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The Use of HMAC-SHA-1-96 within ESP and AH

Status of this Memo

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Abstract

This memo describes the use of the HMAC algorithm [RFC-2104] in conjunction with the SHA-1 algorithm [FIPS-180-1] as an authentication mechanism within the revised IPSEC Encapsulating Security Payload [ESP] and the revised IPSEC Authentication Header [AH]. HMAC with SHA-1 provides data origin authentication and integrity protection.

Further information on the other components necessary for ESP and AH implementations is provided by [Thayer97a].

1. Introduction

This memo specifies the use of SHA-1 [FIPS-180-1] combined with HMAC [RFC-2104] as a keyed authentication mechanism within the context of the Encapsulating Security Payload and the Authentication Header. The goal of HMAC-SHA-1-96 is to ensure that the packet is authentic and cannot be modified in transit.

HMAC is a secret key authentication algorithm. Data integrity and data origin authentication as provided by HMAC are dependent upon the scope of the distribution of the secret key. If only the source and destination know the HMAC key, this provides both data origin

authentication and data integrity for packets sent between the two parties; if the HMAC is correct, this proves that it must have been added by the source.

In this memo, HMAC-SHA-1-96 is used within the context of ESP and AH. For further information on how the various pieces of ESP - including the confidentiality mechanism -- fit together to provide security services, refer to [ESP] and [Thayer97a]. For further information on AH, refer to [AH] and [Thayer97a].

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].

2. Algorithm and Mode

[FIPS-180-1] describes the underlying SHA-1 algorithm, while [RFC-2104] describes the HMAC algorithm. The HMAC algorithm provides a framework for inserting various hashing algorithms such as SHA-1.

HMAC-SHA-1-96 operates on 64-byte blocks of data. Padding requirements are specified in [FIPS-180-1] and are part of the SHA-1 algorithm. If you build SHA-1 according to [FIPS-180-1] you do not need to add any additional padding as far as HMAC-SHA-1-96 is concerned. With regard to "implicit packet padding" as defined in [AH] no implicit packet padding is required.

HMAC-SHA-1-96 produces a 160-bit authenticator value. This 160-bit value can be truncated as described in RFC2104. For use with either ESP or AH, a truncated value using the first 96 bits MUST be supported. Upon sending, the truncated value is stored within the authenticator field. Upon receipt, the entire 160-bit value is computed and the first 96 bits are compared to the value stored in the authenticator field. No other authenticator value lengths are supported by HMAC-SHA-1-96.

The length of 96 bits was selected because it is the default authenticator length as specified in [AH] and meets the security requirements described in [RFC-2104].

2.1 Performance

[Bellare96a] states that "(HMAC) performance is essentially that of the underlying hash function". As of this writing no detailed performance analysis has been done of SHA-1, HMAC or HMAC combined with SHA-1.

[RFC-2104] outlines an implementation modification which can improve per-packet performance without affecting interoperability.

3. Keying Material

HMAC-SHA-1-96 is a secret key algorithm. While no fixed key length is specified in [RFC-2104], for use with either ESP or AH a fixed key length of 160-bits MUST be supported. Key lengths other than 160-bits MUST NOT be supported (i.e. only 160-bit keys are to be used by HMAC-SHA-1-96). A key length of 160-bits was chosen based on the recommendations in [RFC-2104] (i.e. key lengths less than the authenticator length decrease security strength and keys longer than the authenticator length do not significantly increase security strength).

[RFC-2104] discusses requirements for key material, which includes a discussion on requirements for strong randomness. A strong pseudo-random function MUST be used to generate the required 160-bit key.

At the time of this writing there are no specified weak keys for use with HMAC. This does not mean to imply that weak keys do not exist. If, at some point, a set of weak keys for HMAC are identified, the use of these weak keys must be rejected followed by a request for replacement keys or a newly negotiated Security Association.

[ARCH] describes the general mechanism for obtaining keying material when multiple keys are required for a single SA (e.g. when an ESP SA requires a key for confidentiality and a key for authentication).

In order to provide data origin authentication, the key distribution mechanism must ensure that unique keys are allocated and that they are distributed only to the parties participating in the communication.

[RFC-2104] makes the following recommendation with regard to rekeying. Current attacks do not indicate a specific recommended frequency for key changes as these attacks are practically infeasible. However, periodic key refreshment is a fundamental security practice that helps against potential weaknesses of the function and keys, reduces the information avaliable to a cryptanalyst, and limits the damage of an exposed key.

4. Interaction with the ESP Cipher Mechanism

As of this writing, there are no known issues which preclude the use of the HMAC-SHA-1-96 algorithm with any specific cipher algorithm.

5. Security Considerations

The security provided by HMAC-SHA-1-96 is based upon the strength of HMAC, and to a lesser degree, the strength of SHA-1. At the time of this writing there are no practical cryptographic attacks against HMAC-SHA-1-96.

[RFC-2104] states that for "minimally reasonable hash functions" the "birthday attack" is impractical. For a 64-byte block hash such as HMAC-SHA-1-96, an attack involving the successful processing of 2**80 blocks would be infeasible unless it were discovered that the underlying hash had collisions after processing 2**30 blocks. A hash with such weak collision-resistance characteristics would generally be considered to be unusable.

It is also important to consider that while SHA-1 was never developed to be used as a keyed hash algorithm, HMAC had that criteria from the onset.

[RFC-2104] also discusses the potential additional security which is provided by the truncation of the resulting hash. Specifications which include HMAC are strongly encouraged to perform this hash truncation.

As [RFC-2104] provides a framework for incorporating various hash algorithms with HMAC, it is possible to replace SHA-1 with other algorithms such as MD5. [RFC-2104] contains a detailed discussion on the strengths and weaknesses of HMAC algorithms.

As is true with any cryptographic algorithm, part of its strength lies in the correctness of the algorithm implementation, the security of the key management mechanism and its implementation, the strength of the associated secret key, and upon the correctness of the implementation in all of the participating systems. [RFC-2202] contains test vectors and example code to assist in verifying the correctness of HMAC-SHA-1-96 code.

6. Acknowledgments

This document is derived in part from previous works by Jim Hughes, those people that worked with Jim on the combined DES/CBC+HMAC-MD5 ESP transforms, the ANX bakeoff participants, and the members of the IPsec working group.

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7. References

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