Deploying Inter-Domain IP Multicast

Session RST-222
Other Related Presentations

- Multicast Sessions
  - Session #   Title
  - RST-120   Introduction to IP Multicast
  - RST-220   Deploying Scalable IP Multicast
  - RST-222   Deploying Inter-domain IP Multicast
  - RST-320   Troubleshooting IP Multicast
  - RST-321   Multicast Router Arch. & Performance

- MBGP Related Sessions
  - Session #   Title
  - RST-210   Deploying BGP

Agenda

- PIM-SM review (forwarding)
- MBGP (routing)
- MSDP (source discovery)
- MBGP/MSDP Examples
- SSM (Source Specific Multicast)
PIM-SM Review

• Everyone here is a PIM-SM expert, right?

• So just for review...

PIM-SM Shared Tree Join

(*, G) State created only along the Shared Tree.
PIM-SM Sender Registration

Traffic Flow → Receiver (S, G) State created only along the Source Tree.

Source Tree → Source

(S, G) Register (unicast)

RP sends a Register-Stop back to the first-hop router to stop the Register process.

(S, G) Register-Stop (unicast)

(S, G) traffic begins arriving at the RP via the Source tree.

(RP) Join

(S, G) traffic begins arriving at the RP via the Source tree.

Traffic Flow → Receiver

Shared Tree → Source Tree

(S, G) Register (unicast)

(S, G) Register-Stop (unicast)
PIM-SM Sender Registration

Source traffic flows natively along SPT to RP. From RP, traffic flows down the Shared Tree to Receivers.

PIM-SM SPT Switchover

Last-hop router joins the Source Tree. Additional (S, G) State is created along new part of the Source Tree.
Traffic begins flowing down the new branch of the Source Tree. Additional (S, G) State is created along the Shared Tree to prune off (S, G) traffic.

(S, G) Traffic flow is now pruned off of the Shared Tree and is flowing to the Receiver via the Source Tree.
(S, G) traffic flow is no longer needed by the RP so it Prunes the flow of (S, G) traffic.

(S, G) traffic flow is now only flowing to the Receiver via a single branch of the Source Tree.
Agenda

- PIM-SM review (forwarding)
- MBGP (routing)
- MSDP (source discovery)
- MBGP/MSDP Examples
- SSM (Source Specific Multicast)

MBGP—Multiprotocol BGP

- MBGP overview
- MBGP capability negotiation
- MBGP NLRI exchange
- MBGP-DVMRP redistribution
- Unicast to Multicast NLRI Translation
MBGP Overview

• MBGP: Multiprotocol BGP
  (aka multicast BGP in multicast networks)
  – Defined in RFC 2283 (extensions to BGP)
  – Can carry different types of routes
    • Unicast
    • Multicast
  – Both routes carried in same BGP session
  – Does not propagate multicast state info
  – Same path selection and validation rules
    • AS-Path, LocalPref, MED, ...

New multiprotocol attributes

  – MP_REACH_NLRI
  – MP_UNREACH_NLRI

MP_REACH_NLRI and MP_UNREACH_NLRI

  – Address Family Information (AFI) = 1 (IPv4)
    • Sub-AFI = 1 (NLRI is used for unicast)
    • Sub-AFI = 2 (NLRI is used for multicast RPF check)
    • Sub-AFI = 3 (NLRI is used for both unicast and multicast RPF check)
MBGP Overview

• Separate BGP tables maintained
  – Unicast Routing Information Base (U-RIB)
  – Multicast Routing Information Base (M-RIB)

• Unicast RIB (U-RIB)
  – Contains unicast prefixes for unicast forwarding
  – Populated with BGP unicast NLRI
    • AFI = 1, Sub-AFI = 1 or 3

• Multicast RIB (M-RIB)
  – Contains unicast prefixes for RPF checking
  – Populated with BGP multicast NLRI
    • AFI = 1, Sub-AFI = 2 or 3

PIM RPF Calculation Details

Deciding Preference

<table>
<thead>
<tr>
<th>Static Route Table</th>
<th>BGP MRIB</th>
<th>DVMRP Route Table</th>
<th>Unicast Routing Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>(First Match)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route/Mask, Dist.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Default Dist. = 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
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<th>BGP MRIB</th>
<th>DVMRP</th>
<th>Unicast Routing Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Best Path)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route/Mask, Dist.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(IIBG Def. Dist. = 20)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DVMRP Route Table</th>
<th>Unicast Routing Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Longest Match)</td>
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</tr>
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<td>Route/Mask, Dist.</td>
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</tbody>
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</thead>
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</tr>
<tr>
<td>Route/Mask, Dist.</td>
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</tbody>
</table>

Global Command: ip multicast longest-match

IIF, RPF Neighbor

RPF Calculation (Use best Distance unless “Longest Match” is enabled. If enabled, use longest Mask.)
MBGP Overview

- MBGP allows different unicast and multicast topologies and different policies
  - Same IP address may have different meaning
    - Unicast routing information
    - Multicast RPF information
  - For same IPv4 address two different NLRI with different next-hops
  - Can use existing or new BGP peering topology for multicast

MBGP—Capability Negotiation

- OPEN message
  - Establishes BGP sessions between peers
  - Can contain optional parameters
    - Session negotiation is terminated if a parameter is not recognised.
  - New parameter: CAPABILITIES
    - Multiprotocol extension.
    - Multiple routes for same destination.
MBGP—Capability Negotiation

• New keyword on neighbor command
  `neighbor <foo> remote-as <asn> nlri multicast unicast`
  – Configures router to negotiate either or both NLRI
  – If neighbor configures both or subset, common NRLI is used in both directions
  – If there is no match, notification is sent and peering doesn’t come up

• If neighbor doesn’t include the capability parameters in open, Cisco backs off and reopens with no capability parameters
• Peering comes up in unicast-only mode
• Hidden command
  `neighbor <foo> dont-capability-negotiate`
MBGP—Capability Negotiation

AS 123 192.168.100.0/24 192.168.100.2
BGP: 192.168.100.2 open active, local address 192.168.100.1
BGP: 192.168.100.2 sending OPEN, version 4
BGP: 192.168.100.2 OPEN rcvd, version 4
BGP: 192.168.100.2 rcv OPEN w/option parameter type: 2, len: 6
BGP: 192.168.100.2 OPEN has CAPABILITY code: 1, length 4
BGP: 192.168.100.2 OPEN has MP_EXT CAP for afi/safi: 1/1
BGP: 192.168.100.2 went from OpenSent to OpenConfirm
BGP: 192.168.100.2 went from OpenConfirm to Established

AS 321 192.192.25.0/24 192.192.25.0
BGP Session for Unicast and Multicast NLRI

MBGP NLRI Exchange

• BGP/MBGP configuration allows you to:
  – Define which NLRI type are exchanged (unicast, multicast, both)
  – Set NLRI type through route-maps (redistribution)
  – Define policies through standard BGP attributes (for unicast and/or multicast NLRI)

• No redistribution allowed between MBGP and BGP tables
  – NLRI type can be set with set nlri route-map command
MBGP NLRI Exchange

- U-RIB/M-RIB is populated by:
  - Receiving BGP Updates from neighbors
    - MP_REACH_NLRI AFI/SAFI 1 = U-RIB
    - MP_REACH_NLRI AFI/SAFI 2 = M-RIB
    - MP_REACH_NLRI AFI/SAFI 3 = U-RIB & M-RIB
  - Configured/injected locally by:
    - network <foo> <foo-mask> [nlri multicast unicast]
    - redistribute <unicast> route-map <map>
    - aggregate-address <foo> <foo-mask> [nlri multicast unicast]
    - neighbor <foo> default-originate [nlri multicast unicast]

MBGP — NLRI Information

- Storage of arriving NLRI information depends on AFI/SAFI fields in the Update message
  - Unicast RIB only (AFI=1/Safi=1 or old style NLRI)
## MBGP — NLRI Information

### Unicast RIB

<table>
<thead>
<tr>
<th>Network</th>
<th>Next-Hop</th>
<th>Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.192.2.0/24</td>
<td>192.168.200.2</td>
<td>i</td>
</tr>
<tr>
<td>192.192.2.0/24</td>
<td>192.168.200.2</td>
<td>i</td>
</tr>
</tbody>
</table>

### Multicast RIB

<table>
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<th>Path</th>
</tr>
</thead>
<tbody>
<tr>
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<td>192.168.200.2</td>
<td>300 200 1</td>
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- Storage of arriving NLRI information depends on AFI/SAFI fields in the Update message
  - Unicast RIB only (AFI=1/SAFI=1 or old style NLRI)
  - Multicast RIB only (AFI=1/SAFI=2)

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  - Unicast RIB only (AFI=1/SAFI=1 or old style NLRI)
  - Multicast RIB only (AFI=1/SAFI=2)
  - Both RIB’s (AFI=1/SAFI=3)
MBGP — NLRI Information

**Unicast RIB**

<table>
<thead>
<tr>
<th>Network</th>
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<tbody>
<tr>
<td>*i160.10.1.0/24</td>
<td>192.20.2.2</td>
<td>i</td>
</tr>
<tr>
<td>*i160.10.3.0/24</td>
<td>192.20.2.2</td>
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**Multicast RIB**

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<td>*i160.10.3.0/24</td>
<td>192.20.2.2</td>
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</tbody>
</table>

Router bgp 100
network 160.10.1.0 255.255.255.0 nlri unicast
network 160.10.3.0 255.255.255.0 nlri unicast
no auto-summary

New ‘nlri’ keyword used to control RIB population. (e.g. ‘network’ command)
- Unicast RIB only

**Unicast RIB**

<table>
<thead>
<tr>
<th>Network</th>
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</tr>
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<tbody>
<tr>
<td>10.1.2.0/24</td>
<td>192.20.2.2</td>
<td>i</td>
</tr>
<tr>
<td>160.10.1.0/24</td>
<td>192.20.2.2</td>
<td>i</td>
</tr>
<tr>
<td>160.10.3.0/24</td>
<td>192.20.2.2</td>
<td>i</td>
</tr>
<tr>
<td>153.22.0.0/16</td>
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**Multicast RIB**

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New ‘nlri’ keyword used to control RIB population. (e.g. ‘network’ command)
- Unicast RIB only
- Multicast RIB only
New ‘nlri’ keyword used to control RIB population. (e.g. ‘network’ command)
- Unicast RIB only
- Multicast RIB only
- Both RIB’s
**MBGP — NLRI Information**

**Congruent Topologies**

- **AS 123**
- **AS 321**

Routing Update:

```
NLRI: 192.192.25/24
AS_PATH: 321
MED:
Next-Hop: 192.168.100.2
...`

**Unicast Information**

- **MP_REACH NLRI:** 192.192.25/24
- **AFL:** 1, Sub-AFL: 2 (multicast)
- **AS PATH:** 321
- **MED:**
- **Next-Hop:** 192.168.100.2
  ...

**Multicast Information**

- **NLRI:** 192.192.25/24
- **AS_PATH:** 321
- **MED:**
- **Next-Hop:** 192.168.100.2
  ...

**Sender**

192.168.100.0/24
192.192.25.0/24

**Receiver**

192.168.10.0/24

---

**MBGP — NLRI Information**

**Incongruent Topologies**

- **AS 123**
- **AS 321**

Routing Update:

```
routet bgp 321
  . . .
  network 192.192.25.0 n1ri unicast multicast
  neighbor 192.168.100.1 remote-as 123 niri unicast
  neighbor 192.168.200.1 remote-as 123 niri multicast
```

**Sender**

192.168.100.0/24
192.192.25.0/24

**Multicast Traffic**

192.168.200.0/24
Incongruent Topologies

AS 123

1. Unicast Traffic

192.168.100.0/24

2. Multicast Traffic

192.168.200.0/24

AS 321

192.192.25.0/24

RST-222

2976_05_2001_c1

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**12.1 MBGP Syntax Change**

- **New syntax as of 12.1/12.0(7)T**
  - Exception: 12.0S retains old syntax
- **New ‘address-family’ structure**
  - Separate unicast & multicast configs
  - Replaces ‘nlri’ clauses
12.1 MBGP Syntax Change

**Old Syntax**
```
router bgp 5
  network 171.69.214.0 mask 255.255.255.0 nlri unicast multicast
  neighbor 171.69.214.38 remote-as 2 nlri unicast
  neighbor 171.69.214.50 remote-as 2 nlri multicast
```

**New Syntax**
```
router bgp 5
  no bgp default ipv4-unicast
  neighbor 171.69.214.38 remote-as 2
  neighbor 171.69.214.50 remote-as 2
  !
  address-family ipv4 unicast
  neighbor 171.69.214.38 activate
  network 171.69.214.0 mask 255.255.255.0
  exit-address-family
  !
  address-family ipv4 multicast
  neighbor 171.69.214.50 activate
  network 171.69.214.0 mask 255.255.255.0
  exit-address-family
```

DVMRP <-> MBGP Redistribution

**DVMRP can be distributed as any other IGP**
```
router bgp <asn>
  redistribute dvmrp route-map <map>
```

**You can do your typical set operations**

**Used to connect legacy sites to the current native multicast Internet.**

**Currently used at the AMES MIX to connect with the old DVMRP MBONE**
Unicast-Multicast NLRI Translation

- Strictly transitional—not recommended
- BGP stubs that don’t have MBGP support need to get their routes into the MBGP backbone
- Stub gets external routes via existing BGP peering
- Use hidden command
  
  \[ \text{neighbor } <\text{foo}> \text{ translate-update [nri unicast multicast]} \]

Unicast-Multicast NLRI Translation

- BGP Update received by translating router is translated into an MP_REACH_NLRI attribute
  - As if the neighbor sent AFI 1/SAFI 2 routes
Unicast-Multicast NLRI Translation

- Arriving Unicast update intercepted by ‘translate-update’ Front-end
- A translated Multicast update is created & passed to the IN Process
- Original Unicast update is passed on to the IN Process
- Both updates processed normally by the IN Process

BGP Only

Stub AS

192.168.100.0/24

192.192.25.0/24

AS 1

router bgp 1
neighbor 192.168.1.1 remote-as 4
neighbor 192.168.1.1 translate-update
neighbor 192.180.1.1 remote-as 3 nlri unicast multicast
neighbor 192.170.1.1 remote-as 2 nlri unicast multicast

MBGP AS

AS 2

AS 3

AS 4

LO0 192.168.1.1

LO0 192.170.1.1

LO0 192.170.1.1
Unicast-Multicast NLRI Translation

BGP Only
Stub AS

AS 4

192.168.1.1

192.168.100.0/24

Unicast Update

NLR: 192.25/24
AS_PATH: 4
MED:
Next-Hop:
...

AS 1

MBGP AS

AS 2

LOO 192.170.1.1

192.192.25.0/24

AS 3

MBGP AS

Multicast Updates
MP_REACH_NLRI: 192.25/24
AFI: 1, Sub-AFI: 2 (multicast)
AS_PATH: 1, 4
MED:
Next-Hop:
...

AS 4

192.168.1.1

192.192.25.0/24

AS 2

LOO 192.170.1.1

AS 3

LOO 192.170.1.1
Unicast-Multicast NLRI Translation

Unicast Updates

NLRI: 192.192.25/24
AS PATH: 1, 4
MED:
Next-Hop:

MBGP—Summary

• Solves part of inter-domain problem
  – Can exchange multicast routing information
  – Uses standard BGP configuration knobs
  – Permits separate unicast and multicast topologies if desired

• Still must use PIM to:
  – Build distribution trees
  – Actually forward multicast traffic
  – PIM-SM recommended
Agenda

- PIM-SM review (forwarding)
- MBGP (routing)
- **MSDP (source discovery)**
- MBGP/MSDP Examples
- SSM (Source Specific Multicast)

MSDP Concept

- Simple but elegant
  - Utilize inter-domain source trees
  - Reduces problem to locating active sources
  - RP or receiver last-hop can join inter-domain source tree
**MSDP Concepts**

- Works with PIM-SM only
  - RP’s knows about all sources in a domain
    - Sources cause a “PIM Register” to the RP
    - Can tell RP’s in other domains of its sources
      - Via MSDP SA (Source Active) messages
  - RP’s know about receivers in a domain
    - Receivers cause a “(*, G) Join” to the RP
    - RP can join the source tree in the peer domain
      - Via normal PIM (S, G) joins

**MSDP Overview**

**MSDP Example**

- MSDP Peers
- Source Active Messages
  - Source Active Message 192.1.1.1, 224.2.2.2
  - Source Active Message 192.1.1.1, 224.2.2.2
  - Source Active Message 192.1.1.1, 224.2.2.2
  - Source Active Message 192.1.1.1, 224.2.2.2

- Join (*, 224.2.2.2)
- Register 192.1.1.1, 224.2.2.2
MSDP Overview

MSDP Example

Domain A
Domain B
Domain C
Domain D
Domain E

RP
RP
RP
RP
RP

S

Join (S, 224.2.2.2)

MSDP Peers

Multicast Traffic
MSDP Overview

MSDP Example

MSDP Peers
Multicast Traffic

Domain A
Domain B
Domain C
Domain D
Domain E

RP
RP
RP
RP
RP

S

Join (S, 224.2.2.2)

Multicast Traffic

MSDP Peers

Domain C
Domain B
Domain D
Domain E
Domain A
RP
RP
RP
RP
RP

Join (S, 224.2.2.2)

Multicast Traffic

MSDP Peers
MSDP Design Points

- MSDP peers talk via TCP connections
- Source Active (SA) messages
  - Peer-RPF forwarded to prevent loops
    - RPF check on AS-PATH back to the peer RP
    - If successful, flood SA message to other peers
    - Stub sites can be configured to accept all SA messages (similar to static default for routing)
      - Since they have only one exit (e.g., default peer)
  - SA messages stored in local cache
    - On by default in latest releases
    - Reduces join latency

MSDP Peers

- MSDP establishes a neighbor relationship between MSDP peers
  - Peers connect using TCP port 639
  - Peers send keepalives every 60 secs (fixed)
  - Peer connection reset after 75 seconds if no MSDP packets or keepalives are received
- MSDP peers must run BGP!
  - May be an MBGP peer, a BGP peer or both
  - Exception: BGP is unnecessary when peering with only a single MSDP peer.
**MSDP SA Messages**

- **MSDP Source Active (SA) Messages**
  - Used to advertise active Sources in a domain
  - Can also carry 1st multicast packet from source
    - Hack for Bursty Sources (ala SDR)
- **SA Message Contents:**
  - IP Address of Originator (RP address)
  - Number of (S, G)’s pairs being advertised
  - List of active (S, G)’s in the domain
  - Encapsulated Multicast packet

**Receiving SA Messages**

- **SA Message RPF Check**
  - Accept SA’s via single deterministic path
    - Ignore all other arriving SA’s
    - Necessary to prevent SA’s from looping
- **Problem**
  - Need to know MSDP topology of Internet
    - But, MSDP does not distribute topology data!
- **Solution**
  - Use (m)BGP data to infer MSDP topology.
    - Impact:
      - The MSDP topology must follow BGP topology.
      - An MSDP peer must generally also be an m(BGP) peer.
Receiving SA Messages

• RPF Check Rules depend on peering
  – Rule 1: Sending MSDP peer = i(m)BGP peer
  – Rule 2: Sending MSDP peer = e(m)BGP peer
  – Rule 3: Sending MSDP peer != (m)BGP peer

• Exceptions:
  – RPF check is skipped when:
    • Sending MSDP peer = Originating RP
    • Sending MSDP peer = Mesh-Group peer
    • Sending MSDP peer = only MSDP peer
      – (i.e. the ‘default-peer’ or the only ‘msdp-peer’ configured.)

Receiving SA Messages

• Determining Applicable RPF Rule
  – Using IP address of sending MSDP peer
    • Find (m)BGP neighbor w/matching IP address
    • IF (no match found)
      – Use Rule 3
    • IF (matching neighbor = i(m)BGP peer)
      – Use Rule 1
    • ELSE {matching neighbor = e(m)BGP peer}
      – Use Rule 2

• Implication
  – The MSDP peer address must be configured using the same IP address as the (m)BGP peer!
RPF Check Rule 1

- When MSDP peer = i(m)BGP peer
  - Find “Best Path” to RP in BGP Tables
    - Search MRIB first then URIB.
    - If no path to Originating RP found, RPF Fails
  - Note “BGP peer” that advertised path
    (i.e. IP Address of BGP peer that sent us this path)
    - **Warning:**
      - *This is not the same as the Next-hop of the path!!!*
      - *i(m)BGP peers normally do not set Next-hop = Self.*
      - *This is also not necessarily the same as the Router-ID!*
  - Rule 1 Test Condition:
    - MSDP Peer address = BGP peer address?
      - If Yes, RPF Succeeds

- Test Condition:
  - *MSDP Peer address = BGP peer address?*

- **Implications:**
  - The MSDP topology must mirror the (m)BGP topology
    - *Specifically, the MSDP peer address must be the same as the i(m)BGP peer address!*
    - If this condition is not met, RPF Check Rule 1 will fail!!!
  - Pay attention to addresses used when configuring MSDP and i(m)BGP peers.
**Rule 1: MSDP peer = i(m)BGP peer**

**SA RPF Check Succeeds**

```
show ip bgp 172.16.5.1
BGP routing table entry for 172.16.6.0/24, version 8745118
Paths: (1 available, best #1)
  7 5, (received & used)
172.16.5.1 (metric 68096) from 172.16.3.1 (172.16.3.1)
```

**SA RPF Check Fails**

```
show ip bgp 172.16.5.1
BGP routing table entry for 172.16.6.0/24, version 8745118
Paths: (1 available, best #1)
  7 5, (received & used)
172.16.5.1 (metric 68096) from 172.16.4.1 (172.16.4.1)
```
Common Mistake #1:
Failure to use same addresses for MSDP peers as i(m)BGP peers!

i(m)BGP Peer address = 172.16.3.1 (advertising best-path to RP)
MSDP Peer address = 172.16.20.1

MSDP Peer address != i(m)BGP Peer address

SA RPF Check Fails

show ip mbgp 172.16.6.1
BGP routing table entry for 172.16.6.0/24, version 8745118
Paths: (1 available, best #1)
7 5, (received & used)
172.16.5.1 (metric 68096) from 172.16.3.1 (172.16.3.1)

Common Mistake #2:
Failure to follow i(m)BGP topology!
Can happen when RR’s are used.

i(m)BGP Peer address = 172.16.1.1 (advertising best-path to RP)
MSDP Peer address = 172.16.3.1

MSDP Peer address != i(m)BGP Peer address

SA RPF Check Fails

show ip mbgp 172.16.6.1
BGP routing table entry for 172.16.6.0/24, version 8745118
Paths: (1 available, best #1)
7 5, (received & used)
172.16.5.1 (metric 68096) from 172.16.1.1 (172.16.1.1)
• When MSDP peer = e(m)BGP peer
  – Find (m)BGP “Best Path” to RP
    • Search MRIB first then URIB.
      – If no path to Originating RP found, RPF Fails
  – Rule 2 Test Condition:
    • First AS in path to the RP = AS of e(m)BGP peer?
      – If Yes, RPF Succeeds

• Test Condition:
  – First AS in path to the RP = AS of e(m)BGP peer?

• Implication:
  – The MSDP topology must mirror the (m)BGP topology
  – Should MSDP peer with the e(m)BGP peer.
    • Normal case is to configure MSDP peering wherever e(m)BGP peering is configured.
      – Exception: When Rule 3 is used.
Router A's BGP Table

<table>
<thead>
<tr>
<th>Network</th>
<th>Next Hop</th>
<th>Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>172.16.3.0/24</td>
<td>172.16.3.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.3.0/24</td>
<td>172.16.4.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.4.0/24</td>
<td>172.16.3.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.4.0/24</td>
<td>172.16.4.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.4.0/24</td>
<td>172.16.4.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.5.0/24</td>
<td>172.16.3.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.5.0/24</td>
<td>172.16.4.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.5.0/24</td>
<td>172.16.4.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.6.0/24</td>
<td>172.16.3.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.6.0/24</td>
<td>172.16.4.1</td>
<td>3 i</td>
</tr>
<tr>
<td>172.16.6.0/24</td>
<td>172.16.4.1</td>
<td>3 i</td>
</tr>
</tbody>
</table>

First-AS in best-path to RP = 3
AS of MSDP Peer = 3

First-AS in best-path to RP = AS of e(m)BGP Peer

SA RPF Check Succeeds

First-AS in best-path to RP = 3
AS of e(m)BGP Peer = 3

SA RPF Check Fails!
**RPF Check Rule 3**

- **When MSDP peer != (m)BGP peer**
  - Find (m)BGP “Best Path” to RP
    - Search MRIB first then URIB.
      - If no path to Originating RP found, RPF Fails
  - Find (m)BGP “Best Path” to MSDP peer
    - Search MRIB first then URIB.
      - If no path to sending MSDP Peer found, RPF Fails
  - Note AS of sending MSDP Peer
    - Origin AS (last AS) in AS-PATH to MSDP Peer
  - **Rule 3 Test Condition:**
    - First AS in path to RP = Sending MSDP Peer AS ?
      - If Yes, RPF Succeeds

---

**Rule3: MSDP peer != BGP peer**

![Diagram showing RPF Check Succeeds](Diagram)

**First-AS in best-path to RP = 3**
**AS of MSDP Peer = 3**

**SA RPF Check Succeeds**

<table>
<thead>
<tr>
<th>Router A's BGP Table</th>
<th>Network</th>
<th>Next Hop</th>
<th>BGP Peer</th>
</tr>
</thead>
<tbody>
<tr>
<td>172.16.3.0/24</td>
<td>172.16.3.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>172.16.3.0/24</td>
<td>172.16.4.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>172.16.4.0/24</td>
<td>172.16.3.1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>172.16.4.0/24</td>
<td>172.16.4.1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>172.16.5.0/24</td>
<td>172.16.3.1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>172.16.6.2/24</td>
<td>172.16.4.1</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>172.16.6.2/24</td>
<td>172.16.3.1</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>172.16.6.2/24</td>
<td>172.16.3.1</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
**Rule 3: MSDP peer != BGP peer**

First-AS in best-path to RP = 3  
AS of MSDP Peer = 1

First-AS in best-path to RP != AS of MSDP Peer

**SA RPF Check Fails**

**MSDP Configuration**

- **Configure peers**
  
  `ip msdp peer <ip-address> [connect-source <i/f>]`

- **Configure default peer**
  
  `ip msdp default-peer <ip-address> [prefix-list acl]`

- **Mesh groups**
  
  `ip msdp mesh-group <name> <ip-address>`
MSDP Configuration

- **Filtering**
  - Can filter SA in/out, groups, with acls or route-maps

- **TTL Scoping**
  - `ip msdp ttl-threshold <ip-address> <ttl>`

- For more configuration commands see:
  - `ftp://ftpeng.cisco.com/ipmulticast/msdp-commands`

---

Midterm Exam

Which protocol...

- ...is used to propagate forwarding state?
  - PIM-SM - Protocol Independent Multicast-Sparse Mode

- ...maintains routing information for interdomain RPF checking?
  - MBGP - Multiprotocol Border Gateway Protocol

- ...exchanges active source information between RPs?
  - MSDP - Multicast Source Discovery Protocol
Agenda

• PIM-SM review (forwarding)
• MBGP (routing)
• MSDP (source discovery)
  • MBGP/MSDP Examples
• SSM (Source Specific Multicast)

MSDP Application—Anycast RP

• draft-ietf-mboned-anycast-rp-05.txt
• Within a domain, deploy more than one RP for the same group range
• Give each RP the same IP address assignment
• Sources and receivers use closest RP
• May be used intra-domain (enterprise) to provide redundancy and RP load sharing
MSDP Application—Anycast RP

- Sources from one RP are made known to other RPs using MSDP
- When an RP goes down, sources and receivers are taken to new RP via unicast routing
  - Fast convergence

Anycast RP – Overview
Anycast RP – Overview

Rec

RP1
10.1.1.1

Rec

10.1.1.1

RP2

Anycast RP Configuration

interface loopback 0
ip address 10.0.0.2 255.255.255.255
interface loopback 1
ip address 10.1.1.1 255.255.255.255
ip msdp peer 10.0.0.1 connect-source loopback 0
ip msdp originator-id loopback 0

interface loopback 0
ip address 10.0.0.1 255.255.255.255
interface loopback 1
ip address 10.1.1.1 255.255.255.255
ip msdp peer 10.0.0.2 connect-source loopback 0
ip msdp originator-id loopback 0
Putting it all together...

- PIM-SM, MBGP, MSDP
- Public multicast peering (MIX)
- Transit topology examples
- Address allocation
  - GLOP draft-ietf-mboned-static-allocation-00.txt

ISP Requirements at the MIX

- Current solution: MBGP + PIM-SM + MSDP
  - Environment
    - ISPs run iMBGP and PIM-SM (internally)
    - ISPs multicast peer at a public interconnect
  - Deployment
    - Border routers run eMBGP
    - The interfaces on interconnect run PIM-SM
    - RPs’ MSDP peering is fully meshed
    - All peers set a common distance for eMBGP
ISP Requirements at the MIX

Peering Solution: MBGP + PIM-SM + MSDP

Multicast Transit Design Objectives

- PIM Border Constraints
  - Confine registers within domain
  - Confine Admin. local groups
  - Confine RP announcements
  - Control SA advertisements via MSDP

- Border RPF check
  - RPF check multicast sources using prefixes from the M-RIB

- MSDP RPF check
  - RPF check received SA’s toward originating RP
Recommended MSDP SA Filter


! domain-local applications
access-list 111 deny ip any host 224.0.2.2 ! Rwhod
access-list 111 deny ip any host 224.0.1.24 ! Microsoft-ds
access-list 111 deny ip any host 224.0.1.22 ! SVRLOC
access-list 111 deny ip any host 224.0.1.2 ! SGI-Dogfight
access-list 111 deny ip any host 224.0.1.35 ! SVRLOC-DA
access-list 111 deny ip any host 224.0.1.60 ! hp-device-disc

!-- auto-rp groups
access-list 111 deny ip any host 224.0.1.39
access-list 111 deny ip any host 224.0.1.40

!-- scoped groups
access-list 111 deny ip any 239.0.0.0 0.255.255.255

!-- loopback, private addresses (RFC 1918)
access-list 111 deny ip 10.0.0.0 0.255.255.255 any
access-list 111 deny ip 127.0.0.0 0.255.255.255 any
access-list 111 deny ip 172.16.0.0 0.15.255.255 any
access-list 111 deny ip 192.168.0.0 0.0.255.255 any

access-list 111 permit ip any any

!-- Default SSM-range. Do not do MSDP in this range
access-list 111 deny ip any 232.0.0.0 0.255.255.255
access-list 111 permit ip any any

Multicast Boundary Filter

Minimum Recommended

! deny auto-rp groups
access-list 1 deny 224.0.1.40
access-list 1 deny 224.0.1.39

! deny scoped groups
access-list 1 deny 239.0.0.0 0.255.255.255

! permit the rest of 224/4
access-list 1 permit 224.0.0.0 15.255.255.255
PIM Border Constraints

Tail-site Customer

- `int pos0/0` ip pim sparse-dense-mode
- `ip pim send-rp-announce Loopback0 scope 255`
- `ip pim send-rp-discovery Loopback0 scope 255`

Transit AS109

- `pos0/0 1.1.1.1`
- `pos0/0 1.1.1.2`

Checking PIM Border (RP mapping)

- `tail-gw#show ip pim rp mapping`
- **Group(s)**: 224.0.0.0/4
  - RP: 3.3.3.7 (loopback.transit.net), v2v1
  - Info source: 1.1.1.2 (tail.transit.net), via Auto-RP
- **Uptime**: 21:57:41, expires: 00:02:08
Checking PIM Border (RP mapping)

Transit-tail#show ip pim rp mapping
PIM Group-to-RP Mappings
This system is an RP (Auto-RP)
This system is an RP-mapping agent
Group(s) 224.0.0.0/4
RP 3.3.3.7 (loopback.transit.net), v2v1
Info source: 3.3.3.7 (loopback.transit.net), via Auto-RP
Uptime: 22:08:47, expires: 00:02:14

Border RPF Check

ip route 0.0.0.0 0.0.0.0 1.1.1.2
ip route 192.168.100.0 255.255.255.0 1.1.1.1
router bgp 109
... network 192.168.100.0 nri unicast multicast
Single-Homed, ISP RP, Non-MBGP

MSDP RPF Check

Tail-site Customer

- no RP / no MSDP

Transit AS109

- no downstream RP
- no downstream MSDP peering

192.168.100.0/24

Receiver

Note: Access-list 111 = Recommended SA Filter

Single-Homed, Customer RP, Non-MBGP

PIM Border Constraints

Tail-site Customer

int pos0/0
ip pim sparse-mode
ip pim bsr-border
ip multicast boundary 1
ip msdp sa-filter out 1.1.1.2 111
ip msdp sa-filter in 1.1.1.2 111

Transit AS109

192.168.100.0/24

Receiver

Note: Access-list 111 = Recommended SA Filter
Single-Homed, Customer RP, Non-MBGP

PIM Border Constraints

Tail-site Customer

Receiver

192.168.100.0/24

RP

pos0/0 1.1.1.1

Transit AS109

RP

pos0/0 1.1.1.2

int pos0/0
ip pim sparse-mode
ip pim bsr-border
ip multicast boundary 1
ip msdp sa-filter out 1.1.1.1 111
ip msdp sa-filter in 1.1.1.1 111

Note: Access-list 111 = Recommended SA Filter

Single-Homed, Customer RP, Non-MBGP

Border RPF Check

Tail-site Customer

Receiver

192.168.100.0/24

RP

pos0/0 1.1.1.1

Transit AS109

RP

pos0/0 1.1.1.2

ip route 0.0.0.0 0.0.0.0 1.1.1.2

ip route 192.168.100.0 255.255.255.0 1.1.1.1
router bgp 109
...network 192.168.100.0 nri unicast multicast
**Single-Homed, Customer RP, Non-MGBP**

**MSDP RPF Check**

```
ip msdp peer 1.1.1.1 connect-source pos0/0
ip msdp peer 1.1.1.2 connect-source pos0/0
```

**PIM Border Constraints**

```
int pos0/0
ip pim sparse-mode
ip pim bsr-border
ip multicast boundary 1
ip msdp sa-filter out 1.1.1.2 111
ip msdp sa-filter in 1.1.1.2 111
```

**Note:** Access-list 111 = Recommended SA Filter
**Single-Homed, Customer RP, MBGP**

### PIM Border Constraints

**Tail-site Customer**

- pos0/0 1.1.1.1
- 192.168.100.0/24

**Transit AS109**

- pos0/0 1.1.1.2

**Note:** Access-list 111 = Recommended SA Filter

- int pos0/0
- ip pim sparse-mode
- ip pim bsr-border
- ip multicast boundary 1
- ip msdp sa-filter out 1.1.1.1 111
- ip msdp sa-filter in 1.1.1.1 111

---

### Border RPF Check

**Tail-site Customer**

- pos0/0 1.1.1.1
- 192.168.100.0/24

**Transit AS109**

- pos0/0 1.1.1.2

**router bgp 100**

- network 192.168.100.0 nlri unicast multicast
- neighbor 1.1.1.2 remote-as 109 nlri unicast multicast
- neighbor 1.1.1.2 update-source pos0/0

**router bgp 109**

- neighbor 1.1.1.1 remote-as 100 nlri unicast multicast
- neighbor 1.1.1.1 update-source pos 0/0
**Single-Homed, Customer RP, MBGP**

### MSDP RPF Check

- **Tail-site Customer**
  - RP
  - 192.168.100.0/24
  - Receiver

- **Transit AS109**
  - RP

```
ip msdp peer 1.1.1.1 connect-source pos0/0
ip msdp peer 1.1.1.2 connect-source pos0/0
```

**RP pos0/0 1.1.1.1**

**RP pos0/0 1.1.1.2**

**Incongruent Multicast**

- **Unicast Transit**
  - Transit AS110
  - pos1/0 1.1.2.1
  - Unicast

- **Multicast Transit**
  - Transit AS109
  - pos0/0 1.1.1.2

**RP pos0/0 1.1.1.1**

**RP pos0/0 1.1.1.2**

**Dual-Homed, Customer RP, MBGP**

### PIM Border Constraints

- **Customer AS100**
  - RP
  - 192.168.100.0/24
  - Receiver

- **Transit AS109**
  - RP

```
int pos0/0
ip pim sparse-mode
ip pim bsr-border
ip multicast boundary 1
int pos1/0
ip msdp sa-filter out 1.1.1.2 111
ip msdp sa-filter in 1.1.1.2 111
```

**RP pos0/0 1.1.1.1**

**RP pos0/0 1.1.1.2**

**IP pos0/0 1.1.1.1**

**IP pos0/0 1.1.1.2**

**Unicast Transit**

**Transit AS110**

**Multicast Transit**
PIM Border Constraints

Customer AS100

pos0/0 1.1.1.1

pos1/0 1.1.2.1

Transit AS109

pos0/0 1.1.1.2

pos1/0 1.1.2.2

Transit AS110

192.168.100.0/24

Hey, this site knows no multicast so there is no PIM to constrain
Dual-Homed, Customer RP, MBGP
Incongruent Multicast—Unicast

Border RPF Check

Customer AS100

- pos0/0 1.1.1.1
- pos1/0 1.1.2.1

Transit AS109

- Multicast Transit

Transit AS110

- Unicast Transit

Receiver

192.168.100.0/24

router bgp 109
neighbor 1.1.1.1 remote-as 100 nlrri unicast multicast
neighbor 1.1.1.1 update-source pos 0/0

Multicast

Transit

Unicast

Transit
**Dual-Homed, Customer RP, MBGP Incongruent Multicast—Unicast**

### Border RPF Check

- **Customer AS100**
  - RP
  - pos0/0 1.1.1.1
  - pos1/0 1.1.2.1
- **Transit AS109**
  - Multicast Transit
  - pos0/0 1.1.1.2
- **Transit AS110**
  - Unicast Transit
  - pos0/0 1.1.2.2

#### Router Configuration
- `router bgp 110`
- `neighbor 1.1.2.1 remote-as 100`
- `neighbor 1.1.2.1 update-source pos0/0`

### MSDP RPF Check

- **Customer AS100**
  - RP
  - pos0/0 1.1.1.1
  - pos1/0 1.1.2.1
- **Transit AS109**
  - Multicast Transit
  - pos0/0 1.1.1.2
- **Transit AS110**
  - Unicast Transit
  - pos0/0 1.1.2.2

#### MSDP Configuration
- `ip msdp peer 1.1.1.2 connect-source pos0/0`
- `ip msdp peer 1.1.1.1 connect-source pos0/0`

*Again, no multicast clue. Then no MSDP peering.*
Dual-Homed, Customer RP, MBGP Congruent Multicast—Unicast

PIM Border Constraints

Customer AS100

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>pos0/0</td>
<td>1.1.1.1</td>
</tr>
<tr>
<td>pos0/0</td>
<td>1.1.1.2</td>
</tr>
<tr>
<td>pos1/0</td>
<td>1.1.2.1</td>
</tr>
</tbody>
</table>

Transit AS110

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>pos1/0</td>
<td>1.1.2.1</td>
</tr>
<tr>
<td>pos0/0</td>
<td>1.1.2.2</td>
</tr>
</tbody>
</table>

Dual-Homed, Customer RP, MBGP Congruent Multicast—Unicast

PIM Border Constraints

Customer AS100

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>int pos0/0</td>
<td>1.1.1.1</td>
</tr>
<tr>
<td>int pos0/0</td>
<td>1.1.1.2</td>
</tr>
</tbody>
</table>

Transit AS109

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>int pos1/0</td>
<td>1.1.2.1</td>
</tr>
</tbody>
</table>

Transit AS110

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>int pos1/0</td>
<td>1.1.2.1</td>
</tr>
</tbody>
</table>

ip pim sparse-mode
ip pim bsr-border
ip multicast boundary 1
ip msdp sa-filter out 1.1.1.2 111
ip msdp sa-filter in 1.1.1.2 111
ip msdp sa-filter out 1.1.2.2 111
ip msdp sa-filter in 1.1.2.2 111

ip msdp sa-filter out 1.1.1.1 111
ip msdp sa-filter in 1.1.1.1 111
Dual-Homed, Customer RP, MBGP Congruent Multicast—Unicast

PIM Border Constraints

Customer AS100
pos0/0 1.1.1.1
pos0/0 1.1.1.2
pos1/0 1.1.2.1
192.168.100.0/24

Transit AS109

Unicast & Multicast Transit

Transit AS110

Unicast & Multicast Transit

int pos0/0
ip pim sparse-mode
ip pim bsr-border
ip multicast boundary 1
ip msdp sa-filter out 1.1.2.1 111
ip msdp sa-filter in 1.1.2.1 111

Border RPF Check

Customer AS100
pos0/0 1.1.1.1
pos0/0 1.1.1.2
pos1/0 1.1.2.1
192.168.100.0/24

Transit AS109

Unicast & Multicast Transit

Transit AS110

Unicast & Multicast Transit

router bgp 100
network 192.168.100.0 niri unicast multicast
neighbor 1.1.1.2 remote-as 100 niri unicast multicast
neighbor 1.1.1.2 update-source pos0/0
neighbor 1.1.2.2 remote-as 110 niri unicast multicast
neighbor 1.1.2.2 update-source pos1/0
Dual-Homed, Customer RP, MBGP
Congruent Multicast—Unicast

Border RPF Check

Customer AS100

RP

pos0/0 1.1.1.1

pos1/0 1.1.2.1

192.168.100.0/24

Receiver

Transit AS109

Unicast & Multicast
Transit

Transit AS110

Unicast & Multicast
Transit

router bgp 109
neighbor 1.1.1.1 remote-as 100 nlri unicast multicast
eighbor 1.1.1.1 update-source pos 0/0

router bgp 110
neighbor 1.1.2.1 remote-as 100 nlri unicast multicast
neighbor 1.1.2.1 update-source pos 0/0
**Dual-Homed, Customer RP, MBGP Congruent Multicast—Unicast**

MSDP RPF Check

- Customer AS100
- Transist AS109
  - pos0/0 1.1.1.1
  - pos1/0 1.1.2.1
  - ip msdp peer 1.1.1.1 connect-source pos0/0
  - ip msdp peer 1.1.1.2 connect-source pos1/0
  - 192.168.100.0/24
  - pos0/0 1.1.1.2
  - pos0/0 1.1.2.2

- Transist AS110
  - pos0/0 1.1.1.1
  - pos0/0 1.1.2.1
  - ip msdp peer 1.1.1.1 connect-source pos0/0
  - ip msdp peer 1.1.2.1 connect-source pos0/0

**GLOP—Static Allocation of 233/8**

- Temporary allocation of 233/8
  - rfc2770
- Statically assigned by mapping AS number into middle octets.
  - http://gigapop.uoregon.edu/glop/index.html
- Provides each AS with /24 addresses to use while waiting another solution
Agenda

- PIM-SM review (forwarding)
- MBGP (routing)
- MSDP (source discovery)
- MBGP/MSDP Examples
- SSM (Source Specific Multicast)

Source Specific Multicast

- Assume a One-to-Many Multicast Model.
  - Example: Video/Audio broadcasts, Stock Market data
- Why does PIM-SM need a Shared Tree?
  - So that hosts and 1st hop routers can learn who the active source is for the group.
- What if this was already known?
  - Hosts could use IGMPv3 to signal *exactly* which (S,G) SPT to join.
  - The Shared Tree & RP wouldn’t be necessary.
  - Different sources could share the same Group address and not interfere with each other.
- Result: Source Specific Multicast (SSM)
Source Specific Multicast

- Simplify solution for well-known sources, particularly in cases where there is a single source sending to a given group.
  - Allow immediate use of shortest forwarding path to a specific source, without need to create shared tree.
  - Eliminate dependence on MSDP for finding sources.
  - Simplify address allocation for global, single source groups when combined with elimination of shared trees (232/8).

PIM Source Specific Mode

Receiver learns of source, group/port
Receiver sends IGMPv3 (S,G) Join
First-hop sends PIM (S,G) Join directly toward Source

(S, G) Join

IGMPv3 (S, G) Join

Out-of-band source directory, example: web server

Receiver
PIM Source Specific Mode

Result: Shortest path tree rooted at the source, with no shared tree.

Out-of-band source directory, example: web server

Receiver

Objective of SSM Multicast

Optimize multicast forwarding when sources are few and specifically known to receiver in advance of joining.
Where Is SSM?

- Framework
  draft-holbrook-ssm-arch-02.txt
- BCP proposal
  draft-ietf-mboned-ssm232-01.txt
- Supported in IOS 12

More Information

- White Papers
- Web and Mailers
- Cisco Press
  RTFB = “Read the Fine Book”

CCO Multicast page:
http://www.cisco.com/go/ipmulticast

Questions:
  cs-ipmulticast@cisco.com
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  tac@cisco.com
Please Complete Your Evaluation Form
Session RST-222