

## BGP MPLS VPNs

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

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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 vrfl
    mpls traffic-class copy
exit
ip vrf vrf2
    mpls traffic-class value 5
exit
router bgp 300
    ip vrf vrf1
        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 node1_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 192.16\overline{8}.10}9.65/2
        mpls ip
exit
router ospf
    network 192.168.109.0/24 area 0.0.0.0
exit
```


## 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 O 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
exit
```


## 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
exit
```

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
exit
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
exit
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 vrf3
    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 name vrf1-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 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) <br> Configuration Mode | neighbor ip_address activate | Enables the exchange of routing <br> information with a peer router. |
| BGP Address-Family (IPv4/IPv6) <br> Configuration Mode | neighbor ip_address send <br> community $\{$ both $\mid$ extended $\mid$ <br> standard $\}$ | Sends the community attributes to <br> a peer router (neighbor). |
| BGP Address-Family (IPv4/IPv6) <br> Configuration Mode | redistribute connected | Redistributes routes into BGP from <br> another protocol as BGP neighbors. |
| BGP Address-Family (VPNv4) <br> Configuration Mode | neighbor ip_address activate | Enables the exchange of routing <br> 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 <br> vrf vrf_name [ mpls-label input <br> inlabell output outlabell $^{\text {outlabel2 ] }}$ | Configures a pool into the specified <br> VRF. This parameter must be <br> specified with the Next-Hop <br> parameter. inlabell is the MPLS <br> label that identifies inbound traffic <br> destined for this pool. outlabell and <br> outlabel2 specify the MPLS labels <br> to be added to packets sent for <br> subscribers from this pool. |
| Context Configuration Mode | ip vrf vrf_name | Creates a VRF and assigns a <br> VRF-ID. A VRF is created in the <br> router. |
| Context Configuration Mode | ipv6 pool pool_name vrf |  |
| vrf_name | Associates the pool with that VRF. <br> Note: By default the configured <br> ipv6 pool will be associated with <br> the global routing domain. |  |
| Context Configuration Mode Configuration Mode | mpls bgp forwarding | Globally enables MPLS Border <br> Gateway Protocol (BGP) <br> forwarding. |
| Context Configuration Mode | mpls exp value | Globally enables the MPLS <br> forwarding of IPv4 packets along <br> normally routed paths. |
|  | Sets the default behavior as Best <br> Effort using a zero value in the 3-bit <br> MPLS EXP header. This value <br> applies to all the VRFs in the <br> context. The default behavior is to <br> copy the DSCP value of mobile <br> subscriber traffic to the EXP <br> header, if there is no explicit <br> configuration for DSCP to EXP (via <br> the mpls map-dscp-to-exp dscp $n$ <br> exp $m$ command). <br> mpls exp disables the default |  |
| behavior and sets the EXP value to |  |  |
| the configured value. |  |  |$|$


| 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. inlabel identifies inbound COA traffic. outlabel1 and outlabel 2 specify the MPLS labels to be added to the COA response. outlabell is the inner output label; outlabel 2 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 | Isp-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 <br> exp_bit_value dscp <br> 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 $\mid$ <br> implicit-null \} | Configure advertisement of Implicit <br> NULL or Explicit NULL label for <br> all the prefixes advertised by the <br> system in this context. |
| MPLS-LDP Configuration Mode | discovery \{ hello \{ hello-interval <br> seconds $\mid$ hold-interval seconds $\}$ <br> \| transport-address $i p \_a d d r e s s ~$ | Configures the Label Distribution <br> Protocol (LDP) neighbor discovery <br> parameters. |
| MPLS-LDP Configuration Mode | enable | Enables Label Distribution Protocol <br> (LDP). |
| MPLS-LDP Configuration Mode | router-id ip_address | Configures the LDP Router ID. |
| MPLS-LDP Configuration Mode | session timers \{ hold-interval <br> seconds $\mid$ keepalive-interval <br> seconds $\}$ | Configures the LDP session <br> parameters. |

Table 2: VPN-Related Monitoring Commands

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


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

