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Implicit IV for Counter-based Ciphers in Encapsulating Security Payload (ESP)

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Abstract

Encapsulating Security Payload (ESP) sends an initialization vector (IV) or nonce in each packet. The size of IV depends on the applied transform, being usually 8 or 16 octets for the transforms defined by the time this document is written. Some algorithms such as AES-GCM, AES-CCM, AES-CTR and ChaCha20-Poly1305 require a unique nonce but do not require an unpredictable nonce. When using such algorithms the packet counter value can be used to generate a nonce. This avoids sending the nonce itself, and savec in the case of AES-GCM, AES-CCM, AES-CTR and ChaCha20-Poly1305 8 octets per packet. This document describes how to do this.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Requirements notation

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].

2. Introduction

Counter-based AES modes of operation such as AES-CTR ([RFC3686]), AES-CCM ([RFC4309]), and AES-GCM ([RFC4106]) require the specification of an nonce for each ESP packet. The same applies for ChaCha20-Poly1305 ([RFC7634]. Currently this nonce is sent in each ESP packet ([RFC4303]). This practice is designated in this document as "explicit nonce".

In some context, such as IoT, it may be preferable to avoid carrying the extra bytes associated to the IV and instead generate it locally on each peer. The local generation of the nonce is designated in this document as "implicit IV".

The size of this nonce depends on the specific algorithm, but all of the algorithms mentioned above take an 8-octet nonce.

This document defines how to compute the nonce locally when it is implicit. It also specifies how peers agree with the Internet Key Exchange version 2 (IKEv2 - [RFC7296]) on using an implicit IV versus an explicit IV.

This document limits its scope to the algorithms mentioned above. Other algorithms with similar properties may later be defined to use this extension.

This document does not consider AES-CBC ([RFC3602]) as AES-CBC requires the IV to be unpredictable. Deriving it directly from the packet counter as described below is insecure as mentioned in Security Consideration of [RFC3602] and has led to real world chosen plain-text attack such as BEAST [BEAST].

3. Terminology

- IoT: Internet of Things.
- IV: Initialization Vector.
- IIV: Implicit Initialization Vector.
- Nonce: a fixed-size octet string used only once. This is similar to IV, except that in common usage there is no implication of non-predictability.

4. Implicit IV

With the algorithms listed in Section 2, the 8 byte nonce MUST NOT repeat. The binding between a ESP packet and its nonce is provided using the Sequence Number or the Extended Sequence Number. Figure 1 and Figure 2 represent the IV with a regular 4-byte Sequence Number and with an 8-byte Extended Sequence Number respectively.

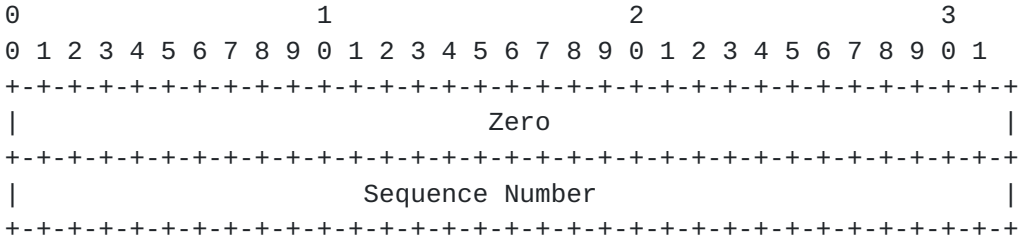

Figure 1: Implicit IV with a 4 byte Sequence Number

- Sequence Number: the 4 byte Sequence Number carried in the ESP packet.

o Zero: a 4 byte array with all bits set to zero.

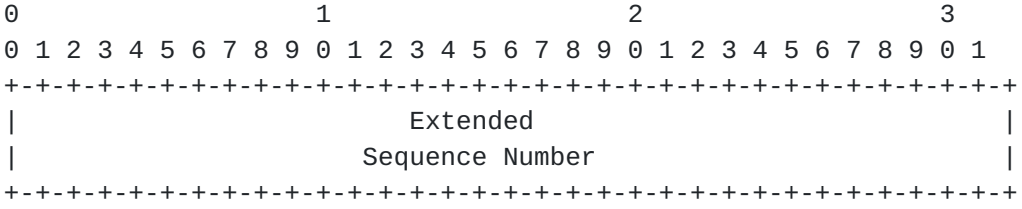

Figure 2: Implicit IV with an 8 byte Extended Sequence Number

o Extended Sequence Number: the 8 byte Extended Sequence Number of the Security Association. The 4 byte low order bytes are carried in the ESP packet.

As the IV MUST NOT repeat for one SPI when Counter-Mode ciphers are used, Implicit IV as described in this document MUST NOT be used in setups with the chance that the Sequence Number overlaps for one SPI. Multicast as described in [RFC5374], [RFC6407] and [I-D.yeung-g-ikev2] is a prominent example, where many senders share one secret and thus one SPI. Section 3.5 of [RFC6407] provides a mechanism that MAY be used to prevent IV collisions when the same key is used by multiple users. The mechanism consists in partitioning the IV space between users by assigning the most significant byte to a user. When implicit IV transforms are used, such mechanism cannot be applied as the IV is not sent, but instead it is derived from the Sequence Number. A similar mechanism could be used by associating the most significant byte of the Sequence Number to a sender, while the 3 remaining bytes will be used to carry the counter value. Such mechanism prevents the use of Extended Sequence Number and limits the number of packet to be sent to 2** 24 = 16777216, that is 16 M.

Unless some mechanism are provided to avoid collision between Sequence Number, (and so IV), Implicit IV MUST NOT be used.

5. Initiator Behavior

An initiator supporting this feature SHOULD propose implicit IV for all relevant algorithms. To facilitate backward compatibility with non-supporting peers the initiator SHOULD also include those same algorithms without Implicit IV (IIV). This may require extra transforms.

6. Responder Behavior

The rules of SA payload processing ensure that the responder will never send an SA payload containing the IIV transform to an initiator that does not support IIV.

7. Security Consideration

Nonce generation for these algorithms has not been explicitly defined. It has been left to the implementation as long as certain security requirements are met. Typically, for AES-GCM, AES-CCM, AES-CTR and ChaCha20-Poly1305, the IV is not allowed being repeated for one particular key. This document provides an explicit and normative way to generate IVs. The mechanism described in this document meets the IV security requirements of all relevant algorithms.

8. IANA Considerations

AES-CCM, AES-GCM and ChaCha20-Poly1305 are likely to implement the implicit IV described in this document. This section limits assignment of new code points to the recommended suites provided in [RFC8221], thus the new Transform Type 1 - Encryption Algorithm Transform IDs [IANA] are as defined below:

- ENCR_AES_CCM_8_IIV

- ENCR_AES_GCM_16_IIV

- ENCR_CHACHA20_POLY1305_IIV

These algorithms should be added with this document as ESP Reference and "Not Allowed" for IKEv2 Reference.

9. Acknowledgements

We would like to thanks people Valery Smyslov for their valuable comments, David Schinazi for its implementation, as well as the ipseceme chairs Tero Kivinen and David Waltermire for moving this work forward.

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