Configuring Scalable Hub-and-Spoke MPLS VPNs

This module explains how to ensure that virtual private network (VPN) clients that connect to the same provider edge (PE) router at the edge of the Multiprotocol (MPLS) Virtual Private Network (VPN) use the hub site. This feature prevents the VPN clients from communicating directly with each other, bypassing the hub site. This feature also provides scalable hub-and-spoke connectivity for subscribers of an MPLS VPN service by removing the requirement of one VRF per spoke.

Module History
This module was first published on May 2, 2005, and last updated on May 2, 2005.

Finding Feature Information in This Module
Your Cisco IOS software release may not support all features. To find information about feature support and configuration, use the “Feature Information for Configuring Scalable Hub-and-Spoke MPLS VPNs” section on page 14.

Contents

- Prerequisites for Configuring Scalable Hub-and-Spoke MPLS VPNs, page 2
- Restrictions for Configuring Scalable Hub-and-Spoke MPLS VPNs, page 2
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- How to Ensure that MPLS VPN Clients Use the Hub PE Router, page 4
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- Additional References, page 13
- Feature Information for Configuring Scalable Hub-and-Spoke MPLS VPNs, page 14
Prerequisites for Configuring Scalable Hub-and-Spoke MPLS VPNs

You must have a working MPLS core network.

Restrictions for Configuring Scalable Hub-and-Spoke MPLS VPNs

- In both the upstream and downstream VRFs, routing protocols are not supported on interfaces configured with this feature. Interfaces that are not configured with this feature, however, do not have this restriction for the upstream or downstream VRFs.
- You can configure this feature only on virtual access interfaces (VAIs) and virtual template interfaces (VTIs).
- Only unnumbered interfaces are supported.
- Multicast is not supported on interfaces configured for hub-and-spoke MPLS VPNs.

Information about Configuring Scalable Hub-and-Spoke MPLS VPNs

To configure this feature, you need to understand the following concepts:
- Overview, page 2
- Upstream and Downstream VRFs, page 3
- Reverse Path Forwarding Check, page 3

Overview

This feature prevents local connectivity between subscribers at the spoke provider edge (PE) router and ensures that a hub site provides subscriber connectivity. Any sites that connect to the same PE router must forward intersite traffic using the hub site. This ensures that the routing done at the spoke site moves from the access-side interface to the network-side interface or from the network-side interface to the access-side interface, but never from the access-side interface to the access-side interface.

This feature prevents situations where the PE router locally switches the spokes without passing the traffic through the hub site. This prevents subscribers from directly connecting to each other.

This feature eases configuration by removing the requirement of one VRF per spoke. In prior releases, when spokes connected to the same PE router, each spoke was configured in a separate VRF to ensure that the traffic between the spokes traversed the central link between the wholesale service provider and the ISP. However, this solution was not scalable. When many spokes connected to the same PE router, configuration of VRFs for each spoke became quite complex and greatly increased memory usage. This was especially true in large-scale environments that supported high-density remote access to Layer 3 VPNs.

Figure 2 shows a sample hub-and-spoke topology.
Upstream and Downstream VRFs

This feature uses two unidirectional VRFs to forward IP traffic between the spokes and the hub PE router:

- The upstream VRF forwards the IP traffic from the spokes toward the hub PE router. This VRF typically contains only a default route but might also contain summary routes and multiple default routes. The default route points to the interface on the hub PE router that connects to the upstream ISP. The router dynamically learns about the default route from the routing updates that the hub PE router or home gateway sends. The upstream VRF also contains the VAsIs that connect the spokes, but it contains no other local interfaces.

- The downstream VRF forwards traffic from the hub PE router back to the spokes. This VRF contains Point-to-Point Protocol (PPP) peer routes for the spokes and per-user static routes received from the Authentication, Authorization, and Accounting (AAA) server. It also contains the routes imported from the hub PE router.

The router redistributes routes from the downstream VRF into Multiprotocol Border Gateway Protocol (MP-BGP). The spoke PE router typically advertises a summary route across the MPLS core for the connected spokes. The VRF configured on the hub PE router imports the advertised summary route.

Reverse Path Forwarding Check

The unicast Reverse Path Forwarding (RPF) check ensures that an IP packet that enters a router uses the correct inbound interface. This feature supports unicast RPF check on the spoke-side interfaces. Because different VRFs are used for downstream and upstream forwarding, the RPF mechanism ensures that source address checks occur in the downstream VRF.
How to Ensure that MPLS VPN Clients Use the Hub PE Router

This section contains the following procedures:
- Configuring the Upstream and Downstream VRFs on the PE Router or the Spoke PE Router, page 4 (required)
- Associating VRFs, page 5 (required)
- Configuring the Downstream VRF for an AAA Server, page 6 (optional)
- Verifying the Configuration, page 6 (optional)

Configuring the Upstream and Downstream VRFs on the PE Router or the Spoke PE Router

To configure the upstream and downstream VRFs on the PE router or on the spoke PE router, use the following procedure.

SUMMARY STEPS

1. enable
2. configure terminal
3. ip vrf vrf-name
4. rd route-distinguisher
5. route-target {import | export | both} route-target-ext-community
6. exit

DETAILED STEPS

<table>
<thead>
<tr>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **Step 1** enable | Enables privileged EXEC mode.  
- Enter your password if prompted. |
| **Example:**  
Router> enable | |
| **Step 2** configure terminal | Enters global configuration mode. |
| **Example:**  
Router# configure terminal | |
| **Step 3** ip vrf vrf-name | Enters VRF configuration mode and defines the VRF instance by assigning a VRF name. |
| **Example:**  
Router(config)# ip vrf U | |
Configuring Scalable Hub-and-Spoke MPLS VPNs

How to Ensure that MPLS VPN Clients Use the Hub PE Router

**Associating VRFs**

The virtual template interface is used to create and configure a virtual access interface (VAI). After you define and configure the VRFs on the PE routers, associate each VRF with the following:

- Interface or subinterface
- Virtual template interface

To associate a VRF, enter the following commands on the PE router.

<table>
<thead>
<tr>
<th>Summary Steps</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <code>enable</code></td>
<td></td>
</tr>
<tr>
<td>2. <code>configure terminal</code></td>
<td></td>
</tr>
<tr>
<td>3. <code>interface virtual-template number</code></td>
<td></td>
</tr>
<tr>
<td>4. <code>ip vrf forwarding vrf-name1 downstream vrf-name2</code></td>
<td></td>
</tr>
<tr>
<td>5. <code>ip unnumbered type number</code></td>
<td></td>
</tr>
<tr>
<td>6. <code>exit</code></td>
<td></td>
</tr>
</tbody>
</table>

**Associating VRFs**

<table>
<thead>
<tr>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 4</strong> <code>rd route-distinguisher</code></td>
<td>Creates routing and forwarding tables.</td>
</tr>
<tr>
<td><strong>Example:</strong></td>
<td></td>
</tr>
<tr>
<td>Router(config-vrf)# rd 1:0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 5</strong> `route-target {import</td>
<td>export</td>
</tr>
<tr>
<td><strong>Example:</strong></td>
<td></td>
</tr>
<tr>
<td>Router(config-vrf)# route-target import 1:0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 6</strong> <code>exit</code></td>
<td>Returns to global configuration mode.</td>
</tr>
<tr>
<td><strong>Example:</strong></td>
<td></td>
</tr>
<tr>
<td>Router(config-vrf)# exit</td>
<td></td>
</tr>
</tbody>
</table>
## DETAILED STEPS

<table>
<thead>
<tr>
<th>Command or Action</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> enable</td>
<td>Enables privileged EXEC mode.</td>
</tr>
<tr>
<td><strong>Example:</strong> Router&gt; enable</td>
<td>Enter your password if prompted.</td>
</tr>
<tr>
<td><strong>Step 2</strong> configure terminal</td>
<td>Enters global configuration mode.</td>
</tr>
<tr>
<td><strong>Example:</strong> Router# configure terminal</td>
<td></td>
</tr>
<tr>
<td><strong>Step 3</strong> interface virtual-template number</td>
<td>Creates a virtual template interface that can be configured and applied dynamically in creating virtual access interfaces. Enters interface configuration mode.</td>
</tr>
<tr>
<td><strong>Example:</strong> Router(config)# interface virtual-template 1</td>
<td></td>
</tr>
<tr>
<td><strong>Step 4</strong> ip vrf forwarding vrf-name1 [downstream vrf-name2]</td>
<td>Associates a virtual template interface with the VRF you specify.</td>
</tr>
<tr>
<td><strong>Example:</strong> Router(config-if)# ip vrf forwarding vpn1 downstream D</td>
<td>• The <em>vrf-name1</em> argument is the name of the VRF associated with the virtual template interface.</td>
</tr>
<tr>
<td></td>
<td>• The <em>vrf-name2</em> argument is the name of the downstream VRF into which the PPP peer route and all of the per-user routes from the AAA server are installed. If an AAA server is used, it provides the VRF membership; you do not need to configure the VRF members on the virtual templates.</td>
</tr>
<tr>
<td><strong>Step 5</strong> ip unnumbered type number</td>
<td>Enables IP processing on an interface without assigning an explicit IP address to the interface.</td>
</tr>
<tr>
<td><strong>Example:</strong> Router(config-if)# ip unnumbered Loopback1</td>
<td>The <em>type</em> and <em>number</em> arguments are the type and number of another interface on which the router has an assigned IP address. It cannot be another unnumbered interface.</td>
</tr>
<tr>
<td><strong>Step 6</strong> exit</td>
<td>Returns to global configuration mode.</td>
</tr>
<tr>
<td><strong>Example:</strong> Router(config-if)# exit</td>
<td></td>
</tr>
</tbody>
</table>

### Configuring the Downstream VRF for an AAA Server

To configure the downstream VRF for an AAA server, enter the following Cisco attribute value:

```
lcp:interface-config=ip vrf forwarding U downstream D
```

For more information about configuring a RADIUS server, see *Configuring Virtual Template Interfaces*.

### Verifying the Configuration

To verify the configuration, perform the following steps.
Configuring Scalable Hub-and-Spoke MPLS VPNs

How to Ensure that MPLS VPN Clients Use the Hub PE Router

SUMMARY STEPS

1. `show ip vrf [brief | detail | interfaces | id] [vrf-name] [output-modifiers]`
2. `show ip route vrf vrf-name`
3. `show running-config [interface type number]`

DETAILED STEPS

**Step 1**

`show ip vrf [brief | detail | interfaces | id] [vrf-name] [output-modifiers]`

Use this command to display information about all of the VRFs configured on the router, including the downstream VRF for each associated VAI.

```
Router# show ip vrf

Name   Default RD   Interface
D      2:0          Loopback2
        Virtual-Access3 [D]
        Virtual-Access4 [D]

U      2:1          Virtual-Access3
        Virtual-Access4
```

`show ip vrf detail vrf-name`

Use this command to display detailed information about the VRF you specify, including all of the VAIs associated with the VRF.

If you do not specify a value for `vrf-name`, detailed information about all of the VRFs configured on the router appears, including all of the VAIs associated with each VRF.

The following example shows how to display detailed information for the VRF called vrf1.

```
Router# show ip vrf detail vrf1

VRF D; default RD 2:0; default VPNID <not set>

    Interfaces:
        Loopback2    Virtual-Access3 [D]  Virtual-Access4 [D]

    Connected addresses are not in global routing table
    Export VPN route-target communities
    RT:2:0
    Import VPN route-target communities
    RT:2:1
    No import route-map
    No export route-map

VRF U; default RD 2:1; default VPNID <not set>

    Interfaces:
        Virtual-Access3    Virtual-Access4

    Connected addresses are not in global routing table
    No Export VPN route-target communities
    Import VPN route-target communities
    RT:2:1
    No import route-map
    No export route-map
```

**Step 2**

`show ip route vrf vrf-name`

Use this command to display the IP routing table for the VRF you specify, and information about the per-user static routes installed in the downstream VRF.

The following example shows how to display the routing table for the downstream VRF named D.
Router# show ip route vrf D

Routing Table: D
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
    D - EIGRP, E - EIGRP external, O - OSPF, IA - OSPF inter area
    N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
    E1 - OSPF external type 1, E2 - OSPF external type 2
    i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
    * - candidate default, U - per-user static route, o - ODR
    P - periodic downloaded static route

Gateway of last resort is not set

    2.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
    U   2.0.0.2/32 [1/0] via 2.8.1.1
    S   2.0.0.0/8 is directly connected, Null0
    U   2.0.0.5/32 [1/0] via 2.8.1.2
    C   2.8.1.2/32 is directly connected, Virtual-Access4
    C   2.8.1.1/32 is directly connected, Virtual-Access3

The following example shows how to display the routing table for the upstream VRF named U.

Router# show ip route vrf U

Routing Table: U
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
    D - EIGRP, E - EIGRP external, O - OSPF, IA - OSPF inter area
    N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
    E1 - OSPF external type 1, E2 - OSPF external type 2
    i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS interarea
    * - candidate default, U - per-user static route, o - ODR
    P - periodic downloaded static route

Gateway of last resort is 100.0.0.20 to network 0.0.0.0

    2.0.0.0/32 is subnetted, 1 subnets
    C   2.0.0.8 is directly connected, Loopback2
    B*  0.0.0.0/0 [200/0] via 100.0.0.20, 1w5d
Step 3  \textbf{show running-config [interface type number]}

Use this command to display information about the virtual access interface you specify, including information about the upstream and downstream VRFs.

The following example shows how to display information about the interface named virtual-access 3.

Router# \textbf{show running-config interface virtual-access 3}

Building configuration...

Current configuration : 92 bytes
!
interface Virtual-Access3
  ip vrf forwarding U downstream D
  ip unnumbered Loopback2
end

The following example shows how to display information about the interface named virtual-access 4.

Router# \textbf{show running-config interface virtual-access 4}

Building configuration...

Current configuration : 92 bytes
!
interface Virtual-Access4
  ip vrf forwarding U downstream D
  ip unnumbered Loopback2
end

---

\section*{Configuration Examples for Configuring Scalable Hub-and-Spoke MPLS VPNs}

This section provides the following configuration examples:

- Configuring the Upstream and Downstream VRFs on the PE Router and the Spoke PE Router: Example, page 9
- Associating VRFs: Example, page 10
- Configuring Scalable Hub-and-Spoke MPLS VPNs—Basic Configuration: Example, page 10
- Configuring Scalable Hub-and-Spoke MPLS VPNs: Example, page 11

\subsection*{Configuring the Upstream and Downstream VRFs on the PE Router and the Spoke PE Router: Example}

The following example configures an upstream VRF named U:

Router> \textbf{enable}
Router# \textbf{configure terminal}
Router(config)# \textbf{ip vrf U}
Router(config-vrf)# \textbf{rd 1:0}
Router(config-vrf)# \textbf{route-target import 1:0}
The following example configures a downstream VRF named D:

```console
Router> enable
Router# configure terminal
Router(config)# ip vrf D
Router(config-vrf)# rd 1:8
Router(config-vrf)# route-target export 1:100
```

### Associating VRFs: Example

The following example associates the VRF named U with the virtual-template 1 interface and specifies the downstream VRF named D:

```console
Router> enable
Router# configure terminal
Router(config)# interface virtual-template 1
Router(config-if)# ip vrf forwarding U downstream D
Router(config-if)# ip unnumbered Loopback1
```

### Configuring Scalable Hub-and-Spoke MPLS VPNs—Basic Configuration: Example

In this example, local authentication is used; that is, the RADIUS server is not used. This example uses the hub-and-spoke topology shown in Figure 3.

![Sample Topology](image)

```console
ip vrf D
  rd 1:8
  route-target export 1:100
!
ip vrf U
  rd 1:0
  route-target import 1:0
!
ip cef
vpdn enable
!
vpdn-group U
  accept-dialin
  protocol pppoe
  virtual-template 1
!
interface Loopback2
```
ip vrf forwarding U
ip address 2.0.0.8 255.255.255.255
!
interface ATM2/0
description Mze ATM3/1/2
no ip address
no atm ilmi-keepalive
pvc 0/16 ilmi
!
pvc 3/100
  protocol pppoe
!
pvc 3/101
  protocol pppoe
!
interface Virtual-Template1
ip vrf forwarding U downstream D
ip unnumbered Loopback2
peer default ip address pool U-pool
ppp authentication chap

---

Configuring Scalable Hub-and-Spoke MPLS VPNs: Example

The following example shows how to connect two Point-to-Point Protocol over Ethernet (PPPoE) clients to a single VRF pair on the spoke PE router named Lipno. Although both PPPoE clients are configured in the same VRF, all communication occurs using the hub PE router. Half-duplex VRFs are configured on the spoke PE. The client configuration is downloaded to the spoke PE from the RADIUS server. This example uses the hub-and-spoke topology shown in Figure 3.

Note

The wholesale provider can forward the user authentication request to the corresponding ISP. If the ISP authenticates the user, the wholesale provider appends the VRF information to the request that goes back to the PE router.

aaa new-model
!
aaa group server radius R
  server 22.0.20.26 auth-port 1812 acct-port 1813
!
aaa authentication ppp default group radius
aaa authorization network default group radius
!
ip vrf D
  description Downstream VRF - to spokes
  rd 1:8
  route-target export 1:100
!
ip vrf U
  description Upstream VRF - to hub
  rd 1:0
  route-target import 1:0
!
ip cef
vpdn enable
!
vpdn-group U
accept-dialin
  protocol pppoe
virtual-template 1
! interface Loopback2
ip vrf forwarding U
ip address 2.0.0.8 255.255.255.255
!
interface ATM2/0
pvc 3/100
protocol pppoe
!
pvc 3/101
protocol pppoe
!
interface virtual-template 1
no ip address
ppp authentication chap
!
router bgp 1
no synchronization
neighbor 100.0.0.34 remote-as 1
neighbor 100.0.0.34 update-source Loopback0
no auto-summary
!
address-family vpnv4
neighbor 100.0.0.34 activate
neighbor 100.0.0.34 send-community extended
auto-summary
exit-address-family
!
address-family ipv4 vrf U
no auto-summary
no synchronization
exit-address-family
!
address-family ipv4 vrf D
redistribute static
no auto-summary
no synchronization
exit-address-family
!
ip local pool U-pool 2.8.1.1 2.8.1.100
ip route vrf D 2.0.0.0 255.0.0.0 Null0
!
radius-server host 22.0.20.26 auth-port 1812 acct-port 1813
radius-server key cisco
Additional References

The following sections provide references related to MPLS VPNs.

Related Documents

<table>
<thead>
<tr>
<th>Related Topic</th>
<th>Document Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic MPLS VPNS</td>
<td>Configuring MPLS Layer 3 VPNS</td>
</tr>
<tr>
<td>MPLS VPN Carrier Supporting Carrier</td>
<td>• MPLS VPN Carrier Supporting Carrier Using LDP and an IGP</td>
</tr>
<tr>
<td></td>
<td>• MPLS VPN Carrier Supporting Carrier with BGP</td>
</tr>
<tr>
<td>MPLS VPN InterAutonomous Systems</td>
<td>• MPLS VPN Inter-AS with ASBRs Exchanging IPv4 Routes and MPLS Labels</td>
</tr>
<tr>
<td></td>
<td>• MPLS VPN Inter-AS with ASBRs Exchanging VPN-IPv4 Addresses</td>
</tr>
</tbody>
</table>

Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>No new or modified standards are supported by this feature, and support for existing standards has not been modified by this feature.</td>
<td>—</td>
</tr>
</tbody>
</table>

MIBs

<table>
<thead>
<tr>
<th>MIB</th>
<th>MIBs Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>No new or modified MIBs are supported by this feature, and support for existing MIBs has not been modified by this feature.</td>
<td>To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use Cisco MIB Locator found at the following URL: <a href="http://www.cisco.com/go/mibs">http://www.cisco.com/go/mibs</a></td>
</tr>
</tbody>
</table>

RFCs

<table>
<thead>
<tr>
<th>RFC</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFC 2547</td>
<td>BGP/MPLS VPNs</td>
</tr>
</tbody>
</table>
Technical Assistance

<table>
<thead>
<tr>
<th>Description</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Cisco Technical Support website contains thousands of pages of searchable technical content, including links to products, technologies, solutions, technical tips, and tools. Registered Cisco.com users can log in from this page to access even more content.</td>
<td><a href="http://www.cisco.com/techsupport">http://www.cisco.com/techsupport</a></td>
</tr>
</tbody>
</table>

Feature Information for Configuring Scalable Hub-and-Spoke MPLS VPNs

Table 1 lists the features in this module and provides links to specific configuration information.

Not all commands may be available in your Cisco IOS software release. For details on when support for specific commands was introduced, see the command reference documents.

Cisco IOS software images are specific to a Cisco IOS software release, a feature set, and a platform. Use Cisco Feature Navigator to find information about platform support and Cisco IOS software image support. Access Cisco Feature Navigator at http://www.cisco.com/go/fn. You must have an account on Cisco.com. If you do not have an account or have forgotten your username or password, click Cancel at the login dialog box and follow the instructions that appear.

Note: Table 1 lists only the Cisco IOS software release that introduced support for a given feature in a given Cisco IOS software release train. Unless noted otherwise, subsequent releases of that Cisco IOS software release train also support that feature.

Table 1  Feature Information for Configuring Scalable Hub-and-Spoke MPLS VPNs

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Releases</th>
<th>Feature Configuration Information</th>
</tr>
</thead>
</table>
| MPLS VPN: Half Duplex VRF Support | 12.3(6) 12.3(11)T | This feature ensures that VPN clients that connect to the same PE router at the edge of the MPLS VPN use the hub site to communicate. The following sections provide information about this feature:  
  - Overview, page 2  
  - Upstream and Downstream VRFs, page 3  
  - Reverse Path Forwarding Check, page 3  
  - How to Ensure that MPLS VPN Clients Use the Hub PE Router, page 4 |