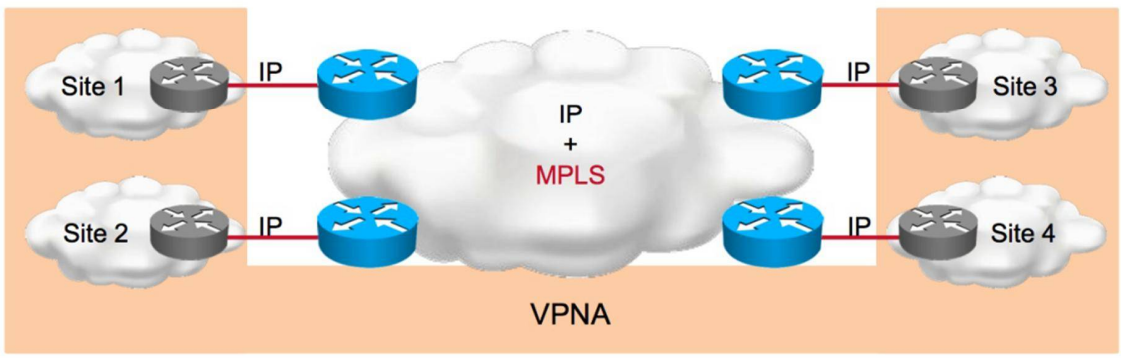
MPLS

2016/7/1

MPLS VPN

- Customers connect to service provider via IP
- Service provider uses MPLS to forward packets between edge routers
- Service provider enables any-to-any connectivity between sites belonging to the same VPN
- Service provider uses virtual routers to isolate customer routing information
- Customers can use any addressing inside their VPN



Enabling VRF

Create a VRF table.	`RP/0/RP0/CPU0:router(config)# vrf vrf-name`
Enter VRF address family configuration mode for the IPv4 address family.	`RP/0/RP0/CPU0:router(config-vrf)# address-family ipv4 unicast`
Specify import route targets.	`RP/0/RP0/CPU0:router(config-vrf-af)# import route-target [as-number:nn | ip-address:nn]`
Specify export route targets.	`RP/0/RP0/CPU0:router(config-vrf-af)# export route-target [as-number:nn | ip-address:nn]`
Assign interfaces to VRFs.	`RP/0/RP0/CPU0:router(config-if)# vrf vrf-name`

Creating VRF Table

`RP/0/RP0/CPU0:router(config)#`

Cisco IOS XR **`vrf vrf-name`**

- This command creates a new VRF or enters configuration of an existing VRF.
- VRF names are case-sensitive.
- VRF names have only local significance.

Assigning RD

- This command assigns a route distinguisher to a VRF.
- A VRF is not operational unless you configure an RD.
- You can use the ASN:nn or A.B.C.D:nn format for RD.
- Each VRF in a PE router must have a unique RD.

Cisco IOS XR configuration

RD is configured under BGP configuration area

```
Router(config)#router bgp AS
Router(config-bgp)#vrf vrf-name
Router(config-bgp-vrf)#rd route-distinguisher
```


VRF Address Family

```
RP/0/RP0/CPU0:router(config-vrf)#
address-family ipv4 unicast
```

- Cisco IOS XR Software only
- This command allows you to enter VRF address family configuration mode for the IPv4 address family

RT

```
RP/0/RP0/CPU0:router(config-vrf-af)#
export route-target [as-number:nn | ip-address:nn]
```

- Allows specification of many export RTs—all to be attached to every exported route

```
RP/0/RP0/CPU0:router(config-vrf-af)#
import route-target [as-number:nn | ip-address:nn]
```

- Allows specification of many import RTs. (Any route where at least one RT attached to the route matches any import RT is imported into the VRF.)

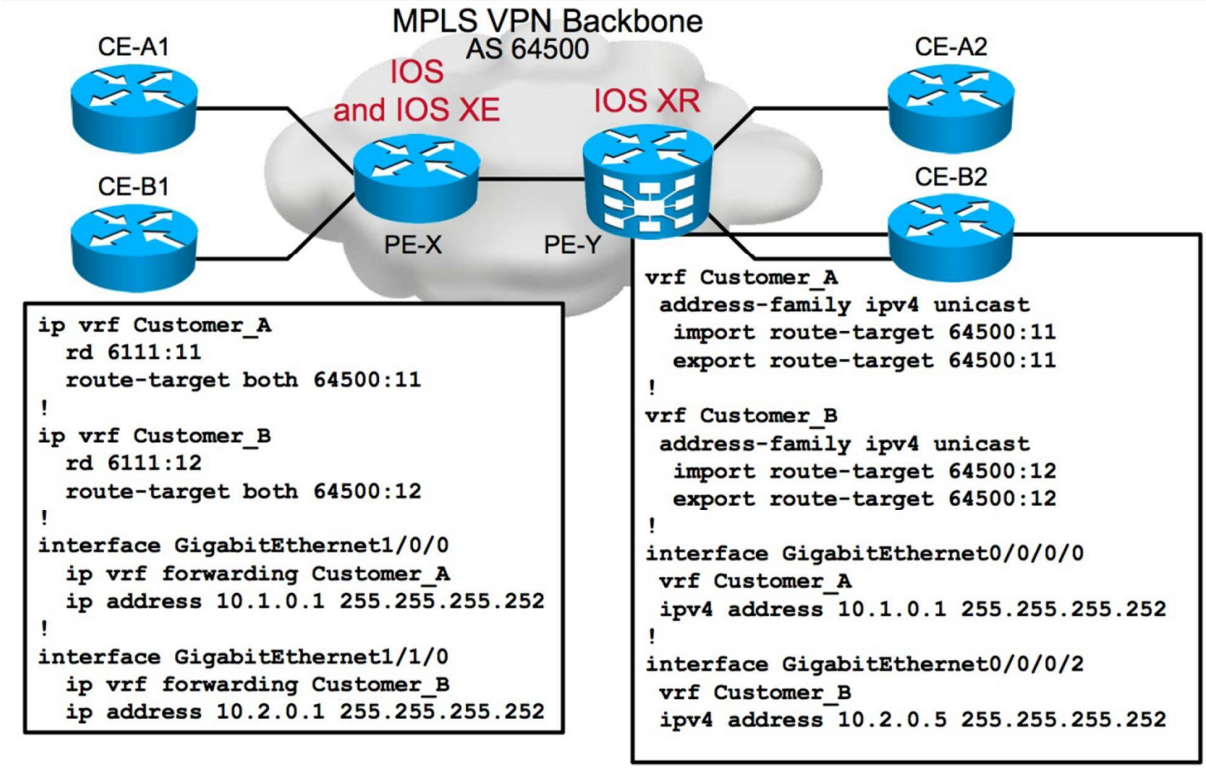
Assigning an Interface to a VRF Table

Cisco IOS XR

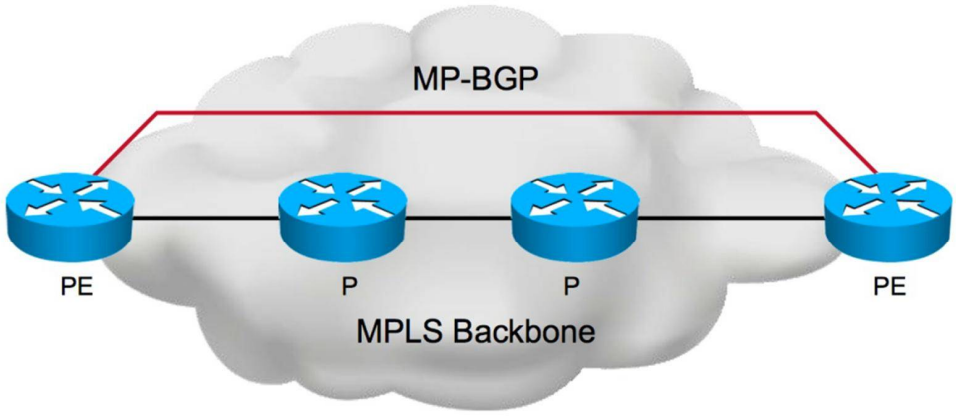
```
RP/0/RP0/CPU0:router(config-if)#
vrf vrf-name
```

- This command associates an interface with the specified VRF.
- The existing IP address is removed from the interface when the interface is put into the VRF—the IP address must be reconfigured.
- Cisco Express Forwarding switching must be enabled on the interface.

Example



MP-BGP



- Layer 3 MPLS VPNs are implemented using MP-BGP to exchange VPN routing information.
- MP-BGP is BGP version 4 with extensions to support other protocols and applications:
  - Layer 3 MPLS VPNs
  - Virtual Private LAN Services (VPLS) using BGP autodiscovery

BGP Address Family

```
RP/0/RP0/CPU0:router(config) #
router bgp as-number
```

- Selects global BGP routing process

```
RP/0/RP0/CPU0:router(config-bgp) #
address-family vpnv4 unicast
```

- Configures VPNv4 prefix

MP-IBGP

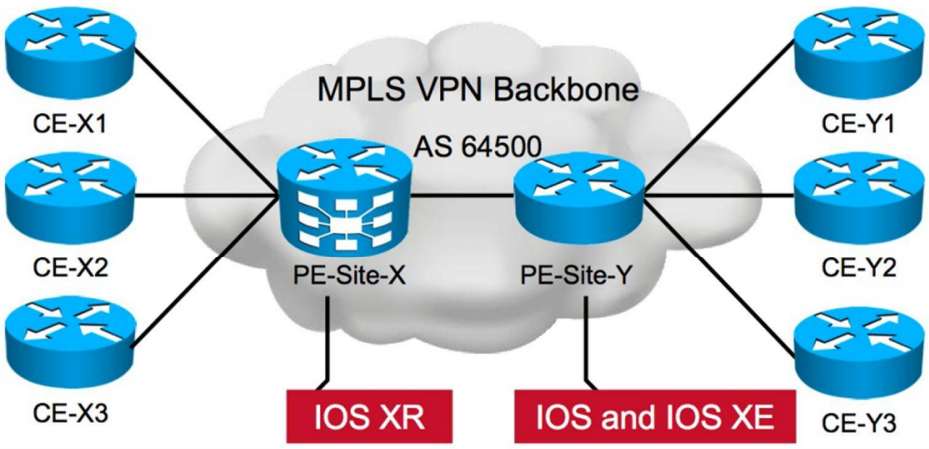
```
RP/0/RP0/CPU0:router(config) #
router bgp as-number
neighbor ip-address remote-as as-number
```

- Configures a neighbor and assigns it a remote autonomous system number

```
RP/0/RP0/CPU0:router(config-bgp-nbr) #
address-family vpnv4 unicast
```

- Enters address family configuration mode for the VPNv4 address family.

Example




```
interface loopback 0
 ipv4 address 172.16.1.2 255.255.255.255
!
router bgp 64500
 address-family vpnv4 unicast
!
 neighbor 172.16.1.1
  remote-as 64500
  update-source Loopback0
  address-family vpnv4 unicast
   next-hop-self
```

```
interface loopback 0
 ip address 172.16.1.1 255.255.255.255
!
router bgp 64500
 neighbor 172.16.1.2 remote-as 64500
 neighbor 172.16.1.2 update-source loopback 0
!
 address-family vpnv4
  neighbor 172.16.1.2 activate
  neighbor 172.16.1.2 next-hop-self
  neighbor 172.16.1.2 send-community both
```


PE-CE Routing Protocol

- PE-CE routing protocols are configured for individual VRFs.
- Cisco IOS and IOS XE Software
  - Per-VRF routing protocols can be configured in two ways:
    - Per-VRF parameters are specified in routing contexts, which are selected with the **address-family** command.
    - A separate OSPF process is started for each VRF.
- Cisco IOS XR Software
  - Per-VRF parameters are specified in the routing contexts.
  - A separate OSPF process can also be configured for each VRF, but using multiple instances of OSPF will use more router resources.

Redistribution

Cisco IOS XR

```
RP/0/RSP0/CPU0:Router(config)#
router bgp as-number
 vrf vrf-name
  address-family ipv4 unicast
    ... Non-BGP redistribution ...
```

- Select the per-VRF BGP context with the **address-family** command.
- Configure CE External Border Gateway Protocol neighbors in VRF contexts, not in global BGP configuration.
- All non-BGP per-VRF routes have to be redistributed into a per-VRF BGP context to be propagated by MP-BGP to other PE routers.

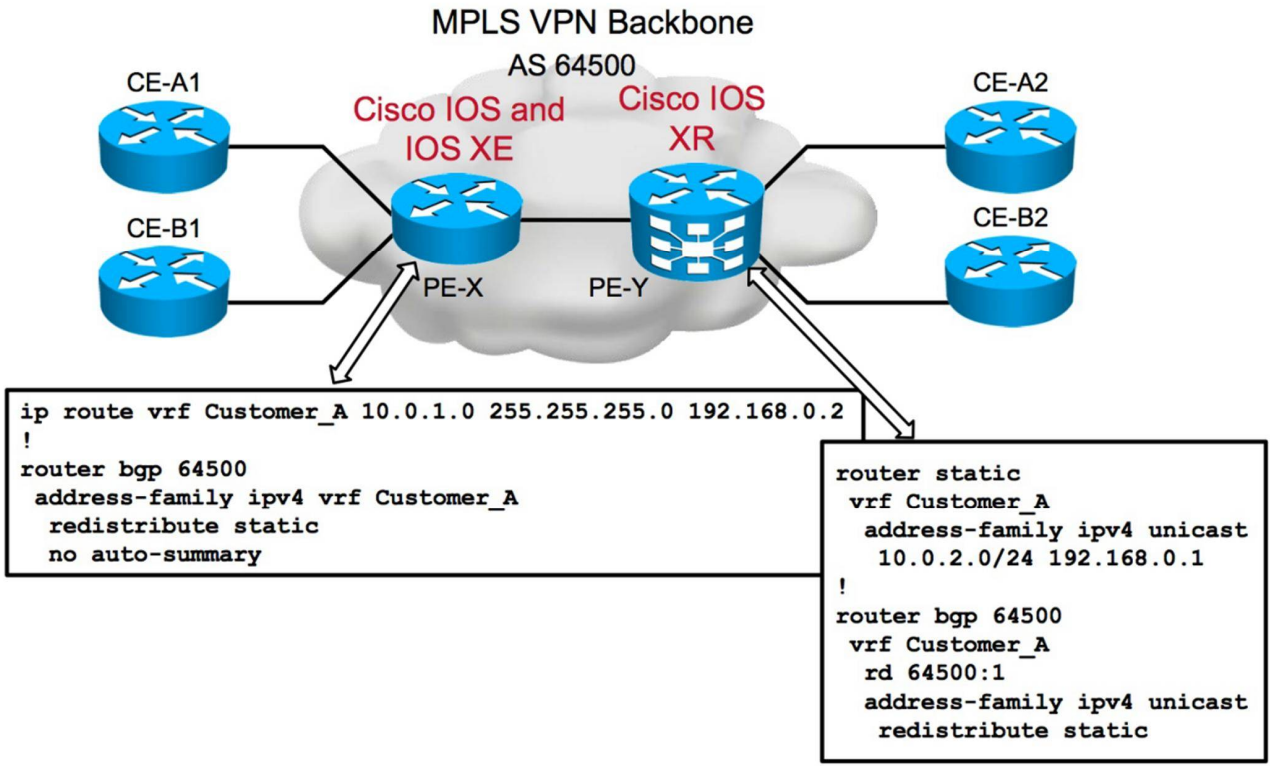
VRF Static Routes

```
RP/0/RSP0/CPU0:Router(config)#
router static
 vrf vrf-name
  address-family ipv4 unicast
   prefix mask [next-hop-address] [interface interface-number]
```

Sample router configuration:

```
router static
 vrf Customer_A
  address-family ipv4 unicast
   10.0.2.0/24 192.168.0.1
!
router bgp 64500
 vrf Customer_A
  rd 64500:1
  address-family ipv4 unicast
   redistribute static
```

Example



Monitoring VRF

Cisco IOS and IOS XE	Cisco IOS XR
• Displays the list of all VRFs configured in the router	
`show ip vrf`	`show vrf all`
• Displays detailed VRF configuration	
`show ip vrf detail`	`show vrf all detail`

```
RP/0/RSP0/CPU0:PE3# show vrf all detail

VRF Customer_1; RD 1:210; VPN ID not set
Description not set
Interfaces:
  GigabitEthernet0/0/0/0
Address family IPV4 Unicast
  Import VPN route-target communities:
    RT:1:210
  Export VPN route-target communities:
    RT:1:210
  No import route policy
  No export route policy
<--- text omitted --->
```

• Displays interfaces associated with VRFs	
`show ip vrf interfaces`	`show ipv4 vrf all interface brief`

VRF Routing

Cisco IOS and IOS XE

- Displays the VRF routing table

show ip route vrf *vrf-name*

Cisco IOS XR

show route vrf *vrf-name*

```
RP/0/RSP0/CPU0:PE1#sh route vrf Customer_1
<--- text omitted --->

O    172.16.1.0/24 [110/2] via 192.168.101.11, 1w6d, GigabitEthernet0/0/0/0
B    172.16.2.0/24 [200/2] via 10.2.1.1 (nexthop in vrf default), 1w6d
C    192.168.101.0/24 is directly connected, 2w0d, GigabitEthernet0/0/0/0
L    192.168.101.10/32 is directly connected, 2w0d, GigabitEthernet0/0/0/0
B    192.168.102.0/24 [200/0] via 10.2.1.1 (nexthop in vrf default), 1w6d
```

- Displays per-VRF MP-BGP parameters

show ip bgp vpnv4 vrf *vrf-name*

show bgp vpnv4 unicast vrf *vrf-name*

MP-BGP session

Cisco IOS and IOS XE

- Displays configured BGP neighbors and the protocols negotiated with these neighbors

show ip bgp neighbors

Cisco IOS XR

show bgp neighbors

```
RP/0/RSP0/CPU0:PE1#show bgp neighbors
BGP neighbor is 10.0.1.1
 Remote AS 64500, local AS 64500, internal link
 Remote router ID 10.0.1.1
  BGP state = Established, up for 2w0d
  Last read 00:00:48, Last read before reset 00:00:00
  Hold time is 180, keepalive interval is 60 seconds
  Configured hold time: 180, keepalive: 60, min acceptable hold time: 3

<--- text omitted --->

  Precedence: internet
  Neighbor capabilities:
    Route refresh: advertised and received
    4-byte AS: advertised and received
    Address family VPNv4 Unicast: advertised and received
```

VPNv4 Table

Cisco IOS and IOS XE	Cisco IOS XR
• Displays the whole VPNv4 table	
`show ip bgp vpnv4 all`	`show bgp vpnv4 unicast`
• Displays only BGP parameters associated with the specified VRF	
`show ip bgp vpnv4 vrf vrf-name`	`show bgp vpnv4 unicast vrf vrf-name`
• Displays only BGP parameters associated with the specified RD	
`show ip bgp vpnv4 rd rd`	`show bgp vpnv4 unicast rd rd`

```
RP/0/RSP0/CPU0:PE1#show bgp vpnv4 unicast rd 1:210
BGP router identifier 10.1.1.1, local AS number 64500
BGP generic scan interval 60 secs
<--- text omitted --->
   Network            Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 1:210 (default for vrf Customer_1)
*> 172.16.1.0/24      192.168.101.11           2         32768 ?
*>i172.16.2.0/24      10.2.1.1                 2    100      0 ?
*> 192.168.101.0/24   0.0.0.0                  0         32768 ?
*>i192.168.102.0/24   10.2.1.1                 0    100      0 ?

Processed 4 prefixes, 4 paths
```


CEF

Cisco IOS and IOS XE	Cisco IOS XR
• Displays per-VRF Cisco Express Forwarding table	
`show ip cef vrf vrf-name`	`show cef vrf vrf-name`
• Displays details of an individual Cisco Express Forwarding entry, including label stack	
`show ip cef vrf vrf-name ip-prefix detail`	`show cef vrf vrf-name ip-prefix detail`
• Displays labels allocated by an MPLS VPN for routes in the specified VRF	
`show mpls forwarding vrf vrf-name`	`show mpls forwarding vrf vrf-name`

```
RP/0/RSP0/CPU0:PE1#sh mpls forwarding vrf Customer_1
Tue Jan  3 12:19:19.574 UTC
Local  Outgoing    Prefix             Outgoing     Next Hop        Bytes
Label  Label       or ID              Interface                    Switched
------ ----------- ------------------ ------------ --------------- ------------
16017  Unlabelled  172.16.1.0/24[V]   Gi0/0/0/0    192.168.101.11  500
16018  Aggregate   Customer_1: Per-VRF Aggr[V]    \
                                      Customer_1                   500
```

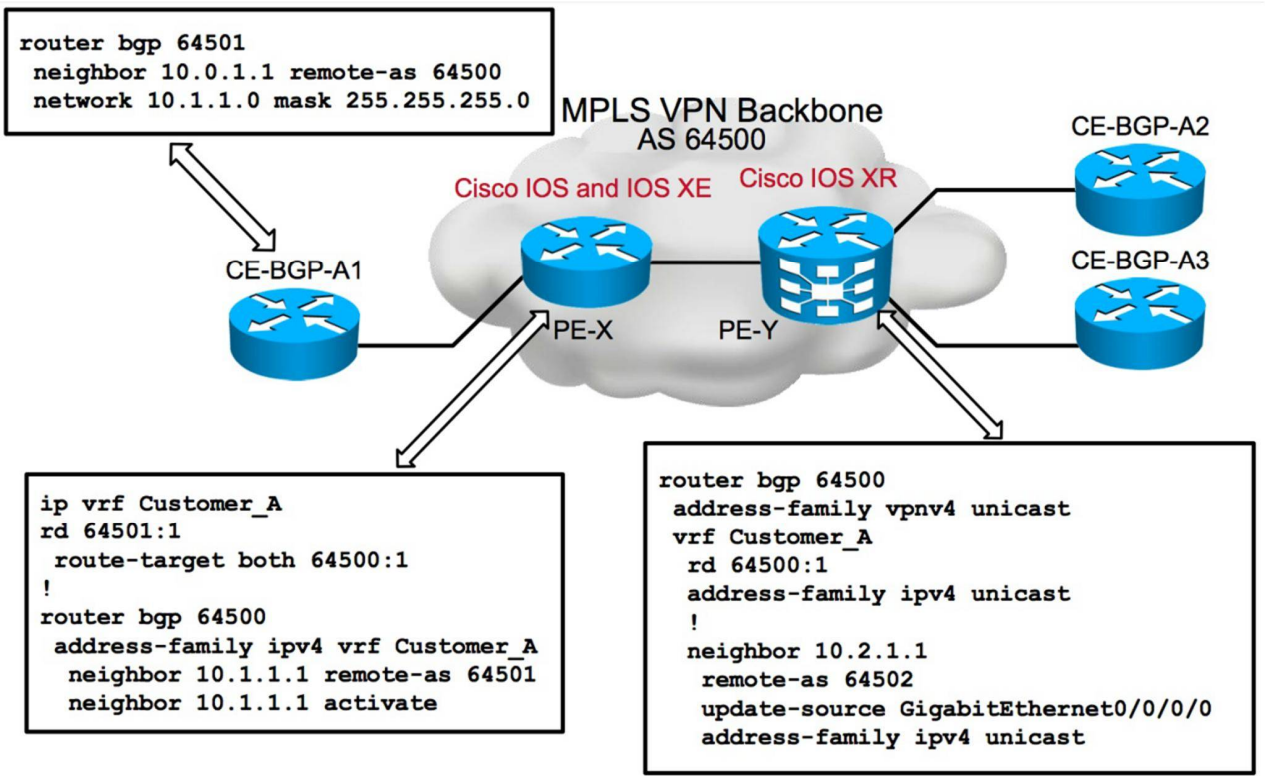
Per-VRF BGP

Cisco IOS XR

```
RP/0/RP0/CPU0:Router(config)#
router bgp as-number
  vrf vrf-name
   address-family ipv4 unicast
    ... Per-VRF BGP definitions ...
```

- Select a per-VRF BGP context with the **address-family** command.
- Configure CE EBGP neighbors in the VRF context, not in the global BGP configuration.
- CE neighbors must be activated with the **neighbor activate** command.

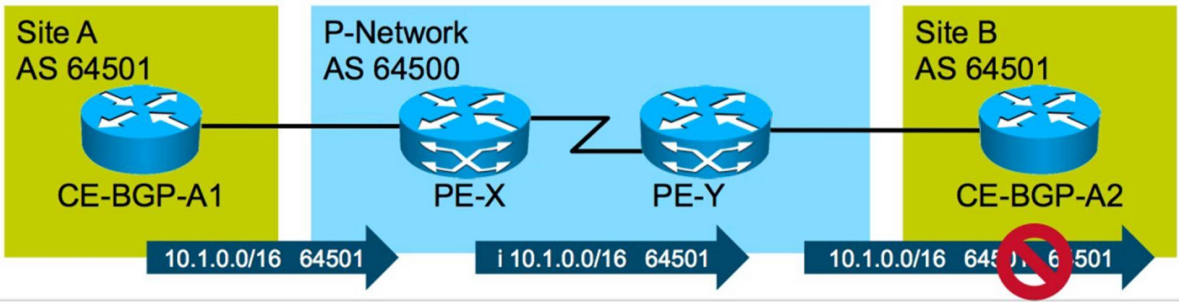
Example



CE Same AS issue

The customer wants to reuse an AS number on several sites:

- CE-BGP-A1 announces network 10.1.0.0/16 to PE-Site-X.
- The prefix announced by CE-BGP-A1 is propagated to PE-Site-Y as an internal route through MP-BGP.
- PE-Site-Y prepends AS 64500 to the AS path and propagates the prefix to CE-BGP-A2.
- CE-BGP-A2 drops the update because AS 64501 is already in the AS path.



As-override

- New AS path update procedures have been implemented to reuse an AS number on all VPN sites.
- The procedures allow the use of private and public AS numbers.
- The same AS number may be used for all sites.
- With **as-override** configured, the AS path update procedure on the PE router is as follows:
  - If the first AS number in the AS path is equal to the neighboring AS, it is replaced with the provider AS number.
  - If the first AS number has multiple occurrences (because of AS path prepend), all occurrences are replaced with the provider AS number.
  - After this operation, the provider AS number is prepended to the AS path.

Cisco IOS and IOS XE

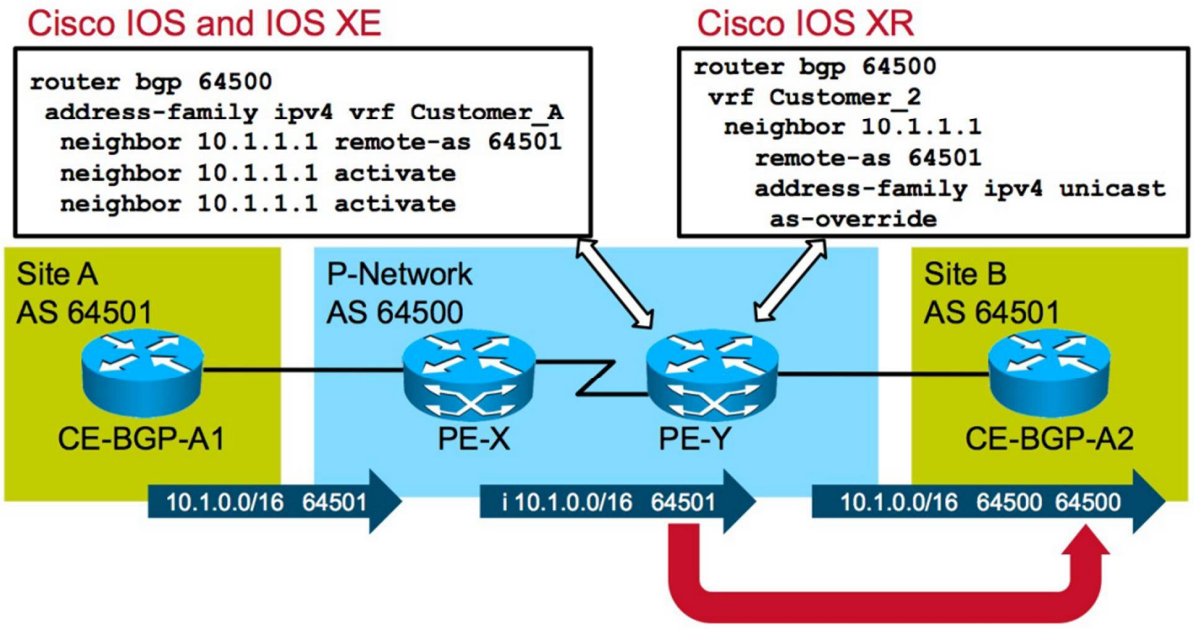
```
Router(config-router-af)#
neighbor ip-address as-override
```

Cisco IOS XR

```
RP/0/RP0/CPU0:router(config-bgp-vrf-nbr-af)#
as-override
```

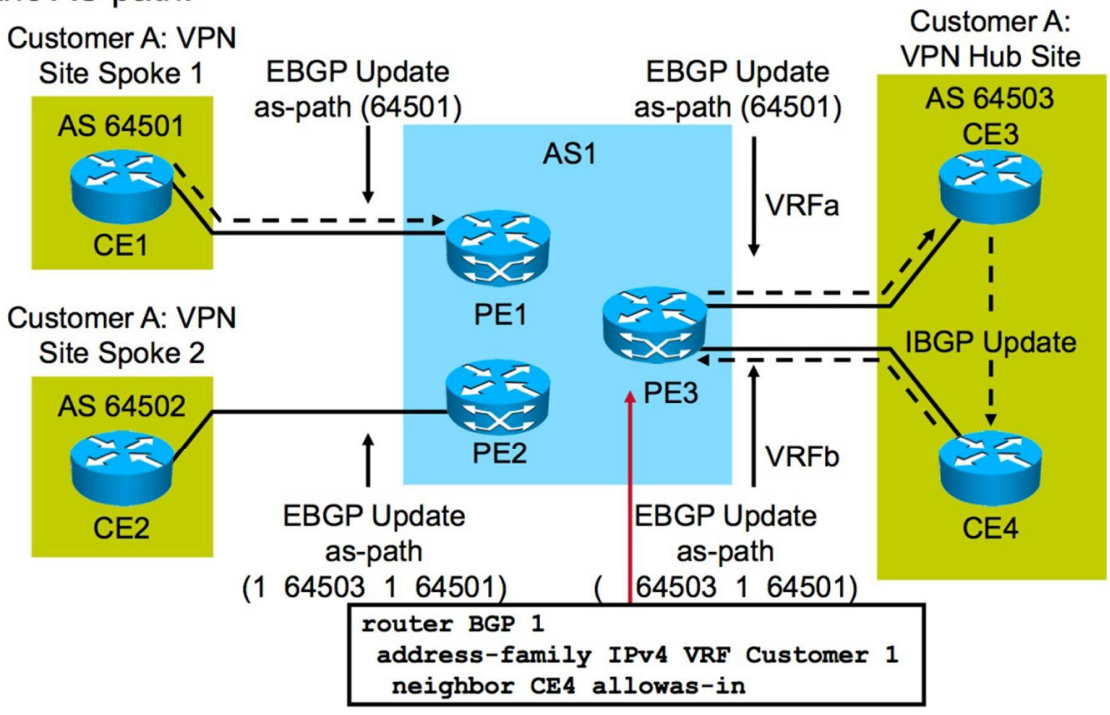
Example

- PE-Site-Y replaces AS 64501 with AS 64500 in the AS path, prepends another copy of AS 64500 to the AS path, and propagates the prefix.

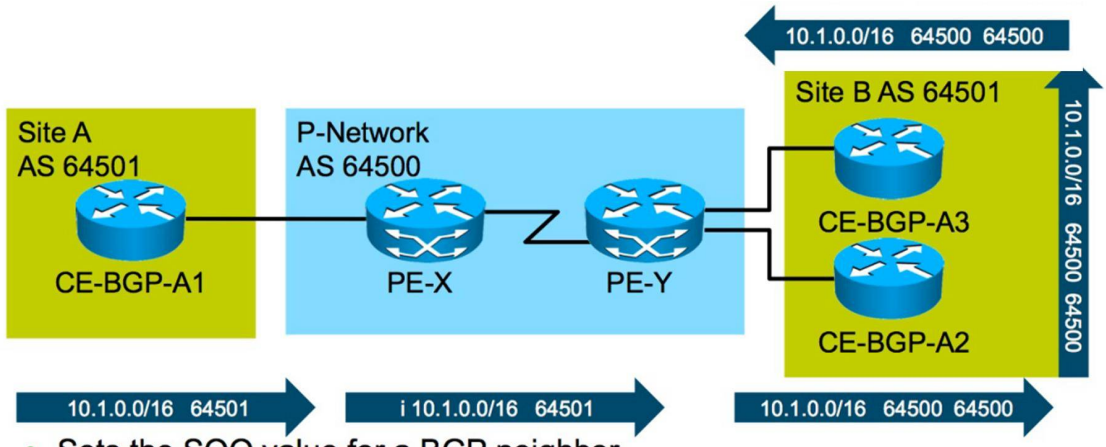


Allowas-in

The BGP route is rejected because the PE3 router sees its own AS number in the AS path.



SOO



- Sets the SOO value for a BGP neighbor

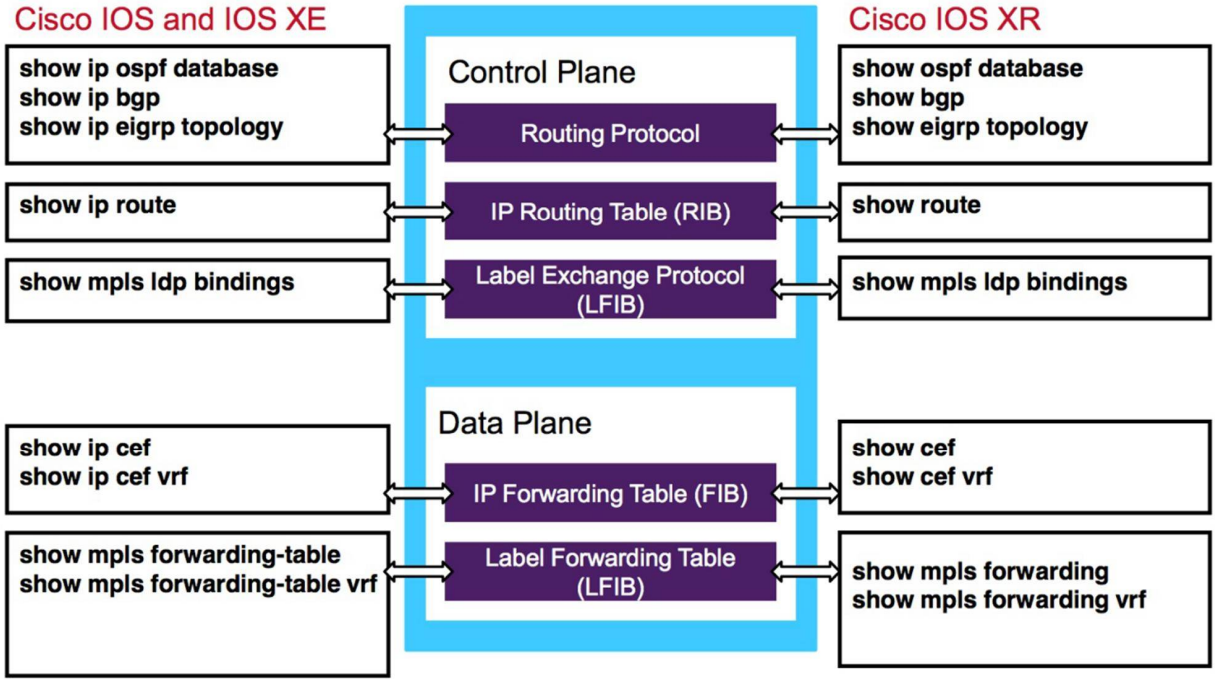
Cisco IOS and IOS XE

```
Router(config-router-af)#
neighbor ip-address soo AS:nn
```

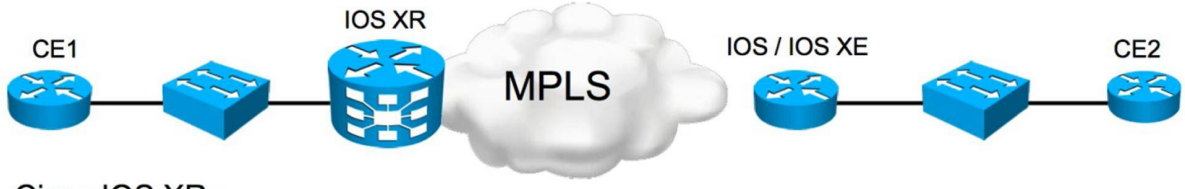
Cisco IOS XR

```
RP/0/RP0/CPU0:Router(config-bgp-vrf-nbr-af)#
site-of-origin AS:nn
```


Troubleshooting Commands



EoMPLS



Cisco IOS XR:

```
interface Loopback0
 ipv4 address 10.1.1.1 255.255.255.255
!
interface Giga0/0/0/0.40 l2transport
 encapsulation dot1q 40
!
l2vpn
xconnect group eompls-group
  p2p eompls-p2p
   interface Gigabit0/0/0/0.40
   neighbor 10.2.2.2 pw-id 123
```

Cisco IOS and IOS XE:

```
ip cef
mpls ip
mpls label protocol ldp
mpls ldp router-id Loopback0 force
!
interface Loopback0
 ip address 10.2.2.2 255.255.255.255
!
pseudowire-class pw-class2
 encapsulation mpls
!
interface Gi0/0/0.40
 encapsulation dot1Q 40
 xconnect 10.1.1.1 123 pw-class pw-class2
```

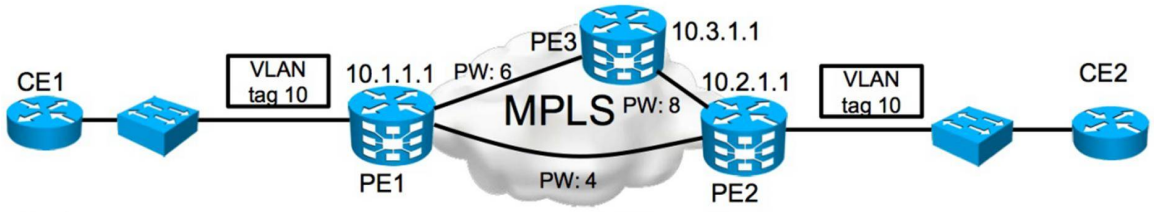

EoMPLS Verification

```
RP/0/RSP0/CPU0:router# show l2vpn xconnect detail
Group eompls-group, XC eompls-p2p, state is up; Interworking none
  AC: Gigabit0/0/0/0.30, state is up
    Type VLAN
    MTU 1500; XC ID 0x5000001; interworking none; MSTi 0
    Statistics:
      packet totals: send 90
      byte totals: send 19056
  PW: neighbor 10.2.2.2, PW ID 123, state is up ( established )
    PW class pw-class1, XC ID 0x5000001
    Encapsulation MPLS, protocol LDP
    PW type VLAN, control word enabled, interworking none
    PW backup disable delay 0 sec
    Sequencing not set
        MPLS         Local                          Remote
      ------------ ------------------------------ ------------------------
      Label        30005                          16003
      Group ID     0x5000300                      0x5000400
      Interface    Gigabit0/0/0/0.30              Gi0/0/0/0.40
      MTU          1500                           1500
      Control word enabled                        enabled
      PW type      VLAN                           VLAN
      VCCV CV type 0x2                            0x2
                   (LSP ping verification)        (LSP ping verification)
      VCCV CC type 0x7                            0x7
                   (control word)                 control word)
                   (router alert label)           (router alert label)
      ------------ ------------------------------ ----------------------
<output truncated>
```

VPLS Configuration

- Prepare MPLS infrastructure:
  - PE routers must have a /32 address on their loopbacks.
  - PE loopback addresses cannot be summarized in the core.
  - Ensure MTU sizes in the core are large enough.
- Enable Layer 2 frame transport on both endpoint attachment circuits.
- Make sure MTU is the same on both endpoint interfaces.
- Configure bridge group and bridge domain.
- Assign interface(s) to the bridge domain.
- Configure VFI with statically defined PWs or neighbor autodiscovery.

Example



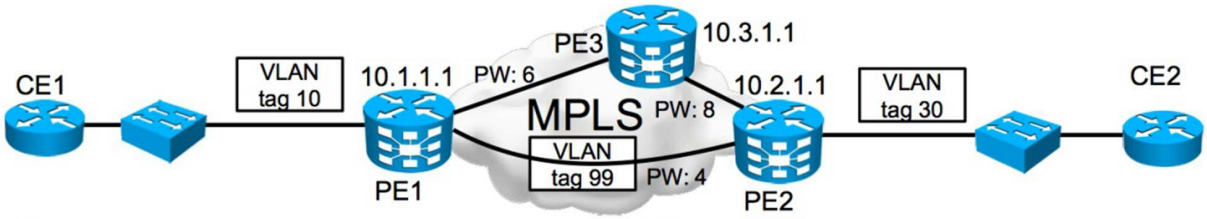
PE1:

```
interface Loopback0
 ipv4 address 10.1.1.1 255.255.255.255
!
interface GigabitEthernet0/0/0/0.10
l2transport
 encapsulation dot1q 10
!
l2vpn
 bridge group VPLS-group1
  bridge-domain VPLS-domain1
  interface GigabitEthernet0/0/0/0.10
  exit
 vfi VPLS-vfi1
  neighbor 10.2.1.1 pw-id 4
  neighbor 10.3.1.1 pw-id 6
```

PE2:

```
interface Loopback0
 ipv4 address 10.2.1.1 255.255.255.255
!
interface GigabitEthernet0/0/0/0.10
l2transport
 encapsulation dot1q 10
!
l2vpn
 bridge group VPLS-group1
  bridge-domain VPLS-domain1
  interface GigabitEthernet0/0/0/0.10
  exit
 vfi VPLS-vfi1
  neighbor 10.1.1.1 pw-id 4
  neighbor 10.3.1.1 pw-id 8
```

Vlan Rewrite



PE1:

```
interface Loopback0
 ipv4 address 10.1.1.1 255.255.255.255
!
interface GigabitEthernet0/0/0/0.10
l2transport
 encapsulation dot1q 10
 rewrite ingress tag translate 1-to-1
dot1q 99 symmetric
!
l2vpn
 bridge group VPLS-group1
  bridge-domain VPLS-domain1
  interface GigabitEthernet0/0/0/0.10
  exit
 vfi VPLS-vfi1
  neighbor 10.2.1.1 pw-id 4
  neighbor 10.3.1.1 pw-id 6
```

PE2:

```
interface Loopback0
 ipv4 address 10.2.1.1 255.255.255.255
!
interface GigabitEthernet0/0/0/0.30
l2transport
 encapsulation dot1q 30
 rewrite ingress tag translate 1-to-1
dot1q 99 symmetric
!
l2vpn
 bridge group VPLS-group3
  bridge-domain VPLS-domain3
  interface GigabitEthernet0/0/0/0.30
  exit
 vfi VPLS-vfi3
  neighbor 10.1.1.1 pw-id 4
  neighbor 10.3.1.1 pw-id 8
```


Verify VPLS

```
RP/0/RSP0/CPU0:PE3# show l2vpn bridge-domain detail
Sat Nov 26 13:48:47.127 UTC
Bridge group: VPLS-group3, bridge-domain: VPLS-domain3, id: 1, state: up, ShgId: 0,
MSTi: 0
  MAC learning: enabled
  MAC withdraw: enabled
    MAC withdraw for Access PW: enabled
  Flooding:
    Broadcast & Multicast: enabled
    Unknown unicast: enabled
  MAC aging time: 300 s, Type: inactivity
  MAC limit: 4000, Action: none, Notification: syslog
  MAC limit reached: no
  MAC port down flush: enabled
  MAC Secure: disabled, Logging: disabled
  Split Horizon Group: none
  Dynamic ARP Inspection: disabled, Logging: disabled
  IP Source Guard: disabled, Logging: disabled
  DHCPv4 snooping: disabled
  IGMP Snooping profile: none
  Bridge MTU: 1500
  MIB cvplsConfigIndex: 2
  Filter MAC addresses:
  Create time: 26/11/2011 11:38:38 (02:10:08 ago)
  No status change since creation
  ACs: 1 (1 up), VFIs: 1, PWs: 1 (1 up), PBBs: 0 (0 up)
  < to be continued>
```

Verify VPLS

```
List of ACs:
    AC: GigabitEthernet0/0/0/0.30, state is up
      Type VLAN; Num Ranges: 1
      VLAN ranges: [30, 30]
      MTU 1504; XC ID 0x840001; interworking none
      MAC learning: enabled
      Flooding:
        Broadcast & Multicast: enabled
        Unknown unicast: enabled
      MAC aging time: 300 s, Type: inactivity
      MAC limit: 4000, Action: none, Notification: syslog
      MAC limit reached: no
      MAC port down flush: enabled
      MAC Secure: disabled, Logging: disabled
      Split Horizon Group: none
      Dynamic ARP Inspection: disabled, Logging: disabled
      IP Source Guard: disabled, Logging: disabled
      DHCPv4 snooping: disabled
      IGMP Snooping profile: none
      Storm Control: disabled
      Static MAC addresses:
      Statistics:
        packets: received 31686, sent 27420
        bytes: received 2156476, sent 1911176
      Storm control drop counters:
        packets: broadcast 0, multicast 0, unknown unicast 0
        bytes: broadcast 0, multicast 0, unknown unicast 0
<to be continued>
```


Verify VPLS

```
List of Access PWs:
  List of VFIs:
    VFI VPLS-vfi3
PW: neighbor 10.7.1.1, PW ID 64500:10, state is up ( established )
        PW class not set, XC ID 0xfffc0005
        Encapsulation MPLS, Auto-discovered (BGP), protocol LDP
        PW type Ethernet, control word disabled, interworking none
        PW backup disable delay 0 sec
        Sequencing not set

          MPLS         Local                          Remote
          ------------ ------------------------------ -------------------------
          Label        30000                          16002
          BGP Peer ID  10.3.1.1                       10.7.1.1
          LDP ID       10.3.1.1                       10.7.1.1
          AII          10.3.1.1                       10.7.1.1
          AGI          64500:10                       64500:10
          Group ID     0x1                            0x1
          Interface    VPLS-vfi3                      VPLS-vfi7
          MTU          1500                           1500
          Control word disabled                       disabled
          PW type      Ethernet                       Ethernet
          VCCV CV type 0x2                            0x2
                       (LSP ping verification)        (LSP ping verification)
          VCCV CC type 0x6                            0x6
                       (router alert label)           (router alert label)
                       (TTL expiry)                   (TTL expiry)
          ------------ ------------------------------ -------------------------
<output truncated>
```