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LDP Hello Cryptographic Authentication
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Abstract

This document introduces a new optional Cryptographic Authentication TLV that LDP can use to secure its Hello messages. It secures the Hello messages against spoofing attacks and some well known attacks against the IP header. This document describes a mechanism to secure the LDP Hello messages using National Institute of Standards and Technology (NIST) Secure Hash Standard family of algorithms.

Requirements Language

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].

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. Introduction

The Label Distribution Protocol (LDP) [RFC5036] sets up LDP sessions that run between LDP peers. The peers could either be directly connected at the link level or could be multiple hops away. An LDP Label Switching Router (LSR) could either be configured with the identity of its peers or could discover them using LDP Hello messages. These messages are sent encapsulated in UDP addressed to "all routers on this subnet" or to a specific IP address. Periodic Hello messages are also used to maintain the relationship between LDP peers necessary to keep the LDP session active.

Since the Hello messages are sent using UDP and not TCP, these messages cannot use the security mechanisms defined for TCP [RFC5926]. While some configuration guidance is given in [RFC5036] to help protect against false discovery messages, it does not provide an explicit security mechanism to protect the Hello messages.

Spoofing a Hello packet for an existing adjacency can cause the valid adjacency to time out and in turn can result in termination of the associated session. This can occur when the spoofed Hello specifies a smaller Hold Time, causing the receiver to expect Hellos within this smaller interval, while the true neighbor continues sending Hellos at the previously agreed lower frequency. Spoofing a Hello packet can also cause the LDP session to be terminated directly, which can occur when the spoofed Hello specifies a different Transport Address, other than the previously agreed one between neighbors. Spoofed Hello messages have been observed and reported as a real problem in production networks [RFC6952].

For Link Hello, [RFC5036] states that the threat of spoofed Hellos can be reduced by accepting Hellos only on interfaces to which LSRs that can be trusted are directly connected, and ignoring Hellos not addressed to the "all routers on this subnet" multicast group. The Generalized TTL Security Mechanism (GTSM) provides a simple and reasonably robust defense mechanism for Link Hello [RFC6720], but it does not secure against packet spoofing attack or replay attack[RFC5082].

Spoofing attacks via Targeted Hellos are a potentially more serious threat. [RFC5036] states that an LSR can reduce the threat of spoofed Targeted Hellos by filtering them and accepting only those originating at sources permitted by an access list. However, filtering using access lists requires LSR resource, and does not prevent IP-address spoofing.

This document introduces a new Cryptographic Authentication TLV which is used in LDP Hello messages as an optional parameter. It enhances the authentication mechanism for LDP by securing the Hello message against spoofing attack. It also introduces a cryptographic sequence number carried in the Hello messages that can be used to protect against replay attacks. The LSRs could be configured to only accept Hello messages from specific peers when authentication is in use.

Using this Cryptographic Authentication TLV, one or more secret keys (with corresponding Security Association (SA) IDs) are configured in each system. For each LDP Hello message, the key is used to generate and verify a HMAC Hash that is stored in the LDP Hello message. For cryptographic hash function, this document proposes to use SHA-1, SHA-256, SHA-384, and SHA-512 defined in US NIST Secure Hash Standard

(SHS) [FIPS-180-3]. The HMAC authentication mode defined in [RFC2104] is used. Of the above, implementations MUST include support for at least HMAC-SHA-256 and SHOULD include support for HMAC-SHA-1 and MAY include support for either of HMAC-SHA-384 or HMAC-SHA-512.

2. Cryptographic Authentication TLV

2.1. Optional Parameter for Hello Message

[RFC5036] defines the encoding for the Hello message. Each Hello message contains zero or more Optional Parameters, each encoded as a TLV. Three Optional Parameters are defined by [RFC5036]. This document defines a new Optional Parameter: the Cryptographic Authentication parameter.

Optional Parameter	Type
IPv4 Transport Address	0x0401 (RFC5036)
Configuration Sequence Number	0x0402 (RFC5036)
IPv6 Transport Address	0x0403 (RFC5036)
Cryptographic Authentication	TBD1 (this document, TBD1 by IANA)

The Cryptographic Authentication TLV Encoding is described in section 2.3.

2.2. LDP Security Association

An LDP Security Association (SA) contains a set of parameters shared between any two legitimate LDP speakers.

Parameters associated with an LDP SA are as follows:

- Security Association Identifier (SA ID)

  This is a 32-bit unsigned integer used to uniquely identify an LDP SA between two LDP peers, as manually configured by the network operator (or, in the future, possibly by some key management protocol specified by the IETF) .

  The receiver determines the active SA by looking at the SA ID field in the incoming Hello message.

  The sender, based on the active configuration, selects an SA to use and puts the correct SA ID value associated with the SA in the LDP Hello message. If multiple valid and active LDP SAs exist for

a given interface, the sender may use any of those SAs to protect the packet.

Using SA IDs makes changing keys while maintaining protocol operation convenient. Each SA ID specifies two independent parts, the authentication algorithm and the authentication key, as explained below.

Normally, an implementation would allow the network operator to configure a set of keys in a key chain, with each key in the chain having fixed lifetime. The actual operation of these mechanisms is outside the scope of this document.

Note that each SA ID can indicate a key with a different authentication algorithm. This allows the introduction of new authentication mechanisms without disrupting existing LDP sessions.

- Authentication Algorithm

  This signifies the authentication algorithm to be used with the LDP SA. This information is never sent in clear text over the wire. Because this information is not sent on the wire, the implementer chooses an implementation specific representation for this information.

  Currently, the following algorithms are supported:

  HMAC-SHA-1, HMAC-SHA-256, HMAC-SHA-384, and HMAC-SHA-512.

- Authentication Key

  This value denotes the cryptographic authentication key associated with the LDP SA. The length of this key is variable and depends upon the authentication algorithm specified by the LDP SA.

- KeyStartAccept

  The time that this LDP router will accept packets that have been created with this LDP Security Association.

- KeyStartGenerate

  The time that this LDP router will begin using this LDP Security Association for LDP Hello message generation.

- KeyStopGenerate

The time that this LDP router will stop using this LDP Security Association for LDP Hello message generation.

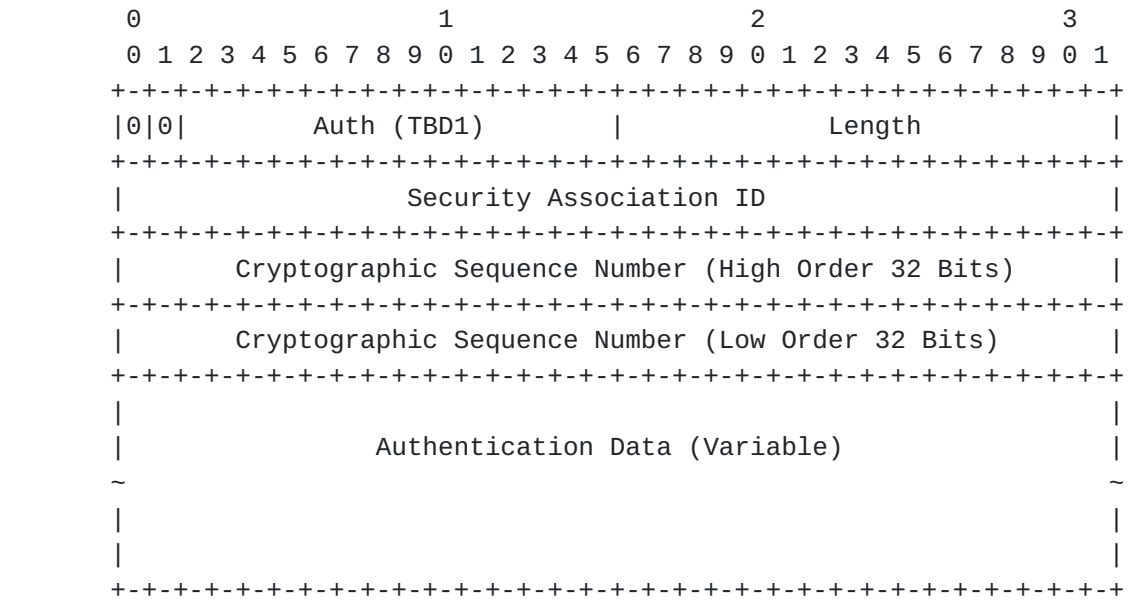
- KeyStopAccept

  The time that this LDP router will stop accepting packets generated with this LDP Security Association.

In order to achieve smooth key transition, KeyStartAccept SHOULD be less than KeyStartGenerate and KeyStopGenerate SHOULD be less than KeyStopAccept. If KeyStartGenerate or KeyStartAccept are left unspecified, the time will default to 0 and the key will be used immediately. If KeyStopGenerate or KeyStopAccept are left unspecified, the time will default to infinity and the key's lifetime will be 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. Any unspecified values are encoded as Zero.

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

2.3. Cryptographic Authentication TLV Encoding



- Type: TBD1, Cryptographic Authentication

- Length: Specifying the length in octets of the value field.

- Security Association ID: 32 bit field that maps to the authentication algorithm and the secret key used to create the message digest carried in LDP payload.

Though the SA ID implies the algorithm, the HMAC output size should not be used by implementers as an implicit hint, because additional algorithms may be defined in the future that have the same output size.

- Cryptographic Sequence Number: 64-bit strictly increasing sequence number that is used to guard against replay attacks. The 64-bit sequence number MUST be incremented for every LDP Hello packet sent by the LDP router. Upon reception, the sequence number MUST be greater than the sequence number in the last LDP Hello packet accepted from the sending LDP neighbor. Otherwise, the LDP packet is considered a replayed packet and dropped.

LDP routers implementing this specification MUST use existing mechanisms to preserve the sequence number's strictly increasing property for the deployed life of the LDP router (including cold restarts). One mechanism for accomplishing this could be to use the high-order 32 bits of the sequence number as a boot count that is incremented anytime the LDP router loses its sequence number state. Techniques such as sequence number space partitioning described above or non-volatile storage preservation can be used but are beyond the scope of this specification. Sequence number wrap is described in Section 2.4.

- Authentication Data:

This field carries the digest computed by the Cryptographic Authentication algorithm in use. The length of the Authentication Data varies based on the cryptographic algorithm in use, which is shown as below:

Auth type	Length
HMAC-SHA1	20 bytes
HMAC-SHA-256	32 bytes
HMAC-SHA-384	48 bytes
HMAC-SHA-512	64 bytes

2.4. Sequence Number Wrap

When incrementing the sequence number for each transmitted LDP packet, the sequence number should be treated as an unsigned 64-bit value. If the lower order 32-bit value wraps, the higher order 32-bit value should be incremented and saved in non-volatile storage. If the LDP router is deployed long enough that the 64-bit sequence number wraps, all keys, independent of key distribution mechanism MUST be reset. This is done to avoid the possibility of replay attacks. Once the keys have been changed, the higher order sequence number can be reset to 0 and saved to non-volatile storage.

3. Cryptographic Authentication Procedure

As noted earlier, the Security Association ID maps to the authentication algorithm and the secret key used to generate and verify the message digest. This specification discusses the computation of LDP Cryptographic Authentication data when any of the NIST SHS family of algorithms is used in the Hashed Message Authentication Code (HMAC) mode.

The currently valid algorithms (including mode) for LDP Cryptographic Authentication include:

HMAC-SHA-1, HMAC-SHA-256, HMAC-SHA-384 and HMAC-SHA-512

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 MAY also include support for HMAC-SHA-384 and HMAC-SHA-512.

Implementations of this standard MUST use HMAC-SHA-256 as the default authentication algorithm.

4. Cross Protocol Attack Mitigation

In order to prevent cross protocol replay attacks for protocols sharing common keys, the two octet LDP Cryptographic Protocol ID is appended to the authentication key prior to use (refer to Section 8). Other protocols using the common key similarly append their own Cryptographic Protocol IDs to their keys prior to use thus ensuring that a different key value is used for each protocol.

5. Cryptographic Aspects

In the algorithm description below, the following nomenclature is used:

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

K is the Authentication Key from the LDP security association.

Ks is a Protocol Specific Authentication Key obtained by appending Authentication Key (K) with the two-octet LDP Cryptographic Protocol ID .

Ko is the cryptographic key used with the hash algorithm.

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

AuthTag is a value which is the same length as the hash output. In case of IPv4, the first 4 octets contain the IPv4 source address followed by the hexadecimal value 0x878FE1F3 repeated (L-4)/4 times. In case of IPv6, the first 16 octets contain the IPv6 source address followed by the hexadecimal value 0x878FE1F3 repeated (L-16)/4 times. This implies that hash output is always a length of at least 16 octets.

5.1. Preparing the Cryptographic Key

The LDP Cryptographic Protocol ID is appended to the Authentication Key (K) yielding a Protocol Specific Authentication Key (Ks). In this application, Ko is always L octets long. Keys that are longer than the bit length of the hash function are hashed to force them to this length, as we describe below. Ks is computed as follows:

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

For higher entropy it is RECOMMENDED that Key Ks should be at least L octets long.

5.2. Computing the Hash

First, the Authentication Data field in the Cryptographic Authentication TLV is filled with the value AuthTag. Then, to compute HMAC over the Hello message it performs:

AuthData = HMAC(Ko, Hello Message)

Hello Message refers to the LDP Hello message excluding the IP and the UDP headers.

5.3. Result

The resultant Hash becomes the Authentication Data that is sent in the Authentication Data field of the Cryptographic Authentication TLV. The length of the Authentication Data field 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 LDP message as transmitted on the wire.

6. Processing Hello Message Using Cryptographic Authentication

6.1. Transmission Using Cryptographic Authentication

Prior to transmitting the Hello message, the Length in the Cryptographic Authentication TLV header is set as per the authentication algorithm that is being used. It is set to 24 for HMAC-SHA-1, 36 for HMAC-SHA-256, 52 for HMAC-SHA-384 and 68 for HMAC-SHA-512.

The Security Association ID field is set to the ID of the current authentication key. The HMAC Hash is computed as explained in Section 3. The resulting Hash is stored in the Authentication Data field prior to transmission. The authentication key MUST NOT be carried in the packet.

6.2. Receipt Using Cryptographic Authentication

The receiving LSR applies acceptability criteria for received Hellos using cryptographic authentication. If the Cryptographic Authentication TLV is unknown to the receiving LSR, the received packet MUST be discarded according to Section 3.5.1.2.2 of [RFC5036].

The receiving LSR locates the LDP SA using the Security Association ID field carried in the message. If the SA is not found, or if the SA is not valid for reception (i.e., current time < KeyStartAccept or current time >= KeyStopAccept), LDP Hello message MUST be discarded, and an error event SHOULD be logged.

If the cryptographic sequence number in the LDP packet is less than or equal to the last sequence number received from the same neighbor, the LDP message MUST be discarded, and an error event SHOULD be logged.

Before the receiving LSR performs any processing, it needs to save the values of the Authentication Data field. The receiving LSR then replaces the contents of the Authentication Data field with AuthTag, computes the Hash, using the authentication key specified by the received Security Association ID field, as explained in Section 3. If the locally computed Hash is equal to the received value of the Authentication Data field, the received packet is accepted for other normal checks and processing as described in [RFC5036]. Otherwise, if the locally computed Hash is not equal to the received value of the Authentication Data field, the received packet MUST be discarded, and an error event SHOULD be logged. The foresaid logging need to be carefully rate limited, since while a LDP router is under attack of a storm of spoofed hellos, the resource taking for logging could be overwelming.

After the LDP Hello message has been successfully authenticated, implementations MUST store the 64-bit cryptographic sequence number for the Hello message received from the neighbor. The saved cryptographic sequence numbers will be used for replay checking for subsequent packets received from the neighbor.

7. Security Considerations

Section 1 of this document describes the security issues arising from the use of unauthenticated LDP Hello messages. In order to address those issues, it is RECOMMENDED that all deployments use the Cryptographic Authentication TLV to authenticate the Hello messages.

The quality of the security provided by the Cryptographic Authentication TLV depends completely on the strength of the cryptographic algorithm in use, the strength of the key being used, and the correct implementation of the security mechanism in communicating LDP implementations. Also, the level of security provided by the Cryptographic Authentication TLV varies based on the authentication type used.

It should be noted that the authentication method described in this document is not being used to authenticate the specific originator of a packet but is rather being used to confirm that the packet has indeed been issued by a router that has access to the Authentication Key.

Deployments SHOULD use sufficiently long and random values for the Authentication Key so that guessing and other cryptographic attacks on the key are not feasible in their environments. In support of these recommendations, management systems SHOULD support hexadecimal input of Authentication Keys.

The mechanism described herein is not perfect . However, this mechanism introduces a significant increase in the effort required for an adversary to successfully attack the LDP Hello protocol while not causing undue implementation, deployment, or operational complexity.

8. IANA Considerations

The IANA is requested to as assign a new TLV from the "Label Distribution Protocol (LDP) Parameters" registry, "TLV Type Name Space".

Value	Meaning	Reference
TBD1	Cryptographic Authentication TLV	this document (sect 2.3)

The IANA is also requested to as assign value from the "Authentication Cryptographic Protocol ID", registry under the "Keying and Authentication for Routing Protocols (KARP) Parameters" category.

Value	Description	Reference
TBD2	LDP Cryptographic Protocol ID	this document (sect 4)

Note to the RFC Editor and IANA (to be removed before publication):

The new value should be assigned from the range 0x400 - 0x4ff using the first free value.

9. Acknowledgements

We are indebted to Yaron Sheffer who helped us enormously in rewriting the draft to get rid of the redundant crypto mathematics that we had added here.

We would also like to thank Liu Xuehu for his work on background and motivation for LDP Hello authentication. And last but not the least, we would also thank Adrian Farrel, Eric Rosen, Sam Hartman, Stephen Farrell, Eric Gray, Kamran Raza and Acee Lindem for their valuable comments.

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