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LISP-Security (LISP-SEC)
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Abstract

This memo specifies LISP-SEC, a set of security mechanisms that provide origin authentication, integrity and anti-replay protection to LISP's EID-to-RLOC mapping data conveyed via mapping lookup process. LISP-SEC also enables verification of authorization on EID-prefix claims in Map-Reply messages.

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 [RFC2119].

Status of this Memo

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1. Introduction

The Locator/ID Separation Protocol [I-D.ietf-lisp] defines a set of
functions for routers to exchange information used to map from non-
routable Endpoint Identifiers (EIDs) to routable Routing Locators
(RLOCs). If these EID-to-RLOC mappings, carried through Map-Reply
messages, are transmitted without integrity protection, an adversary
can manipulate them and hijack the communication, impersonate the
requested EID or mount Denial of Service or Distributed Denial of
Service attacks. Also, if the Map-Reply message is transported
unauthenticated, an adversarial LISP entity can overclaim an EID-prefix
and maliciously redirect traffic directed to a large number of hosts. A
detailed description of "overclaiming" attack is provided in [I-
D.saucez-lisp-security].
This memo specifies LISP-SEC, a set of security mechanisms that provide
origin authentication, integrity and anti-replay protection to LISP's
EID-to-RLOC mapping data conveyed via mapping lookup process. LISP-SEC
also enables verification of authorization on EID-prefix claims in Map-
Reply messages, ensuring that the sender of a Map-Reply that provides
the location for a given EID-prefix is entitled to do so according to
the EID prefix registered in the associated Map Server. Map-Register
security, including the right for a LISP entity to register an EID-
prefix or to claim presence at an RLOC, is out of the scope of LISP-
SEC. Additional security considerations are described in Section 6.

2. Definition of Terms

[I-D.ietf-lisp].

*One-Time Key (OTK): An ephemeral randomly generated key that must
 be used for a single Map-Request/Map-Reply exchange.

* -ITR-OTK: The One-Time Key generated at the ITR.

   -MS-OTK: The One-Time Key generated at the Map-Server.

  Encapsulated Control Message (ECM): A LISP control message that
  is prepended with an additional LISP header. ECM is used by ITRs

to send LISP control messages to a Map-Resolver, by Map-Resolvers
to forward LISP control messages to a Map-Server, and by Map-
Resolvers to forward LISP control messages to an ETR.

*Authentication Data (AD): Metadata that is included either in a
 LISP ECM header or in a Map-Reply message to support
 confidentiality, integrity protection, and verification of EID-
 prefix authorization.

* -OTK-AD: The portion of ECM Authentication Data that contains a
    One-Time Key.

   -EID-AD: The portion of ECM and Map-Reply Authentication Data
    used for verification of EID-prefix authorization.

   -PKT-AD: The portion of Map-Reply Authentication Data used to
    protect the integrity of the Map-Reply message.

For definitions of other terms, notably Map-Request, Map-Reply, Ingress
Tunnel Router (ITR), Egress Tunnel Router (ETR), Map-Server (MS) and
Map-Resolver (MR) please consult the LISP specification

3. LISP-SEC Threat Model

LISP-SEC addresses the control plane threats, described in [I-D.saucez-
lisp-security], that target EID-to-RLOC mappings, including
manipulations of Map-Request and Map-Reply messages, and malicious xTR
EID overclaiming. However LISP-SEC makes two main assumptions that are
not part of [I-D.saucez-lisp-security]. First, the LISP Mapping System
is expected to deliver Map-Request messages to their intended
destinations as identified by the EID. Second, no man-in-the-middle
attack can be mounted within the LISP Mapping System. Furthermore,
while LISP-SEC enables detection of EID prefix over claiming attacks,
it assumes that Map Servers can verify the EID prefix authorization at
time of registration.
Accordingly to the threat model described in [I-D.saucez-lisp-security]
LISP-SEC assumes that any kind of attack, including MITM attacks, can
be mounted in the access network, outside of the boundaries of the LISP
mapping system. An on-path attacker, outside of the LISP mapping
service system can, for instance, hijack mapping requests and replies,
spoofing the identity of a LISP node. Another example of on-path
attack, called over claiming attack, can be mounted by a malicious
Egress Tunnel Router (ETR), by over claiming the EID-prefixes for which
it is authoritative. In this way the ETR can maliciously redirect
traffic directed to a large number of hosts.

4. Protocol Operations

The goal of the security mechanisms defined in [I-D.ietf-lisp] is to
prevent unauthorized insertion of mapping data, by providing origin

authentication and integrity protection for the Map-Registration, and
by using the nonce to detect unsolicited Map-Reply sent by off-path
attackers.

LISP-SEC builds on top of the security mechanisms defined in [I-D.ietf-
lisp] to address the threats described in Section 3 by leveraging the
trust relationships existing among the LISP entities participating to
the exchange of the Map-Request/Map-Reply messages. Those trust
relationships are used to securely distribute a One-Time Key (OTK) that
provides origin authentication, integrity and anti-replay protection to
mapping data conveyed via the mapping lookup process, and that
effectively prevent over claiming attacks. The processing of security
parameters during the Map-Request/Map-Reply exchange is as follows:

> *The ITR-OTK is generated and stored at the ITR, and securely
> transported to the Map-Server.

> *The Map-Server uses the ITR-OTK to compute an HMAC that protects
> the integrity of the mapping data provided by the Map-Server to
> prevent overclaiming attacks. The Map-Server also derives a new
> OTK (MS-OTK) that is passed to the ETR, by applying a Key
> Derivation Function (KDF) to the ITR-OTK.

> *The ETR uses the MS-OTK to compute an HMAC that protects the
> integrity of the Map-Reply sent to the ITR.

> *Finally, the ITR uses the stored ITR-OTK to verify the integrity
> of the mapping data provided by both the Map-Server and the ETR,
> and to verify that no overclaiming attacks were mounted along the
> path between the Map-Server and the ITR.

Section 5 provides the detailed description of the LISP-SEC control
messages and their processing, while the rest of this section describes
the flow of protocol operations at each entity involved in the Map-
Request/Map-Reply exchange:

> *The ITR, upon transmitting a Map-Request message, generates and
> stores an OTK (ITR-OTK). This key is included into the
> Encapsulated Control Message (ECM) that contains the Map-Request
> sent to the Map-Resolver. To provide confidentiality to the ITR-
> OTK over the path between the ITR and its Map-Resolver, the ITR-
> OTK SHOULD be encrypted using a preconfigured key shared between
> the ITR and the Map-Resolver, similar to the key shared between
> the ETR and the Map-Server in order to secure ETR registration
> [I-D.ietf-lisp-ms].

> *The Map-Resolver decapsulates the ECM message, decrypts the ITR-
> OTK, if needed, and forwards through the Mapping System the
> received Map-Request and the ITR-OTK, as part of a new ECM
> message. As described in Section 5.5, the LISP Mapping System

delivers the ECM to the appropriate Map-Server, as identified by
the EID destination address of the Map-Request.

*The Map-Server is configured with the location mappings and
 policy information for the ETR responsible for the destination
 EID address. Using this preconfigured information the Map-Server,
 after the decapsulation of the ECM message, finds the longest
 match EID-prefix that covers the requested EID in the received
 Map-Request. The Map-Server adds this EID-prefix, together with
 an HMAC computed using the ITR-OTK, to a new Encapsulated Control
 Message that contains the received Map-Request.

*The Map-Server derives a new OTK (MS-OTK) by applying a Key
 Derivation Function (KDF) to the ITR-OTK. MS-OTK is included in
 the Encapsulated Control Message sent to the ETR. To provide MS-
 OTK confidentiality over the path between the Map-Server and the
 ETR, the MS-OTK should be encrypted using the key shared between
 the ETR and the Map-Server in order to secure ETR registration
 [I-D.ietf-lisp-ms].

*If the Map-Server is acting in proxy mode, as specified in [I-
 D.ietf-lisp], the ETR is not involved in the generation of the
 Map-Reply. In this case the Map-Server generates the Map-Reply on
 behalf of the ETR as described below.

*The ETR, upon receiving the Encapsulated Map-Request from the
 Map-Server, decrypts the MS-OTK, if needed, and originates a Map-
 Reply that contains the EID-to-RLOC mapping information as
 specified in [I-D.ietf-lisp].

*The ETR computes an HMAC over the original LISP Map-Reply, keyed
 with MS-OTK to protect the integrity of the whole Map-Reply. The
 ETR also copies the EID-prefix authorization data that the Map-
 Server included in the Encapsulated Map-Request into the Map-
 Reply message.

*The ITR, upon receiving the Map-Reply, uses the locally stored
 ITR-OTK to verify the integrity of the EID-prefix authorization
 data included in the Map-Reply by the Map-Server. The ITR
 computes the MS-OTK by applying the same KDF used by the Map-
 Server, and verifies the integrity of the Map-Reply. If the
 integrity checks fail, the Map-Reply MUST be discarded. Also, if
 the EID-prefixes claimed by the ETR in the Map-Reply are not
 equal or less specific than the EID-prefix authorization data
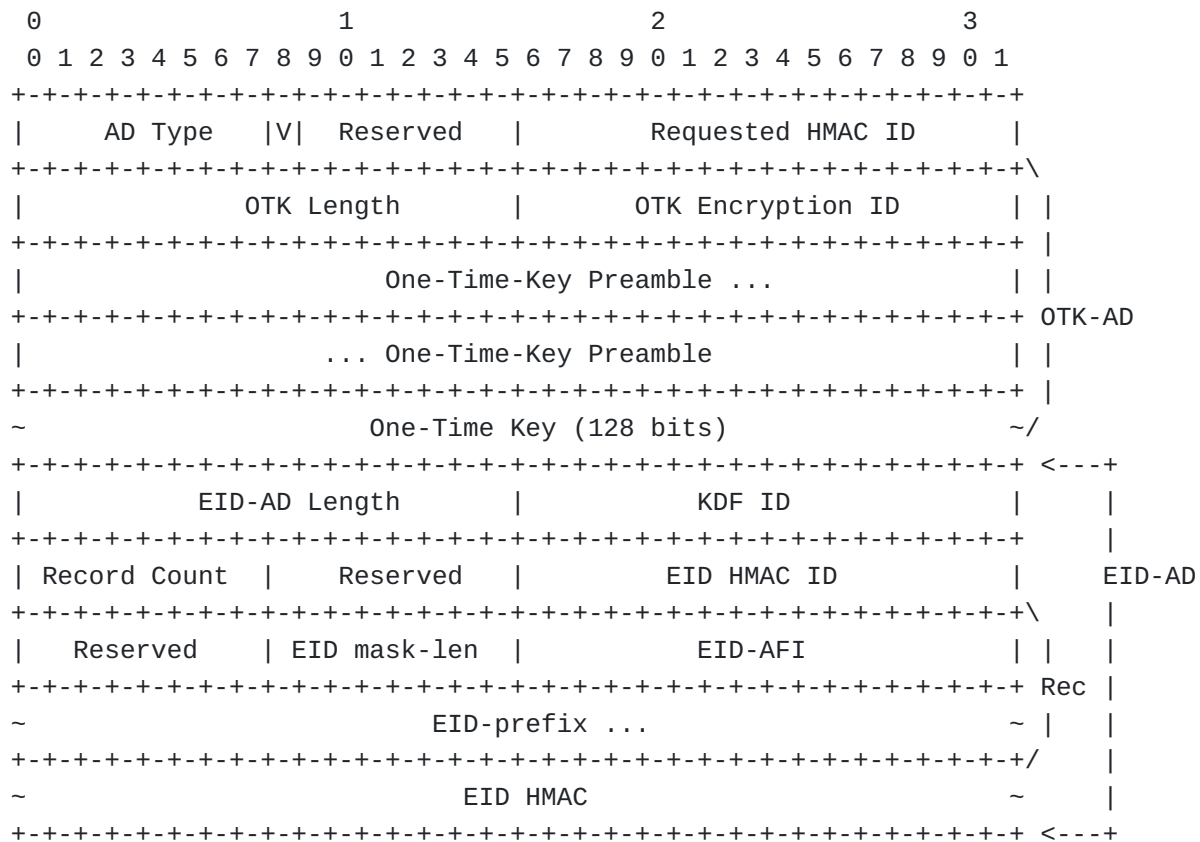 inserted by the Map-Server, the ITR MUST discard the Map-Reply.

5. LISP-SEC Control Messages Details

LISP-SEC metadata associated with a Map-Request is transported within
the Encapsulated Control Message that contains the Map-Request.

LISP-SEC metadata associated with the Map-Reply is transported within
the Map-Reply itself.

5.1. Encapsulated Control Message LISP-SEC Extensions

LISP-SEC uses the ECM (Encapsulated Control Message) defined in [I-
D.ietf-lisp] with Type set to 8, and S bit set to 1 to indicate that
the LISP header includes Authentication Data (AD). The format of the
LISP-SEC ECM Authentication Data is defined in the following figure.
OTK-AD stands for One-Time Key Authentication Data and EID-AD stands
for EID Authentication Data.

```
 0                   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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    AD Type    |V|   Reserved   |        Requested HMAC ID      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+\
|            OTK Length          |        OTK Encryption ID      | |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ |
|                  One-Time-Key Preamble ...                     | |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ OTK-AD
|               ... One-Time-Key Preamble                        | |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ |
~                   One-Time Key (128 bits)                     ~/
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ <---+
|           EID-AD Length        |            KDF ID             |    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+    |
| Record Count  |    Reserved    |         EID HMAC ID           |   EID-AD
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+\   |
|   Reserved    | EID mask-len   |          EID-AFI             | |   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ Rec |
~                       EID-prefix ...                          ~ |   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+/   |
~                          EID HMAC                             ~    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ <---+
```

   *AD Type: 1 (LISP-SEC Authentication Data)

   *V: Key Version bit. This bit is toggled when the sender switches
    to a new OTK wrapping key

   *Reserved: Set to 0 on transmission and ignored on receipt.

   *Requested HMAC ID: The HMAC algorithm requested by the ITR. See
    Section 5.3 for details.

   *OTK Length: The length (in bytes) of the OTK Authentication Data
    (OTK-AD), that contains the OTK Preamble and the OTK.

*OTK Encryption ID: The identifier of the key wrapping algorithm
 used to encrypt the One-Time-Key. When a 128-bit OTK is sent
 unencrypted by the Map-Resolver, the OTK Encryption ID is set to
 NULL_KEY_WRAP_128. See Section 5.4 for more details.

*One-Time-Key Preamble: set to 0 if the OTK is not encrypted. When
 the OTK is encrypted, this field may carry additional metadata
 resulting from the key wrapping operation. When a 128-bit OTK is
 sent unencrypted by Map-Resolver, the OTK Preamble is set to
 0x0000000000000000 (64 bits). See Section 5.4 for details.

*One-Time-Key: the OTK encrypted (or not) as specified by OTK
 Encryption ID. See Section 5.4 for details.

*EID-AD Length: length (in bytes) of the EID Authentication Data
 (EID-AD). The ITR MUST set EID-AD Length to 4 bytes, as it only
 fills the KDF ID field, and all the remaining fields part of the
 EID-AD are not present. An EID-AD MAY contain multiple EID-
 records. Each EID-record is 4-byte long plus the length of the
 AFI-encoded EID-prefix.

*KDF ID: Identifier of the Key Derivation Function used to derive
 the MS-OTK. The ITR SHOULD use this field to indicate the
 recommended KDF algorithm, according to local policy. The Map-
 Server can overwrite the KDF ID if it does not support the KDF ID
 recommended by the ITR. See Section 5.4 for more details.

*Record Count: The number of records in this Map-Request message.
 A record is comprised of the portion of the packet that is
 labeled 'Rec' above and occurs the number of times equal to
 Record Count.

*Reserved: Set to 0 on transmission and ignored on receipt.

*EID HMAC ID: Identifier of the HMAC algorithm used to protect the
 integrity of the EID-AD. This field is filled by Map-Server that
 computed the EID-prefix HMAC. See Section 5.4 for more details.

*EID mask-len: Mask length for EID-prefix.

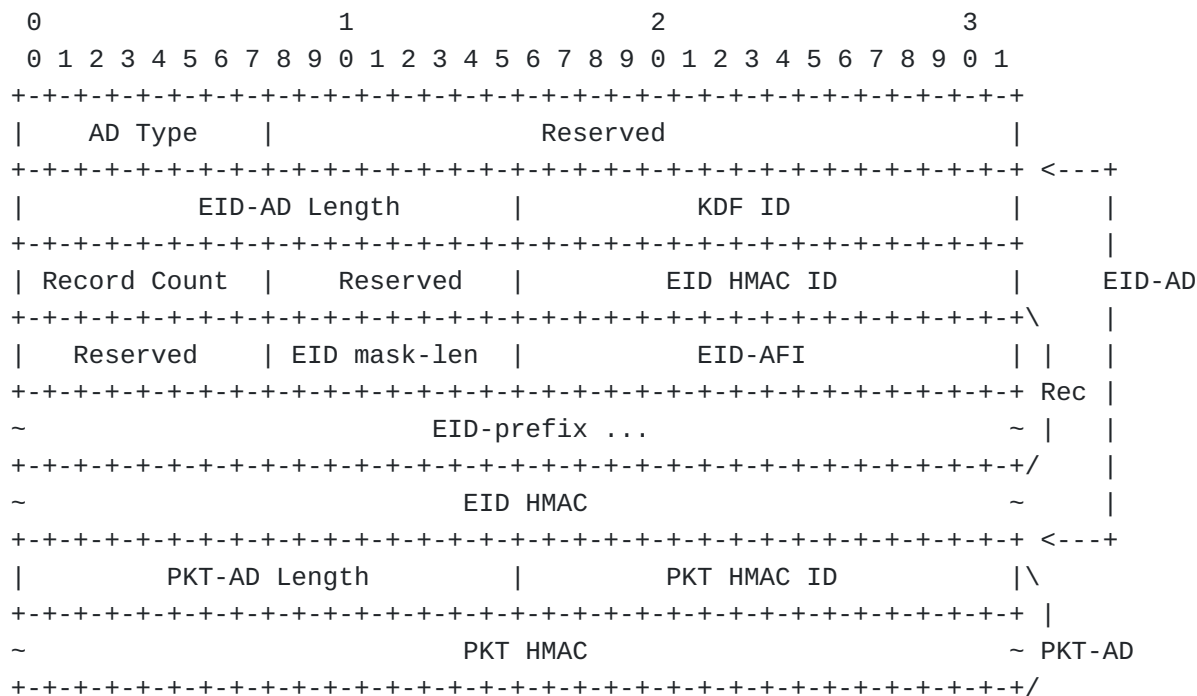*EID-AFI: Address family of EID-prefix according to [RFC5226]

*EID-prefix: The Map-Server uses this field to specify the EID-
 prefix that the destination ETR is authoritative for, and is the
 longest match for the requested EID.

*EID HMAC: HMAC of the EID-AD computed and inserted by Map-Server.
 Before computing the HMAC operation the EID HMAC field MUST be
 set to 0. The HMAC covers the entire EID-AD.

5.2. Map-Reply LISP-SEC Extensions

LISP-SEC uses the Map-Reply defined in [I-D.ietf-lisp], with Type set
to 2, and S bit set to 1 to indicate that the Map-Reply message
includes Authentication Data (AD). The format of the LISP-SEC Map-Reply
Authentication Data is defined in the following figure. PKT-AD is the
Packet Authentication Data that covers the Map-Reply payload.

```
 0                   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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    AD Type    |               Reserved                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ <---+
|         EID-AD Length        |             KDF ID             |     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+     |
| Record Count  |    Reserved   |         EID HMAC ID           |   EID-AD
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+\   |
|   Reserved    | EID mask-len  |           EID-AFI             | |   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ Rec |
~                       EID-prefix ...                          ~ |   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+/   |
~                          EID HMAC                             ~    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ <---+
|       PKT-AD Length          |        PKT HMAC ID             |\
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ |
~                          PKT HMAC                             ~ PKT-AD
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+/
```

   *AD Type: 1 (LISP-SEC Authentication Data)

   *EID-AD Length: length (in bytes) of the EID-AD. An EID-AD MAY
    contain multiple EID-records. Each EID-record is 4-byte long plus
    the length of the AFI-encoded EID-prefix.

   *KDF ID: Identifier of the Key Derivation Function used to derive
    MS-OTK. See Section 5.6 for more details.

   *Record Count: The number of records in this Map-Reply message. A
    record is comprised of the portion of the packet that is labeled
    'Rec' above and occurs the number of times equal to Record Count.

   *Reserved: Set to 0 on transmission and ignored on receipt.

   *EID HMAC ID: Identifier of the HMAC algorithm used to protect the
    integrity of the EID-AD. See Section 5.6 for more details.

   *EID mask-len: Mask length for EID-prefix.

   *EID-AFI: Address family of EID-prefix according to [RFC5226].

*EID-prefix: This field contains an EID-prefix that the
    destination ETR is authoritative for, and is the longest match
    for the requested EID.

   *EID HMAC: HMAC of the EID-AD, as computed by the Map-Server.
    Before computing the HMAC operation the EID HMAC field MUST be
    set to 0. The HMAC covers the entire EID-AD.

   *PKT-AD Length: length (in bytes) of the Packet Authentication
    Data (PKT-AD).

   *PKT HMAC ID: Identifier of the HMAC algorithm used to protect the
    integrity of the Map-reply Location Data.

   *PKT HMAC: HMAC of the whole Map-Reply packet, including the LISP-
    SEC Authentication Data. The scope of the authentication goes
    from the Map-Reply Type field to the PKT HMAC field included.
    Before computing the HMAC operation the PKT HMAC field MUST be
    set to 0. See Section 5.7 for more details.

5.3. ITR Processing

Upon creating a Map-Request, the ITR generates a random ITR-OTK that is
stored locally, together with the nonce generated as specified in [I-
D.ietf-lisp].
The Map-Request MUST be encapsulated in an ECM, with the S-bit set to
1, to indicate the presence of Authentication Data. If the ITR and the
Map-Resolver are configured with a shared key, the ITR-OTK
confidentiality SHOULD be protected by wrapping the ITR-OTK with the
algorithm specified by the OTK Encryption ID field. See Section 5.4 for
further details on OTK encryption.
The Requested HMAC ID field contains the suggested HMAC algorithm to be
used by the Map-Server and the ETR to protect the integrity of the ECM
Authentication data and of the Map-Reply.
The KDF ID field, specifies the suggested key derivation function to be
used by the Map-Server to derive the MS-OTK.
The EID-AD length is set to 4 bytes, since the Authentication Data does
not contain EID-prefix Authentication Data, and the EID-AD contains
only the KDF ID field.
In response to an encapsulated Map-Request that has the S-bit set, an
ITR MUST receive a Map-Reply with the S-bit set, that includes an EID-
AD and a PKT-AD. If the Map-Reply does not include both ADs, the ITR
MUST discard it. In response to an encapsulated Map-Request with S-bit
set to 0, the ITR expects a Map-Reply with S-bit set to 0, and the ITR
SHOULD discard the Map-Reply if the S-bit is set.
Upon receiving a Map-Reply, the ITR must verify the integrity of both
the EID-AD and the PKT-AD, and MUST discard the Map-Reply if one of the
integrity checks fails.

The integrity of the EID-AD is verified using the locally stored ITR-
OTK to re-compute the HMAC of the EID-AD using the algorithm specified
in the EID HMAC ID field. If the EID HMAC ID field does not match the
Requested HMAC ID the ITR SHOULD discard the Map-Reply and send, at the
first opportunity it needs to, a new Map-Request with a different
Requested HMAC ID field, according to ITR's local policy. The ITR MUST
set the EID HMAC ID field to 0 before computing the HMAC.
To verify the integrity of the PKT-AD, first the MS-OTK is derived from
the locally stored ITR-OTK using the algorithm specified in the KDF ID
field. This is because the PKT-AD is generated by the ETR using the MS-
OTK. If the KDF ID in the Map-Reply does not match the KDF ID requested
in the Map-Request, the ITR SHOULD discard the Map-Reply and send, at
the first opportunity it needs to, a new Map-Request with a different
KDF ID, according to ITR's local policy. The derived MS-OTK is then
used to re-compute the HMAC of the PKT-AD using the Algorithm specified
in the PKT HMAC ID field. If the PKT HMAC ID field does not match the
Requested HMAC ID the ITR SHOULD discard the Map-Reply and send, at the
first opportunity it needs to, a new Map-Request with a different
Requested HMAC ID according to ITR's local policy.
Each individual Map-Reply EID-record is considered valid only if: (1)
both EID-AD and PKT-AD are valid, and (2) the intersection of the EID-
prefix in the Map-Reply EID-record with one of the EID-prefixes
contained in the EID-AD is not empty. After identifying the Map-Reply
record as valid, the ITR sets the EID-prefix in the Map-Reply record to
the value of the intersection set computed before, and adds the Map-
Reply EID-record to its EID-to-RLOC cache, as described in [I-D.ietf-
lisp]. An example of Map-Reply record validation is provided in Section
5.3.1.
The ITR SHOULD send SMR triggered Map Requests over the mapping system
in order to receive a secure Map-Reply. If an ITR accepts piggybacked
Map-Replies, it SHOULD also send a Map-Request over the mapping system
in order to securely verify the piggybacked Map-Reply.

5.3.1. Map-Reply Record Validation

The payload of a Map-Reply may contain multiple EID-records. The whole
Map-Reply is signed by the ETR, with the PKT HMAC, to provide integrity
protection and origin authentication to the EID-prefix records claimed
by the ETR. The Authentication Data field of a Map-Reply may contain
multiple EID-records in the EID-AD. The EID-AD is signed by the Map-
Server, with the EID HMAC, to provide integrity protection and origin
authentication to the EID-prefix records inserted by the Map-Server.
Upon receiving a Map-Reply with the S-bit set, the ITR first checks the
validity of both the EID HMAC and of the PKT-AD HMAC. If either one of
the HMACs is not valid, a log message is issued and the Map-Reply is
not processed any further. If both HMACs are valid, the ITR proceeds
with validating each individual EID-record claimed by the ETR by
computing the intersection of each one of the EID-prefix contained in
the payload of the Map-Reply with each one of the EID-prefixes

contained in the EID-AD. An EID-record is valid only if at least one of the intersections is not the empty set.
For instance, the Map-Reply payload contains 3 mapping record EID-prefixes:

    *1.1.1.0/24

    *1.1.2.0/24

    *1.2.0.0/16

The EID-AD contains two EID-prefixes:

    *1.1.2.0/24

    *1.2.3.0/24

The EID-record with EID-prefix 1.1.1.0/24 is not processed since it is not included in any of the EID-ADs signed by the Map-Server. A log message is issued.
The EID-record with EID-prefix 1.1.2.0/24 is stored in the map-cache because it matches the second EID-prefix contained in the EID-AD.
The EID-record with EID-prefix 1.2.0.0/16 is not processed since it is not included in any of the EID-ADs signed by the Map-Server. A log message is issued. In this last example the ETR is trying to over claim the EID-prefix 1.2.0.0/16, but the Map-Server authorized only 1.2.3.0/24, hence the EID-record is discarded.

5.3.2. PITR Processing

The processing performed by a PITR is equivalent to the processing of an ITR. However, if the PITR is directly connected to the ALT, the PITR performs the functions of both the ITR and the Map-Resolver forwarding the Map-Request encapsulated in an ECM header that includes the Authentication Data fields as described in Section 5.5.

5.4. Encrypting and Decrypting an OTK

MS-OTK confidentiality is required in the path between the Map-Server and the ETR, the MS-OTK SHOULD be encrypted using the preconfigured key shared between the Map-Server and the ETR for the purpose of securing ETR registration [I-D.ietf-lisp-ms]. Similarly, if ITR-OTK confidentiality is required in the path between the ITR and the Map-Resolver, the ITR-OTK SHOULD be encrypted with a key shared between the ITR and the Map-Resolver.
The OTK is encrypted using the algorithm specified in the OTK Encryption ID field. When the AES Key Wrap algorithm is used to encrypt a 128-bit OTK, according to [RFC3339], the AES Key Wrap Initialization Value MUST be set to 0xA6A6A6A6A6A6A6A6 (64 bits). The output of the AES Key Wrap operation is 192-bit long. The most significant 64-bit are

copied in the One-Time Key Preamble field, while the 128 less
significant bits are copied in the One-Time Key field of the LISP-SEC
Authentication Data.
When decrypting an encrypted OTK the receiver MUST verify that the
Initialization Value resulting from the AES Key Wrap decryption
operation is equal to 0xA6A6A6A6A6A6A6A6. If this verification fails
the receiver MUST discard the entire message.
When a 128-bit OTK is sent unencrypted the OTK Encryption ID is set to
NULL_KEY_WRAP_128, and the OTK Preamble is set to 0x0000000000000000
(64 bits).

5.5. Map-Resolver Processing

Upon receiving an encapsulated Map-Request with the S-bit set, the Map-
Resolver decapsulates the ECM message. The ITR-OTK, if encrypted, is
decrypted as specified in Section 5.4.
The Map-Resolver, as specified in [I-D.ietf-lisp-ms], originates a new
ECM header with the S-bit set, that contains the unencrypted ITR-OTK,
as specified in Section 5.4, and the other data derived from the ECM
Authentication Data of the received encapsulated Map-Request.
The Map-Resolver then forwards the received Map-Request, encapsulated
in the new ECM header that includes the newly computed Authentication
Data fields.

5.6. Map-Server Processing

Upon receiving an ECM encapsulated Map-Request with the S-bit set, the
Map-Server process the Map-Request according to the value of the S-bit
contained in the Map-Register sent by the ETR during registration.
If the S-bit contained in the Map-Register was clear the Map-Server
decapsulates the ECM and generates a new ECM encapsulated Map-Request
that does not contain an ECM Authentication Data, as specified in [I-
D.ietf-lisp]. The Map-Server does not perform any further LISP-SEC
processing.
If the S-bit contained in the Map-Register was set the Map-Server
decapsulates the ECM and generates a new ECM Authentication Data. The
Authentication Data includes the OTK-AD and the EID-AD, that contains
EID-prefix authorization information, that are ultimately sent to the
requesting ITR.
The Map-Server updates the OTK-AD by deriving a new OTK (MS-OTK) from
the ITR-OTK received with the Map-Request. MS-OTK is derived applying
the key derivation function specified in the KDF ID field. If the
algorithm specified in the KDF ID field is not supported, the Map-
Server uses a different algorithm to derive the key and updates the KDF
ID field accordingly.
The Map-Server and the ETR MUST be configured with a shared key for
mapping registration according to [I-D.ietf-lisp-ms]. If MS-OTK
confidentiality is required, then the MS-OTK SHOULD be encrypted, by

wrapping the MS-OTK with the algorithm specified by the OTK Encryption ID field as specified in Section 5.4.
The Map-Server includes in the EID-AD the longest match registered EID-prefix for the destination EID, and an HMAC of this EID-prefix. The HMAC is keyed with the ITR-OTK contained in the received ECM Authentication Data, and the HMAC algorithm is chosen according to the Requested HMAC ID field. If The Map-Server does not support this algorithm, the Map-Server uses a different algorithm and specifies it in the EID HMAC ID field. The scope of the HMAC operation covers the entire EID-AD, from the EID-AD Length field to the EID HMAC field, which must be set to 0 before the computation.
The Map-Server then forwards the updated ECM encapsulated Map-Request, that contains the OTK-AD, the EID-AD, and the received Map-Request to an authoritative ETR as specified in [I-D.ietf-lisp].

5.6.1. Map-Server Processing in Proxy mode

If the Map-Server is in proxy mode, it generates a Map-Reply, as specified in [I-D.ietf-lisp], with the S-bit set to 1. The Map-Reply includes the Authentication Data that contains the EID-AD, computed as specified in Section 5.6, as well as the PKT-AD computed as specified in Section 5.7.

5.7. ETR Processing

Upon receiving an encapsulated Map-Request with the S-bit set, the ETR decapsulates the ECM message. The OTK field, if encrypted, is decrypted as specified in Section 5.4 to obtain the unencrypted MS-OTK.
The ETR then generates a Map-Reply as specified in [I-D.ietf-lisp] and includes an Authentication Data that contains the EID-AD, as received in the encapsulated Map-Request, as well as the PKT-AD.
The EID-AD is copied from the Authentication Data of the received encapsulated Map-Request.
The PKT-AD contains the HMAC of the whole Map-Reply packet, keyed with the MS-OTK and computed using the HMAC algorithm specified in the Requested HMAC ID field of the received encapsulated Map-Request. If the ETR does not support the Requested HMAC ID, it uses a different algorithm and updates the PKT HMAC ID field accordingly. The scope of the HMAC operation covers the entire PKT-AD, from the Map-Reply Type field to the PKT HMAC field, which must be set to 0 before the computation.
Finally the ETR sends the Map-Reply to the requesting ITR as specified in [I-D.ietf-lisp].

6. Security Considerations

6.1. Mapping System Security

The LISP-SEC threat model described in Section 3, assumes that the LISP Mapping System is working properly and eventually delivers Map-Request messages to a Map-Server that is authoritative for the requested EID. Security is not yet embedded in LISP+ALT but BGP route filtering SHOULD be deployed in the ALT infrastructure to enforce proper routing in the mapping system. The SIDR working group is currently addressing prefix and route advertisement authorization and authentication for BGP. While following SIDR recommendations in the global Internet will take time, applying these recommendations to the ALT, which relies on BGP, should be less complex, as ALT is currently small and with a limited number of operators. Ultimately, deploying the SIDR recommendations in ALT further ensures that the fore mentioned assumption is true.
It is also assumed that no man-in-the-middle attack can be carried out against the ALT router to ALT router tunnels, and that the information included into the Map-Requests, in particular the OTK, cannot be read by third-party entities. It should be noted that the integrity of the Map-Request in the ALT is protected by BGP authentication, and that in order to provide OTK confidentiality in the ALT mapping system the ALT router to ALT router tunnels MAY be deployed using IPsec (ESP). Map-Register security, including the right for a LISP entity to register an EID-prefix or to claim presence at an RLOC, is out of the scope of LISP-SEC.

6.2. Random Number Generation

The ITR-OTK MUST be generated by a properly seeded pseudo-random (or strong random) source. See [RFC4086] for advice on generating security-sensitive random data

6.3. Map-Server and ETR Colocation

If the Map-Server and the ETR are colocated, LISP-SEC does not provide protection from overclaiming attacks mounted by the ETR. However, in this particular case, since the ETR is within the trust boundaries of the Map-Server, ETR's overclaiming attacks are not included in the threat model.

7. IANA Considerations

7.1. HMAC functions

The following HMAC ID values are defined by this memo for use as Requested HMAC ID, EID HMAC ID, and PKT HMAC ID in the LISP-SEC Authentication Data:

```
Name                     Number      Defined In
-------------------------------------------------
NONE                     0
AUTH-HMAC-SHA-1-160      1           [RFC2104]
AUTH-HMAC-SHA-256-128    2           [RFC4634]
```

values 2-65535 are reserved to IANA.

AUTH-HMAC-SHA-1-160 MUST be supported, AUTH-HMAC-SHA-256-128 should be supported.

7.2. Key Wrap Functions

The following OTK Encryption ID values are defined by this memo for use as OTK key wrap algorithms ID in the LISP-SEC Authentication Data:

```
Name                     Number      Defined In
-------------------------------------------------
NULL-KEY-WRAP-128        1
AES-KEY-WRAP-128         2           [RFC3394]
```

values 0 and 3-65535 are reserved to IANA.

NULL-KEY-WRAP-128, and AES-KEY-WRAP-128 MUST be supported.
NULL-KEY-WRAP-128 is used to carry an unencrypted 128-bit OTK, with a 64-bit preamble set to 0x0000000000000000 (64 bits).

7.3. Key Derivation Functions

The following KDF ID values are defined by this memo for use as KDF ID in the LISP-SEC Authentication Data:

```
Name                     Number      Defined In
-------------------------------------------------
NONE                     0
HKDF-SHA1-128            1           [RFC5869]
```

values 2-65535 are reserved to IANA.

HKDF-SHA1-128 MUST be supported

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9. References

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