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                OSPFv2 HMAC-SHA Cryptographic Authentication

Abstract

   This document describes how the National Institute of Standards and
   Technology (NIST) Secure Hash Standard family of algorithms can be
   used with OSPF version 2's built-in, cryptographic authentication
   mechanism. This updates, but does not supercede, the cryptographic
   authentication mechanism specified in RFC 2328.

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.

1. Introduction

   A variety of risks exist when deploying any routing protocol
   [Bell89]. This document provides an update to OSPFv2 Cryptographic
   Authentication, which is specified in Appendix D of RFC 2328. This
   document does not deprecate or supercede RFC 2328. OSPFv2, itself,
   is defined in RFC 2328 [RFC2328].

   This document adds support for Secure Hash Algorithms (SHA) defined
   in the US NIST Secure Hash Standard (SHS), which is defined by NIST
   FIPS 180-2. [FIPS-180-2] includes SHA-1, SHA-224, SHA-256, SHA-384,
   and SHA-512. The Hashed Message Authentication Code (HMAC)
   authentication mode defined in NIST FIPS 198 is used [FIPS-198].

   It is believed that [RFC2104] is mathematically identical to
   [FIPS-198] and it is also believed that algorithms in [RFC4634] are
   mathematically identical to [FIPS-180-2].

   The creation of this addition to OSPFv2 was driven by operator
   requests that they be able to use the NIST SHS family of algorithms
   in the NIST HMAC mode, instead of being forced to use the Keyed-MD5
   algorithm and mode with OSPFv2 Cryptographic Authentication.
   Cryptographic matters are discussed in more detail in the Security
   Considerations section of 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 RFC 2119 [RFC2119].

2. Background

   All OSPF protocol exchanges can be authenticated. The OSPF packet
   header (see Appendix A.3.1 of RFC 2328) includes an Authentication
   Type field and 64 bits of data for use by the appropriate
   authentication scheme (determined by the Type field).

The authentication type is configurable on a per-interface (or,
equivalently, on a per-network/subnet) basis. Additional
authentication data is also configurable on a per-interface basis.

OSPF authentication types 0, 1, and 2 are defined by RFC 2328. This
document provides an update to RFC 2328 that is only applicable to
Authentication Type 2, "Cryptographic Authentication".

3. Cryptographic Authentication with NIST SHS in HMAC Mode

Using this authentication type, a shared secret key is configured in
all routers attached to a common network/subnet. For each OSPF
protocol packet, the key is used to generate/verify a "message
digest" that is appended to the end of the OSPF packet. The message
digest is a one-way function of the OSPF protocol packet and the
secret key. Since the secret key is never sent over the network in
the clear, protection is provided against passive attacks [RFC1704].

The algorithms used to generate and verify the message digest are
specified implicitly by the secret key. This specification discusses
the computation of OSPFv2 Cryptographic Authentication data when any
of the NIST SHS family of algorithms is used in the Hashed Message
Authentication Code (HMAC) mode. Please also see RFC 2328, Appendix
D.

With the additions in this document, the currently valid algorithms
(including mode) for OSPFv2 Cryptographic Authentication include:

        Keyed-MD5   (defined in RFC 2328, Appendix D)
        HMAC-SHA-1   (defined here)
        HMAC-SHA-256   (defined here)
        HMAC-SHA-384   (defined here)
        HMAC-SHA-512   (defined here)

Of the above, implementations of this specification MUST include
support for at least:

        HMAC-SHA-256

and SHOULD include support for:

        HMAC-SHA-1

and SHOULD also (for backwards compatibility with existing
implementations and deployments) include support for:

        Keyed-MD5

and MAY also include support for:

        HMAC-SHA-384
        HMAC-SHA-512

An implementation of this specification MUST allow network operators
to configure ANY authentication algorithm supported by that
implementation for use with ANY given KeyID value that is configured
into that OSPFv2 router.

3.1. Generating Cryptographic Authentication

The overall cryptographic authentication process defined in Appendix
D of RFC 2328 remains unchanged. However, the specific cryptographic
details (i.e., SHA rather than MD5, HMAC rather than Keyed-Hash) are
defined herein. To reduce the potential for confusion, this section
minimises the repetition of text from RFC 2328, Appendix D, which is
incorporated here by reference [RFC2328].

First, following the procedure defined in RFC 2328, Appendix D,
select the appropriate OSPFv2 Security Association for use with this
packet and set the KeyID field to the KeyID value of that OSPFv2
Security Association.

Second, set the Authentication Type to Cryptographic Authentication,
and set the Authentication Data Length field to the length (measured
in bytes, not bits) of the cryptographic hash that will be used.
When any NIST SHS algorithm is used in HMAC mode with OSPFv2
Cryptographic Authentication, the Authentication Data Length is equal
to the normal hash output length (measured in bytes) for the specific
NIST SHS algorithm in use. For example, with NIST SHA-256, the
Authentication Data Length is 32 bytes.

Third, the 32-bit cryptographic sequence number is set in accordance
with the procedures in RFC 2328, Appendix D that are applicable to
the Cryptographic Authentication type.

Fourth, the message digest is then calculated and appended to the
OSPF packet, as described below in Section 3.3. The KeyID,
Authentication Algorithm, and Authentication Key to be used for
calculating the digest are all components of the selected OSPFv2
Security Association. Input to the authentication algorithm consists
of the OSPF packet and the secret key.

3.2. OSPFv2 Security Association

   This document uses the term OSPFv2 Security Association (OSPFv2 SA)
   to refer to the authentication key information defined in Section D.3
   of RFC 2328. The OSPFv2 protocol does not include an in-band
   mechanism to create or manage OSPFv2 Security Associations. The
   parameters of an OSPFv2 Security Association are updated to be:

   Key Identifier (KeyID)
      This is an 8-bit unsigned value used to uniquely identify an
      OSPFv2 SA and is configured either by the router administrator
      (or, in the future, possibly by some key management protocol
      specified by the IETF). The receiver uses this to locate the
      appropriate OSPFv2 SA to use. The sender puts this KeyID value in
      the OSPF packet based on the active OSPF configuration.

   Authentication Algorithm
      This indicates the authentication algorithm (and also the
      cryptographic mode, such as HMAC) to be used. This information
      SHOULD never be sent over the wire in cleartext form. At present,
      valid values are Keyed-MD5, HMAC-SHA-1, HMAC-SHA-256, HMAC-SHA-
      384, and HMAC-SHA-512.

   Authentication Key
      This is the cryptographic key used for cryptographic
      authentication with this OSPFv2 SA. This value SHOULD never be
      sent over the wire in cleartext form. This is noted as "K" in
      Section 3.3 below.

   Key Start Accept
      The time that this OSPF router will accept packets that have been
      created with this OSPF Security Association.

   Key Start Generate
      The time that this OSPF router will begin using this OSPF Security
      Association for OSPF packet generation.

   Key Stop Generate
      The time that this OSPF router will stop using this OSPF Security
      Association for OSPF packet generation.

   Key Stop Accept
      The time that this OSPF router will stop accepting packets
      generated with this OSPF Security Association.

   In order to achieve smooth key transition, KeyStartAccept SHOULD be
   less than KeyStartGenerate and KeyStopGenerate SHOULD be less than
   KeyStopAccept. If KeyStopGenerate and KeyStopAccept are left

unspecified, the key's lifetime is infinite. When a new key replaces
an old, the KeyStartGenerate time for the new key MUST be less than
or equal to the KeyStopGenerate time of the old key.

Key storage SHOULD persist across a system restart, warm or cold, to
avoid operational issues. In the event that the last key associated
with an interface expires, it is unacceptable to revert to an
unauthenticated condition, and not advisable to disrupt routing.
Therefore, the router should send a "last Authentication Key
expiration" notification to the network manager and treat the key as
having an infinite lifetime until the lifetime is extended, the key
is deleted by network management, or a new key is configured.

3.3. Cryptographic Aspects

This describes the computation of the Authentication Data value when
any NIST SHS algorithm is used in the HMAC mode with OSPFv2
Cryptographic Authentication.

In the algorithm description below, the following nomenclature, which
is consistent with [FIPS-198], is used:

   H   is the specific hashing algorithm (e.g., SHA-256).

   K   is the Authentication Key for the OSPFv2 security
         association.

   Ko   is the cryptographic key used with the hash algorithm.

   B   is the block size of H, measured in octets
         rather than bits. Note well that B is the
         internal block size, not the hash size.

            For SHA-1 and SHA-256: B == 64
            For SHA-384 and SHA-512: B == 128

   L   is the length of the hash, measured in octets
         rather than bits.

   XOR   is the exclusive-or operation.

   Opad is the hexadecimal value 0x5c repeated B times.

   Ipad is the hexadecimal value 0x36 repeated B times.

   Apad is the hexadecimal value 0x878FE1F3 repeated (L/4) times.

      Implementation note:
         This definition of Apad means that Apad is always the same
         length as the hash output.

   (1) PREPARATION OF KEY
       In this application, Ko is always L octets long.

       If the Authentication Key (K) is L octets long, then Ko is equal
       to K. If the Authentication Key (K) is more than L octets long,
       then Ko is set to H(K). If the Authentication Key (K) is less
       than L octets long, then Ko is set to the Authentication Key (K)
       with zeros appended to the end of the Authentication Key (K),
       such that Ko is L octets long.

   (2) FIRST-HASH
       First, the OSPFv2 packet's Authentication Trailer (which is the
       appendage described in RFC 2328, Section D.4.3, Page 233, items
       (6)(a) and (6)(d)) is filled with the value Apad, and the
       Authentication Type field is set to 2.

       Then, a First-Hash, also known as the inner hash, is computed as
       follows:

            First-Hash = H(Ko XOR Ipad || (OSPFv2 Packet))

       Implementation Notes:
          Note that the First-Hash above includes the Authentication
          Trailer containing the Apad value, as well as the OSPF packet,
          as per RFC 2328, Section D.4.3.

       The definition of Apad (above) ensures it is always the same
       length as the hash output. This is consistent with RFC 2328.
       The "(OSPFv2 Packet)" mentioned in the First-Hash (above) does
       include the OSPF Authentication Trailer.

       The digest length for SHA-1 is 20 bytes; for SHA-256, 32 bytes;
       for SHA-384, 48 bytes; and for SHA-512, 64 bytes.

   (3) SECOND-HASH
       Then a Second-Hash, also known as the outer hash, is computed as
       follows:

            Second-Hash = H(Ko XOR Opad || First-Hash)

(4) RESULT
    The resulting Second-Hash becomes the Authentication Data that is
    sent in the Authentication Trailer of the OSPFv2 packet. The
    length of the Authentication Trailer is always identical to the
    message digest size of the specific hash function H that is being
    used.

    This also means that the use of hash functions with larger output
    sizes will also increase the size of the OSPFv2 packet as
    transmitted on the wire.

    Implementation Note:
        RFC 2328, Appendix D specifies that the Authentication Trailer
        is not counted in the OSPF packet's own Length field, but is
        included in the packet's IP Length field.

3.4. Message Verification

   Message verification follows the procedure defined in RFC 2328,
   except that the cryptographic calculation of the message digest
   follows the procedure in Section 3.3 above when any NIST SHS
   algorithm in the HMAC mode is in use. Kindly recall that the
   cryptographic algorithm/mode in use is indicated implicitly by the
   KeyID of the received OSPFv2 packet.

   Implementation Notes:
       One must save the received digest value before calculating the
       expected digest value, so that after that calculation the received
       value can be compared with the expected value to determine whether
       to accept that OSPF packet.

       RFC 2328, Section D.4.3 (6) (c) should be read very closely prior
       to implementing the above. With SHA algorithms in HMAC mode, Apad
       is placed where the MD5 key would be put if Keyed-MD5 were in use.

3.5. Changing OSPFv2 Security Associations

   Using KeyIDs makes changing the active OSPFv2 SA convenient. An
   implementation can choose to associate a lifetime with each OSPFv2 SA
   and can thus automatically switch to a different OSPFv2 SA based on
   the lifetimes of the configured OSPFv2 SA(s).

   After changing the active OSPFv2 SA, the OSPF sender will use the
   (different) KeyID value associated with the newly active OSPFv2 SA.
   The receiver will use this new KeyID to select the appropriate (new)
   OSPFv2 SA to use with the received OSPF packet containing the new
   KeyID value.

Because the KeyID field is present, the receiver does not need to try all configured OSPFv2 Security Associations with any received OSPFv2 packet. This can mitigate some of the risks of a Denial-of-Service (DoS) attack on the OSPF instance, but does not entirely prevent all conceivable DoS attacks. For example, an on-link adversary still could generate OSPFv2 packets that are syntactically valid but that contain invalid Authentication Data, thereby forcing the receiver(s) to perform expensive cryptographic computations to discover that the packets are invalid.

4. Security Considerations

This document enhances the security of the OSPFv2 routing protocol by adding, to the existing OSPFv2 Cryptographic Authentication method, support for the algorithms defined in the NIST Secure Hash Standard (SHS) using the Hashed Message Authentication Code (HMAC) mode, and by adding support for the Hashed Message Authentication Code (HMAC) mode.

This provides several alternatives to the existing Keyed-MD5 mechanism. There are published concerns about the overall strength of the MD5 algorithm ([Dobb96a], [Dobb96b], [Wang04]). While those published concerns apply to the use of MD5 in other modes (e.g., use of MD5 X.509v3/PKIX digital certificates), they are not an attack upon Keyed-MD5, which is what OSPFv2 specified in RFC 2328. There are also published concerns about the SHA algorithm [Wang05] and also concerns about the MD5 and SHA algorithms in the HMAC mode ([RR07], [RR08]). Separately, some organisations (e.g., the US government) prefer NIST algorithms, such as the SHA family, over other algorithms for local policy reasons.

The value Apad is used here primarily for consistency with IETF specifications for HMAC-SHA authentication of RIPv2 SHA [RFC4822] and IS-IS SHA [RFC5310] and to minimise OSPF protocol processing changes in Section D.4.3 of RFC 2328 [RFC2328].

The quality of the security provided by the Cryptographic Authentication option depends completely on the strength of the cryptographic algorithm and cryptographic mode in use, the strength of the key being used, and the correct implementation of the security mechanism in all communicating OSPF implementations. Accordingly, the use of high assurance development methods is recommended. It also requires that all parties maintain the secrecy of the shared secret key. [RFC4086] provides guidance on methods for generating cryptographically random bits.

This mechanism is vulnerable to a replay attack by any on-link node.
An on-link node could record a legitimate OSPF packet sent on the
link, then replay that packet at the next time the recorded OSPF
packet's sequence number is valid. This replay attack could cause
significant routing disruptions within the OSPF domain.

Ideally, for example, to prevent the preceding attack, each OSPF
Security Association would be replaced by a new and different OSPF
Security Association before any sequence number were reused. As of
the date this document was published, no form of automated key
management has been standardised for OSPF. So, as of the date this
document was published, common operational practice has been to use
the same OSPF Authentication Key for very long periods of time. This
operational practice is undesirable for many reasons. Therefore, it
is clearly desirable to develop and standardise some automated key-
management mechanism for OSPF.

Because all of the currently specified algorithms use symmetric
cryptography, one cannot authenticate precisely which OSPF router
sent a given packet. However, one can authenticate that the sender
knew the OSPF Security Association (including the OSPFv2 SA's
parameters) currently in use.

Because a routing protocol contains information that need not be kept
secret, privacy is not a requirement. However, authentication of the
messages within the protocol is of interest in order to reduce the
risk of an adversary compromising the routing system by deliberately
injecting false information into the routing system.

The technology in this document enhances an authentication mechanism
for OSPFv2. The mechanism described here is not perfect and need not
be perfect. Instead, this mechanism represents a significant
increase in the work function of an adversary attacking OSPFv2, as
compared with plain-text authentication or null authentication, while
not causing undue implementation, deployment, or operational
complexity. Denial-of-Service attacks are not generally preventable
in a useful networking protocol [VK83].

Because of implementation considerations, including the need for
backwards compatibility, this specification uses the same mechanism
as specified in RFC 2328 and limits itself to adding support for
additional cryptographic hash functions. Also, some large network
operators have indicated they prefer to retain the basic mechanism
defined in RFC 2328, rather than migrate to IP Security, due to
deployment and operational considerations. If all the OSPFv2 routers
supported IPsec, then IPsec tunnels could be used in lieu of this
mechanism [RFC4301]. This would, however, relegate the topology to
point-to-point adjacencies over the mesh of IPsec tunnels.

If a stronger authentication were believed to be required, then the
use of a full digital signature [RFC2154] would be an approach that
should be seriously considered. Use of full digital signatures would
enable precise authentication of the OSPF router originating each
OSPF link-state advertisement, and thereby provide much stronger
integrity protection for the OSPF routing domain.

5. IANA Considerations

   The OSPF Authentication Codes registry entry for Cryptographic
   Authentication (Registry Code 2) has been updated to refer to this
   document as well as to RFC 2328.

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