               Mesh-enhanced Service Location Protocol (mSLP)

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Abstract

   This document describes the Mesh-enhanced Service Location Protocol
   (mSLP). mSLP enhances the Service Location Protocol (SLP) with a
   scope-based fully-meshed peering Directory Agent (DA) architecture.
   Peer DAs exchange new service registrations in shared scopes via
   anti-entropy and direct forwarding. mSLP improves the reliability
   and consistency of SLP DA services, and simplifies Service Agent (SA)
   registrations in systems with multiple DAs. mSLP is backward
   compatible with SLPv2 and can be deployed incrementally.

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1. Introduction

   In the Service Location Protocol (SLPv2 [RFC2608]), Directory Agents
   (DAs) accept service registrations from Service Agents (SAs) and
   answer queries from User Agents (UAs); they enhance the performance
   and scalability of SLPv2. The use of scopes in SLPv2 further
   improves its scalability. In general, a DA can serve multiple
   scopes, and a scope can be served by multiple DAs. When multiple DAs
   are present for a scope, how should they interact with each other?
   This document describes the Mesh-enhanced Service Location Protocol
   (mSLP), addressing this open issue in SLPv2.

   mSLP defines a scope-based fully-meshed peering DA architecture: for
   each scope, all DAs serving the scope form a fully-meshed peer
   relationship (similar to IBGP [RFC1771]). Peer DAs exchange new
   service registrations in shared scopes via anti-entropy [EPID-
   ALGO,UPDA-PROP] and direct forwarding. mSLP improves the reliability
   and consistency of SLP DA services, and simplifies SA registrations
   in systems with multiple DAs.

1.1. Notation Conventions

   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 BCP 14, RFC 2119
   [RFC2119].

1.2. Terminology

Peer DAs (or Peers)
    DAs that share one or multiple scopes are peers.

Peering Connection
    A persistent connection (e.g., TCP) that provides reliable and
    ordered transfers between two peers. The closing of a peering
    connection terminates the peer relationship.

Mesh-enhanced DA (MDA)
    An MDA carries the "mesh-enhanced" attribute keyword in its DA
    Advertisement (DAAdvert) message, maintains peering connections to
    all peers, and properly interacts with peers.

Mesh-enhanced SA (MSA)
    An MSA uses the Mesh Forwarding extension (Section 4.3) when it
    registers with MDAs.

Registration Update
    A registration update refers to a Service Registration (SrvReg) or
    Service Deregistration (SrvDeReg) message.

Registration State
    A registration state refers to an entry in the registration
    database.

Accept DA
    When a DA accepts a registration update from an SA, the DA is the
    accept DA for the update.

Accept Timestamp
    The arrival timestamp of a registration update at its accept DA is
    the accept timestamp of the update. All accept timestamps
    assigned by the same DA MUST be monotonically increasing.

Version Timestamp
    When an MSA sends a registration update to an MDA, the MSA assigns
    a version timestamp to the update. All version timestamps
    assigned by the same MSA MUST be monotonically increasing.

1.3. Compatibility

mSLP is designed as a lightweight enhancement to SLPv2. It is
backward compatible with SLPv2. mSLP defines two enhanced entities:
MDAs and MSAs. They can be deployed incrementally. An enhanced
entity supports extended operations without affecting its original
functionality as defined in RFC 2608 [RFC2608]. For simplicity and

compatibility, an enhanced entity works as a non-enhanced entity to interact with non-enhanced entities. Table 1 summarizes all interactions involving an MDA or MSA.

Interaction	Equivalent To	Defined In
MDA <--> MDA		mSLP
MDA <--> MSA		mSLP
MDA <--> DA	DA <--> DA	RFC 2608
MDA <--> SA	DA <--> SA	RFC 2608
MDA <--> UA	DA <--> UA	RFC 2608
MSA <--> DA	SA <--> DA	RFC 2608
MSA <--> UA	SA <--> UA	RFC 2608

Table 1. Interactions involving an MDA or MSA

2. Scope-based Fully-meshed Peering DA Architecture

```
                              (x,y)
        +----------------------------------------------------+
        |                  +------------+                    |
        |                  | MDA4 (z)   |                    |
        |                  +------------+                    |
        |                       | (z)                        |
  +------------+     (y)   +------------+     (y)   +------------+
  | MDA1 (x,y) | --------- | MDA3 (y,z) | --------- | MDA2 (x,y) |
  +------------+           +------------+           +------------+
```
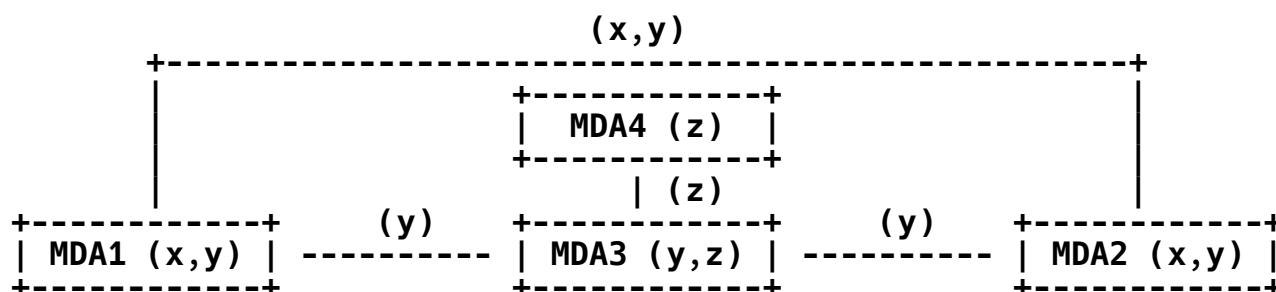
Figure 1. A scope-based fully-meshed peering DA architecture

mSLP employs a scope-based fully-meshed peering DA architecture. For each scope, all MDAs that serve the scope form a fully-meshed peer relationship. Figure 1 shows an example for four MDAs and three scopes (x, y, and z). Note that a single peering connection is needed between two peers for exchanging all service registrations in their shared scopes.

This architecture enhances SLP DA services. First, it improves the consistency among peer DAs by automatically reconciling inconsistent states among them. Second, it enables newly booted and rebooted MDAs to catch up on all new registrations at once from their peers, purely through DA interaction, without involving SAs.

This architecture also simplifies SA registrations. In SLPv2, an SA needs to discover and register with all existing DAs in its scopes, and re-register when new DAs are discovered or old DAs are found to have rebooted. In mSLP, for all MDAs, an MSA only needs to discover and register with a sufficient number of them, such that the union of

their scopes covers its scopes; the registrations will then be propagated automatically to other MDAs in the registration scopes. For example, in Figure 2, MSA1 only needs to discover and register with MDA2, or with both MDA1 and MDA3.
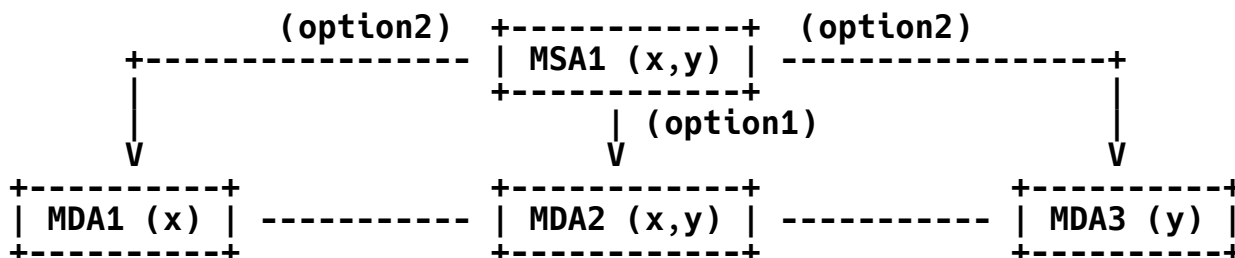
```
           (option2)  +-------------+  (option2)
    +----------------- | MSA1 (x,y) | -----------------+
    |                  +-------------+                 |
    |                       | (option1)                |
    V                       V                          V
+----------+          +-------------+          +----------+
| MDA1 (x) | --------- | MDA2 (x,y) | --------- | MDA3 (y) |
+----------+          +-------------+          +----------+
```

Figure 2. Options for registering with MDAs

Furthermore, this architecture provides scaling advantages. Consider a scope that has N SAs and M DAs, and assume N > M >= 2. Although mSLP and SLPv2 need the same number of SLP messages to distribute registrations from N SAs to M DAs, mSLP can reduce the number of agents needed for taking care of registration distribution, and reduce the number of TCP connections needed if each SA uses TCP for its registrations. More specifically, the agents that need to take care of registration distribution are all N SAs in SLPv2, but only M DAs in mSLP. Also, the number of needed TCP connections is N*M in SLPv2 as each SA has to connect with each DA and register, but only N+M*(M-1)/2 in mSLP as each SA only needs to connect to one contacting DA of a full mesh of M node and register, then registrations are propagated through the DA mesh. For N=100 and M=10, SLPv2 needs 1000 TCP connections, but mSLP only needs 145 such connections.

Note that as mSLP employs full-mesh topology, which is mainly for simplicity and reliability, it cannot scale to a large number of MDAs in a single mesh. In general, mSLP can be applied if the number of MDAs in a mesh is on the order of tens or below. One way to avoid having a large number of MDAs in a mesh is to split the scope into several finer scopes. For example, if we have N MDAs for scope "x", and N is too large, then we can split "x" into two finer scopes: "x-1" and "x-2", with N1 MDAs for "x-1" only, N2 MDAs for "x-2" only, N3 MDAs for both "x-1" and "x-2", and N1+N2+N3=N. Thus, instead of having a large full mesh of size N, we now have two smaller full meshes of size N1+N3 and N2+N3, respectively. Accordingly, a service registration that previously targets for scope "x", now needs to be registered under both "x-1" and "x-2".

3. Peer Relationship Management

3.1. Learning about New Peers

An MDA can learn about new peers via static configuration, DHCP
[RFC2610], and DAAdvert multicast and unicast. In any case, an MDA
MUST get a peer's DAAdvert before establishing a peer relationship to
the peer.

3.2. Establishing a Peering Connection

After getting a new peer's DAAdvert, an MDA establishes a peering
connection (if such a connection does not exist yet) to the peer, and
sends its DAAdvert via the connection (Figure 3). An MDA can
identify a peering connection initiated by a peer by receiving the
peer's DAAdvert from the connection. Normally, a single peering
connection is set up between two peers, but there is a small
possibility that a pair of peering connections might be created
between two peers if they try to initiate a connection to each other
at almost the same time. Thus, when an MDA identifies a new peering
connection initiated by a peer, it SHOULD check whether it has
initiated another peering connection to the peer. If this is the
case, and it has a lower-numbered IP address than the peer, then the
MDA SHOULD terminate the connection it has initiated.

```
    +------+     (1) MDA2's DAAdvert |                      +------+
    |      | <----------------------+                       |      |
    | MDA1 |     (2) Create a Peering Connection            | MDA2 |
    |      | -------------------------------------------->  |      |
    +------+     (3) MDA1's DAAdvert                        +------+
```
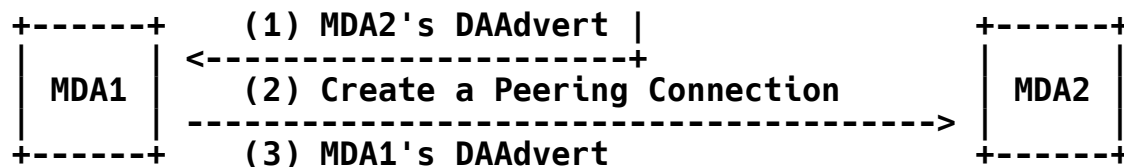
Figure 3. Establishing a peering connection

3.3. Exchanging Information about Existing Peers

After establishing a peering connection, two peers (say, MDA1 and
MDA2) exchange information about their existing peers by forwarding
peers' DAAdverts via the peering connection (Figure 4). MDA1 will
forward the DAAdvert of a peer (say, MDA3) to MDA2 if:

   (1) MDA3 shares scopes with MDA2, and
   (2) MDA3 is an active peer of MDA1 (i.e., there is a peering
       connection between MDA3 and MDA1) or an accept DA for
       registrations currently maintained by MDA1 (i.e., MDA1
       has registrations originally accepted by MDA3).

MDA2 operates similarly. Note that all DAAdverts can be sent as one
TCP stream for efficiency. Exchanging information about existing
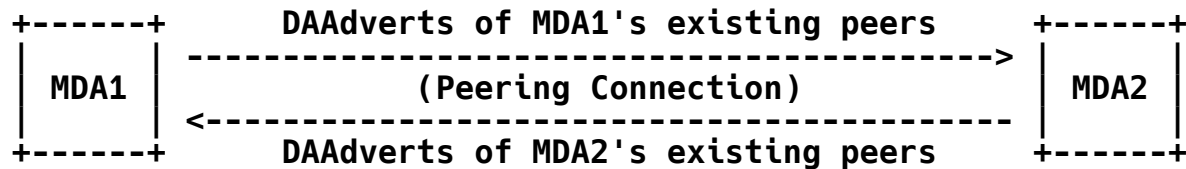peers enables an MDA to learn about new peers incrementally.

```
   +------+      DAAdverts of MDA1's existing peers     +------+
   |      | ------------------------------------------->|      |
   | MDA1 |               (Peering Connection)          | MDA2 |
   |      | <-------------------------------------       |      |
   +------+      DAAdverts of MDA2's existing peers     +------+
```

          Figure 4. Exchanging information about existing peers

3.4. Maintaining a Peer Relationship

```
   +------+                MDA1's DAAdvert                +------+
   |      | ------------------------------------------->|      |
   | MDA1 |               (Peering Connection)          | MDA2 |
   |      | <-------------------------------------       |      |
   +------+                MDA2's DAAdvert                +------+
```
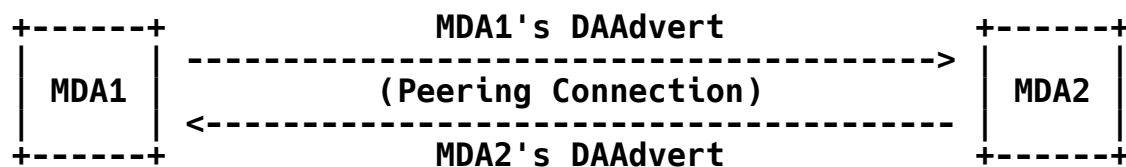
               Figure 5. Maintaining a peer relationship

To detect failures (network partitions and peer crashes), mSLP uses a
heart-beat mechanism. An MDA sends its DAAdvert to peers (Figure 5)
every CONFIG_DA_KEEPALIVE seconds. The timeout value for this
message is CONFIG_DA_TIMEOUT seconds (Section 6).

3.5. Tearing Down a Peer Relationship

An MDA SHOULD tear down a peer relationship when it finds that the
peer has closed the peering connection, when it receives a DAAdvert
multicast from the peer with a DA stateless boot timestamp set to 0
(meaning that the peer is going to shutdown), or when it has not
received the peer's DAAdvert for more than CONFIG_DA_TIMEOUT seconds.

4. Registration Propagation Control

4.1. Accept ID and Propagation Order

When an MDA accepts a registration update from an MSA, the MDA
assigns a unique accept ID to the update. An accept ID has two
components: an accept DA URL and an accept timestamp. The accept
timestamp is a 64-bit integer representing elapsed microseconds since
00:00 Coordinated Universal Time (UTC), January 1, 1900. Figure 6
shows the format for an accept ID entry. A registration state has
the same accept ID as that of the latest update applied to it.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Accept Timestamp                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Accept Timestamp, cont'd.                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Length of Accept DA URL   |        Accept DA URL          \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
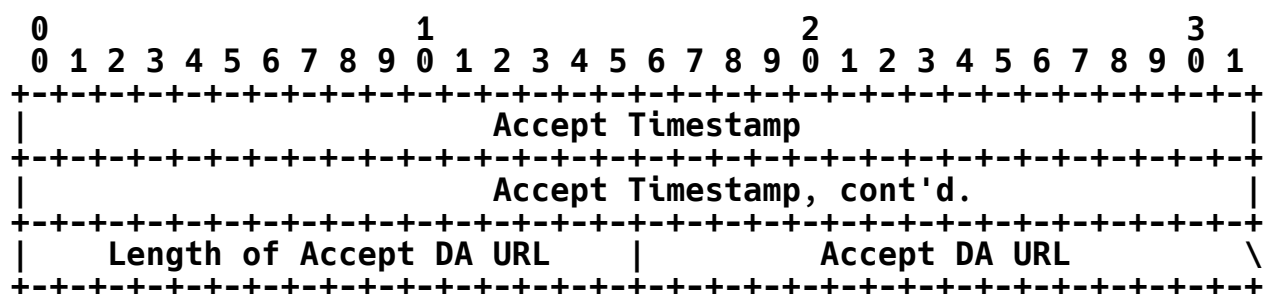
Figure 6. Accept ID entry

An MDA MUST propagate registrations in the increasing order of their
accept IDs, i.e., registrations having the same accept DA MUST be
propagated in the increasing order of their accept timestamps. Note
that registrations having different accept DAs MAY be propagated in
any order.

4.2. Version Timestamp and Registration Version Resolution

When registrations are propagated among MDAs, their arrival
timestamps at MDAs cannot be used for version resolution. For
example, assume that MSA1 sends a registration (R1) to MDA1 first,
and a new version of the same registration (R2) to MDA2 later. When
R1 and R2 are propagated, the arrival timestamp of R1 at MDA2 is
later than that of R2, but R1 SHOULD NOT overwrite R2 at MDA2 as R2
is a newer version.

mSLP resolves registration versions using version timestamps. When
an MSA sends a registration update to an MDA, the MSA assigns a
version timestamp to the update. The version timestamp is a 64-bit
integer representing elapsed microseconds since 00:00 UTC, January 1,
1900. mSLP assumes that each registration is updated only by one SA,
thus an MDA does not need to compare version timestamps from
different MSAs. An MDA installs a registration update if the update
has a newer version timestamp (from an MSA), or the update does not
have the Mesh Forwarding extension (from a non-MSA).

4.3. Mesh Forwarding Extension

The Mesh Forwarding (MeshFwd) extension carries a version timestamp
and an accept ID entry. Figure 7 shows its format and two defined
Forwarding IDs (Fwd-IDs).

The MeshFwd extension is used with a Srv(De)Reg message, but it can
only be used with a fresh SrvReg, or a complete SrvDeReg.

```
      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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     | MeshFwd Extension ID = 0x0006 |   Next Extension Offset (NEO) |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     | NEO, cont'd.  |     Fwd-ID    |      Version Timestamp        |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                   Version Timestamp, cont'd.                  |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |   Version Timestamp, cont'd.  |        Accept ID Entry        \
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

                  Fwd-ID          Abbreviation
                    1               RqstFwd
                    2               Fwded
```
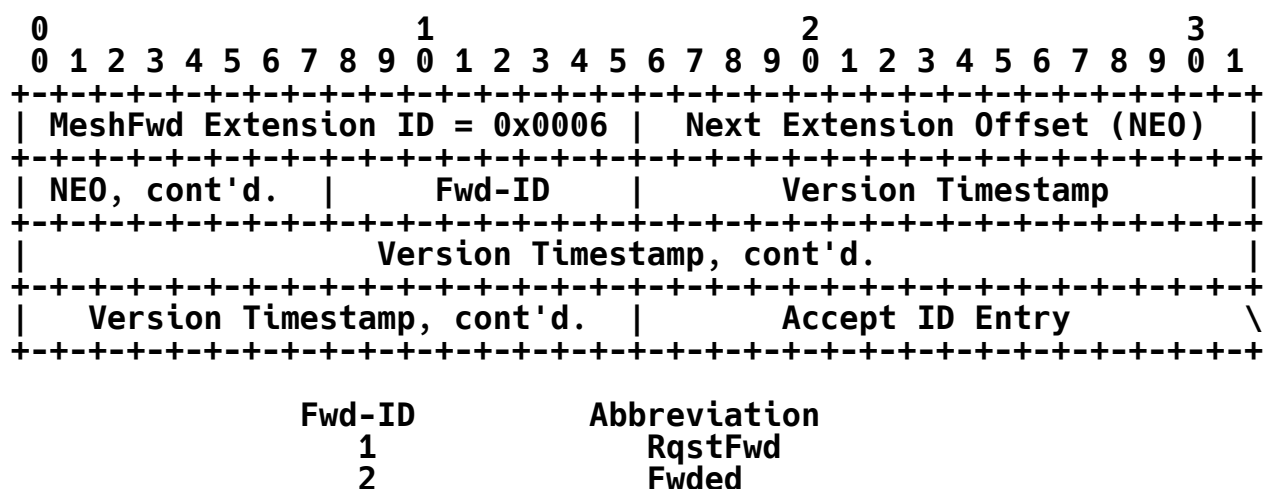
                 Figure 7. MeshFwd extension and its Fwd-IDs

   An MSA uses the RqstFwd MeshFwd extension (Fwd-ID = RqstFwd, accept
   timestamp = 0) in a Srv(De)Reg to explicitly request an MDA (the
   accept DA) to forward the message.

   An MDA uses the Fwded MeshFwd extension (Fwd-ID = Fwded, accept
   timestamp != 0) in each Srv(De)Reg sent from it to another MDA,
   either forwarding a Srv(De)Reg received from an MSA (if the message
   has the RqstFwd MeshFwd extension), or propagating a registration
   state in its database.

4.4. Summary Vector

   An MDA uses a summary vector to represent its received Srv(De)Reg(s)
   that have a MeshFwd extension. This summary vector records the
   latest accept timestamp for each accept DA that appears in the
   MeshFwd extension. For example, consider n MDAs for a scope, if MDAi
   has a summary vector as ((MDA1, T1), (MDA2, T2), ..., (MDAn, Tn)),
   then MDAi has received all registrations originally accepted by MDAj
   up to timestamp Tj, where $1<=i,j<=n$.

   An MDA updates its summary vector when it receives a Srv(De)Reg that
   has a MeshFwd extension. The MDA adds a new accept ID to its summary
   vector if the Srv(De)Reg has a new accept DA; the MDA updates the
   accept timestamp of an existing accept ID in its summary vector if
   the Srv(De)Reg has an existing accept DA.

4.5. Service Deregistration

When an MDA receives a SrvDeReg that has a MeshFwd extension, it
SHOULD retain the corresponding registration in the database, and
mark it as deleted. This way, the registration will not appear in
any query reply, and an earlier SrvReg will not mistakenly cause the
registration to reappear in the database. A registration state will
be purged from the database when it expires.

4.6. Anti-entropy Request Message

The Anti-entropy Request (AntiEtrpRqst) message carries an anti-
entropy type ID and a list of accept ID entries. Figure 8 shows its
format and two defined anti-entropy type IDs.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |     Service Location Header (AntiEtrpRqst Function-ID =  12)   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       Anti-Entropy Type ID    |  Number of Accept ID Entries  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Accept ID Entry 1          . . .          Accept ID Entry k \
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

                    Anti-Entropy Type        Type ID
                        selective               1
                        complete                2
```
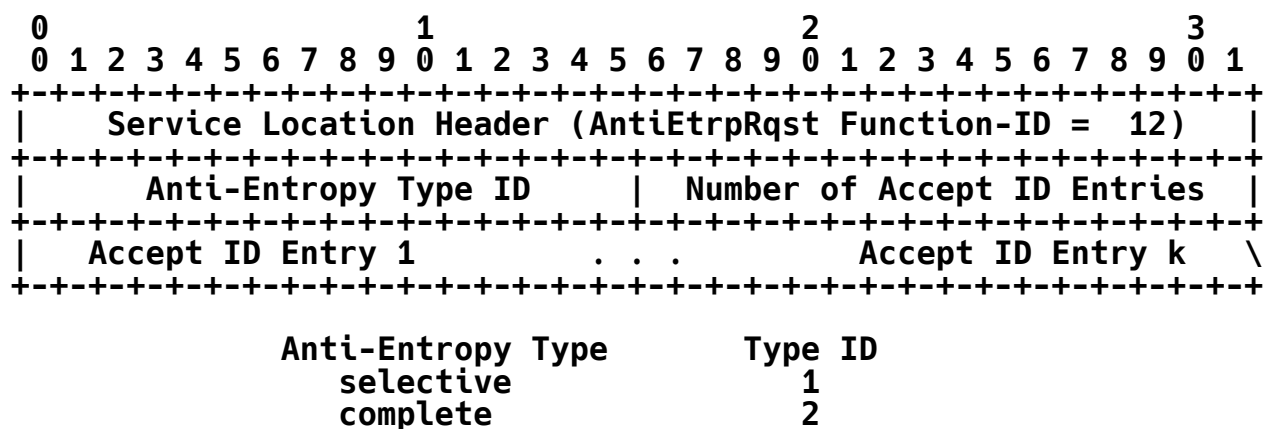
Figure 8. AntiEtrpRqst message and anti-entropy types

The AntiEtrpRqst message is used by an MDA to request new
registration states from a peer. The anti-entropy type is either
selective or complete. If the anti-entropy type is selective, only
registration states that have an accept ID greater than any specified
accept ID in the message are requested. If the anti-entropy type is
complete, all registration states that have an accept ID greater than
any specified accept ID in the message or have an accept DA not
specified in the message are requested.

For example, consider three MDAs (MDA1, MDA2, and MDA3) for a scope.
MDA2 has registration states originally accepted by MDA1, MDA2, and
MDA3. If MDA1 sends a selective AntiEtrpRqst to MDA2 using an accept
ID list as ((MDA2, T2)), then MDA1 only requests registration states
that are originally accepted by MDA2, and have an accept timestamp
greater than T2. If MDA1 sends a complete AntiEtrpRqst to MDA2 using
an accept ID list as ((MDA2, T2)), then MDA1 requests all

registration states originally accepted by MDA1 and MDA3, plus those originally accepted by MDA2 and having an accept timestamp greater than T2.

4.7. Anti-entropy

Anti-entropy is used for exchanging initial registration states when two peers recognize each other for the first time, and for updating new registration states after failures.

When an MDA receives an AntiEtrpRqst from a peer, it sends the requested new registration states in the increasing order of their accept IDs. At last a Service Acknowledgment (SrvAck) message is sent to indicate that the processing of a corresponding AntiEtrpRqst has been completed (Figure 9). A new registration state is sent as a fresh SrvReg with its remaining lifetime. A newly deregistered state is propagated as a SrvDeReg. Note that multiple Srv(De)Reg(s) can be sent as one TCP stream for efficiency.

```
 +------+                    AntiEtrpRqst                    +------+
 |      | ------------------------------------------------->  |      |
 | MDA1 |             (Peering Connection)                   | MDA2 |
 |      | <------------------------------------------------  |      |
 +------+       New States via Srv(De)Reg(s) + SrvAck         +------+
```

      Figure 9. Anti-entropy via AntiEtrpRqst, Srv(De)Reg(s) and SrvAck

4.8. Direct Forwarding

```
 +------+    RqstFwd Srv(De)Reg    +------+    Fwded Srv(De)Reg    +------+
 |      | --------------------->   |      | --------------------->  |      |
 | MSA1 |                          | MDA1 |                         | MDA2 |
 |      | <--------------------    |      |                         |      |
 +------+         SrvAck           +------+                         +------+
```
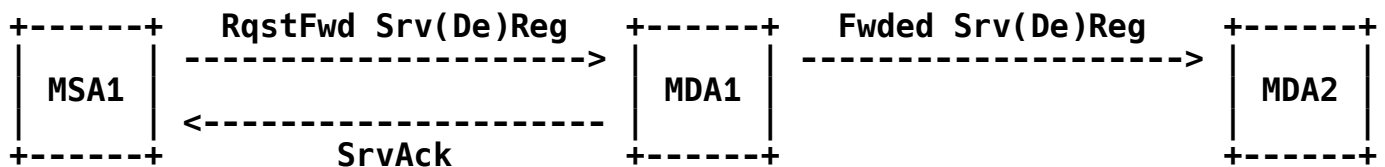
            Figure 10. Direct forwarding of a Srv(De)Reg

After sending all new registration states accepted by itself to a peer (via anti-entropy), an MDA directly forwards newly received registration updates from MSAs to the peer until a failure occurs.

In Figure 10, when a Srv(De)Reg is directly forwarded from MDA1 to MDA2, its Fwd-ID is set to Fwded, and its accept timestamp is set to its arrival timestamp at MDA1. Note that a direct forwarding is performed asynchronously: MDA1 can send a SrvAck to MSA1 before it forwards the Srv(De)Reg to MDA2. Also note that the direct forwarding of a Srv(De)Reg goes only one-hop from its accept DA (say, MDA1) to all MDA1's peers that are in the registration scopes.

4.9. SrvAck Message

According to [RFC2608], a DA MUST reply with a SrvAck to a Srv(De)Reg
when the message is received from an SA. However, an MDA SHOULD NOT
reply with a SrvAck to a Srv(De)Reg if the message is received from a
peer. This is for efficiency because peers exchange Srv(De)Reg
messages via reliable peering connections. Note that an MDA MUST
reply with a SrvAck to an AntiEtrpRqst.

4.10. Control Information

For each registration entry, an MDA maintains the following control
information: an accept ID (for registration propagation), a version
timestamp (for registration version resolution - rejecting previous
updates), and a deletion flag (deregistered or not).

For all registration entries, an MDA maintains a summary vector to
reflect its received registrations so far.

5. Summary

mSLP extends SLPv2 with three new definitions: a new attribute -
"mesh-enhanced" for DAAdvert, a new message extension - MeshFwd, and
a new message type - AntiEtrpRqst.

A UA MAY prefer an MDA to a non-MDA since an MDA is more likely to
reliably contain the complete set of current service registrations
for the UA's scopes.

A non-MSA needs to discover and register with all DAs in its scopes.
It does not use the MeshFwd extension.

A non-MDA accepts Srv(De)Reg(s) from SAs. It does not forward them.

For all MDAs, an MSA only needs to discover and register with
sufficient number of them, such that they cover its scopes. It uses
the MeshFwd extension when it registers with MDAs.

An MDA carries the "mesh-enhanced" attribute keyword in its DAAdvert.
It maintains a peer relationship to each peer. It accepts
registrations from SAs and peers, propagates registrations via anti-
entropy and direct forwarding to peers.

6. Protocol Timing Defaults

Interval Name	Default Value	Defined in
CONFIG_DA_KEEPALIVE	200 seconds	Section 3.4
CONFIG_DA_TIMEOUT	300 seconds	Section 3.4

7. IANA Considerations

The Mesh Forwarding (MeshFwd) extension ID, 0x0006, described in Section 4.3, has been assigned by IANA out of the SLP extension space (RFC 2608, Section 9.1) reserved for "optional to implement" extensions (i.e., the 0x0000-0x3FFF range).

The function-ID of the Anti-entropy Request (AntiEtrpRqst) message type, 12, described in Section 4.6, has been assigned by IANA (RFC 2608, Section 15).

8. Security Considerations

mSLP uses standard SLPv2 authentication. First, an MDA SHOULD authenticate other MDAs before setting up a peer relationship with them so as to prevent any malicious MDA from joining the DA mesh. Second, as a successful attack at an MDA may affect all MDAs in the DA mesh, an MDA SHOULD authenticate MSAs before accepting and forwarding their Srv(De)Reg messages to prevent illegitimate modification or elimination of service registrations. Third, as an MSA depends on the MDA with which it registers to forward its Srv(De)Reg messages, it SHOULD authenticate the MDA to avoid using a malicious MDA.

9. Acknowledgments

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10. References

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12. Full Copyright Statement

Acknowledgement