Multicast VPN

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CCIE R&S
Agenda

- IPv4 MFIB model
- mVPN with GRE
  Brief refresh with Default MDT operation
- mLDP
  LSM Architecture
    P2MP, MP2MP FEC setup
    Root Node Redundancy
- mVPN with mLDP Configuration
- APPENDIX

Global GRE to mLDP Migration Steps
mLDP high-level 7600 implementation example
  GRE Default MDT implementation on c7600
Configuration of used example topology
IPv4 MFIB model
MFIB Overview

• The MFIB/MRIB architecture provides modularity and separation between the multicast control plane (PIM and IGMP) and the multicast forwarding plane (MFIB).

• Enables Multicast High Availability

• This architecture is currently used in the IOS IPv6 Multicast implementation as well as in the IOS-XR multicast implementation.

• Light impact on device operation (more in following slides)
Before MFIB – MDSS/MLSM (7600/6500)

Route Processor

- PIM
- mroute
- IGMP
- MLSM

Active Switch Processor

- Platform depend forwarding
- MLSM
- MSC
- Platform depend forwarding
- Linecard / DFC
MFIB Distributed Architecture

Route Processor

- PIM
- mroute
- IGMP

MRIB

Platform depend forwarding

MRIB Proxy

Linecard / DFC / SPs

- MRIB Proxy
- MFIB

Platform depend forwarding
IPv4 MFIB behavior changes keynotes

- **Obsolete commands:**
  
  show ipmcache, show ipmpacket, ip multi cache-header, ip multi rate-limit in/out, ip multi ttl-threshold, debug ipmpacket, debug ipmpacket fast, debug ipmcache

- **New commands:**
  
  show ipmfib *, show ipmrib *, show mfib *

- **ippim register-rate-limit**: pps -> bps & per router -> per RP

- **On c7600 define ACL for PIM-SM RP mapping & PIM SSM group range in VRF context, otherwise Default MDT punted on PE without receivers!**

- **Statistics pulled on-demand by RP (still periodical on LC)**

- **Introduction of (*, G/Mask) Entries**

  The MFIB architecture introduces (*, G/mask) entries to describe a group range present in a router’s local group-to-RP mapping cache (static, Auto-RP, Bootstrap Router [BSR])

- **Introduction of PIM Register related tunnel interfaces**

  At the RP we have RP decap&encap tunnel interface, on other nodes RP encap tunnel interface (show ippim tunnel)
Multicast VPN

- Transport customer’s multicast traffic across service provider’s infrastructure in similar fashion as MPLS VPN service
  - SP’s core infrastructure unaware of customer’s groups
  - Customer’s groups can overlap
  - Support various multicast operation modes (PIM SM, SSM,..)

Tunneling mechanisms:

**MPLS VPN** – MP2P/P2P LDP FEC elements

**mVPN with GRE** – MP2MP & P2MP dynamically build GRE tunnels

**mVPN with mLDP** – MP2MP & P2MP LDP FEC elements as
Default MDT (MI-PMSI) Overview

- Multicast Traffic flows along the Multi-directional Inclusive PMSI (default-MDT)
- MLDP: Default-MDT instantiated using MP2MP LSP or GRE encapsulation
Data MDTs (S-PMSI) Overview

- Goal: High-rate data flowing via Data-MDT instead of default-MDT
- Data only goes to PE routers that have receivers.

High-Rate Source
S=10.1.1.1
G=238.1.1.1

Receiver
S=10.1.1.1
G=238.1.1.1
GRE-based mVPN

GRE-based mVPNTopology

- PIM Enabled
- MPLS Core

Ingress Router

Egress Router

CE

Receiver

Source

Egress Router

CE

Receiver

Receiver

Node with a receiver

P2MP&MP2MP GRE tunnels
PIM/GRE – Tunnel Interface

- Customer multicast traffic encapsulated in GRE
- Single tunnel appears in each VRF
  All GRE tunnels reachable through the same Tunnel interface
  But each source within that VRF can use different GRE tunnels
Availability

CRS
XR12000
ASR9000
ASR1000
7600
10000
6500
7200
...

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Multicast VPN

Default MDT – BGP Send

• Each PE generates BGP Update with MDT SAFI to RR
Multicast VPN

Default MDT – BGP Receive

- Each PE will receive BGP MDT SAFI of all other PEs from RR
• PE sends (S,G) Joins for all VPN domain PEs as sources.
Multicast VPN

Default MDT – PIM Phase 2

PE-Zilina

PIM
Join

SOURCE 3.3.3.3
GROUP: 239.1.1.7

P & RR - BanskaBystrica

PE-Bratislava

3.3.3.3

1.1.1.1

PIM

PE-Kosice

4.4.4.4

VRF Green

SOURCE: 2.2.2.2
GROUP: 239.1.1.7

SOURCE: 4.4.4.4
GROUP: 239.1.1.7
Core forwarding

Default-MDT Configuration

P-Banska_Bystrica#shipmroute
(3.3.3.3, 239.1.1.1), 00:24:32/00:02:40, flags: sT
   Incoming interface: Ethernet0/0, RPF nbr 10.0.10.1
   Outgoing interface list:
   Ethernet1/0, Forward/Sparse, 00:22:07/00:02:33
   Ethernet2/0, Forward/Sparse, 00:22:07/00:02:40

(4.4.4.4, 239.1.1.1), 00:24:45/00:03:16, flags: sT
   Incoming interface: Ethernet1/0, RPF nbr 10.0.20.1
   Outgoing interface list:
   Ethernet2/0, Forward/Sparse, 00:24:25/00:02:36
   Ethernet0/0, Forward/Sparse, 00:24:45/00:03:16

(2.2.2.2, 239.1.1.1), 00:24:45/00:03:18, flags: sT
   Incoming interface: Ethernet2/0, RPF nbr 10.0.30.1
   Outgoing interface list:
   Ethernet1/0, Forward/Sparse, 00:24:32/00:02:32
   Ethernet0/0, Forward/Sparse, 00:24:45/00:03:18

• MP2MP connectivity over Core’s 239.1.1.1 group achieved
Overlay PIM Signalling of VPN Multicast State

- PIM over MP2MPCore’s group creates state within VPN

This is overlay signalling

VRF mState Table

(S, G): (10.1.1.2, 238.2.2.2)
RPF: 0.0.0.0
IN i/f: Tunnel0
OUT i/f: Ethernet0/0

VRF mState Table

(S, G): (10.1.1.2, 238.2.2.2)
RPF: 192.168.1.0
IN i/f: Ethernet0/0
OUT i/f: Tunnel0
Default MDT forwarding

PE-Zilina (Root)

PE-Bratislava (Egress LSR)

PE-Kosice (Egress LSR)

P-BanskaBystrica

239.1.1.1.1 2.2.2.2 GRE G S Data

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Multipoint LDP
Availability

• 7200 series
  12.2(33)SRE

• 7600 series
  15.1(1)S

• CRS
  soon
mLDP is part of the LSM Architecture

• Label Switch Multicast
  MPLS technology extensions to support multicast using labels
  Point-to-Multipoint LSPs, Multipoint-to-Multipoint LSPs

• Extensions to two protocols to create Multicast LSPs
  P2MP RSVP TE (RFC 4875)
  Multicast LDP (mLDP)

• Multicast Label Switch Paths
  Trees built using labels

• Native multicast mapped onto Multicast LSPs
  PIM at edge of network, LABELS in core of network
LSM Services

- LSM architecture supports a range of services or “clients”
  Over mLDP and P2MP TE control planes

- This presentation focuses on mLDP
  How it supports native multicast and mVPN across a core network
LDP Capabilities Negotiation

- Addition to the original protocol to allow enhancements
  [HTTP](http://tools.ietf.org/html/rfc5561)
- Allows advertising of capability TLVs
  At session initialisation time within the Initialisation Message
  Dynamically during the session within a Capabilities Message
- Several mLDP capability TLVs are defined
  P2MP (Point to Multipoint) – TLV 0x0508
  MP2MP (Multipoint to Multipoint) – TLV 0x0509
FEC Elements
### Multipoint FEC Element Encoding

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Type</td>
<td>P2MP, MP2MP Upstream, MP2MP Downstream</td>
</tr>
<tr>
<td>Address Family</td>
<td>Root LSR address family (IPv4 =1 or IPv6 = 2)</td>
</tr>
<tr>
<td>Address Length</td>
<td>Length of the Root LSR address in octets (IPv4 = 4, IPv6 = 16)</td>
</tr>
<tr>
<td>Root Node Address</td>
<td>Host address of MP LSP root (within MPLS core)</td>
</tr>
<tr>
<td>Opaque Value</td>
<td>One or more elements uniquely identifies MP LSP in context of Root Node.</td>
</tr>
</tbody>
</table>

**Table:**

- **Tree Type**
- **Address Family**
- **Address Length**
- **Root Node Address**
- **Opaque Value Length**
- **Opaque Value(s)...**
Multipoint LSP FEC Elements

- LDP protocol consists of messages which carry TLVs
  Label Mapping Message carries FEC TLV, Label TLV

- FEC elements are carried within a FEC TLV
  FEC elements specify set of packets to be mapped to MP LSP

- mLDP defines three FEC elements for MP LSPs
  P2MP FEC element
  MP2MP downstream FEC element
  MP2MP upstream FEC element

- mLDP FEC elements carry Opaque Values
Root Address

- The root address is selected by the egress router
  mLDP client or application selects it
  Derived from BGP next-hop or statically configured, etc…
- Root address is used to build the MP LSP
- Each LSR in the path resolves next-hop of root address
  Label mapping message then sent to that next-hop
- Resulting in a dynamically created MP LSP
  No pre-computed, traffic engineered path
Opaque Value

- Each MP LSP is identified by a unique opaque value
  Is used to uniquely identify the MP LSP
  Combined with root address to build the MP LSP tree
  The opaque contents varies per application

- Opaque field is a variable length value

- Opaque Value only has meaning to Ingress & Egress PE
  Core router does not need to parse/understand the value

- Value used is application specific
  It can represent the (S, G) stream (PIM-SSM Transit)
  Or can be an LSP identifier (Default/Data MDTs in mVPN)
### Application Specific Opaque Values

- Several opaque types are defined
  - Each represent a multicast application across a MPLS core

<table>
<thead>
<tr>
<th>Opaque Type</th>
<th>Opaque Value</th>
<th>Supported Multicast Application</th>
<th>Signalling</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPV4</td>
<td>(S, G)</td>
<td>PIM-SSM transit of IPv4</td>
<td>In-band</td>
</tr>
<tr>
<td>IPV6</td>
<td>(S, G)</td>
<td>PIM-SSM transit of IPv6</td>
<td>In-band</td>
</tr>
<tr>
<td>MDT</td>
<td>(VPN-ID, MDT#)</td>
<td>mVPN Default-MDT (MDT# = 0)</td>
<td>In-band</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mVPN Data-MDT (MDT# &gt; 0)</td>
<td></td>
</tr>
<tr>
<td>VPNv4</td>
<td>(S, G, RD)</td>
<td>Direct MDT, VPNv4 Transit</td>
<td>In-band</td>
</tr>
<tr>
<td>LSP ID</td>
<td>4 byte value</td>
<td>BGP assigned LSPs</td>
<td>Out-of-band</td>
</tr>
<tr>
<td>CsC</td>
<td>C-FEC</td>
<td>Carrier Supporting Carrier</td>
<td>In-band</td>
</tr>
</tbody>
</table>
P2MP LSP
P2MP LSP Overview

• P2MP LSP is rooted at Ingress LSR

• P2MP LSP is unidirectional
  Traffic from Root (Ingress) to Leaves (Egress)

• Labels provided by downstream LSRs to upstream LSRs
  LSR that wishes to receive the traffic also assigns the label for it
  Downstream allocation ensures different label for every stream

• Opaque value used to uniquely identify P2MP LSP

• Egress LSRs initiate the tree creation
  Unicast reachability to the root address
  Egress LSR driven, hop=by-hop to root

• Upstream LSR will create FEC state if it does not exist
Basic P2MP Creation

Tree Setup

PE-Zilina (Root)

TLV

Label Map Msg

Type = P2MP
FEC: Root = PE-Zilina
Opaque = 200
LABEL: 48

PE-Bratislava (Egress LSR)

PE-Kosice (Egress LSR)

TLV

Label Map Msg

Type = P2MP
FEC: Root = PE-Zilina
Opaque = 200
LABEL: 19

LABEL: 23

Downstream LSP

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Basic P2MP Operation (In-Band)

Multicast Forwarding
General P2MP LSP Usage

- Transit PIM SSM and SM
  Carrying PIM transparently across the core (PIM at edge)
- Data-MDT in an mVPN
- Generally, any One-2-Many traffic application
MP2MP LSP
MP2MP Overview

- M2MP LSP allows leaf LSRs to inject packets into tree
- MP2MP LSP uses a downstream and an upstream path
- Root node statically configured (every leaf can be source)
- Control plane is MP2MP, Data plane replicates as P2MP

<table>
<thead>
<tr>
<th>Downstream Path</th>
<th>Upstream Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Created using P2MP procedure</td>
<td>Created using P2P procedure</td>
</tr>
<tr>
<td>Single replication state exists</td>
<td>Multiple replication states exist</td>
</tr>
<tr>
<td>Not receiver driven but static tree</td>
<td>Usually one per downstream i/f</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Basic MP2MP Downstream Creation

Type is MP2MP Down

Downstream Traffic
Basic MP2MP Upstream Creation

Upstream Traffic

PE-Cadca (Receiver)

PE-Zilina (Root)

PE-Bratislava (Receiver)

PE-Kosice (Receiver)

Type is MP2MP UP

TLV

Label Map Msg
Type = MP Up
Root = PE-Zilina
Opaque = 200

LABEL: 42

TLV

Label Map Msg
Type = MP Up
Root = PE-Zilina
Opaque = 200

LABEL: 44

TLV

Label Map Msg
Type = MP Up
Root = PE-Zilina
Opaque = 200

LABEL: 45

TLV

Label Map Msg
Type = MP Up
Root = PE-Zilina
Opaque = 200

LABEL: 48

TLV

Label Map Msg
Type = MP Up
Root = PE-Zilina
Opaque = 200

LABEL: 48

PE-Bratislava (Receiver)

PE-Kosice (Receiver)

P-BanskaBystrica
Merging Forwarding States

Join (S1, G)

**Upstream Traffic**

**LFIB (DOWN State)**

<table>
<thead>
<tr>
<th>IN</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label</td>
<td>I/F</td>
</tr>
<tr>
<td>64</td>
<td>s0</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Downstream Traffic**

**LFIB (UP State)**

<table>
<thead>
<tr>
<th>IN</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label</td>
<td>I/F</td>
</tr>
<tr>
<td>48</td>
<td>s2</td>
</tr>
<tr>
<td>45</td>
<td>s1</td>
</tr>
</tbody>
</table>

**Multiple Upstream entries for FEC**

**Single Downstream entry for FEC**

PE-Cadca (Receiver)

PE-Zilina (Root)

PE-Bratislava (Receiver)

PE-Kosice (Receiver)

**Plane**

<table>
<thead>
<tr>
<th>Upstream</th>
<th>Downstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>42</td>
</tr>
<tr>
<td>Data</td>
<td>42</td>
</tr>
</tbody>
</table>

P-BanskaBystrica

PE-PE-Kosice (Receiver)
MP2MP Upstream Path Example

- There is a single upstream path from EACH leaf to the root
- There is a downstream LSP from the root to leaves
MP2MP Upstream Path Example continued...

- Upstream path is different for each leaf

![MP2MP Upstream Path Diagram]
General MP2MP usage

- Transiting PIM-BiDir traffic
- Emulating a LAN between LSRs - VPLS support
- Interconnection of Default-MDT in an mVPN
- Generally, any Many-2-Many traffic application
Rood Node Redundancy
Root Node Redundancy

- The root node is a single point of failure in an MP LSP
- Only one root node can be active in an MP LSP
- Root address configured statically or learnt dynamically
  - Depends on the mLDP "client" – for example, PIM or mVPN
  - mLDP can only learn about the root from clients
- Requirements are:
  - Redundancy mechanism in the event of a root failure
  - Fast convergence in selecting a new root
P2MP Root Node Redundancy

- For P2MP LSP the root is derived from global BGP table
  For example, when supporting PIM-SSM transit
- If BGP next-hop prefix of root fails:
  Then new BGP prefix must be chosen to reach root
  Assuming there is a new next-hop available
- Root of an existing P2MP LSP cannot be changed
  A new tree must be built and the old tree removed
- Convergence time is dependant upon BGP
  Replacing the next-hop in a timely manner
MP2MP Root Node Redundancy

- For MP2MP LSPs the root is configured statically
  - If the root fails there is no dynamic way to restore new root
- Solution is to assign multiple roots to a leaf node
- Root redundancy for an MP2MP leaf is as follows:
  - Leaf is configured with same set of roots
  - Leaf joins all configured roots
  - Leaf receives traffic from ALL roots
  - Leaf transmits traffic to only ONE selected root
  - Root selection policy is local to leaf
    - Based on IGP selection
MP2MP Root Node Redundancy

• Leafs join all configured roots (two in this case)
• Leafs will receive traffic from both trees
• Same FEC value different root
MP2MP Root Node Redundancy Summary

• Switch to new root as fast as IGP convergence
• Root selection is a local leaf policy
  Can be based on IGP distance, load, etc…
  Roots can share the tree load from leafs
• A separate MP2MP LSP is created for each root
  Multi-path load balancing is supported
  In both the upstream and downstream directions
MP2MP Anycast Root Node Redundancy

- Root injects same address with different mask
- Longest match is preferred, in this example Root 2
- When longest match disappears, use the next best
MP2MP Anycast Root Node Redundancy

• If the preferred root fails
  LSP rerouted to the next best root based on the mask length
• All MP2MP LSPs will prefer the same root node
• There is a single MP2MP LSP at any given time
  No hot standby path
• No load balancing over the Anycast Roots
LSP Virtual Interface
LSP Virtual Interfaces (LSP-VIF)

- Represents the head and tail-end of MP LSPs
  Appears as RPF or outbound interface in global or VRF mroute table
- Dynamically created on Ingress and Egress LSR
  Not created on P routers
- LSP-VIF are set to unnumbered (IPv4 or v6 interface)
  Preferably from a loopback interface
- A single LSP-VIF can have multiple adjacencies
  Each adjacency represents a unique MP LSP
- Consider LSP-VIF as an NBMA interface
  One interface, many “virtual circuits” or trees
LSP-VIF as an NBMA Interface

- Example, single LSP-VIF can appear in VRF
  But each source within that VRF can use different P2MP LSP
  P2MP LSP all reachable through same LSP-VIF
mLDP Configurations
Applications for mLDP

• mLDP can currently support several network applications
  PIM-SSM transit of IPv4/IPv6
  **Multicast VPN (Default-MDT, Data-MDT)**
  Direct MDT, VPNv4 transit

• Each application has a specific opaque value type
mLDP Configuration Examples

- Multicast VPN
  - Default-MDT
  - Data-MDT
Ingress Router (Root)

Egress Router

LDP with mLDP capability Enabled (No PIM)

Upstream Traffic (towards root)

PIM Enabled

MPLS Core

Downstream Traffic (away from root)

P2MP LSP or MP2MP LSP

Node with a receiver

Source

Receiver

Receiver

Receiver
Multicast VPN with mLDP

- mLDP supports Multicast Distribution Trees (mVPNs)
- mVPN solution is independent of the tunnelling mechanism
  - PIM with GRE encapsulation (Native Multicast)
  - mLDP with MPLS encapsulation
- Default-MDT uses MP2MP LSPs
  - Supports low bandwidth and control traffic between VRFs
- Data-MDT uses P2MP LSPs
  - Supports single high bandwidth source stream from a VRF
- All other operation of the mVPN remains the same
  - PIM neighbours in VRF seen across LSP-VIF
  - VPN multicast state signalling via PIM
- VPN-ID is used in place of MDT Multicast Group address
mLDP Configuration Examples

• Multicast VPN
  Default-MDT
  Data-MDT
Multicast VPN (In-Band)

Default-MDT Scenario

- MDTs use LSP-VIF to transmit VPN multicast packets
- Two static roots defined for Default MDT (Hence, 2 x MP2MP LSPs)
- All other mVPN configuration standard (except no PIM+GRE – LSP instead)
Multicast VPN – PE Routers

Default-MDT Configuration

```plaintext
ip multicast-routing vrf green

vrf definition green
  rd 100:2
  vpn id 100:2
    route-target export 200:2
    route-target import 200:2
!
  address-family ipv4

mdt default mplsldp1.1.1.1 (P-Banska_Bystrica)
mdt default mplsldp2.2.2.2 (PE-Zilina)
exit-address-family
```

VPN ID per RFC2685. Similar to function of MDT Group address identifies PE routers that are part of this mVPN

Roots nodes are statically configured for MP2MP mode. MP2MP is implicit for Default-MDT. Two are defined for redundancy

- This configuration is consistent amongst PE routers with same VPN (Ingress and Egress). No configuration needed on P-routers.
Multicast VPN – Root 1 (P-BanskaBystrica)

Default-MDT LSP (Downstream)

- VPN-ID 100:2 used to construct opaque value
- Two MP2MP trees built - one for each root

**TLV**

<table>
<thead>
<tr>
<th>Label Map Msg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type = MP2MP Down</td>
</tr>
<tr>
<td>Root = 1.1.1.1</td>
</tr>
<tr>
<td>Opaque = [mdt 100:2 0]</td>
</tr>
</tbody>
</table>

**LABEL:** 208

(10.1.1.1, 238.1.1.1)
(10.1.1.2, 238.2.2.2)

**Join**

(10.1.1.1, 238.1.1.1)
(10.1.1.2, 238.2.2.2)
Multicast VPN – Root 1 (P-BanskaBystrica)

Default-MDT LSP (Upstream)

- Root 1 sends upstream label to each PE route
Overlay PIM Signalling of VPN Multicast State

FEC + Label Map Message creates LSP

PIM over MP2MP LSP creates state within VPN

This is overlay signalling
Multicast VPN – PE Routers

PIM Adjacencies and LSP-VIF

PIM Hellos exchanged over Lspvif0 to establish adjacencies (PE-Bratislava, PE-Zilina)

PE-Kosice#showippimvrf green neighbor
192.168.10.18   Serial6/0   04:53:19/00:01:18 v2 1 / G
3.3.3.3         Lspvif0     04:52:32/00:01:28 v2 1 / B S P G
2.2.2.2         Lspvif0     04:52:32/00:01:17 v2 1 / B S P G

Adjacency to Receiver network

PE-Kosice#showipmroutevrf green 238.2.2.2 10.1.1.2
(10.1.1.2, 238.2.2.2), 04:54:18/00:02:40, flags: sT
Incoming interface: Lspvif0, RPF nbr 3.3.3.3
Outgoing interface list:
Serial6/0, Forward/Sparse-Dense, 04:54:18/00:02:40

(S, G) stream from LSP-VIF via PIM neighbour PE-West

Loopback of PE-Bratislava

• The same Lspvif0 is used for both MP2MP LSPs (different roots)
  Source streams will be transmitted to primary root
### mLDP Database for Default-MDTs

**Two entries, one for each root**

| LSM ID | FEC Root | Opaque decoded | Opaque length | Opaque value | RNR active LSP | Candidate RNR ID(s) | Upstream client(s) | Interface | Local Label (D) | Next Hop | Out Label (U) | Path Set ID | Replication client(s) | Expires | Uptime | Interface | Type | Path Set ID | Interface | Out Label (U) | Local Label (D) | Replication client(s) | Expires | Uptime | Interface |
|--------|----------|----------------|---------------|--------------|---------------|------------------|--------------------|-------------------|-----------|----------------|-----------|---------------|-------------|------------------------|---------|--------|-----------|------|-------------|-----------|----------------|---------------|------------------------|---------|--------|-----------|
| 100:2  | 1.1.1.1  | [mdt 100:2 0] | 11 bytes      | 02 000B 00010000000000200000000 | (this entry)  | 4B000003         | 1.1.1.1:0 [Active] | Never             | Ethernet0/0* | 20             | 19         | 3            | Ethernet0/0* | MDT (VRF green)       | 00:11:18 | 3      | Lspvif0    | MP2MP| 4            | Lspvif0   | 22             | 22            | MDT (VRF green)       | 00:11:18 | 5      | Ethernet0/0* |
| 100:2  | 1.1.1.1  | [mdt 100:2 0] | 11 bytes      | 02 000B 00010000000000200000000 | (root: 1.1.1.1) | F3000001        | 1.1.1.1:0 [Active] | Never             | Ethernet0/0* | 22             | 22         | 1            | Ethernet0/0* | MDT (VRF green)       | 00:11:18 | 6      | Lspvif0    | MP2MP| 6            | Lspvif0   | 22             | 22            | MDT (VRF green)       | 00:11:18 | 6      | Ethernet0/0* |

**Display 100:2 vpn-id**

- Two entries, one for each root
- Same Opaque value for each root
- Primary root for upstream forwarding
- Lspvif0 represents BOTH LSPs to roots
- “0” indicates Default-MDT

**MP2MP Entry for Default-MDT**

- “21 rx from LDP neighbour (up)”
- “25 tx to LDP neighbour (down)”

---

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### mLDP database entry for Root 1

```
P-Banska_Bystrica#showmplsmldp database opaque_typemdt 100:2
LSM ID : 3F000001   Type: MP2MP   Uptime : 00:02:12
  FEC Root : 1.1.1.1 (we are the root)
  Opaque decoded : [mdt 100:2 0]
  Opaque length : 11 bytes
  Opaque value : 02 000B 0001000000000200000000
  Upstream client(s) :
    None
  Expires : N/A   Path Set ID : 1
Replication client(s):
  3.3.3.3:0
    Uptime : 00:02:12   Path Set ID : 2
    Out label (D) : 19   Interface : Ethernet0/0*
    Local label (U) : 18   Next Hop : 10.0.10.1
  4.4.4.4:0
    Uptime : 00:02:11   Path Set ID : 3
    Out label (D) : 20   Interface : Ethernet1/0*
    Local label (U) : 19   Next Hop : 10.0.20.1
  2.2.2.2:0
    Uptime : 00:01:52   Path Set ID : 7
    Out label (D) : 21   Interface : Ethernet2/0*
    Local label (U) : 24   Next Hop : 10.0.30.1
```
mLDP Configuration Examples

- Enabling mLDP
- PIM-SSM transit of IPv4
- Multicast VPN
  Default-MDT
  Data-MDT
- Direct-MDT, VPNv4 transit
Data-MDT Scenario

- Data-MDT is a P2MP tree to support high bandwidth (S, G) stream
- Root of tree is PE router where VPN source resides
- All other mVPN configuration standard (except no GRE – LSP instead)
Multicast VPN – PE Routers

Data-MDT Configuration

vrf definition green
  rd 100:2
vnp id 100:2
  route-target export 200:2
  route-target import 200:2
!
  address-family ipv4
mdt default mplsmldp 1.1.1.1
mdt default mplsmldp 2.2.2.2
mdt data mplsmldp 100
mdt data threshold 1
exit-address-family

VPN ID per RFC2685. Similar to function of MDT Group address. 32b Identifies PE routers that are part of this mVPN

Allow 100 P2MP Data-MDT to be created

Create Data-MDT for sources exceeding 1 kbps

• This configuration is consistent amongst PE routers with same VPN (Ingress and Egress)
Multicast VPN – Ingress Router

VRF mRoute table BEFORE MDT switchover

Two SSM entries, on via Default MDT Lspvif0.

PE-Bratislava# showip mroute vrf green verbose

... (10.1.1.1, 238.1.1.1), 00:00:25/00:03:29, flags: sT
  Incoming interface: Serial6/0, RPF nbr 192.168.10.6
  Outgoing interface list:
  Lspvif0, LSM MDT:21000002 (default), Forward/Sparse-Dense, ...

(10.1.1.2, 238.1.2.2), 00:11:14/00:02:48, flags: sT
  Incoming interface: Serial6/0, RPF nbr 192.168.10.6
  Outgoing interface list:
  Lspvif0, LSM MDT:21000002 (default), Forward/Sparse-Dense, ...

D8000000 is the mLDP entry for the MP2MP Default-MDT (Primary)

• Initially all CE originated joins appear via the Default-MDT
Multicast VPN – Ingress Router

VRF mRoute table AFTER MDT switchover

Data-MDT ID # is “1” used as part of opaque value

PE-Bratislava#showipmroutevrf green 10.1.1.2 238.2.2.2 verbose

(10.1.1.2, 238.2.2.2), 00:00:08/00:03:27, flags: sTy
Incoming interface: Serial6/0, RPF nbr 192.168.10.6
MDT TX nr: 1 LSM-ID 4E000003
Outgoing interface list:
Lspvif0, LSM MDT:4E000003(data) Forward/Sparse-Dense, ...

S, G switched to Data-MDT as indicated by “y” flag

Outgoing interface is still Lspvif0 but LSM ID is now 4E000003 for Data-MDT

• When stream switches to P2MP LSP the outgoing interface remains same as MP2MP LSP – but the mLDP database entry changes (LSM ID)
### Multicast VPN – Ingress Router

#### Lspvif adjacencies

**Three adjacencies operating on Lspvif0**

```
PE-Bratislava#show adjacency lspvif 0
```

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Interface</th>
<th>Address</th>
<th>MDT Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP</td>
<td>Lspvif0</td>
<td>4E000003 (5)</td>
<td>Data-MDT</td>
</tr>
<tr>
<td>IP</td>
<td>Lspvif0</td>
<td>58000000 (4)</td>
<td>Default-MDT (Secondary)</td>
</tr>
<tr>
<td>IP</td>
<td>Lspvif0</td>
<td>D8000000 (3)</td>
<td>Default-MDT (Primary)</td>
</tr>
</tbody>
</table>
Multicast VPN – Ingress Router

mLDP Database for Data-MDT

```
PE-Bratislava# show mplsmldp database id 4E000003
System ID : 4E000003
Uptime    : 00:15:00
FEC tree type : P2MP
FEC length : 24 bytes
FEC value  : 00000001 00000006 00100000 00002000 00000001 9C321402
FEC Root   : 3.3.3.3 (we are the root) (we are leaf)
Opaque decoded : [mdt 100:2 1]
Upstream peer ID : none
Local label (D) : no_label
Replication client(s):
MDT uptime: 00:15:00 intrf: Lspvif0 (vrf green)
156.50.20.1:0 uptime: 00:15:00 remote label (D): 112 nhop: 1.1.1.1
```

Entry for Data-MDT

Data-MDT is P2MP

Non-zero indicates the Data-MDT number

(S, G) stream forwarded with label 112 pushed on stack to P-Central
MDT Join message from root received on Default-MDT

*May 2 14:43:24.039: PIM(1): MDT join TLV received for (10.1.1.2,238.2.2.2)
*May 2 14:43:24.039: MLDP: LDP root 3.3.3.3 added
*May 2 14:43:24.039: MLDP: [mdt 100:2 1] label mapping msg sent to 1.1.1.1:0

PE-Kosice#showmplsmldp database opaque_typemdt 100:2 1
System ID : 9E000004
Uptime : 00:03:41
FEC tree type : P2MP
FEC length : 24 bytes
FEC value : 00000001 00000006 00100000 00002000 00000001 9C321402
FEC Root : 3.3.3.3 (we are leaf)
Opaque decoded : [mdt100:2 1]
Upstream peer ID : 1.1.1.1:0
Local label (D) : 414
Replication client(s):
MDT uptime: 00:03:41 intrf: Lspvif0 (vrf green)

PE-Bratislava added as P2MP root for (S, G)

PE-Kosice joins the P2MP tree

Same Opaque value used for all interested receivers

Label 414 used for P2MP

Incoming traffic from LSP forwarded to VRF
GRE

- Widely available across platforms
- Mature
- Core runs PIM & LDP
- When core deployed with SSM no RPs/Roots needed

mLDP

- Limited availability
- Still under development, IETF drafts changes on the fly
- Core runs just LDP
- Have to deploy with multiple Root Nodes to avoid SPOF
Thank you.
APPENDIX
Global GRE to MLDP Migration Steps

• STEP0
  Upgrade *all* routers to IOS release that supports MLDP

• STEP1
  Original Configuration with only PIM/GRE used
  MLDP adjacencies are up by default

• STEP2
  Add MLDP to vrf blue in all PEs that have blue configured
  PIM/GRE still used for data plane (PIM/GRE Preferred)

• STEP3
  Moving vrf blue to MLDP tunnels (MLDP Preferred)
  "mdtpreference mldppim"
7600 – mVPN with mLDP
7600 Ingress PE

1. VLAN + (S,G,VPN-VRF) lookup
2. MET lookup
3. Fabric Replication
4. (S,G,VPN-MDT-LSP) lookup
5. mLDP Label imposition and MET3 OIF Label replication lookup

Egress Module (NNI)

Ingress Module (UNI)
7600 Egress PE

1. VLAN + (Label, VPN-VRF) lookup

2. mLDP Label disposition and MET2 lookup

3. Fabric Replication

4. (S,G,VPN-VRF) lookup

5. (S,G) MET3 OIF replication
mLDP is still under development

12.2(33)SRE3 @ 7200:
PE-1#show mplsmldp database opaque_typemdt 6000:1
LSM ID : 61000005 (RNR LSM ID: AE000006)   Type: MP2MP
Uptime : 00:21:04
  FEC Root        : 10.254.10.10
  Opaque decoded  : [mdt 6000:1 0]
  Opaque length   : 11 bytes
  Opaque value    : 07 000B 0060000000000100000000
...

15.0(1)S3a @ 7600:
PE-2#show mplsmldp database opaque_typemdt 6000:1
LSM ID : 67000001 (RNR LSM ID: 90000004)   Type: MP2MP
Uptime : 00:33:59
  FEC Root        : 10.254.10.10 (we are the root)
  Opaque decoded  : [mdt 6000:1 0]
  Opaque length   : 11 bytes
  Opaque value    : 02 000B 0060000000000100000000
...

Releases are not compatible due to draft state of RFCs, changes needs to be reflected accross releases

15.0(1)S is using current (as of May2011) IETF type
7600 – mVPN with GRE
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

PE-Bratislava Gi1/20 10.254.22.22 Gi3/1 Gi34/0/0 Gi4/0/1 PE-Kosice

Join (10.1.1.1, 238.1.1.1)

PE-Banska_Bystrica#showipmroute 239.9.9.9

(10.254.22.22, 239.9.9.9), 10:33:16/00:02:33, flags: sT
   Incoming interface: GigabitEthernet4/0/0, RPF nbr 10.254.39.0
   Outgoing interface list:
   GigabitEthernet4/0/1, Forward/Sparse, 10:33:16/00:02:33

(10.254.33.33, 239.9.9.9), 10:33:49/00:02:49, flags: sT
   Incoming interface: GigabitEthernet4/0/1, RPF nbr 10.254.1.1
   Outgoing interface list:
   GigabitEthernet4/0/0, Forward/Sparse, 10:33:49/00:02:49
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

PE-Bratislava

Gi1/20

10.254.22.22

VRF

10.254.33.33

Gi3/1

P-Banska_Bystrica

Join (10.1.1.1, 238.1.1.1)

PE-Kosice

PE2-Bratislava#show module

<table>
<thead>
<tr>
<th>Mod</th>
<th>Ports</th>
<th>Card Type</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>7600 ES+</td>
<td>7600-ES+20G3C</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>7600 ES+</td>
<td>7600-ES+2TG3CXL</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>7600 ES+</td>
<td>7600-ES+20G3CXL</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>SFM-capable</td>
<td>16 port 10/100/1000mb RJ45 WS-X6516-GE-TX</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>Route Switch Processor 720 (Active)</td>
<td>RSP720-3C-GE</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>Route Switch Processor 720 (Hot)</td>
<td>RSP720-3C-GE</td>
</tr>
</tbody>
</table>

PE-Bratislava#shippimvrf blue neighbor

PIM Neighbor Table

Mode: B - Bidir Capable, DR - Designated Router, N - Default DR Priority,
P - Proxy Capable, S - State Refresh Capable, G - GenID Capable

<table>
<thead>
<tr>
<th>Neighbor</th>
<th>Interface</th>
<th>Uptime/Expires</th>
<th>Ver</th>
<th>DR</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.254.33.33Tunnel159</td>
<td>00:14:48/00:01:41 v2</td>
<td>1 / DR S P G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.1.1.1</td>
<td>GigabitEthernet1/20</td>
<td>00:00:39/00:01:35 v2</td>
<td>1 / S G</td>
<td></td>
</tr>
</tbody>
</table>
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

Gi1/20 10.254.22.22

VRF Gi3/1

PE-Bratislava

P-Banska_Bystrica

Join (10.1.1.1, 238.1.1.1)

10.254.33.33

10.254.22.22

PE-Bratislava#shipmroutevrf blue

(*, 238.1.1.1), 00:15:43/00:02:38, RP 10.1.1.1, flags: SF

   Incoming interface: GigabitEthernet1/20, RPF nbr 10.1.1.1

   Outgoing interface list:

      Tunnel59, Forward/Sparse, 00:00:58/00:02:38

(10.1.1.1, 238.1.1.1), 00:00:52/00:02:07, flags: FT

   Incoming interface: GigabitEthernet1/20, RPF nbr 10.1.1.1, Registering

   Outgoing interface list:

      Tunnel59, Forward/Sparse, 00:00:52/00:02:38
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

PE-Bratislava#shipmribvrf blue route

(*,224.0.0.0/4) Flags: C

(*,224.0.1.40) RPF nbr: 10.1.1.1 Flags: C
  GigabitEthernet1/20 Flags: A NS
  Tunnel59 Flags: F IC NS Next-hop: 239.9.9.9

(*,238.1.1.1) RPF nbr: 10.1.1.1 Flags: C
  GigabitEthernet1/20 Flags: A
  Tunnel59 Flags: F NS Next-hop: 239.9.9.9

(10.1.1.1,238.1.1.1) RPF nbr: 10.1.1.1 Flags: 
  Tunnel59 Flags: F NS Next-hop: 239.9.9.9
  GigabitEthernet1/20 Flags: A
  Tunnel5 Flags: F
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

PE-Bratislava#shipmfibvrf blue 10.1.1.1 238.1.1.1 verbose
(10.1.1.1,238.1.1.1) Flags: K HW DDE
  Platform Flags: PF
  Slot 6: HW Forwarding: NA/NA, Platform Flags: HF PRTL MT
  Slot 5: HW Forwarding: 0/0, Platform Flags: HF PRTL MT
  Slot 3: HW Forwarding: 0/0, Platform Flags: HF PRTL MT
  Slot 2: HW Forwarding: 0/0, Platform Flags: HF PRTL MT
  Slot 1: HW Forwarding: 870/87000, Platform Flags: HF PRTL MT
  SW Forwarding: 293/0/100/0, Other: 0/0/0
  HW Forwarding: 870/0/100/0, Other: 0/0/0
  GigabitEthernet1/20 Flags: RA A MA
    Platform Flags:
    Tunnel5 Flags: RF F NP
      Platform Flags: NP
      CEF: Adjacency with MAC: 45C0000000000000FF67A4CA0A01010A0101012100DEFF00000000
      Pkts: 0/293
    Tunnel59, MDT/239.9.9.9 Flags: RF F NS
      Platform Flags: HW
      CEF: Adjacency with MAC: 4500000000000000FF2FA2A80AFE1616EF09090900000800
      Pkts: 0/176
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

PE-Bratislava

Gi1/20 10.254.22.22

VRF

Gi3/1

P-Banska_Bystrica

10.254.33.33

Join (10.1.1.1, 238.1.1.1)

PE-Kosice

PE-Bratislava-dfcl#sh ipmfbvrf blue 10.1.1.1 238.1.1.1 verbose

VRF blue

(10.1.1.1,238.1.1.1) Flags: K HW DDE

SW Forwarding: 0/0/0/0, Other: 0/0/0

HW Forwarding: 870/0/100/0, Other: 0/0/0

GigabitEthernet1/20 Flags: RA A MA NS

Tunnel59, MDT/239.9.9.9 Flags: RF F NS

CEF: Adjacency with MAC: 4500000000000000FF2FA2A80AFE1616EF09090900000800

Pkts: 0/0

FF | 2F | A2A8 | 0AFE1616 | EF090909 | 0000 | 0800
TTL=255 | PROTO=47=GRE | CHECKSUM | SRC=10.254.22.22 | DST=239.9.9.9 | GRE HDR | TYPE=IP
Ingress PE datapath

(10.1.1.1, 238.1.1.1)

PE-Bratislava#shipmroute 239.9.9.9
(10.254.22.22, 239.9.9.9), 00:16:25/00:02:50, flags: sT
  Incoming interface: Loopback111, RPF nbr 0.0.0.0
  Outgoing interface list:
    GigabitEthernet3/1, Forward/Sparse, 00:16:25/00:02:50

(10.254.33.33, 239.9.9.9), 00:16:58/stopped, flags: sTIZ
  Incoming interface: GigabitEthernet3/1, RPF nbr 10.254.39.1
  Outgoing interface list:
    MVRF blue, Forward/Sparse, 00:16:58/00:01:01
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

PE-Bratislava

Gi1/20

10.254.22.22

Gi3/1

10.254.33.33

PE-Kosice

P-Banska_Bystrica

Join (10.1.1.1, 238.1.1.1)

PE-Bratislava#shipmrib route 239.9.9.9

(10.254.22.22, 239.9.9.9) RPF nbr: 0.0.0.0 Flags:
GigabitEthernet3/1 Flags: F NS
Null0 Flags: A

(10.254.33.33, 239.9.9.9) RPF nbr: 10.254.39.1 Flags:
Tunnel59 (MVRF blue) Flags: F NS
GigabitEthernet3/1 Flags: A
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

PE-Bratislava#shipmfib 239.9.9.9 10.254.22.22 verbose
Default
(10.254.22.22,239.9.9.9) Flags: K HW
Platform Flags: HW
Slot 6: HW Forwarding: NA/NA, Platform Flags: NA
Slot 5: HW Forwarding: 1000/128000, Platform Flags: HF MT
Slot 3: HW Forwarding: 0/0, Platform Flags: HF MT
Slot 2: HW Forwarding: 0/0, Platform Flags: HF MT
Slot 1: HW Forwarding: 870/111360, Platform Flags: HF MT
SW Forwarding: 252/0/108/0, Other: 0/0/0
HW Forwarding: 1870/0/128/0, Other: 0/0/0
Null0 Flags: RA A MA
Platform Flags:
GigabitEthernet3/1 Flags: RF F NS
Platform Flags: HW
CEF: Adjacency with MAC: 01005E0909090026CB39DB800800
Pkts: 0/252

“HW” = OK, HW_ERR = Defect

Overlay PIM Hellos + punts of new streams until programmed in HW

Sum of all HW switched packets from all PFC/DFCs in system, 870 from Gi1/20 and 1000 from CFC in slot 4
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

Join (10.1.1.1, 238.1.1.1)

PE-Bratislava#shipmfib 239.9.9.9 10.254.22.22 verbose
Default
(10.254.22.22, 239.9.9.9) Flags: K HW
  SW Forwarding: 0/0/0/0, Other: 0/0/0
  HW Forwarding: 870/0/128/0, Other: 0/0/0
Null0 Flags: RA A MA
GigabitEthernet3/1 Flags: RF F NS
  CEF: Adjacency with MAC: 01005E0000000026CB39DB800800
Pkts: 0/0
7600 mVPN with GRE platform

Ingress PE datapath

(10.1.1.1, 238.1.1.1)

PE-Bratislava#shipmfib 239.9.9.9 10.254.22.22 verbose

Default

(10.254.22.22,239.9.9.9) Flags: K HW

SW Forwarding: 0/0/0/0, Other: 0/0/0
HW Forwarding: 524253/0/470/0, Other: 0/0/0
Null0 Flags: RA A MA

GigabitEthernet3/1 Flags: RF F NS

CEF: Adjacency with MAC: 01005E0000000026CB39DB800800
Pkts: 0/0
Ingress PE datapath

1. Two Pass EARL lookup for VRF group 238.1.1.1

**DBUS:**

VLAN = 3448  
DMAC = 0100.5e01.0101  
SMAC = 0017.e05a.6d61  
IP_SA = 10.1.1.1  
IP_DA = 238.1.1.1

**RBUS:**

REWRITE_INFO

i0 - replace bytes from ofs 6 to ofs 13 with seq '00 26 CB 39 DB 80 08 00'.

---

**DBUS:**

DMAC = 0100.5e01.0101  
SMAC = 0026.cb39.db80  
IP_SA = 10.1.1.1  
IP_DA = 238.1.1.1

**RBUS:**

REWRITE_INFO

i0 - replace bytes from ofs 12 to ofs 13 with seq 'CC EE'.

i1 - insert seq '45 00 04 00 A1 95 00 00 FF 2F FD 12 0A FE 16 16 EF 09 09 09 00 00 08 00' before ofs 14.
Ingress PE datapath

Inserted tunnel header decode from rewrite info:

Internet Protocol, Src: 10.254.22.22 (10.254.22.22), Dst: 239.9.9.9 (239.9.9.9)
  Version: 4
  Header length: 20 bytes
  Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
    0000 00.. = Differentiated Services Codepoint: Default (0x00)
    .... ..0. = ECN-Capable Transport (ECT): 0
    .... ...0 = ECN-CE: 0
  Total Length: 1024
  Identification: 0xa195 (41365)
  Flags: 0x00
    0... .... = Reserved bit: Not set
    .0. ..... = Don't fragment: Not set
    ..0. ..... = More fragments: Not set
  Fragment offset: 0
  Time to live: 255
  Protocol: GRE (47)
    Header checksum: 0xfd12 [correct]
      [Good: True]
      [Bad: False]
    Source: 10.254.22.22 (10.254.22.22)
    Destination: 239.9.9.9 (239.9.9.9)
  Generic Routing Encapsulation (IP)
    Flags and version: 0000
      0... ...... = No checksum
      .0... ...... = No routing
      ..0. ...... = No key
      ...0 ...... = No sequence number
      .... 0...... = No strict source route
      .... .000.... = Recursion control: 0
      .... ....0000 = Flags: 0
      .... ......000 = Version: 0
  Protocol Type: IP (0x0800)
Ingress PE datapath

2. EARL lookup for Default MDT group 239.9.9.9

DBUS:
DMAC = 0100.5e01.0101
SMAC = 0026.cb39.db80
L3_PT [8] = 47
IP_SA = 10.254.22.22
IP_DA = 239.9.9.9

RBUS:
REWRITE_INFO
i0 - replace bytes from ofs 0 to ofs 5 with seq '01 00 5E 09 09 09'.
i1 - replace bytes from ofs 12 to ofs 13 with seq '08 00'.
remove bytes from ofs 14 to ofs 17.

DBUS:
DMAC = 0100.5e09.0909
SMAC = 0026.cb39.db80
L3_PT [8] = 47
IP_SA = 10.254.22.22
IP_DA = 239.9.9.9

RBUS:
REWRITE_INFO
i0 - no rewrite.
show platform software multicast ipcmfibvrf blue 238.1.1.1 10.1.1.1 verbose

Multicast CEF Entries for VPN#1

(10.1.1.1, 238.1.1.1)

IOSVPN:256  (1) PI:1 (1) CR:0 (1) Recirc:0 (1) Vlans:3448
AdjPtr:49186 FibRpfNf:1 FibRpfDf:1 FibAddr:0x30060
rwvlans:3448 rwindex:0x7FFA
fmt:Mcast 13rwvld:1 DM:0 mtu:1518 rwtype:L3 met2:0 packets:000000000102315 bytes:000000000012073170
Starting Offset: 0x003D
V E C:3229

MLSVPN:954  (1) PI:1 (1) CR:1 (1) Recirc:1 (1) Vlans:3448
AdjPtr:49187 FibRpfNf:1 FibRpfDf:1 FibAddr:0x30318
rwvlans:3448 rwindex:0x7FFA
fmt:Mcast 13rwvld:0 DM:0 mtu:1522 rwtype:L3 met2:0 packets:0000000000000 bytes:0000000000000

Annotation-data: [0x2A9690D0]
A-vlan: 3448 NS-vlan: 0 RP-rpf-vlan: 0
Anntn flags: [0x100010]  H MT
MTU: 1500 Retry-count: 0
Sec-entries count: 1
Met-handle: 0x2559ED9C New-Met-handle: 0x0
Met2-handle: NULL

HAL L3-data : [0x20BDD2A0]
Flags: 0x4 FIB-index: 0x1E00 ADJ-index: 0xC022 NF-addr: 0xFFFFFFFF ML3 entry type: 0x0 [(S,G) shortcut]
Flags: 0xA0100000 Vpn: 256 Rpf: 3448 Rw_index: 0x7FFA
Adj_mtu: 1514 Met2: 0x0 Met3: 0x3D
V6-data: NULL

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Multicast CEF Entries for VPN#0
(10.254.222, 239.9.9.9)

<table>
<thead>
<tr>
<th>PE2-Bratislava-dfc1#sh mlscefadj entry 114717 detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index: 114717 smac: 0000.0000.0000, dmac: 0100.5e09.0909</td>
</tr>
<tr>
<td>mtu: 9002, vlan: 3229, dindex: 0x7FFA, l3rw_vld: 1</td>
</tr>
<tr>
<td>format: MULTICAST, flags: 0x42000002608 met2: 0, met3: 60</td>
</tr>
<tr>
<td>packets: 104712, bytes: 15287952</td>
</tr>
</tbody>
</table>

**MLVPN:**
- PI: 1 (1)
- CR: 1 (1)
- Recirc: 1 (1)
- Vlan: 3229
- AdjPtr: 114717
- FibRpfNf: 1
- FibRpfDf: 1
- rwvlans: 3229
- rwindex: 0x7FFA
- adjmac: 0000.0000.0000
- fmt: Mcast
- l3rwvld: 1
- DM: 1
- mtu: 9002
- rwtype: L3
- met2: 0
- met3: 0x3C

**IOSVPN:**
- PI: 1 (1)
- CR: 0 (1)
- Recirc: 0 (1)
- Vlan: 3229
- AdjPtr: 114718
- FibRpfNf: 1
- FibRpfDf: 1
- rwvlans: 3229
- rwindex: 0x7FFA
- adjmac: 0000.0000.0000
- fmt: Mcast
- l3rwvld: 0
- DM: 0
- mtu: 8998
- rwtype: L3
- met2: 0
- met3: 0x0

**Annotation data:** [0x2B4B8688]
- A-vlan: 3229
- NS-vlan: 0
- RP-rpf-vlan: 0
- Anntn flags: [0x100010] H MT

**MTU:** 8980
- Retry-count: 0
- Sec-entries count: 1
- Met-handle: 0x2560554C New-Met-handle: 0x0
- Met2-handle: NULL

**HAL L3-data:** [0x2B4E6E8C]
- Flags: 0x4 FIB-index: 0x1EF8 ADJ-index: 0x1C01D NF-addr: 0xFFFFFFFF
- ML3 entry type: 0x0 [(S,G) shortcut]
- Flags: 0xB9400000 Vpn: 953 Rpf: 3229 Rw_index: 0x7FFA
- Adj_mtu: 8994
- Met2: 0x0
- Met3: 0x3C
- V6-data: NULL

3229 VPN 1 EncapVlan
3447 GigabitEthernet3/1
7600 mVPN with GRE platform

Egress PE datapath

```
PE-Bratislava#shipmroutevrf blue

(*, 238.2.2.2), 00:04:38/stopped, RP 10.1.1.1, flags: SJPC
   Incoming interface: GigabitEthernet1/20, RPF nbr 10.1.1.1
   Outgoing interface list: Null

(10.1.2.1, 238.2.2.2), 00:01:08/00:02:21, flags: T
   Incoming interface: Tunnel59, RPF nbr 10.254.33.33
   Outgoing interface list:
      GigabitEthernet1/20, Forward/Sparse, 00:01:08/00:02:22, A
```
7600 mVPN with GRE platform

Egress PE datapath

Join (10.1.2.1, 238.2.2.2)

Gi1/20 10.254.22.22

VRF

PE-Bratislava

10.254.22.22

Gi3/1

P-Banska_Bystrica

(10.1.2.1, 238.2.2.2)

10.254.33.33

Gi1/20

Tunnel59 Flags: F IC NS

Next-hop: 239.9.9.9

(*,224.0.0.0/4) Flags: C

(*,224.0.1.40) RPF nbr: 10.1.1.1 Flags: C

GigabitEthernet1/20 Flags: A NS

Tunnel59 Flags: F IC NS

Next-hop: 239.9.9.9

(*,238.2.2.2) RPF nbr: 10.1.1.1 Flags: C

GigabitEthernet1/20 Flags: A NS

(10.1.2.1,238.2.2.2) RPF nbr: 10.254.33.33 Flags:

Tunnel59 Flags: A NS

Next-hop: 239.9.9.9

GigabitEthernet1/20 Flags: F
7600 mVPN with GRE platform

Egress PE datapath

Join (10.1.2.1, 238.2.2.2)

PE-Bratislava

10.254.22.22

Gi3/1

10.254.33.33

Gi1/20

P-Banska_Bystrica

VE-RF (10.1.2.1, 238.2.2.2)

10.1.2.1

PE-Kosice

PE-Bratislava#showipmfibvrf blue 238.2.2.2 10.1.2.1 verbose

VRF blue

(10.1.2.1, 238.2.2.2) Flags: K HW DDE

Platform Flags: HW

Slot 6: HW Forwarding: NA/NA, Platform Flags: HF MT
Slot 5: HW Forwarding: 0/0, Platform Flags: HF MT
Slot 3: HW Forwarding: 100000/10400000, Platform Flags: HF MT
Slot 2: HW Forwarding: 0/0, Platform Flags: HF MT
Slot 1: HW Forwarding: 0/0, Platform Flags: HF MT

SW Forwarding: 36/0/100/0, Other: 23/23/0

HW Forwarding: 100000/0/100/0, Other: 0/0/0

Tunnel59, MDT/239.9.9.9 Flags: RA A MA NS

Platform Flags:

GigabitEthernet1/20 Flags: RF F

Platform Flags: HW

CEF: Adjacency with MAC: 01005E0202020026CB39DB800800

Pkts: 36/0
7600 mVPN with GRE platform

Egress PE datapath

Join
(10.1.2.1, 238.2.2.2)

PE-Bratislava

Gi3/1

10.254.22.22

Gi1/20

10.1.2.1

238.2.2.2

P-Banska_Bystrica

Tunnel59, MDT/239.9.9.9 Flags: RA A MA

CEF: Adjacency with MAC: 01005E0000000026CB39DB800800

Pkts: 0/0

PE-Bratislava-dfc3#show ipmfibvrf blue 238.2.2.2 10.1.2.1 verbose

(10.1.2.1,238.2.2.2) Flags: K HW DDE

SW Forwarding: 0/0/0/0, Other: 0/0/0

HW Forwarding: 100000/0/100/0, Other: 0/0/0

Gi3/1 Flags: RF F
7600 mVPN with GRE platform

Egress PE datapath

PE-Bratislava#shipmroute 239.9.9.9
(10.254.22.22, 239.9.9.9), 00:16:25/00:02:50, flags: sT
   Incoming interface: Loopback111, RPF nbr 0.0.0.0
   Outgoing interface list:
       GigabitEthernet3/1, Forward/Sparse, 00:16:25/00:02:50

(10.254.33.33, 239.9.9.9), 00:16:58/stopped, flags: sTIZ
   Incoming interface: GigabitEthernet3/1, RPF nbr 10.254.39.1
   Outgoing interface list:
       MVRF blue, Forward/Sparse, 00:16:58/00:01:01
7600 mVPN with GRE platform

Egress PE datapath

Join
(10.1.2.1, 238.2.2.2)

PE-Bratislava

VRF

PE - Kosice

PE - Bratislava#

shipmfib 239.9.9.9 10.254.33.33 verbose

Default

(10.254.33.33,239.9.9.9) Flags: K HW

Platform Flags:  HW

Slot 6: HW Forwarding: NA/NA, Platform Flags:  HF MT

Slot 5: HW Forwarding: 0/0, Platform Flags:  HF MT

Slot 3: HW Forwarding: 203444/25094418, Platform Flags:  HF MT

Slot 2: HW Forwarding: 0/0, Platform Flags:  HF MT

Slot 1: HW Forwarding: 0/0, Platform Flags:  HF MT

SW Forwarding: 0/0/0/0, Other: 0/0/0

HW Forwarding: 203444/0/123/0, Other: 0/0/0

GigabitEthernet3/1 Flags: RA A MA

Platform Flags:

Tunnel59, MDT Decap Flags: RF F NS

Platform Flags:  HW

CEF: OCE (t
7600 mVPN with GRE platform

Egress PE datapath

Join (10.1.2.1, 238.2.2.2)

PE-Bratislava

Gi1/20

10.254.22.22

Gi3/1

P-Banska_Bystrica

10.254.33.33

PE-Kosice

PE-Bratislava-dfc3#sh ipmfib 239.9.9.9 10.254.33.33 verbose

Default

(10.254.33.33,239.9.9.9) Flags: K HW
  SW Forwarding: 0/0/0/0, Other: 0/0/0
  HW Forwarding: 203443/0/123/0, Other: 0/0/0
  GigabitEthernet3/1 Flags: RA A MA
  Tunnel59, MDT Decap Flags: RF F NS
    CEF: OCE (tunnel decap)

Pkt5: 0/0
PE-Bratislava-dfc3#show platform software multicast ipcmfibvrf blue 238.2.2.2 verbose

(10.1.2.1, 238.2.2.2)
MSLVVPN:952  (1) PI:1 (1) CR:1 (1) Recirc:1 (1)
Vlan:3228  AdjPtr:81954  FibRpfNf:1 FibRpfDf:1 FibAddr:0x30218
rwvlans:3228 rwindex:0x7FFA adjmac:0000.0000.0000
fmt: Mcast 13rwvld:1 DM:1 mtu:9222 rwtype:L3 met2:0 met3:0
packets:0000000000000 bytes:000000000012200000
Starting Offset: 0x003E
  V E C:3448 I:0x02139  V E C:3448 I:0x02139

IOSVPN:264  (1) PI:1 (1) CR:0 (1) Recirc:0 (1)
Vlan:3228  AdjPtr:81955  FibRpfNf:1 FibRpfDf:1 FibAddr:0x302F8
rwvlans:3228 rwindex:0x7FFA adjmac:0000.0000.0000 rdt:1 E:0 CAP1:0
fmt: Mcast 13rwvld:0 DM:0 mtu:9218 rwtype:- met2:0 met3:0
packets:0000000000000 bytes:0000000000000

Annotation-data: [0x2C331E34]
A-vlan: 3228 NS-vlan: 0 RP-rpf-vlan: 0
Anntn flags: [0x100010]  H MT
MTU: 9200 Retry-count: 0
Sec-entries count: 1
Met-handle: 0x265709B0 New-Met-handle: 0x0
Met2-handle: NULL

HAL L3-data : [0x2095E818]
Flags: 0x4 FIB-index: 0x1E35 ADJ-index: 0x14022 NF-addr: 0xFFFFFFFF
ML3 entry type: 0x0 [(S,G) shortcut]
Flags: 0xB9400000 Vpn: 952 Rpf: 3228 Rw_index: 0x7FFA
Adj_mtu: 9214 Met2: 0x0 Met3: 0x3E
V6-data: NULL

PE-Bratislava-dfc3#sh mlscefadj entry 81954 detail
Index: 81954  smac: 0000.0000.0000, dmac: 0100.5e02.0202
mtu: 9222, vlan: 3228, dindex: 0x7FFA, l3rw_vld: 1
format: MULTICAST, flags: 0x42000002608
met2: 0, met3: 0
packets: 100000, bytes: 10400000

3448 GigabitEthernet1/20
3228 VPN 1 DecapVlan
PE-Bratislava-dfc3#show platform software multicast ipcmfib 239.9.9.9 10.254.33.33 verbose

Multicast CEF Entries for VPN#0
(10.254.33.33, 239.9.9.9)

IOSVPN:0 (1) PI:1 (1) CR:0 (1) Recirc:0 (1)
Vlan:3447 AdjPtr:426006 FibRpfNf:1 FibRpfDf:1 FibAddr:0x30216
rwvlans:3447 rwindex:0x7FFA adjmac:0026.cb39.db80
fmt:Mcast 13rwvlid:1 DM:0 mtu:9238 rwtype:L3 met2:0
packets:000000203453 bytes:00000000028757268
Starting Offset: 0x000A

V E C:3228

Annotation-data: [0x2C1D11DC]
A-vlan: 3447 Rp-vlan: 0 RP-rpf-vlan: 0
Anntn flags: [0x100010] H MT
MTU: 9220 Retry-count: 0
Sec-entries count: 0
Met-handle: 0x265D8A74 New-Met-handle: 0x0
Met2-handle: NULL

HAL L3-data
Flags: 0x4 FIB-index: 0x00000000 NF-addr: 0xFFFFFFFF

ML3 entry type: 0x0 [(S,G) shortcut]
Flags: 0xA1000000 Vpn: 0 Rpf: 3447 Rw_index: 0x7FFA
Adj_mtu: 9234 Met2: 0x0 Met3: 0xA
V6-data: NULL

PE-Bratislava-dfc3#sh mlscefadj entry 426006 detail
Index: 426006 smac: 0026.cb39.db80, dmac: 0000.0000.0000
mtu: 9238, vlan: 3447, dindex: 0x7FFA, l3rw_vld: 1
format: MULTICAST, flags: 0x2000002608
met2: 0, met3: 10
packets: 403499, bytes: 57161680

3447 GigabitEthernet3/1

3228 VPN 1 DecapVlan
Egress PE datapath

1. Two Pass EARL lookup for VRF group 239.9.9.9

**DBus:**
DMAC = 0100.5e09.0909
SMAC = 0015.624f.f000
IP_SA = 10.254.33.33
IP_DA = 239.9.9.9

**RBUS:**
REWRITE_INFO
i0  - replace bytes from ofs 6 to ofs 13 with seq '00 26 CB 39 DB 80 08 00'.

##############################################################################

**DBus:**
DMAC = 0100.5e09.0909
SMAC = 0026.cb39.db80
IP_SA = 10.254.33.33
IP_DA = 239.9.9.9

**RBUS:**
REWRITE_INFO
i0  - replace bytes from ofs 12 to ofs 17 with seq 'CC EE 00 00 08 00'.
remove bytes from ofs 18 to ofs 37.
2. EARL lookup for VRF group 238.2.2.2

DBUS:
DMAC = 0100.5e09.0909
SMAC = 0026.cb39.db80
IP_SA = 10.1.2.1
IP_DA = 238.2.2.2

RBUS:
REWRITE_INFO
  i0 - replace bytes from ofs 0 to ofs 5 with seq '01 00 5E 02 02 02'.
  i1 - replace bytes from ofs 12 to ofs 13 with seq '08 00'.
  remove bytes from ofs 14 to ofs 17.

DBUS:
DMAC = 0100.5e02.0202
SMAC = 0026.cb39.db80
IP_SA = 10.1.2.1
IP_DA = 238.2.2.2

RBUS:
REWRITE_INFO
  i0 - no rewrite.
### IPv4 MFIB

<table>
<thead>
<tr>
<th>Slot</th>
<th>Linecard status</th>
<th>Broker status</th>
</tr>
</thead>
<tbody>
<tr>
<td>*6/1</td>
<td>sync</td>
<td>enabled</td>
</tr>
<tr>
<td>6/0</td>
<td>sync</td>
<td>enabled</td>
</tr>
<tr>
<td>5/0</td>
<td>sync</td>
<td>enabled</td>
</tr>
<tr>
<td>3/0</td>
<td>sync</td>
<td>enabled</td>
</tr>
<tr>
<td>2/0</td>
<td>sync</td>
<td>enabled</td>
</tr>
<tr>
<td>1/0</td>
<td>sync</td>
<td></td>
</tr>
</tbody>
</table>

### IPv6 MFIB

<table>
<thead>
<tr>
<th>Slot</th>
<th>Linecard status</th>
<th>Broker status</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPv4:Default</td>
<td>126 entries, 243 items</td>
<td></td>
</tr>
</tbody>
</table>

| Slot | Table state | |
|------|-------------|
| 6/1  | Sync        |
| 6/0  | Sync        |
| 5/0  | Sync        |
| 3/0  | Sync        |
| 2/0  | Sync        |
| 1/0  | Sync        |

### IPv4:blue, 8 entries, 12 items

| Slot | Table state | |
|------|-------------|
| 6/1  | Sync        |
| 6/0  | Sync        |
| 5/0  | Sync        |
| 3/0  | Sync        |
| 2/0  | Sync        |
| 1/0  | Sync        |

"Sync" = OK, other states such as "Reloading" "Purge" etc. signals problems, however those states can be temporarily seen after SSO switchover.

All PFCs (SPs) & DFCs (LCs) & Standby-RP as MFIB clients having local copy of MFIB database.

Global multicast routing

VRF multicast routing