Improving Mapping Services in LISP Networks
draft-boucadair-lisp-subscribe-01

Abstract

   Mapping Services in Locator/ID Separation Protocol (LISP) networks
   are key to proper LISP forwarding operation. When considering the
   deployment of LISP at large scale, these Mapping Services are even
   more crucial for the sake of the LISP forwarding efficiency. This
   document introduces two additional LISP messages that are meant to
   facilitate the dynamic discovery of Mapping Systems, improve Ingress
   Tunnel Routers (ITR) recovery times and optimize the solicitation of
   the LISP Mapping System as a function of the ITR location, in
   particular.

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

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1. Introduction

   Locator/ID Separation Protocol (LISP, [[RFC6830](RFC6830)]) operation relies
   upon a mapping mechanism that is used by ingress/egress Tunnel
   Routers (xTR) to forward traffic over the LISP network. The ability
   of dynamically discovering the Map-Resolver and Map-Server entities
   that provide such mapping services is meant to facilitate global LISP
   operation. In particular, the ability to inform Ingress Tunnel

Routers (ITR) of a LISP network about the availability and the status
of several Mapping Services is likely to improve the overall LISP
forwarding serviceability.

1.1. Issues

This section lists a set of issues that need further investigation:

Discover ITRs: Current LISP design does not allow to automatically
   discover active ITRs of a LISP domain (nor the mapping system of a
   given domain is aware of ITRs of the same domaine that can solicit
   its services, let alone ITRs of other domains). The solution
   proposed in this document allows to fill that gap.

Optimize EID-ROLC resolution time: Leaf LISP networks can be better
   serviced, for example by avoiding the cascading of Map-Resolvers,
   or by avoiding the solicitation of a Map-Resolver that is located
   an ocean away, etc. Policies should be taken into account when
   configuring Map-Resolver information on an ITR for improving EID-
   to-RLOC resolution. These policies should be modified and
   adjusted according to various events (e.g., installation of an
   additional Map-Resolver).

Accomodate Map-Resolvers constraints: Allows for the protocol to
   redirect a requesting ITR to another Map-Resolver when some events
   occur, such as an overload of the initially targeted Map-Resolver
   or when Map-Resolvers are optimized to service a set of
   destination EIDs, etc.

Faster Recovery of mapping entries: Whenever an ITR fails for some
   reason, the faulty ITR needs to recover at least the list of
   mappings for the most popular prefixes in a timely manner, in
   particular. Policies for mapping entries (to be recovered) are
   deployment-specific.

Receive push notifications: For LISP leaf networks that would need
   to maintain an up-to-date mapping table for a set of destination
   EIDs (or even the global mapping table) to avoid issues such as
   the loss of a first packet or to optimize LISP forwarding delay
   (and therefore the overall forwarding efficiency), a dynamic push
   mechanism would be helpful.

1.2. Assumptions

This document makes the following assumptions:

o Various LISP players (network operators, service providers, etc.)
   are likely to deploy and operate different LISP Mapping Systems.

Multiple Mapping Systems will therefore coexist for various
reasons, e.g., avoid country-centric governance, allow for
distinct technologies to implement the mapping service, business
opportunities, service innovation, etc.

o Interconnection between these Mapping Systems is required for the
   sake of global connectivity and also to minimize the risk of
   fragmenting the Internet.

o Mapping Services are supposed to be dimensioned to maintain a
   global mapping database for the entire LISP-enabled Internet.

o Mapping Service providers may offer advanced services to their
   customers such as maintain local caches (a la CDN), or update ITR
   mapping entries that match some criteria requested by a leaf LISP
   network, redirect ITR requests to the closest Map-Resolvers,
   structure the mapping resolution service so that the resolution
   time is optimized, etc.

o The entries of the mapping tables are exchanged between these
   Mapping systems so that Map-Request messages can be processed as
   close to the LISP leaf networks as possible.

o A leaf LISP-enabled network subscribes to the Mapping Service
   provided by one or several Mapping Service operators.

o The contribution of each player involved in the provisioning and
   the operation of a LISP-based connectivity forwarding service
   should be rationalized so that clear interfaces are defined and
   adequate mechanisms for troubleshooting, diagnosis and repair
   purposes can be easily implemented and adopted. The inability of
   identifying what is at the origin of the degradation of a LISP
   connectivity service is seen as one of the hurdles that are likely
   to jeopardize LISP deployments at large scale.

1.3. Improving LISP Mapping Services

This document specifies a couple of additional LISP messages that are
meant to improve the subscription to Mapping Services, let alone
their serviceability. They are described in the following sections.

A simple method to redirect ITR-originated mapping requests towards
another Map-Resolver when some conditions are met (e.g., overload of
a Map-Resolver, enforcement of traffic engineering policies, etc.) is
defined in Section 2 and Section 3. Section 8 specifies how advanced
Map-Resolver forwarding policies are installed in ITRs.

2. Map-Subscribe Message Format

The format of the Map-Subscribe message is shown in Figure 1.

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Type  |U|B|I|           Reserved          | Filter Len    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Nonce . . .                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         . . . Nonce                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         Key ID          |     Authentication Data Length    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                     Authentication Data                     ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                        Expiry Timer                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Length        |                                             |
   +-+-+-+-+-+-+-+-+                                             :
   :                          Filter                            :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                ...
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Length        |                                             |
   +-+-+-+-+-+-+-+-+                                             :
   :                          Filter                            :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: Map-Subscribe Message Format

The description of the fields is as follows:

o Type is to be defined (see Section 11).

o U (unsolicited-map-reply bit): When set, this flag indicates that
   the originating ITR is ready to receive unsolicited Map-Reply
   messages.

o B (bulk-support bit): When set, this flag indicates that the
   originating ITR supports mapping bulk retrieval method (e.g.,
   [I-D.boucadair-lisp-bulk]).

o I (immediate-retrieval bit): When set, this flag indicates that
   the originating ITR requests immediate retrieval of the portion of
   the mapping table that matches the filters included in the
   request.

o Reserved: reserved bits, MUST be sent as 0 and MUST be ignored
   when received.

o Filter Len: This field indicates in bytes, the length of the
   filters included in the request. It is equal to (sum of "8+Length
   of Filter"), where "Filter" denotes the filters included in the
   message.

o Nonce, Key ID, Authentication Data Length, and Authentication Data
   are similar to those of a LISP Map-Request message ([RFC6830]).

o Expiry Timer: This field indicates, in seconds, the validity timer
   for the subscription.

o Length: This field indicates, in octets, the length of the filter
   that is encoded in the "Filter" field.

o Filter: This field carries a destination EID (or a set thereof)
   that is encoded as an UTF-8 string. This specification allows to
   convey IP prefix literals, Names and/or AS numbers. One or
   multiple filters may be present in a request. IPv4 prefixes are
   encoded as IPv4-mapped IPv6 prefixes [RFC4291] (i.e., starting
   with ::ffff:0:0/96). A mix of names, IP prefixes and AS numbers
   may be enclosed in the same request. The value 0 is used to
   delete existing filters. Filters MUST be applied in the order
   they appear in the request.

3. Map-Subscribe-Ack Message Format

The format of the Map-Subscribe-Ack message is shown in Figure 2.

```
        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
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       | Type  |U|B|I|R|   Reserved      | Result      | Filter Len  |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                         Nonce . . .                          |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                         . . . Nonce                          |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |            Key ID             |  Authentication Data Length   |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       ~                     Authentication Data                       ~
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                         Expiry Timer                         |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       | Length        |                                              |
       +-+-+-+-+-+-+-+-+-+                                             :
       :                           Filter                            :
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                   ...
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       | Length        |                                              |
       +-+-+-+-+-+-+-+-+-+                                             :
       :                           Filter                            :
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                                                              |
       |                  Redirect Map-Resolver                       |
       |                  IP Address (128 bits)                       |
       |                                                              |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

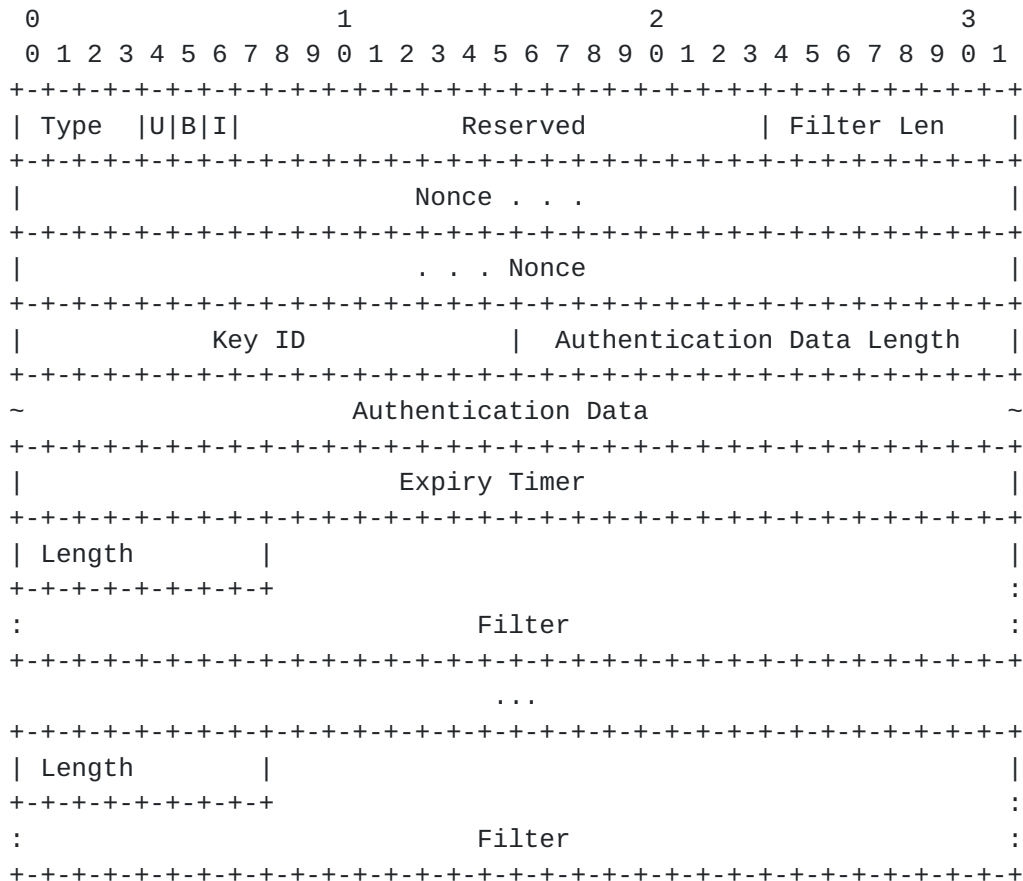   Figure 2: Map-Subscribe-Ack Message Format

   The description of the fields is as follows:

   o Type is to be defined (see Section 11).

   o U (unsolicited-map-reply bit): When set, this flag indicates that
      the Map-Resolver can issue unsolicited Map-Reply messages.

   o B (bulk-support bit): When set, this flag indicates that the Map-
      Resolver supports mapping bulk retrieval method (e.g.,
      [I-D.boucadair-lisp-bulk]).

   o I (immediate-retrieval bit): When set, this flag indicates that
      the Map-Resolver will initiate an immediate retrieval cycle of the

portion of the mapping table that matches the filters included in
the request.

o R (Redirect bit): When set, this flag indicates that a redirect
   Map-Resolver is enclosed in the message.

o Reserved: reserved bits, MUST be set to 0 and MUST be ignored when
   received.

o Result: indicates the result code of the processing of the Map-
   Subscribe request. The following codes are defined:

   0: SUCCESS. This code is used to indicate the request is
      successfully processed.

   1: PARTIAL-FILTERS-INSTALLED-LIMIT. This code is used to indicate
      a request is successfully processed but some filters were not
      installed because the number of filters carried in the initial
      Map-Subscribe message exceeds the filter limit.

   2: PARTIAL-FILTERS-INSTALLED-BAD. This code is used to indicate a
      request is successfully processed but some filters were not
      installed because they were malformed.

   3: PARTIAL-FILTERS-INSTALLED-LOCAL. This code is used to indicate
      a request is successfully processed but some filters were not
      installed because of local reasons. The ITR SHOULD, after a
      certain timer expires, send a Map-Subscribe request message for
      the set of filters that are not included in the Map-Subscribe-
      Ack message received by the ITR in response to its initial Map-
      Subscribe request message.

   4: FILTERS-PROHIBITED. This code is used to indicate a request is
      successfully processed but the installation of filters is
      prohibited.

o Filter Len: This field indicates in bytes, the length of the
   filters included in the message. It is equal to (sum of "8+Length
   of Filter"), where Filter represents the filters included in the
   message.

o Nonce, Key ID, Authentication Data Length, and Authentication Data
   are similar to those of a LISP Map-Request message ([RFC6830]).

o Expiry Timer: This field indicates, in seconds, the validity timer
   for the subscription.

   o Length: This field indicates, in octets, the length of the filter
      that is encoded in the "Filter" field.

   o Filter: This field carries the set of filters that were
      successfully installed.

   o Redirect Map-Resolver IP Address (128 bits): When the R-bit is
      set, this field carries the IP address of the Map-Resolver where
      mapping requests should be redirected. An IPv4 address is encoded
      as an IPv4-mapped IPv6 address.

4. Generating a Map-Subscribe Message

   An ITR uses the U-bit to inform a Map-Resolver whether it is ready to
   handle unsolicited Map-Reply messages or not. The ITR MUST set the
   U-bit when it supports such capability.

   An ITR uses the B-bit to inform a Map-Resolver whether it supports
   the mapping bulk transfer method or not. The ITR MUST set to the
   B-bit when it supports such method (e.g., [I-D.boucadair-lisp-bulk]).

   An ITR that joins the LISP network is likely to delete all
   notifications that are bound to its RLOCs. It does so by including a
   Null filter prior to any filter that it wishes the Map-Resolver to
   record.

   An ITR that loses its mapping cache for some reason SHOULD generate a
   Map-Subscribe message towards its Map-Resolver(s) with the I-bit set.

   An ITR MAY generate several Map-Subscribe messages to make the Map-
   Resolver install the required filters. Nevertheless, an ITR MUST
   expect that the Map-Resolver may limit the number of filters that may
   be installed. Filters that are not accepted or not processed by the
   Map-Resolvers are not included in a Map-Subscribe-Ack message.

   An ITR that wants to delete one or a set of filters MUST generate a
   Map-Subscribe message which carries those filters with an Expiry
   Timer set to 0.

5. Processing a Map-Subscribe Message

   A Map-Resolver that does not support the Map-Subscribe message MUST
   silently ignore any Map-Subscribe message it receives.

   Map-Resolvers MUST support a configurable parameter to enable/disable
   the processing of Map-Subscribe messages. The default value is set
   to "enabled".

A Map-Resolver SHOULD support a configuration parameter to limit the number of filters per leaf LISP network, per ITR, etc.

If a Map-Resolver receives a Map-Subscribe message and is enabled to process it, a Map-Resolver MUST reply with a Map-Subscribe-Ack message to acknowledge the receipt of the corresponding Map-Subscribe message.

When building a Map-Subscribe-Ack message, the Map-Resolver MUST:

o Set the U-bit if it supports the unsolicited Map-Reply capability, except if a redirect Map-Resolver is to be returned.

o Set the B-bit if it supports a method for mapping bulk transfer, except if a redirect Map-Resolver is to be returned.

o Set the R-bit if it wants to inform the requesting ITR about another Map-Resolver it should contact. The Map-Resolver MAY return a set of filters that are to be applied by the ITR to select the Map-Resolver (i.e., destination EID Map-Resolver address selection).

o Echo the I-bit if the Map-Resolver accepts to initiate unsolicited mapping retrievals, except if a redirect Map-Resolver is to be returned.

o If no redirect is enabled and the request includes one or several filters, the Map-Resolver MUST echo the filters it succeeds to install, and in the same order of appearance, in the Map-Subscribe-Ack message.

o If the Map-Resolver is configured with maximum and minimum values for the expiry timer, the Map-Resolver MUST adjust the Expiry Timer enclosed in the request so that it does not exceed these boundary values.

If the I-bit is set in the Map-Subscribe request and the Map-Resolver supports the unsolicited mapping retrieval capability, the Map-Resolver SHOULD generate unsolicited Map-Reply messages or dedicated bulk transfer messages that carry the EID-RLOC mapping entries that match the filters already present in the Mapping System for that ITR or that match those carried by the Map-Subscribe message.

If filters are included in the request, the Map-Resolver MUST extract those filters and update its mapping system subscription for that ITR accordingly. In particular, the Map-Resolver MUST delete all filters that are active for that ITR if a Null filter is included in the Map-Subscribe request or if the expiry timer is null.

If filters are not allowed for a given ITR, the 'Result' field MUST
be set to FILTERS-PROHIBITED.

If all filters are successfully installed, the 'Result' field MUST be
set to SUCCESS.

If the Map-Resolver fails to install some of the filters included in
a request because the filter limits for that ITR are exceeded, it
MUST NOT echo the corresponding filters in the Map-Subscribe-Ack
message. The 'Result' field MUST be set to PARTIAL-FILTERS-
INSTALLED-LIMIT.

If the Map-Resolver fails to install some of the filters included in
a request because these filters were malformed, it MUST NOT echo the
corresponding filters in the Map-Subscribe-Ack message; only
successfully installed filters MUST be included. The 'Result' field
MUST be set to PARTIAL-FILTERS-INSTALLED-BAD.

If, for some other reasons, the Map-Resolver fails to apply the
filters included in a request, it MUST NOT echo the said filters in
the Map-Subscribe-Ack message; only the successfully installed
filters MUST be included. The 'Result' field MUST be set to PARTIAL-
FILTERS-INSTALLED-LOCAL.

If a filter that is included in the request is more specific than a
filter that is already present in the mapping system for the same
ITR, the Map-Resolver MUST NOT add a new filter but MUST include the
old filter in the response to the requesting ITR.

If a more specific filter exists in the mapping system for the same
ITR, the Map-Resolver MUST replace the old filter (i.e., the one
already stored in the system) with the new filter (i.e., the one
included in the Map-Subscribe message).

A Map-Resolver that is overloaded or configured by means of a
specific policy to redirect requests sent by a set of ITRs to other
Map-Resolvers, the Map-Resolver MUST reply with a Map-Subscribe-Ack
message with the R-bit set and 'Redirect Map-Resolver IP Address'
field set to the redirect Map-Resolver'address. All other bit flags
MUST be returned unset. Moreover, the Expiry Timer MUST be set to 0.
No Filter MUST be included in the message.

If an event matches one of the filters that have been installed by an
ITR, the Map-Resolvers MUST generate the corresponding unsolicited
mapping update message (e.g., Map-Reply, mapping bulk method).

   Upon expiry of the validity timer associated with a filter, the Map-
   Resolver MUST delete that filter from its mapping subscription
   system.

6. **Processing a Map-Subscribe-Ack Message**

   Upon receipt of a Map-Subscribe-Ack message, the ITR MUST check
   whether the message matches a Map-Subscribe message it sent to the
   same Map-Resolver. If no matching state is found, the message MUST
   be silently dropped. If a state is found, in addition to
   authentication checks, the ITR MUST proceed as follows:

   o If the U-bit is set, it should expect that unsolicited Map-Reply
      messages will be received from this Map-Resolver. Appropriate
      security mechanisms (e.g., Access Control Lists) SHOULD be
      activated to allow the processing of these incoming unsolicited
      Map-Reply messages.

   o If the B-bit is set, it should expect that (unsolicited) mapping
      bulk transfer messages are supported by this Map-Resolver.
      Appropriate security mechanisms (e.g., Access Control Lists)
      SHOULD be activated to allow the processing of these incoming
      unsolicited bulk transfer messages.

   o If the R-bit is set and the 'Redirect Map-Resolver IP Address'
      field embeds a valid IP address, the ITR MUST update its Map-
      Resolver contact information with the new Map-Resolver's IP
      address. The ITR MUST use that IP address for subsequent
      exchanges. Optionally, if filters were included in the reply sent
      by the Map-Resolver, these filters are used for the destination
      EID Map-Resolver address selection.

   o If the message includes one or several filters, the ITR MUST check
      whether the same set of filters as those included in the Map-
      Subscribe request are carried in the Map-Subscribe-Ack message.
      Filters that are not returned in the Map-Subscribe-Ack message may
      not be valid or have exceeded a limit. The "Result" code
      indicates the reason for not installing these filters. In
      particular:

      * An ITR that receives the result code set to PARTIAL-FILTERS-
         INSTALLED-LIMIT MUST NOT try to install new filters unless it
         clears all the filters maintained by the Map-Resolver or it
         removes some of them.

      * An ITR that receives the result code set to PARTIAL-FILTERS-
         INSTALLED-BAD MUST NOT resend the same filters that were not

returned in the Map-Subscribe-Ack message, in subsequent Map-
Subscribe requests.

* An ITR that receives the result code set to FILTERS-PROHIBITED
  MUST NOT include the filters that were not returned in the Map-
  Subscribe-Ack message, in a Map-Subscribe message sent to that
  Map-Resolver.

* An ITR that receives the result code set to PARTIAL-FILTERS-
  INSTALLED-LOCAL SHOULD wait for at least 60 seconds before
  issuing another Map-Subscribe message to install the filters
  that were not returned in the Map-Subscribe-Ack message.

o The ITR MUST adjust the Expiry Timer carried in the Map-Subscribe-
  Ack. Subscription should be renewed before the expiry of that
  timer.

7. Subscription to Multiple Resolvers

In order to subscribe to multiple Map-Resolvers, an ITR sends Map-
Subscribe messages to a list of Map-Resolvers. Each of these
requests is handled as specified in Section 4.

8. Mapping Policy Table

Section 2 and Section 3 specifies a solution for a Map-Resolver to
redirect an ITR to another Map-Resolver. This section focuses on the
dynamic provisioning of advanced mapping resolution forwarding policy
tables.

This section assumes that the entity managing a leaf LISP network has
subscribed to a Mapping Service using a variety of means, including
static or dynamic such as
[I-D.boucadair-connectivity-provisioning-protocol]. For the sake of
network automation, we assume that the outcome of such negotiation is
translated into appropriate provisioning actions, which include in
particular the identity of Map-Resolvers that will be solicited by
the ITRs of the leaf LISP network.

The provisioning information may be as simple as a list of IP
addresses or names, but it may also be enriched with traffic
engineering rules, such as priority information, geolocation
information of the a Map-Resolver, the set of destination EIDs that
are serviced by a given Map-Resolver, etc. A leaf LISP network can
be provisioned with a list of Map-Resolvers together with policies to
instruct the ITR how to contact these Map-Resolvers. These policies
are enclosed in a Mapping Policy Table. This table is similar to the
one defined in [RFC6724].

   Typically, the Mapping Policy Table may be structured as follows:

   o Destination EID range

   o Map-Resolver IP address

   o Tie-breaking rules

   An ITR may use the selection algorithm defined in Section 6 of
   [RFC6724] to contact a Map-Resolver.

   <<to be completed>>

9. Sample Examples

   This section includes a set of examples to illustrate the usage of
   the methods defined in Section 2.

9.1. Map-Resolver Redirect

   The example shown in Figure 3, illustrates an example of an ITR
   (ITR1) that is redirected to another Map-Resolver (MR2).

```
          +--------+                  +--------+ +--------+
          |  ITR1  |                  |  MR1   | |  MR2   |
          +--------+                  +--------+ +--------+
              |                           |          |
              |Map-Subscribe              |          |
              |-------------------------->|          |
              | Map-Subscribe-Ack (R, MR2)|          |
              |<--------------------------|          |
              |Map-Subscribe              |          |
              |------------------------------------->|
              |                           Map-Subscribe-Ack|
              |<-------------------------------------|
              |                                      |
              |Map-Request                           |
              |------------------------------------->|
              |                             Map-Reply|
              |<-------------------------------------|
```
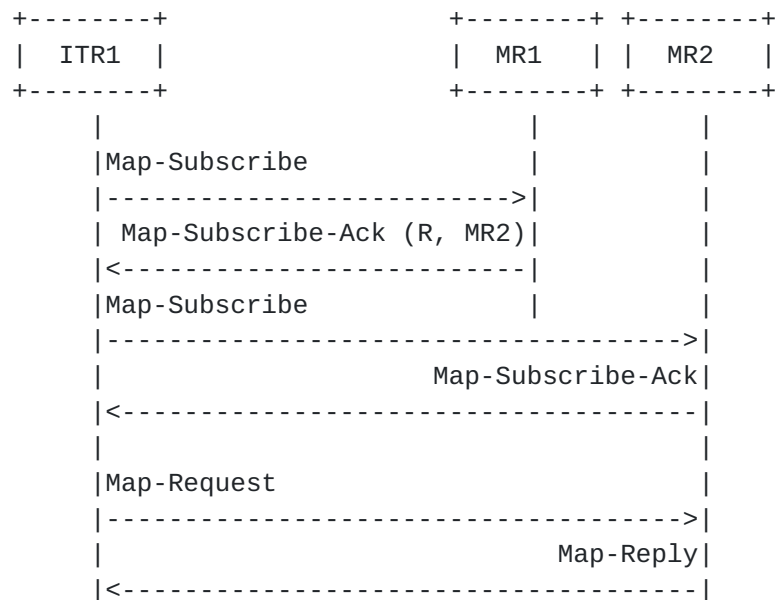
              Figure 3: Example of Map-Resolver Redirection

9.2. **Mapping Cache Retrieval**

   The example shown in Figure 4, illustrates an example of an ITR
   (ITR1) that restores its mapping tables upon reboot according to the
   filters already present in the mapping system. The example in
   Figure 4, indicates how an ITR retrieves the mappings that match the
   filters included in the Map-Subscribe request. The example in
   Figure 5, assumes that multiple records bound to distinct EIDs are
   included in the same Map-Reply message.

   This procedure applies to ITRs which do not store the mapping table
   in a permanent memory storage facility.

   Owing to this procedure, the ITR is ready-to-serve as soon as reboot
   is completed or right after a mapping cache clear event.

```
            +--------+                  +--------+
            |  ITR1  |                  |   MR   |
            +--------+                  +--------+
                 |                           |
                 |                           |
                 |Map-Subscribe(d_EID, d_EID2,|
                 |..., d_EIDn)               |
                 |-------------------------->|
                 |    Map-Subscribe-Ack (d_EID,|
                 |        d_EID2, ..., d_EIDn)|
                 |<--------------------------|
                 |                           |
                       <<ITR Reboot>>
                 |Map-Subscribe(I)           |
                 |-------------------------->|
                 |         Map-Subscribe-Ack (I)|
                 |<--------------------------|
                 |              Map-Reply (d_EID)|
                 |<--------------------------|
                 |             Map-Reply (d_EID2)|
                 |<--------------------------|
                             ....
                 |             Map-Reply (d_EIDn)|
                 |<--------------------------|
```

      Figure 4: Example of Mapping Cache Retrieval: Matching the Filters
                     Installed in the Mapping System

```
            +--------+                    +--------+
            |  ITR1  |                    |   MR   |
            +--------+                    +--------+
                 |                             |
                 |                             |
                 |Map-Subscribe(d_EID, d_EID2,|
                 |..., d_EIDn)                |
                 |--------------------------->|
                 |    Map-Subscribe-Ack (d_EID,|
                 |         d_EID2, ..., d_EIDn)|
                 |<---------------------------|
                 |                             |
                       <<ITR Reboot>>
                 |Map-Subscribe(I)            |
                 |--------------------------->|
                 |          Map-Subscribe-Ack (I)|
                 |<---------------------------|
                 |   Map-Reply (d_EID, d_EID2,
                 |                       ..., )|
                 |<---------------------------|
```

Figure 5: Example of Bulk Mapping Cache Retrieval: Matching the
           Filters Installed in the Mapping System

```
            +--------+                    +--------+
            |  ITR1  |                    |   MR   |
            +--------+                    +--------+
                 |                             |
                 |                             |
                       <<ITR Reboot>>
                 |                             |
                 |Map-Subscribe(I, d_EID      |
                 | d_EID2, ..., d_EIDn)       |
                 |--------------------------->|
                 | Map-Subscribe-Ack (I, d_EID|
                 |         d_EID2, ..., d_EIDn)|
                 |<---------------------------|
                 |              Map-Reply (d_EID)|
                 |<---------------------------|
                 |             Map-Reply (d_EID2)|
                 |<---------------------------|
                             ....
                 |             Map-Reply (d_EIDn)|
                 |<---------------------------|
```

Figure 6: Example of Mapping Cache Retrieval: Matching the Filters
               Conveyed in the request

9.3. Unsolicited Map-Reply

   The example shown in Figure 7, illustrates an ITR (ITR1) that is
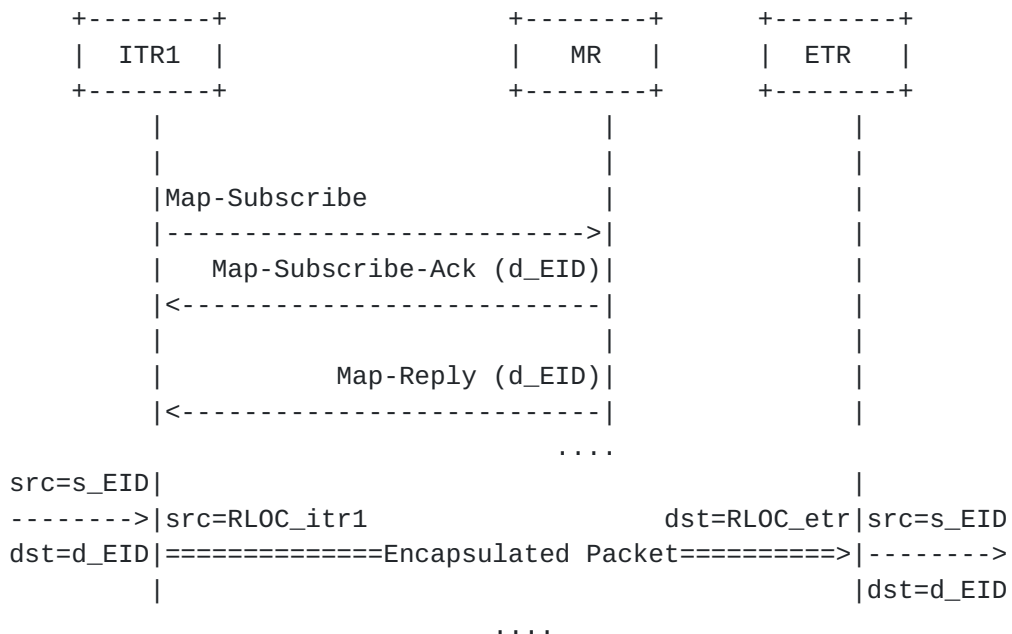   notified with the new EID-RLOC mapping that it subscribed to.

```
        +--------+                   +--------+    +--------+
        | ITR1   |                   |  MR    |    |  ETR   |
        +--------+                   +--------+    +--------+
             |                            |             |
             |                            |             |
             |Map-Subscribe               |             |
             |--------------------------->|             |
             |    Map-Subscribe-Ack (d_EID)|            |
             |<---------------------------|             |
             |                            |             |
             |           Map-Reply (d_EID)|             |
             |<---------------------------|             |
                               ....
    src=s_EID|                                          |
    -------->|src=RLOC_itr1               dst=RLOC_etr|src=s_EID
    dst=d_EID|=============Encapsulated Packet=========>|-------->
             |                                          |dst=d_EID
                               ....
```

                Figure 7: Example of Unsolicited Map-Reply

10. Security Considerations

   This document does not introduce any additional security issues other
   than those discussed in [RFC6830] and [RFC6833].

11. IANA Considerations

   To be completed.

12. Acknowledgments

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