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Your Time Is Now

Scaling BGP

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BRKRST-3321

Agenda

- Introduction
- Goal
- Scale Challenges
- Memory Utilization
- Full mesh iBGP
- Update Groups
- Slow Peer
- RR Problems & Solutions
- Deployment
- Multi-Session
- MPLS VPN
- OS Enhancements
- Key Takeaways

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“We’re Gonna Need a Bigger Boat”

Jaws

Goal of this Session

Covered

- Causes of scale challenges
- Solutions for scaling BGP
- What you control
  - Pick the right BGP feature
  - Design the network properly

Not covered

- Scaling numbers
  - # neighbors, # prefixes, #convergence time
- Buy a bigger box

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Success of BGP - Scale Challenges

- BGP has been around forever
- Very robust
- Scales the Internet’s growth
- More features
- More multipath, faster convergence

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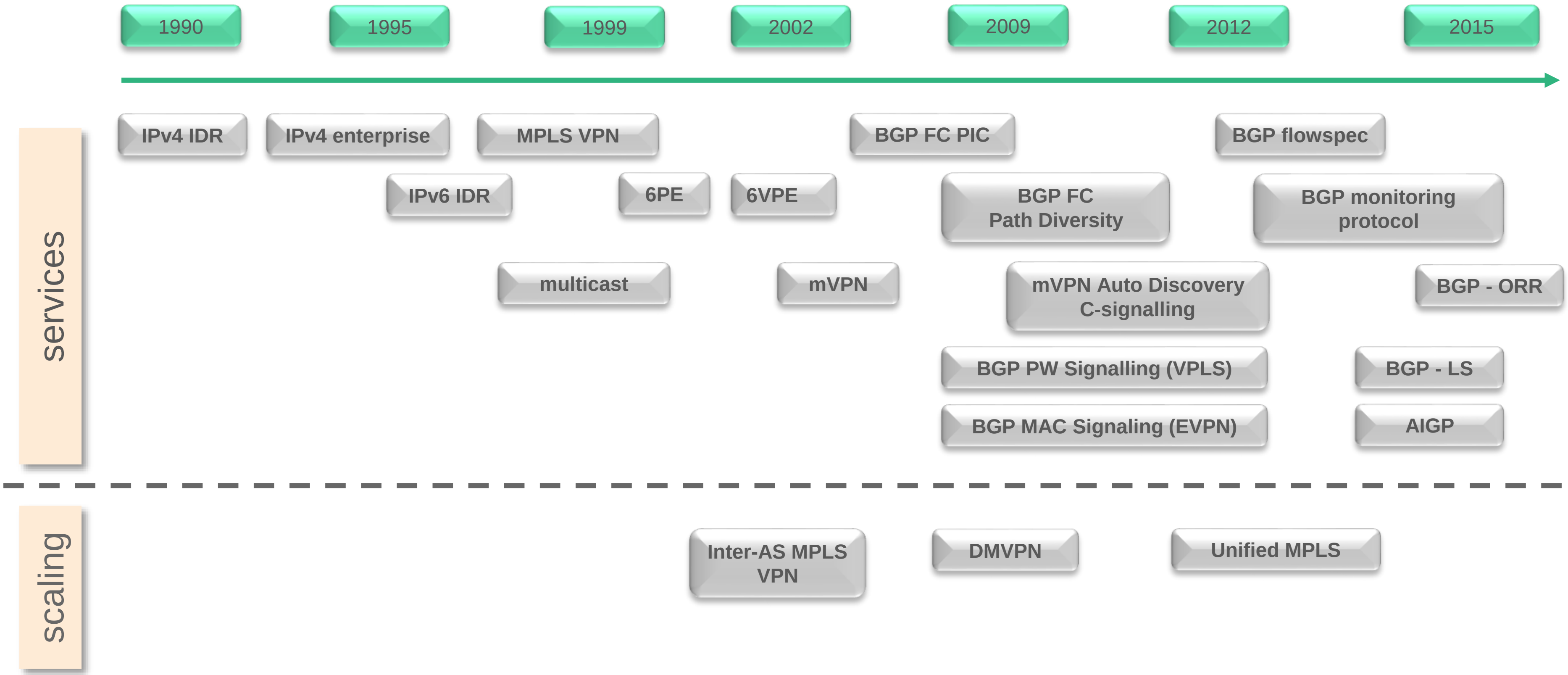
More Services by BGP



1990

1995

1999

2002

2009

2012

2015

services

IPv4 IDR

IPv4 enterprise

MPLS VPN

BGP FC PIC

BGP flowspec

IPv6 IDR

6PE

6VPE

BGP FC Path Diversity

BGP monitoring protocol

multicast

mVPN

mVPN Auto Discovery C-signalling

BGP - ORR

BGP PW Signalling (VPLS)

BGP - LS

BGP MAC Signaling (EVPN)

AIGP

scaling

Inter-AS MPLS VPN

DMVPN

Unified MPLS

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Service Address Families

For Your Reference

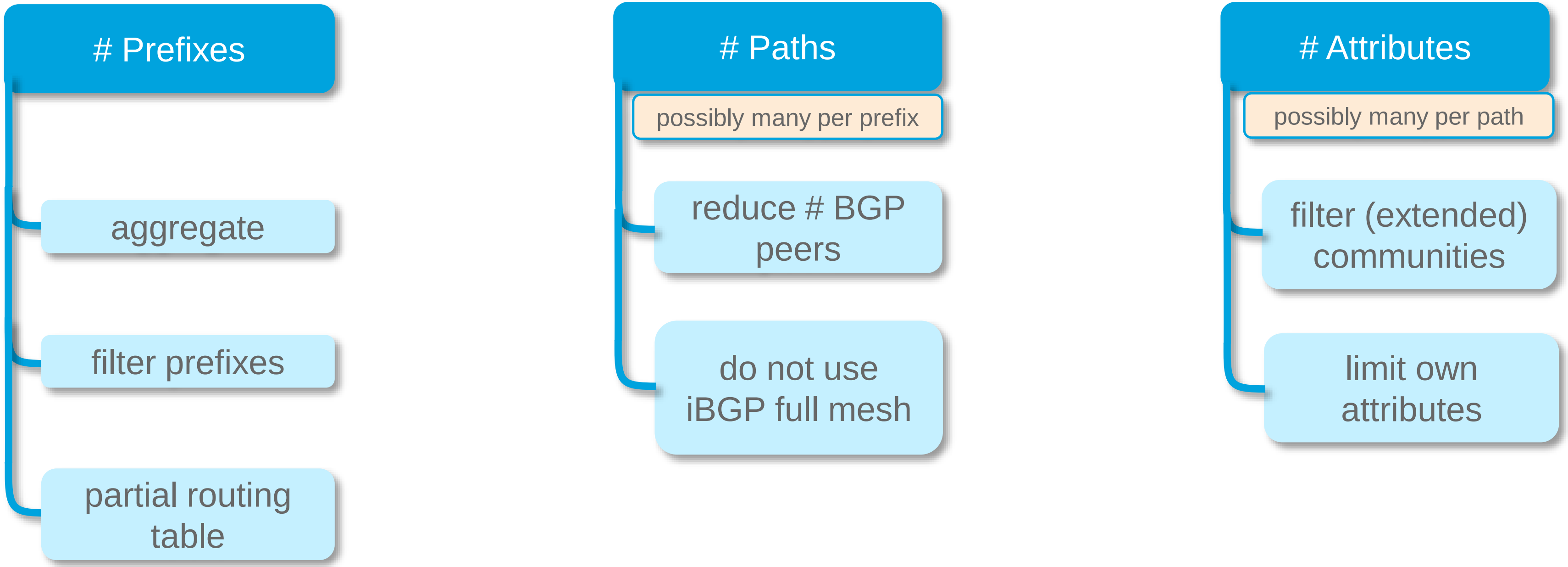
IPv4 unicast vpn Layer 2

IPv6 multicast multicast in overlay linkstate

IPv4 unicast	IPv6 unicast	vpnv4 unicast	nsap unicast	IPv4 Flowspec
IPv4 multicast	IPv6 multicast	vpnv4 multicast	l2vpn vpls	IPv6 Flowspec
IPv4 MVPN	IPv6 MVPN	vpnv6 unicast	l2vpn evpn	vpnv4 Flowspec
IPv4 MDT		vpnv6 multicast	l2vpn mspw	vpnv6 Flowspec
IPv4 tunnel		rtfilter unicast	linkstate	

Memory Utilization

High Memory Utilization - Solutions



# Prefixes

- aggregate
- filter prefixes
- partial routing table

Paths

possibly many per prefix

- reduce # BGP peers
- do not use iBGP full mesh

Attributes

possibly many per path

- filter (extended) communities
- limit own attributes

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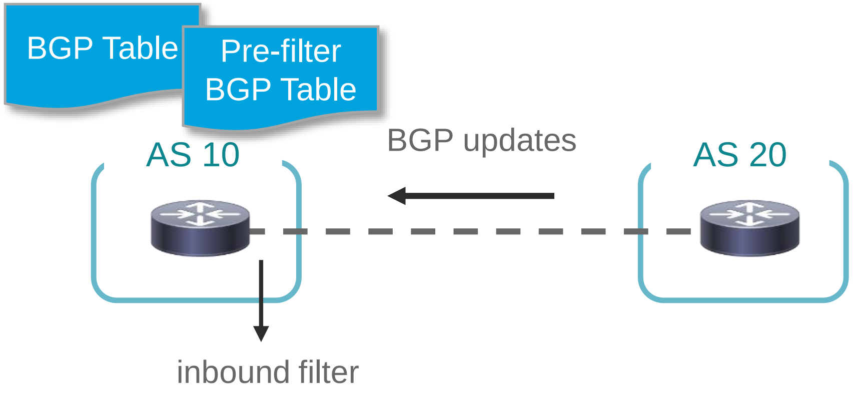
High Memory Utilization

soft reconfiguration inbound



BGP Table

Pre-filter BGP Table

AS 10

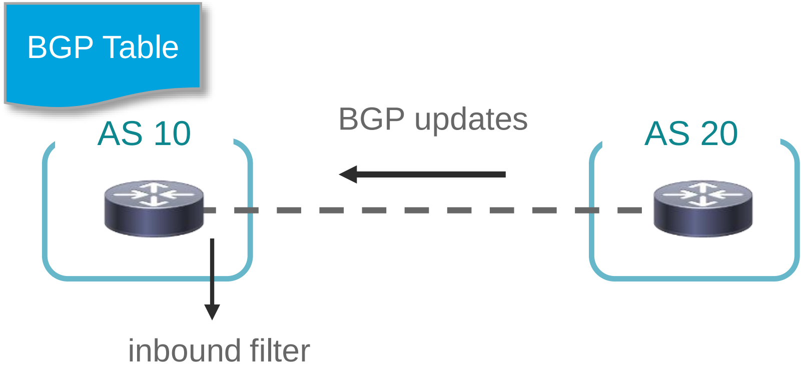
BGP updates

AS 20

inbound filter

- Filtered prefixes are stored: much more memory used
- Support only on router itself
- Changed filter: re-apply policy to table with filtered prefixes

route refresh



BGP Table

AS 10

BGP updates

AS 20

inbound filter

- Filtered prefixes are dropped
- Support needed on peer, but this a very old feature
- Changed filter: router sends out route refresh request to peer to get the full table from peer again

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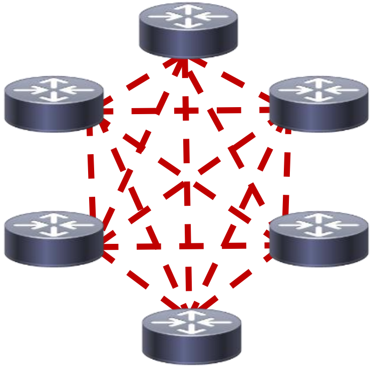
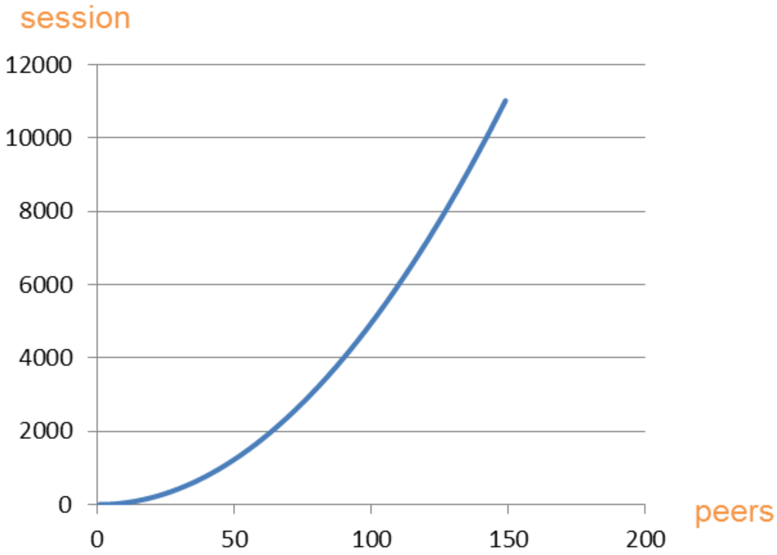
Full Mesh iBGP

Is Full Mesh iBGP Scalable?

- Per BGP standard: iBGP needs to be full mesh
- Total iBGP sessions = n * (n-1) / 2
- Sessions per BGP speaker = n - 1





- Two solutions
  1. Confederations
  2. Route reflectors

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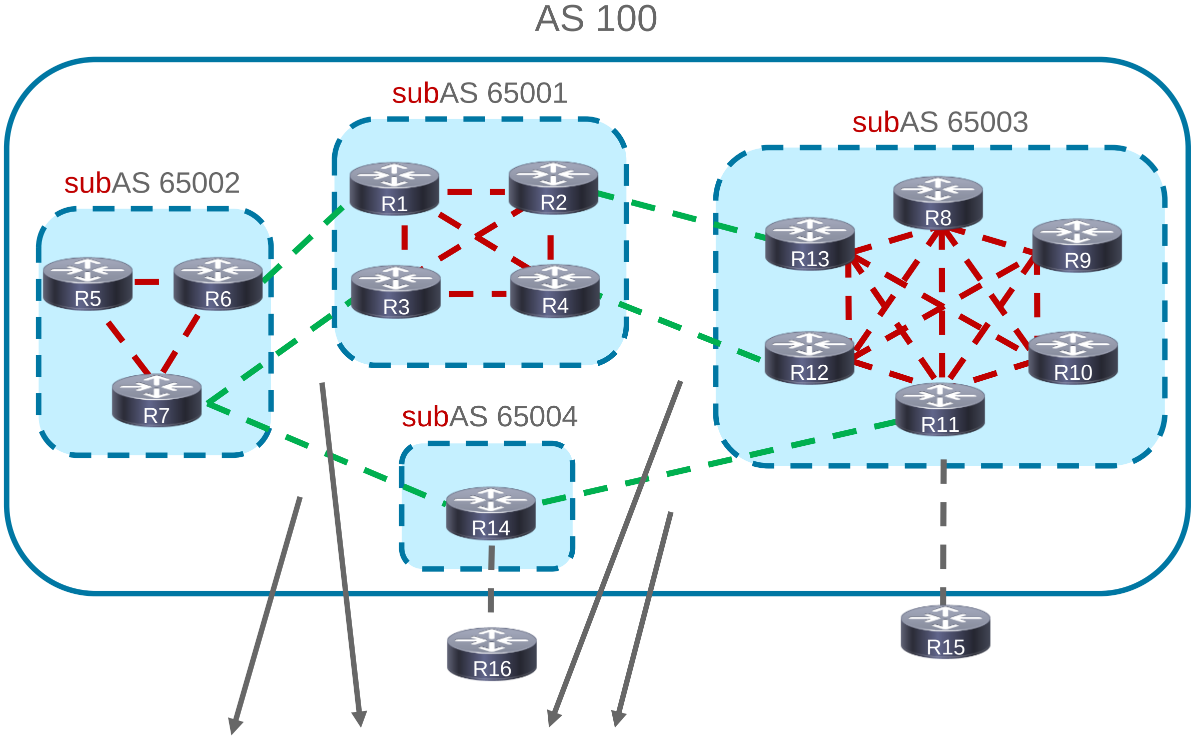
Confederations

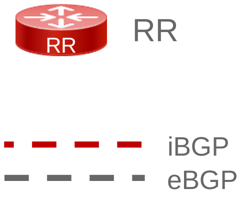
- Create # of sub-AS inside the larger confederation
- Conferation AS looks like normal AS to the outside
- Full mesh iBGP still needed inside subAS
- No full mesh needed between subAS (it’s eBGP)
- Every BGP peer needs to be in a subAS
- Each subAS can have different IGP with next-hop-self within confed
- No connectivity needed between any subAS’s



- Flexible confed eBGP peerings
- Redundancy needed vs increased memory/CPU
- But full mesh between subAS’s is not needed

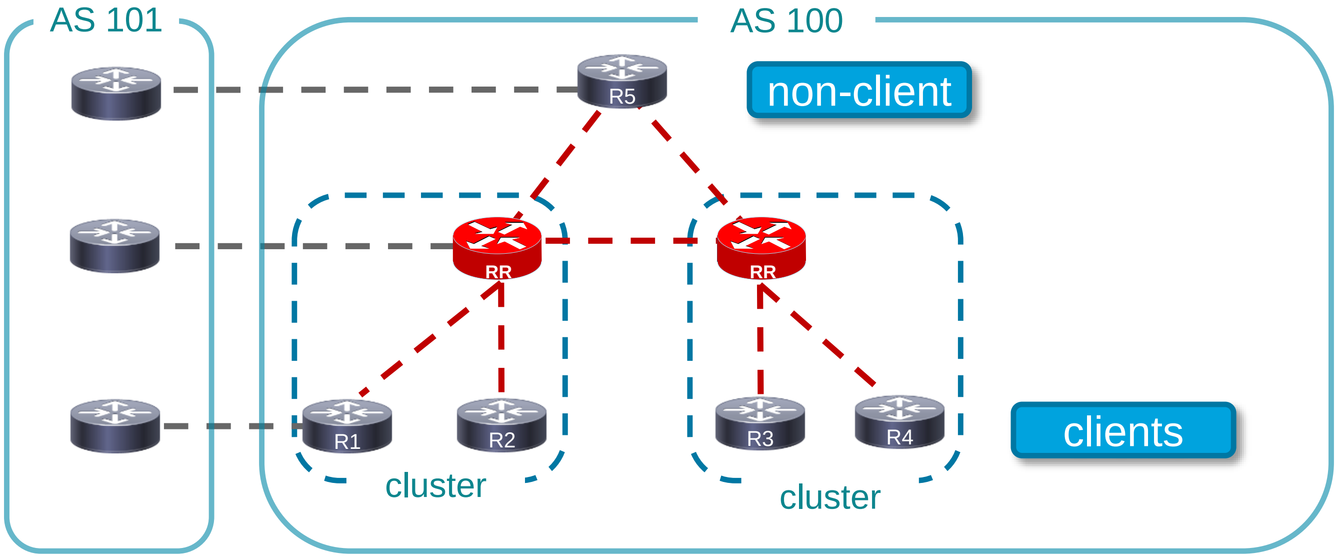
Route Reflectors

- A route reflector is an iBGP speaker that reflects routes learned from iBGP peers to other iBGP peers, called RR clients
- iBGP full mesh is turned into hub-and-spoke
- RR is the hub in a hub-and-spoke design



Any router can peer eBGP

RR clients are regular iBGP peers



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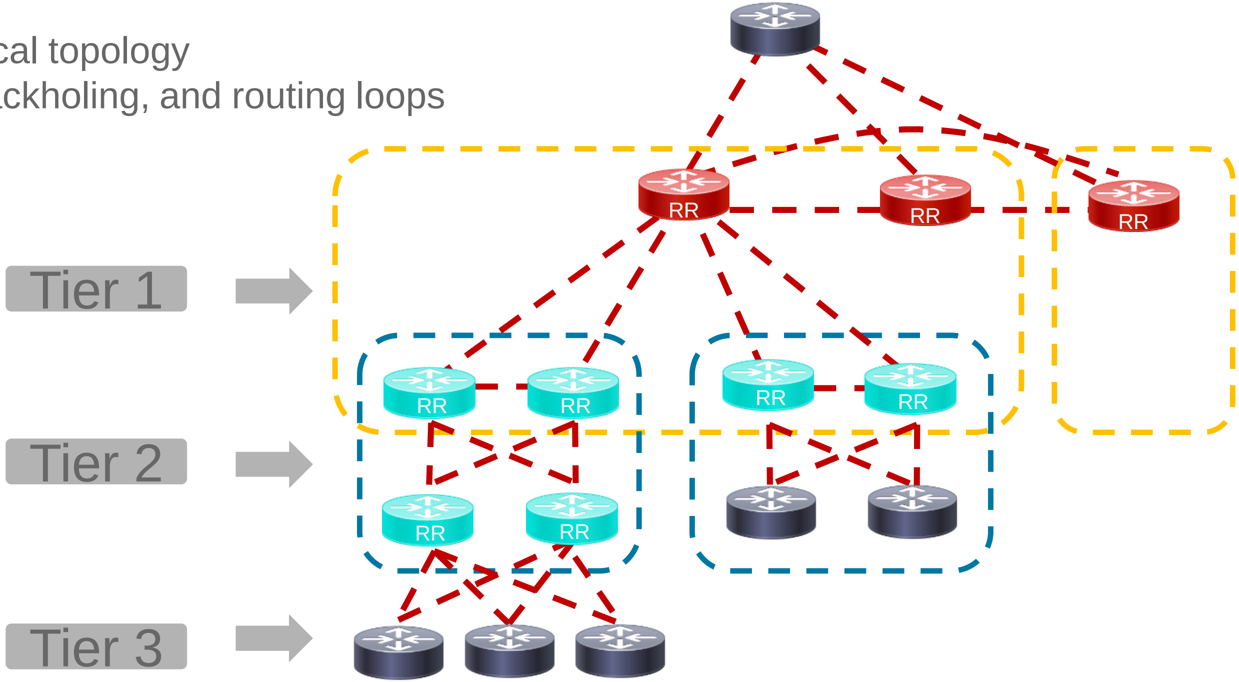
Hierarchical Route Reflectors

RR

RR & RR client

- Chain RRs to keep the full mesh between RRs and non-clients small
- Make RRs clients of other RRs
- RR is a RR and RR client at the same time
- iBGP topology should follow physical topology
  - Prevents suboptimal routing, blackholing, and routing loops

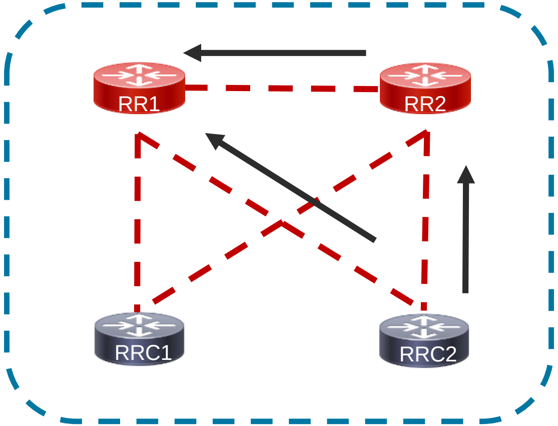


  - RRs in top tier need to be fully meshed

  - There is no limit to the amount of tiers

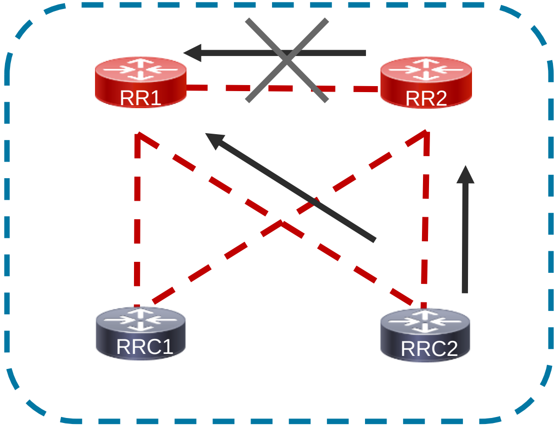
Route Reflector – Same Cluster-ID or Not?

RR1 and RR2 have different cluster-ID (default)



- RR1 stores the path from RR2
- RR1 uses additional CPU and memory
- Potentially for many routes
- Additional memory and processor overhead on RR

RR1 and RR2 have the same cluster-ID



- RR1 has only 1 path for routes from RRC2
- If one link RR to RR-client fails
  - iBGP session remains up, it is between loopback IP addresses
- Less redundant paths

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Picking RRs

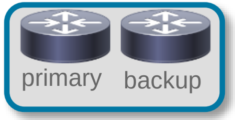
How many?

Redundancy

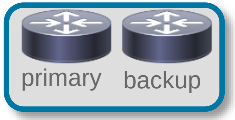
Sets of two

Services

- To scale: sets (per group of) address families



service 1
(one or more AFs)



service 2
(one or more AFs)

Where?

Location

- Geo
- Datacenter
- Region

Which kind?

Dedicated RR

No forwarding (no FIB)
RIB and BGP/IGP

Needed Resources

Memory
CPU

7200

ASR1K

Virtual router

- Mobility
- Manageability
- Same BGP implementation and software version as deployed on the Edge (XE/XR)
- Reduced physical footprint (power/cooling/cabling)
- Performance (multi-core) / memory (64-bit)

CSR1000V

ASR9Kv
(vRR)

BGP RR Scale - Selective RIB Download

- To block some or all of the BGP prefixes into the RIB (and FIB)
- Only for RR which is not in the forwarding path
- Saves on memory and CPU
- Implemented as filter extension to table-map command

- For AFs IPv4/6
  - not needed for AFs vpnv4/6
- Benefit
  - ASR1k testing indicated 300% of RR-client session scaling (in order of 1000s)

configuration

```
router bgp 1

 address-family ipv4
  table-map block-into-fib filter

route-map block-into-fib deny 10
```

no BGP prefixes in RIB

```
RR1#show ip route bgp


RR1#
```

no BGP prefixes in FIB

```
RR1#show ip cef



RR1#
```

configuration IOS-XR

```
route-policy block-into-fib
 if destination in (...) then
   drop
 else
   pass
 end-if
```

```
router bgp 1

 address-family ipv4 unicast
  table-policy block-into-fib
```

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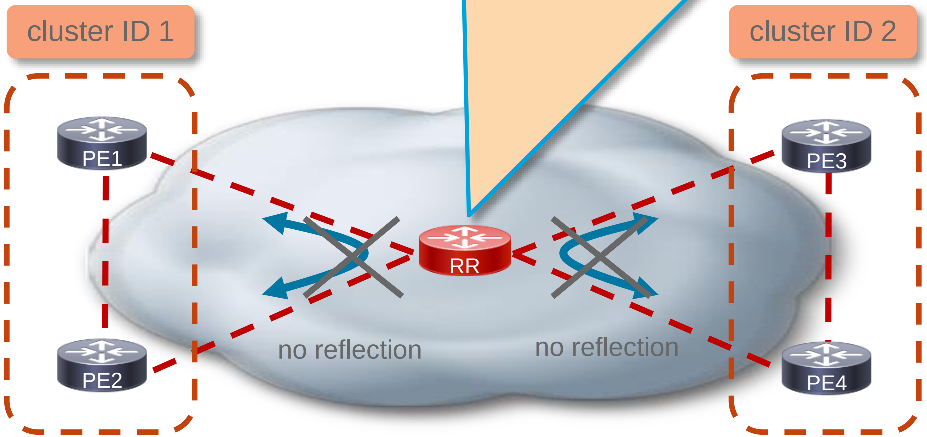
Multi-Cluster ID

```
router bgp 1
 no bgp client-to-client reflection intra-cluster cluster-id 0.0.0.1
 no bgp client-to-client reflection intra-cluster cluster-id 0.0.0.2
```

- An RR can belong to multiple clusters
  - On IBGP neighbor of RR: cluster IDs on a per-neighbor basis
  - The global cluster ID is still there
  - Intra-cluster client-to-client reflection can be disabled, when clients are meshed
  - Can be disabled for all clusters or per cluster
    - More work - sending more updates - for RR clients
    - Less work - sending fewer updates - for RRs



- Each set of peers in cluster ID has its own update group
- Loop-prevention mechanism is modified
  - Taking into account multiple cluster IDs

Full Mesh eBGP

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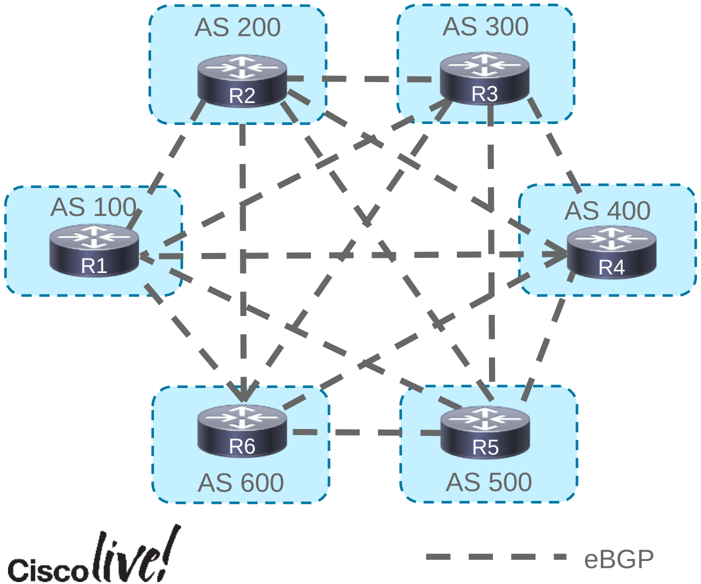
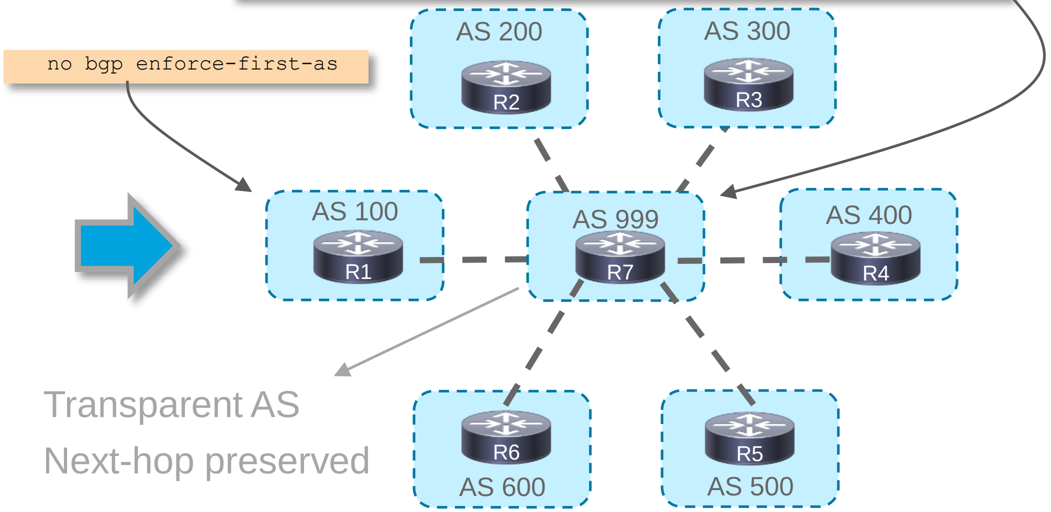
BGP Route Server

- Alternative to eBGP full mesh
- Used by IX (Internet eXchange) providers
- Operational simplicity
- Reduces CPU/memory/configuration
- Context policy can be used

```
router bgp 999
 route-server-context rs-context
  !
  address-family ipv4 unicast
   import-map rs-import-map
 !
 neighbor 10.1.1.1 remote-as 100
 !
 address-family ipv4
  neighbor 10.1.1.1 route-server-client context rs-context
!
ip as-path access-list 100 permit ^200$
!
route-map rs-import-map permit 10
 match as-path 100
```





`no bgp enforce-first-as`

Transparent AS

Next-hop preserved

Update Groups

Grouping of BGP Neighbors: Optimization

Configuration/administration

- peer groups
- templates, session-groups, af-groups, neighbor-group

- CLI only

- BGP neighbors with same outbound policy will be put in the same update group regardless if
  - peer-groups are defined
  - templates are defined
  - neighbors are individually defined

Performance/scalability

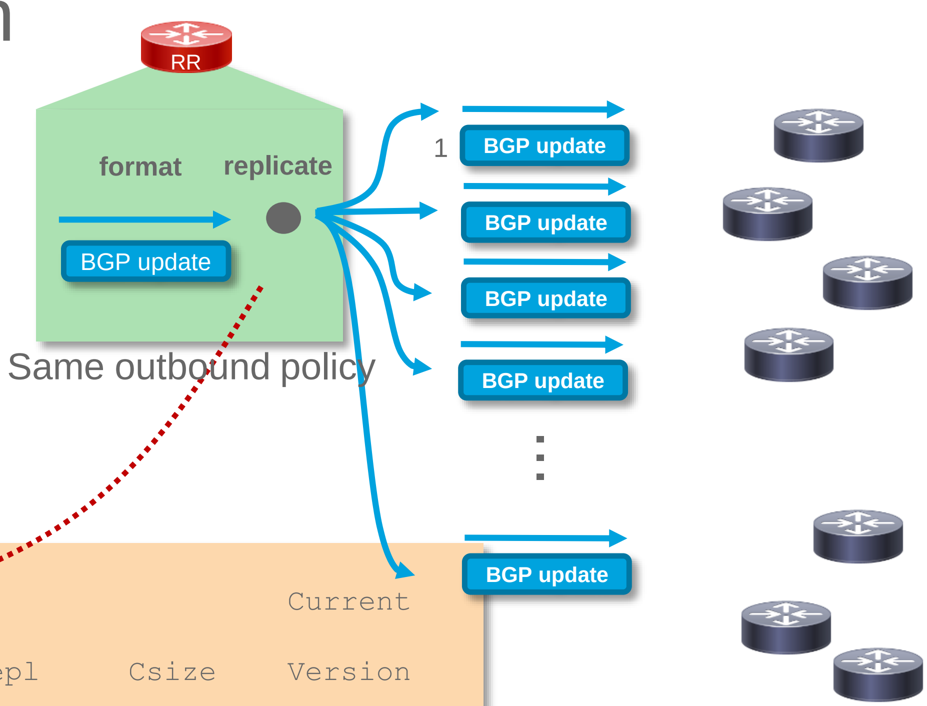
- update groups

- Dynamic grouping BGP of peers according to common outbound policy
- Networks that have the same best-path attributes can be grouped into the same message improving packing efficiency
- BGP formats the update messages once and then replicates to all members of the update group
- replication instead of formatting updates per neighbor: efficiency
- dynamic = policy changes, update group membership changes
- AF independent : a peer can belong to different update groups in different address families

IOS

Update Group Replication

- Update groups are very usefull on all BGP speakers
  - but mostly on RR due to
    - # of peers
    - equal outbound policy
- iBGP typically has no outbound policy
  - RRs have large number of iBGP peers in one update group



```
RR#show ip bgp replication 2
                                                                    Current
Next
Index  Members          Leader      MsgFmt    MsgRepl     Csize     Version
Version
    2       101       10.100.1.2      2013      24210    0/2000        3201/0
```

update group 2

total # of members

formatting according to leader's policy

# of formatted messages

# of replications

size of cache

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Update Groups in IOS

- Cache = place to store formatted BGP message, before they are send
- Cache is adaptive -> faster convergence
  - queue depth from 100 to 5000
    - Number of peers in an update groups
    - Installed system memory
    - Type of address family
    - Type of peers in an update group
- Parallel processing of Route-Refresh/new BGP peers
  - By tracking the (re-)starting BGP peers: process full update to these peers, while maintaining transient updates to established peers
  - By using special refresh update groups for (re-)starting peers

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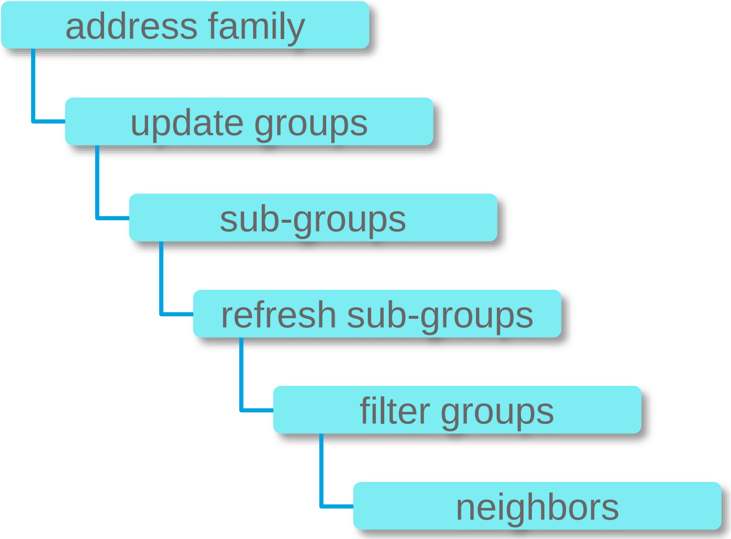
IOS-XR

Update Groups in IOS XR



```
RP/0/6/CPU0:router#show bgp vpnv4 unicast update-group

Update group for VPNv4 Unicast, index 0.2:
  Attributes:
    Internal
    Common admin
    First neighbor AS: 1
    Send communities
    Send extended communities
    Route Reflector Client
    4-byte AS capable
    Send AIGP
    Minimum advertisement interval: 0 secs
  Update group desynchronized: 0
  Sub-groups merged: 5
  Number of refresh subgroups: 0
  Messages formatted: 36, replicated: 68
  All neighbors are assigned to sub-group(s)
    Neighbors in sub-group: 0.2, Filter-Groups num:3
     Neighbors in filter-group: 0.3(RT num: 3)
      10.1.100.1
     Neighbors in filter-group: 0.1(RT num: 3)
      10.1.100.2
     Neighbors in filter-group: 0.2(RT num: 3)
      10.1.100.8
```

Slow Peer

Slow Peer

IOS

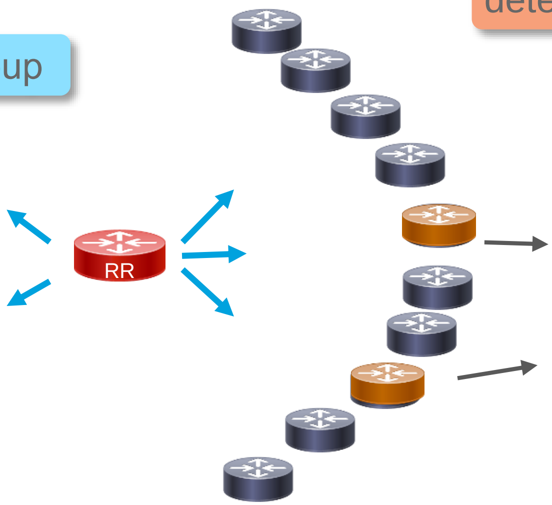
update group 1

detection phase track peer queue

protection phase "slow" update group

recovery phase

slow update group is no longer slow



- slow peer = cannot keep up with the rate at which we are generating update messages over a prolonged period of time (order of minutes)
- filled up cache: blocking all peers

Possible causes

- High CPU
- Transport issues (packet loss/loaded links/TCP)

convergence speed of update goup OK

```
%BGP-5-SLOWPEER_DETECT: Neighbor IPv4 Unicast 10.100.1.1 has been detected as a slow peer
```

```
%BGP-5-SLOWPEER_RECOVER: Slow peer IPv4 Unicast 10.100.1.1 has recovered
```

Allows for fast and slow peers to proceed at the their own speed

Slow Peer CLI

configuration

detection

- per AF
- per VRF
- per peer
- per peer policy template

protection

static

- per AF
- per peer(-group)
- per peer policy template

dynamic

- per VRF
- per peer
- per peer policy template

optional: permanent = peer is not moved back automatically to the update group

show commands

show bgp ... *slow* command

clear commands

clear bgp ... slow command

This is a forced clear of the slow-peer status; the peer is moved to the original update group

Old Slow Peer Solution

Solution before this feature: manual movement

- Create a different outbound policy for the slow peer
- Policy must be different than any other
  - You do not want the slow peer to move to another already existing update group
- Use something that does not affect the actual policy
  - For example: change minimum advertisement interval (MRAI) of the peer (under AF)
  - Also avoiding the cause for a full update (equivalent of a route-refresh)

```
router bgp 1
 address-family vpnv4
  neighbor 10.100.1.1 advertisement-interval 1
```

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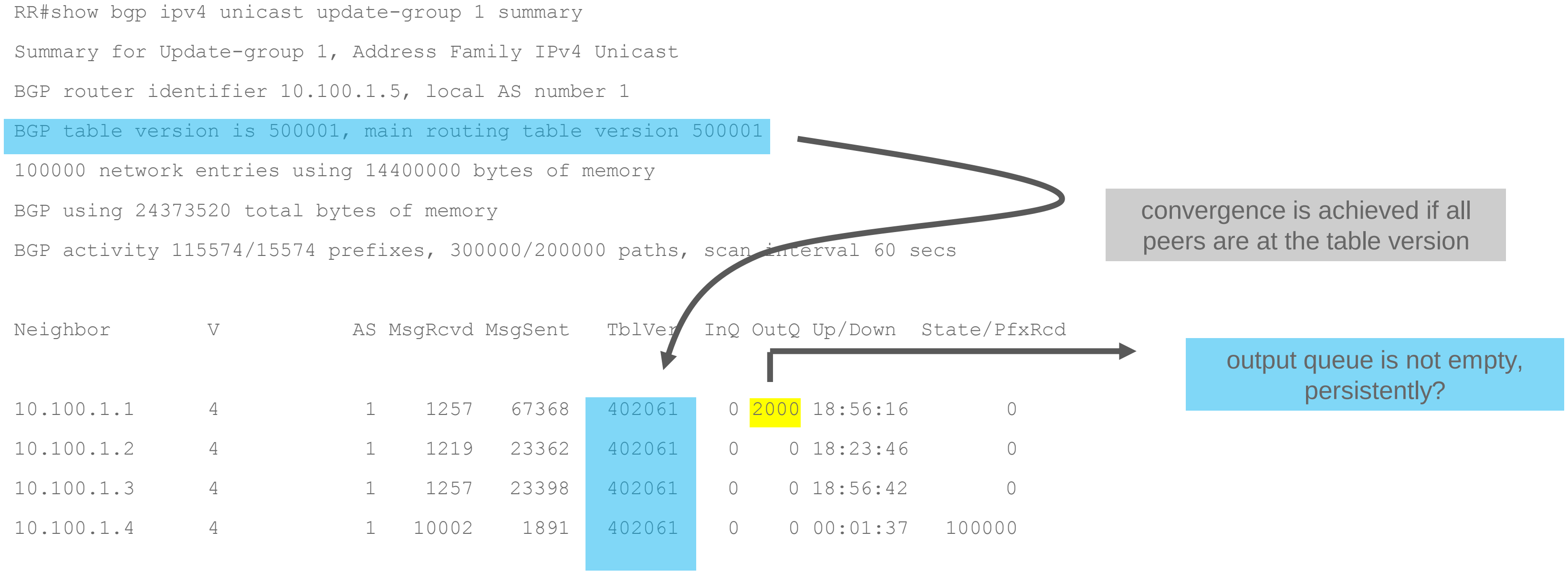
Slow Peer Mechanism Details

Identifying Slow Peer

For Your Reference



```
RR#show bgp ipv4 unicast update-group 1 summary
Summary for Update-group 1, Address Family IPv4 Unicast
BGP router identifier 10.100.1.5, local AS number 1
BGP table version is 500001, main routing table version 500001
100000 network entries using 14400000 bytes of memory
BGP using 24373520 total bytes of memory
BGP activity 115574/15574 prefixes, 300000/200000 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd

10.100.1.1      4            1    1257   67368   402061    0 2000 18:56:16        0
10.100.1.2      4            1    1219   23362   402061    0    0 18:23:46        0
10.100.1.3      4            1    1257   23398   402061    0    0 18:56:42        0
10.100.1.4      4            1   10002    1891   402061    0    0 00:01:37   100000
```

convergence is achieved if all peers are at the table version

output queue is not empty, persistently?

RR Problems & Solutions

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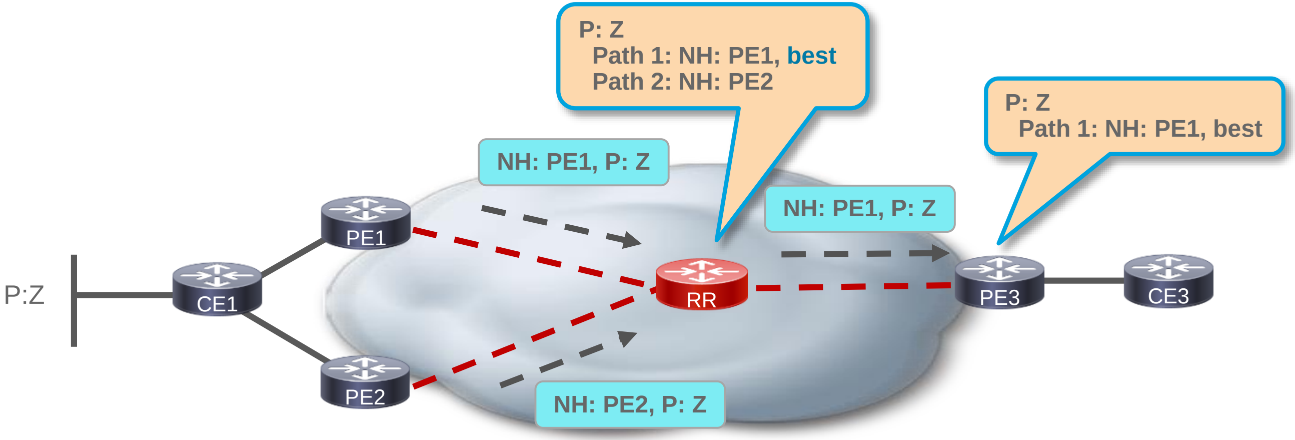
Best Path Selection - Route Advertisement on RR



ingress PE does not learn 2nd path

- The BGP4 protocol specifies the selection and propagation of a single best path for each prefix
- If RRs are used, only the best path will be propagated from RRs to ingress BGP speakers
  - Multipath on the RR does not solve the issue of RR only sending best path
- This behavior results in number of disadvantages for new applications and services

Why Having Multiple Paths?

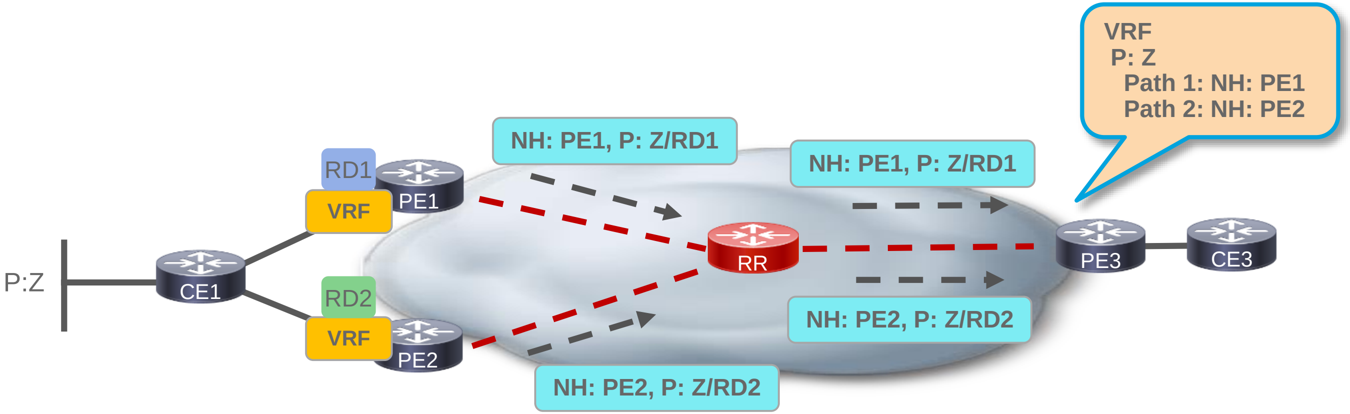
- Convergence
  - BGP Fast Convergence (multiple paths in local BGP table)
  - BGP PIC Edge (backup paths ready in forwarding plane)
- Multipath load balancing
  - ECMP
- Allow hot potato routing
  - = use optimal route
  - The optimal route is not always known on the border routers
- Prevent oscillation
  - The additional info on backup paths leads to local recovery as opposed to relying on iBGP
  - Stop persistent route oscillations caused by comparison of paths based on MED in topologies where route reflectors or the confederation structure hide some paths (pretty rare)

Diverse BGP Path Distribution

Overview

- VPN unique RD (Route Distinguisher)
- BGP Best External
- BGP shadow RR / session
- BGP Add-Path
- BGP ORR

Unique RD for MPLS VPN



- Unique RD per VRF per PE
- One IPv4 prefix in one VRF becomes unique vpnv4 prefix per VPN per PE
- RR advertises all paths
- Available since the beginning of MPLS VPN, but only for MPLS VPN

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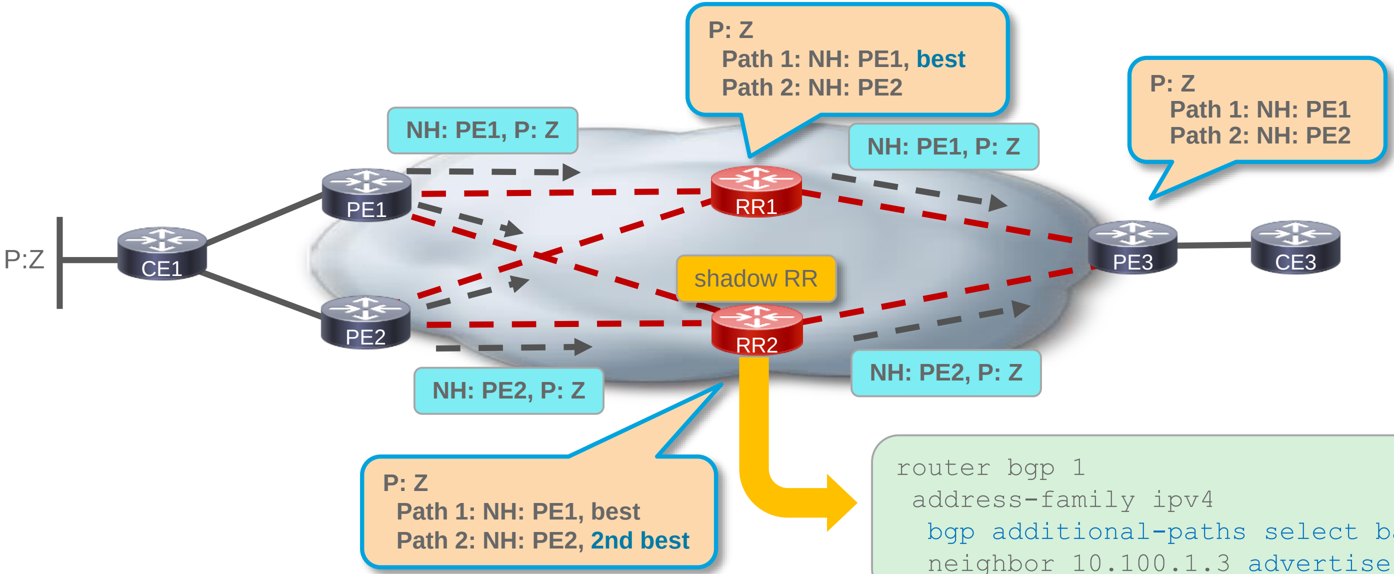
Shadow Route Reflector (aka RR Topologies)

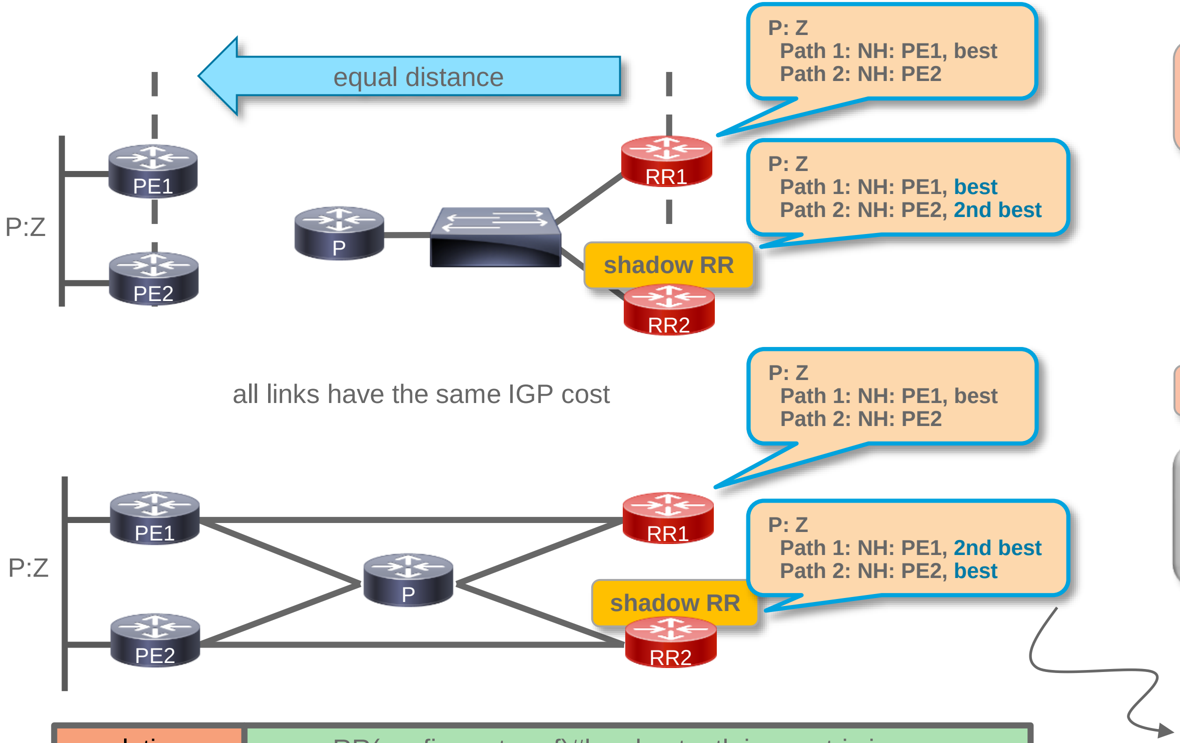


```
router bgp 1
 address-family ipv4
  bgp additional-paths select backup
  neighbor 10.100.1.3 advertise diverse-path backup
```

- Easy deployment
- One additional “shadow” RR per cluster
- RR2 does announce the 2nd best path, which is different from the primary best path on RR1 by next hop

Shadow Route Reflector – RR Placement

Note: primary RRs do not need diverse path code



P: Z
Path 1: NH: PE1, best
Path 2: NH: PE2

P: Z
Path 1: NH: PE1, best
Path 2: NH: PE2, 2nd best

all links have the same IGP cost

P: Z
Path 1: NH: PE1, best
Path 2: NH: PE2

P: Z
Path 1: NH: PE1, 2nd best
Path 2: NH: PE2, best

RR and shadow RR are co-located.
They‘re on same vlan with same IGP metric towards prefix.

Note: primary and shadow RRs do not need to turn off IGP metric check

RR and shadow RR are not co-located.

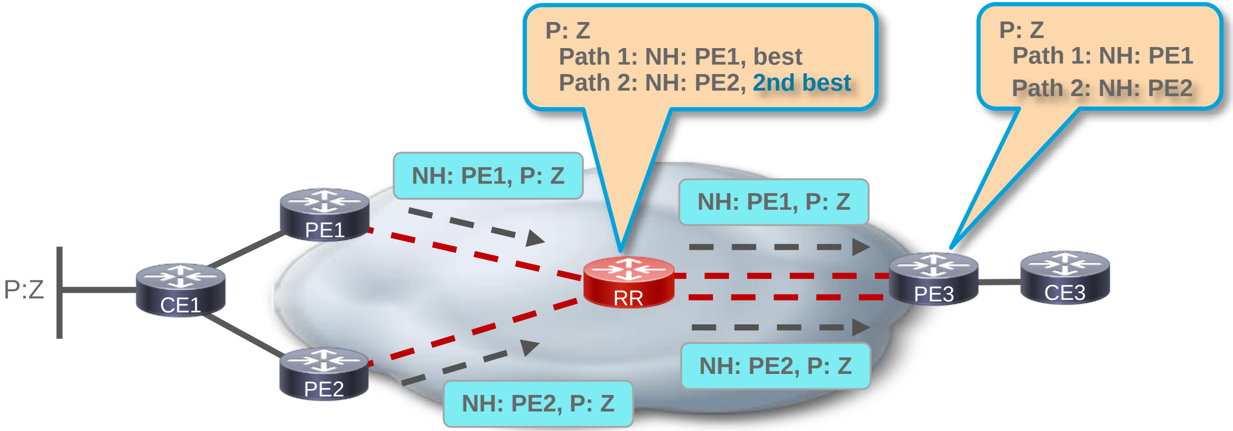
Note: primary and shadow RRs need to turn IGP metric check off.
All RRs to calculate the same best path so that primary and shadow RRs do not advertise the same path

RR2 advertises same path as RR1 !

solution	RR(config-router-af)#bgp bestpath igp-metric ignore

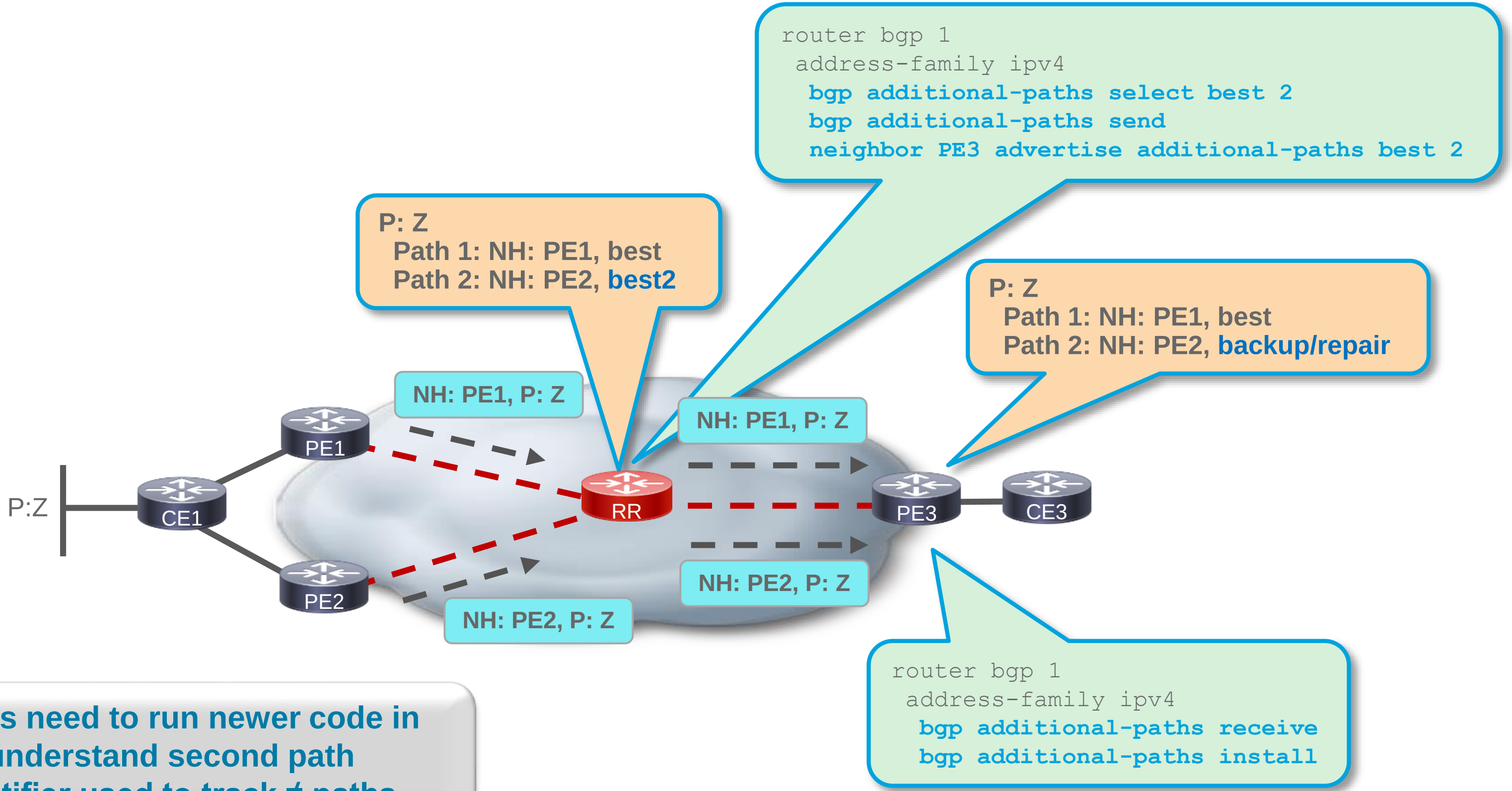
Shadow Session

Note: second session from RR to RR-client (PE3) has diverse-path command in order to advertise 2nd best path



- Easy deployment – only RR needs diverse path code and new iBGP session per each extra path (CLI knob on RR)
- Shadow iBGP session does announce the 2nd best path
  - 2nd session between a pair of routers is no issue (use different loopback interfaces)

ADD Path



```
router bgp 1
 address-family ipv4
  bgp additional-paths select best 2
  bgp additional-paths send
  neighbor PE3 advertise additional-paths best 2
```

P: Z
Path 1: NH: PE1, best
Path 2: NH: PE2, best2

P: Z
Path 1: NH: PE1, best
Path 2: NH: PE2, backup/repair

```
router bgp 1
 address-family ipv4
  bgp additional-paths receive
  bgp additional-paths install
```

- **PE routers need to run newer code in order to understand second path**
- **Path-identifier used to track ≠ paths**

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Add Path - Possibilities

add-all-path

- RR will do the first best path computation and then send all paths to the border routers
- Pros
  - all paths are available on border routers
- Cons
  - all paths stored
  - more BGP info is exchanged
- Usecase: ECMP, hot potato routing

```
bgp additional-paths select all
```

add-n-path

- RR will do best path computation for up to n paths and send n paths to the border routers
- This is the only mandatory selection mode
- Pros
  - less storage used for paths
  - less BGP info exchanged
- Cons
  - more best path computation
- Usecase: Primary + n-1 backup scenario
  (n is limited to 3 (IOS) or 2 (IOS-XR), to preserve CPU power) = fast convergence

```
bgp additional-paths select best<N>
```

multipath

- RR will do the first best path computation and then send all multipaths to the border routers
- Use case: load balancing and primary + backup scenario

IOS-XR only

For Your Reference

Add-Path - IOS-XR

- Path selection is configured in a route-policy
- Global command, per address family, to turn on add-path in BGP
- Configuration in VPNv4 mode applies to all VRF IPv4-Unicast AF modes unless overridden at individual VRFs

example config

```
router bgp 1
 address-family vpnv4
  additional-paths install backup    (deprecated)
  additional-paths advertise
  additional-paths receive
  additional-paths selection route-policy apx
```

example RPL config

add-n-path

```
route-policy ap1
 if community matches-any (1:1) then
  set path-selection backup 1 install
 elseif destination in (10.1.0.0/16, 10.2.0.0/16)then
 set path-selection backup 1 advertise install
endif
```

add-all-path

```
route-policy ap2
 set path-selection all advertise
```

multipath

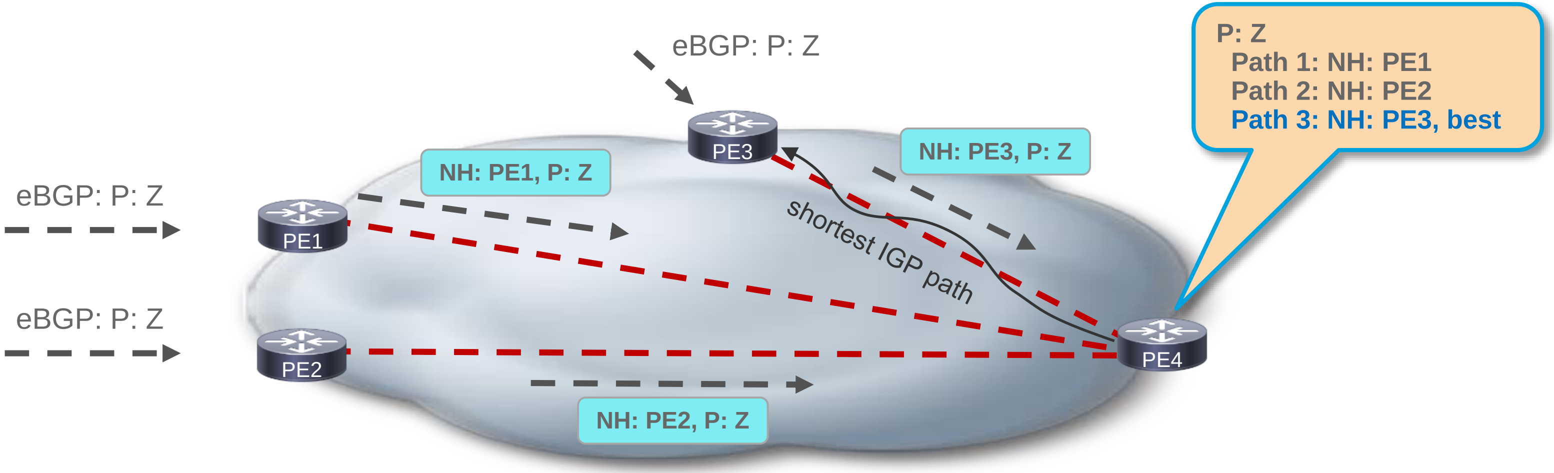
```
route-policy ap3
 set path-selection multipath advertise
```

```
route-policy ap4
 set path-selection backup 1 install multipath-protect advertise
```

needed to have a non-multipath path as backup path

Hot Potato Routing - No RR

- Hot potato routing = packets are passed on (to next AS) as soon as received
- Shortest path though own AS must be used
- In transit AS: same prefix could be announced many times from many eBGP peers



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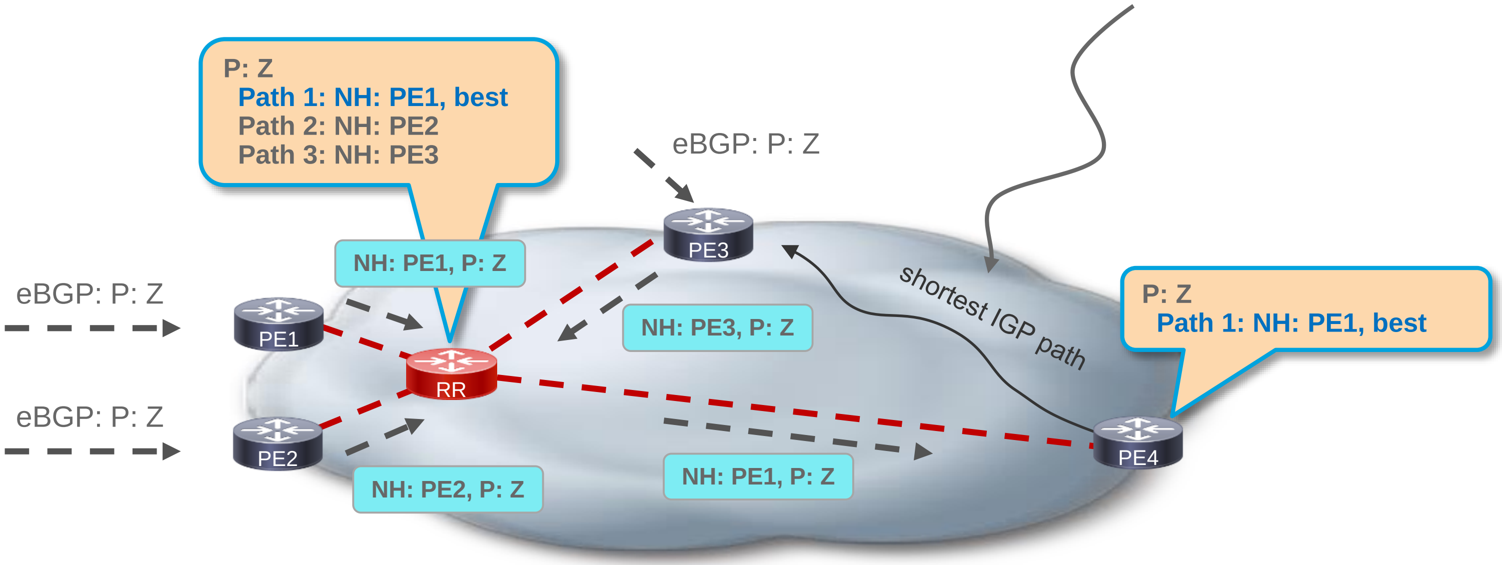
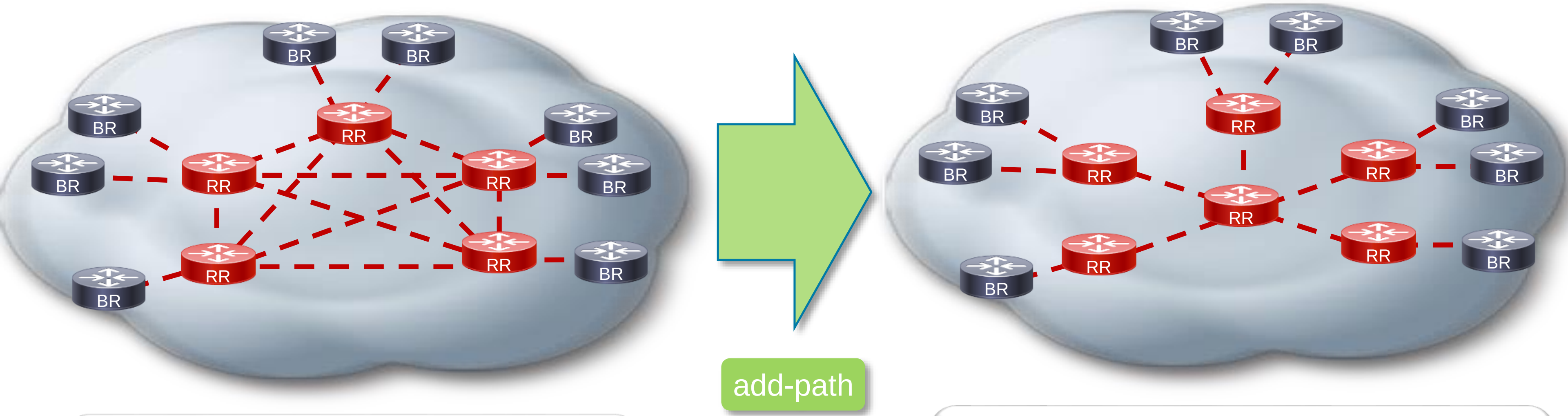
Hot Potato Routing - With RR

- Introducing RRs break hot potato routing
- Solutions: *Unique RD* for MPLS VPN or *Add Path*

Step 8 in the BGP best path selection algorithm



Hot Potato Routing in Large Transit SP



- **Large transit ISPs with full mesh iBGP between regional RRs and hub/spoke between local BR and RR**
- **Full mesh and global hot potato routing**

- ***add-all-path* could be deployed between centralized and regional RR's**
- **Also possible: remove the need for regional RR if all BR routers support add-path**

BR Border Router

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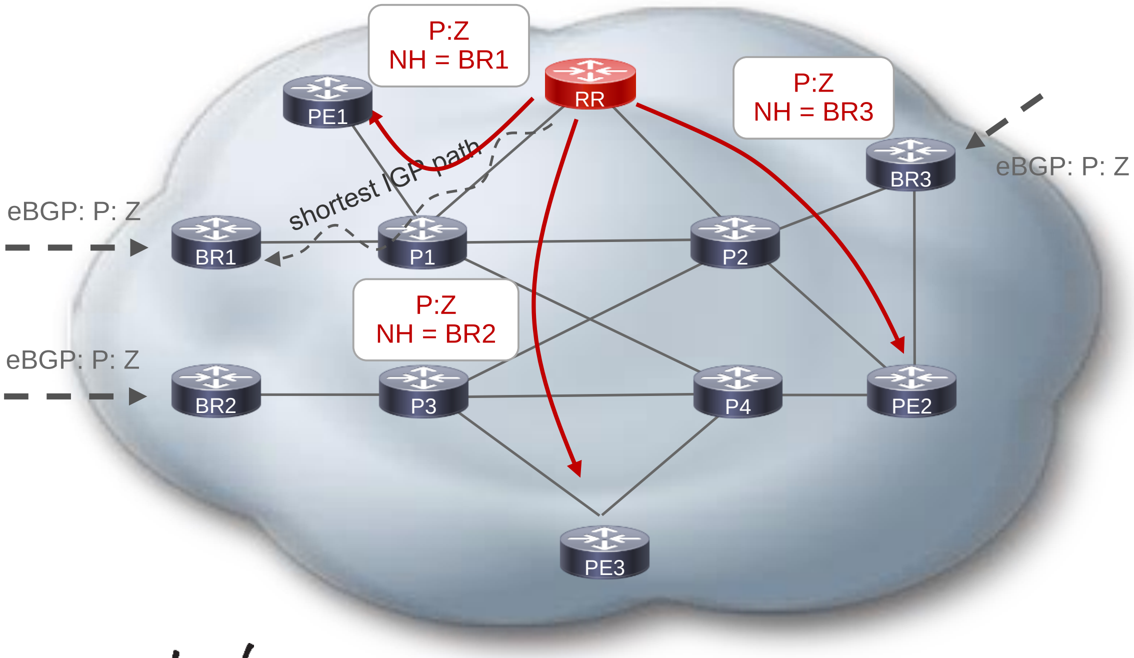
BGP Optimal Route Reflection (ORR)

- Another way to allow hot-potato routing with RR
- Step 8 in the BGP best path selection algorithm is still the issue



- The RR can choose to send a different best path to different BGP border routers or set of border routers
- The RR will perform the BGP best path calculation from the perspective of the ingress border router
- The RR can run a Shortest Path First (SPF) calculation with the ingress border router as the root of the tree and calculate the cost to every other router

- **Only RR needs ORR code**
- **Must have Link-State routing protocol**
- **Support per address family**

Fast Convergence

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BGP PIC (Prefix Independent Convergence) Edge

Problem

- Convergence in flat FIB is prefix dependent
  - More prefixes -> more convergence time
- Classical convergence (flat FIB)
  - Routing protocols react - update RIB - update CEF table (for affected prefixes)
  - Time is proportional to # of prefixes

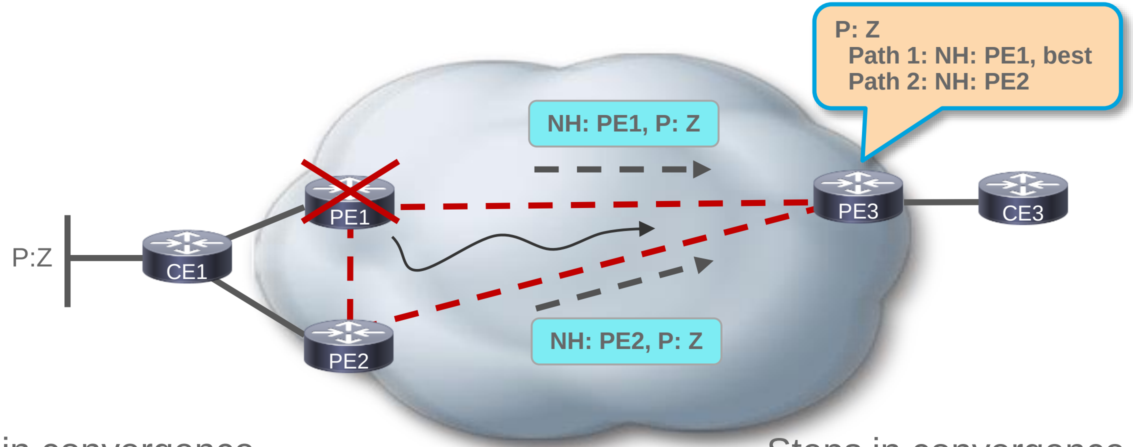
Solution

- The idea of PIC:
  - In both SW and HW:
    - Pre-install a backup path in RIB
    - Pre-install a backup path in FIB
    - Pre-install a backup path in LFIB

Result

- Improved convergence
- Reduce packet loss
- Have the same convergence time for all BGP prefixes (PIC)

MPLS VPN Dual Homed CE - No PIC Edge



Steps in convergence

1. Egress PE goes down
2. IGP notifies ingress PE in sub-second

Steps in convergence on ingress PE

1. Ingress PE recomputes BGP bestpath
2. Ingress PE installs new BGP bestpath in RIB
3. Ingress PE installs new BGP bestpath in FIB
4. Ingress PE reprograms hardware

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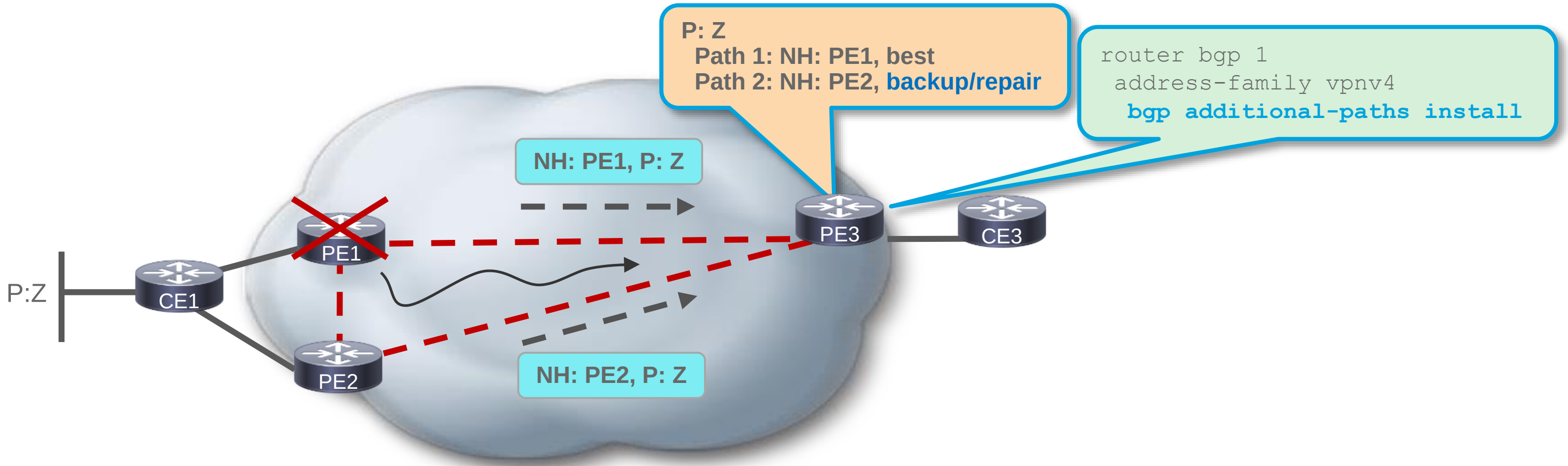
MPLS VPN Dual-Homed CE - PIC Edge



P: Z
Path 1: NH: PE1, best
Path 2: NH: PE2, **backup/repair**

```
router bgp 1
 address-family vpnv4
  bgp additional-paths install
```

Steps in convergence

1. Egress PE goes down
2. IGP notifies ingress PE in sub-second

Steps in convergence on ingress PE

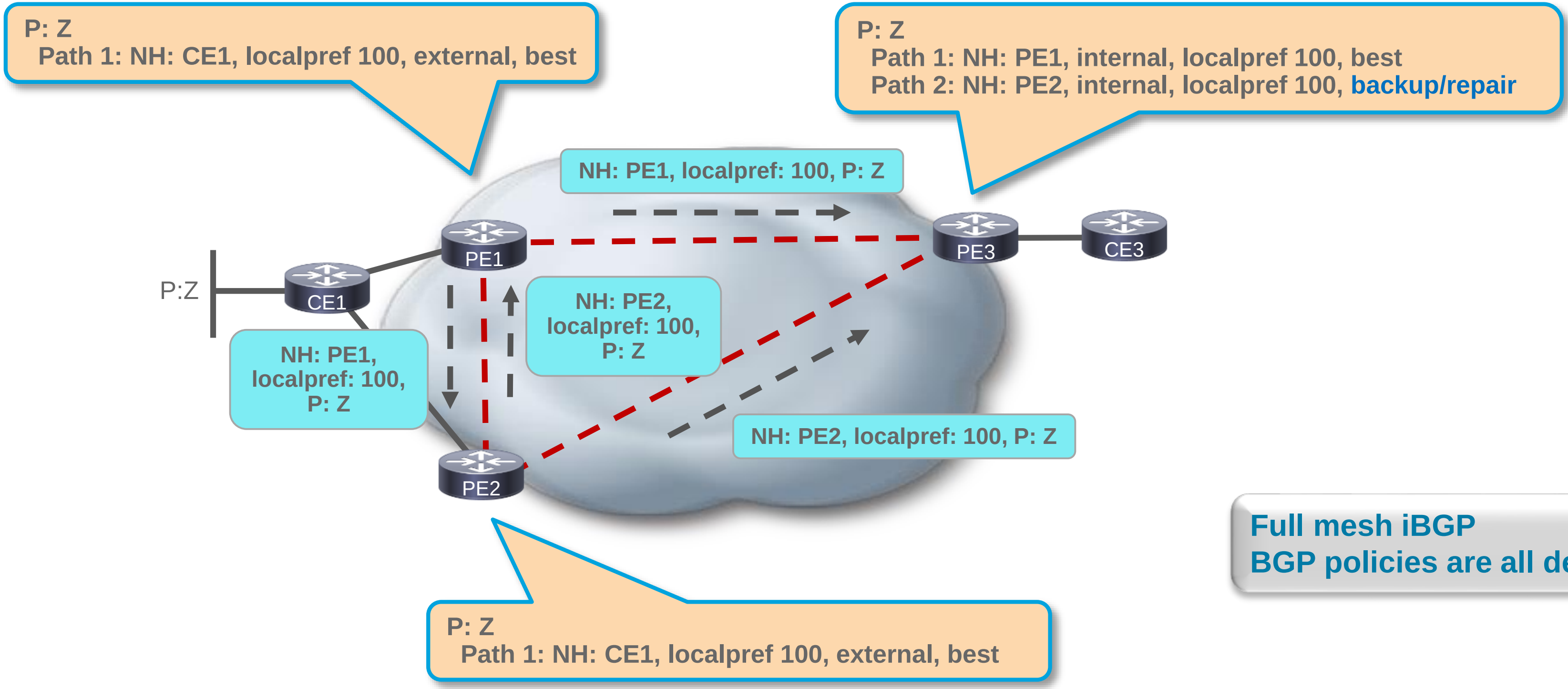
1. Switch to repair path with new Next Hop
2. Ingress PE reprograms hardware

We eliminate convergence dependence on:

- Scanning of the BGP table
- Bestpath calculation (because there is a pre-computed backup/repair path)
- Time to generate and propagate updates (PE and RR)
- Updating the FIB (with PIC the FIB update is prefix independent)

this scales to the number of prefixes

No BGP Best External – Default BGP Policy



P: Z
Path 1: NH: CE1, localpref 100, external, best

P: Z
Path 1: NH: PE1, internal, localpref 100, best
Path 2: NH: PE2, internal, localpref 100, backup/repair

NH: PE1, localpref: 100, P: Z

NH: PE2, localpref: 100, P: Z

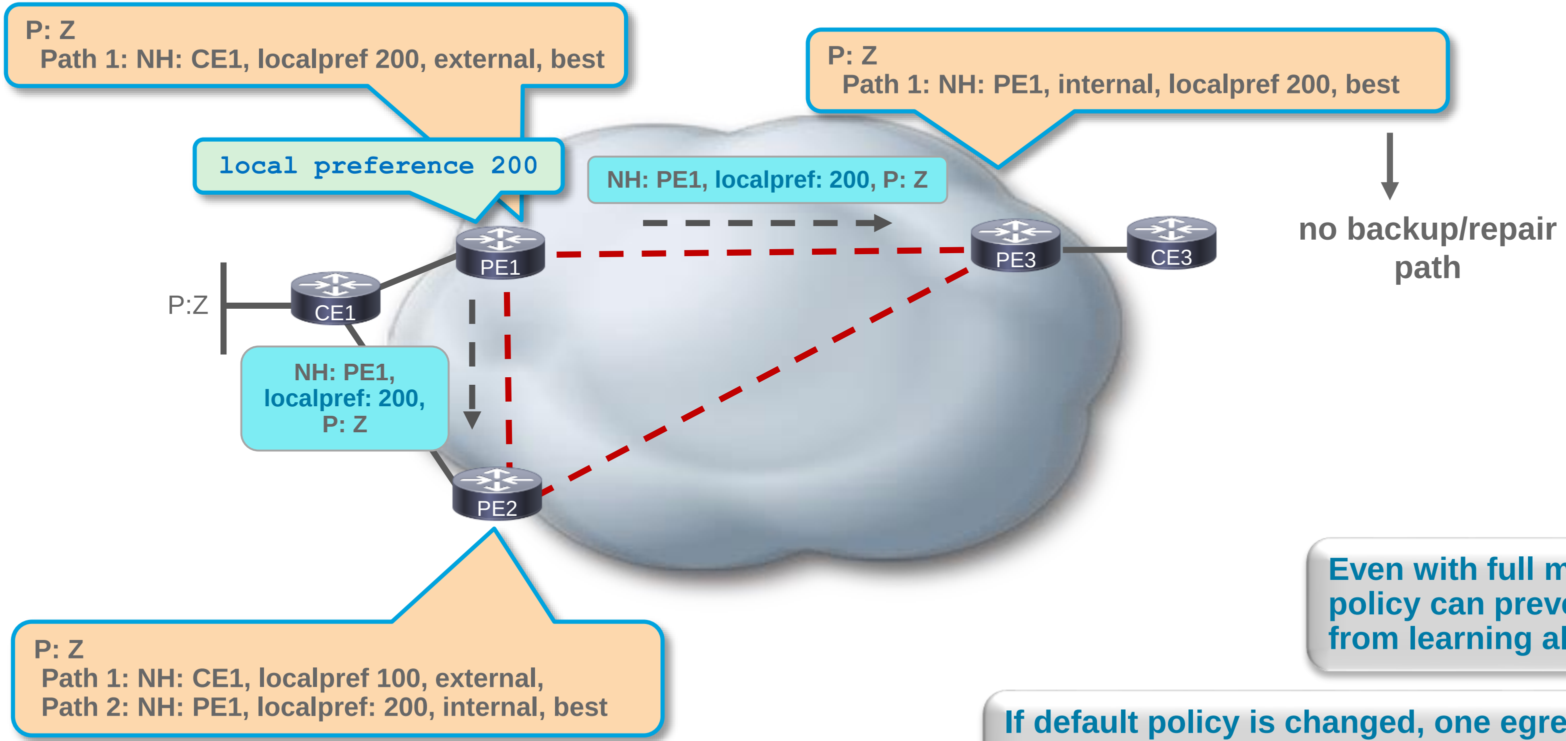
NH: PE1, localpref: 100, P: Z

NH: PE2, localpref: 100, P: Z

P: Z
Path 1: NH: CE1, localpref 100, external, best

Full mesh iBGP
BGP policies are all default

No BGP Best External - Changed BGP Policy



P: Z
Path 1: NH: CE1, localpref 200, external, best

`local preference 200`

NH: PE1, localpref: 200, P: Z

P: Z
Path 1: NH: PE1, internal, localpref 200, best

no backup/repair path

NH: PE1, localpref: 200, P: Z

P: Z
Path 1: NH: CE1, localpref 100, external,
Path 2: NH: PE1, localpref: 200, internal, best

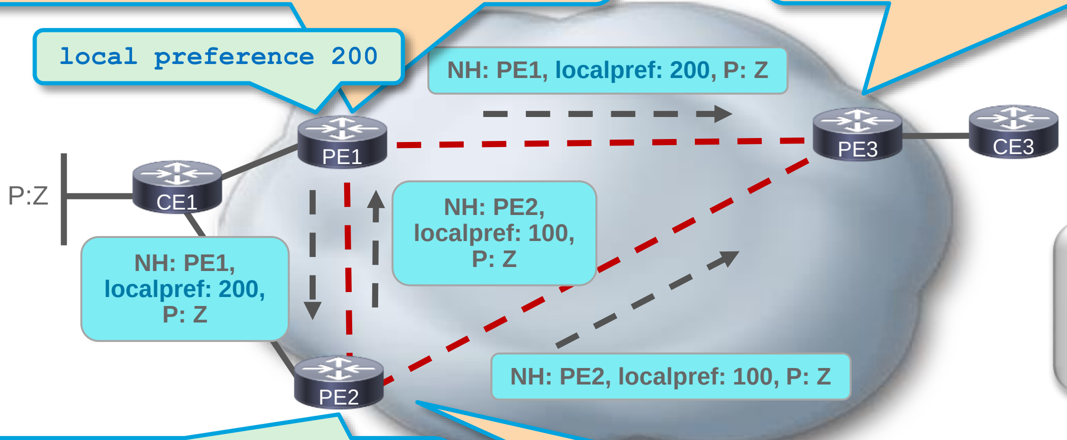
Even with full mesh in iBGP, policy can prevent egress PE from learning all paths

If default policy is changed, one egress PE could have iBGP path to other egress PE as best path and not its own external BGP path

BGP Best External - Changed BGP Policy

P: Z
Path 1: NH: CE1, external, best
Path 2: NH: PE2, localpref 100, internal, **backup/repair**

P: Z
Path 1: NH: PE1, internal, localpref 200, best
Path 2: NH: PE2, localpref 100, internal, **backup/repair**


local preference 200
NH: PE1, localpref: 200, P: Z
PE1
PE3
CE3
P:Z
CE1
NH: PE2, localpref: 100, P: Z
NH: PE1, localpref: 200, P: Z
NH: PE2, localpref: 100, P: Z
PE2

- **With Best External, the backup PE (PE2) still propagates its own best external path to the RRs or iBGP peers**
- **PE1 and PE3 learn 2 paths**

```
router bgp 1
 address-family vpnv4
  bgp additional-paths install
  bgp additional-paths select best-external
  neighbor x.x.x.x advertise best-external
```

P: Z
Path 1: NH: CE1, external, best **backup/repair, advertise-best-external**
Path 1: NH: PE1, localpref: 200, internal, best

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Deployment

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BGP Selective Download

- Access router RIB holds full Internet routing table, but fewer routes in FIB
  - Example: ME switches, ASR900
- FIB holds default route and selective more specific routes
- Enterprise CPE devices will receive full Internet routes through their BGP peering with the access router(s)

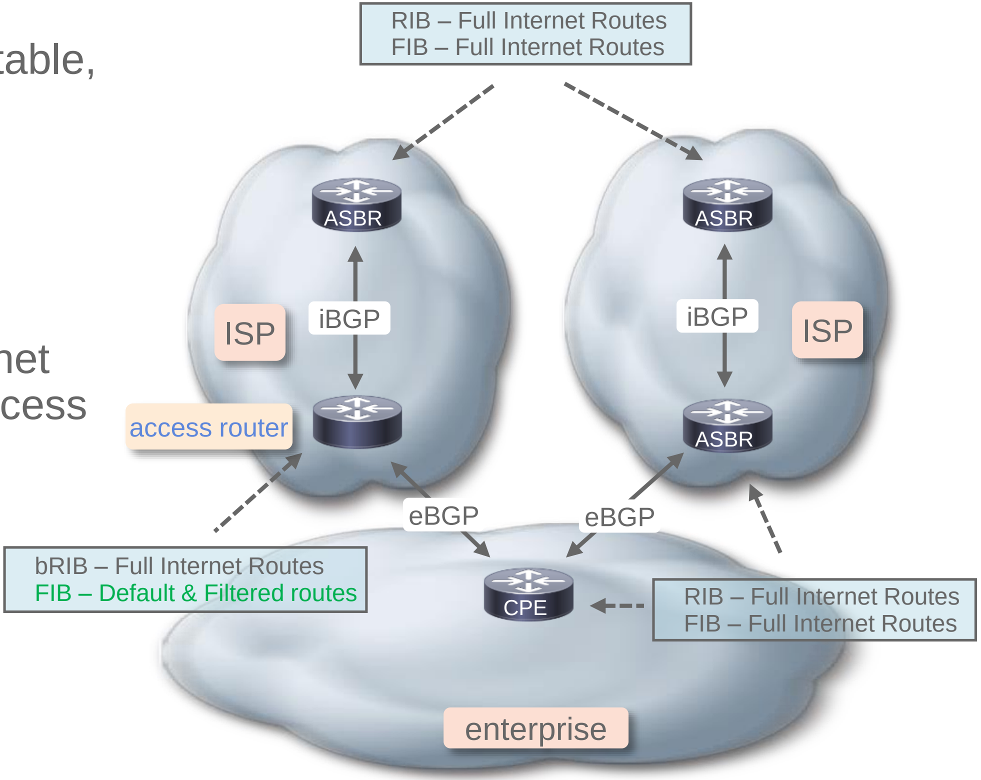
configuration

```
router bgp 1

 address-family ipv4
  table-map filter-into-fib filter

route-map filter-into-fib deny 10
 match community 100

ip community-list 100 permit 65510:100
```


RIB – Full Internet Routes
FIB – Full Internet Routes
ASBR
ASBR
ISP
iBGP
iBGP
ISP
access router
ASBR
eBGP
eBGP
bRIB – Full Internet Routes
FIB – Default & Filtered routes
CPE
RIB – Full Internet Routes
FIB – Full Internet Routes
enterprise

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Path MTU Discovery (PMTUD)

- MSS (Max Segment Size) – Limit on the largest segment that can traverse a TCP session
  - Anything larger must be fragmented & re-assembled at the TCP layer
  - MSS is 536 bytes by default for client BGP without PMTUD
  - Enable PMTU for BGP with
    - Older command "**`ip tcp path-mtu-discovery`**"
    - Newer command "**`bgp transport path-mtu-discovery`**" (PMTUD now on by default)

- 536 bytes is inefficient for Ethernet (MTU of 1500 or more) or POS (MTU of 4470) networks
  - TCP is forced to break large segments into 536 byte chunks
  - Adds overheads
  - Slows BGP convergence and reduces scalability

- TCP MSS set per neighbor (IOS-XR 5.4)

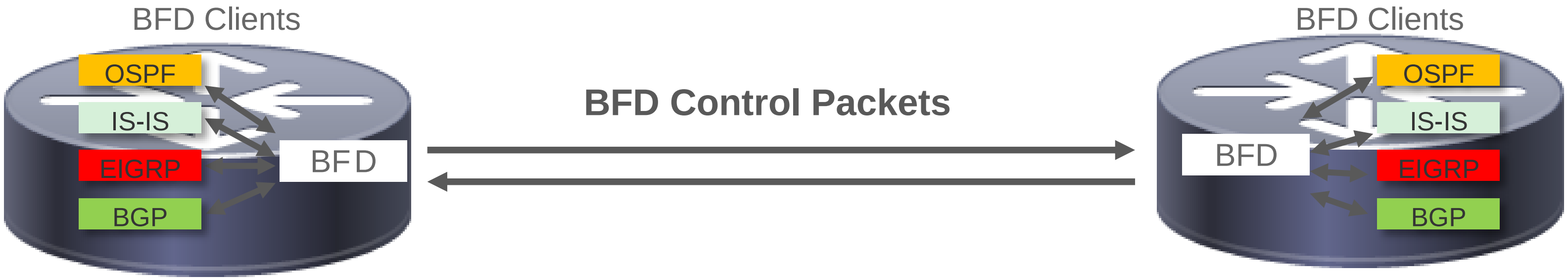
Session/Timers

- Timers = keepalive and holdtime
  - Default is ok
  - Smallest is 3/9 for keepalive/holdtime
  - Scaling <> small timers
- Use BFD
  - Built for speed
  - When failure occurs, BFD notifies BFD client (in 10s of msecs)

- Do not use Fast Session Deactivation (FSD)
  – Tracks the route to the BGP peer
  – A temporary loss of IGP route, will kill off the iBGP sessions
  – Very dangerous for iBGP peers
    - IGP may not have a route to a peer for a split second
    - FSD would tear down the BGP session
  – It is off by default

```
neighbor x.x.x.x fall-over
```

  – Next Hop Tracking (NHT), enabed by default, does the job fine



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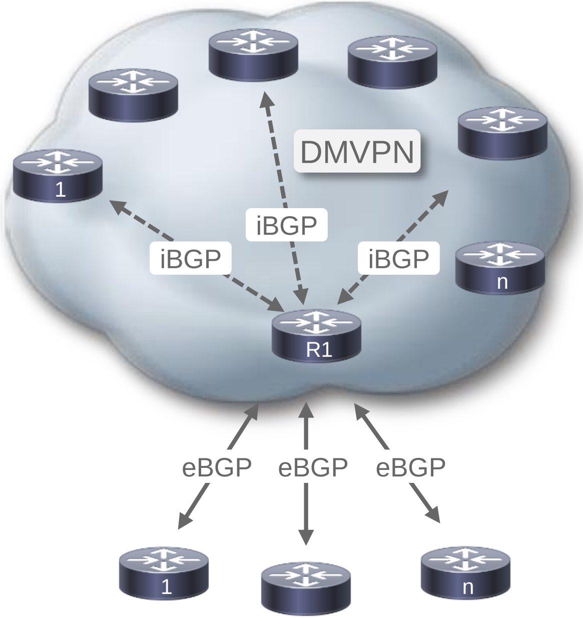
IOS

Dynamic Neighbors

- Remote peers are defined by IP address range
- Less configuration for defining neighbors
- Remote initiate BGP session
- Enterprise networks (DMVPN, ...)
- iBGP and limited eBGP (limited nr of ASNs)

configuration

```
router bgp 1
 bgp listen range 192.168.0.0/16 peer-group 192-16
 bgp listen range 10.1.1.0/24 peer-group 10-24
 bgp listen limit 1000
 neighbor 10-24 peer-group
 neighbor 10-24 remote-as 1
 neighbor 192-16 peer-group
 neighbor 192-16 remote-as 2 alternate-as 3 4 5 6 7
 neighbor 192-16 ebgp-multihop 2
 neighbor 192-16 update-source Loopback0
```



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Multisession

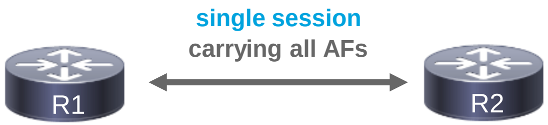
IOS

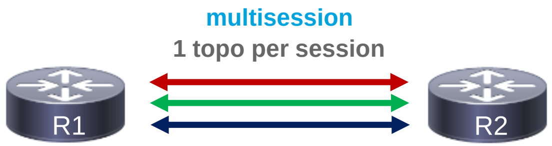
Multisession

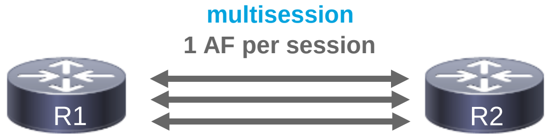
- BGP Multisession = multiple BGP (TCP) sessions between 2 BGP speakers
  - Even if there is only one BGP neighbor statement defined between the BGP speakers in the configuration

- Introduced with Multi Topology Routing (MTR)
  - One session per topology

- Now: possibility to have one session per AF/group of AFs
  - Good for incremental deployment of AFs
    - Avoids a BGP reset
    - But multisession needs to be enabled beforehand
  - Good for troubleshooting
  - Good for issues when BGP session resets
    - For example “malformed update”
  - Not so good for scalability
  - IOS only and not enabled by default


single session
carrying all AFs


multisession
1 topo per session


multisession
1 AF per session

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IOS

For Your Reference

Multisession

capability

```
BGP: 10.100.1.2 passive rcvd OPEN w/ optional parameter type 2 (Capability)
len 3
BGP: 10.100.1.2 passive OPEN has CAPABILITY code: 131, length 1
BGP: 10.100.1.2 passive OPEN has MULTISESSION capability, without grouping
```

multisession for MTR

```
R2#show bgp ipv4 unicast neighbors
BGP neighbor is 10.100.1.1,  remote AS 1, internal link
…
  BGP multisession with 3 sessions (3 established), first up for 00:05:43
  Neighbor sessions:
    3 active, is multisession capable
    Session: 10.100.1.1 session 1
      Topology IPv4 Unicast
    Session: 10.100.1.1 session 2
      Topology IPv4 Unicast voice
    Session: 10.100.1.1 session 3
      Topology IPv4 Unicast video
```

1 session per topology

multisession without MTR

```
R2#show ip bgp neighbors 10.100.1.1 | include session|address family
  BGP multisession with 3 sessions (3 established), first up for 00:02:29
  Neighbor sessions:
    3 active, is multisession capable
    Session: 10.100.1.1 session 1
    Session: 10.100.1.1 session 2
    Session: 10.100.1.1 session 3
    Route refresh: advertised and received(new) on session 1, 2, 3
    Multisession Capability: advertised and received
For address family: IPv4 Unicast
  Session: 10.100.1.1 session 1
  session 1 member
For address family: IPv6 Unicast
  Session: 10.100.1.1 session 2
  session 2 member
For address family: VPNv4 Unicast
  Session: 10.100.1.1 session 3
  session 3 member
```

1 session per address family

IOS

Multisession

Conclusion

- Increases # of TCP sessions
- Not really needed
- Current default behavior = multisession is off
  - Can be turned on by “neighbor x.x.x.x transport multi-session”
- Makes sense to have IPv4 and IPv6 on seperate TCP sessions
  - IPv6 over IPv4 (or IPv4 over IPv6) can be done, but next hop mediation is needed

MPLS VPN Scaling

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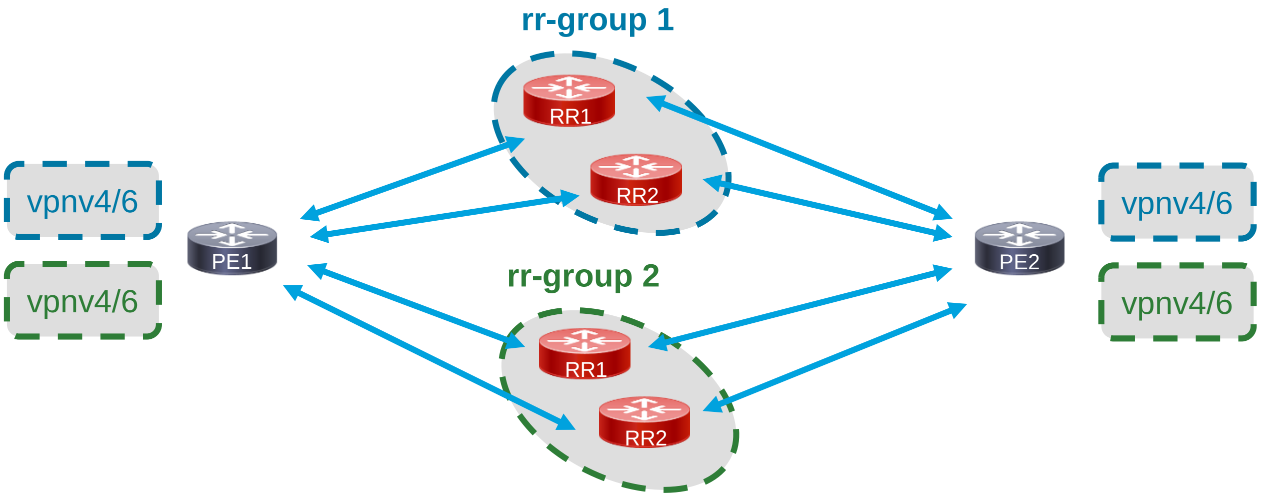
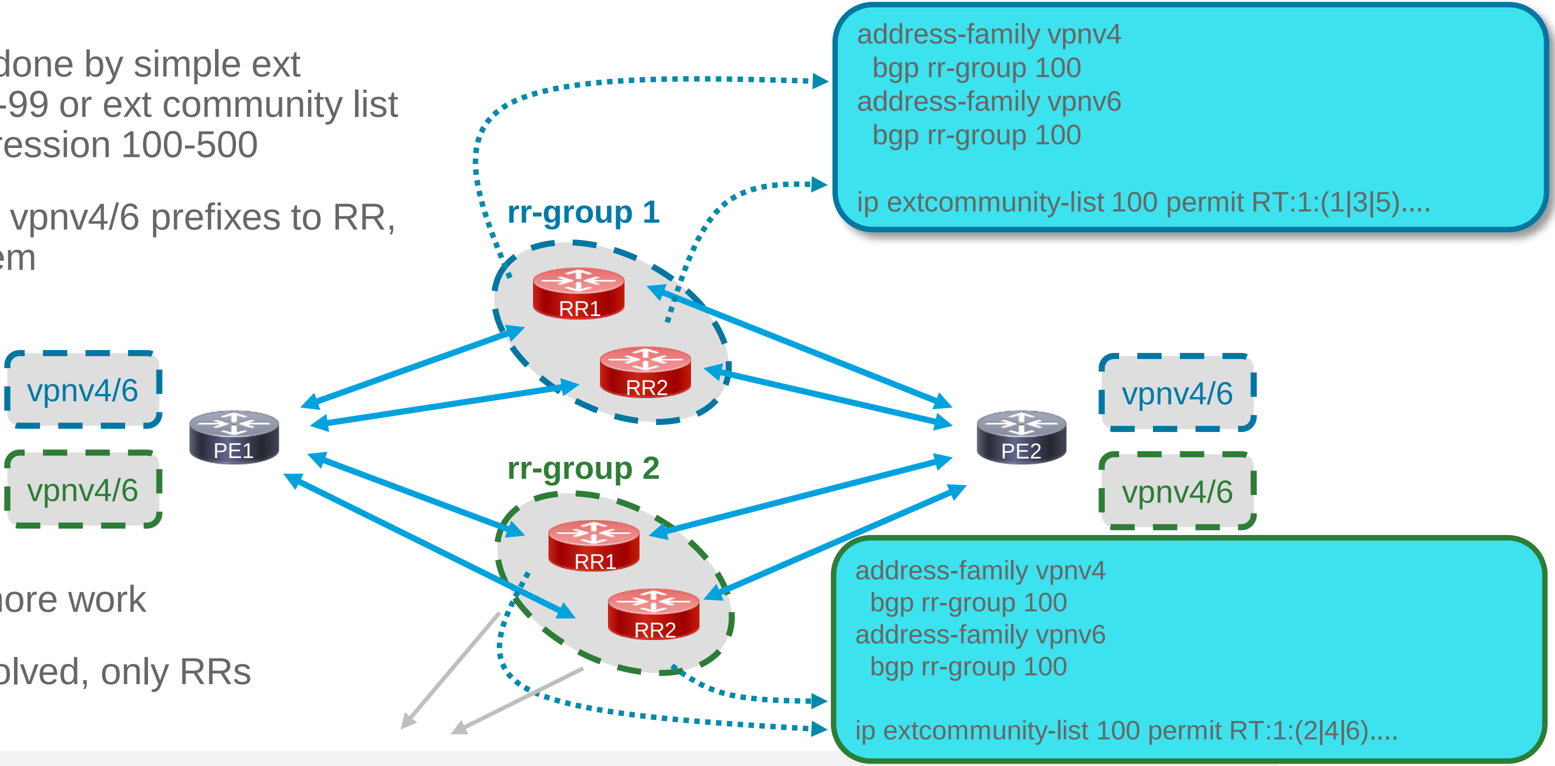
RR-groups

- Use one RR (set of RRs) for a subset of prefixes
  - By carving up range of RTs
- Only for vpnv4/6
  - RR only stores and advertises the specific range of prefixes
- Less storage on RR, but more RRs needed + more peerings



RR-groups Configuration Example

- Dividing of RTs done by simple ext community list 1-99 or ext community list with regular expression 100-500
- PEs still send all vpnv4/6 prefixes to RR, but RR filters them



```
address-family vpnv4
  bgp rr-group 100
address-family vpnv6
  bgp rr-group 100

ip extcommunity-list 100 permit RT:1:(1|3|5)....
```

```
address-family vpnv4
  bgp rr-group 100
address-family vpnv6
  bgp rr-group 100

ip extcommunity-list 100 permit RT:1:(2|4|6)....
```

- Dividing RT = more work
- PEs are not involved, only RRs

```
BGP(4): 10.100.1.1 rcvd UPDATE w/ attr: nexthop 10.100.1.1, origin ?, localpref 100, metric 0, extended community RT:1:10001
BGP(4): 10.100.1.1 rcvd 1:10001:100.1.1.2/32, label 22 -- DENIED due to:  extended community not supported;
```

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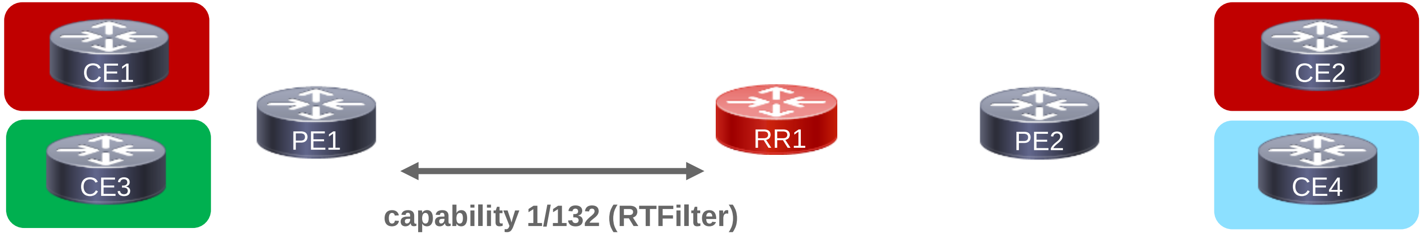
Route Target Constraint (RTC)

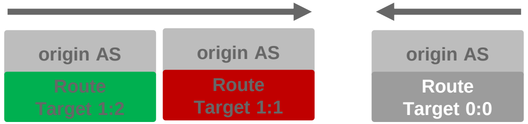
BGP capability exchange
OPEN message



capability 1/132 (RTFilter)
for vpnv4 & vpnv6

AF RTFilter exchange

MP_REACH_NLRI
AF RTFilter

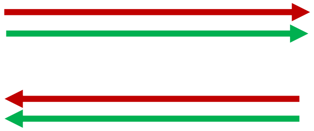


PE1 installs Default
RT filter for RR

RR installs RT filter RT:1:1 & RT 1:2
for PE1 (implicitly denying all else)

AF vpnv4/6 prefixes exchange

PE sends all its
vpnv4/6 prefixes to RR



RR sends only RED and green (not
blue) vpnv4/6 prefixes to PE1

Route Target Constraint (RTC)

- Results
  - Eliminates the waste of processing power on the PE and the waste of bandwidth
  - Number of vpnv4 formatted message is reduced by 75%
  - BGP Convergence time is reduced by 20 - 50%
  - The more sparse the VPNs (few common VPNs on PEs), the more performance gain
- Note: PE and RR need the support for RTC
  - Incremental deployment is possible (per PE)
  - Behavior towards non-RT Constraint peers is not changed
- Note
  - RTC clients of RR with different set of importing RTs will be in the same update group on the RR
    - In IOS-XR, different filter group under same subgroup

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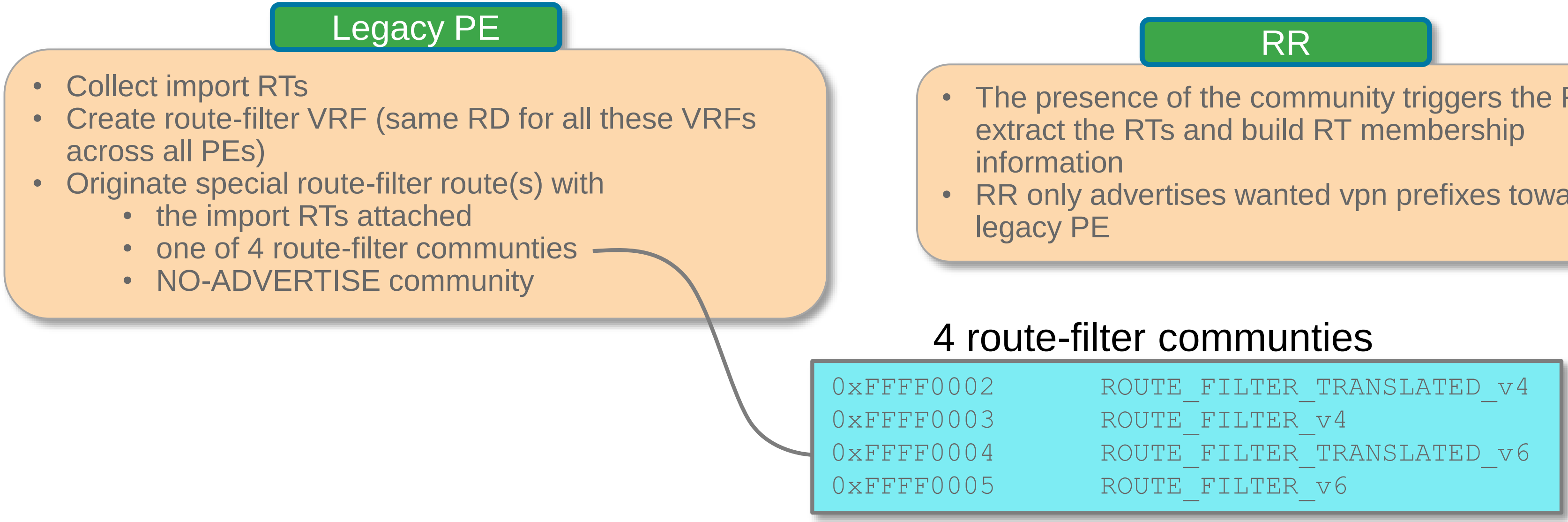
Legacy PE RT Filtering

- Problem: If one PE does not support RTC (legacy prefix), then all RRs in one cluster must store and advertise all vpn prefixes to the PE
- Solution: Legacy PE sends special prefixes to mimic RTC behavior, without RTC code



Legacy PE

- Collect import RTs
- Create route-filter VRF (same RD for all these VRFs across all PEs)
- Originate special route-filter route(s) with
  - the import RTs attached
  - one of 4 route-filter communties
  - NO-ADVERTISE community

RR

- The presence of the community triggers the RR to extract the RTs and build RT membership information
- RR only advertises wanted vpn prefixes towards legacy PE

4 route-filter communties

0xFFFF0002	ROUTE_FILTER_TRANSLATED_v4
0xFFFF0003	ROUTE_FILTER_v4
0xFFFF0004	ROUTE_FILTER_TRANSLATED_v6
0xFFFF0005	ROUTE_FILTER_v6

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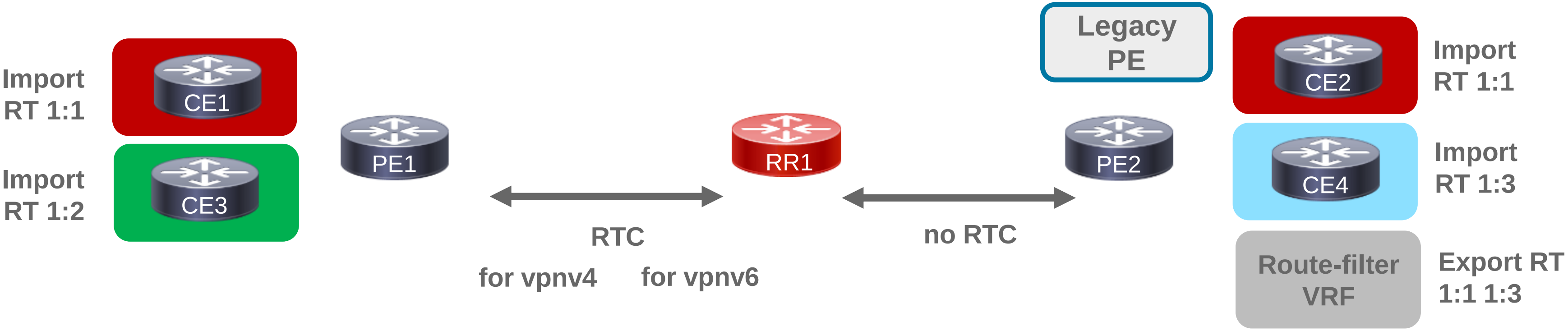
Legacy PE RT Filtering



legacy PE sends route-filter VRF route(s) with unique RD, route-filter community and importing RTs

vpnv4/6 update with prefix(es) RT membership information

```
9999:9999:9.9.9.9/32

Community: 4294901762
Extended Community: RT:0.1.0.0:1
RT:0.1.0.0:3
no-export no-advertise
```

RD:prefix

One of 4 route-filter communities
All import RTs of the legacy PE
NO-ADVERTISE NO-EXPORT community

AF vpnv4/6 prefixes exchange

PE1 sends all its vpnv4/6 prefixes to RR

RR sends only RED (not green) vpnv4/6 prefixes to PE2

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Legacy PE RT Filtering - Configuration

For Your Reference

RR config

```
router bgp 1
 address-family vpnv4
  neighbor 10.100.1.2 route-reflector-client
  neighbor 10.100.1.2 accept-route-legacy-rt
```

Legacy PE config

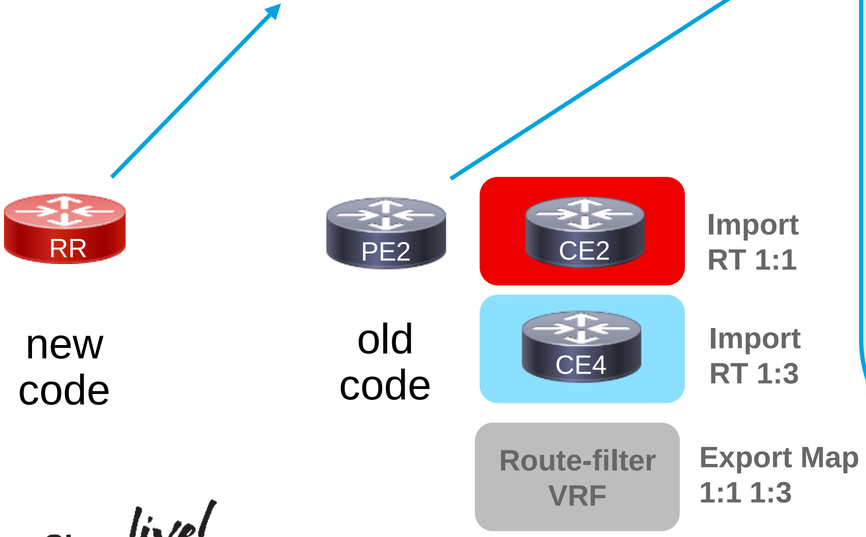
```
ip vrf route-filter
 rd 9999:9999
 export map SET_RT

router bgp 1
 address-family vpnv4
  neighbor 10.100.1.3 route-map legacy_PE out
 address-family ipv4 vrf route-filter
  network 9.9.9.9 mask 255.255.255.255

ip route vrf route-filter 9.9.9.9 255.255.255.255 Null0
ip prefix-list match_RT_1 seq 5 permit 9.9.9.9/32

route-map SET_RT permit 10
 match ip address prefix-list match_RT_1
 set community 4294901762 (equals 0xFFFF0002)
 set extcommunity rt  0.1.0.0:1 0.1.0.0:3 additive

route-map legacy_PE permit 10
 match ip address prefix-list match_RT_1
 set community no-export no-advertise additive
```



Full Internet in a VRF?

- Why? Because design dictates it
- Unique RD, so that RR can advertise 2 paths?

PRO

- Remove Internet routing table from P routers
- Security: move Internet into VPN, out of global
- Added flexibility
- More flexible DDOS mitigation

CON

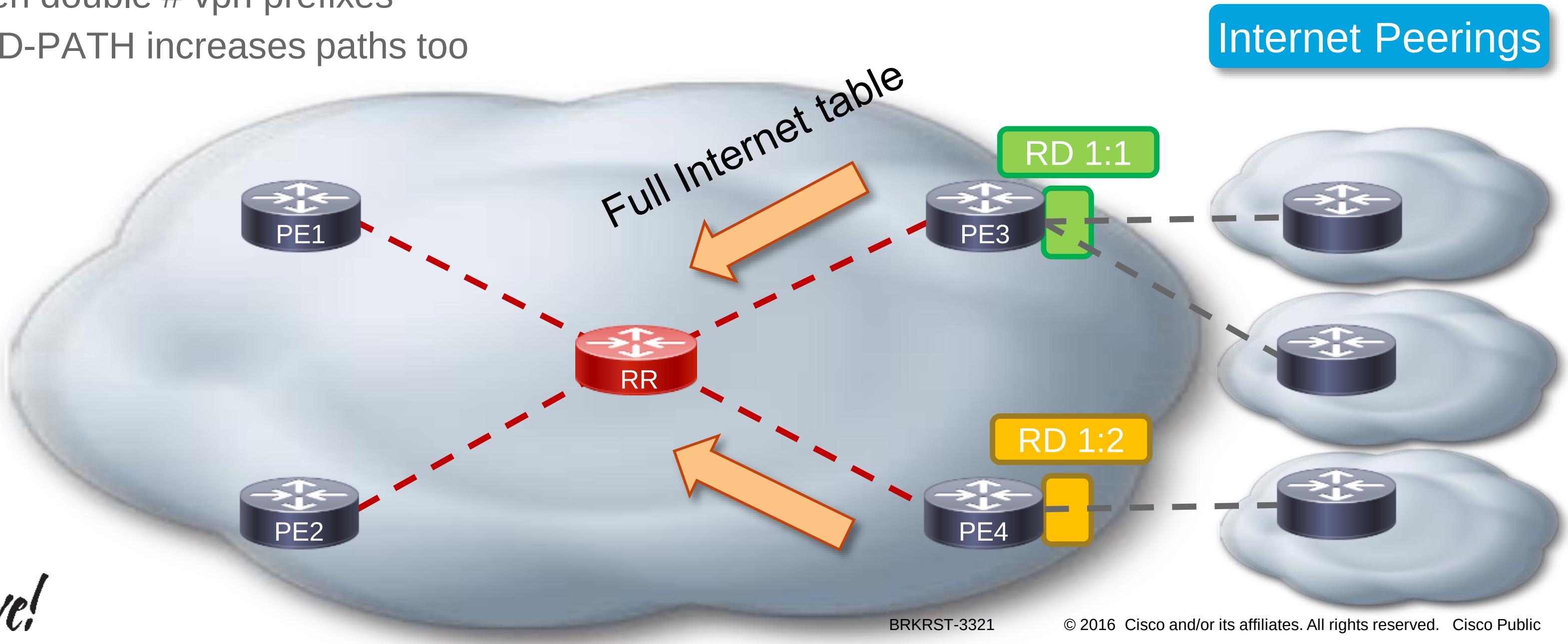
- Increased memory and bandwidth consumption

- Platform must support enough MPLS labels
  – Label allocation is per-prefix by default
  – Perhaps per-ce or per-vrf label allocation is wanted here
  – Now also per-CE and per-VRF label allocation for 6PE (in IOS-XR)

Full Internet in a VRF?

Considerations

- Two Internet gateways for redundancy
- RRs are present: unique RDs needed
  - Then double # vpn prefixes
  - ADD-PATH increases paths too

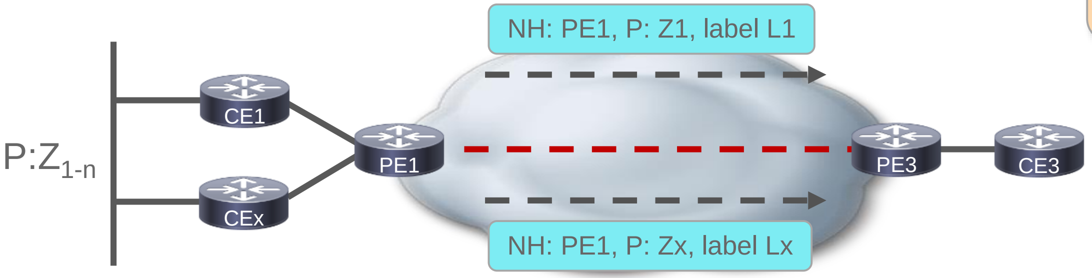


Label Allocation Mode: Per-CE Label

- One unique label per prefix is always the default
- Per-CE : one MPLS label per next-hop (so per connected CE router)
- No IP lookup needed after label lookup
- Caveats
  - No granular load balancing because the bottom label is the same for all prefixes from one CE, if platform load balances on bottom label
  - eBGP load balancing & BGP PIC is not supported (it makes usage of label diversity), unless resilient per-ce label
  - Only single hop eBGP supported, no multihop

2 CEs = 2 labels

- Number of prefixes (n) is much larger than number of CE routers (x) per VPN
- Number of MPLS labels used is very low



Per-CE Label: Caveats - PIC

Resilient per-ce is enabled by configuring regular per-ce commands (label allocation mode or in RPL)

Before failure
Best paths:

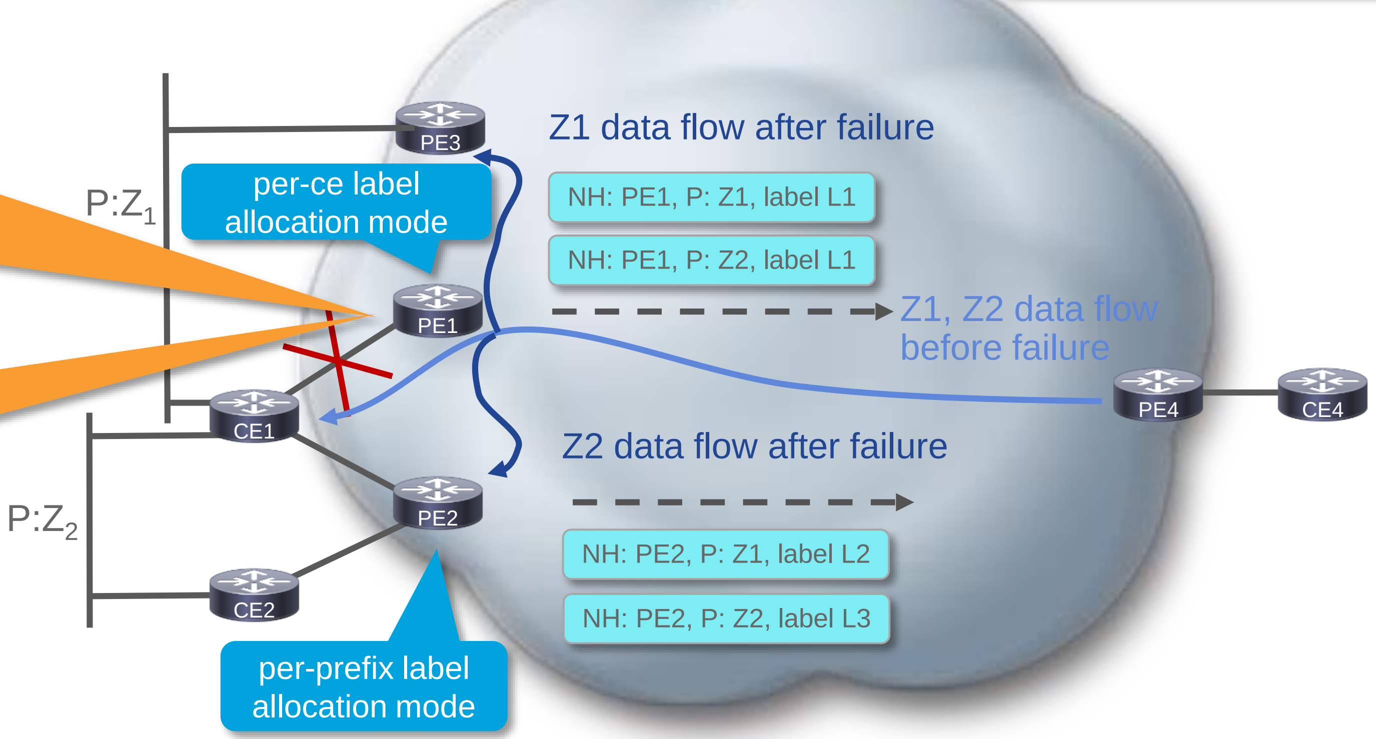
Z1: CE1
Z2: eibgp multipath to CE1 and PE2

Backup paths (PIC):

Z1 via PE3

After failure
Best paths:

Z1: PE3
Z2: PE2



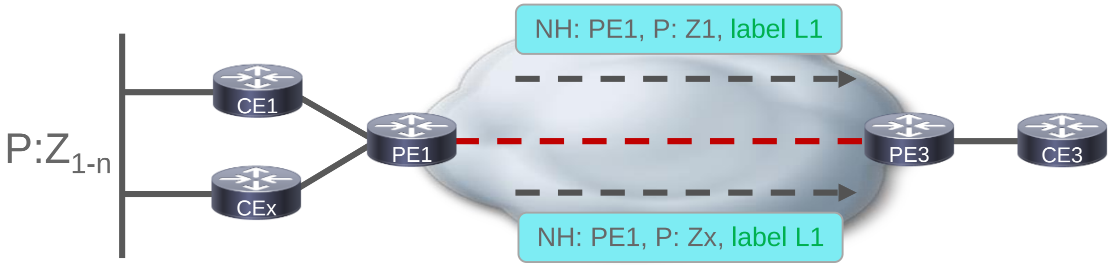
P:Z1
P:Z2
PE3
PE1
PE2
PE4
CE1
CE2
CE4
per-ce label allocation mode
per-prefix label allocation mode
Z1 data flow after failure
NH: PE1, P: Z1, label L1
NH: PE1, P: Z2, label L1
Z1, Z2 data flow before failure
Z2 data flow after failure
NH: PE2, P: Z1, label L2
NH: PE2, P: Z2, label L3

Solution: resilient per-ce : “hack” by doing IP lookup after label lookup
Per-prefix customized resilience

Label Allocation Mode: Per-VRF Label

- Per-VRF : one MPLS label per VRF (all CE routers in the VRF)
  - Con: IP lookup needed after label lookup
  - Con: No granular load balancing because the bottom label is the same for all prefixes, if platform load balances on bottom label
  - Potential forwarding loop during local traffic diversion to support PIC
  - No support for EIBGP multipath

Number of MPLS labels used per VRF is 1 !



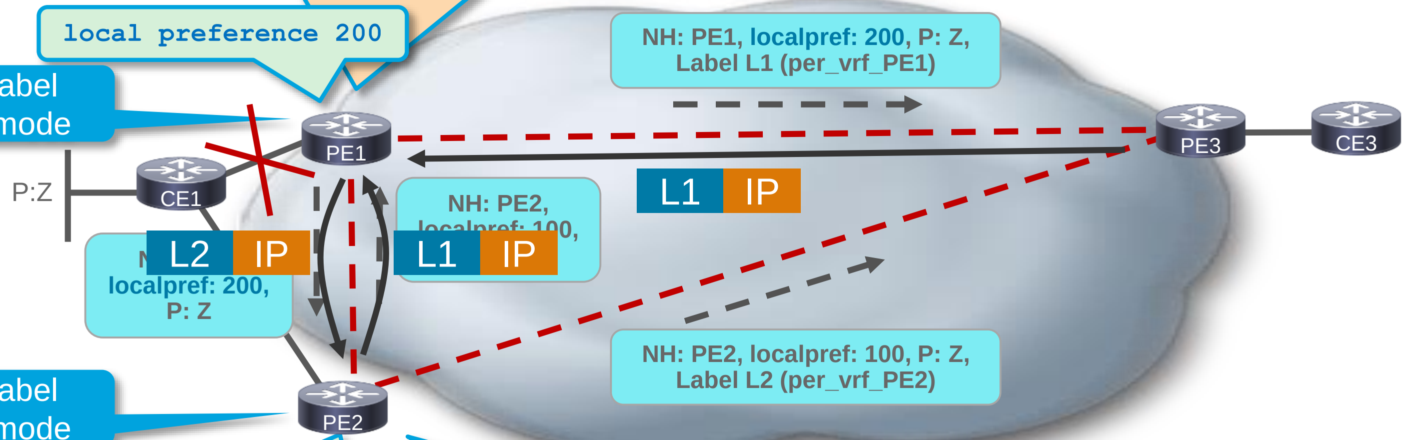
IOS-XR can do selective label mode (prefix | CE | VRF) with RPL

Per-VRF Label: Caveats – Transient loop with PIC

P: Z
 Path 1: NH: CE1, external, best
 Path 2: NH: PE2, localpref 100, internal, **backup/repair**

```
local preference 200
```

per-VRF label allocation mode



NH: PE1, localpref: 200, P: Z, Label L1 (per_vrf_PE1)

NH: PE2, localpref: 100,

N localpref: 200, P: Z

NH: PE2, localpref: 100, P: Z, Label L2 (per_vrf_PE2)

per-VRF label allocation mode

```
router bgp 1
 address-family vpnv4
  bgp additional-paths install
  bgp additional-paths select best-external
  neighbor x.x.x.x advertise best-external
```

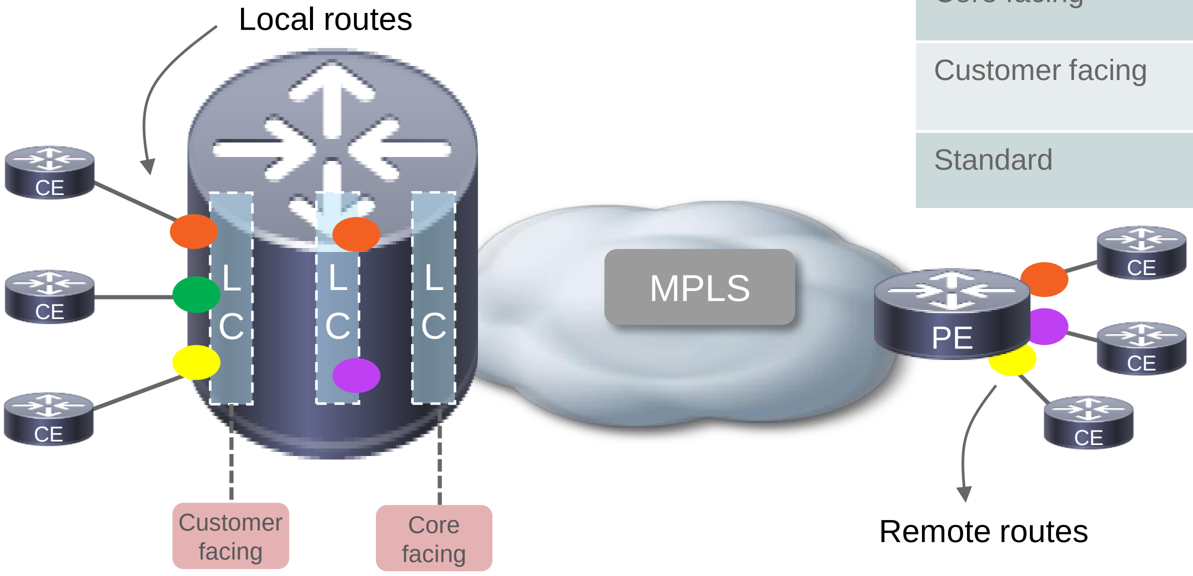
P: Z
 Path 1: NH: CE1, external, best **backup/repair, advertise-best-external**
 Path 1: NH: PE1, localpref: 200, internal, best

IOS-XR

Selective VRF Download (SVD)

- Download to a line card only those prefixes and labels from a VRF that are actively required to forward traffic through that line card
- In IOS-XR 4.2.0 and enabled by default

Linecard Role	Which routes are present?
Core facing	routes for all VRFs, but only the local routes
Customer facing	routes only for VRFs which the LC is interested in (local and remote routes)
Standard	all routes are present



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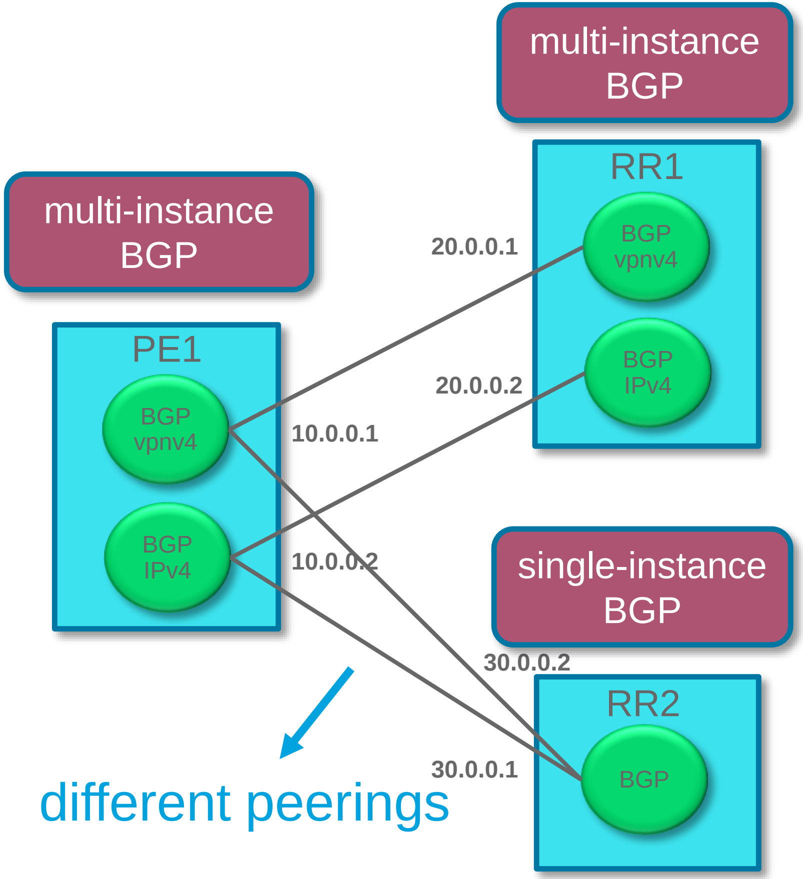
OS Enhancements

Multi-Instance BGP

- A new IOS-XR BGP architecture to support multiple BGP instances
- Each BGP instance is a separate process running on the same or a different RP/DRP node
- Different prefix tables
- Multiple ASNs are possible
- Solves the 32-bit OS virtual memory limit
- Different BGP routers: isolate services/AFs on common infrastructure
- Achieve higher prefix scale (especially on a RR) by having different instances carrying different BGP tables
- Achieve higher session scale by distributing the overall peering sessions between instances



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ASR9K: Scaling Enhancement

- BGP RIB Scale enhancement in 5.1.1
  - Only for RSP440-SE
  - Reload is needed

- Get more virtual address space for BGP process
  - From 2 GB to 2.5 GB

```
RP/0/RSP1/CPU0:router(admin-config)#hw-module profile scale ?
  default   Default scale profile
  l3        L3 scale profile
  l3xl      L3 XL scale profile
```

Profile	Layer 3 (Prefixes)	Layer 2 (MAC Table)
default	Small (512k)	Large (512k)
l3	Large (1,000k)	Small (128k)
l3xl	Extra large (1,300k)	Minimal
l3xl (5.1.1 RSP3)	Extra large (2,500k)	Minimal

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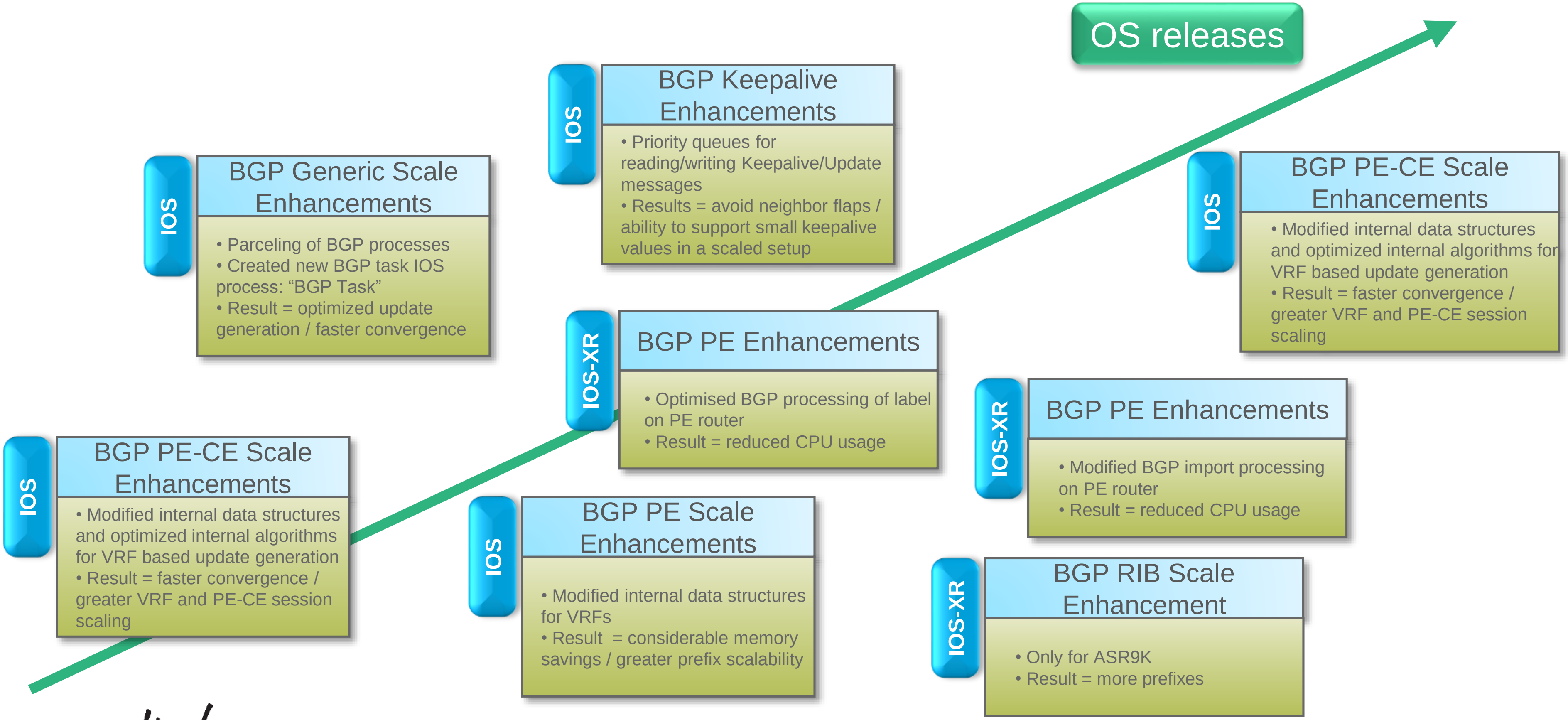
For Your Reference

OS Scaling Enhancements for BGP



OS releases

IOS

BGP Generic Scale Enhancements

- Parceling of BGP processes
- Created new BGP task IOS process: “BGP Task”
- Result = optimized update generation / faster convergence

IOS

BGP PE-CE Scale Enhancements

- Modified internal data structures and optimized internal algorithms for VRF based update generation
- Result = faster convergence / greater VRF and PE-CE session scaling

IOS

BGP Keepalive Enhancements

- Priority queues for reading/writing Keepalive/Update messages
- Results = avoid neighbor flaps / ability to support small keepalive values in a scaled setup

IOS-XR

BGP PE Enhancements

- Optimised BGP processing of label on PE router
- Result = reduced CPU usage

IOS

BGP PE Scale Enhancements

- Modified internal data structures for VRFs
- Result = considerable memory savings / greater prefix scalability

IOS

BGP PE-CE Scale Enhancements

- Modified internal data structures and optimized internal algorithms for VRF based update generation
- Result = faster convergence / greater VRF and PE-CE session scaling

IOS-XR

BGP PE Enhancements

- Modified BGP import processing on PE router
- Result = reduced CPU usage

IOS-XR

BGP RIB Scale Enhancement

- Only for ASR9K
- Result = more prefixes

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Key Takeaways

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Takeaway : When is the Boat Not Big Enough?

For Your Reference

Convergence

Measure
Prefix instability
Traffic drops
Table Versions
Timestamps

IOS	IOS-XR	NX-OS
	show bgp convergence	show bgp convergence detail
show bgp all summary	show bgp table	
	show bgp process performance-statistics detail	

Memory

IOS	IOS-XR	NX-OS
show bgp all summary	show bgp table	show bgp internal mem-stats detail - look for “Grand total”, “Private memory”, “Shared memory”
show processes memory sorted	show process memory <job-id> location <>	show system resource
	show watchdog memory-state	
	show memory compare start | end | report	
	show bgp scale	

CPU

IOS	IOS-XR	NX-OS
show processes cpu history show processes cpu | include BGP	show processes cpu show processes bgp show processes cpu | include bgp	show processes cpu history show processes cpu | include bgp show process cpu detailed <bgp pid>

Key Takeaways

- Design
    - Topology
    - Features
    - Address families
    - Full mesh iBGP / RRs

- Memory and CPU

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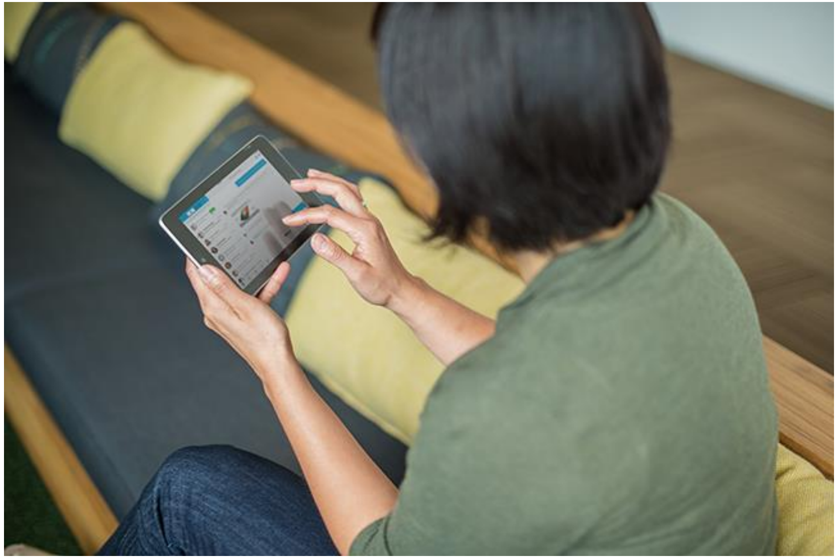

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