CHAPTER 32

Spanning Multiple Autonomous Systems

This chapter describes how to configure spanning multiple autonomous systems using the Prime Fulfillment provisioning process.

Overview

The inter-autonomous system for MPLS VPNs feature allows an MPLS VPN to span service providers and autonomous systems. An autonomous system is a single network or group of networks that is controlled by a common system administration group and that uses a single, clearly defined routing protocol.

As VPNs grow, their requirements expand. In some cases, VPNs need to reside on different autonomous systems in different geographic areas. Also, some VPNs need to extend across multiple service providers (overlapping VPNs). Regardless of the complexity and location of the VPNs, the connection between autonomous systems must be seamless to the customer.

The inter-autonomous systems for MPLS VPNs feature provides that seamless integration of autonomous systems and service providers. Separate autonomous systems from different service providers can communicate by exchanging IPv4 network layer reachability information (NLRI) in the form of VPN-IPv4 addresses. The autonomous systems' border edge routers use the Exterior Border Gateway Protocol (eBGP) to exchange that information. An Interior Gateway Protocol (IGP) then distributes the network layer information for VPN-IPv4 prefixes throughout each VPN and each autonomous system. Routing information uses the following protocols:

- Within an autonomous system, routing information is shared using an IGP.
- Between autonomous systems, routing information is shared using an eBGP. An eBGP allows a service provider to set up an inter-domain routing system that guarantees the loop-free exchange of routing information between separate autonomous systems.

An MPLS VPN with inter-autonomous system support allows a service provider to provide to customers scalable Layer 3 VPN services, such as web hosting, application hosting, interactive learning, electronic commerce, and telephony service. A VPN service provider supplies a secure, IP-based network that shares resources on one or more physical networks.

The primary function of eBGP is to exchange network reachability information between autonomous systems, including information about the list of autonomous system routes. The autonomous systems use EGBP border edge routers to distribute the routes, which include label switching information. Each border edge router rewrites the next-hop and MPLS labels. See Routing Between Autonomous Systems, page 32-2 for more information.

Inter-autonomous system configurations supported in an MPLS VPN can include:

- *Interprovider VPN*: MPLS VPNs that include two or more autonomous systems, connected by separate border edge routers. The autonomous systems exchange routes using eBGP. No Interior Gateway Protocol (IGP) or routing information is exchanged between the autonomous systems.
- *BGP Confederations*: MPLS VPNs that divide a single autonomous system into multiple subautonomous systems, and classify them as a single, designated confederation. The network recognizes the confederation as a single autonomous system. The peers in the different autonomous systems communicate over eBGP sessions; however, they can exchange route information as if they were iBGP peers.

Benefits

The inter-autonomous system MPLS VPN feature provides the following benefits:

- Allows a VPN to cross more than one service provider backbone

  The inter-autonomous systems for MPLS VPNs feature allows service providers, running separate autonomous systems, to jointly offer MPLS VPN services to the same end customer. A VPN can begin at one customer site and traverse different VPN service provider backbones before arriving at another site of the same customer. Previously, MPLS VPNs could only traverse a single BGP autonomous system service provider backbone. The inter-autonomous system feature allows multiple autonomous systems to form a continuous (and seamless) network between a service provider's customer sites.

- Allows a VPN to exist in different areas

  The inter-autonomous systems for MPLS VPNs feature allows a service provider to create a VPN in different geographic areas. Having all VPN traffic flow through one point (between the areas) allows for better rate control of network traffic between the areas.

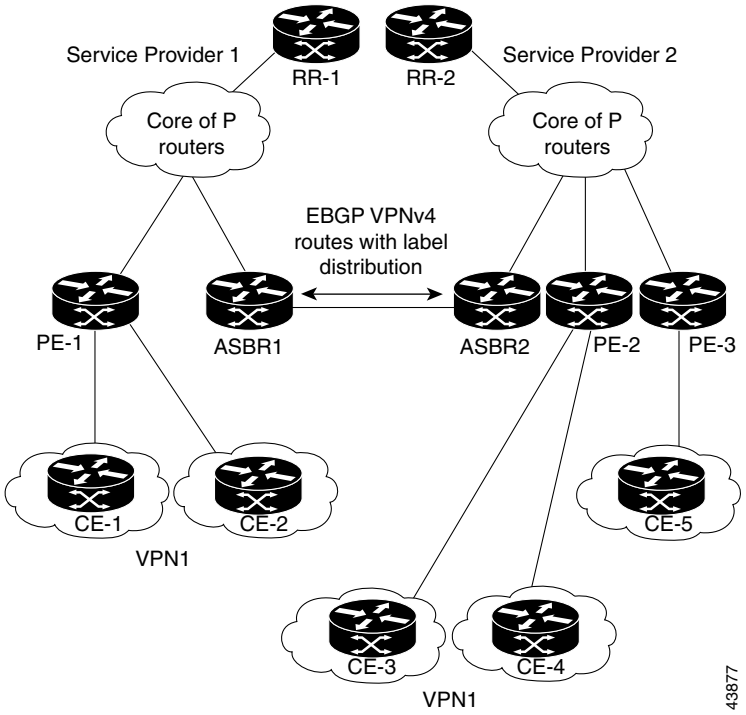
- Allows confederations to optimize iBGP meshing

  The inter-autonomous systems feature can make iBGP meshing in an autonomous system more organized and manageable. You can divide an autonomous system into multiple, separate subautonomous systems and then classify them into a single confederation (even though the entire VPN backbone appears as a single autonomous system). This capability allows a service provider to offer MPLS VPNs across the confederation because it supports the exchange of labeled VPN-IPv4 network layer reachability information between the subautonomous systems that form the confederation.

Routing Between Autonomous Systems

Figure 32-1 illustrates one MPLS VPN consisting of two separate autonomous systems. Each autonomous system operates under different administrative control and runs a different IGP. Service providers exchange routing information through eBGP border edge routers (ASBR1 and ASBR2).

Figure 32-1 eBGP Connection Between Two Autonomous Systems



This configuration uses the following process to transmit information:

1. The provider edge router (PE-1) assigns a label for a route before distributing that route. The PE router uses the multiprotocol extensions of a Border Gateway Protocol (BGP) to transmit label mapping information. The PE router distributes the route as a VPN-IPv4 address. The address label and the VPN identifier are encoded as part of the NLRI.
2. The two route reflectors (RR-1 and RR-2) reflect VPN-IPv4 internal routes within the autonomous system. The autonomous systems' border edge routers (ASBR1 and ASBR2) advertise the VPN-IPv4 external routes.
3. The eBGP border edge router (ASBR1) redistributes the route to the next autonomous system, (ASBR2). ASBR1 specifies its own address as the value of the eBGP next hop attribute and assigns a new label. The ASBR1 address ensures the following:
   - The next hop router is always reachable in the service provider (P) backbone network.
   - The label assigned by the distributing router is properly interpreted. The label associated with a route must be assigned by the corresponding next hop router.
4. The eBGP border edge router (ASBR2) redistributes the route in one of the following ways, depending on its configuration:
   - If the iBGP neighbors are configured with the **neighbor next-hop-self** command, ASBR2 changes the next hop address of updates received from the eBGP peer, then forwards it on.
   - If the iBGP neighbors are not configured with the **neighbor next-hop-self** command, the next hop address does not get changed. ASBR2 must propagate a host route for the eBGP peer through the IGP.

To propagate the eBGP VPN-IPv4 neighbor host route, use the **redistribute connected subnets** command. The eBGP VPN-IPv4 neighbor host route is automatically installed in the routing table when the neighbor comes up. This is essential to establish the label-switched path between PE routers in different autonomous systems.

Exchanging VPN Routing Information

Autonomous systems exchange VPN routing information (routes and labels) to establish connections. To control connections between autonomous systems, the PE routers and eBGP border edge routers maintain a Label Forwarding Information Base (LFIB). The LFIB manages the labels and routes that the PE routers and eBGP border edge routers receive during the exchange of VPN information.

Figure 32-2 illustrates the exchange of VPN route and label information between autonomous systems. The autonomous systems use the following guidelines to exchange VPN routing information:

Routing information includes:

- The destination network (N)
- The next hop field associated with the distributing router
- A local MPLS label (L)

An *RD1: route distinguisher* is part of a destination network address to make the VPN-IPv4 route globally unique in the VPN service provider environment.

The *ASBRs* are configured to change the next hop (next-hop-self) when sending VPN-IPv4 NLRIs to the iBGP neighbors. Therefore, the ASBRs must allocate a new label when they forward the NLRI to the iBGP neighbors.

Figure 32-2 Exchanging Routes and Labels Between Two Autonomous Systems

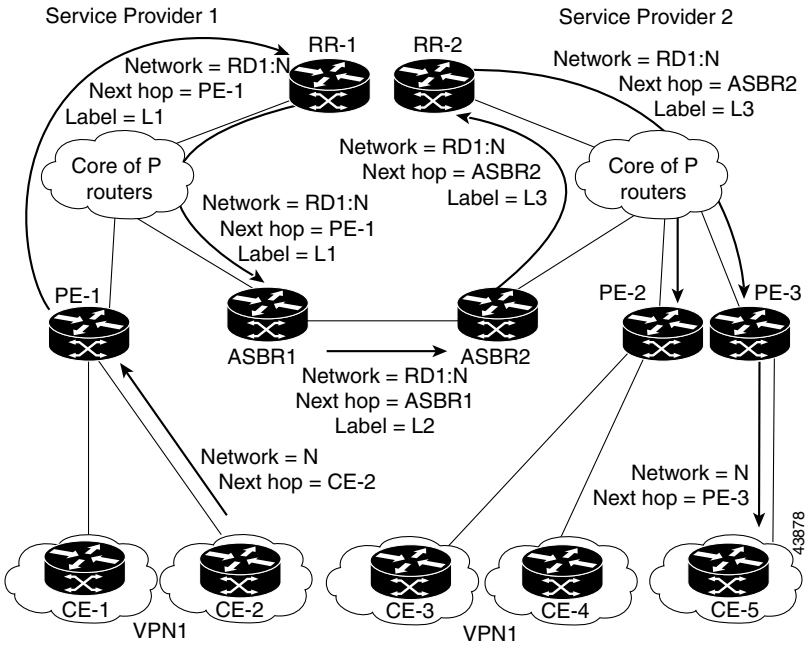


Figure 32-3 illustrates the exchange of VPN route and label information between autonomous systems. The only difference is that ASBR2 is configured with the **redistribute connected** command, which propagates the host routes to all PEs. The **redistribute connected** command is necessary because ASBR2 is not the configured to change the next hop address.

Figure 32-3 Host Routes Propagated to All PEs Between Two Autonomous Systems

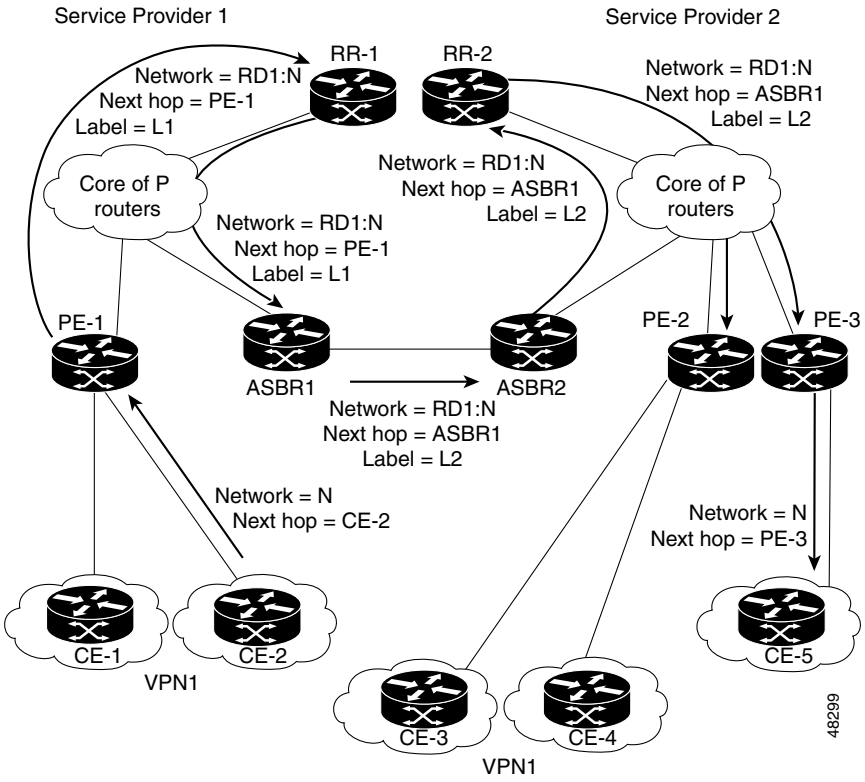


Figure 32-4 illustrates how packets are forwarded between autonomous systems in an interprovider network using the following packet forwarding method:

Packets are forwarded to their destination via MPLS. Packets use the routing information stored in the LFIB of each PE router and eBGP border edge router. The service provider VPN backbone uses dynamic label switching to forward labels.

Each autonomous system uses standard multi-level labeling to forward packets between the edges of the autonomous system routers (for example, from CE-5 to PE-3). Between autonomous systems, only a single level of labeling is used, corresponding to the advertised route.

A data packet carries two levels of labels when traversing the VPN backbone:

- The first label (*IGP route label*) directs the packet to the correct PE router or eBGP border edge router. (For example, the IGP label of ASBR2 points to the ASBR2 border edge router.)
- The second label (*VPN route label*) directs the packet to the appropriate PE router or eBGP border edge router.

Figure 32-4 Forwarding Packets Between Two Autonomous Systems

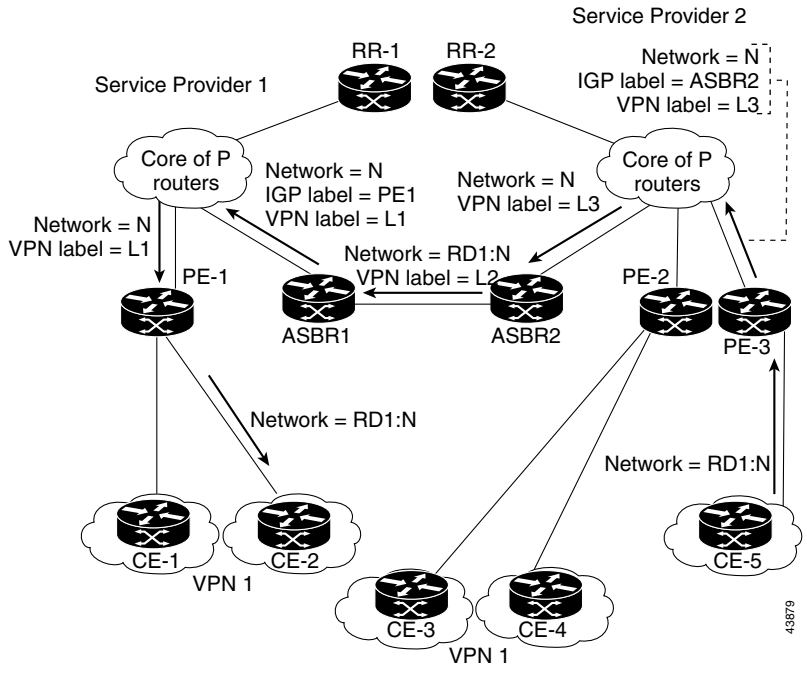
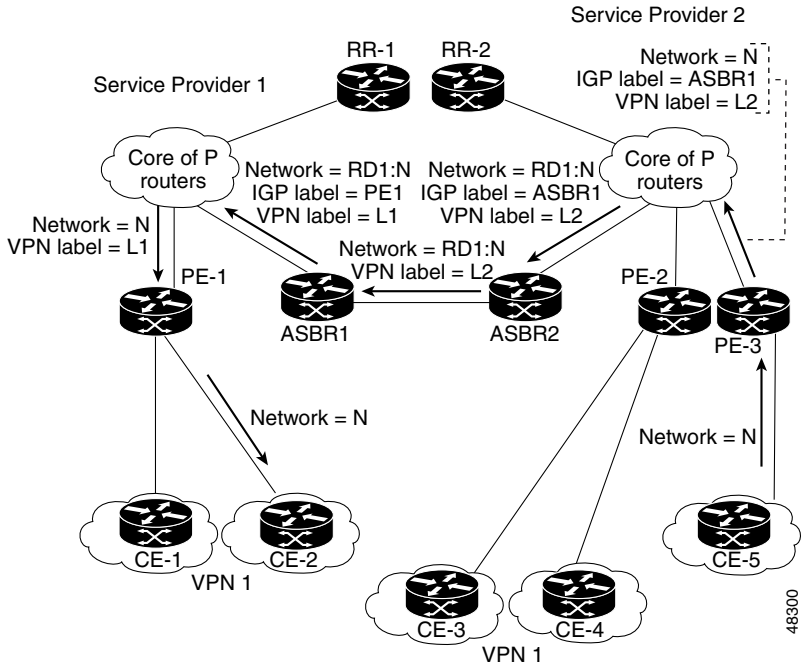


Figure 32-5 illustrates shows the same packet forwarding method, except the eBGP router (ASBR1) forwards the packet without reassigning it a new label.

Figure 32-5 Forwarding Packets Without Reassigning a New Label



Routing Between Subautonomous Systems in a Confederation

A VPN can span service providers running in separate autonomous systems or between multiple subautonomous systems that have been grouped together to form a confederation.

A confederation reduces the total number of peer devices in an autonomous system. A confederation divides an autonomous system into subautonomous systems and assigns a confederation identifier to the autonomous systems.

In a confederation, each subautonomous system is fully meshed with other subautonomous systems. The subautonomous systems communicate using an IGP, such as Open Shortest Path First (OSPF) or Intermediate System-to-Intermediate System (IS-IS). Each subautonomous system also has an eBGP connection to the other subautonomous systems. The confederation eBGP (CeBGP) border edge routers forward next-hop-self addresses between the specified subautonomous systems. The next-hop-self address forces the BGP to use a specified address as the next hop rather than letting the protocol choose the next hop.

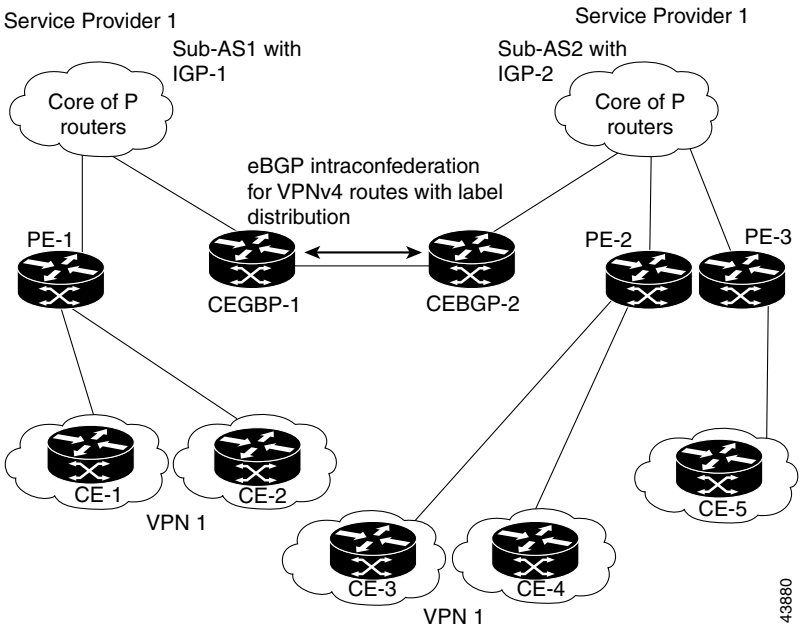
You can configure a confederation with separate subautonomous systems in two ways:

- You can configure a router to forward next-hop-self addresses between only the CeGRP border edge routers (both directions). The subautonomous systems (iBGP peers) at the subautonomous system border do not forward the next-hop-self address. Each subautonomous system runs as a single IGP domain. However, the CeGRP border edge router addresses are known in the IGP domains.
- You can configure a router to forward next-hop-self addresses between the CeGRP border edge routers (both directions) and within the iBGP peers at the subautonomous system border. Each subautonomous system runs as a single IGP domain but also forwards next-hop-self addresses between the PE routers in the domain. The CeGRP border edge router addresses are known in the IGP domains.

Figure 32-6 illustrates a typical MPLS VPN confederation configuration. In this confederation configuration:

- The two CeGRP border edge routers exchange VPN-IPv4 addresses with labels between the two subautonomous systems.
- The distributing router changes the next-hop addresses and labels and uses a next-hop-self address.
- IGP-1 and IGP-2 know the addresses of CEGRP-1 and CEBGP-2.

Figure 32-6 EGBP Connection Between Two AS's in a Confederation



In this confederation configuration:

- CeGRP border edge routers function as neighboring peers between the subautonomous systems. The subautonomous systems use eGRP to exchange route information.
- Each CeGRP border edge router (CEBGP-1, CEBGP-2) assigns a label for the route before distributing the route to the next subautonomous system. The CeGRP border edge router distributes the route as a VPN-IPv4 address by using the multiprotocol extensions of BGP. The label and the VPN identifier are encoded as part of the NLRI.
- Each PE and CeGRP border edge router assigns its own label to each VPN-IPv4 address prefix before redistributing the routes. The CeGRP border edge routers exchange VPN-IPv4 addresses with the labels.

  The next-hop-self address is included in the label (as the value of the eGRP next-hop attribute). Within the subautonomous systems, the CeGRP border edge router address is distributed throughout the iBGP neighbors and the two CeGRP border edge routers are known to both confederations.

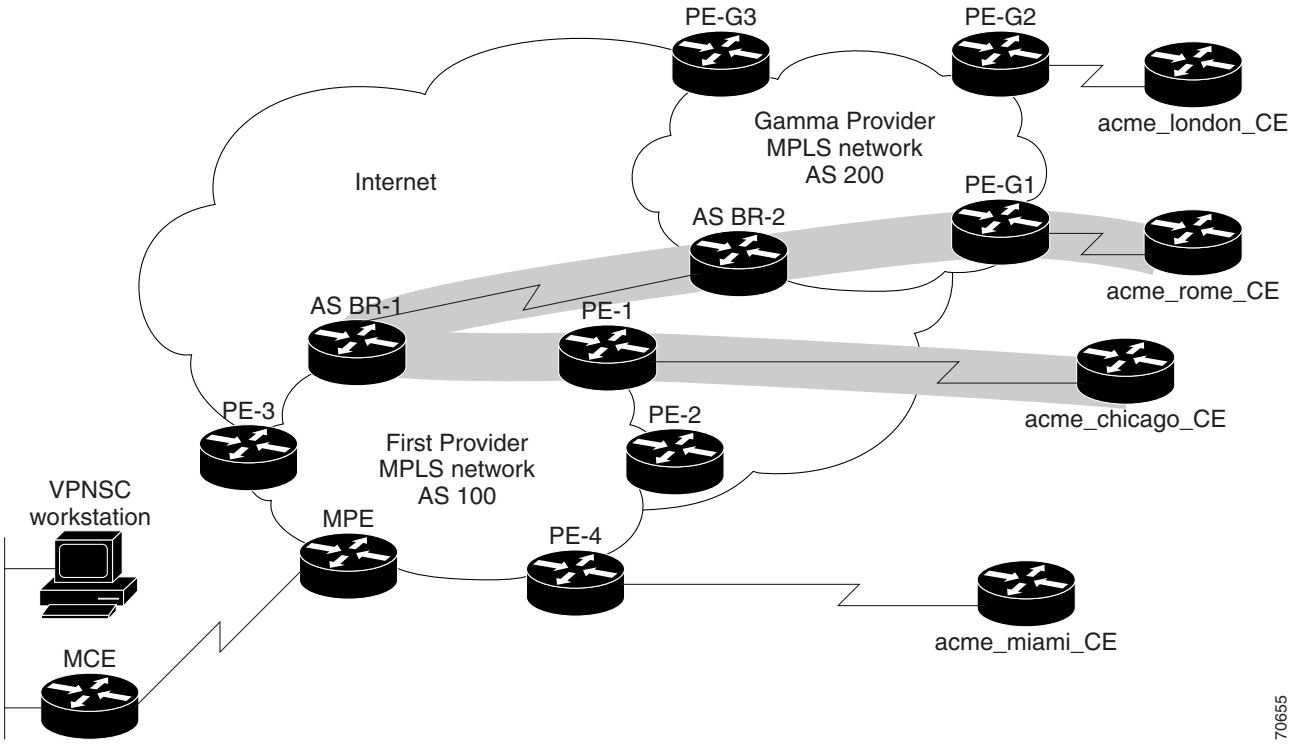
Using Prime Fulfillment to Span Multiple Autonomous Systems

As described in Exchanging VPN Routing Information, page 32-4, autonomous systems exchange VPN routing information (routes and labels) to establish connections. To control connections between autonomous systems, the PE routers and Exterior BGP ASBRs (Autonomous System Boundary Routers) maintain a Label Forwarding Information Base (LFIB). The LFIB manages the labels and routes that the PE routers and eGRP border edge routers receive during the exchange of VPN information.

The *ASBRs* are configured to change the next hop (next-hop-self) when sending VPN-IPv4 network layer reachability information to their iBGP neighbors. Therefore, the ASBRs must allocate a new label when they forward the NLRI to their iBGP neighbors.

Figure 32-7 shows the example Prime Fulfillment network used in this section.

Figure 32-7 Example VPN Network with Two Autonomous Systems



In order for traffic from Acme_Chicago in AS 100 to reach Acme_Rome in AS 200, Prime Fulfillment must provision two links only:

- The link between Acme_Chicago and PE-1
- The link between Acme_Rome and PE-G1

As shown in Figure 32-7, Prime Fulfillment routes the VPN traffic from PE-1 to ASBR-1, from ASBR-1 to ASBR-2, then from ASBR-2 to PE-G1; finally the traffic is routed to its destination, Acme-Rome.

ASBR-1 and ASBR-2 must run BGP (Border Gateway Protocol). Then iMP-BGP (interior Multiprotocol BGP) handles the routes between PE-1 to ASBR-1 in AS 100 and the routes between PE-2 to ASBR-2 in AS 200. eMP-BGP (exterior Multiprotocol BGP) handles the routes between ASBR-1 and ASBR-2.

Tip The service provider must configure a VPN-IPv4 eGRP session between directly connected Autonomous System Boundary Routers (ASBRs). This is a one-time setup procedure that the service provider must manage. Prime Fulfillment does not provision the link between the ASBR devices that span autonomous systems.

A VPN-IPv4 address (also referred to as a *VPNv4* address) is the combination of the IPv4 address and the 8-byte route distinguisher (RD). Combining the RD and the IPv4 address makes the IPv4 route globally unique across the MPLS VPN network. BGP considers an IPv4 address as different from another IPv4 address that has the same network and subnet mask when the route distinguishers are different.

Using Templates to Support Inter-Autonomous System Solutions

This section covers how Prime Fulfillment supports inter-autonomous system (inter-AS) and inter-provider VPNs through Prime Fulfillment templates.

Note Prime Fulfillment currently supports only the inter-AS 10B Hybrid model for L2TPV3 networks. This is the solution documented in the this section.

Inter-AS 10B Hybrid Model

The current release of Prime Fulfillment provides two pairs of template scripts for provisioning and decommissioning inter-AS 10B Hybrid VPNs:

- Provisioning and decommissioning VPN-independent inter-AS 10B Hybrid CLIs on an Autonomous System Border Router (ASBR)
- Provisioning and decommissioning VPN-specific inter-AS 10B Hybrid CLIs on an ASBR

Using the second pair of template scripts, the provider can create a new pair of data-files for provisioning and decommissioning a new inter-AS VPN on the ASBR, as and when added.The default inter-AS scripts can be modified to create or change scripts for modifying inter-AS configuration.

The following commands are supported in the VPN-independent inter-AS 10B Hybrid default templates:

- Provisioning resolve in VRF (RiV) VRF for L2TPV3 tunnel on an ASBR
- L2TPV3 tunnel configuration
- ASBR-facing interface provisioning
- BGP configuration:
  - BGP configuration with a **peer-group**
  - eBGP configuration
  - BGP **address-family ipv4** configuration
  - BGP **address-family ipv4 tunnel** configuration
  - BGP **address-family vpnv4** configuration
- Default route configuration through an L2TPV3 tunnel interface

The following commands are supported in the VPN-specific inter-AS 10B Hybrid default templates:

- Provisioning VRF for a customer VPN
- Recommended/standard route target (RT) support for full-mesh and hub-and-spoke VPN types. Spoke RTs are optional.
- RT-rewrite configuration:
  - Extended community (**extcommunity-list**) provisioning
  - Route maps provisioning

Inter-AS RT-Rewrite

Prime Fulfillment supports inter-AS RT-rewrite configuration on the ASBR. Velocity Template Language (VTL) template scripts for provisioning and decommissioning of RT-rewrite commands are provided as part of the inter-AS 10B hybrid templates, covered in the next section. You can edit these VTL scripts to create your own templates for the respective use-case.

Creating the Inter-AS Templates

Note For additional coverage of creating and using templates in Prime Fulfillment, see Chapter 49, "Using Templates and Data Files with Policies and Service Requests"

The default inter-AS templates are provided in the Examples templates directory in Prime Fulfillment. The templates are created from the Service Design window, which you access by choosing:

Service Design > Templates > Examples

The templates for Inter-AS 10b hybrid are:

- Configure_PE_as_ASBR_non_VPN_Specific_Template_TMPL_
- Remove_PE_as_ASBR_non_VPN_Specific_Template_TMPL_
- Configure_PE_as_ASBR_VPN_Specific_Template_TMPL_
- Remove_PE_as_ASBR_VPN_Specific_Template_TMPL_

You can create and change templates, using the default provisioning and decommissioning scripts, based on the respective use-case. Because the inter-AS configurations are mostly a one time setup, the templates are downloaded from the device console only, but are not attached to a service request.

The Prime Fulfillment templates feature supports a basic deployment check to determine whether the template data file was successfully deployed or whether there was any command that failed to deploy. In addition, you can select the data-type for the variables, which facilitates entering the right values during data-file creation in the user interface.

After you successfully create the template data file that contains the inter-AS CLIs, you can download the template data file onto the ASBR or route reflector using the Prime Fulfillment Device Console window, which you access by choosing:

Service Inventory > Device Console

The templates you created under Service Design can be selected for deployment on a device or a device-group.

Note The Prime Fulfillment templates feature is not model-based, so no template deployment history or stack is saved, no template roll-back is supported, and no template CLI audit is supported when you download the templates using the Device Console. You can also select templates in a service request, and have them downloaded onto the PE routers, in case you need to download specific iBGP commands on the PE routers.