

# **BGP MPLS VPNs**

This chapter describes services that are supported for Border Gateway Protocol (BGP) Multi-Protocol Label Switching (MPLS) Virtual Private Networks (VPNs).



#### **Important**

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It includes the following topics:

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# Introduction

Service providers require the ability to support a large number of corporate Access Point Names (APNs) which have a number of different addressing models and requirements. UGP uses BGP MPLS Layer 3 VPNs to segregate corporate customer APNs in a highly scalable manner. This solution conforms to RFC 4364 – *BGP/MPLS IP Virtual Private Networks (VPNs)*.

The BGP/MPLS solution supports the following scenarios:

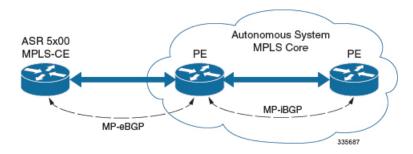
- MPLS-CE Connected to PE, on page 2
- UGP as a PE, on page 2

UGP also supports VPNv6 as described in RFC 4659 – *BGP-MPLS IP Virtual Private Network (VPN) Extension for IPv6 VPN*. See IPv6 Support for BGP MPLS VPNs, on page 4 for details.

### **MPLS-CE Connected to PE**

In this scenario the UGP functions as an MPLS-CE (Customer Edge) network element connected to a Provider Edge (PE) Label Edge Router (LER), which in turn connects to the MPLS core (RFC 4364). See the figure below.

Figure 1: UGP MPLS-CE to PE



The MPLS-CE functions like a PE router within its own Autonomous System (AS). It maintains Virtual Routing and Forwarding (VRF) routes and exchanges VPN route information with the PE via an MP-eBGP (Multi-Protocol-external BGP) session.

The PE is also configured with VRFs and exchanges VPN routes with other PEs in its AS via MP-iBGP (Multi-Protocol-internal BGP) connections and the MPLS-CE via an MP-eBGP connection.

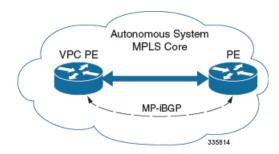
The EBGP connection allows the PE to change next-hop IP addresses and labels in the routes learned from IBGP peers before advertising them to the MPLS-CE. The MPLS-CE in this case uses only MP-eBGP to advertise and learn routes. Label Distribution Protocol (LDP) and Resource Reservation Protocol (RSVP) are not required because of direct-connect EBGP peering. The MPLS-CE in this scenario pushes/pops a single label (learned over the MP-eBGP connection) to/from the PE.

### **UGP** as a PE

### **Overview**

In this scenario, the UGP functions as a PE router sitting at the edge of the MPLS core. See the figure below.

Figure 2: UGP as a PE



The UGP eliminates the need for an ASBR or PE as shown in the first two scenarios. In this scenario, two main requirements are introduced: IBGP functionality and MPLS label distribution protocols.

The UGP can be configured to add two labels:

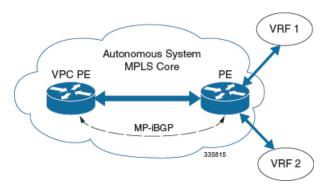
- an outer label learned from LDP or RSVP-TE (RSVP-Traffic Engineering)
- an inner label learned from MP-iBGP

This solution supports traffic engineering and QoS initiated via the UGP.

# **Sample Configuration**

In this example, VRFs are configured on the ASR 5500 PE and pools are associated with VRFs. The UGP exchanges VPN routes with its IBGP peers (PE routers) and learns the MPLS paths to reach PEs via LDP. The UGP forwards the packets to the next-hop with two labels – an inner label learned from PE and an outer label learned from the next hop IBGP neighbor.

Figure 3: Sample Configuration



```
mpls ip
 protocol ldp
    enable
  exit
exit
ip vrf vrf1
 mpls traffic-class copy
exit
ip vrf vrf2
 mpls traffic-class value 5
exit
router bgp 300
    route-target export 300 1
      route-target import 300 1
      route-distinguisher 300 1
  exit
    ip vrf vrf2
      route-target export 300 2
        route-target import 300 2
        route-distinguisher 300 2
  exit
  router-id 2.2.2.2
  neighbor 192.168.107.20 remote-as 300
  neighbor 192.168.107.20 update-source nodel loopback
```

```
address-family vpnv4
neighbor 192.168.107.20 activate
neighbor 192.168.107.20 send-community both
neighbor 192.168.107.20 next-hop-self
exit

address-family ipv4 vrf vrf1
redistribute connected
exit

address-family ipv4 vrf vrf2
redistribute connected
exit

interface interface to internet
ip address 192.168.109.65/24
mpls ip
exit
router ospf
network 192.168.109.0/24 area 0.0.0.0
```

# **IPv6 Support for BGP MPLS VPNs**

### **Overview**

The UGP supports VPNv6 as described in RFC 4659 – BGP-MPLS IP Virtual Private Network (VPN) Extension for IPv6 VPN.

An IPv6 VPN is connected over an IPv6 interface or sub-interface to the Service Provider (SP) backbone via a PE router. The site can be both IPv4 and IPv6 capable. Each VPNv6 has its own address space which means a given address denotes different systems in different VPNs. This is achieved via a VPNv6 address-family which prepends a Route Distinguisher (RD) to the IP address.

A VPNv6 address is a 24-byte quantity beginning with an 8-byte RD and ending with a 16-byte IPv6 address. When a site is IPv4 and IPv6 capable, the same RD can be used for the advertisement of both IPv4 and IPv6 addresses.

The system appends RD to IPv6 routes and exchanges the labeled IPv6-RD using the VPNv6 address-family. The Address Family Identifier (AFI) and Subsequent Address Family Identifier (SAFI) fields for VPNv6 routes will be set to 2 and 128 respectively.

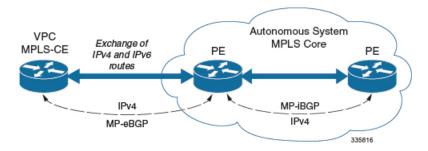
The IPv6 VPN traffic will be transported to the BGP speaker via IPv4 tunneling. The BGP speaker advertises to its peer a Next Hop Network Address field containing a VPN-IPv6 address whose 8-octet RD is set to zero and whose 16-octet IPv6 address is encoded as an IPv4-mapped IPv6 address (RFC 4291) containing the IPv4 address of the advertising router. It is assumed that only EBGP peering will be used to exchange VPNv6 routes.

Support for VPN-IPv6 assumes the following:

- Dual Stack (IPv4/IPv6) routing
- IPv6 pools in VRFs
- BGP peering over a directly connected IPv4 interface

See the figure below.

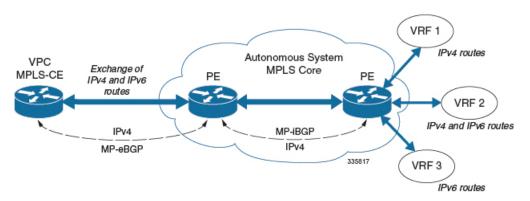
Figure 4: IPv6-RD Support for VPNv6



# **Sample Configuration**

This example assumes three VRFs. VRF 1 has only IPv4 routes, VRF f2 has both IPv4 and IPv6 routes, and VRF 3 has only IPv6 routes.

Figure 5: VPNv6 Sample Configuration



### Configure VRFs.

```
ip vrf vrf1
exit
ip vrf vrf2
exit
ip vrf vrf3
exit
```

#### Enable MPLS BGP forwarding.

mpls bgp forwarding

#### Configure pools.

```
ip pool vrf1-pool 51.52.53.0 255.255.255.0 private 0 vrf vrf1
exit
ip pool vrf2-pool 51.52.53.0 255.255.255.0 private 0 vrf vrf2
exit
ipv6 pool vrf2-v6pool prefix 2005:0101::/32 private 0 vrf vrf2
exit
ipv6 pool vrf3-v6pool prefix 2005:0101::/32 private 0 vrf vrf3
xit
```

#### Configure interfaces.

```
interface ce interface to rtr
 ip address 192.168.110.90 255.255.255.0
exit.
interface ce_v6_interface
 ip address 2009:0101:0101:0101::1/96
exit
interface ce loopback loopback
 ip address 52.1.2.3 255.255.255.255
exit
interface vrf1-loop loopback
 ip vrf forwarding vrf1
 ip address 1.52.53.54 255.255.255.255
exit.
interface vrf2-loop loopback
 ip vrf forwarding vrf2
 ip address 2.52.53.54 255.255.255.255
exit
interface vrf2-v6loop loopback
  ip vrf forwarding vrf2
  ip address 2005:0202:0101::1/128
exit
interface vrf3-v6loop loopback
  ip vrf forwarding vrf3
  ip address 2005:0303:0101::1/128
```

#### Configure BGP along with address families and redistribution rules.

```
router bgp 800
  router-id 1.1.1.1
neighbor 192.168.110.20 remote-as 1003
 neighbor 192.168.110.20 activate
address-family vpnv4
 neighbor 192.168.110.20 activate
  neighbor 192.168.110.20 send-community both
address-family vpnv6 neighbor 192.168.110.20 activate
 neighbor 192.168.110.20 send-community both
exit
ip vrf vrf1
 route-distinguisher 800 1
  route-target export 800 1
  route-target import 800 1
exit
address-family ipv4 vrf vrf1
 redistribute connected
  redistribute static
exit
ip vrf vrf2
 route-distinguisher 800 2
  route-target export 800 2
  route-target import 800 2
exit
address-family ipv4 vrf vrf2
 redistribute connected
  redistribute static
address-family ipv6 vrf vrf2
 redistribute connected
  redistribute static
exit
ip vrf vrf3
 route-distinguisher 800 3
  route-target export 800 3
  route-target import 800 3
exit
address-family ipv6 vrf
 redistribute connected
 redistribute static
exit
```

#### Configure APNs.

```
apn walmart51.com
  selection-mode sent-by-ms
  accounting-mode none
  aaa group walmart-group
  authentication pap 1 chap 2 allow-noauth
  ip context-name Gi ce
  ip address pool na\overline{m}e vrfl-pool
exit
apn amazon51.com
  selection-mode sent-by-ms
  accounting-mode none
 aaa group amazon-group
  authentication pap 1 chap 2 allow-noauth
  ip context-name Gi ce
  ip address pool name vrf2-pool
  ipv6 address prefix-pool vrf2-v6pool
exit
apn apple51.com
  selection-mode sent-by-ms
 accounting-mode none
 aaa group apple-group
  authentication pap 1 chap 2 allow-noauthip context-name \operatorname{Gi\_ce}
  ipv6 address prefix-pool vrf3-v6pool
exit
aaa-group amazon-group
 radius ip vrf vrf2
aaa group default
exit
gtpp group default
exit
ip igmp profile default
exit
```

Bind physical interfaces with the port.

### **VPN-Related CLI Commands**

VPN-related features and functions are supported across several CLI command modes. The following tables identify commands associated with configuration and monitoring of VPN-related functions.

For detailed information regarding the use of the commands listed below, see the *Command Line Interface Reference*.

**Table 1: VPN-Related Configuration Commands** 

CLI Mode	Command	Description
BGP Address-Family (IPv4/IPv6) Configuration Mode	neighbor ip_address activate	Enables the exchange of routing information with a peer router.
BGP Address-Family (IPv4/IPv6) Configuration Mode	neighbor ip_address send community { both   extended   standard }	Sends the community attributes to a peer router (neighbor).
BGP Address-Family (IPv4/IPv6) Configuration Mode	redistribute connected	Redistributes routes into BGP from another protocol as BGP neighbors.
BGP Address-Family (VPNv4) Configuration Mode	neighbor ip_address activate	Enables the exchange of routing information with a peer router.

CLI Mode	Command	Description
BGP Address-Family (VPNv4) Configuration Mode	neighbor ip_address send community { both   extended   standard }	Sends the extended-community attribute to a peer router. In VPN, route-distinguisher and route-target are encoded in the BGP extended-community. This command enables sending of BGP routes with extended community to a neighbor.
BGP Address-Family (VRF) Configuration Mode	neighbor ip_address activate	Enables the exchange of routing information with a peer router.
BGP Address-Family (VRF) Configuration Mode	neighbor ip_address send community { both   extended   standard }	Sends the extended-community attribute to a peer router. In VPN, route-distinguisher and route-target are encoded in the BGP extended-community. This command enables sending of BGP routes with extended community to a neighbor.
BGP Address-Family (VRF) Configuration Mode	redistribute connected	Redistributes routes into BGP from another protocol as BGP neighbors.
BGP Configuration Mode	address-family { ipv4 vrf vrf_name   vpnv4 }	Enables the exchange of IPv4 VRF routing information. There is a different mode for each address-family.
BGP Configuration Mode	address-family { ipv6 vrf vrf_name   vpnv6 }	Configures a VPNv6 address family and IPv6 VRF routing in BGP.
BGP Configuration Mode	ip vrf vrf_name	Adds a VRF to BGP and switches to the VRF Configuration mode to allow configuration of BGP attributes for the VRF.
BGP IP VRF Configuration Mode	route-distinguisher { as_value   ip_address } rd_value	Assigns a Route Distinguisher (RD) for the VRF. The RD value must be a unique value on the router for each VRF.
BGP IP VRF Configuration Mode	route-target { both   import   export } { as_value   ip_address } rt_value	Adds a list of import and export route-target extended communities to the VRF.

CLI Mode	Command	Description
Context Configuration Mode	ip pool pool_name addr_range vrf vrf_name [ mpls-label input inlabel1 output outlabel1 outlabel2 ]	Configures a pool into the specified VRF. This parameter must be specified with the Next-Hop parameter. <i>inlabel1</i> is the MPLS label that identifies inbound traffic destined for this pool. <i>outlabel1</i> and <i>outlabel2</i> specify the MPLS labels to be added to packets sent for subscribers from this pool.
Context Configuration Mode	ip vrf vrf_name	Creates a VRF and assigns a VRF-ID. A VRF is created in the router.
Context Configuration Mode	ipv6 pool pool_name vrf vrf_name	Associates the pool with that VRF.  Note: By default the configured ipv6 pool will be associated with the global routing domain.
Context Configuration Mode	mpls bgp forwarding	Globally enables MPLS Border Gateway Protocol (BGP) forwarding.
Context Configuration Mode	mpls exp value	Sets the default behavior as Best Effort using a zero value in the 3-bit MPLS EXP header. This value applies to all the VRFs in the context. The default behavior is to copy the DSCP value of mobile subscriber traffic to the EXP header, if there is no explicit configuration for DSCP to EXP (via the mpls map-dscp-to-exp dscp n exp m command).
		mpls exp disables the default behavior and sets the EXP value to the configured <i>value</i> .
Context Configuration Mode	mpls ip	Globally enables the MPLS forwarding of IPv4 packets along normally routed paths.

CLI Mode	Command	Description
Context Configuration Mode	radius change-authorize-nas-ip ip_address ip_address { encrypted   key } value port port_num mpls input inlabel output outlabel1 outlabel2	Configures COA traffic to use the specified MPLS labels. <i>inlabel</i> identifies inbound COA traffic. <i>outlabel1</i> and <i>outlabel2</i> specify the MPLS labels to be added to the COA response. <i>outlabel1</i> is the inner output label; <i>outlabel2</i> is the outer output label.
Ethernet Interface Configuration Mode	mpls ip	Enables dynamic MPLS forwarding of IP packets on this interface.
Exec Mode	clear ip bgp peer	Clears BGP sessions.
Exec Mode	lsp-ping ip_prefix_FEC	Checks MPLS Label-Switched Path (LSP) connectivity for the specified forwarding equivalence class (FEC). It must be followed by an IPv4 or IPv6 FEC prefix.
Exec Mode	lsp-traceroute ip_prefix_FEC	Discovers MPLS LSP routes that packets actually take when traveling to their destinations. It must be followed by an IPv4 or IPv6 FEC prefix.
IP VRF Context Configuration Mode	mpls map-dscp-to-exp dscp dscp_bit_value exp exp_bit_value	Maps the final differentiated services code point (DSCP) bit value in the IP packet header to the final Experimental (EXP) bit value in the MPLS header for incoming traffic.
IP VRF Context Configuration Mode	mpls map-exp-to-dscp exp exp_bit_value dscp dscp_bit_value	Maps the incoming EXP bit value in the MPLS header to the internal DSCP bit value in IP packet headers for outgoing traffic.
MPLS-IP Configuration Mode	protocol ldp	Creates the MPLS protocol family configuration modes, or configures an existing protocol and enters the MPLS-LDP Configuration Mode in the current context. This command configures the protocol parameters for the MPLS protocol family.

CLI Mode	Command	Description
MPLS-LDP Configuration Mode	advertise-labels { explicit-null   implicit-null }	Configure advertisement of Implicit NULL or Explicit NULL label for all the prefixes advertised by the system in this context.
MPLS-LDP Configuration Mode	<pre>discovery { hello { hello-interval seconds   hold-interval seconds }   transport-address ip_address }</pre>	Protocol (LDP) neighbor discovery
MPLS-LDP Configuration Mode	enable	Enables Label Distribution Protocol (LDP).
MPLS-LDP Configuration Mode	router-id ip_address	Configures the LDP Router ID.
MPLS-LDP Configuration Mode	session timers { hold-interval seconds   keepalive-interval seconds }	Configures the LDP session parameters.

### **Table 2: VPN-Related Monitoring Commands**

CLI Mode	Command	Description
Exec Mode show Commands	show ip bgp neighbors	Displays information regarding BGP neighbors.
Exec Mode show Commands	show ip bgp vpnv4 { all   route-distinguisher   vrf }	Displays all VPNv4 routing data, routing data for a VRF or a route-distinguisher.
Exec Mode show Commands	show ip bgp vpnv6	Displays contents of VPNv6 routing table.
Exec Mode show Commands	show ip bgp vpnv6 { all   route-distinguisher   vrf }	Displays all VPNv6 routing data, routing data for a VRF or a route-distinguisher.
Exec Mode show Commands	show ip pool	Displays pool details including the configured VRF.
Exec Mode show Commands	show mpls cross-connect	Displays MPLS cross-connect information. MPLS tunnel cross-connects between interfaces and Label-Switched Paths (LSPs) connect two distant interface circuits of the same type via MPLS tunnels that use LSPs as the conduit.

CLI Mode	Command	Description
Exec Mode show Commands	show mpls ftn [ vrf vrf_name	Displays MPLS FEC-to-NHLFE (FTN) table information.
Exec Mode show Commands	show mpls ftn [ vrf vrf_name ]	Displays contents of the MPLS FTN table for a specified VRF.
Exec Mode show Commands	show mpls ilm	Displays MPLS Incoming Label Map (ILM) table information.
Exec Mode show Commands	show mpls ldp	Displays the MPLS LDP information.
Exec Mode show Commands	show mpls nexthop-label-forwarding-entry	Displays MPLS Next-Hop Label Forwarding Entry (NHLFE) table information.