nonce
    based on the IV in the Encrypted Payload, using rules that are
    specific to the authenticated encryption algorithm; see Sections
    3.1 and 4 (below) for AES GCM and AES CCM.

o   The plaintext (P) consists of the concatenation of the IKE
    Payloads to be encrypted with the Padding (if any) and the Pad
    Length, as shown in Figure 2 (below).  The plaintext structure in
    Figure 2 applies to all encryption algorithms used with the IKEv2
    Encrypted Payload, and is unchanged from [RFC4306].

   o  The associated data (A) is described in Section 5 (below).

```
                          1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     ~                   IKE Payloads to be Encrypted                ~
     +               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     !               !           Padding (0-255 octets)             !
     +-+-+-+-+-+-+-+-+               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     !                               !  Pad Length   !
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
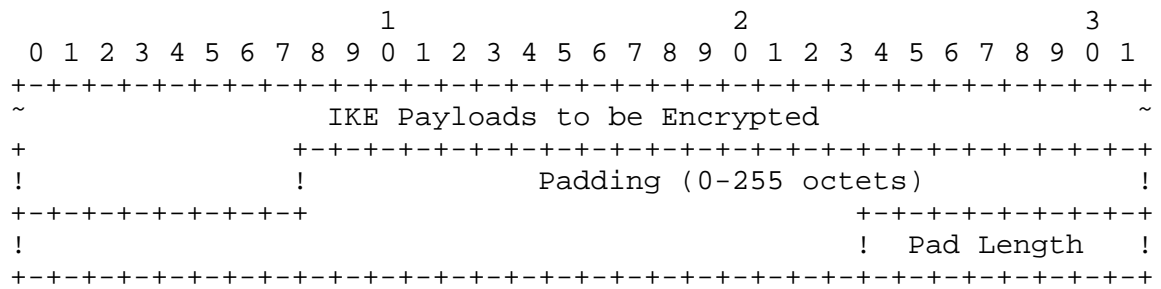
             Figure 2. IKEv2 Encrypted Payload Plaintext (P)

   The IKE Payloads are as specified in [RFC4306].

   Padding MAY contain any value chosen by the sender.

   Pad Length is the number of octets in the Padding field.  There are
   no alignment requirements on the length of the Padding field; the
   recipient MUST accept any amount of Padding up to 255 octets.

   The ciphertext output of authenticated encryption algorithms, as
   defined by [RFC5116], incorporates data that allows checks on the
   integrity and authenticity of the ciphertext and associated data.
   Thus, there is no need for a separate Integrity Check Value (ICV)
   field in the IKEv2 Encrypted Payload Data structure.

3.1.  AES GCM and AES CCM Initialization Vector (IV)

   This section is based on Section 3.1 of [RFC4106] and Section 3.1 of
   [RFC4309].  The Initialization Vector requirements are common to AES
   GCM and AES CCM, and are the same as the requirements for ESP.

   The Initialization Vector (IV) MUST be eight octets.  The IV MUST be
   chosen by the encryptor in a manner that ensures that the same IV
   value is used only once for a given key.  The encryptor MAY generate
   the IV in any manner that ensures uniqueness.  Common approaches to
   IV generation include incrementing a counter for each packet and
   linear feedback shift registers (LFSRs).

3.2.  AES GCM and AES CCM Ciphertext (C) Construction

   This section is based on Section 6 of [RFC4106] and Section 3.1 of
   [RFC4309] with generalizations to match the interfaces specified in
   [RFC5116].  The constructions for AES GCM and AES CCM are different,
   but in each case, the construction is the same as for ESP.

For AES GCM and AES CCM, the Ciphertext field consists of the output
of the authenticated encryption algorithm.  (Note that this field
incorporates integrity check data.)

The AES GCM ICV consists solely of the AES GCM Authentication Tag.
Implementations MUST support a full-length 16 octet ICV, MAY support
8 or 12 octet ICVs, and MUST NOT support other ICV lengths.

AES CCM provides an encrypted ICV.  Implementations MUST support ICV
sizes of 8 octets and 16 octets.  Implementations MAY also support 12
octet ICVs and MUST NOT support other ICV lengths.

4.  AES GCM and AES CCM Nonce (N) Format

Specific authenticated encryption algorithms MAY use different nonce
formats, but they SHOULD use the default nonce format specified in
this section.

The default nonce format uses partially implicit nonces (see Section
3.2.1 of [RFC5116]) as follows:

o  The implicit portion of the nonce is the salt that is part of the
   IKEv2 Keying Material shared by the encryptor and decryptor (see
   Section 7.1); the salt is not included in the IKEv2 Encrypted
   Payload.

o  The explicit portion of the nonce is the IV that is included in
   the IKEv2 Encrypted Payload.

When this default nonce format is used, both the encryptor and
decryptor construct the nonce by concatenating the salt with the IV,
in that order.

For the use of AES GCM with the IKEv2 Encrypted Payload, this default
nonce format MUST be used and a 12 octet nonce MUST be used.  Note
that this format matches the one specified in Section 4 of [RFC4106],
providing compatibility between the use of AES GCM in IKEv2 and ESP.
All of the requirements of Section 4 of [RFC4106] apply to the use of
AES GCM with the IKEv2 Encrypted Payload.

For the use of AES CCM with the IKEv2 Encrypted Payload, this default
nonce format MUST be used and an 11 octet nonce MUST be used.  Note
that this format matches the one specified in Section 4 of [RFC4309],
providing compatibility between the use of AES CCM in IKEv2 and ESP.
All of the requirements of Section 4 of [RFC4309] apply to the use of
AES CCM with the IKEv2 Encrypted Payload.

5.  IKEv2 Associated Data (A)

   This section is based on Section 5 of [RFC4106] and Section 5 of
   [RFC4309], both of which refer to associated data as Additional
   Authenticated Data (AAD).  The associated data construction described
   in this section applies to all authenticated encryption algorithms,
   but differs from the construction used with ESP because IKEv2
   requires different data integrity coverage.

5.1.  Associated Data (A) Construction

   The associated data (A) MUST consist of the partial contents of the
   IKEv2 message, starting from the first octet of the Fixed IKE Header
   through the last octet of the Payload Header of the Encrypted Payload
   (i.e., the fourth octet of the Encrypted Payload), as shown in Figure
   3.  This includes any payloads that are between the Fixed IKE Header
   and the Encrypted Payload.

```
                        1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                         IKEv2 Header                          ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                   Unencrypted IKE Payloads                    ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ! Next Payload  !C!  RESERVED   !         Payload Length        !
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

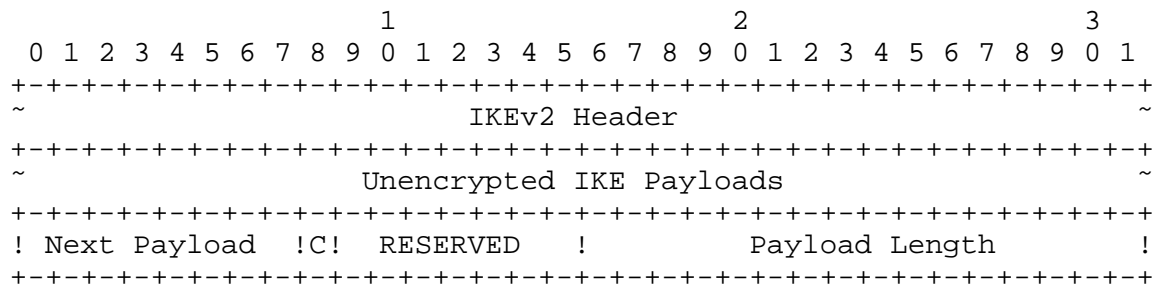             Figure 3. IKEv2 Encrypted Payload Associated Data (A) for
                          Authenticated Encryption

   The Initialization Vector and Ciphertext fields shown in Figure 1
   (above) MUST NOT be included in the associated data.

5.2.  Data Integrity Coverage

   The data integrity coverage of the IKEv2 Encrypted Payload
   encompasses the entire IKEv2 message that contains the Encrypted
   Payload.  When an authenticated encryption algorithm is used with the
   Encrypted Payload, this coverage is realized as follows:

   1. The associated data (A) covers the portion of the IKEv2 message
      starting from the first octet of the Fixed IKE Header through the
      last octet of the Payload Header of the Encrypted Payload (fourth
      octet of the Encrypted Payload).  This includes any Payloads
      between the Fixed IKE Header and the Encrypted Payload.  The
      Encrypted Payload is always the last payload in an IKEv2 message
      [RFC4306].

2. The IV is an input to the authenticated encryption algorithm's
   integrity check.  A successful integrity check at the receiver
   verifies that the correct IV was used, providing data integrity
   coverage for the IV.

3. The plaintext (IKE Payloads, Padding and Pad Length) is covered by
   the authenticated encryption algorithm's integrity check.

6.  AES GCM and AES CCM Encrypted Payload Expansion

   The expansion described in Section 7 of [RFC4106] and Section 6 of
   [RFC4309] applies to the use of the AES GCM and AES CCM combined
   modes with the IKEv2 Encrypted Payload.  See Section 7 of [RFC4106]
   and Section 6 of [RFC4309].

7.  IKEv2 Conventions for AES GCM and AES CCM

   This section describes the conventions used to generate keying
   material and salt values for use with AES GCM and AES CCM using the
   IKEv2 [RFC4306] protocol.  The identifiers and attributes needed to
   use AES GCM and AES CCM with the IKEv2 Encrypted Payload are also
   specified.

7.1.  Keying Material and Salt Values

   This section is based on Section 8.1 of [RFC4106] and Section 7.1 of
   [RFC4309].  The Keying Material and Salt Values for AES GCM and AES
   CCM are different, but have the same structure as the Keying Material
   and Salt Values used with ESP.

   IKEv2 makes use of a Pseudo-Random Function (PRF) to derive keying
   material.  The PRF is used iteratively to derive keying material of
   arbitrary size, from which keying material for specific uses is
   extracted without regard to PRF output boundaries; see Section 2.14
   of [RFC4306].

   This subsection describes how the key derivation specified in Section
   2.14 of [RFC4306] is used to obtain keying material for AES GCM and
   AES CCM.  When AES GCM or AES CCM is used with the IKEv2 Encrypted
   Payload, the SK_ai and SK_ar integrity protection keys are not used;
   each key MUST be treated as having a size of zero (0) octets.  The
   size of each of the SK_ei and SK_er encryption keys includes
   additional salt bytes.  The size and format of each of the SK_ei and
   SK_er encryption keys MUST be:

   o  For AES GCM, each encryption key has the size and format of the
      "KEYMAT requested" material specified in Section 8.1 of [RFC4106]
      for the AES key size being used.  For example, if the AES key size

is 128 bits, each encryption key is 20 octets, consisting of a
16-octet AES cipher key followed by 4 octets of salt.

o  For AES CCM, each key has the size and format of the "KEYMAT
   requested" material specified in Section 7.1 of [RFC4309] for the
   AES key size being used.  For example, if the AES key size is 128
   bits, each encryption key is 19 octets, consisting of a 16-octet
   AES cipher key followed by 3 octets of salt.

7.2.  IKEv2 Identifiers

   This section is unique to the IKEv2 Encrypted Payload usage of AES
   GCM and AES CCM.  It reuses the identifiers used to negotiate ESP
   usage of AES GCM and AES CCM.

   The following identifiers, previously allocated by IANA, are used to
   negotiate the use of AES GCM and AES CCM as the Encryption (ENCR)
   Transform for IKEv2 (i.e., for use with the IKEv2 Encrypted Payload):

        14 for AES CCM with an 8-octet ICV;
        15 for AES CCM with a 12-octet ICV;
        16 for AES CCM with a 16-octet ICV;

        18 for AES GCM with an 8-octet ICV;
        19 for AES GCM with a 12-octet ICV; and
        20 for AES GCM with a 16-octet ICV.

   A 16-octet ICV size SHOULD be used with IKEv2, as the higher level of
   security that it provides by comparison to smaller ICV sizes is
   appropriate to IKEv2's key exchange and related functionality.

   In general, the use of 12-octet ICVs (values 15 and 19) is NOT
   RECOMMENDED in order to reduce the number of options for ICV size.
   If an ICV size larger than 8 octets is appropriate, 16-octet ICVs
   SHOULD be used.

7.3.  Key Length

   This section is based on Section 8.4 of [RFC4106] and Section 7.4 of
   [RFC4309].  The Key Length requirements are common to AES GCM and AES
   CCM and are identical to the key length requirements for ESP.

   Because the AES supports three key lengths, the Key Length attribute
   MUST be specified when any of the identifiers for AES GCM or AES CCM,
   specified in Section 7.2 of this document, is used.  The Key Length
   attribute MUST have a value of 128, 192, or 256.  The use of the
   value 192 is NOT RECOMMENDED.  If an AES key larger than 128 bits is

appropriate, a 256-bit AES key SHOULD be used.  This reduces the
number of options for AES key length.

8.  IKEv2 Algorithm Selection

   This section applies to the use of any authenticated encryption
   algorithm with the IKEv2 Encrypted Payload and is unique to that
   usage.

   IKEv2 (Section 3.3.3 of [RFC4306]) specifies that both an encryption
   algorithm and an integrity checking algorithm are required for an IKE
   SA (Security Association).  This document updates [RFC4306] to
   require that when an authenticated encryption algorithm is selected
   as the encryption algorithm for any SA (IKE or ESP), an integrity
   algorithm MUST NOT be selected for that SA.  This document further
   updates [RFC4306] to require that if all of the encryption algorithms
   in any proposal are authenticated encryption algorithms, then the
   proposal MUST NOT propose any integrity transforms.

9.  Test Vectors

   See Section 9 of [RFC4106] and Section 8 of [RFC4309] for references
   that provide AES GCM and AES CCM test vectors.

10.  RFC 5116 AEAD_* Algorithms

   This section adds new algorithms to the AEAD_* algorithm framework
   defined in [RFC5116] to encompass the usage of AES GCM and AES CCM
   with IKEv2.  An AEAD_* algorithm does not have any attributes or
   parameters; each AEAD_* algorithm identifier defined in this document
   completely specifies the AES key size and the ICV size to be used
   (e.g., AEAD_AES_128_GCM uses a 128-bit AES key and a 16-octet ICV).

   AEAD_* algorithm coverage of the AES GCM and AES CCM authenticated
   encryption algorithms used with IKEv2 requires specification of eight
   additional AEAD_* algorithms beyond the four algorithms specified in
   [RFC5116]:

   o  Four AEAD_* algorithms are specified to allow 8- and 12-octet ICVs
      to be used with the AES GCM and AEAD_* algorithms specified in
      [RFC5116].

   o  The version of AES CCM used with IPsec (see [RFC4309]) uses an
      11-octet nonce instead of the 12-octet nonce used by the version
      of AES CCM specified in [RFC5116].  Six AEAD_* algorithms are
      specified for this short nonce version of AES CCM.

   This document recommends against the use of 192-bit AES keys, and
   therefore does not specify AEAD_* algorithms for 192-bit AES keys.

10.1.  AES GCM Algorithms with 8- and 12-octet ICVs

   The following four AEAD_* algorithms are identical to the AEAD_*
   algorithms specified in [RFC5116], except that an 8-octet ICV is used
   instead of a 16-octet ICV.

10.1.1.  AEAD_AES_128_GCM_8

   This algorithm is identical to AEAD_AES_128_GCM (see Section 5.1 of
   [RFC5116]), except that the tag length, t, is 8, and an
   authentication tag with a length of 8 octets (64 bits) is used.

   An AEAD_AES_128_GCM_8 ciphertext is exactly 8 octets longer than its
   corresponding plaintext.

10.1.2.  AEAD_AES_256_GCM_8

   This algorithm is identical to AEAD_AES_256_GCM (see Section 5.2 of
   [RFC5116]), except that the tag length, t, is 8, and an
   authentication tag with a length of 8 octets (64 bits) is used.

   An AEAD_AES_256_GCM_8 ciphertext is exactly 8 octets longer than its
   corresponding plaintext.

10.1.3.  AEAD_AES_128_GCM_12

   This algorithm is identical to AEAD_AES_128_GCM (see Section 5.1 of
   [RFC5116]), except that the tag length, t, is 12, and an
   authentication tag with a length of 12 octets (64 bits) is used.

   An AEAD_AES_128_GCM_12 ciphertext is exactly 12 octets longer than
   its corresponding plaintext.

10.1.4.  AEAD_AES_256_GCM_12

   This algorithm is identical to AEAD_AES_256_GCM (see Section 5.2 of
   [RFC5116], except that the tag length, t, is 12 and an authentication
   tag with a length of 12 octets (64 bits) is used.

   An AEAD_AES_256_GCM_12 ciphertext is exactly 12 octets longer than
   its corresponding plaintext.

10.2.  AES CCM Algorithms with an 11-octet Nonce

   The following four AEAD algorithms employ the AES CCM algorithms with
   an 11 octet nonce as specified in [RFC4309].

10.2.1.  AEAD_AES_128_CCM_SHORT

   The AEAD_AES_128_CCM_SHORT authenticated encryption algorithm is
   identical to the AEAD_AES_128_CCM algorithm (see Section 5.3 of
   [RFC5116]), except that it uses a nonce that is one octet shorter.
   AEAD_AES_128_CCM_SHORT works as specified in [CCM].  It uses AES-128
   as the block cipher by providing the key, nonce, associated data, and
   plaintext to that mode of operation.  The formatting and counter
   generation function are as specified in Appendix A of [CCM], and the
   values of the parameters identified in that appendix are as follows:

        the nonce length n is 11,

        the tag length t is 16, and

        the value of q is 3.

   An authentication tag with a length of 16 octets (128 bits) is used.
   The AEAD_AES_128_CCM_SHORT ciphertext consists of the ciphertext
   output of the CCM encryption operation concatenated with the
   authentication tag output of the CCM encryption operation.  Test
   cases are provided in [CCM].  The input and output lengths are as
   follows:

        K_LEN is 16 octets,

        P_MAX is $2^{24} - 1$ octets,

        A_MAX is $2^{64} - 1$ octets,

        N_MIN and N_MAX are both 11 octets, and

        C_MAX is $2^{24} + 15$ octets.

   An AEAD_AES_128_CCM_SHORT ciphertext is exactly 16 octets longer than
   its corresponding plaintext.

10.2.2.  AEAD_AES_256_CCM_SHORT

   This algorithm is identical to AEAD_AES_128_CCM_SHORT, but with the
   following differences:

        K_LEN is 32 octets, instead of 16, and

        AES-256 CCM is used instead of AES-128 CCM.

   An AEAD_AES_256_CCM_SHORT ciphertext is exactly 16 octets longer than
   its corresponding plaintext.

10.2.3.  AEAD_AES_128_CCM_SHORT_8

   This algorithm is identical to AEAD_AES_128_CCM_SHORT, except that
   the tag length, t, is 8, and an authentication tag with a length of 8
   octets (64 bits) is used.

   An AEAD_AES_128_CCM_SHORT_8 ciphertext is exactly 8 octets longer
   than its corresponding plaintext.

10.2.4.  AEAD_AES_256_CCM_SHORT_8

   This algorithm is identical to AEAD_AES_256_CCM_SHORT, except that
   the tag length, t, is 8, and an authentication tag with a length of 8
   octets (64 bits) is used.

   An AEAD_AES_256_CCM_SHORT_8 ciphertext is exactly 8 octets longer
   than its corresponding plaintext.

10.2.5.  AEAD_AES_128_CCM_SHORT_12

   This algorithm is identical to AEAD_AES_128_CCM_SHORT, except that
   the tag length, t, is 12, and an authentication tag with a length of
   12 octets (64 bits) is used.

   An AEAD_AES_128_CCM_SHORT_12 ciphertext is exactly 12 octets longer
   than its corresponding plaintext.

10.2.6.  AEAD_AES_256_CCM_SHORT_12

   This algorithm is identical to AEAD_AES_256_CCM_SHORT, except that
   the tag length, t, is 12, and an authentication tag with a length of
   8 octets (64 bits) is used.

   An AEAD_AES_256_CCM_SHORT_12 ciphertext is exactly 12 octets longer
   than its corresponding plaintext.

10.3.  AEAD_* Algorithms and IKEv2

   The following table lists the AES CCM and AES GCM AEAD_* algorithms
   that can be negotiated by IKEv2 and provides the IKEv2 Encryption
   (ENCR) Transform Identifier and Key Length Attribute combination that
   is used to negotiate each algorithm.

```
     +--------------------------+-----------------+-------------+
     | AEAD algorithm           | ENCR Identifier | Key Length  |
     +--------------------------+-----------------+-------------+
     | AEAD_AES_128_GCM         |       20        |     128     |
     | AEAD_AES_256_GCM         |       20        |     256     |
     | AEAD_AES_128_GCM_8       |       18        |     128     |
     | AEAD_AES_256_GCM_8       |       18        |     256     |
     | AEAD_AES_128_GCM_12      |       19        |     128     |
     | AEAD_AES_256_GCM_12      |       19        |     256     |
     | AEAD_AES_128_CCM_SHORT   |       16        |     128     |
     | AEAD_AES_256_CCM_SHORT   |       16        |     256     |
     | AEAD_AES_128_CCM_SHORT_8 |       14        |     128     |
     | AEAD_AES_256_CCM_SHORT_8 |       14        |     256     |
     | AEAD_AES_128_CCM_SHORT_12|       15        |     128     |
     | AEAD_AES_256_CCM_SHORT_12|       15        |     256     |
     +--------------------------+-----------------+-------------+
```

   Each of the above AEAD_* algorithms is identical to the algorithm
   designated by the combination of the IKEv2 ENCR Identifier and Key
   Length Attribute shown on the same line of the table.

11.  Security Considerations

   For authenticated encryption security considerations, see the
   entirety of [RFC5116], not just its security considerations section;
   there are important security considerations that are discussed
   outside the security considerations section of that document.

   The security considerations for the use of AES GCM and AES CCM with
   ESP apply to the use of these algorithms with the IKEv2 Encrypted
   Payload, see Section 10 of [RFC4106] and Section 9 of [RFC4309].  Use
   of AES GCM and AES CCM with IKEv2 does not create additional security
   considerations beyond those for the use of AES GCM and AES CCM with
   ESP.

   For IKEv2 security considerations, see Section 5 of [RFC4306].

12.  IANA Considerations

   The Encryption Transform identifiers specified in Section 7.2 have
   been previously assigned by IANA for use with ESP.  This document
   extends their usage to IKEv2 for the Encrypted Payload.  No IANA
   actions are required for this usage extension.

   IANA has added the following entries to the Authenticated Encryption
   with Associated Data (AEAD) Parameters Registry:

```
   +--------------------------+---------------+--------------------+
   | Name                     | Reference     | Numeric Identifier |
   +--------------------------+---------------+--------------------+
   | AEAD_AES_128_GCM_8       | Section 10.1.1 |         5         |
   | AEAD_AES_256_GCM_8       | Section 10.1.2 |         6         |
   | AEAD_AES_128_GCM_12      | Section 10.1.3 |         7         |
   | AEAD_AES_256_GCM_12      | Section 10.1.4 |         8         |
   | AEAD_AES_128_CCM_SHORT   | Section 10.2.1 |         9         |
   | AEAD_AES_256_CCM_SHORT   | Section 10.2.2 |        10         |
   | AEAD_AES_128_CCM_SHORT_8 | Section 10.2.3 |        11         |
   | AEAD_AES_256_CCM_SHORT_8 | Section 10.2.4 |        12         |
   | AEAD_AES_128_CCM_SHORT_12| Section 10.2.5 |        13         |
   | AEAD_AES_256_CCM_SHORT_12| Section 10.2.6 |        14         |
   +--------------------------+---------------+--------------------+
```

   An IANA registration of an AEAD algorithm does not constitute an
   endorsement of that algorithm or its security.

13.  Acknowledgments

   See Section 13 of [RFC4106] and Section 12 of [RFC4309] for AES GCM
   and AES CCM acknowledgments.

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## 14.  References

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