White Paper

Internet **Connectivity** Options

Introduction

Internet access is perhaps one of the most popular services that Service Providers offer their customers. Customers have flexibility to purchase MPLS VPN services Internet connectivity from separate Service Providers. Customers can alternatively offer Internet connectivity directly from their network may it be from one of their remote sites or the central site. In the latter case, the Internet Service Provider (ISP) does not need to distinguish customer's Internet and VPN traffic, because all traffic traversing through a Service Provider network would be MPLS VPN traffic. Customers who do not purchase Internet connectivity from a Service Provider do need to work out additional variables:

- Routing
- Appropriate location for Internet access within the network
- Network Implementation Translation (NAT) implementation, if the network does not use public addresses
- Security
- Additional management and monitoring

The best way to offload these responsibilities is to purchase services from a Service Provider.

ISPs, Service Providers, and customers often wonder about the best and most highly recommended way to set up Internet connectivity. This varies widely, depending on the topology, requirements, and available resources. This paper will illustrate the advantages and disadvantages of several methods, while recommending a method for the most popular network topology.

This document offers a high-level analysis of the methods used to secure networks. For further analysis of MPLS security, please refer to the draft in progress by Michael Behringer:

http://www.ietf.org/internet-drafts/draft-behringer-mpls-security-03.txt

There are various possible combinations for using a network infrastructure to implement Internet connectivity, depending on how a Service Provider carries MPLS VPN and Internet traffic. The options at the infrastructure level are:

1. Shared MPLS VPN and Internet Connectivity
2. Partially Shared
3. Full Separation

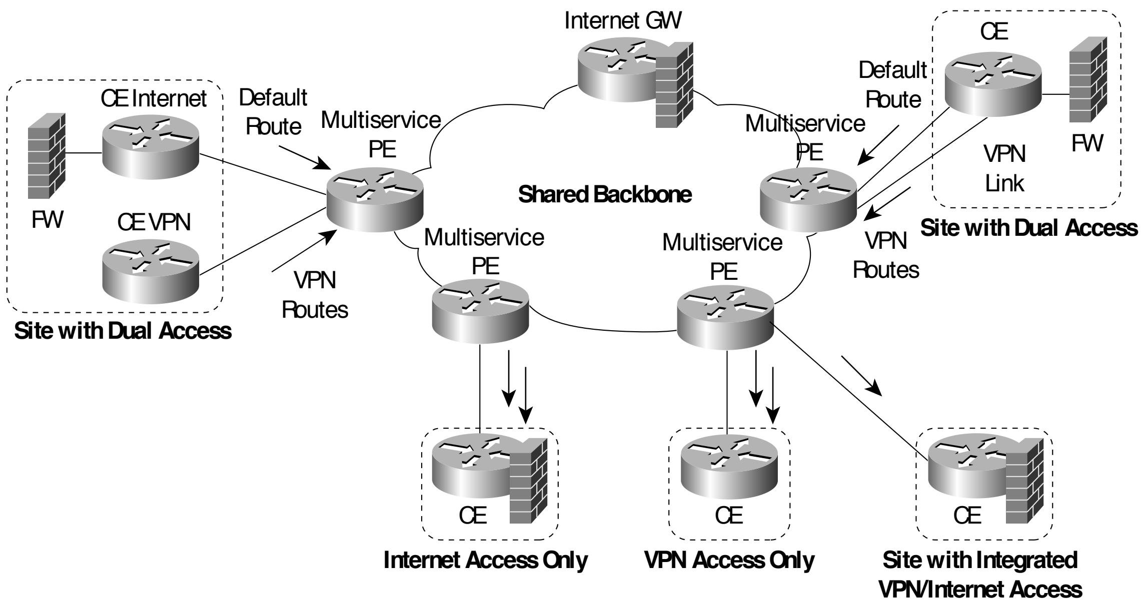
Customers of a Service Provider can always choose to use either multiservice or dedicated CEs, regardless of the infrastructure that the Service Provider has implemented. In addition, Hub/Spoke or fully meshed configuration for customers sites can also be implemented over any aforementioned infrastructure.

Let's take a look at the semantics of each of these options and various connectivity implementation options for each one.

Shared MPLS VPN and Internet Connectivity

Figure 1 shows that both P routers and PE routers support Internet and VPN traffic. A single PE router may connect both Internet and VPN customers.

Figure 1. Shared MPLS VPN and Internet Connectivity



- PE routers may or may not have a full Internet routing table
- PEs and Internet GW in the same iBGP area
- Share IGP and EGP
- MP-iBGP among PEs as appropriate

Advantages

- One backbone, one network
- Single edge router
- Easier management
- Can offer centralized services
- Single PEs to manage

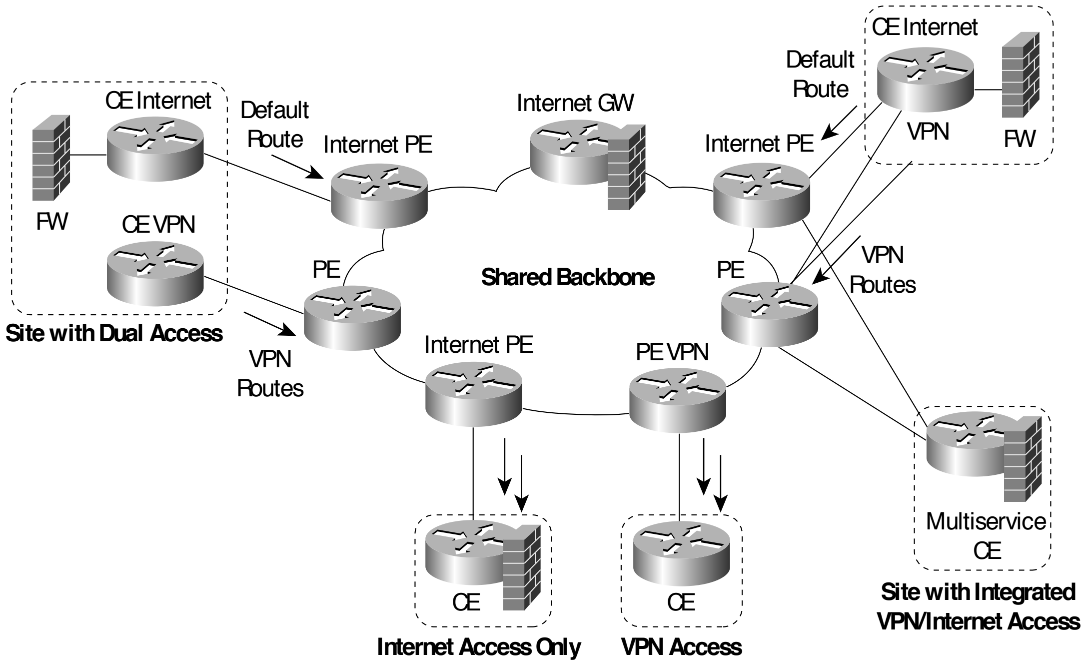
Disadvantages

- Security (both EGP in the same DB)
- Performance (memory/CPU)

Partial Separation

Figure 2 demonstrates that P routers are shared, but use separate PE routers for Internet and VPN services. Two interfaces will be required on a CE to terminate two types of connections on separate PEs.

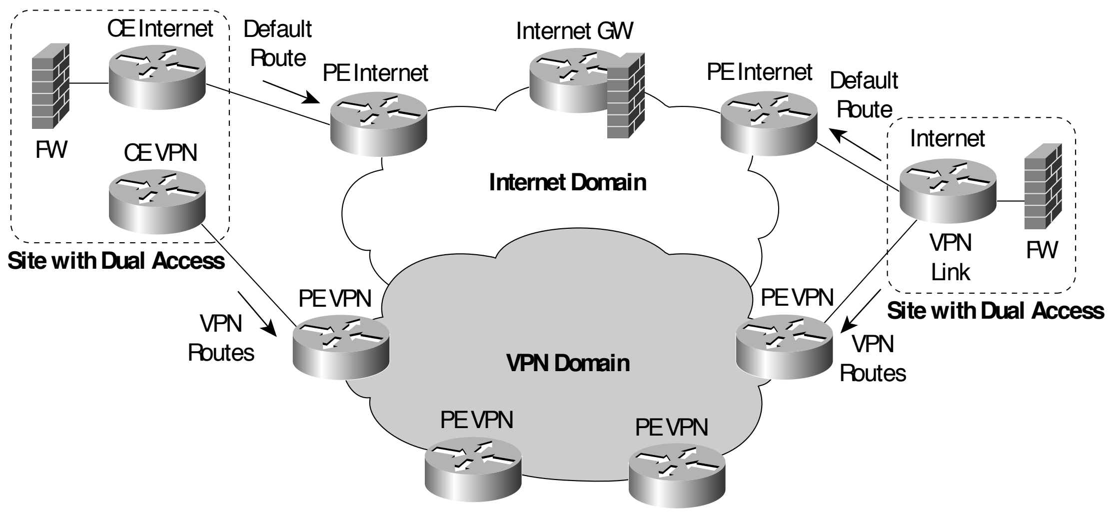
Figure 2. Partial Separation



Full Separation

Figure 3 shows neither PE nor P routers are shared. Internet and VPN traffic run over completely separate backbones.

Figure 3. Full Separation



Advantages

- Physical separation between Intranet/Extranet and Internet
- Separate IGP and EGP

Disadvantages

- Need to maintain two separate networks
- May not be an economical solution

Over the infrastructures mentioned above, Internet connectivity can be obtained via:

1. Customer Managed Internet Access
2. Simple Solution
3. Sub-interfaces
4. Firewall
5. Multiple ISPs
6. per VRF NAT with a separate Internet Gateway
7. VRFLite(MultiVRF) CE

These represent a high level implementation. Several additional components need to be selected for each option, as they play an important role. Routing, firewall, and address translation are each key components. These could be in an overlapping or single VPN environment.

Routing

Location of Internet routing table.

Address Translation

Most ISPs need to solve the issue of address translation deployment, because most customers combine public and private addresses. NAT could be deployed at CPE side, per VRF at centralized PE that connects to the Internet gateway (NAT-PE), or any other PE in the path previous to the NAT-PE.

Firewall

Security is the single most important concern for customers when they connect to public networks; therefore, firewall deployment is a necessity. An appropriate location should be selected for a firewall to block unauthorized traffic into a customer's private network. There are several criteria to select when deploying a firewall:

- Managed vs. unmanaged by an ISP
- Shared vs. dedicated per-customer sites
- Network- vs. router-based
  - Network-based: appliance (ie: Cisco PIX)
  - Router-based: Cisco IOS Software

Several permutations are possible based on these criteria:

1. No NAT, no firewall
2. NAT, but no firewall

3. Firewall, but no NAT
4. NAT and firewall

This list could continue if combined with various locations for deployment. This document will briefly cover a few popular scenarios and later focus on the most practical one in detail.

Customer Managed Internet Access

This scenario has existed since the advent of the Internet. Customers manage their firewall, NAT, and routing for Internet connectivity. Customers can have one or more gateways to the Internet, depending on their infrastructure (Centralized or Distributed). This approach gives customers complete control of the network.

Simple Solution

As the name implies, this is the simplest setup. It is also known as Static Default Routing on a PE.

When a customer uses global address space, NAT is not required. If a customer uses private address space, NAT could be deployed at a CPE, on a PE that is directly connected to VPN CPE, or on a PE that acts as a gateway to the Internet within an ISP network.

CPE does not need to receive full Internet routing in the simple solution. For CPE-PE, routing is handled on the PE that is directly connected to a VPN-CPE for distributing routes within a VPN. Between PE and CPE, static route, RIPv2, OSPF or eBGP can be used to update routing information. No additional configuration is required on a CPE, provided that it has a default static route to the PE to reach the Internet.

Figure 4. Simple Solution

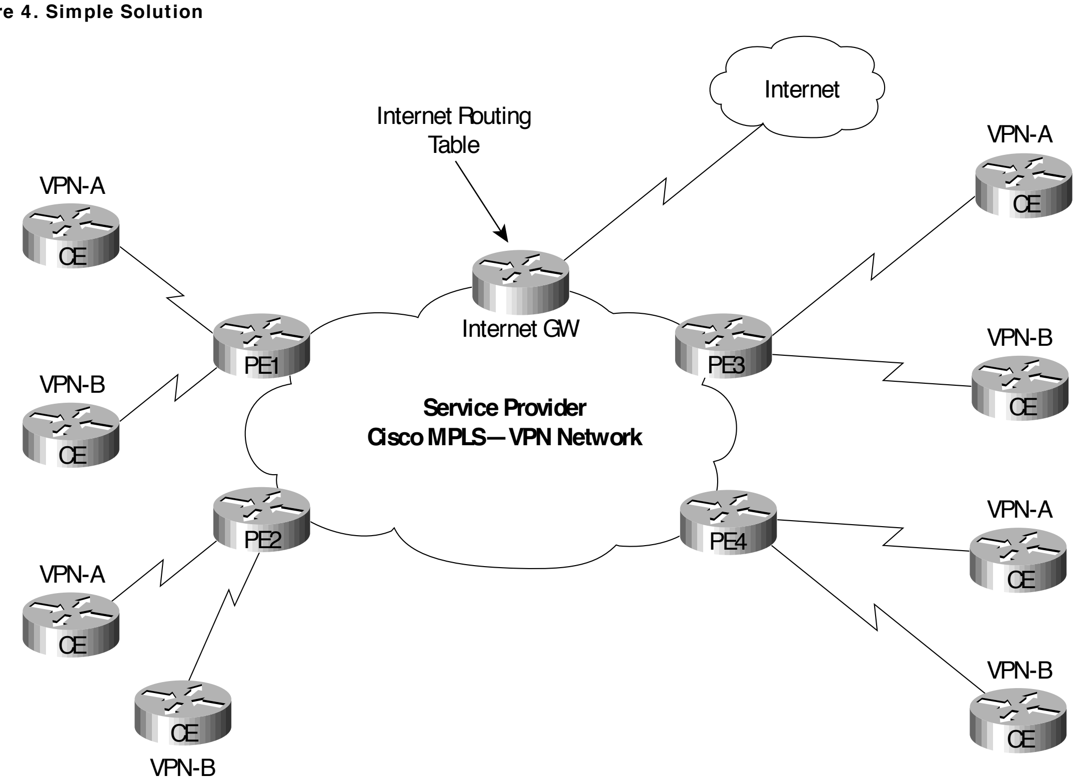
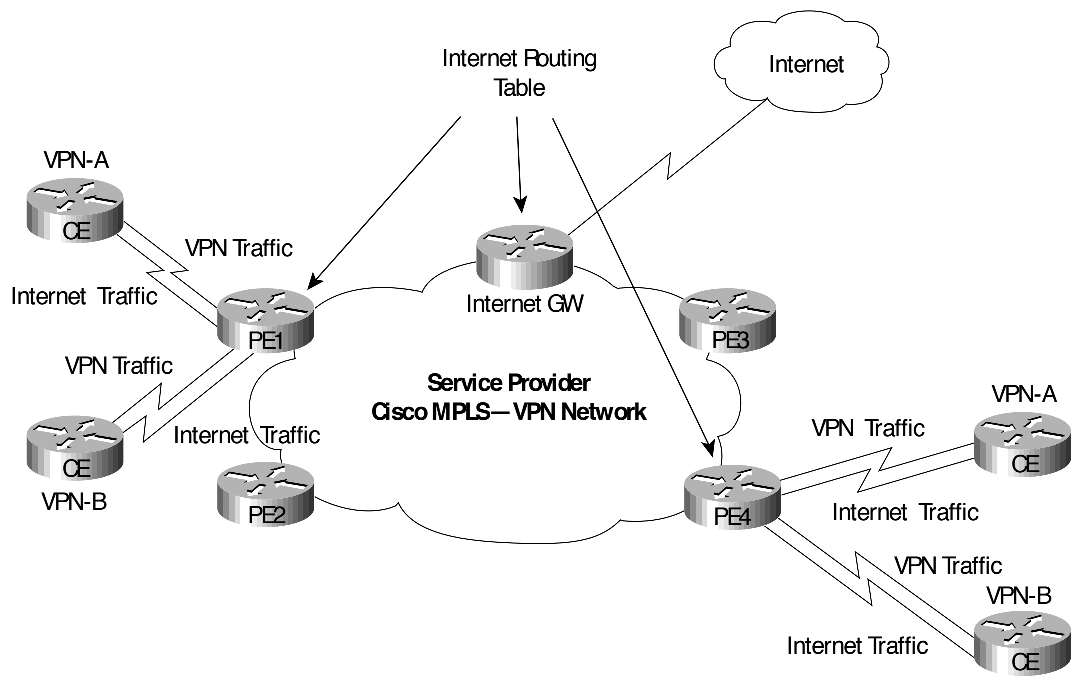


Figure 4 shows a full mesh topology where various VPN sites connect to adjacent PEs. Internet routing table is present only on Internet-GW.

VPN to Internet via Sub-interfaces

Some ISP customers may prefer to exchange routes directly with the Internet. In another words, VPN sites will need to exchange routes directly with the Internet. It is important to install routes from customer VPN sites in the Global routing table and to advertise full or partial Internet routing table to customer VPN site. Thus full or partial Internet routes should be present on PEs that physically connect to VPN sites. For a PE to distribute routes from a global routing table to a VPN site, there must be a second interface that is not bound to a VRF.

Figure 5. VPN to Internet via Sub-Interface



This interface can be a sub-interface, tunnel interface, or separate physical interface. One interface or a sub-interface can carry VPN traffic and other Internet traffic. Figure 5 shows various customers sites using separate interfaces for VPN and Internet traffic. In this case, separate BGP sessions are required between PE- and CE- routers for VPN and Internet traffic. The drawback with this implementation is VPN customers with these requirements will have recurring costs for additional links. ISPs will need to distribute Internet routes to the participating PEs, which will be carrying larger routing tables and in turn requiring more router resources. Complexity also increases on PE configuration side. ISPs will need to filter Internet routes for non-participating PEs.

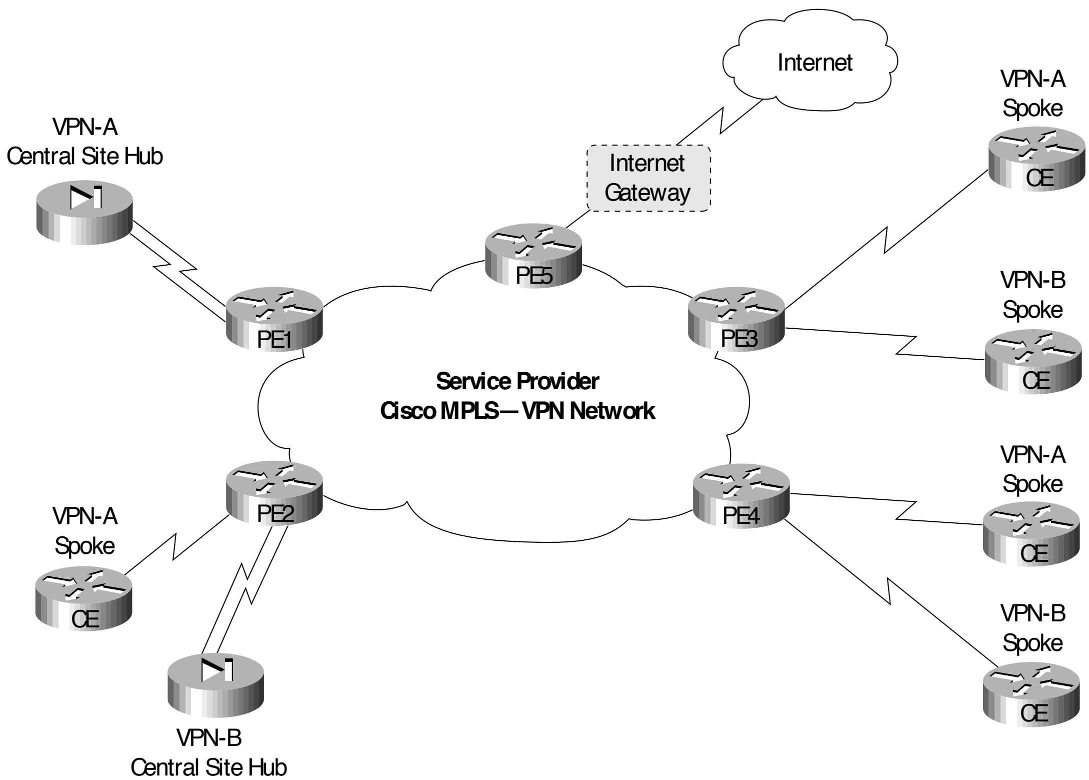
Internet access via Firewall

A firewall can be deployed at many points within the network to protect VPN traffic from the Internet traffic. It is usually present at the ISP site, behind the Internet gateway facing the Internet. This firewall would be shared amongst the ISP customers, leaving them with limited choices.

If a VPN topology were fully meshed, then deploying a firewall at every site facing the ISP network could be one solution. If a customer topology followed the central site (hub/spoke) model, then deploying a firewall at the Hub site would be sufficient. In the latter case, VPN sites would import a default route to the central site CE, which is generated and updated by the central site CE.

Figure 6 shows a hub/spoke topology where a Cisco IOS firewall is deployed on a. CE router at a hub site.

Figure 6. Internet Access via Firewall



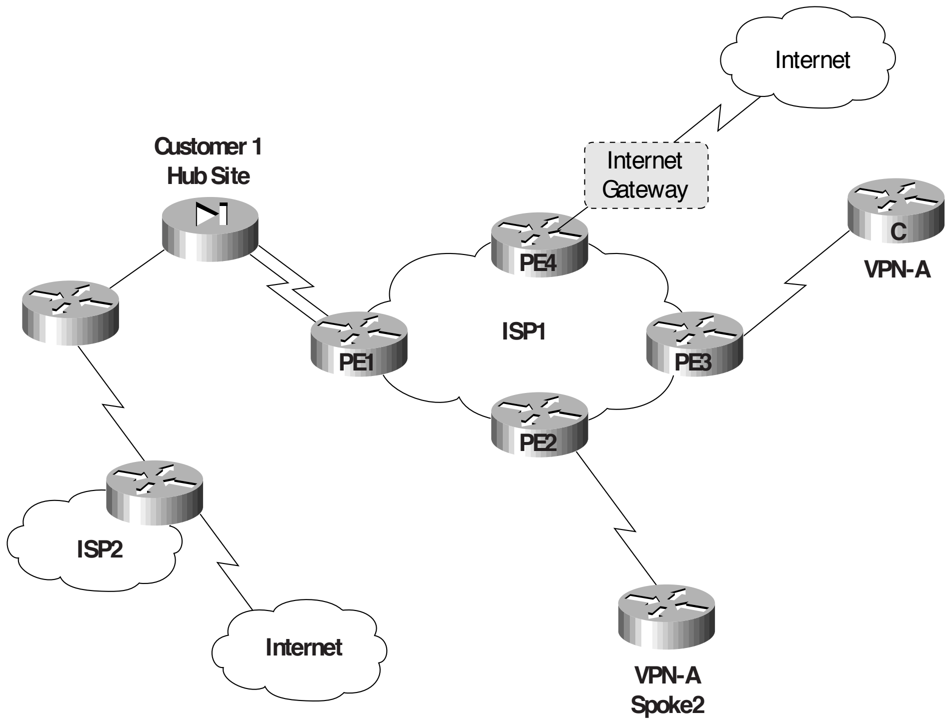
Notice, Internet traffic from any Spoke VPN sites need to pass through a firewall. Since the central site is providing firewall services (as shown in figure 6), a static default route pointing to the central site firewall should be installed in associated FIB tables for each spoke sites.

Multiple ISPs

Some customers may choose to obtain Internet Connectivity via different Service Providers. Several combinations are possible depending on whether the customer network uses full mesh or hub and spoke model. In either case, exit points in the network needs to be planned out so that traffic load is well distributed. Exit point will be selected based on the best path determined by a routing protocol.

Figure 7 shows an example where Customer1 has Internet connectivity and MPLS/VPN services from ISP1. MPLS/ VPN and Internet traffic is routed over separate interfaces. There is another exit point for Internet traffic at the hub site which is routed via Service Provider ISP2 network.

Figure 7.



Internet access via per VRF NAT with a separate Internet Gateway

This scenario follows principles of MPLS Managed Shared Services model. It consists of:

- Centralized single NAT-PE with per VRF NAT for separate VPNs
- Internet routing table on the Internet Gateway
- Topology
  - Fully meshed: non-overlapping VPNs with private addresses
  - Hub and Spoke: non-overlapping VPNs with private addresses
- Infrastructure
  - Multiservice (shared) for MPLS VPN and Internet connectivity

This implementation allows:

- The ISP to load share with Internet Gateway
- Physically separate VPN and Internet routing tables
- No other PE in the cloud would have to maintain Internet routing table
- No restrictions for the customer of using public or private addresses
- Separate NAT functionality allowing more services take advantage of one NAT-PE

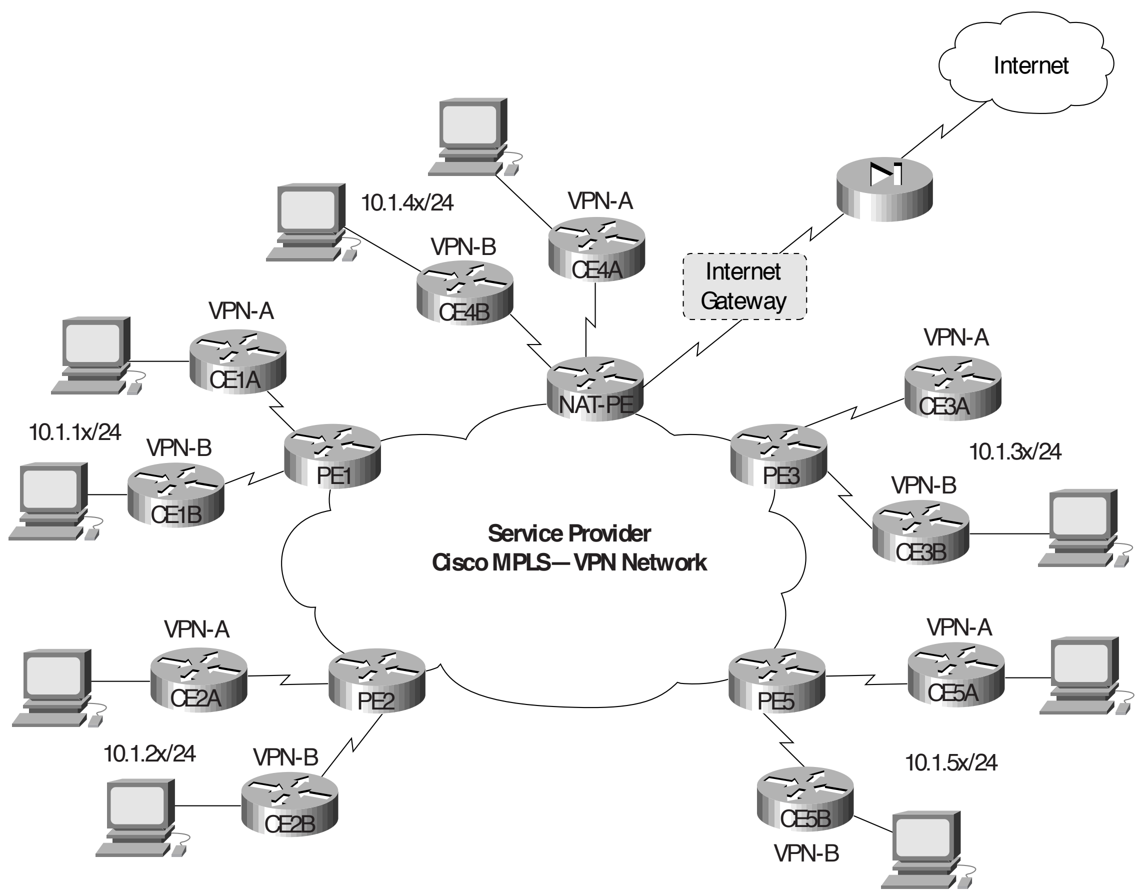
ISP customers can offload NAT responsibility to their ISPs. ISPs can expand their services portfolio and subsequently increase revenue.

Case A: with Fully Meshed Topology

Figure 8 shows part of a typical Service Provider network. Several geographically dispersed customer sites are part of VPN-A and VPN-B. Some of these sites connect directly to the NAT-PE where address translation takes place. Others connect via various PEs. The interface directly connecting to the Internet Gateway will be the outside interface.

The interfaces connecting to other PEs or adjacent VPN sites will be inside interfaces.

Figure 8. Per VRF NAT with fully meshed VPN sites



CE-PE

Use static default route for VPN and Internet traffic to directly connected PE.

PE

The PE does not carry any Internet routes. They only carry routes for appropriate VPN sites and the backbone.

A default static route is applied to participating PEs FIB tables that are associated with customers' VRFs, which need to support Internet connectivity service. The next-hop address used in the static route is an address of the interface from which the Internet routes are learned, rather than an address of the loopback interface on the Internet Gateway. This will eliminate sub-optimal routing and the possibility of black-holing traffic designated for the Internet. The route to this interface would be known via IGP.

The other option is to use the next-hop address of the NAT-PE. The NAT-PE would neighbor with the Internet Gateway, so it can get updates on addresses used on the Internet Gateway. This will avoid the distribution of any subnets of Internet Gateway to the PEs. The drawback to this option is similar to that of using the next-hop address of a loopback interface. Alternatively, this should not be a concern if the back-up interfaces are used on the Internet Gateway.

Additionally, the next-hop of the default static route will be present in the global routing table, but not in the VRF table. Since there is no redistribution between IPv4 and VPN-IPv4 routes, additional technique is required to resolve the next-hop address for the Internet Gateway from within a VRF. This is achieved by using 'global' keyword within the static default route configuration on an appropriate PE.

All the traffic is forwarded with the appropriate VPN label attached. The need for this is dictated by overlapping private IP addresses that have not been translated to unique public IP addresses. When NAT-PE receives these packets, it needs to recognize the associated VPN, so it can select appropriate pools for translation.

NAT-PE

NAT occurs on the NAT-PE for all customers that use private addresses and need Internet connectivity. In this scenario, the ISP has only one Internet Gateway that is directly connected to the NAT-PE.

Since the translation occurs on a dedicated NAT-PE, translated public addresses could be updated by means of routing protocol to the neighbor Internet Gateway, via IGP to forward the returned traffic from the internet to appropriate VPNs. Internet Gateway will forward the response traffic back to the NAT-PE. NAT-PE will translate addresses back to the original private IP addresses, and then forward the traffic to the appropriate VPNs.

The other option is to follow the distributed model and deploy per VRF NAT on PEs where VRFs are present. This would complicate configuration and make management of IP address pools awkward.

Note: there are no MP-iBGP sessions set up between the PEs and the Internet Gateway. The Internet Gateway does not have any knowledge of VPNs. It receives packets as IPv4 packets from the NAT-PE, and forwards the return traffic to the NAT-PE. Upon receiving the packets, NAT translation occurs again on outside to inside path.

- The Internet services interfaces should be configured as NAT outside on the NAT-PE.
- The VRF interfaces and core facing MPLS-enabled interface should be configured as NAT inside on the NAT-PE.
- The interface connecting to the Internet Gateway is a non-VRF interface.

Inside to Outside packet flow on the NAT-PE:

Translations will take place on the NAT-PE interface that is physically connected to the Internet Gateway.

As a packet arrives on the NAT-PE destined for the Internet:

- Route lookup occurs
- NAT receives the packet
- NAT translates the packet

- Stores the VRF table ID in the translation entry
- Packet is switched to the egress interface

Outside to Inside packet flow on the NAT-PE:

NAT receives the packet before routing and performs lookup on the translation table. NAT performs the reverse translation, and also sets the VRF table ID in the packet descriptor header. This enables the subsequent route lookup to occur on the right Forwarding Information Block (FIB). If the outgoing interface is in a VRF on the same PE, then the packet is forwarded as an IP packet. If the destination is on a remote PE, then the packet is imposed with labels and forwarded on the core facing interface.

Internet Gateway

The Internet Gateway holds full Internet routes, translated networks, and appropriate backbone routes. It forwards IP packets to and from the NAT-PE to the Internet.

Configuration Check List

In addition to the basic IGP, VRF, and MP-iBGP configuration:

1. Static default route with 'global' keyword option on a participating PE pointing to the next-hop address of the Internet Gateway.
2. NAT on a NAT-PE for every VRF. Could use same or dedicated pool per VRF.
   – Dedicated pools are used in this example.
3. Static route pointing to each VRFs on a NAT-PE.

VPN-A and VPN-B use overlapping private address space.

NAT-PE Sample Configuration

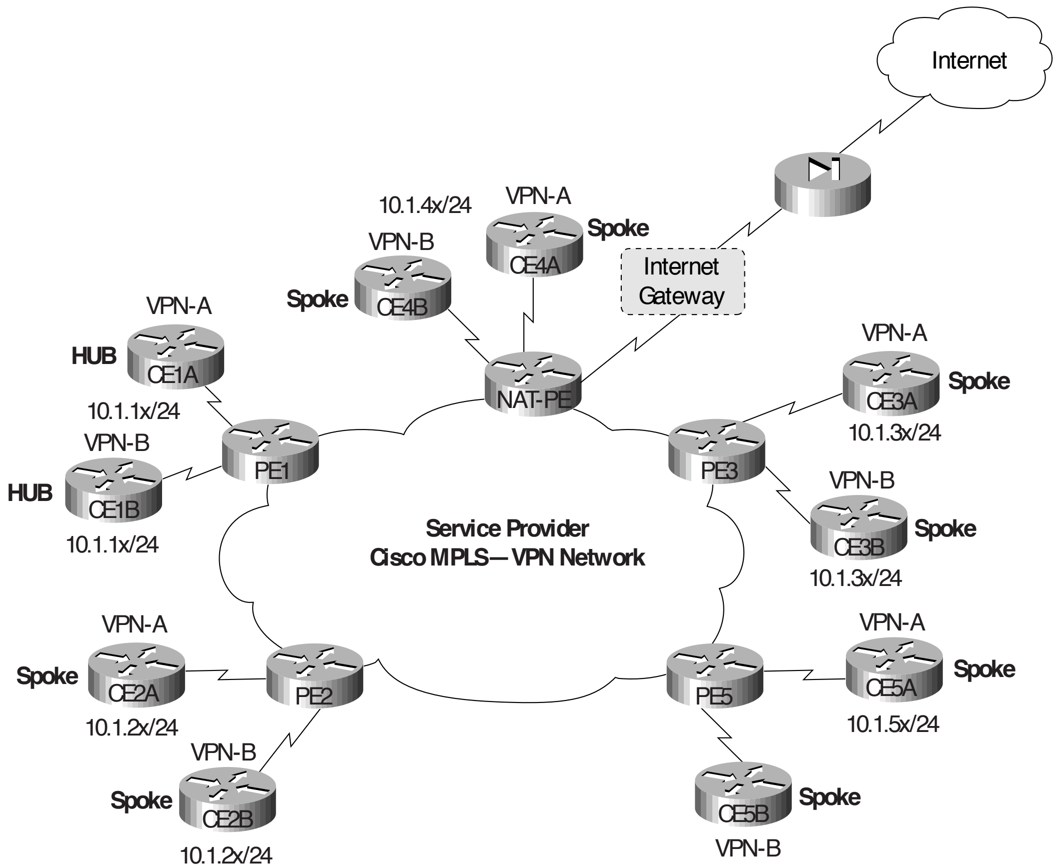
```
hostname NAT-PE
!
ip nat pool pool1 171.1.1.2 171.1.254.254 mask 255.255.0.0
ip nat pool pool2 171.2.1.2 171.2.254.254 mask 255.255.0.0
!
ip nat inside source list 1 pool pool1 vrf VPN-A
ip nat inside source list 1 pool pool2 vrf VPN-B
!
ip route vrf VPN-A 171.1.0.0 0.0.255.255 ge1/0
ip route vrf VPN-B 171.2.0.0 0.0.255.255 ge1/0
!(ge1/0 is the Gigbit Ethernet interface on Internet Gateway which is directly
!connected to the NAT-PE).

Interface ge1/0
description interface directly connected to the Internet Gateway
ip nat outside
!
Interface ge1/1
description interface to another PE
ip nat inside
!
access-list 1 permit 10.1.0.0 0.0.255.255
```

Notice, no NAT configuration required on any other CEs or PEs. Configure PEs for appropriate MP-iBGP sessions with NAT-PE and other PEs where additional sites belonging to the same VPNs are located.

CASE B: with Hub & Spoke Topology

Figure 9. Hub and Spoke Topology



Note: in this topology (Figure 9), CE1A and CE1B are Hub sites, while the rest are spoke sites. The requirement is that all spoke traffic must be forwarded via Hub site to the appropriate destination. The only difference here is that on PE2, PE3, NAT-PE and PE5, the next hop in the default static route will be that of CE1A's interface for the sites in VPN-A and CE1B's for the sites in VPN-B. The next hop address used on PE1 will be that of the interface facing the Internet on the Internet Gateway.

The rest of the process for forwarding/receiving the Internet traffic to and from the NAT-PE from PE1 will be the same as described in Case A. The only difference is that a Service Provider must ensure that PE1 (PE serving the Hub site) can support the traffic load.

VRFLite(MultiVRF) CE

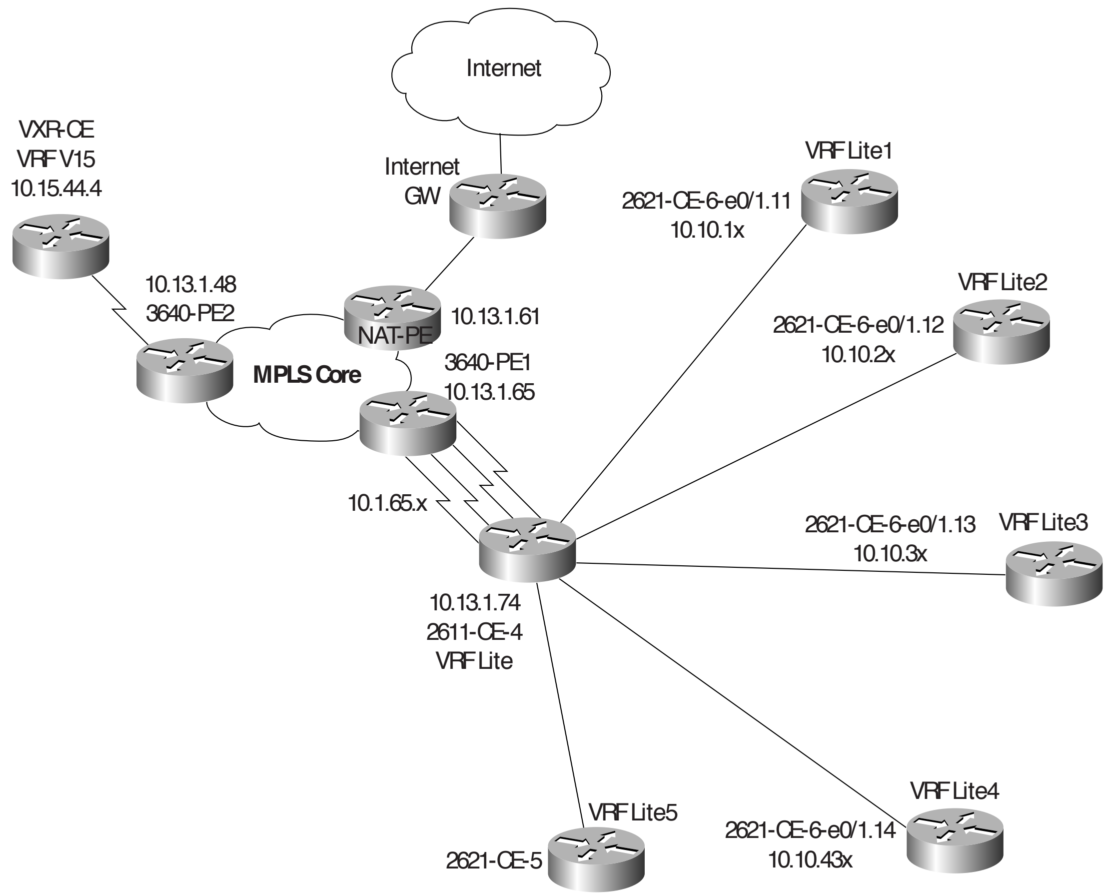
If VRF Lite is deployed at a customer site, Internet connectivity still can be offered by combining #1 with VRF Lite. Overlapping address space is supported in VRF Lite, because routing-forwarding tables are kept separate on a VRF CE for each VPN. If address translation is required, it can be performed using a NAT-PE (see Case #6).

The following example demonstrates a Service Provider offering Internet connectivity over VRF Lite:

- There are 2 PE routers in the network and one CE, 2611 configured for VRF-lite
- In this case study, all sub-interfaces off the 2621-CE6 can communicate with VXR-CE, but not with each other.2611-CE5 can communicate with VXR-CE, but not with any host off 2621-CE6All traffic off 2611-CE-4 is segmented into 5 separate VRFs (labeled vrflite1-5)
- These two connections use OSPF as the routing protocol to exchange updates with 2611-CE4, (but other routing protocols may be used as well).
- All other hosts off 2611-CE4 use a combination of OSPF, EBGP, RIPv2 and static routes.

Topology

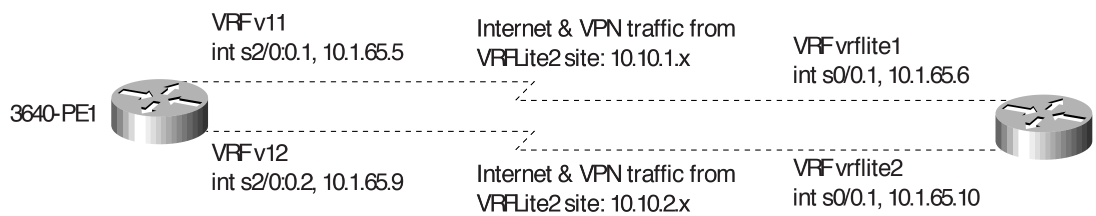
Figure 10. VRF Lite



Separate FIB tables are maintained on 2611-CE-4 for each VRFs. Figure 11, shows detailed connectivity information between 3640-PE1 and 2611-CE-4(VRF Lite CE). Notice, there is no separate sub-interface for Internet traffic.

Internet and VPN traffic from each VRFLite sites(VRFLite1, VRFLite2…etc.), will be sent on their associated sub-interfaces from 2611-CE-4 to 3640-PE1. Default static route for the Internet, is present in each FIB table on 2611-CE-4 and 3640-PE1. Thus returning Internet traffic for each of the VRF Lite Site, will go over the associated sub-interface from 3640-PE1 to 2611-CE-4. Appropriate FIB tables will be consulted on 2611-CE-4 before forwarding the traffic to remote VRFLite sites (ie: VRFLite1, VRFLite2.).

Figure11. VRF Lite CE-PE



Mappings between VRFs on 2640-PE1 and 2611-CE-4:

3640-PE1 VRFs	2611-CE-4 VRFs
v11	vrflite1
v12	vrflite2
v13	vrflite3
v14	vrflite4
v15	vrflite5

Configurations for Some CE and PE Routers

3640-PE1

```
3640-PE-WEST-1#sh run
hostname 3640-PE-WEST-1
ip subnet-zero
!
ip vrf v11
 rd 11:1
 route-target export 11:1
 route-target import 11:1
!
ip vrf v12
 rd 12:1
 route-target export 12:1
 route-target import 12:1
!
ip vrf v13
 rd 13:1
 route-target export 13:1
 route-target import 13:1
!
ip vrf v14
 rd 14:1
 route-target export 14:1
```

```
 route-target import 14:1
!
ip vrf v15
 rd 15:1
 route-target export 15:1
 route-target import 15:1
!
ip cef
!
controller T1 2/0
 framing esf
 linecode b8zs
 channel-group 0 timeslots 1-24
!
interface Loopback0
 description Router ID
 ip address 10.13.1.65 255.255.255.255
!
interface FastEthernet1/0
 description FE to GSR-P-CENTRAL-A - 4.16
 ip address 10.13.4.18 255.255.255.252
 duplex auto
 speed auto
!
interface Serial2/0:0
 description T1 connection to CE - VRF_Lite
 no ip address
 encapsulation frame-relay
!
interface Serial2/0:0.1 point-to-point
 description PE to VRF_Lite CE connection 1
 ip vrf forwarding v11
 ip address 10.1.65.5 255.255.255.252
 frame-relay interface-dlci 21
!
interface Serial2/0:0.2 point-to-point
 description PE to VRF_Lite CE connection 2
 ip vrf forwarding v12
 ip address 10.1.65.9 255.255.255.252
 frame-relay interface-dlci 22
!
interface Serial2/0:0.3 point-to-point
 description PE to VRF_Lite CE connection 3
 ip vrf forwarding v13
 ip address 10.1.65.13 255.255.255.252
 frame-relay interface-dlci 23
!
interface Serial2/0:0.4 point-to-point
 description PE to VRF_Lite CE connection 4
 ip vrf forwarding v14
 ip address 10.1.65.17 255.255.255.252
 frame-relay interface-dlci 24
!
interface Serial2/0:0.5 point-to-point
 description PE to VRF_Lite CE connection 5
 ip vrf forwarding v15
 ip address 10.1.65.21 255.255.255.252
```

```
 frame-relay interface-dlci 25
!
router ospf 15 vrf v15
 log-adjacency-changes
 area 15 virtual-link 220.1.65.22
 redistribute bgp 1 subnets
 network 10.1.65.20 0.0.0.3 area 15
!
router ospf 11 vrf v11
 log-adjacency-changes
 area 11 virtual-link 220.1.65.6
 redistribute bgp 1 subnets
 network 10.1.65.4 0.0.0.3 area 11
!
router ospf 12 vrf v12
 log-adjacency-changes
 redistribute bgp 1 subnets
 network 10.1.65.8 0.0.0.3 area 12
!
router ospf 13 vrf v13
 log-adjacency-changes
 redistribute bgp 1 subnets
 network 10.1.65.12 0.0.0.3 area 13
!
router ospf 14 vrf v14
 log-adjacency-changes
 redistribute bgp 1 subnets
 network 10.1.65.16 0.0.0.3 area 14
!
router ospf 1
 log-adjacency-changes
 network 10.13.1.65 0.0.0.0 area 6
 network 10.13.4.16 0.0.0.3 area 6
!
router bgp 1
 no synchronization
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 neighbor 10.13.1.48 remote-as 1
 neighbor 10.13.1.48 update-source Loopback0
 neighbor 10.13.1.48 activate
 neighbor 10.13.1.61 remote-as 1
 neighbor 10.13.1.61 update-source Loopback0
 neighbor 10.13.1.61 activate
 no auto-summary
 !
 address-family ipv4 vrf v15
 redistribute ospf 15
 default-metric 10
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family ipv4 vrf v14
 redistribute ospf 14 match internal external 1 external 2
 default-metric 10
 no auto-summary
```

```
 no synchronization
 exit-address-family
 !
 address-family ipv4 vrf v13
 redistribute ospf 13 match internal external 1 external 2
 default-metric 10
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family ipv4 vrf v12
 redistribute ospf 12 match internal external 1 external 2
 default-metric 10
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family ipv4 vrf v11
 redistribute ospf 11
 default-metric 10
 no auto-summary
 no synchronization
 exit-address-family
!
 address-family vpnv4
 neighbor 10.13.1.48 activate
 neighbor 10.13.1.48 send-community extended
 neighbor 10.13.1.61 activate
 neighbor 10.13.1.61 send-community extended
 no auto-summary
 exit-address-family
!
ip classless
no ip http server
ntp clock-period 17179973
end
```

2611-CE-4

```
2611-CE-4#sh run
hostname 2611-CE-4
!
ip vrf vrflite1
 rd 81:81
 !
ip vrf vrflite2
 rd 82:82
 !
ip vrf vrflite3
 rd 83:83
 !
ip vrf vrflite4
 rd 84:84
 !
ip vrf vrflite5
 rd 85:85
!
ip cef
```

```
frame-relay switching
cns event-service server
!
interface Loopback0
 description Router ID
 ip address 10.13.1.74 255.255.255.255
!
interface Serial0/0
 description T1 connection to PE - VRF_Lite
 no ip address
 encapsulation frame-relay
 no fair-queue
 service-module t1 clock source internal
 service-module t1 timeslots 1-24 speed 56
 frame-relay intf-type dce
!
interface Serial0/0.1 point-to-point
 description VRF_Lite CE to PE connection 1
 ip vrf forwarding vrflite1
 ip address 10.1.65.6 255.255.255.252
 frame-relay interface-dlci 21
!
interface Serial0/0.2 point-to-point
 description VRF_Lite CE to PE connection 2
 ip vrf forwarding vrflite2
 ip address 10.1.65.10 255.255.255.252
 frame-relay interface-dlci 22
!
interface Serial0/0.3 point-to-point
 description VRF_Lite CE to PE connection 3
 ip vrf forwarding vrflite3
 ip address 10.1.65.14 255.255.255.252
 frame-relay interface-dlci 23
!
interface Serial0/0.4 point-to-point
 description VRF_Lite CE to PE connection 4
 ip vrf forwarding vrflite4
 ip address 10.1.65.18 255.255.255.252
 frame-relay interface-dlci 24
!
interface Serial0/0.5 point-to-point
 description VRF_Lite CE to PE connection 5
 ip vrf forwarding vrflite5
 ip address 10.1.65.22 255.255.255.252
 frame-relay interface-dlci 25
!
interface Ethernet0/1
 description Subinterfaces to Host CE
 no ip address
 half-duplex
!
interface Ethernet0/1.11
 description VRF_Lite CE to host 1 (dup addr)
 encapsulation dot1Q 11
 ip vrf forwarding vrflite1
 ip address 10.10.1.1 255.255.255.0
!
```

```
interface Ethernet0/1.12
 description VRF_Lite CE to host 2
 encapsulation dot1Q 12
 ip vrf forwarding vrflite2
 ip address 10.10.2.1 255.255.255.0
!
interface Ethernet0/1.13
 description VRF_Lite CE to host 3
 encapsulation dot1Q 13
 ip vrf forwarding vrflite3
 ip address 10.10.3.1 255.255.255.0
!
interface Ethernet0/1.14
 description VRF_Lite CE to host 4
 encapsulation dot1Q 14
 ip vrf forwarding vrflite4
 ip address 10.10.4.1 255.255.255.0
!
interface Ethernet1/0
 description VRF_Lite CE to host 5 (dup addr)
 ip vrf forwarding vrflite5
 ip address 10.10.1.1 255.255.255.0
 half-duplex
!
router ospf 11 vrf vrflite1
 log-adjacency-changes
 area 11 virtual-link 220.1.65.5
 network 10.10.1.0 0.0.0.255 area 0
 network 10.1.65.4 0.0.0.3 area 11
!
router ospf 12 vrf vrflite2
 log-adjacency-changes
 redistribute rip subnets
 network 10.1.65.8 0.0.0.3 area 12
!
router ospf 13 vrf vrflite3
 log-adjacency-changes
 redistribute bgp 13 subnets
 network 10.1.65.12 0.0.0.3 area 13
!
router ospf 14 vrf vrflite4
 log-adjacency-changes
 redistribute connected
 redistribute static subnets
 network 10.1.65.16 0.0.0.3 area 14
!
router ospf 15 vrf vrflite5
 log-adjacency-changes
 area 15 virtual-link 220.1.65.21
 network 10.10.1.0 0.0.0.255 area 0
 network 10.1.65.20 0.0.0.3 area 15
!
router rip
 version 2
 !
 address-family ipv4 vrf vrflite2
 version 2
```

```
 redistribute ospf 12
 network 10.10.2.0
 default-metric 1
 no auto-summary
 exit-address-family
!
router bgp 13
 bgp log-neighbor-changes
 !
 address-family ipv4 vrf vrflite5
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family ipv4 vrf vrflite4
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family ipv4 vrf vrflite3
 redistribute ospf 13 match internal
 neighbor 10.10.3.2 remote-as 3
 neighbor 10.10.3.2 activate
 no auto-summary
 no synchronization
 network 10.10.3.0
 exit-address-family
 !
 address-family ipv4 vrf vrflite2
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family ipv4 vrf vrflite1
 no auto-summary
 no synchronization
 exit-address-family
!
ip classless
ip route vrf vrflite4 10.4.4.0 255.255.255.0 10.10.4.2
```

2611-CE-5

```
2611-CE-5#sh run
hostname 2611-CE-5
!
ip cef
!
interface Loopback0
 description Router ID
 ip address 10.13.1.75 255.255.255.255
!
interface Ethernet1/0
 description Host to VRF_Lite CE 5 (dup addr)
 ip address 10.10.1.2 255.255.255.0
 half-duplex
!
router ospf 5
```

```
 log-adjacency-changes
 network 10.10.1.0 0.0.0.255 area 0
!
ip classless
```

2621-CE-6

```
hostname 2621-CE-6
!
memory-size iomem 30
ip subnet-zero
ip cef
!
interface Loopback0
 description Router ID
 ip address 10.13.1.76 255.255.255.255
!
interface Loopback41
 description Host 4 loopback 1
 ip address 10.4.4.1 255.255.255.252
!
interface Loopback42
 description Host 4 loopback 2
 ip address 10.4.4.5 255.255.255.252
!
interface Loopback43
 description Host 4 loopback 3
 ip address 10.4.4.9 255.255.255.252
!
interface Ethernet0/1
 description Subinterfaces to VRF-Lite CE
 no ip address
 half-duplex
!
interface Ethernet0/1.11
 description Host to VRF_Lite CE 1 (dup addr)
 encapsulation dot1Q 11
 ip address 10.10.1.2 255.255.255.0
!
interface Ethernet0/1.12
 description Host to VRF_Lite CE 2
 encapsulation dot1Q 12
 ip address 10.10.2.2 255.255.255.0
!
interface Ethernet0/1.13
 description Host to VRF_Lite CE 3
 encapsulation dot1Q 13
 ip address 10.10.3.2 255.255.255.0
!
interface Ethernet0/1.14
 description Host to VRF_Lite CE 4
 encapsulation dot1Q 14
 ip address 10.10.4.2 255.255.255.0
!
router ospf 1
 log-adjacency-changes
 network 10.10.1.0 0.0.0.255 area 0
!
```

```
router rip
 version 2
 network 10.10.2.0
!
router bgp 3
 bgp log-neighbor-changes
 neighbor 10.10.3.1 remote-as 13
 neighbor 10.10.3.1 update-source Ethernet0/1.13
!
ip classless
ip route 10.1.65.16 255.255.255.252 10.10.4.1
```

Closing Remarks

Internet access is the most basic and common requirement for many businesses. By offering additional sets of services to their customers across VPNs, Service Providers can increase services portfolio, differentiate themselves from their competition, increase customer satisfaction, and increase revenue.

This document assessed several methods available to provide Internet connectivity; including the advantages and drawbacks associated with each method.

In any case, Service Providers can select the most appropriate way of providing this service, based on their topology and customer requirements.

An Enterprise (ISP) customer should consider these factors when selecting Internet access:

1. Multiple ISPs, only getting Internet connectivity: set up Enterprise network to use the best BGP path to the Internet exit points.
2. Multiple ISPs, getting MPLS VPN and Internet connectivity through one and only Internet connectivity through other: set up their network to use best BPG path to Internet exit points.
3. Same ISP for MPLS VPN and Internet connectivity:
   - Two sub-Interfaces from a CE to the same PE or two sub-interfaces to two separate PEs: default route for the Internet traffic over one sub-interface. Static or dynamic routes with a PE for MPLS VPN over another Sub-interface.
   - Over one Interface: static route for Internet traffic, dynamic routes for MPLS VPN.
4. Same ISP, but want all INET routes: do eBGP session with ISP's Internet GW. This could be done with 3a or 3b.

ISPs must consider the following checklist while designing a network to support Internet connectivity service:

1. Shared, full separation, or partial separation (multiservice or not?) at the infrastructure level for VPN traffic and Internet traffic
2. Overlapping or non-overlapping VPNs
3. VRF or non-VRF interface for Internet access
4. Huband spoke or fully-meshed topology
5. Public versus private addresses
6. Centralized or distributed NAT; single or multiple centralized NAT PEs

7. Firewall:
   - Managed or unmanaged
   - Location
   - Type (integrated in Cisco IOS Software or appliance-based)
8. Use of a global routing table or a static route to separate and forward traffic
9. Internet routing table location
   - CEs or PEs
   - Single or multiple Internet gateways
10. Static or dynamic routing between CEs and PEs

Security Considerations

In a multiservice environment, VPN and Internet traffic share the same wire. It is critical that a Service Provider implement strong security policies to ensure VPNs are not threatened by Internet traffic.

When possible, use several of the following techniques:

- Multiple layers of filtering
- Anti-spoofing
- SSH
- Intrusion detection
- Multi-virus scanning
- Rate-limiting
- Route filtering within a VPN
- Limiting numbers of routes within a VPN
- Route dampening
- MD5 authentication for routing protocols
- Physical separation of Internet and VPN routes

In any case, the provider should assure invisibility of edge and core to the Internet, as well to the VPN networks. As specified in RFC2547 (and as discussed in draft-behringer-mpls-security-07.txt) MPLS network guarantees:

- Address space, Routing and Traffic separation
- Invisible SP core
- Resistance to attacks

MPLS network does not address basic security concerns such as securing network elements against:

- Misconfigured Core
- Internal core attacks
- External core attacks
- Attacks to VPNs from the same VPNs
- Unauthorized access

Thus, additional security measurements as mentioned above should be considered.

The following drafts, which discuss additional security methods, are in progress:

- http://www.ietf.org/internet-drafts/draft-ietf-ppvpn-ipsec-2547-02.txt

Scalability Considerations

Internet gateway must be correctly sized to handle the Internet Routing Table.

Provider edge routers must be correctly sized to support numbers of sites connected to a PE.

References

http://www.cisco.com/go/mpls

http://www.cisco.com/go/security

http://www.ietf.org/internet-drafts/draft-ietf-ppvpn-ipsec-2547-02.txt

Book "MPLS and VPN Architectures" releases by Cisco Press.

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