                   MVPN: Using Bidirectional P-Tunnels

                   draft-rosen-l3vpn-mvpn-bidir-03.txt

Abstract

   The documents specifying multicast support for BGP/MPLS IP VPNs allow
   customer multicast data to be transported through a service
   provider's network through a set multicast tunnels. Such tunnels are
   advertised by BGP in a BGP attribute known as the "Provider Multicast
   Service Interface (PMSI) Tunnel Attribute". The base specifications
   allow the PMSI Tunnel Attribute to advertise bidirectional multicast
   distribution trees as "PMSI Tunnels"; however, those documents do not
   provide all the necessary details for using those tunnels. These
   details are provided in this document. This document also specifies
   the procedures for assigning customer multicast flows to specific
   bidirectional PMSI tunnels.

Status of this Memo

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

   Internet-Drafts are working documents of the Internet Engineering
   Task Force (IETF), its areas, and its working groups. Note that
   other groups may also distribute working documents as
   Internet-Drafts.

   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."

   The list of current Internet-Drafts can be accessed at
   http://www.ietf.org/ietf/1id-abstracts.txt.

   The list of Internet-Draft Shadow Directories can be accessed at
   http://www.ietf.org/shadow.html.

Copyright and License Notice

Table of Contents

1. Specification of requirements

   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 base documents for MVPN, [MVPN] and [MVPN-BGP], define a "PMSI
Tunnel Attribute" (PTA) that may be carried in the BGP "I-PMSI A-D
routes" and BGP "S-PMSI A-D routes" that are defined therein. The
base documents define the way that bidirectional P-tunnels are
identified in the PTA, and the way in which the identifier of a
bidirectional P-tunnel is encoded in the PTA.

However, those documents do not contain the full set of
specifications governing the use of the PTA to advertise
bidirectional P-Tunnels. These specifications are provided in this
document.

This document also specifies the procedures for assigning customer
multicast flows to specific bidirectional PMSI tunnels.

Two kinds of bidirectional P-tunnel are discussed in this document:

  - Multicast distribution trees that are created through the use of
    BIDIR-PIM [BIDIR-PIM].

  - Multipoint-to-multipoint Label Switched Paths (MP2MP LSPs),
    created by Label Distribution Protocol (LDP) Multipoint-to-
    Multipoint extensions [mLDP].

This document also specifies three methods of using MP2MP LSPs as
P-tunnels:

  - Partial mesh of MP2MP LSPs. In this method, when a set of PEs
    have multicast data to send and/or receive to/from each other,
    each PE becomes the root of a MP2MP LSP. This method is
    presented in [MVPN], section 11.2.3. The detailed specification
    is provided in this document.

  - Single MP2MP LSP with PE Distinguisher Labels. This method is
    presented in [MVPN], section 11.2.2. The detailed specification
    is provided in this document.

  - Single MP2MP LSP without PE Distinguisher Labels.

In the following, we will sometimes speak of an S-PMSI A-D route
being "ignored". When we say the route is "ignored", we do not mean
that it's normal BGP processing is not done, but that the route is
not considered when determining which P-tunnel to use when sending
multicast data, and that the MPLS label values it conveys are not
used. We will generally use "ignore" in quotes to indicate this
meaning.

3. Advertising Bidirectional P-tunnels

In this specification, we consider the use of bidirectional P-tunnels as advertised in the PTA of a BGP S-PMSI A-D route.

3.1. BIDIR-PIM P-Tunnels

A BIDIR-PIM P-tunnel may be advertised in the PTA of an Intra-AS I-PMSI A-D route or in the PTA of an S-PMSI A-D route.

As is the case with other PIM-created P-tunnels, to transmit packets on a BIDIR-PIM P-tunnel, one uses the GRE encapsulation as specified in [MVPN] section 12.

Each BIDIR-PIM P-Tunnel is identified by a unique P-group address [MVPN, section 3.1]. (The P-group address is called a "P-Multicast Group" in [MVPN-BGP]). A BIDIR-PIM P-group address is always associated with a unique "Rendezvous Point Address" (RPA).

Every PE that needs to join a particular BIDIR-PIM P-tunnel must be able to determine the RPA that corresponds to the P-tunnel's P-group address. PIM Join/Prune messages are sent along the path from the PE to the RPA. Any P routers along that path must also be able to determine the RPA, so that they too can send PIM Join/Prune messages towards the RPA. The method of mapping a P-group address to an RPA may be static configuration, or some automated means of RPA discovery that is outside the scope of this specification.

If a BIDIR-PIM P-tunnel is to be used, it is RECOMMENDED that the path from each PE in the tunnel to the RPA consist entirely of point-to-point links. On a point-to-point link, there is no ambiguity in determining which router is upstream towards a particular RPA, so the BIDIR-PIM "Designated Forwarder Election" is very quick and simple. Use of a BIDIR-PIM P-tunnel containing multiaccess links is possible, but considerably more complex.

When a BGP A-D route's PTA specifies a BIDIR-PIM P-tunnel, the PE Distinguisher Labels attribute SHOULD NOT be included; if it is included, it MUST be ignored. The PE Distinguisher Labels attribute is not needed because the "distinguished PE" for a particular packet can be identified by placing its IP address in the IP source address field of the GRE encapsulation used to send that packet on the P-tunnel.

There are two different methods of using BIDIR-PIM P-Tunnels, the "Single BIDIR-PIM P-Tunnel method", and the "Partial Mesh of

   BIDIR-PIM P-Tunnels method". The choice of method is determined by
   provisioning.

   If the "Single BIDIR-PIM P-Tunnel" method is being used, all PEs in a
   given MVPN MUST identify the same P-tunnel. The identity of this
   P-tunnel is known by provisioning. For example, by using this
   method, and identifying the tunnel in the PTA of the Intra-AS I-PMSI
   A-D routes, one may use a BIDIR-PIM P-tunnel to instantiate an MI-
   PMSI.

   If the Partial Mesh of BIDIR-PIM P-Tunnels method is being used, the
   PEs MUST identify different P-Tunnels (by advertising different P-
   group addresses in their PTAs). If a particular P-group address is
   advertised by a particular PE, then one of that PE's addresses MUST
   be the RPA corresponding to that P-group.

   For example, by using this method, and identifying the tunnel in the
   PTA of an S-PMSI A-D route, one may implement the "Partitioned Sets
   of PEs" method of supporting C-BIDIR, as discussed in section 11.2 of
   [MVPN] and section 3.6 of [CONSID].

[3.2](3.2). MP2MP LSPs

   An MP2MP LSP is identified by an "MP2MP FEC element" [mLDP]. The FEC
   element contains the IP address of the "root", followed by an "opaque
   value" that identifies the MP2MP LSP uniquely in the context of the
   root's IP address. This opaque value may be configured or
   autogenerated, and within an MVPN, there is no need for different
   roots to use the same opaque value.

   The method of using MP2MP LSPs (partial mesh, single with PE
   Distinguisher Labels, single without PE Distinguisher Labels) is
   determined by provisioning. It SHOULD be possible to configure this
   on a per-MVPN basis.

[3.2.1](3.2.1). Partial Mesh of MP2MP LSPs

   A partial mesh of MP2MP LSPs is not useful for instantiating an
   I-PMSI. The LSPs of the partial mesh are therefore only advertised
   in the PTAs of S-PMSI A-D routes.

   A partial mesh of MP2MP LSPs is useful for implementing the
   "Partitioned Sets of PEs" method of supporting C-BIDIR, as discussed
   in section 11.2 of [MVPN] and section 3.6 of [CONSID].

   Section 5.1 of this document specifies the procedures for

transmitting all kinds of customer data flows, whether unidirectional
or bidirectional, on a partial mesh of MP2MP LSPs. The sending and
receiving of PE-PE PIM control packets on a partial mesh of MP2MP
LSPs is outside the scope of this specification.

When this method is being used:

  - Each PE that is participating in the mesh MUST advertise, in the
    PTA of an S-PMSI A-D route, a MP2MP LSP of which it is the root.
    (The LSP root address is part of the P-tunnel identifier field
    carried in the PTA.) A PE MUST "participate in the mesh" if any
    of the following conditions holds:

      * The "Partitioned Sets of PEs" method of supporting C-BIDIR
        traffic is being used, and the PE's route to the Rendezvous
        Point Address (RPA) for one or more C-BIDIR groups is via a
        VRF interface.

      * The "Partitioned Sets of PEs" method is being used, it is
        desired to transmit some or all of the customer
        unidirectional multicast traffic (for the given MVPN) on the
        same LSPs used for carrying C-BIDIR traffic, and the PE has
        customer multicast traffic to transmit to other PEs.

    There may be other conditions under which a PE needs to
    participate in a partial mesh of MP2MP LSPs; these are outside
    the scope of the current specification.

  - The PE Distinguisher Labels Attribute [MVPN-BGP] MUST NOT be
    included; if included, it MUST be ignored.

3.2.2. **Single MP2MP LSP without PE Distinguisher Labels**

When this method is being used:

  - the MP2MP LSP can be advertised in the PTA of an Intra-AS I-PMSI
    A-D route, or in the PTA of an S-PMSI A-D route. When advertised
    in the PTA of an Intra-AS I-PMSI A-D route, the MP2MP LSP can be
    used to instantiate an MI-PMSI.

  - The LSP does not have to be advertised by its root. In fact, the
    root of the LSP does not even need to be a PE router.

  - The PE Distinguisher Labels Attribute MUST NOT be included, but
    if included, it MUST be ignored.

- If two or more PEs of the same MVPN advertise a MP2MP LSP in
     their Intra-AS I-PMSI A-D routes, they SHOULD advertise the same
     MP2MP LSP. Any scenario in which they do not advertise the same
     MP2MP LSP in their Intra-0I A-D routes is outside the scope of
     this document.

   This method cannot be used to support the "Partitioned Set of PEs"
   method discussed in [MVPN] section 11.2 and [CONSID] section 3.6.
   Also, this method is not compatible with the procedures of [MVPN]
   section 9.1.1.

   3.2.3. **Single MP2MP LSP with PE Distinguisher Labels**

   In this method, the MP2MP LSP MUST be advertised in the PTA of an
   Intra-AS I-PMSI A-D route or an S-PMSI A-D route originated by the
   root of the LSP. That route MUST include a "PE Distinguisher Labels"
   Attribute. Violation of these conditions MUST cause the route to be
   ignored.

   The PE at the root of the LSP SHOULD use the PE Distinguisher Labels
   Attribute to bind an upstream-assigned MPLS label to the IP address
   of some or all of the other PEs that attach to the same MVPN (as
   determined by the RTs of the A-D route). That is, the PE at the root
   of the P-tunnel assigns a distinct label to some or all of the other
   PEs attaching to the same MVPN.

   An MP2MP LSP with PE Distinguisher Labels can be used to instantiate
   an MI-PMSI. In this case, the PE at the root MUST use the PE
   Distinguisher Labels Attribute to bind an upstream-assigned MPLS
   label to the IP address of each other PE that attaches to the same
   MVPN. This set of PEs is learned via the reception of Intra-AS
   I-PMSI A-D routes.

   An MP2MP LSP with PE Distinguisher Labels can also be used to support
   the "Partitioned Set of PEs" method discussed in [MVPN] section 11.2
   and [CONSID] section 3.6. In this case, it is not necessary to bind
   an upstream-assigned label to the IP address of a particular PE in
   the MVPN unless that PE has advertised a unicast VPN-IP route to one
   of the C-RPAs of that MVPN.

   3.2.4. **Identifying a MP2MP LSP**

   To identify a MP2MP LSP, the PTA of a BGP A-D route contains an MP2MP
   FEC Element [mLDP] in its "Tunnel Identifier" field. This contains
   the IP address of the root of the LSP, as well as an "Opaque Value"
   which is unique at the root. The mLDP specification supports the use

of several different ways of constructing the tunnel identifiers.
This specification does not place any restrictions on the types of
tunnel identifier that might be used. However, a given
implementation might not support every possible type of tunnel
identifier. Future revisions of this specification will establish
one or two types of tunnel identifier as being "mandatory to
support".

[4](4). Associating Received Packets with VRFs

When a packet is received from a bidirectional P-tunnel, the packet
is first associated one or more VRFs, and then processed in the
context of that VRF or VRFs. If the bidirectional P-tunnel was
advertised in the PTA of an A-D route that did not specify an MPLS
label, then all packets received from the P-tunnel are associated
with the same set of VRFs. If the bidirectional P-tunnel was
advertised in the PTA of an A-D route, and the PTA does specify an
MPLS label, then received packets will carry a label that must be
processed in order to determine the context. If the P-tunnel is a
MP2MP LSP, this label appears below the label that identifies the LSP
itself.

[5](5). Data Transmission and Reception

[5.1](5.1). Partial Mesh of MP2MP LSPs

[5.1.1](5.1.1). Binding (C-S,C-G) to Bidirectional P-tunnels

When PE1 advertises an S-PMSI A-D route that binds a (C-S,C-G) flow
to a bidirectional P-tunnel, or when PE1 sends an S-PMSI Join message
that binds a (C-S,C-G) flow to a bidirectional P-tunnel, the
semantics are as follows. PE1 is stating that any (C-S,C-G) traffic
that it needs to transmit to other PEs will be transmitted on the
specified P-tunnel. Any other PE that needs to receive such traffic
from PE1 (i.e., any other PE that needs to receive (C-S,C-G) traffic
and which has selected PE1 as the upstream PE for C-S) MUST join that
P-tunnel.

If a PE has joined the P-tunnel, but does not need to receive the
(C-S,C-G) traffic, or if it needs to receive (C-S,C-G) traffic but
has not selected PE1 as the upstream PE for C-S, then the PE MUST
discard any such received traffic.

5.1.2. Binding (C-*,C-G) Flows from Unidirectional C-trees

When PE1 advertises an S-PMSI A-D route or sends an S-PMSI Join
message that binds (C-*,C-G) [MVPN-WILD] to a bidirectional P-tunnel,
where C-G is not a "Source-Specific Multicast" (SSM) group, and the
(C-*,C-G) traffic is traveling on a unidirectional shared C-tree, the
semantics are as follows. PE1 is stating that any traffic to C-G
that is traveling the shared C-tree and which PE1 needs to transmit
to other PEs will be transmitted on the specified P-tunnel.

Any other PE that needs to receive such traffic from PE1 (i.e., any
other PE that needs to receive (C-*,C-G) traffic and which has
selected PE1 as the upstream PE for the C-RP corresponding to the C-G
group) MUST join that P-tunnel.

If a PE has joined the P-tunnel, but does not need to receive the
(C-*,C-G) traffic, or if it needs to receive (C-*,C-G) traffic but
has not selected PE1 as the upstream PE for the C-RP that corresponds
to C-G, then the PE MUST discard any such received traffic.

5.1.3. Binding (C-*,C-G) Flows from Bidirectional C-trees

When PE1 advertises an S-PMSI A-D route or sends an S-PMSI Join
message that binds (C-*,C-G) to a bidirectional P-tunnel, where C-G
is not an SSM group, and the (C-*,C-G) traffic is traveling on a
bidirectional shared C-tree, the semantics are as follows:

  - PE1 is stating that any traffic to C-G that it (PE1) needs to
    send downstream will be sent on the specified P-tunnel

  - Any other PE that is interested in receiving (C-*,C-G) traffic
    MUST join the specified P-tunnel

  - Any other PE, say PE2, that (a) has traffic to C-G to send
    upstream and (b) has selected PE1 as its upstream PE for the
    C-RPA corresponding to C-G, MUST join the specified P-tunnel, and
    MUST send such traffic on the specified P-tunnel.

  - If a PE, say PE3, has joined the specified P-tunnel, but does not
    need to receive the (C-*,C-G) traffic, or has not selected PE1 as
    the upstream PE for the C-RPA corresponding to C-G, then PE3 MUST
    NOT send any (C-*,C-G) traffic on that P-tunnel, and MUST discard
    any (C-*,C-G) traffic it received on that P-tunnel.

These procedures implement the "Partitioned Set of PEs" scheme
described in section 11.2 of [MVPN].

The specification given so far requires an S-PMSI A-D route or an
S-PMSI Join message to be sent for each (C-*,C-G) that is using a
bidirectional C-tree. A more efficient method is given in the next
section.

5.1.4. **Binding (C-*,C-*)**

With regard to the procedures of this section, the "all BIDIR-PIM"
wildcard [MVPN-WILD] is treated identically to the (C-*,C-*)
wildcard, except that it applies only to customer BIDIR-PIM flows.

When PE1 advertises an S-PMSI A-D route or sends an S-PMSI Join
message that binds (C-*,C-*) to a specified bidirectional P-tunnel of
which PE1 is the root, the semantics are as that the bidirectional
P-tunnel is to be used to carry C-multicast traffic in the following
sets of cases:

  1. If PE1 has (C-S,C-G) traffic that is traveling on a
     source-specific C-tree, and PE1 needs to transmit that data to
     one or more other PEs, and PE1 has not bound (C-S,C-G) or
     (C-*,C-G) to a different P-tunnel, then the (C-S,C-G) traffic
     is sent by PE1 on the specified bidirectional P-tunnel.

  2. If PE1 has (C-*,C-G) traffic that is traveling on a
     unidirectional shared C-tree, and PE1 needs to transmit that
     data to one or more other PEs, and PE1 has not bound (C-*,C-G)
     to a different P-tunnel, then the (C-*,C-G) traffic is sent by
     PE1 on the specified bidirectional P-tunnel.

  3. If PE1 has (C-*,C-G) traffic that is traveling on a
     bidirectional shared C-tree, and PE1 needs to transmit that
     data to one or more other PEs, and PE1 has not bound (C-*,C-G)
     to a different P-tunnel, then the (C-*,C-G) traffic is sent by
     PE1 on the specified bidirectional P-tunnel.

  4. Consider some other PE, PE2, that has received the S-PMSI A-D
     route or S-PMSI Join message from PE1. If PE2 has (C-*,C-G)
     traffic that is traveling on a bidirectional shared C-tree, and
     PE2 needs to transmit that traffic UPSTREAM, and PE2 has
     selected PE1 as the upstream PE for the C-RPA corresponding to
     C-G, and PE1 has not bound (C-*,C-G) to any other P-tunnel,
     then the (C-*,C-G) traffic is sent by by PE2 on the specified
     bidirectional P-tunnel.

     5. If a PE receives traffic from a particular bidirectional
        P-tunnel, and the traffic is traveling a unidirectional
        (C-*,C-G) or (C-S,C-G) tree, and the root of the bidirectional
        P-tunnel is not the PE's selected upstream PE for the (C-*,C-G)
        or (C-S,C-G), the PE MUST discard the traffic.

     6. If a PE receives traffic from a particular bidirectional
        P-tunnel, and the traffic is traveling a bidirectional
        (C-*,C-G) tree, and the PE's selected upstream PE for the C-RPA
        corresponding to C-G is not the root of the bidirectional
        P-tunnel, then the PE MUST discard the traffic.

   With respect to traffic traveling a bidirectional C-tree, these
   procedures implement, for S-PMSIs, the "partitioning" scheme
   described in section 11.2 of [MVPN], without the need to send an
   S-PMSI A-D route for each (C-*,C-G) that is using a bidirectional
   C-tree. Each PE becomes the root of a bidirectional P-tunnel, and
   binds the double wildcard selector to it. The bidirectional
   P-tunnels serve as the "partitions". The bidirectional P-tunnel
   rooted at PE1 becomes the default P-tunnel for all traffic that PE1
   needs to send downstream to other PEs. It also becomes the default
   P-tunnel for all traffic that others PEs need to send upstream, as
   long as those other PEs have selected PE1 as the upstream PE for the
   C-RPA corresponding to that traffic.

   Note that other PEs SHOULD NOT join the specified bidirectional
   P-tunnel unless they have a need to send or receive data over it. A
   PE knows when it needs to receive data by virtue of having certain
   multicast state in its C-PIM instance. With regard to multicast data
   traveling on a bidirectional (C-*,C-G) tree, a PE may not know
   whether it has to send data until such data actually arrives over a
   VRF interface; the PE may be on a "sender-only" branch. However, the
   PE in this case would have to know, through provisioning or some
   automatic procedure such as "Bootstrap Routing Protocol for PIM"
   (BSR) [BSR], the set of C-RPAs that are being used to support
   (C-*,C-G) traffic. For each C-RPA, the PE could join the
   bidirectional P-tunnel advertised by its selected upstream PE for
   that C-RPA. Alternatively the PE could defer joining the P-tunnel
   until it actually has data to send.

5.2. **Single MP2MP LSP With PE Distinguisher Labels**

   The procedures for transmitting data on a single MP2MP LSP with PE
   Distinguisher Labels differ from the procedures for transmitting data
   on a partial mesh of MP2MP LSPs only in the following way. Let PE1
   be the root of the P-tunnel. When a packet that is traveling on a
   unidirectional C-tree is transmitted on the P-tunnel by a particular
   PE, say PE2, PE2 must push on the packet's label stack the label that
   PE1 assigned to PE2 via the procedure above. When a packet that is
   traveling on a bidirectional C-tree is transmitted on the P-tunnel by
   PE2, PE2 must push on the packet's label stack the label that PE1
   assigned to PE3, where PE3 is the upstream PE that PE2 has selected
   for the C-RPA corresponding to C-G.

   For unidirectional flows, this allows the transmitter to be
   identified, and for bidirectional flows, this allows the partition to
   be identified. Packets received from the wrong upstream PE or from
   the wrong partition MUST be discarded. (In effect, this is a case of
   tunnel hierarchy, where the PE Distinguisher Labels represent a set
   of MP2MP LSPs that are being tunneled through a single bidirectional
   P-tunnel.)

   If the PTA identifying the bidirectional P-tunnel contains an MPLS
   label, then that label shall appear in the label stack immediately
   preceding the label specified in the PE Distinguisher Labels
   attribute.

5.3. **Single MP2MP LSP Without PE Distinguisher Labels**

   No special rules are needed for this case; the general procedures
   specified in [MVPN] and [MVPN-BGP] are used.

5.4. **BIDIR-PIM P-Tunnel**

   Packets are transmitted using GRE encapsulation as described in
   sections 12.1.1 and 12.2.1 of [MVPN].

   It is possible to implement the "Partitioned Sets of PEs" scheme
   ([MVPN] section 11.2 and [CONSID] section 3.6) using either a single
   BIDIR-PIM P-Tunnel or using a partial mesh of BIDIR-PIM P-Tunnels.

5.4.1. **Single BIDIR-PIM P-Tunnel**

In this method, the rules for transmitting packets of a given C-flow
on a BIDIR-PIM P-Tunnel are essentially the same as the rules given
in section 5.2, except that a particular "distinguished PE" is
identified not by the use of a PE Distinguisher Label, but by the use
of the IP Source Address field of the GRE header. For unidirectional
C-flows, the IP source address field of the GRE header identifies the
PE that transmitted the packet onto the P-tunnel. For bidirectional
C-flows, suppose that PE1 is transmitting a packet over the P-tunnel,
that the packet's C-group address is C-G, and that PE1 has selected
PE2 as the upstream PE corresponding to the C-RPA that corresponds to
C-G. Then when PE1 transmits the packet over the P-tunnel, the IP
source address field of the GRE header will contain the IP address of
PE2.

5.4.2. **Partial Mesh of BIDIR-PIM P-Tunnels**

In this method, the rules for for transmitting packets of a given
C-flow on a BIDIR-PIM P-Tunnel are essentially the same as the rules
given in section 5.1.

6. **IANA Considerations**

Both [MVPN] and [MVPN-BGP] discuss the use of the "PE Distinguisher
Labels" Attribute, but neither document has asked IANA to define a
codepoint for it. We now ask IANA to assign a codepoint for this
attribute, as an optional transitive attribute, referencing [MVPN],
[MVPN-BGP], and this document.

7. **Security Considerations**

There are no additional security considerations beyond those of
[MVPN] and [MVPN-BGP].

8. **Acknowledgments**

The authors wish to thank Karthik Subramanian, Rajesh Sharma, and
Apoorva Karan for their input. We also thank Yakov Rekhter for his
valuable critique.

9. Authors' Addresses

Arjen Boers
ZTE Corporation
114 Rue Gallieni
92100 Boulogne Billancourt
France

E-mail: arjen.boers@zte.com.cn

Yiqun Cai
Cisco Systems, Inc.
170 Tasman Drive
San Jose, CA, 95134
E-mail: ycai@cisco.com

Eric C. Rosen
Cisco Systems, Inc.
1414 Massachusetts Avenue
Boxborough, MA, 01719
E-mail: erosen@cisco.com

IJsbrand Wijnands
Cisco Systems, Inc.
De kleetlaan 6a Diegem 1831
Belgium
E-mail: ice@cisco.com

10. Normative References

[BIDIR-PIM] "Bidirectional Protocol Independent Multicast", Handley,
Kouvelas, Speakman, Vicisano, RFC 5015, October 2007

[mLDP] "Label Distribution Protocol Extensions for
Point-to-Multipoint and Multipoint-to-Multipoint Label Switched
Paths", Minei, Kompella, Wijnands, Thomas,
draft-ietf-mpls-ldp-p2mp-11.txt, October 2010

[MVPN] "Multicast in MPLS/BGP IP VPNs", Rosen, Aggarwal, et. al.,
draft-ietf-l3vpn-2547bis-mcast-10.txt, January 2010

   [MVPN-BGP] "BGP Encodings and Procedures for Multicast in MPLS/BGP IP
   VPNs", Aggarwal, Rosen, Morin, Rekhter,
   draft-ietf-l3vpn-2547bis-mcast-bgp-08.txt, September 2009

   [MVPN-WILD] "MVPN: S-PMSI Wild Card Selectors", Cai, Rosen, Wijnands,
   draft-rosen-l3vpn-mvpn-wildcards-03.txt, February 2011

   [RFC2119] "Key words for use in RFCs to Indicate Requirement
   Levels.", Bradner, March 1997

11. Informative References

   [BSR] "Bootstrap Router (BSR) Mechanism for PIM", N. Bhaskar, et.al.,
   RFC 5059, January 2008

   [CONSID] "Mandatory Features in a Layer 3 Multicast BGP/MPLS VPN
   Solution", Morin, Niven-Jenkins, Kamite, Zhang, Leymann, Bitar,
   draft-ietf-l3vpn-mvpn-considerations-06.txt, February 2010