Network Working Group   D. Farinacci
Internet-Draft   D. Meyer
Intended status: Experimental   J. Zwiebel
Expires: January 10, 2012   S. Venaas
                                                           cisco Systems
                                                            July 9, 2011

LISP for Multicast Environments
draft-ietf-lisp-multicast-07

Abstract

   This draft describes how inter-domain multicast routing will function
   in an environment where Locator/ID Separation is deployed using the
   LISP architecture.

Status of this Memo

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

   Internet-Drafts are working documents of the Internet Engineering
   Task Force (IETF). Note that other groups may also distribute
   working documents as Internet-Drafts. The list of current Internet-
   Drafts is at http://datatracker.ietf.org/drafts/current/.

   Internet-Drafts are draft documents valid for a maximum of six months
   and may be updated, replaced, or obsoleted by other documents at any
   time. It is inappropriate to use Internet-Drafts as reference
   material or to cite them other than as "work in progress."

   This Internet-Draft will expire on January 10, 2012.

Table of Contents

1. Requirements Notation

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].

2. Introduction

   The Locator/ID Separation Architecture [LISP] provides a mechanism to
   separate out Identification and Location semantics from the current
   definition of an IP address. By creating two namespaces, an EID
   namespace used by sites and a Locator (RLOC) namespace used by core
   routing, the core routing infrastructure can scale by doing
   topological aggregation of routing information.

   Since LISP creates a new namespace, a mapping function must exist to
   map a site's EID prefixes to its associated locators. For unicast
   packets, both the source address and destination address must be
   mapped. For multicast packets, only the source address needs to be
   mapped. The destination group address doesn't need to be mapped
   because the semantics of an IPv4 or IPv6 group address are logical in
   nature and not topology-dependent. Therefore, this specifications
   focuses on to map a source EID address of a multicast flow during
   distribution tree setup and packet delivery.

   This specification will address the following scenarios:

   1. How a multicast source host in a LISP site sends multicast
       packets to receivers inside of its site as well as to receivers
       in other sites that are LISP enabled.

   2. How inter-domain (or between LISP sites) multicast distribution
       trees are built and how forwarding of multicast packets leaving a
       source site toward receivers sites is performed.

   3. What protocols are affected and what changes are required to such
       multicast protocols.

   4. How ASM-mode, SSM-mode, and Bidir-mode service models will
       operate.

   5. How multicast packet flow will occur for multiple combinations of
       LISP and non-LISP capable source and receiver sites, for example:

       A. How multicast packets from a source host in a LISP site are
           sent to receivers in other sites when they are all non-LISP
           sites.

       B. How multicast packets from a source host in a LISP site are
           sent to receivers in both LISP-enabled sites and non-LISP
           sites.

       C. How multicast packets from a source host in a non-LISP site
           are sent to receivers in other sites when they are all LISP-

enabled sites.

D. How multicast packets from a source host in a non-LISP site
    are sent to receivers in both LISP-enabled sites and non-LISP
    sites.

This specification focuses on what changes are needed to the
multicast routing protocols to support LISP-Multicast as well as
other protocols used for inter-domain multicast, such as Multi-
protocol BGP (MBGP) [RFC4760]. The approach proposed in this
specification requires no changes to the multicast infrastructure
inside of a site when all sources and receivers reside in that site,
even when the site is LISP enabled. That is, internal operation of
multicast is unchanged regardless of whether or not the site is LISP
enabled or whether or not receivers exist in other sites which are
LISP-enabled.

Therefore, we see changes only to PIM-ASM [RFC4601], MSDP [RFC3618],
and PIM-SSM [RFC4607]. Bidir-PIM [RFC5015], which typically does not
run in an inter-domain environment is not addressed in depth in this
version of the specification.

Also, the current version of this specification does not describe
multicast-based Traffic Engineering relative to the TE-ITR and TE-ETR
descriptions in [LISP].

3. Definition of Terms

   The terminology in this section is consistent with the definitions in
   [LISP] but is extended specifically to deal with the application of
   the terminology to multicast routing.

   LISP-Multicast: a reference to the design in this specification.
      That is, when any site that is participating in multicast
      communication has been upgraded to be a LISP site, the operation
      of control-plane and data-plane protocols is considered part of
      the LISP-Multicast architecture.

   Endpoint ID (EID):   a 32-bit (for IPv4) or 128-bit (for IPv6) value
      used in the source address field of the first (most inner) LISP
      header of a multicast packet. The host obtains a destination
      group address the same way it obtains one today, as it would when
      it is a non-LISP site. The source EID is obtained via existing
      mechanisms used to set a host's "local" IP address. An EID is
      allocated to a host from an EID prefix block associated with the
      site the host is located in. An EID can be used by a host to
      refer to another host, as when it joins an SSM (S-EID,G) route
      using IGMP version 3 [RFC4604]. LISP uses Provider Independent
      (PI) blocks for EIDs; such EIDs MUST NOT be used as LISP RLOCs.
      Note that EID blocks may be assigned in a hierarchical manner,
      independent of the network topology, to facilitate scaling of the
      mapping database. In addition, an EID block assigned to a site
      may have site-local structure (subnetting) for routing within the
      site; this structure is not visible to the global routing system.

   Routing Locator (RLOC):   the IPv4 or IPv6 address of an ingress
      tunnel router (ITR), the router in the multicast source host's
      site that encapsulates multicast packets. It is the output of a
      EID-to-RLOC mapping lookup. An EID maps to one or more RLOCs.
      Typically, RLOCs are numbered from topologically-aggregatable
      blocks that are assigned to a site at each point to which it
      attaches to the global Internet; where the topology is defined by
      the connectivity of provider networks, RLOCs can be thought of as
      Provider Assigned (PA) addresses. Multiple RLOCs can be assigned
      to the same ITR device or to multiple ITR devices at a site.

   Ingress Tunnel Router (ITR):   a router which accepts an IP multicast
      packet with a single IP header (more precisely, an IP packet that
      does not contain a LISP header). The router treats this "inner"
      IP destination multicast address opaquely so it doesn't need to
      perform a map lookup on the group address because it is
      topologically insignificant. The router then prepends an "outer"
      IP header with one of its globally-routable RLOCs as the source
      address field. This RLOC is known to other multicast receiver

sites which have used the mapping database to join a multicast
tree for which the ITR is the root. In general, an ITR receives
IP packets from site end systems on one side and sends LISP-
encapsulated multicast IP packets out all external interfaces
which have been joined.

An ITR would receive a multicast packet from a source inside of
its site when 1) it is on the path from the multicast source to
internally joined receivers, or 2) when it is on the path from the
multicast source to externally joined receivers.

Egress Tunnel Router (ETR):   a router that is on the path from a
multicast source host in another site to a multicast receiver in
its own site. An ETR accepts a PIM Join/Prune message from a site
internal PIM router destined for the source's EID in the multicast
source site. The ETR maps the source EID in the Join/Prune
message to an RLOC address based on the EID-to-RLOC mapping. This
sets up the ETR to accept multicast encapsulated packets from the
ITR in the source multicast site. A multicast ETR decapsulates
multicast encapsulated packets and replicates them on interfaces
leading to internal receivers.

xTR: is a reference to an ITR or ETR when direction of data flow is
not part of the context description. xTR refers to the router that
is the tunnel endpoint. Used synonymously with the term "Tunnel
Router". For example, "An xTR can be located at the Customer Edge
(CE) router", meaning both ITR and ETR functionality can be at the
CE router.

LISP Header: a term used in this document to refer to the outer
IPv4 or IPv6 header, a UDP header, and a LISP header. An ITR
prepends headers and an ETR strips headers. A LISP encapsulated
multicast packet will have an "inner" header with the source EID
in the source field; an "outer" header with the source RLOC in the
source field: and the same globally unique group address in the
destination field of both the inner and outer header.

(S,G) State: the formal definition is in the PIM Sparse Mode
[RFC4601] specification. For this specification, the term is used
generally to refer to multicast state. Based on its topological
location, the (S,G) state resides in routers can be either
(S-EID,G) state (at a location where the (S,G) state resides) or
(S-RLOC,G) state (in the Internet core).

(S-EID,G) State: refers to multicast state in multicast source and
receiver sites where S-EID is the IP address of the multicast
source host (its EID). An S-EID can appear in an IGMPv3 report,
an MSDP SA message or a PIM Join/Prune message that travels inside

     of a site.

   (S-RLOC,G) State: refers to multicast state in the core where S is
      a source locator (the IP address of a multicast ITR) of a site
      with a multicast source. The (S-RLOC,G) is mapped from (S-EID,G)
      entry by doing a mapping database lookup for the EID prefix that
      S-EID maps to. An S-RLOC can appear in a PIM Join/Prune message
      when it travels from an ETR to an ITR over the Internet core.

   uLISP Site: a unicast only LISP site according to [LISP] which has
      not deployed the procedures of this specification and therefore,
      for multicast purposes, follows the procedures from Section 9.

   mPETR: this is a multicast proxy-ETR that is responsible for
      advertising a very coarse EID prefix which non-LISP and uLISP
      sites can target their (S-EID,G) PIM Join/Prune message to. mPETRs
      are used so LISP source multicast sites can send multicast packets
      using source addresses from the EID namespace. mPETRs act as Proxy
      ETRs for supporting multicast routing in a LISP infrastructure.
      It is likely an uPITR [INTWORK] and a mPETR will be co-located
      since the single device advertises a coarse EID-prefix in the
      underlying unicast routing system.

   Mixed Locator-Sets: this is a locator-set for a LISP database
      mapping entry where the RLOC addresses in the locator-set are in
      both IPv4 and IPv6 format.

   Unicast Encapsulated PIM Join/Prune Message: this is a standard PIM
      Join/Prune message (encapsulated in a LISP Encapsulated Control
      Message with destination UDP port 4342) which is sent by ETRs at
      multicast receiver sites to an ITR at a multicast source site.
      This message is sent periodically as long as there are interfaces
      in the oif-list for the (S-EID,G) entry the ETR is joining for.

[4](#). Basic Overview

   LISP, when used for unicast routing, increases the site's ability to
   control ingress traffic flows. Egress traffic flows are controlled
   by the IGP in the source site. For multicast, the IGP coupled with
   PIM can decide which path multicast packets ingress. By using the
   traffic engineering features of LISP, a multicast source site can
   control the egress of its multicast traffic. By controlling the
   priorities of locators from a mapping database entry, a source
   multicast site can control which way multicast receiver sites join to
   the source site.

   At this point in time, we don't see a requirement for different
   locator-sets, priority, and weight policies for multicast than we
   have for unicast. However, when traffic engineering policies are
   different for unicast versus multicast flows, it will be desirable to
   use multicast-based priority and weight values in Map-Reply messages.

   The fundamental multicast forwarding model is to encapsulate a
   multicast packet into another multicast packet. An ITR will
   encapsulate multicast packets received from sources that it serves in
   another LISP multicast header. The destination group address from
   the inner header is copied to the destination address of the outer
   header. The inner source address is the EID of the multicast source
   host and the outer source address is the RLOC of the encapsulating
   ITR.

   The LISP-Multicast architecture will follow this high-level protocol
   and operational sequence:

   1. Receiver hosts in multicast sites will join multicast content the
       way they do today, they use IGMP. When they use IGMPv3 where
       they specify source addresses, they use source EIDs, that is they
       join (S-EID,G). If the multicast source is external to this
       receiver site, the PIM Join/Prune message flows toward the ETRs,
       finding the shortest exit (that is the closest exit for the Join/
       Prune message and the closest entrance for the multicast packet
       to the receiver).

   2. The ETR does a mapping database lookup for S-EID. If the mapping
       is cached from a previous lookup (from either a previous Join/
       Prune for the source multicast site or a unicast packet that went
       to the site), it will use the RLOC information from the mapping.
       The ETR will use the same priority and weighting mechanism as for
       unicast. So the source site can decide which way multicast
       packets egress.

3. The ETR will build two PIM Join/Prune messages, one that contains
    a (S-EID,G) entry that is unicast to the ITR that matches the
    RLOC the ETR selects, and the other which contains a (S-RLOC,G)
    entry so the core network can create multicast state from this
    ETR to the ITR.

4. When the ITR gets the unicast Join/Prune message (see Section 3
    for formal definition), it will process (S-EID,G) entries in the
    message and propagate them inside of the site where it has
    explicit routing information for EIDs via the IGP. When the ITR
    receives the (S-RLOC,G) PIM Join/Prune message it will process it
    like any other join it would get in today's Internet. The S-RLOC
    address is the IP address of this ITR.

5. At this point there is (S-EID,G) state from the joining host in
    the receiver multicast site to the ETR of the receiver multicast
    site. There is (S-RLOC,G) state across the core network from the
    ETR of the multicast receiver site to the ITR in the multicast
    source site and (S-EID,G) state in the source multicast site.
    Note, the (S-EID,G) state is the same S-EID in each multicast
    site. As other ETRs join the same multicast tree, they can join
    through the same ITR (in which case the packet replication is
    done in the core) or a different ITR (in which case the packet
    replication is done at the source site).

6. When a packet is originated by the multicast host in the source
    site, it will flow to one or more ITRs which will prepend a LISP
    header by copying the group address to the outer destination
    address field and insert its own locator address in the outer
    source address field. The ITR will look at its (S-RLOC,G) state,
    where S-RLOC is its own locator address, and replicate the packet
    on each interface a (S-RLOC,G) joined was received on. The core
    has (S-RLOC,G) so where fanout occurs to multiple sites, a core
    router will do packet replication.

7. When either the source site or the core replicates the packet,
    the ETR will receive a LISP packet with a destination group
    address. It will decapsulate packets because it has receivers
    for the group. Otherwise, it would have not received the packets
    because it would not have joined. The ETR decapsulates and does
    a (S-EID,G) lookup in its multicast FIB to forward packets out
    one or more interfaces to forward the packet to internal
    receivers.

This architecture is consistent and scalable with the architecture
presented in [LISP] where multicast state in the core operates on
locators and multicast state at the sites operates on EIDs.

Alternatively, [LISP] also has a mechanism where (S-EID,G) state can
reside in the core through the use of RPF-vectors [RFC5496] in PIM
Join/Prune messages. However, few PIM implementations support RPF
vectors and LISP should avoid S-EID state in the core. See Section 5
for details.

However, we have some observations on the algorithm above. We can
scale the control plane but at the expense of sending data to sites
which may have not joined the distribution tree where the
encapsulated data is being delivered. For example, one site joins
(S-EID1,G) and another site joins (S-EID2,G). Both EIDs are in the
same multicast source site. Both multicast receiver sites join to
the same ITR with state (S-RLOC,G) where S-RLOC is the RLOC for the
ITR. The ITR joins both (S-EID1,G) and (S-EID2,G) inside of the
site. The ITR receives (S-RLOC,G) joins and populates the oif-list
state for it. Since both (S-EID1,G) and (S-EID2, G) map to the one
(S-RLOC,G) packets will be delivered by the core to both multicast
receiver sites even though each have joined a single source-based
distribution tree. This behavior is a consequence of the many-to-one
mapping between S-EIDs and a S-RLOC.

There is a possible solution to this problem which reduces the number
of many-to-one occurrences of (S-EID,G) entries aggregating into a
single (S-RLOC,G) entry. If a physical ITR can be assigned multiple
RLOC addresses and these addresses are advertised in mapping database
entries, then ETRs at receiver sites have more RLOC address options
and therefore can join different (RLOC,G) entries for each (S-EID,G)
entry joined at the receiver site. It would not scale to have a one-
to-one relationship between the number of S-EID sources at a source
site and the number of RLOCs assigned to all ITRs at the site, but we
can reduce the "n" to a smaller number in the "n-to-1" relationship.
And in turn, reduce the opportunity for data packets to be delivered
to sites for groups not joined.

5. **Source Addresses versus Group Addresses**

   Multicast group addresses don't have to be associated with either the
   EID or RLOC namespace. They actually are a namespace of their own
   that can be treated as logical with relatively opaque allocation.
   So, by their nature, they don't detract from an incremental
   deployment of LISP-Multicast.

   As for source addresses, as in the unicast LISP scenario, there is a
   decoupling of identification from location. In a LISP site, packets
   are originated from hosts using their allocated EIDs, those addresses
   are used to identify the host as well as where in the site's topology
   the host resides but not how and where it is attached to the
   Internet.

   Therefore, when multicast distribution tree state is created anywhere
   in the network on the path from any multicast receiver to a multicast
   source, EID state is maintained at the source and receiver multicast
   sites, and RLOC state is maintained in the core. That is, a
   multicast distribution tree will be represented as a 3-tuple of
   {(S-EID,G) (S-RLOC,G) (S-EID,G)} where the first element of the
   3-tuple is the state stored in routers from the source to one or more
   ITRs in the source multicast site, the second element of the 3-tuple
   is the state stored in routers downstream of the ITR, in the core, to
   all LISP receiver multicast sites, and the third element in the
   3-tuple is the state stored in the routers downstream of each ETR, in
   each receiver multicast site, reaching each receiver. Note that
   (S-EID,G) is the same in both the source and receiver multicast
   sites.

   The concatenation/mapping from the first element to the second
   element of the 3-tuples is done by the ITR and from the second
   element to the third element is done at the ETRs.

6. **Locator Reachability Implications on LISP-Multicast**

   Multicast state as it is stored in the core is always (S,G) state as
   it exists today or (S-RLOC,G) state as it will exist when LISP sites
   are deployed. The core routers cannot distinguish one from the
   other. They don't need to because it is state that RPFs against the
   core routing tables in the RLOC namespace. The difference is where
   the root of the distribution tree for a particular source is. In the
   traditional multicast core, the source S is the source host's IP
   address. For LISP-Multicast the source S is a single ITR of the
   multicast source site.

   An ITR is selected based on the LISP EID-to-RLOC mapping used when an
   ETR propagates a PIM Join/Prune message out of a receiver multicast
   site. The selection is based on the same algorithm an ITR would use
   to select an ETR when sending a unicast packet to the site. In the
   unicast case, the ITR can change on a per-packet basis depending on
   the reachability of the ETR. So an ITR can change relatively easily
   using local reachability state. However, in the multicast case, when
   an ITR goes unreachable, new distribution tree state must be built
   because the encapsulating root has changed. This is more significant
   than an RPF-change event, where any router would typically locally
   change its RPF-interface for its existing tree state. But when an
   encapsulating LISP-Multicast ITR goes unreachable, new distribution
   state must be rebuilt and reflect the new encapsulator. Therefore,
   when an ITR goes unreachable, all ETRs that are currently joined to
   that ITR will have to trigger a new Join/Prune message for (S-RLOC,G)
   to the new ITR as well as send a unicast encapsulated Join/Prune
   message telling the new ITR which (S-EID,G) is being joined.

   This issue can be mitigated by using anycast addressing for the ITRs
   so the problem does reduce to an RPF change in the core, but still
   requires a unicast encapsulated Join/Prune message to tell the new
   ITR about (S-EID,G). The problem with this approach is that the ETR
   really doesn't know when the ITR has changed so the new anycast ITR
   will get the (S-EID,G) state only when the ETR sends it the next time
   during its periodic sending procedures.

7. Multicast Protocol Changes

A number of protocols are used today for inter-domain multicast routing:

IGMPv1-v3, MLDv1-v2:   These protocols do not require any changes for
    LISP-Multicast for two reasons. One being that they are link-
    local and not used over site boundaries and second they advertise
    group addresses that don't need translation. Where source
    addresses are supplied in IGMPv3 and MLDv2 messages, they are
    semantically regarded as EIDs and don't need to be converted to
    RLOCs until the multicast tree-building protocol, such as PIM, is
    received by the ETR at the site boundary. Addresses used for IGMP
    and MLD come out of the source site's allocated addresses which
    are therefore from the EID namespace.

MBGP: Even though MBGP is not a multicast routing protocol, it is
    used to find multicast sources when the unicast BGP peering
    topology and the multicast MBGP peering topology are not
    congruent. When MBGP is used in a LISP-Multicast environment, the
    prefixes which are advertised are from the RLOC namespace. This
    allows receiver multicast sites to find a path to the source
    multicast site's ITRs. MBGP peering addresses will be from the
    RLOC namespace.

MSDP: MSDP is used to announce active multicast sources to other
    routing domains (or LISP sites). The announcements come from the
    PIM Rendezvous Points (RPs) from sites where there are active
    multicast sources sending to various groups. In the context of
    LISP-Multicast, the source addresses advertised in MSDP will
    semantically be from the EID namespace since they describe the
    identity of a source multicast host. It will be true that the
    state stored in MSDP caches from core routers will be from the EID
    namespace. An RP address inside of site will be from the EID
    namespace so it can be advertised and reached by internal unicast
    routing mechanism. However, for MSDP peer-RPF checking to work
    properly across sites, the RP addresses must be converted or
    mapped into a routable address that is advertised and maintained
    in the BGP routing tables in the core. MSDP peering addresses can
    come out of either the EID or a routable address namespace. And
    the choice can be made unilaterally because the ITR at the site
    will determine which namespace the destination peer address is out
    of by looking in the mapping database service.

PIM-SSM: In the simplest form of distribution tree building, when
    PIM operates in SSM mode, a source distribution tree is built and
    maintained across site boundaries. In this case, there is a small
    modification to the operation of the PIM protocol (but not to any

message format) to support taking a Join/Prune message originated
inside of a LISP site with embedded addresses from the EID
namespace and converting them to addresses from the RLOC namespace
when the Join/Prune message crosses a site boundary. This is
similar to the requirements documented in [RFC5135].

PIM-Bidir: Bidirectional PIM is typically run inside of a routing
domain, but if deployed in an inter-domain environment, one would
have to decide if the RP address of the shared-tree would be from
the EID namespace or the RLOC namespace. If the RP resides in a
site-based router, then the RP address is from the EID namespace.
If the RP resides in the core where RLOC addresses are routed,
then the RP address is from the RLOC namespace. This could be
easily distinguishable if the EID address were well-known address
allocation block from the RLOC namespace. Also, when using
Embedded-RP for RP determination [RFC3956], the format of the
group address could indicate the namespace the RP address is from.
However, refer to Section 10 for considerations core routers need
to make when using Embedded-RP IPv6 group addresses. When using
Bidir-PIM for inter-domain multicast routing, it is recommended to
use staticly configured RPs so core routers think the Bidir group
is associated with an ITR's RLOC as the RP address and site
routers think the Bidir group is associated with the site resident
RP with an EID address. With respect to DF-election in Bidir PIM,
no changes are required since all messaging and addressing is
link-local.

PIM-ASM: The ASM mode of PIM, the most popular form of PIM, is
deployed in the Internet today is by having shared-trees within a
site and using source-trees across sites. By the use of MSDP and
PIM-SSM techniques described above, we can get multicast
connectivity across LISP sites. Having said that, that means
there are no special actions required for processing (*,G) or
(S,G,R) Join/Prune messages since they all operate against the
shared-tree which is site resident. Just like with ASM, there is
no (*,G) in the core when LISP-Multicast is in use. This is also
true for the RP-mapping mechanisms Auto-RP and BSR.

Based on the protocol description above, the conclusion is that there
are no protocol message format changes, just a translation function
performed at the control-plane. This will make for an easier and
faster transition for LISP since fewer components in the network have
to change.

It should also be stated just like it is in [LISP] that no host
changes, whatsoever, are required to have a multicast source host
send multicast packets and for a multicast receiver host to receive
multicast packets.

8. LISP-Multicast Data-Plane Architecture

   The LISP-Multicast data-plane operation conforms to the operation and
   packet formats specified in [LISP]. However, encapsulating a
   multicast packet from an ITR is a much simpler process. The process
   is simply to copy the inner group address to the outer destination
   address. And to have the ITR use its own IP address (its RLOC), and
   as the source address. The process is simpler for multicast because
   there is no EID-to-RLOC mapping lookup performed during packet
   forwarding.

   In the decapsulation case, the ETR simply removes the outer header
   and performs a multicast routing table lookup on the inner header
   (S-EID,G) addresses. Then the oif-list for the (S-EID,G) entry is
   used to replicate the packet on site-facing interfaces leading to
   multicast receiver hosts.

   There is no Data-Probe logic for ETRs as there can be in the unicast
   forwarding case.

8.1. ITR Forwarding Procedure

   The following procedure is used by an ITR, when it receives a
   multicast packet from a source inside of its site:

   1. A multicast data packet sent by a host in a LISP site will have
       the source address equal to the host's EID and the destination
       address equal to the group address of the multicast group. It is
       assumed the group information is obtained by current methods.
       The same is true for a multicast receiver to obtain the source
       and group address of a multicast flow.

   2. When the ITR receives a multicast packet, it will have both S-EID
       state and S-RLOC state stored. Since the packet was received on
       a site-facing interface, the RPF lookup is based on the S-EID
       state. If the RPF check succeeds, then the oif-list contains
       interfaces that are site-facing and external-facing. For the
       site-facing interfaces, no LISP header is prepended. For the
       external-facing interfaces a LISP header is prepended. When the
       ITR prepends a LISP header, it uses its own RLOC address as the
       source address and copies the group address supplied by the IP
       header the host built as the outer destination address.

8.1.1. Multiple RLOCs for an ITR

   Typically, an ITR will have a single RLOC address but in some cases
   there could be multiple RLOC addresses assigned from either the same
   or different service providers. In this case when (S-RLOC,G) Join/

Prune messages are received for each RLOC, there is a oif-list
merging action that must take place. Therefore, when a packet is
received from a site-facing interface that matches on a (S-EID,G)
entry, the interfaces of the oif-list from all (RLOC,G) entries
joined to the ITR as well as the site-facing oif-list joined for
(S-EID,G) must be part be included in packet replication. In
addition to replicating for all types of oif-lists, each oif entry
must be tagged with the RLOC address, so encapsulation uses the outer
source address for the RLOC joined.

8.1.2. Multiple ITRs for a LISP Source Site

Note when ETRs from different multicast receiver sites receive
(S-EID,G) joins, they may select a different S-RLOC for a multicast
source site due to policy (the multicast ITR can return different
multicast priority and weight values per ETR Map-Request). In this
case, the same (S-EID,G) is being realized by different (S-RLOC,G)
state in the core. This will not result in duplicate packets because
each ITR in the multicast source site will choose their own RLOC for
the source address for encapsulated multicast traffic. The RLOC
addresses are the ones joined by remote multicast ETRs.

When different (S-EID,G) traffic is combined into a single (RLOC,G)
core distribution tree, this may cause traffic to go to a receiver
multicast site when it does not need to. This happens when one
receiver multicast site joins (S1-EID,Gi) through a core distribution
tree of (RLOC1,Gi) and another multicast receiver site joins (S2-
EID,Gi) through the same core distribution tree of (RLOC1,Gi). When
ETRs decapsulate such traffic, they should know from their local
(S-EID,G) state if the packet should be forwarded. If there is no
(S-EID,G) state that matches the inner packet header, the packet is
discarded.

8.2. ETR Forwarding Procedure

The following procedure is used by an ETR, when it receives a
multicast packet from a source outside of its site:

1. When a multicast data packet is received by an ETR on an
    external-facing interface, it will do an RPF lookup on the S-RLOC
    state it has stored. If the RPF check succeeds, the interfaces
    from the oif-list are used for replication to interfaces that are
    site-facing as well as interfaces that are external-facing (this
    ETR can also be a transit multicast router for receivers outside
    of its site). When the packet is to be replicated for an
    external-facing interface, the LISP encapsulation header are not
    stripped. When the packet is replicated for a site-facing
    interface, the encapsulation header is stripped.

   2. The packet without a LISP header is now forwarded down the
       (S-EID,G) distribution tree in the receiver multicast site.

8.3. Replication Locations

   Multicast packet replication can happen in the following topological
   locations:

   o In an IGP multicast router inside a site which operates on S-EIDs.

   o In a transit multicast router inside of the core which operates on
      S-RLOCs.

   o At one or more ETR routers depending on the path a Join/Prune
      message exits a receiver multicast site.

   o At one or more ITR routers in a source multicast site depending on
      what priorities are returned in a Map-Reply to receiver multicast
      sites.

   In the last case the source multicast site can do replication rather
   than having a single exit from the site. But this only can occur
   when the priorities in the Map-Reply are modified for different
   receiver multicast site so that the PIM Join/Prune messages arrive at
   different ITRs.

   This policy technique, also used in [ALT] for unicast, is useful for
   multicast to mitigate the problems of changing distribution tree
   state as discussed in Section 6.

9. **LISP-Multicast Interworking**

   This section will describe the multicast corollary to [INTWORK] which
   describes the interworking of multicast routing among LISP and non-
   LISP sites.

9.1. **LISP and non-LISP Mixed Sites**

   Since multicast communication can involve more than two entities to
   communicate together, the combinations of interworking scenarios are
   more involved. However, the state maintained for distribution trees
   at the sites is the same regardless of whether or not the site is
   LISP enabled or not. So most of the implications are in the core
   with respect to storing routable EID prefixes from either PA or PI
   blocks.

   Before we enumerate the multicast interworking scenarios, we must
   define 3 deployment states of a site:

   o A non-LISP site which will run PIM-SSM or PIM-ASM with MSDP as it
      does today. The addresses for the site are globally routable.

   o A site that deploys LISP for unicast routing. The addresses for
      the site are not globally routable. Let's define the name for
      this type of site as a uLISP site.

   o A site that deploys LISP for both unicast and multicast routing.
      The addresses for the site are not globally routable. Let's
      define the name for this type of site as a LISP-Multicast site.

   We will not consider a LISP site enabled for multicast purposes only
   but do consider a uLISP site as documented in [INTWORK]. In this
   section we don't discuss how a LISP site sends multicast packets when
   all receiver sites are LISP-Multicast enabled; that has been
   discussed in previous sections.

   The following scenarios exist to make LISP-Multicast sites interwork
   with non-LISP-Multicast sites:

   1. A LISP site must be able to send multicast packets to receiver
       sites which are a mix of non-LISP sites and uLISP sites.

   2. A non-LISP site must be able to send multicast packets to
       receiver sites which are a mix of non-LISP sites and uLISP sites.

   3. A non-LISP site must be able to send multicast packets to
       receiver sites which are a mix of LISP sites, uLISP sites, and
       non-LISP sites.

   4. A uLISP site must be able to send multicast packets to receiver
       sites which are a mix of LISP sites, uLISP sites, and non-LISP
       sites.

   5. A LISP site must be able to send multicast packets to receiver
       sites which are a mix of LISP sites, uLISP sites, and non-LISP
       sites.

9.1.1. LISP Source Site to non-LISP Receiver Sites

   In the first scenario, a site is LISP capable for both unicast and
   multicast traffic and as such operates on EIDs. Therefore there is a
   possibility that the EID prefix block is not routable in the core.
   For LISP receiver multicast sites this isn't a problem but for non-
   LISP or uLISP receiver multicast sites, when a PIM Join/Prune message
   is received by the edge router, it has no route to propagate the
   Join/Prune message out of the site. This is no different than the
   unicast case that LISP-NAT in [INTWORK] solves.

   LISP-NAT allows a unicast packet that exits a LISP site to get its
   source address mapped to a globally routable address before the ITR
   realizes that it should not encapsulate the packet destined to a non-
   LISP site. For a multicast packet to leave a LISP site, distribution
   tree state needs to be built so the ITR can know where to send the
   packet. So the receiver multicast sites need to know about the
   multicast source host by its routable address and not its EID
   address. When this is the case, the routable address is the
   (S-RLOC,G) state that is stored and maintained in the core routers.
   It is important to note that the routable address for the host cannot
   be the same as an RLOC for the site because we want the ITRs to
   process a received PIM Join/Prune message from an external-facing
   interface to be propagated inside of the site so the site-part of the
   distribution tree is built.

   Using a globally routable source address allows non-LISP and uLISP
   multicast receiver to join, create, and maintain a multicast
   distribution tree. However, the LISP multicast receiver site will
   want to perform an EID-to-RLOC mapping table lookup when a PIM Join/
   Prune message is received on a site-facing interface. It does this
   because it wants to find a (S-RLOC,G) entry to Join in the core. So
   we have a conflict of behavior between the two types of sites.

   The solution to this problem is the same as when an ITR wants to send
   a unicast packet to a destination site but needs determine if the
   site is LISP capable or not. When it is not LISP capable, the ITR
   does not encapsulate the packet. So for the multicast case, when ETR
   receives a PIM Join/Prune message for (S-EID,G) state, it will do a
   mapping table lookup on S-EID. In this case, S-EID is not in the

mapping database because the source multicast site is using a
routable address and not an EID prefix address. So the ETR knows to
simply propagate the PIM Join/Prune message to a external-facing
interface without converting the (S-EID,G) because it is an (S,G)
where S is routable and reachable via core routing tables.

Now that the multicast distribution tree is built and maintained from
any non-LISP or uLISP receiver multicast site, the way packet
forwarding model is performed can be explained.

Since the ITR in the source multicast site has never received a
unicast encapsulated PIM Join/Prune message from any ETR in a
receiver multicast site, it knows there are no LISP-Multicast
receiver sites. Therefore, there is no need for the ITR to
encapsulate data. Since it will know a priori (via configuration)
that its site's EIDs are not routable (and not registered to the
mapping database system), it assumes that the multicast packets from
the source host are sent by a routable address. That is, it is the
responsibility of the multicast source host's system administrator to
ensure that the source host sends multicast traffic using a routable
source address. When this happens, the ITR acts simply as a router
and forwards the multicast packet like an ordinary multicast router.

There is an alternative to using a LISP-NAT scheme just like there is
for unicast [INTWORK] forwarding by using Proxy Tunnel Routers
(PxTRs). This can work the same way for multicast routing as well,
but the difference is that non-LISP and uLISP sites will send PIM
Join/Prune messages for (S-EID,G) which make their way in the core to
multicast PxTRs. Let's call this use of a PxTR as a "Multicast
Proxy-ETR" (or mPETR). Since the mPETRs advertise very coarse EID
prefixes, they draw the PIM Join/Prune control traffic making them
the target of the distribution tree. To get multicast packets from
the LISP source multicast sites, the tree needs to be built on the
path from the mPETR to the LISP source multicast site. To make this
happen the mPETR acts as a "Proxy ETR" (where in unicast it acts as a
"Proxy ITR", or an uPITR [INTWORK]).

The existence of mPETRs in the core allows source multicast site ITRs
to encapsulate multicast packets according to (S-RLOC,G) state. The
(S-RLOC,G) state is built from the mPETRs to the multicast ITRs. The
encapsulated multicast packets are decapsulated by mPETRs and then
forwarded according to (S-EID,G) state. The (S-EID,G) state is built
from the non-LISP and uLISP receiver multicast sites to the mPETRs.

9.1.2. Non-LISP Source Site to non-LISP Receiver Sites

Clearly non-LISP multicast sites can send multicast packets to non-
LISP receiver multicast sites. That is what they do today. However,

discussion is required to show how non-LISP multicast sites send
multicast packets to uLISP receiver multicast sites.

Since uLISP receiver multicast sites are not targets of any (S,G)
state, they simply send (S,G) PIM Join/Prune messages toward the non-
LISP source multicast site. Since the source multicast site, in this
case has not been upgraded to LISP, all multicast source host
addresses are routable. So this case is simplified to where a uLISP
receiver multicast site looks to the source multicast site as a non-
LISP receiver multicast site.

9.1.3. Non-LISP Source Site to Any Receiver Site

When a non-LISP source multicast site has receivers in either a non-
LISP/uLISP site or a LISP site, one needs to decide how the LISP
receiver multicast site will attach to the distribution tree. We
know from Section 9.1.2 that non-LISP and uLISP receiver multicast
sites can join the distribution tree, but a LISP receiver multicast
site ETR will need to know if the source address of the multicast
source host is routable or not. We showed in Section 9.1.1 that an
ETR, before it sends a PIM Join/Prune message on an external-facing
interface, does a EID-to-RLOC mapping lookup to determine if it
should convert the (S,G) state from a PIM Join/Prune message received
on a site-facing interface to a (S-RLOC,G). If the lookup fails, the
ETR can conclude the source multicast site is a non-LISP site so it
simply forwards the Join/Prune message (it also doesn't need to send
a unicast encapsulated Join/Prune message because there is no ITR in
a non-LISP site and there is namespace continuity between the ETR and
source).

For a non-LISP source multicast site, (S-EID,G) state could be
limited to the edges of the network with the use of multicast proxy-
ITRs (mPITRs). The mPITRs can take native, unencapsulated multicast
packets from non-LISP source multicast and uLISP sites and
encapsulate them to ETRs in receiver multicast sites or to mPETRs
that can decapsulate for non-LISP receiver multicast or uLISP sites.
The mPITRs are responsible for sending (S-EID,G) joins to the non-
LISP source multicast site. To connect the distribution trees
together, multicast ETRs will need to be configured with the mPITR's
RLOC addresses so they can send both (S-RLOC,G) joins to build a
distribution tree to the mPITR as well as for sending unicast joins
to mPITRs so they can propogate (S-EID,G) joins into source multicast
sites. The use of mPITRs is undergoing more study and is work in
progress.

9.1.4. Unicast LISP Source Site to Any Receiver Sites

   In the last section, it was explained how an ETR in a multicast
   receiver site can determine if a source multicast site is LISP-
   enabled by looking into the mapping database. When the source
   multicast site is a uLISP site, it is LISP enabled but the ITR, by
   definition is not capable of doing multicast encapsulation. So for
   the purposes of multicast routing, the uLISP source multicast site is
   treated as non-LISP source multicast site.

   Non-LISP receiver multicast sites can join distribution trees to a
   uLISP source multicast site since the source site behaves, from a
   forwarding perspective, as a non-LISP source site. This is also the
   case for a uLISP receiver multicast site since the ETR does not have
   multicast functionality built-in or enabled.

   Special considerations are required for LISP receiver multicast sites
   since they think the source multicast site is LISP capable, the ETR
   cannot know if ITR is LISP-Multicast capable. To solve this problem,
   each mapping database entry will have a multicast 2-tuple (Mpriority,
   Mweight) per RLOC. When the Mpriority is set to 255, the site is
   considered not multicast capable. So an ETR in a LISP receiver
   multicast site can distinguish whether a LISP source multicast site
   is LISP-Multicast site from a uLISP site.

9.1.5. LISP Source Site to Any Receiver Sites

   When a LISP source multicast site has receivers in LISP, non-LISP,
   and uLISP receiver multicast sites, it has a conflict about how it
   sends multicast packets. The ITR can either encapsulate or natively
   forward multicast packets. Since the receiver multicast sites are
   heterogeneous in their behavior, one packet forwarding mechanism
   cannot satisfy both. However, if a LISP receiver multicast site acts
   like a uLISP site then it could receive packets like a non-LISP
   receiver multicast site making all receiver multicast sites have
   homogeneous behavior. However, this poses the following issues:

   o LISP-NAT techniques with routable addresses would be required in
      all cases.

   o Or alternatively, mPETR deployment would be required forcing
      coarse EID prefix advertisement in the core.

   o But what is most disturbing is that when all sites that
      participate are LISP-Multicast sites but then a non-LISP or uLISP
      site joins the distribution tree, then the existing joined LISP
      receiver multicast sites would have to change their behavior.
      This would create too much dynamic tree-building churn to be a

     viable alternative.

   So the solution space options are:

   1. Make the LISP ITR in the source multicast site send two packets,
       one that is encapsulated with (S-RLOC,G) to reach LISP receiver
       multicast sites and another that is not encapsulated with
       (S-EID,G) to reach non-LISP and uLISP receiver multicast sites.

   2. Make the LISP ITR always encapsulate packets with (S-RLOC,G) to
       reach LISP-Multicast sites and to reach mPETRs that can
       decapsulate and forward (S-EID,G) packets to non-LISP and uLISP
       receiver multicast sites.

9.2. LISP Sites with Mixed Address Families

   A LISP database mapping entry that describes the locator-set,
   Mpriority and Mweight per locator address (RLOC), for an EID prefix
   associated with a site could have RLOC addresses in either IPv4 or
   IPv6 format. When a mapping entry has a mix of RLOC formatted
   addresses, it is an implicit advertisement by the site that it is a
   dual-stack site. That is, the site can receive IPv4 or IPv6 unicast
   packets.

   To distinguish if the site can receive dual-stack unicast packets as
   well as dual-stack multicast packets, the Mpriority value setting
   will be relative to an IPv4 or IPv6 RLOC See [LISP] for packet format
   details.

   If you consider the combinations of LISP, non-LISP, and uLISP sites
   sharing the same distribution tree and considering the capabilities
   of supporting IPv4, IPv6, or dual-stack, the number of total
   combinations grows beyond comprehension.

   Using some combinatorial math, we have the following profiles of a
   site and the combinations that can occur:

   1. LISP-Multicast IPv4 Site

   2. LISP-Multicast IPv6 Site

   3. LISP-Multicast Dual-Stack Site

   4. uLISP IPv4 Site

   5. uLISP IPv6 Site

   6. uLISP Dual-Stack Site

   7. non-LISP IPv4 Site

   8. non-LISP IPv6 Site

   9. non-LISP Dual-Stack Site

   Lets define (m n) = m!/(n!*(m-n)!), pronounced "m choose n" to
   illustrate some combinatorial math below.

   When 1 site talks to another site, the combinatorial is (9 2), when 1
   site talks to another 2 sites, the combinatorial is (9 3). If sum
   this up to (9 9), we have:

   (9 2) + (9 3) + (9 4) + (9 5) + (9 6) + (9 7) + (9 8) + (9 9) =

     36 +   84 + 126 + 126 +   84 +   36 + 9   +   1

   Which results in the total number of cases to be considered at 502.

   This combinatorial gets even worse when you consider a site using one
   address family inside of the site and the xTRs use the other address
   family (as in using IPv4 EIDs with IPv6 RLOCs or IPv6 EIDs with IPv4
   RLOCs).

   To rationalize this combinatorial nightmare, there are some
   guidelines which need to be put in place:

   o Each distribution tree shared between sites will either be an IPv4
      distribution tree or an IPv6 distribution tree. Therefore, we can
      avoid head-end replication by building and sending packets on each
      address family based distribution tree. Even though there might
      be an urge to do multicast packet translation from one address
      family format to the other, it is a non-viable over-complicated
      urge. Multicast ITRs will only encapsulate packets where the
      inner and outer headers are from the same address family.

   o All LISP sites on a multicast distribution tree must share a
      common address family which is determined by the source site's
      locator-set in its LISP database mapping entry. All receiver
      multicast sites will use the best RLOC priority controlled by the
      source multicast site. This is true when the source site is
      either LISP-Multicast or uLISP capable. This means that priority-
      based policy modification is prohibited. When a receiver
      multicast site ETR receives a (S-EID,G) join, it must select a
      S-RLOC for the same address family as S-EID.

   o A mixed multicast locator-set with the best multicast priority
      values MUST NOT be configured on multicast ITRs. A mixed locator-
      set can exist (for unicast use), but the multicast priorities MUST
      be the set for the same address family locators.

   o When the source site is not LISP capable, it is up to how
      receivers find the source and group information for a multicast
      flow. That mechanism decides the address family for the flow.

9.3. Making a Multicast Interworking Decision

   This Multicast Interworking section has shown all combinations of
   multicast connectivity that could occur. As you might have already
   concluded, this can be quite complicated and if the design is too
   ambitious, the dynamics of the protocol could cause a lot of
   instability.

   The trade-off decisions are hard to make and we want the same single
   solution to work for both IPv4 and IPv6 multicast. It is imperative
   to have an incrementally deployable solution for all of IPv4 unicast
   and multicast and IPv6 unicast and multicast while minimizing (or
   eliminating) both unicast and multicast EID namespace state.

   Therefore the design decision to go with uPITRs [INTWORK] for unicast
   routing and mPETRs for multicast routing seems to be the sweet spot
   in the solution space so we can optimize state requirements and avoid
   head-end data replication at ITRs.

10. Considerations when RP Addresses are Embedded in Group Addresses

   When ASM and PIM-Bidir is used in an IPv6 inter-domain environment, a
   technique exists to embed the unicast address of an RP in a IPv6
   group address [RFC3956]. When routers in end sites process a PIM
   Join/Prune message which contain an embedded-RP group address, they
   extract the RP address from the group address and treat it from the
   EID namespace. However, core routers do not have state for the EID
   namespace, need to extract an RP address from the RLOC namespace.

   Therefore, it is the responsibility of ETRs in multicast receiver
   sites to map the group address into a group address where the
   embedded-RP address is from the RLOC namespace. The mapped RP-
   address is obtained from a EID-to-RLOC mapping database lookup. The
   ETR will also send a unicast (*,G) Join/Prune message to the ITR so
   the branch of the distribution tree from the source site resident RP
   to the ITR is created.

   This technique is no different than the techniques described in this
   specification for translating (S,G) state and propagating Join/Prune
   messages into the core. The only difference is that the (*,G) state
   in Join/Prune messages are mapped because they contain unicast
   addresses encoded in an Embedded-RP group address.

11. **Taking Advantage of Upgrades in the Core**

   If the core routers are upgraded to support [RFC5496], then we can
   pass EID specific data through the core without, possibly, having to
   store the state in the core.

   By doing this we can eliminate the ETR from unicast encapsulating PIM
   Join/Prune messages to the source site's ITR.

   However, this solution is restricted to a small set of workable cases
   which would not be good for general use of LISP-Multicast. In
   addition due to slow convergence properties, it is not being
   recommended for LISP-Multicast.

12. Mtrace Considerations

   Mtrace functionality must be consistent with unicast traceroute
   functionality where all hops from multicast receiver to multicast
   source are visible.

   The design for mtrace for use in LISP-Multicast environments is to be
   determined but should build upon the mtrace version 2 specified in
   [MTRACE].

13. Security Considerations

Refer to the [LISP] specification.

14. Acknowledgments

   The authors would like to gratefully acknowledge the people who have
   contributed discussion, ideas, and commentary to the making of this
   proposal and specification. People who provided expert review were
   Scott Brim, Greg Shepherd, and Dave Oran. Other commentary from
   discussions at Summer 2008 Dublin IETF were Toerless Eckert and
   Ijsbrand Wijnands.

   We would also like to thank the MBONED working group for constructive
   and civil verbal feedback when this draft was presented at the Fall
   2008 IETF in Minneapolis. In particular, good commentary came from
   Tom Pusateri, Steve Casner, Marshall Eubanks, Dimitri Papadimitriou,
   Ron Bonica, Lenny Guardino, Alia Atlas, and Jesus Arango.

   An expert review of this specification was done by Yiqun Cai and
   Liming Wei. We thank them for their detailed comments.

   This work originated in the Routing Research Group (RRG) of the IRTF.
   The individual submission [MLISP] was converted into this IETF LISP
   working group draft.

15. IANA Considerations

This document makes no request of the IANA.

16. References

16.1. Normative References

   [LISP]   Farinacci, D., Fuller, V., Meyer, D., and D. Lewis,
                "Locator/ID Separation Protocol (LISP)",
                draft-ietf-lisp-15.txt (work in progress).

   [RFC2119]   Bradner, S., "Key words for use in RFCs to Indicate
                Requirement Levels", BCP 14, RFC 2119, March 1997.

   [RFC3618]   Fenner, B. and D. Meyer, "Multicast Source Discovery
                Protocol (MSDP)", RFC 3618, October 2003.

   [RFC3956]   Savola, P. and B. Haberman, "Embedding the Rendezvous
                Point (RP) Address in an IPv6 Multicast Address",
                RFC 3956, November 2004.

   [RFC4601]   Fenner, B., Handley, M., Holbrook, H., and I. Kouvelas,
                "Protocol Independent Multicast - Sparse Mode (PIM-SM):
                Protocol Specification (Revised)", RFC 4601, August 2006.

   [RFC4604]   Holbrook, H., Cain, B., and B. Haberman, "Using Internet
                Group Management Protocol Version 3 (IGMPv3) and Multicast
                Listener Discovery Protocol Version 2 (MLDv2) for Source-
                Specific Multicast", RFC 4604, August 2006.

   [RFC4607]   Holbrook, H. and B. Cain, "Source-Specific Multicast for
                IP", RFC 4607, August 2006.

   [RFC4760]   Bates, T., Chandra, R., Katz, D., and Y. Rekhter,
                "Multiprotocol Extensions for BGP-4", RFC 4760,
                January 2007.

   [RFC5015]   Handley, M., Kouvelas, I., Speakman, T., and L. Vicisano,
                "Bidirectional Protocol Independent Multicast (BIDIR-
                PIM)", RFC 5015, October 2007.

   [RFC5135]   Wing, D. and T. Eckert, "IP Multicast Requirements for a
                Network Address Translator (NAT) and a Network Address
                Port Translator (NAPT)", BCP 135, RFC 5135, February 2008.

   [RFC5496]   Wijnands, IJ., Boers, A., and E. Rosen, "The Reverse Path
                Forwarding (RPF) Vector TLV", RFC 5496, March 2009.

16.2. Informative References

   [ALT]   Farinacci, D., Fuller, V., and D. Meyer, "LISP Alternative
                Topology (LISP-ALT)", draft-ietf-lisp-alt-07.txt (work in
                progress).

   [INTWORK]   Lewis, D., Meyer, D., and D. Farinacci, "Interworking LISP
                with IPv4 and IPv6", draft-ietf-lisp-interworking-02.txt
                (work in progress).

   [MLISP]   Farinacci, D., Meyer, D., Zwiebel, J., and S. Venaas,
                "LISP for Multicast Environments",
                draft-farinacci-lisp-multicast-01.txt (work in progress).

   [MTRACE]   Asaeda, H., Jinmei, T., Fenner, W., and S. Casner, "Mtrace
                Version 2: Traceroute Facility for IP Multicast",
                draft-ietf-mboned-mtrace-v2-08.txt (work in progress).

Appendix A. Document Change Log

A.1. Changes to draft-ietf-lisp-multicast-07.txt

   o Posted July 2011. Fixing IDnits errors.

A.2. Changes to draft-ietf-lisp-multicast-06.txt

   o Posted June 2011 to complete working group last call.

   o Added paragraph to section 8.1.2 based on Jesus comment about
      making it more clear what happens when two (S-EID,G) trees use the
      same (RLOC,G) tree.

   o Make more references to [INTWORK] when mentioning uPITRs and
      uPETRs.

   o Made many changes based on editorial and wordsmithing comments
      from Alia.

A.3. Changes to draft-ietf-lisp-multicast-05.txt

   o Posted April 2011 to reset expiration timer.

   o Updated references.

A.4. Changes to draft-ietf-lisp-multicast-04.txt

   o Posted October 2010 to reset expiration timer.

   o Updated references.

A.5. Changes to draft-ietf-lisp-multicast-03.txt

   o Posted April 2010.

   o Added section 8.1.2 to address Joel Halpern's comment about
      receiver sites joining the same source site via 2 different RLOCs,
      each being a separate ITR.

   o Change all occurences of "mPTR" to "mPETR" to become more
      consistent with uPITRs and uPETRs described in [INTWORK]. That
      is, an mPETR is a LISP multicast router that decapsulates
      multicast packets that are encapsulated to it by ITRs in multicast
      source sites.

   o Add clarifications in section 9 about how homogeneous multicast
      encapsulation should occur. As well as describing in this

section, how to deal with mixed-locator sets to avoid
heterogeneous encapsulation.

o Introduce concept of mPITRs to help reduce (S-EID,G) to the edges
   of LISP global multicast network.

A.6. Changes to draft-ietf-lisp-multicast-02.txt

o Posted September 2009.

o Added Document Change Log appendix.

o Specify that the LISP Encapsulated Control Message be used for
   unicasting PIM Join/Prune messages from ETRs to ITRs.

A.7. Changes to draft-ietf-lisp-multicast-01.txt

o Posted November 2008.

o Specified that PIM Join/Prune unicast messages that get sent from
   ETRs to ITRs of a source multicast site get LISP encapsulated in
   destination UDP port 4342.

o Add multiple RLOCs per ITR per Yiqun's comments.

o Indicate how static RPs can be used when LISP is run using Bidir-
   PIM in the core.

o Editorial changes per Liming comments.

o Add Mttrace Considersations section.

A.8. Changes to draft-ietf-lisp-multicast-00.txt

o Posted April 2008.

o Renamed from draft-farinacci-lisp-multicast-01.txt.

Authors' Addresses

    Dino Farinacci
    cisco Systems
    Tasman Drive
    San Jose, CA
    USA

    Email: dino@cisco.com

    Dave Meyer
    cisco Systems
    Tasman Drive
    San Jose, CA
    USA

    Email: dmm@cisco.com

    John Zwiebel
    cisco Systems
    Tasman Drive
    San Jose, CA
    USA

    Email: jzwiebel@cisco.com

    Stig Venaas
    cisco Systems
    Tasman Drive
    San Jose, CA
    USA

    Email: stig@cisco.com