为mVPN使用非分段全局表组播(GTM)

目录

简介

本文档介绍mVPN的全局表组播(GTM)非分段。

先决条件

要求

本文档没有任何特定的要求。

使用的组件

本文档不限于特定的软件和硬件版本。

本文档中的信息都是基于特定实验室环境中的设备编写的。本文档中使用的所有设备最初均采用原始（默认）配置。如果您的网络处于活动状态，请确保您了解所有命令的潜在影响。

背景信息

NG mVPN(RFC 6513/6514)具有许多配置文件。大多数配置文件在PE路由器上都有虚拟专用网络(VPN)或虚拟路由/转发(VRF)。某些配置文件(配置文件7和 在全局环境中。对于已经全局化的配置文件，GTM中引入了BGP自动发现(AD)。对于VRF情景中的配置文件，配置文件现在可在全局情景中通过组播分布树(MDT)提供。这些都是非分段的GTM模型。非分段GTM使用的步骤在IETF草案draft-ietf-bess-mvpn-global-table-mcast中描述。

RFC 7524和draft-ietf-bess-mvpn-global-table-mcast(RFC 7716)都要求通过BGP单播路由（地址系列ipv4单播或地址系列ipv4组播）到达GTM源地址。

草案draft-ietf-bess-mvpn-global-table-mcast与RFC 7524相比的优势在于，保留了与常规NG mVPN相同的过程(RFC 6514)。

使用GTM时，mVPN可以是非分段式或分段式。

架构

在本文中，边界路由器一词用于连接两个网段的ABR、ASBR或聚合路由器。通常，ABR位于无缝MPLS网络中。使用AS-MPLS VPN时使用ASBR。并且，当GTM重叠非分段路由器连接核心网络的两个部分时，当任一部分运行不同的组播核心树协议时，将使用汇聚路由器。例如，聚合路由器可以将核心网络的PIM部分与核心网络的mLDP部分连接。

对于任何型号，均可使用SAFI 2。优点是SAFI 2可以拥有与SAFI 1不同的拓扑。因此，可以更改组播的RPF，而不更改单播转发。

边界路由器不支持双封装。这意味着，路由器不能同时在两种或模式核心树协议上转发组播。当您从一个核心树迁移到另一个核心树时，通常可以使用此方法。在迁移期间，入口PE转发到两个核心树。这在边界路由器上是不可能的。

GTM架构支持非分段和分段的GTM。本文档仅介绍未分段的GTM。

GTM Overlay Non-Segmented的步骤在draft-ietf-bess-mvpn-global-table-mcast中描述。遵循的步骤与RFC 6513/6514中的步骤相同，但进行了一些更改。

RFC 6513/6514有哪些变化？

使用GTM时，以下几点适用。其中一些与RFC 6513/6514相同；一些则不同。

- 不支持单一转发选择(SFS)。
- 支持AF IPv6。
- 支持C-PIM和C-BGP信令。
- 面向边缘的PE路由器的接口上没有VRF。这些接口现在处于全局状态。在草案draft-ietf-bess-mvpn-global-table-mcast中，这些路由器称为协议边界路由器(PBR)。这些路由器在LSM核心树协议和PIM之间进行接口。我们将这些路由器称为边界路由器。

- 核心网络运行标签交换组播(LSM)核心树协议。
- 支持mLDP、P2MP TE（静态和动态）和IR。
- 支持默认、分区以及数据MDT
- 由于GTM中没有VPNv4/6前缀，因此VRF路由导入EC和源AS EC连接到IPv4单播(SAFI 1)或组播(SAFI 2)前缀。

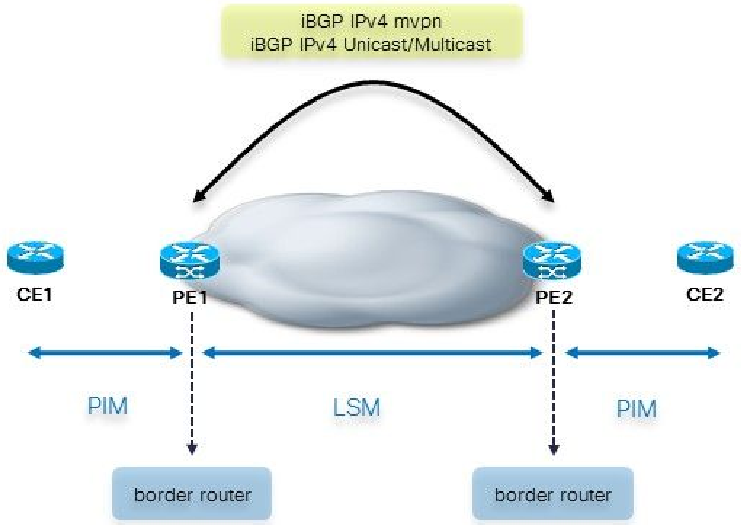
路由类型1、3和5具有RT。在Cisco IOS® XR中，这些RT必须存在于GTM中，即使根据草案，这不是必需的。您必须在BGP下配置RT以使用GTM。这些RT与VRF中用于常规mVPN的RT类似，但现在应用于全局情景。
路由类型4、6和7传输标识上游PE路由器的RT。全局管理员字段是上游PE的IP地址。对于GTM，本地管理员字段设置为0（在非GTM或常规mVPN中标识VRF）。

PE路由器成为标签交换组播(LSM)核心树协议(mLDP、P2MP流量工程、入口复制(IR))和PIM之间的互连路由器。因此，核心网络的一部分运行LSM，而核心网络的一部分运行PIM。让我们呼叫作为网络LSM部分与网络PIM部分（边界路由器）之间的接口的核心路由器。在接下来的几个示例中，这些路由器称为C-PE路由器（C表示Core）。

这些边界路由器是具有GTM所需配置的路由器。其它路由器都不是GTM感知路由器。
GTM的配置类似于常规mVPN配置文件所需的配置。只是边缘接口不在VRF中。
没有常规的路由标识符，因为没有VRF。由于不存在常规路由标识符(RD)，但是使用RD的信令与BGP，所以全零RD和全一RD用于GTM的信令。要使用此功能，必须配置BGP命令global-table-multicast。

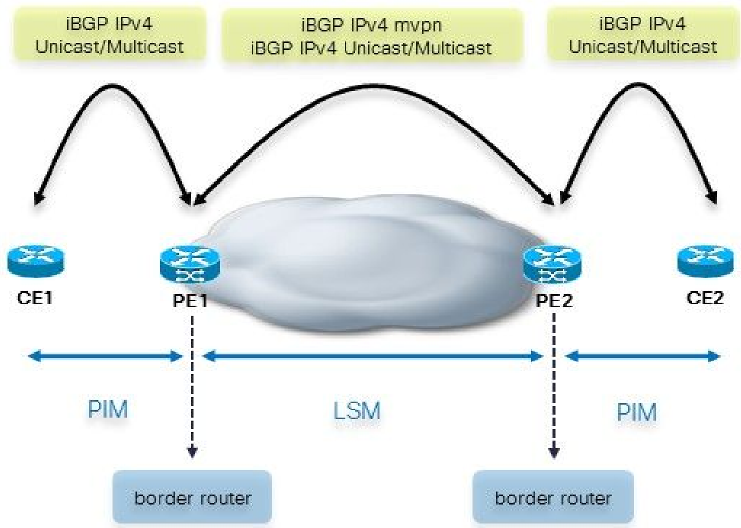
使用GTM时，单播路由不在VPNv4/6中。因此，必须在AF IPv4或AF IPv6和SAFI 1或SAFI 2的BGP中提供单播可达性。这意味着边界路由器（没有VRF的PE路由器）之间仍必须使用BGP。请参阅映像1。

图1



在边界和CE路由器之间没有BGP。当边界路由器将iBGP中的路由通告给其他边界路由器时，它会添加组播属性。
需要注意的是，CE和PE路由器之间可能存在BGP。请参阅图2。

图2



在这种情况下，当PE路由器从eBGP向iBGP转发单播路由到其他PE路由器时，它会添加组播属性。如果CE将带有组播属性的单播路由通告给PE路由器，则PE路由器保持组播属性不变，并将单播

路由转发给其他PE路由器。默认情况下，对于eBGP会话，组播属性将被删除。因此，当PE路由将单播路由从iBGP通告到eBGP到CE路由时，没有组播属性。

当PE路由器通过iBGP通告单播前缀时，它会附加扩展社区(EC)VRF路由导入(VRF-RI)和EC源AS。另一个PE路由器在eBGP中传播这些路由之前会将其删除。

当eBGP会话在两个ASBR之间时，会出现Inter-AS MPLS VPN和Inter-AS mVPN。在这种情况下，可以保留组播属性。由于默认行为是在eBGP会话上删除它们，您需要对两个ASBR之间的eBGP会话配置命令send-multicast-attributes。

对于有RR的情况，可以有iBGP到iBGP的传播。此情况适用于无缝MPLS的内联ABR（存在下一跳自身）。由于默认行为是保留iBPG会话的组播属性，内联ABR需要使用send-multicast-attributes-disable命令来删除它们。

配置更改

您必须在路由器BGP下的地址系列(AF)ipv4 mVPN下配置*global-table-multicast*。这允许全零RD和全一RD的操作。

在全局环境中，必须为AF ipv4在multicast-routing下配置*import-rt*和*export-rt*。这是因为不再为VRF配置RT，因为GTM没有VRF。这些RT不得与用于常规mVPN的任何RT重叠。

路由器pim命令（rpf topology和mdt命令）现在在全局环境中配置。

组播路由命令（bgp auto-discovery和mdt命令）现在已在全局环境中配置。

路由通告

在边界路由器之间有一个通告源前缀的iBGP。入口边界路由器如何获知源前缀？有三种可能性。

图3显示了这三个可能的场景。

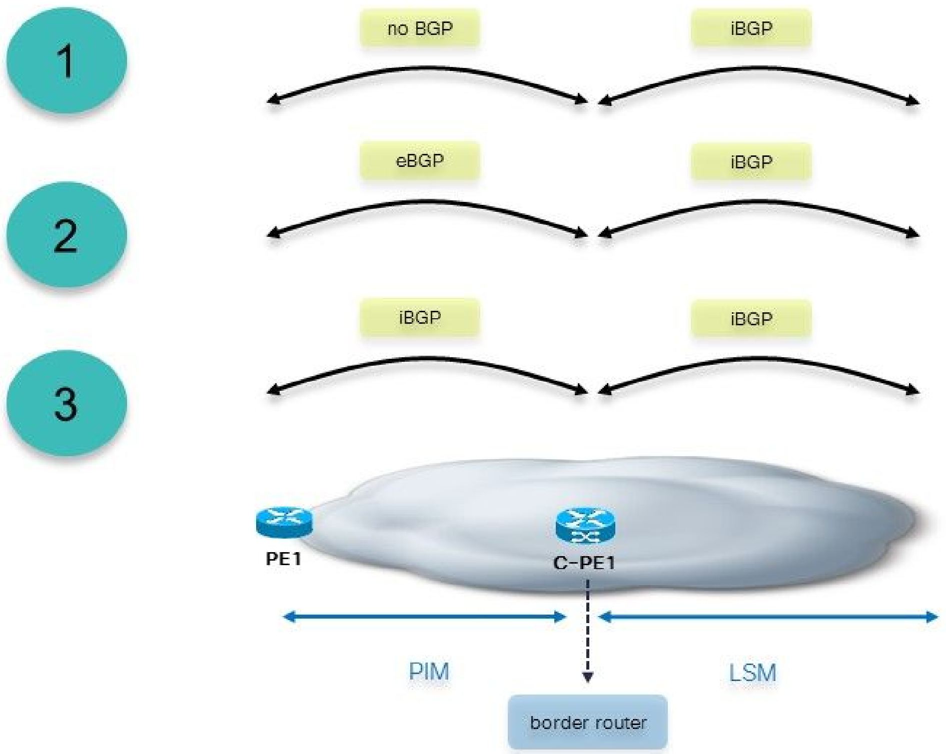


图3

1. 边界路由器从PE收到作为非BGP前缀的前缀。边界路由器需要将这些前缀重分发到BGP。此边界路由器添加组播属性。
2. 边界路由器具有指向PE路由器的eBGP会话。边界路由器在通过iBGP将前缀传播到其他边界路由器之前添加组播属性。如果通过eBGP会话接收的前缀已经具有组播属性，则保留这些前缀并按原样转发它们。边界路由器不会覆盖它们。
3. 入口边界路由器从iBGP获取源前缀。在本例中，入口边界路由器是RR。此方案用于无缝MPLS，其中边界路由器是ABR。

当边界路由器从另一个边界路由器通告收到的iBGP前缀时，它会先删除组播属性，然后再将前缀发送到PE路由器。边界路由器必须在路由器BGP下禁用命令send-multicast-attributes，这样才会发生这种情况。

Examples

以下是几个例子.第一个示例从将配置文件12转换为GTM部署开始。

示例1：配置文件12：默认MDT - mLDP - P2MP - BGP-AD - BGP C组播信令

图4显示此网络。指向CE路由器的PE路由器上没有VRF。

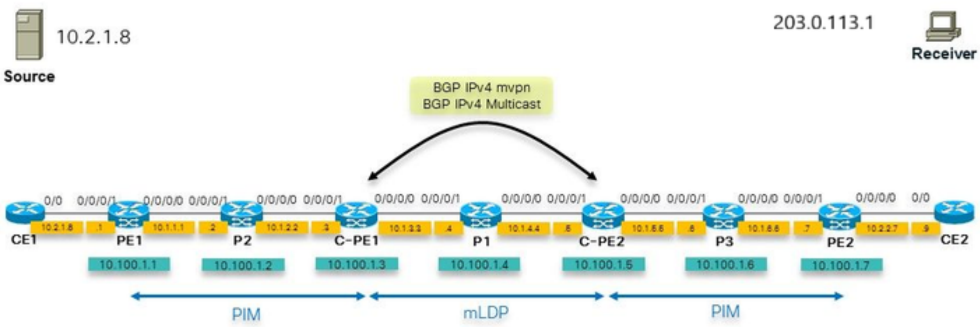


图4

请注意，内部核心网络运行mLDP。外部核心网络运行PIM。因此，连接PIM和mLDP核心的边界路由器需要将PIM转换为mLDP，反之亦然。

源不能在边界路由器C-PE2上获知为IGP路由。IGP就是ISIS。如果是这种情况，则边界路由器上的RPF将使用指向P1的ISIS路由。如果是这种情况，则RPF会失败，因为没有PIM邻居关系。您希望C-PE2路由器为10.2.1.8选择RPF，并使其指向MDT作为RPF接口。这可以是基于mLDP、P2MP或IR的MDT。

解决方案是使用SAFI 2。它用于在BGP中将源获知为AFI 2路由。因此，边界路由器(C-PE2)将源作为BGP SAFI 2路由(show route ipv4 multicast)。源的RPF指向MDT接口。

使用SAFI 2会更改RPF，而所有来源的RPF现在都使用SAFI 2。这意味着全局中所有源的RPF都使用SAFI 2，其中包括入口PE的RPF，例如VPN服务。启用SAFI 2后，所有RPF仅通过SAFI 2执行。由于只有源位于SAFI 2中，因此入口PE路由器的RPF发生故障。要执行此操作，可以在router rib下配置**rump always-replicate**命令。由于全局中只有源前缀的RPF和PE路由器的RPF必须工作，因此您可以为rump always-replicate命令配置访问列表，并仅指定全局中的源和访问列表中的入口PE路由器。这样，如果边界路由器已经为SAFI 1运行BGP，并且此SAFI 1携带大量前缀，则这些前缀不会全部重分发到SAFI 2 RIB并且不必要地使用内存。

或者，您可以在路由器BGP下为地址系列ipv4组播配置距离bgp 20 20 20。这可以确保如果全局中的源也通过IGP的AFI 2获知，则BGP获知的源优先，因为iBGP的距离与IGP的距离相比较低。

配置

这是边界路由器的配置。

```
hostname C-PE1

router rib
```

```
 address-family ipv4
 rump always-replicate
 !
route-policy global-one
 set core-tree mldp-default
end-policy
!
route-policy sources-in-ISIS
 if destination in (10.2.1.0/24) then
   pass
endif
end-policy

!
router isis 1
 is-type level-1
 net 49.0001.0000.0000.0003.00
 address-family ipv4 unicast
 metric-style wide
 mpls traffic-eng level-1
 mpls traffic-eng router-id Loopback0
 !
 interface Loopback0
 address-family ipv4 unicast
 !
 address-family ipv4 multicast
 !
 !
 interface GigabitEthernet0/0/0/0
 address-family ipv4 unicast
 !
 address-family ipv4 multicast
 !
 !
 interface GigabitEthernet0/0/0/1
 address-family ipv4 unicast
 !
 address-family ipv4 multicast
 !
 !
!
router bgp 1
 address-family ipv4 unicast
 !
 address-family ipv4 multicast
 redistribute connected route-policy loopback
 redistribute isis 1 route-policy sources-in-ISIS
 !
 address-family ipv4 mvpn
 global-table-multicast
 !
 neighbor 10.100.1.5
 remote-as 1
 update-source Loopback0
 address-family ipv4 multicast
  next-hop-self
 !
 address-family ipv4 mvpn
 !
 !
mpls ldp
 mldp
 address-family ipv4
  rib unicast-always
```

```
 !
 !
 router-id 10.100.1.3
 address-family ipv4
 !
 interface GigabitEthernet0/0/0/0
 address-family ipv4
 !
 !
 interface GigabitEthernet0/0/0/1
 address-family ipv4
 !
 !
!
multicast-routing
 address-family ipv4
interface Loopback0
  enable
 !
 interface GigabitEthernet0/0/0/1
  enable
 !
mdt source Loopback0
 export-rt 1:1
 import-rt 1:1
 bgp auto-discovery mldp
 !
 mdt default mldp p2mp
 mdt data mldp 10 immediate-switch
 !
!
router pim
 address-family ipv4
 rpf topology route-policy global-one
 mdt c-multicast-routing bgp
 interface Loopback0
  enable
 !
 interface GigabitEthernet0/0/0/1
 !
 !
!
```

注：您可以执行全局带内mLDP，而不是使用mLDP执行GTM。不这样做的原因是BGP用作重叠信令协议或使用默认MDT进行流聚合。对于GTM模型，您可以使用默认和数据MDT，而对于全局带内mLDP，每个mLDP状态有一个组播流。此外，使用GTM时，支持稀疏模式要容易得多，而使用带内mLDP时，存在限制（例如，放置RP的位置）。PIM作为重叠信令协议最容易支持稀疏模式。

边界路由器上必须有下一个配置：

- 使用AF ipv4 mvpn配置的BGP
- BGP AD已启用
- 指定的MDT
- 在路由器bgp下配置的import-rt和export-rt
- 路由器bgp AF ipv4/6 mvpn下配置的全局表组播

或者，必须在路由器BGP下启用SAFI 2

故障排除

- 首先，边界路由必须存在route-type 1路由。
- 验证内部核心中的核心树。这是mLDP。那么，mLDP信令是否正常？检查mLDP数据库条目中的默认MDT和可能的数据MDT。
- 检查BGP中的源路由。
- 检查出口边界路由器上的RPF。
- 检查边界路由器上BGP（路由类型6和7）中的C组播信令。

入口边界路由器

入口边界路由器上的出口接口是Lmdt接口。

```
RP/0/0/CPU0:C-PE1#show mrib route 203.0.113.1 10.2.1.8

IP Multicast Routing Information Base
Entry flags: L - Domain-Local Source, E - External Source to the Domain,
   C - Directly-Connected Check, S - Signal, IA - Inherit Accept,
   IF - Inherit From, D - Drop, ME - MDT Encap, EID - Encap ID,
   MD - MDT Decap, MT - MDT Threshold Crossed, MH - MDT interface handle
   CD - Conditional Decap, MPLS - MPLS Decap, EX - Extranet
   MoFE - MoFRR Enabled, MoFS - MoFRR State, MoFP - MoFRR Primary
   MoFB - MoFRR Backup, RPFID - RPF ID Set, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
   NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
   II - Internal Interest, ID - Internal Disinterest, LI - Local Interest,
   LD - Local Disinterest, DI - Decapsulation Interface
   EI - Encapsulation Interface, MI - MDT Interface, LVIF - MPLS Encap,
   EX - Extranet, A2 - Secondary Accept, MT - MDT Threshold Crossed,
   MA - Data MDT Assigned, LMI - mLDP MDT Interface, TMI - P2MP-TE MDT Interface
   IRMI - IR MDT Interface

(10.2.1.8,203.0.113.1) RPF nbr: 10.1.2.2 Flags: RPF
 Up: 00:08:58
 Incoming Interface List
   GigabitEthernet0/0/0/1 Flags: A, Up: 00:08:58
 Outgoing Interface List
   Lmdtdefault Flags: F LMI MA, Up: 00:08:58

RP/0/0/CPU0:C-PE1#show mfib route 203.0.113.1 10.2.1.8

IP Multicast Forwarding Information Base
Entry flags: C - Directly-Connected Check, S - Signal, D - Drop,
 IA - Inherit Accept, IF - Inherit From, EID - Encap ID,
 ME - MDT Encap, MD - MDT Decap, MT - MDT Threshold Crossed,
 MH - MDT interface handle, CD - Conditional Decap,
 DT - MDT Decap True, EX - Extranet, RPFID - RPF ID Set,
 MoFE - MoFRR Enabled, MoFS - MoFRR State, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
 NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
 EG - Egress, EI - Encapsulation Interface, MI - MDT Interface,
 EX - Extranet, A2 - Secondary Accept
Forwarding/Replication Counts: Packets in/Packets out/Bytes out
Failure Counts: RPF / TTL / Empty Olist / Encap RL / Other
```

```
(10.2.1.8,203.0.113.1),   Flags:
 Up: 01:47:24
 Last Used: 00:00:00
 SW Forwarding Counts: 1197/1197/239400
 SW Replication Counts: 1197/0/0
 SW Failure Counts: 0/0/0/0/0
 Lmdtdefault Flags:  F LMI, Up:01:47:24
 GigabitEthernet0/0/0/1 Flags:  A, Up:01:47:24

RP/0/0/CPU0:C-PE1#show route ipv4 multicast

Codes: C - connected, S - static, R - RIP, B - BGP, (>) - Diversion path
      D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
      N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
      E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
      i - ISIS, L1 - IS-IS level-1, L2 - IS-IS level-2
      ia - IS-IS inter area, su - IS-IS summary null, * - candidate default
      U - per-user static route, o - ODR, L - local, G  - DAGR, l - LISP
      A - access/subscriber, a - Application route
      M - mobile route, r - RPL, (!) - FRR Backup path

Gateway of last resort is not set

i L1 10.1.1.0/24 [255/20] via 10.1.2.2, 1d21h, GigabitEthernet0/0/0/1
C    10.1.2.0/24 is directly connected, 1d21h, GigabitEthernet0/0/0/1
L    10.1.2.3/32 is directly connected, 3d19h, GigabitEthernet0/0/0/1
i L1 10.1.3.0/24 [115/20] via 10.1.3.4, 3d13h, GigabitEthernet0/0/0/0
L    10.1.3.3/32 is directly connected, 3d19h, GigabitEthernet0/0/0/0
i L1 10.1.4.0/24 [115/20] via 10.1.3.4, 3d13h, GigabitEthernet0/0/0/0
i L1 10.1.5.0/24 [115/30] via 10.1.3.4, 3d12h, GigabitEthernet0/0/0/0
i L1 10.1.6.0/24 [255/40] via 10.1.3.4, 1d21h, GigabitEthernet0/0/0/0
i L1 10.2.1.0/24 [255/30] via 10.1.2.2, 1d21h, GigabitEthernet0/0/0/1
i L1 10.2.2.0/24 [255/50] via 10.1.3.4, 1d21h, GigabitEthernet0/0/0/0
i L1 10.100.1.1/32 [255/30] via 10.1.2.2, 1d21h, GigabitEthernet0/0/0/1
i L1 10.100.1.2/32 [255/20] via 10.1.2.2, 1d21h, GigabitEthernet0/0/0/1
L    10.100.1.3/32 is directly connected, 1d21h, Loopback0
i L1 10.100.1.4/32 [115/20] via 10.1.3.4, 3d13h, GigabitEthernet0/0/0/0
i L1 10.100.1.5/32 [115/30] via 10.1.3.4, 3d12h, GigabitEthernet0/0/0/0
i L1 10.100.1.6/32 [255/40] via 10.1.3.4, 1d21h, GigabitEthernet0/0/0/0
i L1 10.100.1.7/32 [255/50] via 10.1.3.4, 1d21h, GigabitEthernet0/0/0/0

RP/0/0/CPU0:C-PE1#show pim rpf 10.2.1.8

Table: IPv4-Multicast-default
* 10.2.1.8/32 [255/30]
   via GigabitEthernet0/0/0/1 with rpf neighbor 10.1.2.2
```

出口边界路由器

对于源路由，VRF Route-Import EC和Source-AS EC附加到IPv4单播或组播前缀。在这里，它是IPv4组播路由：

```
RP/0/0/CPU0:C-PE2#show bgp ipv4 multicast 10.2.1.0/24
BGP routing table entry for 10.2.1.0/24
Versions:
 Process           bRIB/RIB  SendTblVer
 Speaker                 32          32
Last Modified: Sep 12 08:34:56.441 for 15:09:58
Paths: (1 available, best #1)
```

```
 Not advertised to any peer
 Path #1: Received by speaker 0
 Not advertised to any peer
 Local
   10.100.1.3 (metric 30) from 10.100.1.3 (10.100.1.3)
     Origin incomplete, metric 30, localpref 100, valid, internal, best, group-best
     Received Path ID 0, Local Path ID 1, version 32
     Extended community: VRF Route Import:10.100.1.3:0 Source AS:1:0
```

注：如果由于任何原因，VRF RI EC和源AS EC不存在，则出口边界路由器上的RPF将失败。

路由没有以下EC时的示例：

```
RP/0/0/CPU0:C-PE2#show bgp ipv4 multicast 10.2.1.0/24
BGP routing table entry for 10.2.1.0/24
Versions:
 Process           bRIB/RIB  SendTblVer
 Speaker                277         277
Last Modified: Sep 13 04:08:37.441 for 00:00:02
Paths: (1 available, best #1)
 Not advertised to any peer
 Path #1: Received by speaker 0
 Not advertised to any peer
 Local
   10.100.1.3 (metric 30) from 10.100.1.3 (10.100.1.1)
     Origin incomplete, metric 0, localpref 100, valid, internal, best, group-best
     Received Path ID 0, Local Path ID 1, version 277
     Originator: 10.100.1.1, Cluster list: 10.100.1.3
```

因此，RPF发生故障：

```
RP/0/0/CPU0:C-PE2#show pim rpf 10.2.1.8

Table: IPv4-Multicast-default
* 10.2.1.8/32 [200/30]
   via Null with rpf neighbor 0.0.0.0

RP/0/0/CPU0:C-PE2#show bgp ipv4 mvpn

BGP router identifier 10.100.1.5, local AS number 1
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0   RD version: 0
BGP main routing table version 56
BGP NSR Initial initsync version 4 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
Global table multicast is enabled
BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best
             i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
  Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 0:0:0
*>i[1][10.100.1.3]/40 10.100.1.3                    100      0 i
*> [1][10.100.1.5]/40 0.0.0.0                                0 i
*>i[3][32][10.2.1.8][32][203.0.113.1][10.100.1.3]/120
```

```
                     10.100.1.3                    100      0 i
*> [7][0:0:0][1][32][10.2.1.8][32][203.0.113.1]/184
                     0.0.0.0                                0 i

Processed 4 prefixes, 4 paths
```

可使用关键字rd all-zero-rd指定命令。然后，它显示所有带有全零RD的条目。

```
RP/0/0/CPU0:C-PE2#show bgp ipv4 mvpn rd all-zero-rd

BGP router identifier 10.100.1.5, local AS number 1
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0   RD version: 0
BGP main routing table version 56
BGP NSR Initial initsync version 4 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
Global table multicast is enabled
BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best
             i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
  Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 0:0:0
*>i[1][10.100.1.3]/40 10.100.1.3                    100      0 i
*> [1][10.100.1.5]/40 0.0.0.0                                0 i
*>i[3][32][10.2.1.8][32][203.0.113.1][10.100.1.3]/120
                     10.100.1.3                    100      0 i
*> [7][0:0:0][1][32][10.2.1.8][32][203.0.113.1]/184
                     0.0.0.0                                0 i

Processed 4 prefixes, 4 paths
```

1类路由：

```
RP/0/0/CPU0:C-PE2#show bgp ipv4 mvpn rd all-zero-rd [1][10.100.1.3]/40

BGP routing table entry for [1][10.100.1.3]/40, Route Distinguisher: 0:0:0
Versions:
 Process           bRIB/RIB  SendTblVer
 Speaker                 43          43
Last Modified: Sep  8 07:42:43.786 for 1d17h
Paths: (1 available, best #1, not advertised to EBGP peer)
 Not advertised to any peer
 Path #1: Received by speaker 0
 Not advertised to any peer
 Local
   10.100.1.3 (metric 30) from 10.100.1.3 (10.100.1.3)
     Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported
     Received Path ID 0, Local Path ID 1, version 43
     Community: no-export
     Extended community: RT:1:1
     PMSI: flags 0x00, type 2, label 0, ID 0x060001040a6401030007010004000000001
     Source AFI: IPv4 MVPN, Source VRF: default, Source Route Distinguisher: 0:0:0
```

PMSI解码：

PMSI：标志0x00，类型2，标签0,ID 0x060001040a640103000701000400000001

上一个命令解码的PMSI为：

The PMSI Tunnel Type is : 2 : mLDP P2MP LSP The PMSI Tunnel ID is : 0x060001040a640103000701000400000001 FEC Element FEC Element Type : 6 : P2MP AF Type : 1 Address Length : 4 Root Node Address : 10.100.1.3 MP Opaque Length : 7 MP Opaque Value Element Opaque Type : 1 : LSP ID Global Opaque Length : 4 Global ID (Generic LSP Identifier) : 1

数据MDT通过来自C-PE1的路由类型3 AD路由发出信号。

```
RP/0/0/CPU0:C-PE2#show bgp ipv4 mvpn rd all-zero-rd [3][32][10.2.1.8]
[32][203.0.113.1][10.100.1.3]/120

BGP routing table entry for [3][32][10.2.1.8][32][203.0.113.1][10.100.1.3]/120, Route
Distinguisher: 0:0:0
Versions:
 Process           bRIB/RIB  SendTblVer
 Speaker                 56          56
Last Modified: Sep 10 00:51:52.786 for 00:04:57
Paths: (1 available, best #1, not advertised to EBGP peer)
 Not advertised to any peer
 Path #1: Received by speaker 0
 Not advertised to any peer
 Local
   10.100.1.3 (metric 30) from 10.100.1.3 (10.100.1.3)
     Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported
     Received Path ID 0, Local Path ID 1, version 56
     Community: no-export
     Extended community: RT:1:1
     PMSI: flags 0x00, type 2, label 0, ID 0x060001040a640103000701000400000007
     Source AFI: IPv4 MVPN, Source VRF: default, Source Route Distinguisher: 0:0:0
```

解码的PMSI显示全局LSP标识符为7。然后，将此项用于此数据MDT的mLDP数据库条目。

PMSI：标志0x00，类型2，标签0,ID 0x060001040a640103000701000400000007

上一个命令解码的PMSI为：

The PMSI Tunnel Type is : 2 : mLDP P2MP LSP The PMSI Tunnel ID is : 0x060001040a640103000701000400000007 FEC Element FEC Element Type : 6 : P2MP AF Type : 1 Address Length : 4 Root Node Address : 10.100.1.3 MP Opaque Length : 7 MP Opaque Value Element Opaque Type : 1 : LSP ID Global Opaque Length : 4 Global ID (Generic LSP Identifier) : 7

使用接下来的命令，您可以检查入口PE通告的数据MDT的内容。请注意，这是GTM，因此下一个命令中没有VRF。

```
RP/0/0/CPU0:C-PE2#show pim mdt mldp remote
Core                   MDT              Cache Max DIP Local VRF Routes
Identifier             Source           Count Agg     Entry Using Cache
[global-id 7]          10.100.1.3       1     255 N   N     1
```

```
RP/0/0/CPU0:C-PE2#show pim mdt mldp cache

Core Source      Cust (Source, Group)               Core Data        Expires
10.100.1.3       (10.2.1.8, 203.0.113.1)              [global-id 7]    never
```

路由类型7未连接PMSI:

```
RP/0/0/CPU0:C-PE2#show bgp ipv4 mvpn rd all-zero-rd
[7][0:0:0][1][32][10.2.1.8][32][203.0.113.1]/184

BGP routing table entry for [7][0:0:0][1][32][10.2.1.8][32][203.0.113.1]/184, Route
Distinguisher: 0:0:0
Versions:
 Process           bRIB/RIB  SendTblVer
 Speaker                 52          52
Last Modified: Sep 10 00:51:51.786 for 00:07:37
Paths: (1 available, best #1)
 Advertised to peers (in unique update groups):
   10.100.1.3
 Path #1: Received by speaker 0
 Advertised to peers (in unique update groups):
   10.100.1.3
 Local
   0.0.0.0 from 0.0.0.0 (10.100.1.5)
     Origin IGP, localpref 100, valid, redistributed, best, group-best, import-candidate
     Received Path ID 0, Local Path ID 1, version 52
     Extended community: RT:10.100.1.3:0
```

RT标识上游PE路由器。全局管理员字段是上游PE的IP地址。对于GTM，本地管理员字段设置为0。

```
RP/0/0/CPU0:C-PE2#show mrib route 203.0.113.1 10.2.1.8

IP Multicast Routing Information Base
Entry flags: L - Domain-Local Source, E - External Source to the Domain,
   C - Directly-Connected Check, S - Signal, IA - Inherit Accept,
   IF - Inherit From, D - Drop, ME - MDT Encap, EID - Encap ID,
   MD - MDT Decap, MT - MDT Threshold Crossed, MH - MDT interface handle
   CD - Conditional Decap, MPLS - MPLS Decap, EX - Extranet
   MoFE - MoFRR Enabled, MoFS - MoFRR State, MoFP - MoFRR Primary
   MoFB - MoFRR Backup, RPFID - RPF ID Set, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
   NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
   II - Internal Interest, ID - Internal Disinterest, LI - Local Interest,
   LD - Local Disinterest, DI - Decapsulation Interface
   EI - Encapsulation Interface, MI - MDT Interface, LVIF - MPLS Encap,
   EX - Extranet, A2 - Secondary Accept, MT - MDT Threshold Crossed,
   MA - Data MDT Assigned, LMI - mLDP MDT Interface, TMI - P2MP-TE MDT Interface
   IRMI - IR MDT Interface

(10.2.1.8,203.0.113.1) RPF nbr: 10.100.1.3 Flags: RPF
 Up: 00:52:34
 Incoming Interface List
   Lmdtdefault Flags: A LMI, Up: 00:52:34
 Outgoing Interface List
   GigabitEthernet0/0/0/0 Flags: F NS, Up: 00:52:34
```

传入接口必须是Lmdt接口。

```
RP/0/0/CPU0:C-PE2#show mfib route 203.0.113.1 10.2.1.8

IP Multicast Forwarding Information Base
Entry flags: C - Directly-Connected Check, S - Signal, D - Drop,
 IA - Inherit Accept, IF - Inherit From, EID - Encap ID,
 ME - MDT Encap, MD - MDT Decap, MT - MDT Threshold Crossed,
 MH - MDT interface handle, CD - Conditional Decap,
 DT - MDT Decap True, EX - Extranet, RPFID - RPF ID Set,
 MoFE - MoFRR Enabled, MoFS - MoFRR State, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
 NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
 EG - Egress, EI - Encapsulation Interface, MI - MDT Interface,
 EX - Extranet, A2 - Secondary Accept
Forwarding/Replication Counts: Packets in/Packets out/Bytes out
Failure Counts: RPF / TTL / Empty Olist / Encap RL / Other

(10.2.1.8,203.0.113.1),   Flags:
 Up: 02:31:00
 Last Used: never
 SW Forwarding Counts: 0/2037/407400
 SW Replication Counts: 0/2037/407400
 SW Failure Counts: 0/0/0/0/0
 Lmdtdefault Flags:  A LMI, Up:02:31:00
 GigabitEthernet0/0/0/0 Flags:  NS EG, Up:02:31:00
```

检查SAFI 2路由：

```
RP/0/0/CPU0:C-PE2#show route ipv4 multicast

Codes: C - connected, S - static, R - RIP, B - BGP, (>) - Diversion path
      D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
      N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
      E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
      i - ISIS, L1 - IS-IS level-1, L2 - IS-IS level-2
      ia - IS-IS inter area, su - IS-IS summary null, * - candidate default
      U - per-user static route, o - ODR, L - local, G  - DAGR, l - LISP
      A - access/subscriber, a - Application route
      M - mobile route, r - RPL, (!) - FRR Backup path

Gateway of last resort is not set

i L1 10.1.2.0/24 [115/30] via 10.1.4.4, 3d12h, GigabitEthernet0/0/0/1
i L1 10.1.3.0/24 [115/20] via 10.1.4.4, 3d12h, GigabitEthernet0/0/0/1
C    10.1.4.0/24 is directly connected, 1d21h, GigabitEthernet0/0/0/1
L    10.1.4.5/32 is directly connected, 3d12h, GigabitEthernet0/0/0/1
C    10.1.5.0/24 is directly connected, 1d21h, GigabitEthernet0/0/0/0
L    10.1.5.5/32 is directly connected, 3d12h, GigabitEthernet0/0/0/0
B    10.2.1.0/24 [200/30] via 10.100.1.3, 1d17h
i L1 10.100.1.3/32 [115/30] via 10.1.4.4, 3d12h, GigabitEthernet0/0/0/1
i L1 10.100.1.4/32 [115/20] via 10.1.4.4, 3d12h, GigabitEthernet0/0/0/1
L    10.100.1.5/32 is directly connected, 1d21h, Loopback0
```

请注意，源的路由是SAFI 2（在AF IPv4组播中），因为它在RIB AF IPv4组播中。

请注意，下一跳是C-PE1的环回10.100.1.3，因为该路由器在路由器BGP下的AF ipv4组播下具有下一跳自身。

```
RP/0/0/CPU0:C-PE2#show bgp ipv4 multicast 10.2.1.0/24
BGP routing table entry for 10.2.1.0/24
Versions:
 Process           bRIB/RIB  SendTblVer
 Speaker                 34          34
Last Modified: Sep  8 07:42:18.786 for 1d17h
Paths: (1 available, best #1)
 Not advertised to any peer
 Path #1: Received by speaker 0
 Not advertised to any peer
 Local
   10.100.1.3 (metric 30) from 10.100.1.3 (10.100.1.3)
     Origin incomplete, metric 30, localpref 100, valid, internal, best, group-best
     Received Path ID 0, Local Path ID 1, version 34
     Extended community: VRF Route Import:10.100.1.3:0 Source AS:1:0
```

源的RPF指向Lmdt接口及其上的PIM邻居。RPF在IPv4组播表中执行。

```
RP/0/0/CPU0:C-PE2#show pim rpf 10.2.1.8

Table: IPv4-Multicast-default
* 10.2.1.8/32 [200/30]
   via Lmdtdefault with rpf neighbor 10.100.1.3
```

检查入口边界路由器是否被识别为PE路由器。

```
RP/0/0/CPU0:C-PE2#show pim pe

MVPN Provider Edge Router information


PE Address : 10.100.1.3 (0x1071da64)
 RD: 0:0:0 (valid), RIB_HLI 0, RPF-ID 3, Remote RPF-ID 0, State: 1, S-PMSI: 2
 PPMP_LABEL: 0, MS_PMSI_HLI: 0x00000, Bidir_PMSI_HLI: 0x00000, MLDP-added: [RD 0, ID 0, Bidir ID
0, Remote Bidir ID 0], Counts(SHR/SRC/DM/DEF-MD): 0, 1, 0, 0, Bidir: GRE RP Count 0, MPLS RP
Count 0RSVP-TE added: [Leg 0, Ctrl Leg 0, Part tail 0 Def Tail 0, IR added: [Def Leg 0, Ctrl Leg
0, Part Leg 0, Part tail 0, Part IR Tail Label 0
 bgp_i_pmsi: 1,0/0 , bgp_ms_pmsi/Leaf-ad: 0/0, bgp_bidir_pmsi: 0, remote_bgp_bidir_pmsi: 0,
PMSIs: I 0x106a2d50, 0x0, MS 0x0, Bidir Local: 0x0, Remote: 0x0, BSR/Leaf-ad 0x0/0, Autorp-
disc/Leaf-ad 0x0/0, Autorp-ann/Leaf-ad 0x0/0
 IIDs: I/6: 0x1/0x0, B/R: 0x0/0x0, MS: 0x0, B/A/A: 0x0/0x0/0x0

 Bidir RPF-ID: 4, Remote Bidir RPF-ID: 0
 I-PMSI:   MLDP-P2MP, Opaque: [global-id 1] (0x106a2d50)
 I-PMSI rem:  (0x0)
 MS-PMSI:  (0x0)
 Bidir-PMSI:  (0x0)
 Remote Bidir-PMSI:  (0x0)
 BSR-PMSI:  (0x0)
 A-Disc-PMSI:  (0x0)
 A-Ann-PMSI:  (0x0)
 RIB Dependency List: 0x1016446c
 Bidir RIB Dependency List: 0x0
   Sources: 1, RPs: 0, Bidir RPs: 0
```

包含PMSI(I-PMSI)存在。

您会看到mLDP数据库中两个边界路由器之间形成默认MDT的两个P2MP mLDP条目。还有一个以

C-PE1作为数据MDT根的P2MP mLDP条目。

```
RP/0/0/CPU0:C-PE2#show mpls mldp database brief

LSM ID    Type    Root              Up Down Decoded Opaque Value
0x00007   P2MP    10.100.1.3        1  1    [global-id 1]
0x00008   P2MP    10.100.1.5        0  2    [global-id 1]
0x0000B   P2MP    10.100.1.3        1  1    [global-id 7]
```

示例2：配置文件20默认MDT - P2MP-TE - BGP-AD - PIM - C组播信令

这与示例1非常相似。现在核心层有P2MP TE。隧道设置为自动隧道。通过BGP AD发现尾端路由器。与示例1的另一个不同之处在于，现在重叠协议是PIM。请看**图5**。

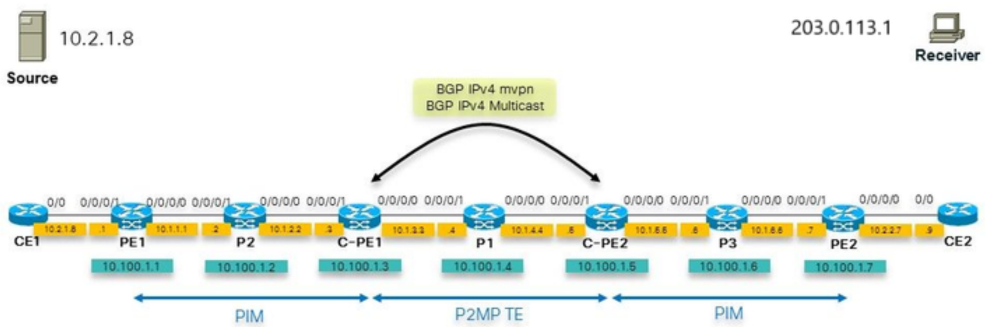


图5

配置

这是边界路由器的配置：

```
hostname C-PE1
logging console debugging
router rib
 address-family ipv4
 rump always-replicate
  !
!
line default
 timestamp disable
 exec-timeout 0 0
!
ipv4 unnumbered mpls traffic-eng Loopback0
interface Loopback0
```

```
 ipv4 address 10.100.1.3 255.255.255.255
!
interface MgmtEth0/0/CPU0/0
 shutdown
!
interface GigabitEthernet0/0/0/0
 ipv4 address 10.1.3.3 255.255.255.0
 load-interval 30
!
interface GigabitEthernet0/0/0/1
 ipv4 address 10.1.2.3 255.255.255.0
!
interface GigabitEthernet0/0/0/2
 shutdown
!
interface GigabitEthernet0/0/0/3
 shutdown
!
interface GigabitEthernet0/0/0/4
 shutdown
!
interface GigabitEthernet0/0/0/5
 shutdown
!
interface GigabitEthernet0/0/0/6
 shutdown
!
interface GigabitEthernet0/0/0/7
 shutdown
!
interface GigabitEthernet0/0/0/8
 shutdown
!
route-policy loopback
 if destination in (10.100.1.3/32) then
   pass
 endif
end-policy
!
route-policy global-one
 set core-tree p2mp-te-default
end-policy
!
route-policy sources-in-ISIS
 if destination in (10.2.1.0/24) then
   pass
 endif
end-policy
!
router isis 1
 is-type level-1
 net 49.0001.0000.0000.0003.00
 address-family ipv4 unicast
metric-style wide
 mpls traffic-eng level-1
 mpls traffic-eng router-id Loopback0
 !
 interface Loopback0
 address-family ipv4 unicast
 !
address-family ipv4 multicast
 !
 !
 interface GigabitEthernet0/0/0/0
```

```
 address-family ipv4 unicast
 !
address-family ipv4 multicast
 !
 !
 interface GigabitEthernet0/0/0/1
 address-family ipv4 unicast
 !
address-family ipv4 multicast
 !
 !
!
router bgp 1
 address-family ipv4 unicast
 !
 address-family ipv4 multicast
 redistribute connected route-policy loopback
 redistribute ospf 1
 redistribute isis 1 route-policy sources-in-ISIS
 !
 address-family ipv4 mvpn
global-table-multicast
 !
 neighbor 10.100.1.5
 remote-as 1
 update-source Loopback0
 address-family ipv4 multicast
  next-hop-self
 !
 address-family ipv4 mvpn
 !
 !
!
mpls oam
!
rsvp
 interface GigabitEthernet0/0/0/0
 bandwidth 1000000
 !
 interface GigabitEthernet0/0/0/1
 bandwidth 1000000
 !
!
mpls traffic-eng
 interface GigabitEthernet0/0/0/0
 auto-tunnel backup
 !
 !
 interface GigabitEthernet0/0/0/1
 auto-tunnel backup
 !
 !
 auto-tunnel p2mp
 tunnel-id min 1000 max 2000
 !
!
mpls ldp
 log
 neighbor
 !
 mldp
 logging notifications
 address-family ipv4
  rib unicast-always
```

```
 !
 !
 router-id 10.100.1.3
 address-family ipv4
 !
 interface GigabitEthernet0/0/0/0
 address-family ipv4
 !
 !
 interface GigabitEthernet0/0/0/1
 address-family ipv4
 !
 !
!
multicast-routing
address-family ipv4
 interface Loopback0
  enable
 !
 interface GigabitEthernet0/0/0/1
  enable
 !
mdt source Loopback0
 export-rt 1:1
 import-rt 1:1
 bgp auto-discovery p2mp-te
 !
 mdt default p2mp-te
 mdt data p2mp-te 100 immediate-switch
 !
!
router pim
 address-family ipv4
rpf topology route-policy global-one
 interface Loopback0
  enable
 !
 interface GigabitEthernet0/0/0/1
 !
 !
!
```

故障排除

入口边界路由器

检查RD全零是否存在。必须存在route-type 1路由才能构建基于P2MP TE隧道的P2MP TE。

```
RP/0/0/CPU0:C-PE1#show bgp ipv4 mvpn rd all-zero-rd
BGP router identifier 10.100.1.3, local AS number 1
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0   RD version: 0
BGP main routing table version 140
BGP NSR Initial initsync version 4 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
Global table multicast is enabled
BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best
```

```
            i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
  Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 0:0:0
*> [1][10.100.1.3]/40 0.0.0.0                               0 i
*>i[1][10.100.1.5]/40 10.100.1.5                  100      0 i

Processed 2 prefixes, 2 paths
```

更详细地检查路由类型1路由：

```
RP/0/0/CPU0:C-PE1#show bgp ipv4 mvpn rd all-zero-rd [1][10.100.1.5]/40

BGP routing table entry for [1][10.100.1.5]/40, Route Distinguisher: 0:0:0
Versions:
 Process           bRIB/RIB  SendTblVer
 Speaker                135        135
Last Modified: Sep 12 08:21:42.207 for 00:20:14
Paths: (1 available, best #1, not advertised to EBGP peer)
 Not advertised to any peer
 Path #1: Received by speaker 0
 Not advertised to any peer
 Local
   10.100.1.5 (metric 30) from 10.100.1.5 (10.100.1.5)
     Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported
     Received Path ID 0, Local Path ID 1, version 135
     Community: no-export
     Extended community: RT:1:1
     PMSI: flags 0x00, type 1, label 0, ID 0x000003e8000003e80a640105
     Source AFI: IPv4 MVPN, Source VRF: default, Source Route Distinguisher: 0:0:0
```

检查MDT Default上的PIM邻居：

```
RP/0/0/CPU0:C-PE1#show pim neighbor

PIM neighbors in VRF default
Flag: B - Bidir capable, P - Proxy capable, DR - Designated Router,
     E - ECMP Redirect capable
     * indicates the neighbor created for this router

Neighbor Address             Interface              Uptime    Expires  DR pri   Flags

10.1.2.2                     GigabitEthernet0/0/0/1 6d02h     00:01:16 1      B
10.1.2.3*                    GigabitEthernet0/0/0/1 6d02h     00:01:15 1 (DR) B E
10.100.1.3*                  Loopback0              6d02h     00:01:32 1 (DR) B E
10.100.1.3*                  Tmdtdefault            00:36:21  00:01:40 1
10.100.1.5                   Tmdtdefault            00:17:37  00:01:26 1 (DR)
```

检查MRIB路由。传出接口必须是Tmdt:

```
RP/0/0/CPU0:C-PE1#show mrib route 203.0.113.1

IP Multicast Routing Information Base
Entry flags: L - Domain-Local Source, E - External Source to the Domain,
   C - Directly-Connected Check, S - Signal, IA - Inherit Accept,
   IF - Inherit From, D - Drop, ME - MDT Encap, EID - Encap ID,
```

```
   MD - MDT Decap, MT - MDT Threshold Crossed, MH - MDT interface handle
   CD - Conditional Decap, MPLS - MPLS Decap, EX - Extranet
   MoFE - MoFRR Enabled, MoFS - MoFRR State, MoFP - MoFRR Primary
   MoFB - MoFRR Backup, RPFID - RPF ID Set, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
   NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
   II - Internal Interest, ID - Internal Disinterest, LI - Local Interest,
   LD - Local Disinterest, DI - Decapsulation Interface
   EI - Encapsulation Interface, MI - MDT Interface, LVIF - MPLS Encap,
   EX - Extranet, A2 - Secondary Accept, MT - MDT Threshold Crossed,
   MA - Data MDT Assigned, LMI - mLDP MDT Interface, TMI - P2MP-TE MDT Interface
   IRMI - IR MDT Interface

(10.2.1.8,203.0.113.1) RPF nbr: 10.1.2.2 Flags: RPF
 Up: 00:09:10
 Incoming Interface List
   GigabitEthernet0/0/0/1 Flags: A, Up: 00:09:10
 Outgoing Interface List
   Tmdtdefault Flags: F NS TMI, Up: 00:09:10
```

检查每个边界路由器是否有一条P2MP TE隧道作为头端路由器：

```
RP/0/0/CPU0:C-PE1#show mpls traffic-eng tunnels tabular

          Tunnel   LSP     Destination          Source           FRR  LSP  Path
            Name    ID         Address         Address  State  State Role  Prot
----------------- ----- --------------- --------------- ------ ------ ---- -----
 ^tunnel-mte1001 10004      10.100.1.5      10.100.1.3     up  Inact Head
auto_C-PE2_mt1000 10005      10.100.1.3      10.100.1.5     up  Inact Tail
^ = automatically created P2MP tunnel
```

触发数据MDT后，我们将路由类型3和4路由：

```
RP/0/0/CPU0:C-PE1#show bgp ipv4 mvpn rd all-zero-rd

BGP router identifier 10.100.1.3, local AS number 1
BGP generic scan interval 60 secs
Non-stop routing is enabled
BGP table state: Active
Table ID: 0x0   RD version: 0
BGP main routing table version 143
BGP NSR Initial initsync version 4 (Reached)
BGP NSR/ISSU Sync-Group versions 0/0
Global table multicast is enabled
BGP scan interval 60 secs

Status codes: s suppressed, d damped, h history, * valid, > best
             i - internal, r RIB-failure, S stale, N Nexthop-discard
Origin codes: i - IGP, e - EGP, ? - incomplete
  Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 0:0:0
*> [1][10.100.1.3]/40 0.0.0.0                                0 i
*>i[1][10.100.1.5]/40 10.100.1.5                    100      0 i
*> [3][32][10.2.1.8][32][203.0.113.1][10.100.1.3]/120
                     0.0.0.0                                0 i
*>i[4][3][0:0:0][32][10.2.1.8][32][203.0.113.1][10.100.1.3][10.100.1.5]/224
                     10.100.1.5                    100      0 i
```

```
Processed 4 prefixes, 4 paths
```

路由类型3向所有末端路由器通告数据MDT的信号：

```
RP/0/0/CPU0:C-PE1#show bgp ipv4 mvpn rd all-zero-rd
[3][32][10.2.1.8][32][203.0.113.1][10.100.1.3]/120

BGP routing table entry for [3][32][10.2.1.8][32][203.0.113.1][10.100.1.3]/120, Route
Distinguisher: 0:0:0
Versions:
 Process           bRIB/RIB  SendTblVer
 Speaker                141         141
Last Modified: Sep 12 08:46:17.207 for 00:00:41
Paths: (1 available, best #1, not advertised to EBGP peer)
 Advertised to peers (in unique update groups):
   10.100.1.5
 Path #1: Received by speaker 0
 Advertised to peers (in unique update groups):
   10.100.1.5
 Local
   0.0.0.0 from 0.0.0.0 (10.100.1.3)
     Origin IGP, localpref 100, valid, redistributed, best, group-best, import-candidate
     Received Path ID 0, Local Path ID 1, version 141
     Community: no-export
     Extended community: RT:1:1
     PMSI: flags 0x01, type 1, label 0, ID 0x000003ed000003ed0a640103
```

PMSI解码：

PMSI：标志0x01，类型1，标签0,ID 0x000003ed000003ed0a640103

上一个命令解码的PMSI为：

The PMSI Tunnel Type is : 1 : RSVP-TE P2MP LSP The PMSI Tunnel ID is : 0x000003ed000003ed0a640103 Extended Tunnel ID : 1005 Reserved part (should be zero): 0X0000 Tunnel ID : 1005 P2MP ID : 10.100.1.3

以下内容也可以看到：

```
RP/0/0/CPU0:C-PE1#show pim mdt cache

Core Source      Cust (Source, Group)                Core Data        Expires
10.100.1.3       (10.2.1.8, 203.0.113.1)               [p2mp 6]         never

  Leaf AD:   10.100.1.5
```

路由类型4向头端路由器通告哪个路由器是末端：

```
RP/0/0/CPU0:C-PE1#show bgp ipv4 mvpn rd all-zero-rd
[4][3][0:0:0][32][10.2.1.8][32][203.0.113.1][10.100.1.3][10.100.1.5]/224

BGP routing table entry for
[4][3][0:0:0][32][10.2.1.8][32][203.0.113.1][10.100.1.3][10.100.1.5]/224, Route Distinguisher:
0:0:0
```

```
Versions:
 Process           bRIB/RIB  SendTblVer
 Speaker                143         143
Last Modified: Sep 12 08:46:17.207 for 00:01:25
Paths: (1 available, best #1)
 Not advertised to any peer
 Path #1: Received by speaker 0
 Not advertised to any peer
 Local
   10.100.1.5 (metric 30) from 10.100.1.5 (10.100.1.5)
     Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported
     Received Path ID 0, Local Path ID 1, version 143
     Extended community: SEG-NH:10.100.1.5:0 RT:10.100.1.3:0
     Source AFI: IPv4 MVPN, Source VRF: default, Source Route Distinguisher: 0:0:0
```

检查是否已设置P2MP TE隧道的Data MDT:

```
RP/0/0/CPU0:C-PE1#show mpls traffic-eng tunnels tabular

          Tunnel   LSP     Destination          Source           FRR  LSP  Path
            Name    ID         Address         Address  State  State Role  Prot
----------------- ----- --------------- --------------- ------ ------ ---- -----
 ^tunnel-mte1001 10004      10.100.1.5      10.100.1.3     up  Inact Head
  ^tunnel-mte1005 10002      10.100.1.5      10.100.1.3     up  Inact Head
auto_C-PE2_mt1000 10005      10.100.1.3      10.100.1.5     up  Inact Tail
^ = automatically created P2MP tunnel
```

出口边界路由器

检查传入接口是否为Tmdt接口：

```
RP/0/0/CPU0:C-PE2#show mrib route 203.0.113.1

IP Multicast Routing Information Base
Entry flags: L - Domain-Local Source, E - External Source to the Domain,
   C - Directly-Connected Check, S - Signal, IA - Inherit Accept,
   IF - Inherit From, D - Drop, ME - MDT Encap, EID - Encap ID,
   MD - MDT Decap, MT - MDT Threshold Crossed, MH - MDT interface handle
   CD - Conditional Decap, MPLS - MPLS Decap, EX - Extranet
   MoFE - MoFRR Enabled, MoFS - MoFRR State, MoFP - MoFRR Primary
   MoFB - MoFRR Backup, RPFID - RPF ID Set, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
   NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
   II - Internal Interest, ID - Internal Disinterest, LI - Local Interest,
   LD - Local Disinterest, DI - Decapsulation Interface
   EI - Encapsulation Interface, MI - MDT Interface, LVIF - MPLS Encap,
   EX - Extranet, A2 - Secondary Accept, MT - MDT Threshold Crossed,
   MA - Data MDT Assigned, LMI - mLDP MDT Interface, TMI - P2MP-TE MDT Interface
   IRMI - IR MDT Interface

(10.2.1.8,203.0.113.1) RPF nbr: 10.100.1.3 Flags: RPF
 Up: 00:18:03
 Incoming Interface List
   Tmdtdefault Flags: A TMI, Up: 00:18:00
 Outgoing Interface List
   GigabitEthernet0/0/0/0 Flags: F NS, Up: 00:18:03
```

出口边界路由器上的RPF指向入口边界路由器。入口接口为Tmdtdefault。注意TE隧道的T:

```
RP/0/0/CPU0:C-PE2#show pim rpf 10.2.1.8

Table: IPv4-Multicast-default
* 10.2.1.8/32 [200/30]
   via Tmdtdefault with rpf neighbor 10.100.1.3
```

示例3：如示例1所示，但PE和边界路由器之间有iBGP

请看**图6**。

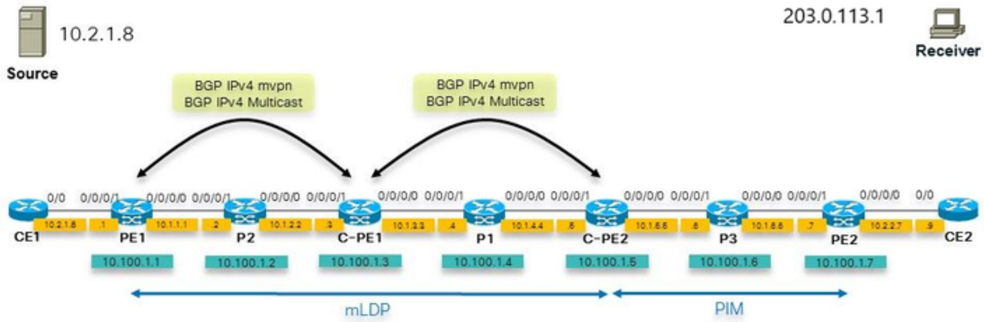


图6

我们看到的是非对称设置，其中有一个核心网络，其中一端是mLDP，另一端是PIM，另一端是GTM。这可能发生在核心树的迁移期间。C-PE1路由器必须是BGP IPv4组播和BGP IPv4 mVPN的RR。现在，PE1上需要我们在示例1中的C-PE1上进行的PIM和组播路由配置。

示例4：无缝MPLS

我们通过无缝MPLS（统一MPLS）部署GTM。PE路由器必须了解GTM，只有思科IOS XR路由器才能理解GTM，并且PE路由器必须在PIM域中发起PIM RPF-Proxy矢量。需要此PIM RPF-Proxy vector，以便P路由器可以将RPF映射到代理IP地址(ABR)。从Cisco IOS XR 5.3.2开始，Cisco IOS XR可以在全局环境中发起RPF-Proxy Vector。因此，GTM可以有RPF代理矢量。

要发起PIM RPF-Proxy Vector，PE路由器必须具有以下配置：

```
router pim
address-family [ipv4|ipv6]
```

```
 rpf-vector
 !
!
```

注:Cisco IOS XR早期版本中引入了对解释PIM RPF-Proxy Vector（这是P路由器必须执行的操作）的支持。

这允许通过无缝MPLS部署GTM。