CISCO VALIDATED DESIGN

Intelligent WAN Deployment Guide

September 2017

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Deploying the Cisco Intelligent WAN

This guide focuses on how to deploy the base Cisco Intelligent WAN (IWAN). The advanced features are covered in the IWAN Advanced Deployment Series of guides.

The advanced guides are as follows:

- IWAN High Availability and Scalability Deployment Guide
- IWAN Multiple Data Center Deployment Guide
- IWAN Multiple Transports Deployment Guide
- IWAN Multiple VRF Deployment Guide
- IWAN Public Key Infrastructure Deployment Guide
- IWAN NetFlow Monitoring Deployment Guide
- IWAN Remote Site 4G LTE Deployment Guide

For design details, see Intelligent WAN Design Summary. For configuration details, see Intelligent WAN Configuration Files Guide.

For an automated way to deploy IWAN, use the APIC-EM IWAN Application. For more information, see the Cisco IWAN Application on APIC-EM User Guide.

If want to use TrustSec with your IWAN deployment, see "Configuring SGT Propagation" in the User-to-Data-Center Access Control Using TrustSec Deployment Guide.

DEPLOYMENT DETAILS

How to Read Commands

This guide uses the following conventions for commands that you enter at the command-line interface (CLI).

Commands to enter at a CLI prompt:

```
configure terminal
```

Commands that specify a value for a variable:

```
ntp server 10.10.48.17
```

Commands with variables that you must define:

```
class-map [highest class name]
```

Commands at a CLI or script prompt:

```
Router# enable
```

Long commands that line wrap are underlined. Enter them as one command:

```
police rate 10000 pps burst 10000
packets conform-action
```

Noteworthy parts of system output (or of device configuration files) are highlighted:

```
interface Vlan64
  ip address 10.5.204.5 255.255.255.0
```

Design Parameters

The procedures in this section provide examples for most settings. The actual settings and values that you use are determined by your current network configuration.

This deployment guide uses certain standard design parameters and references various network infrastructure services that are not located within the WAN. These parameters are listed in the following table.

Table 1 *Universal design parameters*

Network service	IP address
Domain name	cisco.local
Active Directory, DNS server, DHCP server	10.4.48.10
Cisco Secure Access Control System (ACS)	10.4.48.15
Network Time Protocol (NTP) server	10.4.48.17

PROCESS

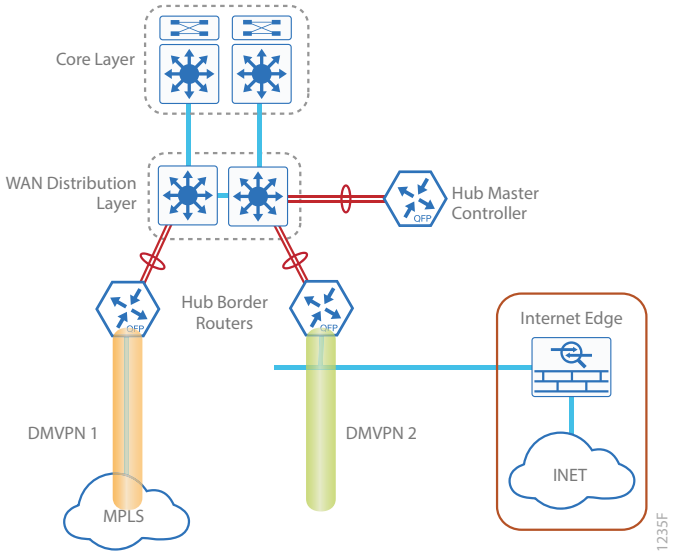
Configuring DMVPN Hub Router

1. Configure the distribution switch
2. Configure the routing protocol on the distribution switch
3. Configure the WAN aggregation platform
4. Configure IP multicast routing
5. Configure connectivity to the LAN
6. Configure the routing protocol on the LAN
7. Configure the WAN-facing VRF
8. Connect to the MPLS WAN or Internet
9. Configure IKEv2 and IPsec
10. Configure the mGRE tunnel
11. Configure the routing protocol on the WAN

Use this process for the IWAN hybrid design model and repeat it for each DMVPN hub router. This process can also be used for a dual Internet or dual MPLS design by changing the underlying transports.

The diagram below shows the hub location of the IWAN hybrid design model with a primary border router for the MPLS transport and a secondary border router for the Internet transport.

Figure 1 *IWAN hybrid design model: Hub location*



Reader Tip

If you plan to deploy Cisco Wide Area Application Services in the future, all hub routers must be the same product model, like the routers listed in the table below.

Table 2 *DMVPN hub router IP addresses*

DMVPN cloud	Hostname	Loopback IP address	Port channel IP address
Hybrid—Primary WAN	HY-MPLS1-ASR1002X-1	10.6.32.241/32	10.6.32.2/30
Hybrid—Secondary WAN	HY-INET1-ASR1002X-2	10.6.32.242/32	10.6.32.6/30

Reader Tip

Whenever IWAN is designed with WAAS leveraging AppNav, please ensure that the Loopback IP address that is being used for PfR is not also used as the AppNav Service Controller address. This is applicable for any Hub IWAN router that is part of an AppNav Cluster.

Procedure 1 Configure the distribution switch

Reader Tip

This process assumes that the distribution switch has already been configured following the guidance in the Campus LAN Layer 2 Access with Simplified Distribution Deployment Guide. Only the procedures required to support the integration of the WAN aggregation router into the deployment are included.

The LAN distribution switch is the path to the organization's main campus and data center. A Layer 3 port-channel interface connects to the distribution switch to the WAN aggregation router and the internal routing protocol peers across this interface.

Tech Tip

As a best practice, use the same channel numbering on both sides of the link where possible.

Step 1: Configure the Layer 3 port-channel interface and assign the IP address.

```
interface Port-channel1
 description HY-MPLS1-ASR1002X-1
 no switchport
 ip address 10.6.32.1 255.255.255.252
 ip pim sparse-mode
 load-interval 30
 no shutdown
```

Step 2: Configure EtherChannel member interfaces.

Configure the physical interfaces to tie to the logical port-channel using the **channel-group** command. The number for the port-channel and channel-group must match. Not all router platforms can support link aggregation control protocol (LACP) in order to negotiate with the switch, so to keep the design consistent across the network, EtherChannel is configured statically, which also reduces startup times.

Also apply the egress QoS macro that was defined in the platform configuration procedure in order to ensure traffic is prioritized appropriately.

```
interface GigabitEthernet1/0/1
 description HY-MPLS1-ASR1002X-1 Gig0/0/0

interface GigabitEthernet2/0/1
 description HY-MPLS1-ASR1002X-1 Gig0/0/1

interface range GigabitEthernet1/0/1, GigabitEthernet2/0/1
  no switchport
  channel-group 1 mode on
  logging event link-status
  logging event trunk-status
  logging event bundle-status
  load-interval 30
  no shutdown
  macro apply EgressQoS
```

Procedure 2 Configure the routing protocol on the distribution switch

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the LAN

Step 1: Allow EIGRP to form neighbor relationships across the port channel interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Port-channel1
   no passive-interface
   authentication mode md5
   authentication key-chain LAN-KEY
  exit-af-interface
 exit-address-family
```

Step 2: If you had previously configured EIGRP stub routing on your WAN distribution switch, disable the feature.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
 no eigrp stub
 exit-address-family
```

Step 3: On the distribution layer switch, configure the Layer 3 interface connected to the LAN core to summarize the WAN network ranges.

Tech Tip

It is a best practice to summarize IP routes from the WAN distribution layer towards the core.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Port-channel38
   summary-address 10.6.32.0 255.255.240.0
   summary-address 10.7.0.0 255.255.0.0
   summary-address 10.255.240.0 255.255.248.0
  exit-af-interface
 exit-address-family
```

Option 2: OSPF on the LAN

Step 1: Configure OSPF Area 0 by using the network summary address and the loopback interface IP address as the router-id.

```
router ospf 100
 router-id 10.6.32.240
 network 10.6.0.0 0.1.255.255 area 0
```

Step 2: Turn on passive-interface as the default and remove it for the LAN interfaces associated with the Hub MC and Hub BRs.

```
router ospf 100
 passive-interface default
 no passive-interface Vlan350
 no passive-interface Port-channel1
 no passive-interface Port-channel2
```

Procedure 3 Configure the WAN aggregation platform

Within this design, there are features and services that are common across all WAN aggregation routers. These are system settings that simplify and secure the management of the solution.

To complete the base configuration for this router, follow the steps in “Configure the platform base features” in Appendix B.

Procedure 4 Configure IP multicast routing

Optional

This optional procedure includes additional steps for configuring IP Multicast on a router. Skip this procedure if you do not want to use IP Multicast in your environment.

In this design, which is based on sparse mode multicast operation, Auto RP is used to provide a simple yet scalable way to provide a highly resilient RP environment.

Step 1: Enable IP Multicast routing on the platform in the global configuration mode.

```
ip multicast-routing
```

Step 2: The Cisco ASR1000 series and ISR4000 series routers require the **distributed** keyword.

```
ip multicast-routing distributed
```

Step 3: Configure every Layer 3 switch and router to discover the IP Multicast RP with autorp. Use the **ip pim autorp listener** command to allow for discovery across sparse mode links. This configuration provides for future scaling and control of the IP Multicast environment and can change based on network needs and design.

```
ip pim autorp listener
```

Step 4: Enable sparse mode multicast operation.

```
ip pim sparse-mode
```

Procedure 5 Configure connectivity to the LAN

Any links to adjacent distribution layers should be Layer 3 links or Layer 3 EtherChannels.

Step 1: Enable QoS support for port-channel interfaces.

```
platform qos port-channel-aggregate 1
```

Tech Tip

This only applies to ASR1000 routers. If there is a requirement to configure QoS on the port-channel interface, make sure to enable platform support before you create the port-channel interface on the router.

```
platform qos port-channel-aggregate [port-channel number]
```

If you apply this command globally for an existing port-channel-interface that already has been configured, you will receive an error:

```
"Port-channel 1 has been configured with non-aggregate mode already, please use
different interface number that port-channel interface hasn't been configured"
```

If you need to apply a QoS policy to an existing port-channel interface, you must first delete the existing port-channel interface and configure platform support for that port-channel interface number.

Step 2: Configure Layer 3 port-channel interface.

```
interface Port-channel1
  ip address 10.6.32.2 255.255.255.252
  ip pim sparse-mode
  no shutdown
```

Step 3: Configure EtherChannel member interfaces.

Configure the physical interfaces to tie to the logical port-channel using the channel-group command. The number for the port-channel and channel-group must match.

```
interface GigabitEthernet0/0/0
 description IW-WAN-D3750X Gig1/0/1

interface GigabitEthernet0/0/1
 description IW-WAN-D3750X Gig2/0/1

interface range GigabitEthernet0/0/0, GigabitEthernet0/0/1
  no ip address
  channel-group 1
  cdp enable
  no shutdown
```

Procedure 6 Configure the routing protocol on the LAN

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the LAN

The following table shows the EIGRP LAN delay in use.

Table 3 EIGRP LAN delay for IWAN hub routers

LAN Interface	EIGRP LAN Delay (10 usec)
All LAN	50000

Step 1: Configure IP unicast routing authentication key.

```
key chain LAN-KEY
 key 1
   key-string c1sco123
```

Step 2: Configure IP unicast routing using EIGRP named mode.

EIGRP is configured facing the LAN distribution or core layer. In this design, the port-channel interface and the loopback must be EIGRP interfaces. The loopback may remain a passive interface. Passive interfaces are used to prevent accidental peering and to reduce the EIGRP traffic on a network segment. The network range must include both interface IP addresses, either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface default
   passive-interface
  exit-af-interface
 network 10.6.0.0 0.1.255.255
 eigrp router-id 10.6.32.241
 nsf
 exit-address-family
```

Step 3: Configure the EIGRP interface.

Allow EIGRP to form neighbor relationships across the interface to establish peering adjacencies and exchange route tables. In this step, you configure EIGRP authentication by using the authentication key specified in the previous procedure.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Port-channel1
   no passive-interface
   authentication mode md5
   authentication key-chain LAN-KEY
  exit-af-interface
 exit-address-family
```

Step 4: At the hub location where there are multiple border routers, the interface throughput delay setting should be set to influence the EIGRP routing protocol path preference.

Tech Tip

If you are using Port-channel interfaces with two Gigabit Ethernet members as recommended in this guide, you will have to double the LAN path delay to 500000 microseconds (usec), instead of the standard IWAN setting of 250000.

Set the internal LAN path to 500000 microseconds (usec). The delay command is entered in 10 usec units.

```
interface Port-channel1
  delay 50000
```

Option 2: OSPF on the LAN

Step 1: Configure OSPF Area 0 by using the network summary address and the loopback interface IP address as the router-id.

```
router ospf 100
 router-id 10.6.32.241
 network 10.6.0.0 0.1.255.255 area 0
```

Step 2: Turn on passive-interface as the default and remove it for the LAN interface.

```
router ospf 100
 passive-interface default
 no passive-interface Port-channel1
```

Procedure 7 Configure the WAN-facing VRF

Next, you create a WAN-facing VRF in order to support FVRF for DMVPN. The VRF name is arbitrary but it is useful to select a name that describes the VRF. The VRF must be enabled for IPv4.

Table 4 VRF assignments

IWAN design	Primary WAN VRF	Secondary WAN VRF
Hybrid	IWAN-TRANSPORT-1	IWAN-TRANSPORT-2

This design uses VRF Lite, so the selection is only locally significant to the device. It is a best practice to use the same VRF/RD combination across multiple devices when using VRFs in a similar manner. However, this convention is not strictly required.

Step 1: Configure the primary WAN VRF.

Example: Primary WAN in IWAN hybrid design model

```
vrf definition IWAN-TRANSPORT-1
 address-family ipv4
```

Procedure 8 Connect to the MPLS WAN or Internet

Each IWAN DMVPN hub requires a connection to the WAN transport, which is either MPLS or Internet.

If you are using MPLS in this design, the DMVPN hub is connected to the service provider's MPLS PE router. The IP addressing used between IWAN CE and MPLS PE routers must be negotiated with your MPLS carrier.

If you are using the Internet in this design, the DMVPN hub is connected through a Cisco Adaptive Security Appliance (ASA) 5500 using a DMZ interface specifically created and configured for a VPN termination router.

The IP address that you use for the Internet-facing interface of the DMVPN hub router must be an Internet-routable address. There are two possible methods for accomplishing this task:

- Assign a routable IP address directly to the router.
- Assign a non-routable RFC-1918 address directly to the router and use a static NAT on the Cisco ASA 5500 to translate the router IP address to a routable IP address.

This design assumes that the Cisco ASA 5500 is configured for static NAT for the DMVPN hub router.

Option 1: MPLS WAN physical WAN interface

The DMVPN design is using FVRF, so you must place the WAN interface into the VRF configured in the previous procedure.

Step 1: Enable the interface, give it a description, select the VRF, and assign the IP address.

The physical interface bandwidth setting should be set to match the bandwidth of the respective transport, which should correspond to the actual interface speed or, if you are using a subrate service, use the policed rate from the carrier.

Configure **hold-queue in** and **hold-queue out** with a queue length of 4096 to avoid drops above and beyond the QoS policy drops.

```
interface GigabitEthernet0/0/3
 description MPLS1
 bandwidth 600000
 vrf forwarding IWAN-TRANSPORT-1
 ip address 192.168.6.1 255.255.255.252
 hold-queue 4096 in
 hold-queue 4096 out
 no shutdown
```

Step 2: Configure the VRF-specific default routing.

The VRF created for FVRF must have its own default route to the MPLS. This default route points to the MPLS PE router's IP address and is used by DMVPN for tunnel establishment.

```
ip route vrf IWAN-TRANSPORT-1 0.0.0.0 0.0.0.0 192.168.6.2
```

Option 2: Internet WAN physical WAN interface

The DMVPN design is using FVRF, so you must place the WAN interface into the VRF configured the previous procedure.

Step 1: Enable the interface, give it a description, select the VRF, and assign the IP address.

The physical interface bandwidth setting should be set to match the bandwidth of the respective transport, which should correspond to the actual interface speed or, if you are using a subrate service, use the policed rate from the carrier.

Configure **hold-queue in** and **hold-queue out** with a queue length of 4096 to avoid drops above and beyond the QoS policy drops.

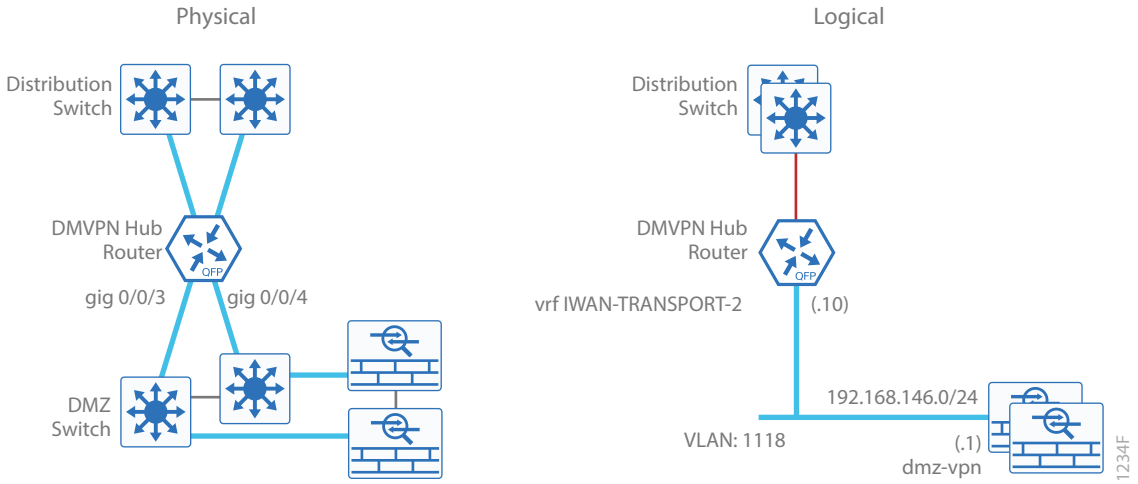
```
interface GigabitEthernet0/0/3
 description INET1
 bandwidth 900000
 vrf forwarding IWAN-TRANSPORT-2
 ip address 192.168.146.10 255.255.255.0
 hold-queue 4096 in
 hold-queue 4096 out
 no shutdown
```

Step 2: Configure the VRF-specific default routing.

The VRF created for FVRF must have its own default route to the Internet. This default route points to the Cisco ASA 5500's DMZ interface IP address.

```
ip route vrf IWAN-TRANSPORT-2 0.0.0.0 0.0.0.0 192.168.146.1
```

Figure 2 *Physical and logical views for DMZ connection*



Procedure 9 Configure IKEv2 and IPsec

To complete the IKEv2 and IPsec configuration for this router, follow the steps in "Configure IKEv2 and IPsec for a DMVPN border router" in Appendix B.

Procedure 10 Configure the mGRE tunnel

The parameters in the table below are used in this procedure. This procedure applies to the primary WAN hub router in the IWAN hybrid design model.

Table 5 DMVPN tunnel parameters

DMVPN cloud	Tunnel VRF	Tunnel number	Tunnel IP address	NHRP network ID/ tunnel key
Hybrid–Primary WAN	IWAN-TRANSPORT-1	100	10.6.34.1/23	1100
Hybrid–Secondary WAN	IWAN-TRANSPORT-2	200	10.6.36.1/23	1200

Step 1: Configure the basic interface settings.

The tunnel number is arbitrary, but it is best to begin tunnel numbering at 10 or above, because other features deployed in this design may also require tunnels and they may select lower numbers by default.

The tunnel interface bandwidth setting should be set to match the bandwidth of the respective transport, which should correspond to the actual interface speed or, if you are using a subrate service, use the policed rate from the carrier.

Configure the **ip mtu** to 1400 and the **ip tcp adjust-mss** to 1360. There is a 40 byte difference that corresponds to the combined IP and TCP header length.

Tech Tip

An IPv6 underlay requires an **ip mtu** of 1380 and an **ip tcp adjust-mss** of 1340.

Configure **hold-queue in** and **hold-queue out** with a queue length of 4096 to avoid drops above and beyond the QoS policy drops.

```
interface Tunnel100
 description MPLS1
 bandwidth 600000
 ip address 10.6.34.1 255.255.254.0
 no ip redirects
 ip mtu 1400
 ip tcp adjust-mss 1360
 hold-queue 4096 in
 hold-queue 4096 out
```

Step 2: Configure the tunnel.

DMVPN uses mGRE tunnels. This type of tunnel requires a source interface only. Use the same source interface that you use to connect to the MPLS or Internet. Set the **tunnel vrf** command to the VRF defined previously for FVRF.

Enabling encryption on this interface requires that you apply the IPsec profile configured in the previous procedure.

```
interface Tunnel100
 tunnel source GigabitEthernet0/0/3
 tunnel mode gre multipoint
 tunnel key 1100
 tunnel vrf IWAN-TRANSPORT-1
 tunnel protection ipsec profile DMVPN-IPSEC-PROFILE
```

Step 3: Configure NHRP.

The DMVPN hub router acts in the role of NHRP server for all of the spokes. NHRP is used by remote routers to determine the tunnel destinations for peers attached to the mGRE tunnel. NHRP requires all devices within a DMVPN cloud to use the same network ID and authentication key. The routing protocol relies on a multicast transport and requires that NHRP automatically add routers to the multicast NHRP mappings.

The **ip nhrp redirect** command allows the DMVPN hub to notify spoke routers that a more optimal path may exist to a destination network, which may be required for DMVPN spoke-spoke direct communications.

```
interface Tunnel100
 ip nhrp authentication cisco123
 ip nhrp map multicast dynamic
 ip nhrp server-only
 ip nhrp network-id 1100
 ip nhrp redirect
```

Step 4: (Optional) Enable PIM non-broadcast multiple access (NBMA) mode for the DMVPN tunnel.

Spoke-to-spoke DMVPN networks present a unique challenge because the spokes cannot directly exchange information with one another, even though they are on the same logical network. This inability to directly exchange information can also cause problems when running IP Multicast.

To resolve this issue requires a method where each remote PIM neighbor has its join messages tracked separately. A router in PIM NBMA mode treats each remote PIM neighbor as if it were connected to the router through a point-to-point link.

Tech Tip

Do not enable PIM on the Internet DMZ interface, as no multicast traffic should be requested from this interface.

```
interface Tunnel100
 ip pim nbma-mode
```

Procedure 11 Configure the routing protocol on the WAN

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

The following table shows the DMVPN tunnel names and EIGRP WAN delay in use.

Table 6 EIGRP WAN delay for IWAN hybrid hub routers

DMVPN Tunnel	EIGRP WAN Delay (10 usec)
Tunnel100	1000 (MPLS1)
Tunnel200	2000 (INET1)

Step 1: Configure the EIGRP values for the mGRE tunnel interface.

Spoke-to-spoke DMVPN networks present a unique challenge because the spokes cannot directly exchange information with one another, even though they are on the same logical network. This limitation requires that the DMVPN hub router advertise routes from other spokes on the same network. This advertisement of these routes would normally be prevented by split horizon and can be overridden by the **no split-horizon** command.

The EIGRP hello interval is increased to 20 seconds and the EIGRP hold time is increased to 60 seconds in order to accommodate up to 2000 remote sites on a single DMVPN cloud. Increasing the EIGRP timers also slows down the routing convergence to improve network stability and the IWAN design allows PfR to initiate the fast failover, so changing the timers is recommended for all IWAN deployments.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel100
   hello-interval 20
   hold-time 60
   no passive-interface
   no split-horizon
  exit-af-interface
 exit-address-family
```

Step 2: Configure EIGRP neighbor authentication.

Neighbor authentication enables the secure establishment of peering adjacencies and exchange route tables over the DMVPN tunnel interface.

```
key chain WAN-KEY
 key 1
  key-string c1sco123

router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel100
   authentication mode md5
   authentication key-chain WAN-KEY
  exit-af-interface
 exit-address-family
```

Step 3: Configure EIGRP network summarization.

The IP assignments for the entire network were designed so they can be summarized within a few aggregate routes. As configured below, the **summary-address** command suppresses the more specific routes. If any network within the summary is present in the route table, the summary is advertised to the remote sites, which offers a measure of resiliency. If the various networks cannot be summarized, then EIGRP continues to advertise the specific routes.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel100
   summary-address 10.6.0.0 255.255.0.0
   summary-address 10.7.0.0 255.255.0.0
   summary-address 10.255.240.0 255.255.248.0
  exit-af-interface
```

Step 4: Configure EIGRP summary metrics.

If there are many component routes to be summarized and the component routes are frequently updated, the metrics are also updated frequently, which may cause a spike in CPU usage. The **summary-metric** command explicitly sets the metric for the summary regardless of the component route metric, which reduces the computational load on a router.

The first value is the bandwidth metric in Kbits per second. The second value is the delay metric in 10 usecs. The third value is the reliability metric where 255 is 100% reliable. The fourth value is the effective bandwidth metric (loading) where 255 is 100% loaded. The fifth value is the MTU of the path.

Tech Tip

EIGRP uses the path's minimum bandwidth as part of the metric calculation. The path's minimum bandwidth is defined in a route advertisement in the minimum bandwidth path attribute. Setting the summary metric bandwidth (first value) to 10 Mbps essentially removes the ability to differentiate between a 10 Mbps tunnel (MPLS1) and a 100 Mbps circuit (INET1) because both paths have a minimum bandwidth of 10 Mbps. Setting the summary metric bandwidth to 10 Gbps as recommended in this guide allows the calculations on the branch router to differentiate tunnel bandwidth, regardless of the size of each path.

Use the identical values for each summary address defined in the previous step.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   summary-metric 10.6.0.0/16 10000000 10000 255 1 1500
   summary-metric 10.7.0.0/16 10000000 10000 255 1 1500
   summary-metric 10.255.240.0/21 10000000 10000 255 1 1500
  exit-af-topology
```

Step 5: Configure the throughput delay on the tunnel interface.

The tunnel interface throughput delay setting should be set to influence the EIGRP routing protocol path preference. Set the primary WAN path to 10000 usec and the secondary WAN path to 20000 usec to prefer one over the other. The delay command is entered in 10 usec units.

```
interface Tunnel100
  delay 1000
```

Step 6: Proceed to "Configuring the Firewall and DMZ Switch."

Option 2: BGP on the WAN

The following table shows the tunnel DMVPN IP subnets and metrics in use.

Table 7 DMVPN tunnel subnets and metrics

DMVPN hub router	DMVPN Tunnels	OSPF Metric
HY-MPLS1-ASR1002X-1	10.6.34.0/23	1000
HY-INET1-ASR1002X-2	10.6.36.0/23	1200

Step 1: Configure BGP values for the tunnel interface.

Use a private AS number for the BGP process. Assign this router's loopback address as the BGP router-id. Log the neighbor changes. Create a listen range that includes the subnet range of the tunnel interface. For internal BPG, use the same AS number for the remote sites. Create the route reflector and use the tunnel as the update source interface. Adjust the BGP hello and hold timers to 20 seconds and 60 seconds, respectively.

```
router bgp 65100
 bgp router-id 10.6.32.241
 bgp log-neighbor-changes
 bgp listen range 10.6.34.0/23 peer-group MPLS1-SPOKES
 neighbor MPLS1-SPOKES peer-group
 neighbor MPLS1-SPOKES remote-as 65100
 neighbor MPLS1-SPOKES description MPLS1 Spoke Route Reflector
 neighbor MPLS1-SPOKES update-source Tunnel100
 neighbor MPLS1-SPOKES timers 20 60
```

Step 2: Create the static null routes for the enterprise summary prefix and the site-specific prefixes.

```
ip route 10.4.0.0 255.252.0.0 Null0 254
ip route 10.6.0.0 255.255.0.0 Null0 254
ip route 10.4.0.0 255.255.0.0 Null0 254
```

Step 3: Configure the BGP address family.

Define the network statements for the default network, the enterprise summary prefix, the site-specific prefixes and the local MC loopback IP address the router will advertise to the remote sites. Configure BGP dynamic neighbors for the remote sites. Set the BGP distance and redistribute the internal networks.

Tech Tip

The syntax for the **distance bgp** command is as follows:

distance bgp *external-distance internal-distance local-distance*

external-distance—Administrative distance for BGP external routes. External routes are routes for which the best path is learned from a neighbor external to the autonomous system. Accept table values are from 1 to 255. The default is 20. Routes with a distance of 255 are not installed in the routing table.

internal-distance—Administrative distance for BGP internal routes. Internal routes are those routes that are learned from another BGP entity within the same autonomous system. Accept table values are from 1 to 255. The default is 200. Routes with a distance of 255 are not installed in the routing table.

local-distance—Administrative distance for BGP local routes. Local routes are those networks listed with a network router configuration command, often as back doors, for that router or for networks that are being redistributed from another process. Accept table values are from 1 to 255. The default is 200. Routes with a distance of 255 are not installed in the routing table.

```
router bgp 65100
 address-family ipv4
  bgp redistribute-internal
  network 0.0.0.0
  network 10.4.0.0 mask 255.252.0.0
  network 10.4.0.0 mask 255.255.0.0
  network 10.6.0.0 mask 255.255.0.0
  network 10.6.32.251 mask 255.255.255.255
  neighbor MPLS1-SPOKES activate
  neighbor MPLS1-SPOKES route-reflector-client
  neighbor MPLS1-SPOKES next-hop-self all
  neighbor MPLS1-SPOKES weight 50000
  neighbor MPLS1-SPOKES soft-reconfiguration inbound
  distance bgp 201 19 200
 exit-address-family
```

Step 4: Create the prefix lists for BGP.

Define the prefix-lists for the default network, the enterprise summary prefix, the site-specific prefixes, the local MC loopback IP address, and the subnet ranges for the DMVPN tunnels.

```
ip prefix-list DEFAULT-ROUTE seq 10 permit 0.0.0.0/0
ip prefix-list ENTERPRISE-PREFIX seq 10 permit 10.4.0.0/14
ip prefix-list LOCALDC-PREFIX seq 10 permit 10.4.0.0/16
ip prefix-list LOCALDC-PREFIX seq 20 permit 10.6.0.0/16
ip prefix-list LOCALMCLOOPBACK seq 10 permit 10.6.32.251/32
ip prefix-list TUNNEL-DMVPN seq 10 permit 10.6.34.0/23
```

Step 5: Create and apply the prefix route maps for BGP.

Define the route map to block prefixes inbound on the tunnel interface. Define the route map to allow prefixes to go out on the tunnel interface. Apply the route maps to the BGP address family. Configure BGP to display communities in the format AA:NN.

Example: MPLS hub border router—HY-MPLS1-ASR1002X-1

```
route-map MPLS1-IN deny 10
 description All Blocked Prefixes to come IN on BGP
 match ip address prefix-list DEFAULT-ROUTE ENTERPRISE-PREFIX LOCALDC-PREFIX LOCALMCLOOPBACK TUNNEL-DMVPN


route-map MPLS1-IN permit 1000
```

```
 description Allow Everything Else

route-map MPLS1-OUT permit 10
 description All Allowed Prefixes to Go OUT on BGP to Spokes
 match ip address prefix-list DEFAULT-ROUTE ENTERPRISE-PREFIX LOCALDC-PREFIX LOCALMCLOOPBACK

router bgp 65100
 address-family ipv4
  neighbor MPLS1-SPOKES route-map MPLS1-IN in
  neighbor MPLS1-SPOKES route-map MPLS1-OUT out
exit-address-family
```

Example: INET hub border router—HY-INET1-ASR1002X-2

```
route-map INET1-IN deny 10
 description All Blocked Prefixes to come IN on BGP
 match ip address prefix-list DEFAULT-ROUTE ENTERPRISE-PREFIX LOCALDC-PREFIX LOCALMCLOOPBACK TUNNEL-DMVPN

route-map INET1-IN permit 1000
 description Allow Everything Else

route-map INET1-OUT permit 10
 description All Allowed Prefixes to Go OUT on BGP to Spokes
 match ip address prefix-list DEFAULT-ROUTE ENTERPRISE-PREFIX LOCALDC-PREFIX LOCALMCLOOPBACK

router bgp 65100
 address-family ipv4
  neighbor INET1-SPOKES route-map INET1-IN in
  neighbor INET1-SPOKES route-map INET1-OUT out
exit-address-family
```

Step 6: Create and apply the BGP to OSPF redistribution route map for OSPF.

Define the route map to block null routes from being distributed into OSPF. Set the metric to the appropriate value for this DMVPN hub router. Apply the route map to the OSPF process.

Example: MPLS hub border router—HY-MPLS1-ASR1002X-1

```
route-map REDIST-BGP-TO-OSPF deny 20
 description Block Null routes to be distributed from BGP to OSPF
 match ip address prefix-list DEFAULT-ROUTE ENTERPRISE-PREFIX LOCALDC-PREFIX

route-map REDIST-BGP-TO-OSPF permit 1000
 description Set metric on all routes
 set metric 1000
 set metric-type type-1

router ospf 100
 redistribute bgp 65100 subnets route-map REDIST-BGP-TO-OSPF
```

Example: INET hub border router—HY-INET1-ASR1002X-2

```
route-map REDIST-BGP-TO-OSPF deny 20
 description Block Null routes to be distributed from BGP to OSPF
 match ip address prefix-list DEFAULT-ROUTE ENTERPRISE-PREFIX LOCALDC-PREFIX

route-map REDIST-BGP-TO-OSPF permit 1000
 description Set metric on all routes
 set metric 1200
 set metric-type type-1

router ospf 100
 redistribute bgp 65100 subnets route-map REDIST-BGP-TO-OSPF
```

PROCESS

Configuring the Firewall and DMZ Switch

1. Configure the DMZ switch for DMVPN hub router
2. Configure firewall DMZ interface
3. Configure network address translation
4. Configure security policy

If necessary, configure the DMZ and firewall for the Internet WAN.

Tech Tip

If the firewall is owned by the service provider, they will have to perform the same procedures and steps to allow DMVPN traffic into their DMZ as described in this process.

To avoid UDP500 session timeouts, the firewall policy must allow the required protocols from the "Firewall policy rules for DMVPN hub routers" table into their DMZ network where the hub BRs are located.

Procedure 1 Configure the DMZ switch for DMVPN hub router

Reader Tip

This procedure assumes that the switch has already been configured following the guidance in the Campus LAN Layer 2 Access with Simplified Distribution Deployment Guide. Only the procedures required to support the integration of the firewall into the deployment are included.

Step 1: Set the DMZ switch to be the spanning tree root for the VLAN that contains the DMVPN hub router.

```
vlan 1118
 name dmz-vpn

spanning-tree vlan 1118 root primary
```

Step 2: Configure the interface that is connected to the DMVPN hub routers. Repeat as necessary.

```
interface GigabitEthernet1/0/1
 description HY-INET1-ASR1002X-2 (gig0/0/3)
 switchport access vlan 1118
 switchport host
 logging event link-status
 load-interval 30
 no shutdown
 macro apply EgressQoS
```

Step 3: Configure the interfaces that are connected to the appliances as a trunk.

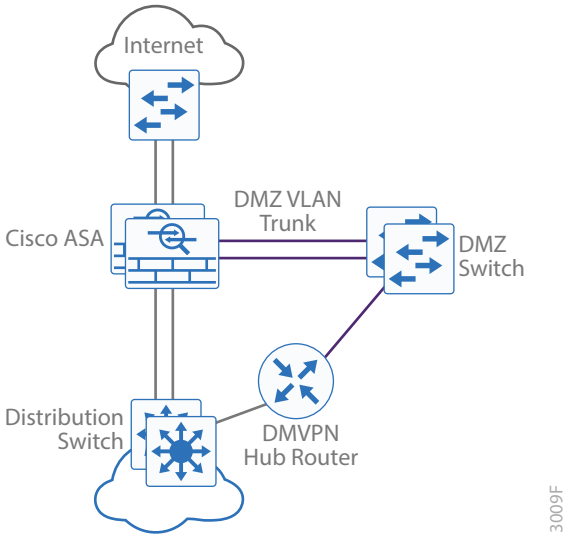
```
interface GigabitEthernet1/0/48
 description IE-ASA5545Xa Gig0/1

interface GigabitEthernet2/0/48
 description IE-ASA5545Xb Gig0/1

interface range GigabitEthernet1/0/48, GigabitEthernet2/0/48
 switchport trunk allowed vlan add 1118
 switchport mode trunk
 logging event link-status
 logging event trunk-status
 load-interval 30
 no shutdown
 macro apply EgressQoS
```

Procedure 2 Configure firewall DMZ interface

The firewall's DMZ is a portion of the network where, typically, traffic to and from other parts of the network is tightly restricted. Organizations place network services in a DMZ for exposure to the Internet. These servers are typically not allowed to initiate connections to the 'inside' network, except for specific circumstances.

The DMZ network is connected to the appliances on the appliances' GigabitEthernet interface via a VLAN trunk to allow the greatest flexibility if new VLANs must be added to connect additional DMZs. The trunk connects the appliances to a 2960X access-switch stack to provide resiliency. The DMZ VLAN interfaces on the Cisco ASA are each assigned an IP address, which will be the default gateway for each of the VLAN subnets. The DMZ switch only offers Layer 2 switching capability; the DMZ switch's VLAN interfaces do not have an IP address assigned, save for one VLAN interface with an IP address for management of the switch.

Figure 3 *DMZ VLAN topology and services*



Tech Tip

By setting the DMZ connectivity as a VLAN trunk, you get the greatest flexibility.

Step 1: In **Configuration > Device Setup > Interfaces**, click the interface that is connected to the DMZ switch. (Example: GigabitEthernet0/1)

Step 2: Click **Edit**.

Step 3: Select **Enable Interface**, and then click **OK**.

Step 4: On the Interface pane, click **Add > Interface**.

Step 5: In the **Hardware Port** list choose the interface configured in Step 1. (Example: GigabitEthernet0/1)

Step 6: In the **VLAN ID** box, enter the VLAN number for the DMZ VLAN. (Example: 1118)

Step 7: In the **Subinterface ID** box, enter the VLAN number for the DMZ VLAN. (Example: 1118)

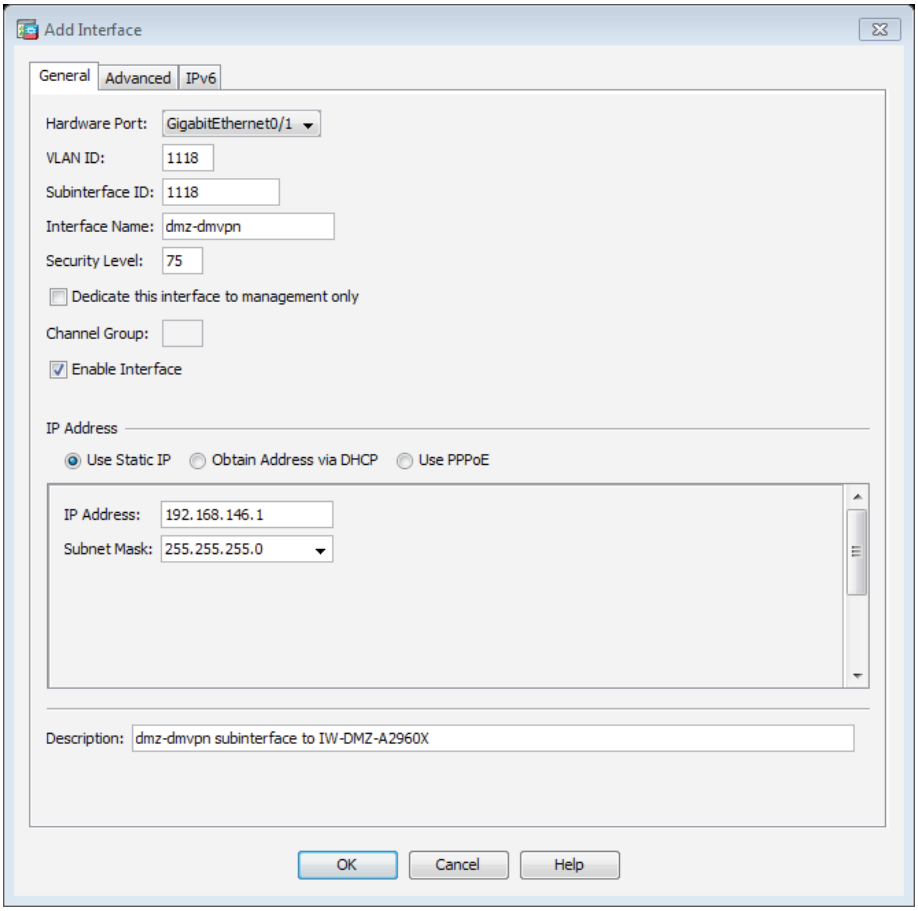
Step 8: Enter an **Interface Name**. (Example: dmz-dmvpn)

Step 9: In the **Security Level** box, enter a value of **75**.

Step 10: Enter the interface **IP Address**. (Example: 192.168.146.1)

Step 11: Enter the interface **Subnet Mask**, and then click **OK**. (Example: 255.255.255.0)

Step 12: Click **Apply**.

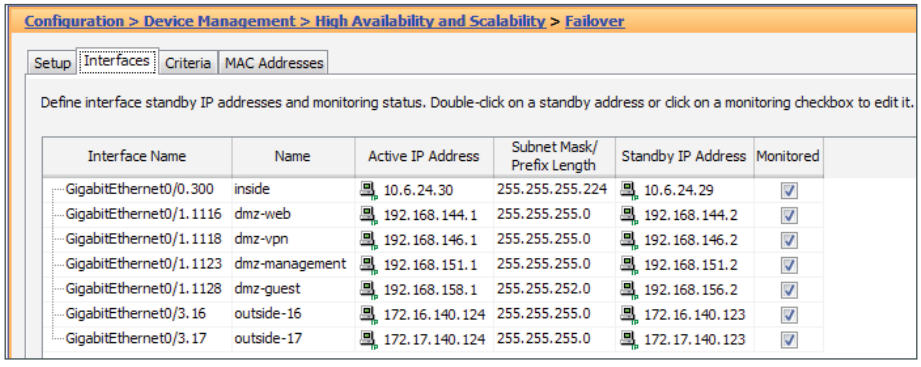


Step 13: In **Configuration > Device Management > High Availability >** click **Failover**.

Step 14: On the **Interfaces** tab, for the interface created in Step 4, enter the IP address of the standby unit in the **Standby IP address** column. (Example: 192.168.146.2)

Step 15: Select **Monitored**.

Step 16: Click **Apply**.



Procedure 3 Configure network address translation

The DMZ network uses private network (RFC 1918) addressing that is not Internet routable, so the firewall must translate the DMZ address of the DMVPN hub router to an outside public address.

The following table shows the example-DMZ-address-to-public-IP-address mapping for the hybrid design.

Table 8 DMVPN NAT address mapping

DMVPN	DMVPN hub router DMZ address	DMVPN hub router public address (externally routable after NAT)
IWAN-TRANSPORT-2	192.168.146.10	172.16.140.1 (ISP-A on hybrid)

First, to simplify the configuration of the security policy, you create the External DMZ network objects that are used in the firewall policies.

Table 9 External DMZ firewall network objects

Network object name	Object type	IP address	Description
outside-dmvpn-2-ISPa	Host	172.16.140.1	DMVPN hub router 2 on ISP A (outside)

Step 1: Navigate to **Configuration > Firewall > Objects > Network Objects/Groups**.

Step 2: Click **Add > Network Object**.

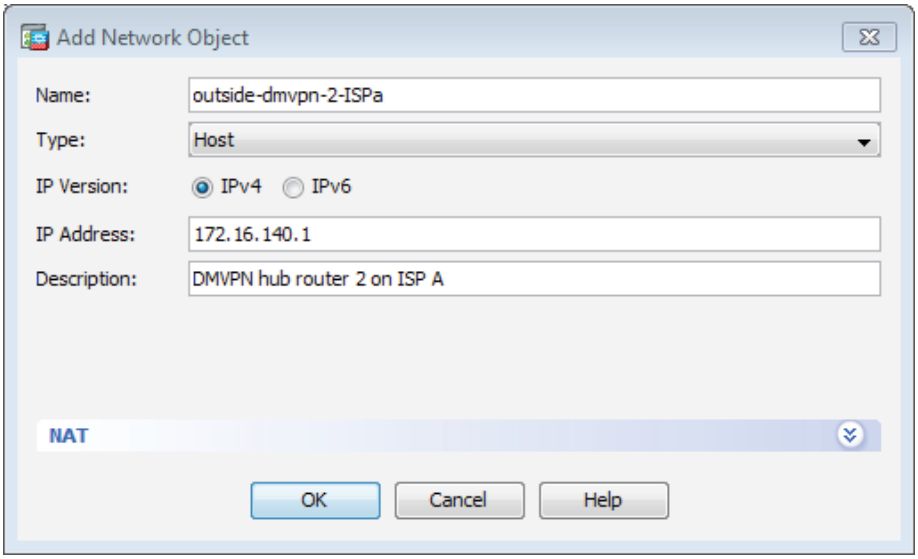
The Add Network Object dialog box appears.

Step 3: In the **Name** box, enter the name. (Example: outside-dmvpn-2-ISPa)

Step 4: In the **Type** list, choose **Host** or **Network**. (Example: Host)

Step 5: In the **IP Address** box, enter the address. (Example: 172.16.140.1)

Step 6: In the **Description** box, enter a useful description, and then click **OK**. (Example: DMVPN hub router 2 on ISP A)



Step 7: Repeat Step 2 through Step 6 for each object listed in the above table. If an object already exists, then skip to the next object listed in the table.

Step 8: After adding all of the objects listed, click **Apply** on the Network Objects/Groups pane.

Next, you add a network object for the private DMZ address of the DMVPN hub router.

Table 10 Private DMZ firewall network objects

Network object name	Object type	IP address	Description
dmz-dmvpn-2	Host	192.168.146.10	DMVPN hub router 2 on vpn-dmz

Step 9: Navigate to **Configuration > Firewall > Objects > Network Objects/Groups**.

Step 10: Click **Add > Network Object**.

The Add Network Object dialog box appears.

Step 11: In the **Name** box, enter the name. (Example: dmz-dmvpn-2)

Step 12: In the **Type** list, choose **Host** or **Network**. (Example: Host)

Step 13: In the **IP Address** box, enter the address. (Example: 192.168.146.10)

Step 14: In the **Description** box, enter a useful description, and then click **OK**. (Example: DMVPN hub router 2 on vpn-dmz)

Step 15: Click the two down arrows. The NAT pane expands.

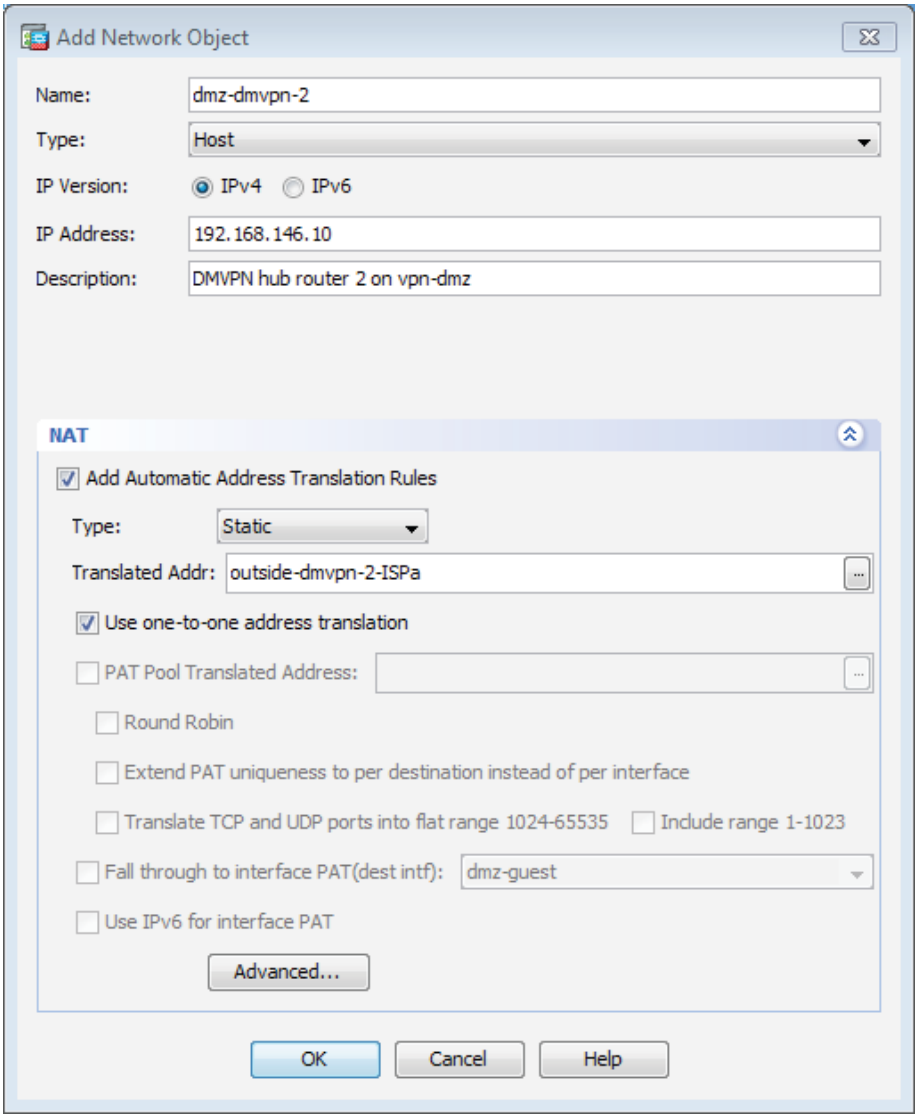
Step 16: Select **Add Automatic Address Translation Rules**.

Step 17: In the **Translated Address** list, choose the network object created previously. (Example: outside-dm-vpn-2-ISPa)

Step 18: Select **Use one-to-one address translation**, and then click **OK**.

Step 19: Repeat Step 10 through Step 18 for each object listed in the above table. If an object already exists, then skip to the next object listed in the table.

Step 20: After adding all of the objects listed, on the Network Objects/Groups pane, click **Apply**.



Procedure 4 Configure security policy

The VPN DMZ provides an additional layer of protection to lower the likelihood of certain types of misconfiguration of the DMVPN routers exposing the business network to the Internet. A filter allows only DMVPN related traffic to reach the DMVPN hub routers from the DMVPN spoke routers on the Internet.

Step 1: Navigate to **Configuration > Firewall > Access Rules**.

Table 11 Firewall policy rules for DMVPN hub routers

Interface	Action	Source	Destination	Service	Description	Logging enable/ level
Any	Permit	any4	dmz-vpn-network	udp/4500	(required) Allow (non500-ISAK-MP) traffic to the DMVPN hub routers	Selected/ Default
Any	Permit	any4	dmz-vpn-network	udp/isakmp	(required) Allow ISAKMP (UDP500) traffic to the DMVPN hub routers	Selected/ Default
Any	Permit	any4	dmz-vpn-network	Esp	(required) Allow ESP IP protocol 50 IPsec traffic to the DMVPN hub routers	Selected/ Default
Any	Permit	any4	dmz-vpn-network	icmp/echo	(optional) Allow remote ping diagnostic traffic [ICMP Type 0, Code 0]	Selected/ Default
Any	Permit	any4	dmz-vpn-network	icmp/echo reply	(optional) Allow remote pings re-ply diagnostic traffic [ICMP Type 8, Code 0]	Selected/ Default
Any	Permit	any4	dmz-vpn-network	icmp/time-exceeded	(optional) ICMP Type 11, Code 0	Selected/ Default
Any	Permit	any4	dmz-vpn-network	icmp/port-unreachable	(optional) ICMP Type 3, Code 3	Selected/ Default
Any	Permit	any4	dmz-vpn-network	>udp/1023	(optional) UDP high ports	Selected/ Default

Step 2: Click the rule that denies traffic from the DMZ toward other networks.

Caution

Be sure to perform this step for *every* rule listed in the previous table. Inserting the rules above the DMZ-to-any rule keeps the added rules in the same order as listed, which is essential for the proper execution of the security policy.

Step 3: Click **Add > Insert**.

The Add Access Rule dialog box appears.

Step 4: In the **Interface** list, choose the interface. (Example: Any)

Step 5: For the **Action** option, select the action. (Example: Permit)

Step 6: In the **Source** box, choose the source. (Example: any4)

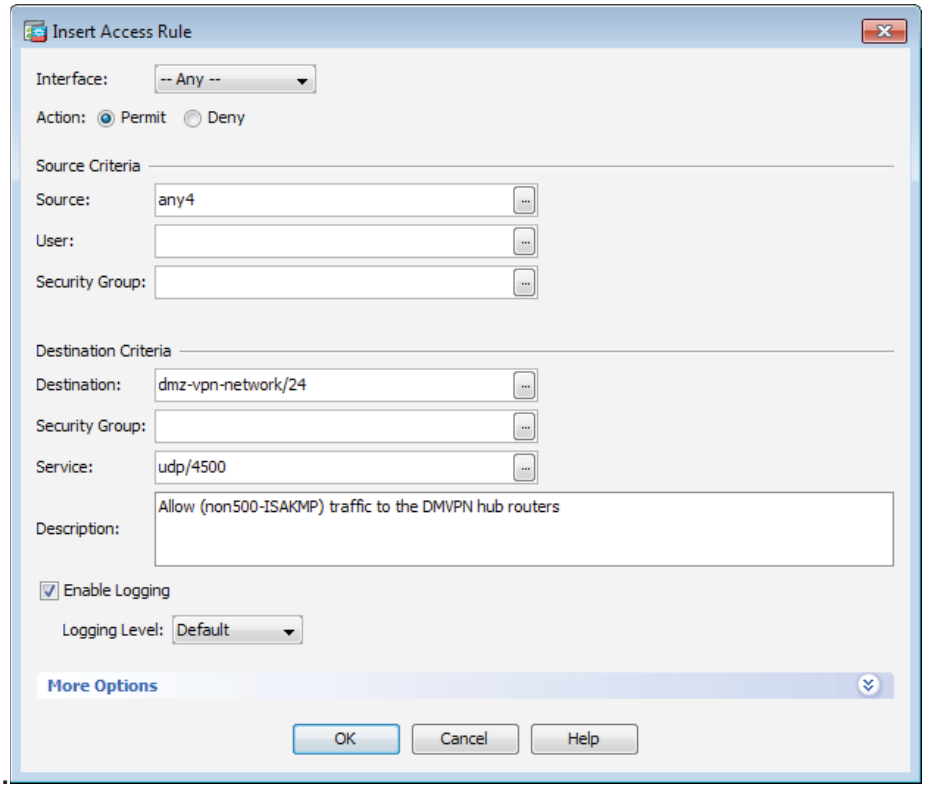
Step 7: In the **Destination** box, choose the destination. (Example: dmz-vpn-network)

Step 8: In the **Service** box, enter the service. (Example: udp/4500)

Step 9: In the **Description** box, enter a useful description. (Example: Allow (non500-ISAKMP) traffic to the DM-VPN hub routers)

Step 10: Select or clear **Enable Logging**. (Example: Selected)

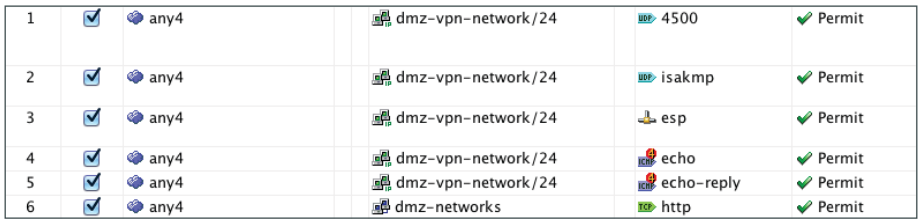
Step 11: In the **Logging Level** list, choose the logging level value, and then click **OK**. (Example: Default)



Step 12: Repeat Step 2 through Step 11 for all rules listed in the above table.

Step 13: After adding all of the rules in the order listed, click **Apply** on the Access Rules pane.

Figure 4 *Firewall rules summary*



PROCESS

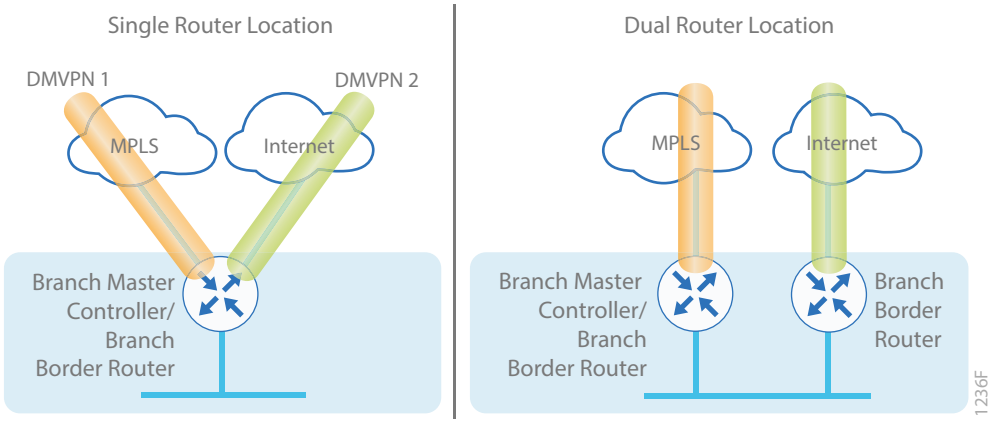
Configuring Remote-Site DMVPN Router

1. Configure the WAN remote site router
2. Configure IP multicast routing
3. Configure the WAN-facing VRF
4. Connect to the MPLS WAN
5. Configure IKEv2 and IPsec
6. Configure the mGRE Tunnel
7. Configure the routing protocol on the WAN
8. Configure IP multicast routing on tunnel
9. Connect router to access layer switch
10. Configure access layer interfaces

The procedures in this process describe configuring a single-router, dual-link design. You also use them when configuring the first router of a dual-router, dual-link design.

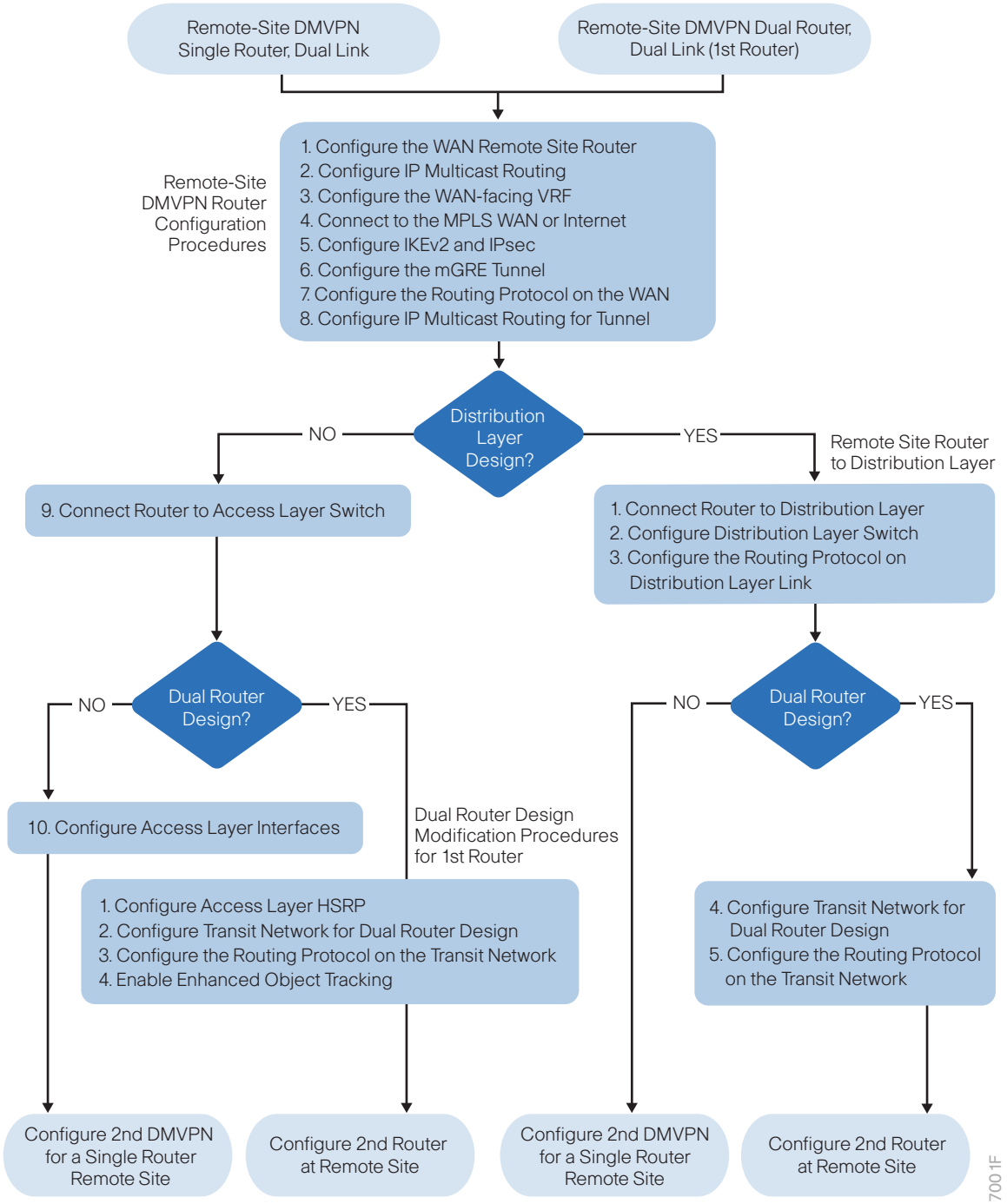
The diagram below shows the remote site options of the IWAN hybrid design model with a single-router and dual-router location.

Figure 5 *IWAN hybrid design model: Remote site locations*



Refer to the following flowchart to help you navigate through the required procedures for your environment.

Figure 6 *Remote-site DMVPN router configuration flowchart*



Procedure 1 Configure the WAN remote site router

Within this design, there are features and services that are common across all WAN remote site routers. These are system settings that simplify and secure the management of the solution.

To complete the base configuration for this router, follow the steps in "Configure the platform base features" in Appendix B.

Step 1: Increase the hold-queue on the loopback interface.

Increase the **hold-queue in** and **hold-queue out** to a queue length of 1024 on the loopback interface to allow the RTP application-table to be properly exported using Flexible Net Flow.

```
interface Loopback0
 hold-queue 1024 in
 hold-queue 1024 out
```

Procedure 2 Configure IP multicast routing

Optional

This optional procedure includes additional steps for configuring IP Multicast on a router. Skip this procedure if you do not want to use IP Multicast in your environment.

In this design, which is based on sparse mode multicast operation, Auto RP is used to provide a simple yet scalable way to provide a highly resilient RP environment.

Step 1: Enable IP Multicast routing on the platform in the global configuration mode.

```
ip multicast-routing
```

Step 2: Every Layer 3 switch and router must be configured to discover the IP Multicast RP with autorp. Use the **ip pim autorp listener** command to allow for discovery across sparse mode links. This configuration provides for future scaling and control of the IP Multicast environment and can change based on network needs and design.

```
ip pim autorp listener
```

Step 3: All Layer 3 interfaces in the network must be enabled for sparse mode multicast operation.

```
ip pim sparse-mode
```

Procedure 3 Configure the WAN-facing VRF

You create a WAN-facing VRF in order to support FVRF for DMVPN. The VRF name is arbitrary, but it is useful to select a name that describes the VRF. The VRF must be enabled for IPv4.

Table 12 VRF assignments

IWAN design model	Primary WAN VRF	Secondary WAN VRF
Hybrid	IWAN-TRANSPORT-1	IWAN-TRANSPORT-2

This design uses VRF Lite, so the selection is only locally significant to the device. It is a best practice to use the same VRF/RD combination across multiple devices when using VRFs in a similar manner. However, this convention is not strictly required.

Step 1: Configure the primary WAN VRF.

Example: Primary WAN in the IWAN hybrid design model

```
vrf definition IWAN-TRANSPORT-1
 address-family ipv4
```

Procedure 4 Connect to the MPLS WAN

The remote sites that are using DMVPN can use either static or dynamically assigned IP addresses. Cisco tested the design with static addresses for MPLS connections and DHCP assigned external addresses for Internet connections, which also provides a dynamically configured default route.

The MPLS DMVPN spoke router is connected to the service provider's MPLS PE router. The IP addressing used between IWAN CE and MPLS PE routers must be negotiated with your MPLS carrier.

The DMVPN design uses FVRF, so you must place this interface into the VRF configured in the previous procedure.

Step 1: Enable the interface, select VRF, and assign the IP address.

Example: Primary WAN in IWAN hybrid design model

```
interface GigabitEthernet0/0
 description MPLS1
 vrf forwarding IWAN-TRANSPORT-1
 ip address 192.168.6.5 255.255.255.252
 no shutdown
```

Do not enable PIM on this interface because no multicast traffic should be requested from this interface.

Step 2: Configure the VRF-specific default routing.

The VRF created for FVRF must have its own default route to the Internet. This default route points to the MPLS PE router's IP address and is used by DMVPN for tunnel establishment.

```
ip route vrf IWAN-TRANSPORT-1 0.0.0.0 0.0.0.0 192.168.6.6
```

Procedure 5 Configure IKEv2 and IPsec

To complete the IKEv2 and IPsec configuration for this router, follow the steps in "Configure IKEv2 and IPsec for a remote site router" in Appendix B.

Procedure 6 Configure the mGRE Tunnel

The parameters in the table below are used in this procedure. This procedure applies to the Primary WAN remote site router in the IWAN hybrid design model.

Table 13 DMVPN tunnel parameters

Design model	Tunnel VRF	Tunnel number	Tunnel network	NHRP network ID/ tunnel key
Hybrid–Primary WAN	IWAN-TRANSPORT-1	100	10.6.34.0/23	1100
Hybrid–Secondary WAN	IWAN-TRANSPORT-2	200	10.6.36.0/23	1200

Step 1: Configure basic interface settings.

The tunnel number is arbitrary, but it is best to begin tunnel numbering at 10 or above, because other features deployed in this design may also require tunnels and they may select lower numbers by default.

You must set the bandwidth to match the bandwidth of the respective transport that corresponds to the actual interface speed. Or, if you are using a subrate service, use the policed rate from the carrier. QoS and PfR require the correct bandwidth setting in order to operate properly.

Configure the **ip mtu** to 1400 and the **ip tcp adjust-mss** to 1360. There is a 40 byte difference, which corresponds to the combined IP and TCP header length.

Tech Tip

An IPv6 underlay requires an **ip mtu** of 1380 and an **ip tcp adjust-mss** of 1340.

```
interface Tunnel100
 description MPLS1
 bandwidth 200000
 ip address 10.6.34.11 255.255.254.0
 no ip redirects
 ip mtu 1400
 ip tcp adjust-mss 1360
```

Step 2: Configure the tunnel.

DMVPN uses mGRE tunnels. This type of tunnel requires a source interface only. The source interface should be the same interface used in to connect to the MPLS or Internet. Set the **tunnel vrf** command to the VRF defined previously for FVRF.

Enabling encryption on this interface requires the application of the IPsec profile configured in the previous procedure.

```
interface Tunnel100
 tunnel source GigabitEthernet0/0
 tunnel mode gre multipoint
 tunnel key 1100
 tunnel vrf IWAN-TRANSPORT-1
 tunnel protection ipsec profile DMVPN-IPSEC-PROFILE
```

Step 3: Configure NHRP.

The DMVPN hub router is the NHRP server for all of the spokes. Remote routers use NHRP in order to determine the tunnel destinations for peers attached to the mGRE tunnel.

The spoke router requires an additional configuration statement in order to define the NHRP server. This statement includes the NBMA definition for the DMVPN hub router tunnel endpoint. Spoke routers require the NHRP multicast keyword in this statement.

When hub BRs are added for horizontal scaling or a second data center is added as a transit site, spoke routers require additional NHS statements for each BR in their environment. The configuration details are covered in subsequent sections of this guide.

The value used for the next hop server (NHS) is the mGRE tunnel address for the DMVPN hub router. The NBMA entry must be set to either the MPLS DMVPN hub router's actual public address or the outside NAT value of the DMVPN hub, as configured on the Cisco ASA 5500. This design uses the values shown in the following tables.

Table 14 DMVPN tunnel NHRP parameters: IWAN hybrid design model

	Transport 1	Transport 2
VRF	IWAN-TRANSPORT-1	IWAN-TRANSPORT-2
DMVPN hub public address (actual)	192.168.6.1	192.168.146.10
DMVPN hub public address (externally routable after NAT)	n/a (MPLS1)	172.16.140.1
DMVPN hub tunnel IP address (NHS)	10.6.34.1	10.6.36.1
Tunnel number	100	200
NHRP network ID	1100	1200

NHRP requires all devices within a DMVPN cloud to use the same network ID and authentication key.

This design supports DMVPN spoke routers that receive their external IP addresses through DHCP. It is possible for these routers to acquire different IP addresses after a reload. When the router attempts to register with the NHRP server, it may appear as a duplicate to an entry already in the cache and be rejected. The **registration no-unique** option allows you to overwrite existing cache entries. This feature is only required on NHRP clients

(DMVPN spoke routers). The **if-state nhrp** option ties the tunnel line-protocol state to the reachability of the NHRP NHS, and if the NHS is unreachable, the tunnel line-protocol state changes to down. This feature is used in conjunction with EOT.

```
interface Tunnel100
 ip nhrp authentication cisco123
 ip nhrp network-id 1100
 ip nhrp nhs 10.6.34.1 nbma 192.168.6.1 multicast
 ip nhrp registration no-unique
 if-state nhrp
```

By default, NHRP will not install shortcuts for paths not seen in the Routing Information Base (RIB) of the router. In a location with a single router and multiple WAN transports, only the preferred path is in the RIB. If you have a remote site location with more than one WAN transport, you need to disable the **nhrp route-watch** feature on each of the tunnel interfaces in order to allow NHRP to install the non-preferred shortcut path and allow PfR to maintain this information.

```
interface Tunnel100
 no nhrp route-watch
```

Procedure 7 Configure the routing protocol on the WAN

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

The following table shows the DMVPN tunnel names and EIGRP WAN delay in use.

Table 15 EIGRP WAN delay for IWAN hybrid remote-site routers

DMVPN Tunnel	EIGRP WAN Delay (10 usec)
Tunnel100	1000 (MPLS1)
Tunnel200	20000 (INET1)

A single EIGRP process runs on the DMVPN spoke router. All interfaces on the router are EIGRP interfaces, but only the DMVPN tunnel interface is non-passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address. All DMVPN spoke routers should run EIGRP stub-site routing to improve network stability and reduce resource utilization. It is a best practice use the EIGRP AS number and remote site id in the form of AS:NN for the stub-site command.

Step 1: Configure an EIGRP process for DMVPN using EIGRP named mode on the spoke router.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface default
   passive-interface
  exit-af-interface
  af-interface Tunnel100
   no passive-interface
  exit-af-interface
  network 10.6.34.0 0.0.1.255
  network 10.7.0.0 0.0.255.255
  network 10.255.0.0 0.0.255.255
  eigrp router-id 10.255.241.11
  eigrp stub-site 400:11
 exit-address-family
```

Step 2: Configure EIGRP values for the mGRE tunnel interface.

The EIGRP hello interval is increased to 20 seconds and the EIGRP hold time is increased to 60 seconds in order to accommodate up to 2000 remote sites on a single DMVPN cloud. Increasing the EIGRP timers also slows down the routing convergence in order to improve network stability and the IWAN design allows PfR to initiate the fast failover, so changing the timers is recommended for all IWAN deployments.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel100
   hello-interval 20
   hold-time 60
  exit-af-interface
 exit-address-family
```

Step 3: Configure EIGRP neighbor authentication. Neighbor authentication enables the secure establishment of peering adjacencies and exchange route tables over the DMVPN tunnel interface.

```
key chain WAN-KEY
 key 1
  key-string c1sco123

router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel100
   authentication mode md5
   authentication key-chain WAN-KEY
  exit-af-interface
 exit-address-family
```

Step 4: Configure EIGRP network summarization.

The remote-site LAN networks must be advertised. The IP assignment for the remote sites was designed so that all of the networks in use can be summarized within a single aggregate route. As configured below, the **summary-address** command suppresses the more specific routes. If any network within the summary is present in the route table, the summary is advertised to the DMVPN hub, which offers a measure of resiliency. If the various LAN networks cannot be summarized, then EIGRP continues to advertise the specific routes.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel100
   summary-address 10.7.0.0 255.255.248.0
  exit-af-interface
 exit-address-family
```

Step 5: Configure the throughput delay on the tunnel interface.

The tunnel interface throughput delay setting should be set to influence the routing protocol path preference. Set the primary WAN path to 10000 usec and the secondary WAN path to 200000 usec to prefer one over the other. The delay command is entered in 10 usec units.

```
interface Tunnel100
 delay 1000
```

Step 6: Add stub-site wan-interface.

You add one command to each af-interface tunnel in order to identify it as the stub-site wan-interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel100
   stub-site wan-interface
  exit-af-interface
 exit-address-family
```

Step 7: Block the tunnel addresses from being advertised on the WAN by using IP prefix lists and a route map.

```
ip prefix-list TUNNEL-ROUTES seq 10 permit 10.6.34.0/23
ip prefix-list TUNNEL-ROUTES seq 20 permit 10.6.36.0/23

route-map BLOCK_TUNNEL_ROUTES deny 10
 description Block the tunnel routes
 match ip address prefix-list TUNNEL-ROUTES

route-map BLOCK_TUNNEL_ROUTES permit 20
 description Permit the rest of the routes
```

Step 8: Apply an outbound distribute list to the tunnel interface.

Use the route map from the previous step to block the routes.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK_TUNNEL_ROUTES out Tunnel100
  exit-af-topology
exit-address-family
```

Step 9: Proceed to Procedure 8 “Configure IP multicast routing on tunnel.”

Option 2: BGP on the WAN

Step 1: Configure BGP values for the mGRE tunnel interface.

Use a private AS number for the BGP process. Assign this router's loopback address as the BGP router-id. Log the neighbor changes. For internal BPG, use the same AS number for the remote sites. Use the tunnel interface as the update source. Adjust the BGP hello and hold timers to 20 seconds and 60 seconds, respectively. Peer to the hub border router.

```
router bgp 65100
 bgp router-id 10.255.241.11
 bgp log-neighbor-changes
 neighbor MPLS1-HUB peer-group
 neighbor MPLS1-HUB remote-as 65100
 neighbor MPLS1-HUB description To IWAN MPLS1 Hub Router
 neighbor MPLS1-HUB update-source Tunnel100
 neighbor MPLS1-HUB timers 20 60
 neighbor 10.6.34.1 peer-group MPLS1-HUB
```

Step 2: Configure the BGP address family.

Advertise an aggregate address for the site-specific super-net prefix and redistribute connected routes into BGP. Set next-hop-self, set the weight to 50000, and turn on soft reconfiguration inbound. Activate the BGP connection to the DMVPN hub border router and set the BGP distance.

```
router bgp 65100
 address-family ipv4
  aggregate-address 10.7.0.0 255.255.248.0 summary-only
  redistribute connected
  neighbor MPLS1-HUB next-hop-self all
  neighbor MPLS1-HUB weight 50000
  neighbor MPLS1-HUB soft-reconfiguration inbound
  neighbor 10.6.34.1 activate
  distance bgp 201 19 200
exit-address-family
```

Step 3: Create the prefix lists for BGP.

Define the prefix-lists for the loopback ip address and the site-specific prefixes.

```
ip prefix-list LOCAL-LOOPBACKS seq 10 permit 10.255.241.11/32
ip prefix-list LOCAL-SUBNETS seq 10 permit 10.7.0.0/21
```

Step 4: Create and apply the prefix route maps for BGP.

Define the route map to allow prefixes to go out on the tunnel interface. Apply the route map to the BGP address family for the hub border router.

```
route-map SPOKE-OUT permit 10
 description Match the local networks
 match ip address prefix-list LOCAL-LOOPBACKS LOCAL-NETS

router bgp 65100
 address-family ipv4
  neighbor MPLS1-HUB route-map SPOKE-OUT out
```

Procedure 8 Configure IP multicast routing on tunnel

Optional

This optional procedure includes additional steps for configuring IP Multicast for a DMVPN tunnel on a router with IP Multicast already enabled. Skip this procedure if you do not want to use IP Multicast in your environment.

Step 1: Configure PIM on the DMVPN tunnel interface.

Enable IP PIM sparse mode on the DMVPN tunnel interface.

```
interface Tunnel100
 ip pim sparse-mode
```

Step 2: Configure the DR priority for the DMVPN spoke router.

Proper multicast operation across a DMVPN cloud requires that the hub router assumes the role of PIM designated router (DR). Spoke routers should never become the DR. You can prevent that by setting the DR priority to 0 for the spokes.

```
interface Tunnel100
 ip pim dr-priority 0
```

Procedure 9 Connect router to access layer switch

Optional

If you are using a remote-site distribution layer, skip to the "Deploying an IWAN Remote-Site Distribution Layer" section of this guide.

> ***Reader Tip***
>
> This guide includes only the steps needed in order to complete the access layer configuration. For complete access layer configuration details, refer to the Campus LAN Layer 2 Access with Simplified Distribution Deployment Guide.

Layer 2 EtherChannels are used to interconnect the CE router to the access layer in the most resilient method possible. If your access layer device is a single fixed configuration switch, a simple Layer 2 trunk between the router and switch is used.

In the access layer design, the remote sites use collapsed routing, with 802.1Q trunk interfaces to the LAN access layer. The VLAN numbering is locally significant only.

Option 1: Layer 2 EtherChannel from router to access layer switch

Step 1: Configure port-channel interface on the router.

```
interface Port-channel1
 description RS12-A2960X
 no shutdown
```

Step 2: Configure EtherChannel member interfaces on the router.

Configure the physical interfaces to tie to the logical port-channel using the channel-group command. The number for the port-channel and channel-group must match. Not all router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet0/1
 description RS12-A2960X Gig1/0/47

interface GigabitEthernet0/2
 description RS12-A2960X Gig2/0/47

interface range GigabitEthernet0/1, GigabitEthernet0/2
  no ip address
  channel-group 1
  no shutdown
```

Step 3: Configure EtherChannel member interfaces on the access layer switch.

Connect the router EtherChannel uplinks to separate switches in the access layer switch stack.

The physical interfaces that are members of a Layer 2 EtherChannel are configured prior to configuring the logical port-channel interface. Doing the configuration in this order allows for minimal configuration and reduces errors because most of the commands entered to a port-channel interface are copied to its members interfaces and do not require manual replication.

Configure two physical interfaces to be members of the EtherChannel. Also, apply the egress QoS macro that was defined in the LAN switch platform configuration procedure to ensure traffic is prioritized appropriately.

Not all connected router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet1/0/47
 description RS12-2911-1 Gig0/1

interface GigabitEthernet2/0/47
 description RS12-2911-1 Gig0/2

interface range GigabitEthernet1/0/24, GigabitEthernet2/0/24
 switchport
 macro apply EgressQoS
 channel-group 1 mode on
 logging event link-status
 logging event trunk-status
 logging event bundle-status
```

Step 4: Configure EtherChannel trunk on the access layer switch.

An 802.1Q trunk is used, which allows the router to provide the Layer 3 services to all the VLANs defined on the access layer switch. The VLANs allowed on the trunk are pruned to only the VLANs that are active on the access layer switch. When using EtherChannel the interface type will be port-channel and the number must match the channel group configured in the previous step. DHCP Snooping and address resolution protocol (ARP) inspection are set to trust.

```
interface Port-channel1
 description RS12-2911-1
 switchport trunk allowed vlan 64,69
 switchport mode trunk
 ip arp inspection trust
 spanning-tree portfast trunk
 ip dhcp snooping trust
 load-interval 30
 no shutdown
```

The Cisco Catalyst 3750 Series Switch requires the **switchport trunk encapsulation dot1q** command.

Option 2: Layer 2 trunk from router to access layer switch

Step 1: Enable the physical interface on the router.

```
interface GigabitEthernet0/2
 description RS11-A2960X Gig1/0/48
 no ip address
 no shutdown
```

Step 2: Configure the trunk on the access layer switch.

Use an 802.1Q trunk for the connection, which allows the router to provide the Layer 3 services to all the VLANs defined on the access layer switch. The VLANs allowed on the trunk are pruned to only the VLANs that are active on the access switch. DHCP Snooping and ARP inspection are set to trust.

```
interface  GigabitEthernet1/0/48
 description RS11-2921 Gig0/2
 switchport trunk allowed vlan 64,69
 switchport mode trunk
 ip arp inspection trust
 spanning-tree portfast trunk
 logging event link-status
 logging event trunk-status
 ip dhcp snooping trust
 load-interval 30
 no shutdown
 macro apply EgressQoS
```

The Cisco Catalyst 3750 Series Switch requires the **switchport trunk encapsulation dot1q** command.

Procedure 10 Configure access layer interfaces

Optional

If you are using a dual router design, skip to the "Modifying the First Router for Dual Router Design" section of this guide.

Step 1: Create subinterfaces and assign VLAN tags.

After the physical interface or port-channel has been enabled, then the appropriate data or voice subinterfaces can be mapped to the VLANs on the LAN switch. The subinterface number does not need to equate to the 802.1Q tag, but making them the same simplifies the overall configuration. The subinterface portion of the configuration should be repeated for all data or voice VLANs.

```
interface [type][number].[sub-interface number]
 encapsulation dot1Q [dot1q VLAN tag]
```

Step 2: Configure IP settings for each subinterface.

This design uses an IP addressing convention with the default gateway router assigned an IP address and IP mask combination of **N.N.N.1 255.255.255.0** where N.N.N is the IP network and 1 is the IP host.

When you are using a centralized DHCP server, your routers with LAN interfaces connected to a LAN using DHCP for end-station IP addressing must use an IP helper.

If the remote-site router is the first router of a dual-router design, then HSRP is configured at the access layer. This requires a modified IP configuration on each subinterface.

```
interface [type][number].[sub-interface number]
 ip address [LAN network 1] [LAN network 1 netmask]
 ip helper-address 10.4.48.10
 ip pim sparse-mode
```

Example: Layer 2 port-channel

```
interface Port-channel1
 no ip address
 no shutdown

 interface Port-channel1.64
 description Data
 encapsulation dot1Q 64
 ip address 10.7.18.1 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim sparse-mode
```

```
interface Port-channel1.69
 description Voice
 encapsulation dot1Q 69
 ip address 10.7.19.1 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim sparse-mode
```

Example: Layer 2 Gigabit Ethernet

```
interface GigabitEthernet0/2
 no ip address
 no shutdown

interface GigabitEthernet0/2.64
 description Data
 encapsulation dot1Q 64
 ip address 10.7.2.1 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim sparse-mode

interface GigabitEthernet0/2.69
 description Voice
 encapsulation dot1Q 69
 ip address 10.7.3.1 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim sparse-mode
```

PROCESS

Adding Second DMVPN for a Single-Router Remote Site

1. Configure the WAN-facing VRF
2. Connect to the Internet
3. Configure the mGRE Tunnel
4. Configure the routing protocol on the WAN
5. Configure IP multicast routing for tunnel

This set of procedures includes the additional steps necessary to add a second DMVPN link to a remote-site router that has already been configured with a DMVPN link in the "Configuring Remote-Site DMVPN Router" process in this guide.

Procedure 1 Configure the WAN-facing VRF

You create a WAN-facing VRF in order to support FVRF for DMVPN. The VRF name is arbitrary, but it is useful to select a name that describes the VRF. The VRF must be enabled for IPv4.

Table 16 VRF assignments

IWAN design model	Primary WAN VRF	Secondary WAN VRF
Hybrid	IWAN-TRANSPORT-1	IWAN-TRANSPORT-2

This design uses VRF Lite, so the selection is only locally significant to the device. It is a best practice to use the same VRF/RD combination across multiple devices when using VRFs in a similar manner. However, this convention is not strictly required.

Step 1: Configure the secondary WAN VRF.

Example: Secondary WAN in the hybrid design model

```
vrf definition IWAN-TRANSPORT-2
 address-family ipv4
```

Procedure 2 Connect to the Internet

The remote sites that are using DMVPN can use either static or dynamically assigned IP addresses. Cisco tested the design with DHCP assigned external addresses for Internet connections, which also provides a dynamically configured default route.

The DMVPN spoke router connects directly to the Internet without a separate firewall. This connection is secured in two ways. Because the Internet interface is in a separate VRF, no traffic can access the global VRF except

traffic sourced through the DMVPN tunnel. This design provides implicit security. Additionally, an IP access list permits only the traffic required for an encrypted tunnel, as well as DHCP and various ICMP protocols for trouble-shooting.

Step 1: Enable the interface, select VRF and enable DHCP.

The DMVPN design uses FVRF, so you must place this interface into the VRF configured in the previous procedure.

```
interface GigabitEthernet0/1
 ip vrf forwarding IWAN-TRANSPORT-2
 ip address dhcp
 no cdp enable
 no shutdown
```

Step 2: Configure and apply the access list.

The IP access list must permit the protocols specified in the following table. The access list is applied inbound on the WAN interface, so filtering is done on traffic destined to the router.

Table 17 Required DMVPN protocols

Name	Protocol	Usage
non500-isakmp	UDP 4500	IPsec via NAT-T
isakmp	UDP 500	ISAKMP
esp	IP 50	IPsec
bootpc	UDP 68	DHCP

Example

```
interface GigabitEthernet0/1
 ip access-group ACL-INET-PUBLIC in

ip access-list extended ACL-INET-PUBLIC
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit esp any any
 permit udp any any eq bootpc
```

The additional protocols listed in the following table may assist in troubleshooting, but are not explicitly required to allow DMVPN to function properly.

Table 18 Optional protocols: DMVPN spoke router

Name	Protocol	Usage
icmp echo	ICMP Type 0, Code 0	Allow remote pings
icmp echo-reply	ICMP Type 8, Code 0	Allow ping replies (from your requests)
icmp ttl-exceeded	ICMP Type 11, Code 0	Allow traceroute replies (from your requests)
icmp port-unreachable	ICMP Type 3, Code 3	Allow traceroute replies (from your requests)
UDP high ports	UDP > 1023, TTL=1	Allow remote traceroute

The additional optional entries for an access list to support ping are as follows:

```
permit icmp any any echo
permit icmp any any echo-reply
```

The additional optional entries for an access list to support traceroute are as follows:

```
permit icmp any any ttl-exceeded      ! for traceroute (sourced)
permit icmp any any port-unreachable  ! for traceroute (sourced)
permit udp any any gt 1023 ttl eq 1   ! for traceroute (destination)
```

Procedure 3 Configure the mGRE Tunnel

This procedure uses the parameters in the table below. This procedure applies to the secondary WAN.

Table 19 DMVPN tunnel parameters

Design model	Tunnel VRF	Tunnel number	Tunnel network	NHRP network ID/ tunnel key
Hybrid—Primary WAN	IWAN-TRANSPORT-1	100	10.6.34.0/23	1100
Hybrid—Secondary WAN	IWAN-TRANSPORT-2	200	10.6.36.0/23	1200

Step 1: Configure the basic interface settings.

The tunnel number is arbitrary, but it is best to begin tunnel numbering at 10 or above, because other features deployed in this design may also require tunnels and they may select lower numbers by default.

The bandwidth setting must be set to match the bandwidth of the respective transport, which corresponds to the actual interface speed. Or, if you are using a subrate service, use the policed rate from the carrier. QoS and PfR require the correct bandwidth setting in order to operate properly.

Configure the **ip mtu** to 1400 and the **ip tcp adjust-mss** to 1360. There is a 40 byte difference, which corresponds to the combined IP and TCP header length.

Tech Tip

An IPv6 underlay requires an **ip mtu** of 1380 and an **ip tcp adjust-mss** of 1340.

```
interface Tunnel200
 description INET1
 bandwidth 50000
 ip address 10.6.36.11 255.255.254.0
 no ip redirects
 ip mtu 1400
 ip tcp adjust-mss 1360
```

Step 2: Configure the tunnel.

DMVPN uses mGRE tunnels. This type of tunnel requires a source interface only. Use the same source interface that you use to connect to the Internet. Set the **tunnel vrf** command to the VRF defined previously for FVRF.

Tech Tip

The crypto configurations have been simplified in this version of the guide in order to minimize the number of variations from previous guides. With the new configurations, it is not necessary to configure IKEv2 and IPsec again. All IKEv2 and IPsec sessions use the same parameters.

Enabling encryption on this interface requires the application of the IPsec profile configured previously.

```
interface Tunnel200
 tunnel source GigabitEthernet0/1
 tunnel mode gre multipoint
 tunnel key 1200
 tunnel vrf IWAN-TRANSPORT-2
 tunnel protection ipsec profile DMVPN-IPSEC-PROFILE
```

Step 3: Configure NHRP.

The DMVPN hub router is the NHRP server for all of the spokes. NHRP is used by remote routers to determine the tunnel destinations for peers attached to the mGRE tunnel.

The spoke router requires several additional configuration statements in order to define the NHRP server and NHRP map statements for the DMVPN hub router mGRE tunnel IP address. Spoke routers require the NHRP static multicast mapping.

When hub BRs are added for horizontal scaling or a second data center is added as a transit site, spoke routers require additional NHS statements for each BR in their environment. The configuration details are covered in subsequent sections of this guide.

The value used for the NHS is the mGRE tunnel address for the DMVPN hub router. The map entries must be set to the outside NAT value of the DMVPN hub, as configured on the Cisco ASA 5500. This design uses the values shown in the following tables.

Table 20 DMVPN tunnel NHRP parameters: IWAN hybrid design model

	Transport 1	Transport 2
VRF	IWAN-TRANSPORT-1	IWAN-TRANSPORT-2
DMVPN hub public address (actual)	192.168.6.1	192.168.146.10
DMVPN hub public address (externally routable after NAT)	n/a (MPLS1)	172.16.140.1
DMVPN hub tunnel IP address (NHS)	10.6.34.1	10.6.36.1
Tunnel number	100	200
NHRP network ID	1100	1200

NHRP requires all devices within a DMVPN cloud to use the same network ID and authentication key. The NHRP cache holdtime should be configured to 600 seconds.

This design supports DMVPN spoke routers that receive their external IP addresses through DHCP. It is possible for these routers to acquire different IP addresses after a reload. When the router attempts to register with the NHRP server, it may appear as a duplicate to an entry already in the cache and be rejected. The **registration no-unique** option allows you to overwrite existing cache entries. This feature is only required on NHRP clients (DMVPN spoke routers). The **if-state nhrp** option ties the tunnel line-protocol state to the reachability of the NHRP NHS, and if the NHS is unreachable, the tunnel line-protocol state changes to down. This feature is used in conjunction with EOT.

```
interface Tunnel200
 ip nhrp authentication cisco123
 ip nhrp network-id 1200
 ip nhrp nhs 10.6.36.1 nbma 172.16.140.1 multicast
 ip nhrp registration no-unique
 if-state nhrp
```

By default, NHRP will not install shortcuts for paths not seen in the RIB of the router. In a location with a single router and multiple WAN transports, only the preferred path is in the RIB. If you have a remote site location with more than one WAN transport, you need to disable the **nhrp route-watch** feature on each of the tunnel interfaces in order to allow NHRP to install the non-preferred shortcut path.

```
interface Tunnel200
 no nhrp route-watch
```

Procedure 4 Configure the routing protocol on the WAN

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

The following table shows the DMVPN tunnel names and EIGRP WAN delay in use.

Table 21 EIGRP WAN delay for IWAN hybrid remote-site routers

DMVPN Tunnel	EIGRP WAN Delay (10 usec)
Tunnel100	1000 (MPLS1)
Tunnel200	20000 (INET1)

A single EIGRP process runs on the DMVPN spoke router, which has already been enabled during the first DMVPN tunnel's configuration. All interfaces on the router are EIGRP interfaces, but only the DMVPN tunnel interfaces are non-passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements.

Step 1: Add the network range for the secondary DMVPN tunnel and configure as non-passive.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
   af-interface Tunnel200
    no passive-interface
   exit-af-interface
 network 10.6.36.0 0.0.1.255
exit-address-family
```

Step 2: Configure EIGRP values for the mGRE tunnel interface.

The EIGRP hello interval is increased to 20 seconds and the EIGRP hold time is increased to 60 seconds in order to accommodate up to 2000 remote sites on a single DMVPN cloud. Increasing the EIGRP timers also slows down the routing convergence to improve network stability and the IWAN design allows PfR to initiate the fast failover, so changing the timers is recommended for all IWAN deployments.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
   af-interface Tunnel200
    hello-interval 20
    hold-time 60
   exit-af-interface
 exit-address-family
```

Step 3: Configure EIGRP neighbor authentication. Neighbor authentication enables the secure establishment of peering adjacencies and exchange route tables over the DMVPN tunnel interface.

```
key chain WAN-KEY
 key 1
  key-string c1sco123


router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel200
   authentication mode md5
   authentication key-chain WAN-KEY
  exit-af-interface
 exit-address-family
```

Step 4: Configure EIGRP route summarization.

The remote-site LAN networks must be advertised. The IP assignment for the remote sites was designed so that all of the networks in use can be summarized within a single aggregate route. As configured below, the **summary-address** command suppresses the more specific routes. If any network within the summary is present in the route table, the summary is advertised to the DMVPN hub, which offers a measure of resiliency. If the various LAN networks cannot be summarized, EIGRP continues to advertise the specific routes.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel200
   summary-address 10.7.0.0 255.255.248.0
  exit-af-interface
 exit-address-family
```

Step 5: Configure the throughput delay on the tunnel interface.

The tunnel interface throughput delay setting should be set to influence the routing protocol path preference. Set the primary WAN path to 10000 usec and the secondary WAN path to 200000 usec to prefer one over the other. The delay command is in 10 usec units.

```
interface Tunnel200
 delay 20000
```

Step 6: Add stub-site wan-interface.

You add one command to each af-interface tunnel in order to identify it as the stub-site wan-interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel200
   stub-site wan-interface
  exit-af-interface
 exit-address-family
```

Step 7: Apply an outbound distribute list to the tunnel interface.

Use the route map from the previous procedure to block the routes.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK_TUNNEL_ROUTES out Tunnel200
  exit-af-topology
exit-address-family
```

Step 8: Proceed to Procedure 5,"Configure IP multicast routing for tunnel."

Option 2: BGP on the WAN

Step 1: Configure BGP values for the mGRE tunnel interface.

A single BGP process runs on the DMVPN spoke router, which has already been enabled during the first DMVPN tunnel's configuration. For internal BPG, use the same AS number for the remote sites. Use the tunnel interface as the update source. Adjust the BGP hello and hold timers to 20 seconds and 60 seconds, respectively. Peer to the hub border router.

```
router bgp 65100
 neighbor INET1-HUB peer-group
 neighbor INET1-HUB remote-as 65100
 neighbor INET1-HUB description To IWAN INET1 Hub Router
 neighbor INET1-HUB update-source Tunnel200
 neighbor INET1-HUB timers 20 60
 neighbor 10.6.36.1 peer-group INET1-HUB
```

Step 2: Configure the BGP address family.

Set next-hop-self, set the weight to 50000, and turn on soft reconfiguration inbound. Activate the BGP connection to the DMVPN hub border router.

```
router bgp 65100
 address-family ipv4
  neighbor INET1-HUB next-hop-self all
  neighbor INET1-HUB weight 50000
  neighbor INET1-HUB soft-reconfiguration inbound
  neighbor 10.6.36.1 activate
exit-address-family
```

Step 3: Apply the prefix route maps for BGP.

The route map to allow prefixes to go out on the tunnel interface was already defined. Apply the route map to the BGP address family for the hub border router.

```
router bgp 65100
 address-family ipv4
  neighbor INET1-HUB route-map SPOKE-OUT out
```

Procedure 5 Configure IP multicast routing for tunnel

Optional

This optional procedure includes additional steps for configuring IP Multicast for a DMVPN tunnel on a router with IP Multicast already enabled. Skip this procedure if you do not want to use IP Multicast in your environment.

Step 1: Configure PIM on the DMVPN tunnel interface.

Enable IP PIM sparse mode on the DMVPN tunnel interface.

```
interface Tunnel200
 ip pim sparse-mode
```

Step 2: Configure the DR priority for the DMVPN spoke router.

Proper multicast operation across a DMVPN cloud requires that the hub router assumes the role of PIM DR. Spoke routers should never become the DR. You can prevent that by setting the DR priority to 0 for the spokes.

```
interface Tunnel200
 ip pim dr-priority 0
```

PROCESS

Modifying the First Router for Dual Router Design

1. Configure access layer HSRP
2. Configure transit network for dual router design
3. Configure the routing protocol on the transit network
4. Enable enhanced object tracking

This process is required when the first router has already been configured using the "Configuring Remote-Site DMVPN Router" process.

Procedure 1 Configure access layer HSRP

You need to configure HSRP to enable the use of a Virtual IP (VIP) as a default gateway that is shared between two routers. The HSRP active router is the router connected to the primary WAN link and the HSRP standby router is the router connected to the secondary WAN link.

Step 1: Configure the HSRP active router with a standby priority that is higher than the HSRP standby router.

The router with the higher standby priority value is elected as the HSRP active router. The preempt option allows a router with a higher priority to become the HSRP active, without waiting for a scenario where there is no router in the HSRP active state. The following table shows the relevant HSRP parameters for the router configuration.

Table 22 WAN remote-site HSRP parameters (dual router)

Router	HSRP role	VIP	Real IP address	HSRP priority	PIM DR priority
Primary	Active	.1	.2	110	110
Secondary	Standby	.1	.3	105	105

The assigned IP addresses override those configured in the previous procedure, so the default gateway IP address remains consistent across locations with single or dual routers.

The dual-router access-layer design requires a modification for resilient multicast. The PIM DR should be on the HSRP active router. The DR is normally elected based on the highest IP address, and has no awareness of the HSRP configuration. In this design, the HSRP active router has a lower real IP address than the HSRP standby router, which requires a modification to the PIM configuration. The PIM DR election can be influenced by explicitly setting the DR priority on the LAN-facing subinterfaces for the routers.

Tech Tip

The HSRP priority and PIM DR priority are shown in the previous table to be the same value; however, you are not required to use identical values.

Step 2: This procedure should be repeated for all data or voice subinterfaces.

```
interface [type][number].[sub-interface number]
 encapsulation dot1Q [dot1q VLAN tag]
 ip address [LAN network 1 address] [LAN network 1 netmask]
 ip helper-address 10.4.48.10
 ip pim sparse-mode
 ip pim dr-priority 110
 standby version 2
 standby 1 ip [LAN network 1 gateway address]
 standby 1 priority 110
 standby 1 preempt
 standby 1 authentication md5 key-string c1sco123
```

Example: Layer 2 link

```
interface GigabitEthernet0/2
 no ip address
 no shutdown

interface GigabitEthernet0/2.64
 description Data
 encapsulation dot1Q 64
 ip address 10.7.18.2 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim dr-priority 110
 ip pim sparse-mode
 standby version 2
 standby 1 ip 10.7.18.1
 standby 1 priority 110
 standby 1 preempt
 standby 1 authentication md5 key-string c1sco123

interface GigabitEthernet0/2.69
 description Voice
 encapsulation dot1Q 69
 ip address 10.7.19.2 255.255.255.0
 ip helper-address 10.4.48.10
```

```
ip pim dr-priority 110
ip pim sparse-mode
standby version 2
standby 1 ip 10.7.19.1
standby 1 priority 110
standby 1 preempt
standby 1 authentication md5 key-string c1sco123
```

Procedure 2 Configure transit network for dual router design

The transit network is configured between the two routers. This network is used for router-router communication and to avoid hair-pinning. The transit network should use an additional subinterface on the router's physical interface that is already being used for data or voice.

Step 1: Configure the transit network between the two routers.

There are no end stations connected to this network, so HSRP and DHCP are not required.

```
interface [type][number].[sub-interface number]
 encapsulation dot1Q [dot1q VLAN tag]
 ip address [transit net address] [transit net netmask]
 ip pim sparse-mode
```

Example

```
interface GigabitEthernet0/2.99
 description Transit Net
 encapsulation dot1Q 99
 ip address 10.7.16.9 255.255.255.252
 ip pim sparse-mode
```

Step 2: Add transit network VLAN to the access layer switch.

If the VLAN does not already exist on the access layer switch, configure it now.

```
vlan 99
 name Transit-net
```

Step 3: Add transit network VLAN to existing access layer switch trunk.

```
interface GigabitEthernet1/0/48
 switchport trunk allowed vlan add 99
```

Procedure 3 Configure the routing protocol on the transit network

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the transit network

The following table shows the EIGRP transit network delay in use.

Table 23 EIGRP transit network delay for IWAN remote-site routers

LAN Interface	EIGRP LAN Delay (10 usec)
Transit	24000

A single EIGRP process runs on the DMVPN spoke router, which has already been enabled when configuring the DMVPN tunnel. All interfaces on the router are EIGRP interfaces, but only the DMVPN tunnel interface and transit network are non-passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements.

Step 1: Configure the transit network subinterface as non-passive.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
   af-interface GigabitEthernet0/2.99
    no passive-interface
   exit-af-interface
 exit-address-family
```

Step 2: Configure EIGRP neighbor authentication. Neighbor authentication enables the secure establishment of peering adjacencies and exchange route tables over the transit network interface.

```
key chain LAN-KEY
 key 1
  key-string c1sco123

router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface GigabitEthernet0/2.99
   authentication mode md5
   authentication key-chain LAN-KEY
  exit-af-interface
 exit-address-family
```

Step 3: Configure the throughput delay on the transit network interface.

At a remote site location where there are multiple border routers, the interface throughput delay setting should be set to influence the routing protocol path preference. Set the transit network LAN path to 240000 usec. The delay command is entered in 10 usec units.

```
interface GigabitEthernet0/2.99
 delay 24000
```

Option 2: OSPF on the transit network

A single OSPF process runs on the DMVPN spoke router.

Step 1: Configure OSPF Area 0 by using the network summary address and the loopback interface IP address as the router-id. Turn on default information originate in order to advertise a default route into the OSPF domain.

```
router ospf 100
 router-id 10.255.241.12
 network 10.7.16.0 0.0.7.255 area 0
 network 10.255.241.12 0.0.0.0 area 0
 default-information originate
```

Step 2: Turn on passive-interface as the default and remove it for the transit network LAN interface.

```
router ospf 100
 passive-interface default
 no passive-interface GigabitEthernet0/2.99
```

Step 3: Create a route map to block local subnets from OSPF and tag all the rest of the BGP routes coming into OSPF.

Block the local subnets using the **LOCAL-SUBNETS** prefix list created previously. Tag the rest of the routes from BGP with a value of 1.

```
route-map REDIST-BGP-TO-OSPF deny 10
 description Do not redistribute LOCAL SUBNETS into OSPF
 match ip address prefix-list LOCAL-SUBNETS


route-map REDIST-BGP-TO-OSPF permit 20
 description Identify routes redistributed from BGP
 set tag 1
```

Step 4: Redistribute BGP into OSPF by using the route map from the previous step.

```
router ospf 100
 redistribute bgp 65100 subnets route-map REDIST-BGP-TO-OSPF
```

Step 5: Create a route map to block the routes with a tag value of 1.

Block routes with a tag of 1, but allow all internal, external type 1 and external type 2.

```
route-map REDIST-OSPF-TO-BGP deny 10
 description Block all routes redistributed from BGP
 match tag 1

route-map REDIST-OSPF-TO-BGP permit 20
 description Redistribute all other routes
 match route-type internal
 match route-type external type-1
 match route-type external type-2
```

Step 6: Redistribute OSPF into BGP using the route map from the previous step.

```
router bgp 65100
 address-family ipv4
  redistribute ospf 100 route-map REDIST-OSPF-TO-BGP
 exit-address-family
```

Step 7: Update the prefix list for BGP.

Define an additional prefix-list for the second remote site router's loopback ip address.

```
ip prefix-list LOCAL-LOOPBACKS seq 20 permit 10.255.243.12/32
```

Step 8: Remove redistribute connected, and then add redistribute internal.

The **redistribute connected** command is needed only for single router sites without a distibution layer. When adding a second router to a remote site, remove the **redistribute connected** command and add the **bgp redistribute-internal** command.

```
router bgp 65100
 address-family ipv4
  no redistribute connected
  bgp redistribute-internal
 exit-address-family
```

Example: First router at a dual-router site—RS12-2911-1

```
router ospf 100
 router-id 10.255.241.12
 redistribute bgp 65100 subnets route-map REDIST-BGP-TO-OSPF
 passive-interface default
 no passive-interface GigabitEthernet0/2.99
```

```
 network 10.7.16.0 0.0.7.255 area 0
 network 10.255.241.12 0.0.0.0 area 0
 default-information originate

router bgp 65100
 bgp router-id 10.255.241.12
 bgp log-neighbor-changes
 neighbor MPLS1-HUB peer-group
 neighbor MPLS1-HUB remote-as 65100
 neighbor MPLS1-HUB description To IWAN MPLS1 Hub Router
 neighbor MPLS1-HUB update-source Tunnel100
 neighbor MPLS1-HUB timers 20 60
 neighbor 10.6.34.1 peer-group MPLS1-HUB

 address-family ipv4
  bgp redistribute-internal
  aggregate-address 10.7.16.0 255.255.248.0 summary-only
  redistribute ospf 100 route-map REDIST-OSPF-TO-BGP
  neighbor MPLS1-HUB next-hop-self all
  neighbor MPLS1-HUB weight 50000
  neighbor MPLS1-HUB soft-reconfiguration inbound
  neighbor MPLS1-HUB route-map SPOKE-OUT out
  neighbor 10.6.34.1 activate
  distance bgp 201 19 200
 exit-address-family

ip prefix-list LOCAL-LOOPBACKS seq 10 permit 10.255.241.12/32
ip prefix-list LOCAL-LOOPBACKS seq 20 permit 10.255.243.12/32

ip prefix-list LOCAL-SUBNETS seq 10 permit 10.7.16.0/21

route-map SPOKE-OUT permit 10
 description Match the local networks
 match ip address prefix-list LOCAL-LOOPBACKS LOCAL-SUBNETS

route-map REDIST-BGP-TO-OSPF deny 10
```

```
 description Do not redistribute LOCAL SUBNETS into OSPF
 match ip address prefix-list LOCAL-SUBNETS

route-map REDIST-BGP-TO-OSPF permit 20
 description Identify routes redistributed from BGP
 set tag 1

route-map REDIST-OSPF-TO-BGP deny 10
 description Block all routes redistributed from BGP
 match tag 1

route-map REDIST-OSPF-TO-BGP permit 20
 description Redistribute all other routes
 match route-type internal
 match route-type external type-1
 match route-type external type-2
```

Procedure 4 Enable enhanced object tracking

The HSRP active router remains the active router unless the router is reloaded or fails. Having the HSRP router remain as the active router can lead to undesired behavior. If the primary WAN transport were to fail, the HSRP active router would learn an alternate path through the transit network to the HSRP standby router and begin to forward traffic across the alternate path. This is sub-optimal routing, and you can address it by using EOT.

The HSRP active router can track the state of its DMVPN tunnel interface. If the tunnel line-protocol state changes to down, this implies that the path to the primary site is no longer viable. This is a benefit of using the **if-state nhrp** feature with a DMVPN tunnel configuration.

This procedure is valid only on the router connected to the primary transport.

Step 1: Configure EOT.

A tracked object is created based on tunnel line-protocol state. If the tunnel is up, the tracked object status is Up; if the tunnel is down, the tracked object status is Down. A short delay is added after the tunnel interface comes back up in order to ensure that routing has converged properly before changing the HSRP active router.

```
track 50 interface Tunnel100 line-protocol
 delay up 20
```

[Optional] An alternate method is to track the loopback IP address of the primary hub border router. If the loopback IP address is reachable, the tracked object status is Up; if the IP address is unreachable, the tracked object status is Down.

```
track 50 ip route 10.6.32.241 255.255.255.255 reachability
 delay up 20
```

Step 2: Link HSRP with the tracked object.

All data or voice subinterfaces should enable HSRP tracking.

HSRP can monitor the tracked object status. If the status is down, the HSRP priority is decremented by the configured priority. If the decrease is large enough, the HSRP standby router preempts.

```
interface [interface type] [number].[sub-interface number]
 standby 1 track 50 decrement 10
```

Example

```
track 50 interface Tunnel100 line-protocol
 delay up 20

interface GigabitEthernet0/2.64
 standby 1 track 50 decrement 10

interface GigabitEthernet0/2.69
 standby 1 track 50 decrement 10
```

PROCESS

Configuring Second DMVPN Router at Remote Site

1. Configure the WAN remote site router
2. Configure IP multicast routing
3. Configure the WAN-facing VRF
4. Connect to the Internet
5. Configure IKEv2 and IPsec
6. Configure the mGRE tunnel
7. Configure the routing protocol on the WAN
8. Configure IP multicast routing for tunnel
9. Connect router to access layer switch
10. Configure access layer interfaces
11. Configure access layer HSRP
12. Configure transit network for dual router design
13. Configure the routing protocol on the transit network

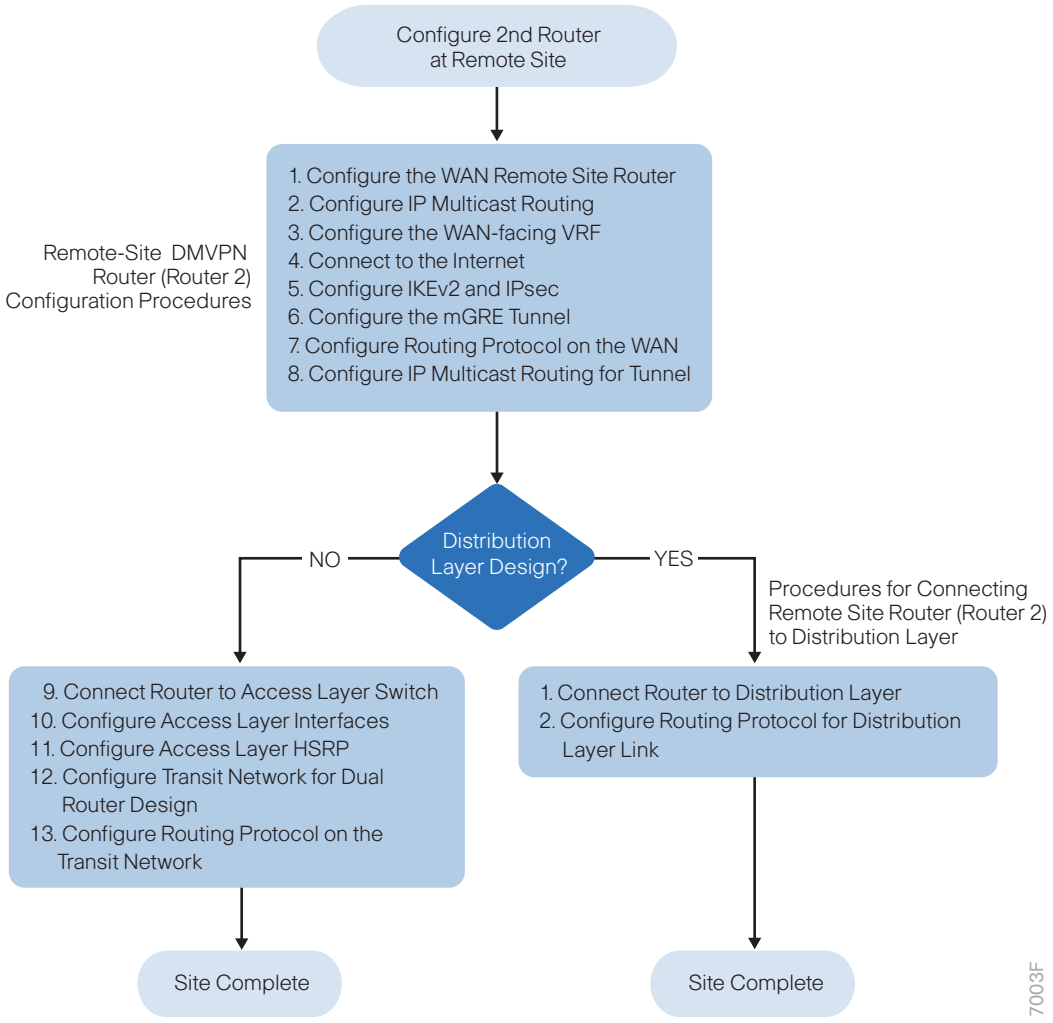
Use these procedures when configuring the second router of a dual-router design.

This set of procedures includes the additional steps necessary to configure a second router as a DMVPN spoke router when the first router has already been configured with the process "Configuring Remote-Site DMVPN Spoke Router."

The previous process, "Modifying the First Router for Dual Router Design," must also be completed.

The following flowchart provides details about how to complete the configuration of a remote-site DMVPN spoke router.

Figure 7 *Remote-site DMVPN second router configuration flowchart*



Procedure 1 Configure the WAN remote site router

Within this design, there are features and services that are common across all WAN remote-site routers. These are system settings that simplify and secure the management of the solution.

To complete the base configuration for this router, follow the steps in “Configure the platform base features” in Appendix B.

Procedure 2 Configure IP multicast routing

Optional

This optional procedure includes additional steps for configuring IP Multicast on a router. Skip this procedure if you do not want to use IP Multicast in your environment.

In this design, which is based on sparse mode multicast operation, Auto RP is used to provide a simple yet scalable way to provide a highly resilient RP environment.

Step 1: Enable IP Multicast routing on the platforms in the global configuration mode.

```
ip multicast-routing
```

Step 2: Every Layer 3 switch and router must be configured to discover the IP Multicast RP with autorp. Use the **ip pim autorp listener** command to allow for discovery across sparse mode links. This configuration provides for future scaling and control of the IP Multicast environment and can change based on network needs and design.

```
ip pim autorp listener
```

Step 3: All Layer 3 interfaces in the network must be enabled for sparse mode multicast operation.

```
ip pim sparse-mode
```

Procedure 3 Configure the WAN-facing VRF

A WAN-facing VRF is created to support FVRF for DMVPN. The VRF name is arbitrary, but it is useful to select a name that describes the VRF. The VRF must be enabled for IPv4.

Table 24 VRF assignments

IWAN design model	Primary WAN VRF	Secondary WAN VRF
Hybrid	IWAN-TRANSPORT-1	IWAN-TRANSPORT-2

This design uses VRF Lite, so the selection is only locally significant to the device. It is a best practice to use the same VRF/RD combination across multiple devices when using VRFs in a similar manner. However, this convention is not strictly required.

Step 1: Configure the secondary WAN VRF.

Example: Secondary WAN in the IWAN hybrid design model

```
vrf definition IWAN-TRANSPORT-2
 address-family ipv4
```

Procedure 4 Connect to the Internet

The remote sites using DMVPN can use either static or dynamically assigned IP addresses. Cisco tested the design with a DHCP assigned external address, which also provides a dynamically configured default route.

The DMVPN spoke router connects directly to the Internet without a separate firewall. This connection is secured in two ways. Because the Internet interface is in a separate VRF, no traffic can access the global VRF except traffic sourced through the DMVPN tunnel. This design provides implicit security. Additionally, an IP access list permits only the traffic required for an encrypted tunnel, as well as DHCP and various ICMP protocols for troubleshooting.

Step 1: Enable the interface, select VRF and enable DHCP.

The DMVPN design uses FVRF, so you must place this interface into the VRF configured in the previous procedure.

```
interface GigabitEthernet0/0
 vrf forwarding IWAN-TRANSPORT-2
 ip address dhcp
 no cdp enable
 no shutdown
```

Do not enable PIM on this interface because no multicast traffic should be requested from this interface.

Step 2: Configure and apply the access list.

The IP access list must permit the protocols specified in the following table. The access list is applied inbound on the WAN interface, so filtering is done on traffic destined to the router.

Table 25 Required DMVPN protocols

Name	Protocol	Usage
non500-isakmp	UDP 4500	IPsec via NAT-T
isakmp	UDP 500	ISAKMP
esp	IP 50	IPsec
bootpc	UDP 68	DHCP

Example

```
interface GigabitEthernet0/0
 ip access-group ACL-INET-PUBLIC in

ip access-list extended ACL-INET-PUBLIC
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit esp any any
 permit udp any any eq bootpc
```

The additional protocols listed in the following table may assist in troubleshooting, but are not explicitly required to allow DMVPN to function properly.

Table 26 Optional protocols: DMVPN spoke router

Name	Protocol	Usage
icmp echo	ICMP Type 0, Code 0	Allow remote pings
icmp echo-reply	ICMP Type 8, Code 0	Allow ping replies (from your requests)
icmp ttl-exceeded	ICMP Type 11, Code 0	Allow traceroute replies (from your requests)
icmp port-unreachable	ICMP Type 3, Code 3	Allow traceroute replies (from your requests)
UDP high ports	UDP > 1023, TTL=1	Allow remote traceroute

The additional optional entries for an access list to support ping are as follows:

```
permit icmp any any echo
permit icmp any any echo-reply
```

The additional optional entries for an access list to support traceroute are as follows:

```
permit icmp any any ttl-exceeded      ! for traceroute (sourced)
permit icmp any any port-unreachable  ! for traceroute (sourced)
permit udp any any gt 1023 ttl eq 1   ! for traceroute (destination)
```

Procedure 5 Configure IKEv2 and IPsec

To complete the IKEv2 and IPsec configuration for this router, follow the steps in "Configure IKEv2 and IPsec for a remote site router" in Appendix B.

Procedure 6 Configure the mGRE tunnel

This procedure uses the parameters in the table below. This procedure applies to the Secondary WAN.

Table 27 DMVPN tunnel parameters

IWAN design model	Tunnel VRF	Tunnel number	Tunnel network	NHRP network ID/ tunnel key
Hybrid—Primary WAN	IWAN-TRANSPORT-1	100	10.6.34.0/23	1100
Hybrid—Secondary WAN	IWAN-TRANSPORT-2	200	10.6.36.0/23	1200

Step 1: Configure basic interface settings.

The tunnel number is arbitrary, but it is best to begin tunnel numbering at 10 or above, because other features deployed in this design may also require tunnels and they may select lower numbers by default.`

You must set the bandwidth setting to match the bandwidth of the respective transport, which corresponds to the actual interface speed. Or, if you are using a subrate service, use the policed rate from the carrier. QoS and PfR require the correct bandwidth setting to operate properly.

Configure the **ip mtu** to 1400 and the **ip tcp adjust-mss** to 1360. There is a 40 byte difference, which corresponds to the combined IP and TCP header length.

Tech Tip

An IPv6 underlay requires an **ip mtu** of 1380 and an **ip tcp adjust-mss** of 1340.

```
interface Tunnel200
 description INET1
 bandwidth 30000
 ip address 10.6.36.12 255.255.254.0
 no ip redirects
 ip mtu 1400
 ip tcp adjust-mss 1360
```

Step 2: Configure the tunnel.

DMVPN uses mGRE tunnels. This type of tunnel requires a source interface only. The source interface should be the same interface you use to connect to the Internet. You should set the **tunnel vrf** command to the VRF defined previously for FVRF.

To enable encryption on this interface, you must apply the IPsec profile that you configured in the previous procedure.

```
interface Tunnel200
 tunnel source GigabitEthernet0/0
 tunnel mode gre multipoint
 tunnel key 1200
 tunnel vrf IWAN-TRANSPORT-2
 tunnel protection ipsec profile DMVPN-IPSEC-PROFILE
```

Step 3: Configure NHRP.

The spoke router requires an additional configuration statement to define the NHRP server. This statement includes the NBMA definition for the DMVPN hub router tunnel endpoint. Spoke routers require the NHRP multicast keyword in this statement.

When hub BRs are added for horizontal scaling or a second data center is added as a transit site, spoke routers require additional NHS statements for each BR in their environment. The configuration details are covered in subsequent sections of this guide.

The value used for the NHS is the mGRE tunnel address for the DMVPN hub router. The NBMA entry must be set to either the MPLS DMVPN hub router's actual public address or the outside NAT value of the DMVPN hub, as configured on the Cisco ASA 5500. This design uses the values shown in the following tables.

Table 28 DMVPN tunnel NHRP parameters: IWAN hybrid design model

	Transport 1	Transport 2
VRF	IWAN-TRANSPORT-1	IWAN-TRANSPORT-2
DMVPN hub public address (actual)	192.168.6.1	192.168.146.10
DMVPN hub public address (externally routable after NAT)	n/a (MPLS1)	172.16.140.1
DMVPN hub tunnel IP address (NHS)	10.6.34.1	10.6.36.1
Tunnel number	100	200
NHRP network ID	1100	1200

NHRP requires all devices within a DMVPN cloud to use the same network ID and authentication key. The NHRP cache holdtime should be configured to 600 seconds.

This design supports DMVPN spoke routers that receive their external IP addresses through DHCP. It is possible for these routers to acquire different IP addresses after a reload. When the router attempts to register with the NHRP server, it may appear as a duplicate to an entry already in the cache and be rejected. The **registration no-unique** option allows you to overwrite existing cache entries. This feature is only required on NHRP clients (DMVPN spoke routers). The **if-state nhrp** option ties the tunnel line-protocol state to the reachability of the NHRP NHS, and if the NHS is unreachable the tunnel line-protocol state changes to down. This feature is used in conjunction with EOT.

```
interface Tunnel200
 ip nhrp authentication cisco123
 ip nhrp network-id 1200
 ip nhrp nhs 10.6.36.1 nbma 172.16.140.1 multicast
 ip nhrp registration no-unique
 if-state nhrp
```

It is not necessary to disable **nhrp route-watch** on the second router of a dual router remote site location because there is only one WAN path in the RIB.

Procedure 7 Configure the routing protocol on the WAN

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

The following table shows the DMVPN tunnel names and EIGRP WAN delay in use.

Table 29 EIGRP WAN delay for IWAN hybrid remote-site routers

DMVPN Tunnel	EIGRP WAN Delay (10 usec)
Tunnel100	1000 (MPLS1)
Tunnel200	20000 (INET1)

A single EIGRP process runs on the DMVPN spoke router. All interfaces on the router are EIGRP interfaces, but only the DMVPN tunnel interface is non-passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address. All DMVPN spoke routers should run EIGRP stub-site routing in order to improve network stability and reduce resource utilization. It is a best practice use the EIGRP AS number and remote site id in the form of AS:NN for the stub-site command.

Step 1: Configure an EIGRP process for DMVPN by using EIGRP named mode on the spoke router.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface default
   passive-interface
  exit-af-interface
  af-interface Tunnel200
   no passive-interface
  exit-af-interface
network 10.6.36.0 0.0.1.255
network 10.7.0.0 0.0.255.255
network 10.255.0.0 0.0.255.255
eigrp router-id 10.255.243.12
eigrp stub-site 400:12
exit-address-family
```

Step 2: Configure EIGRP values for the mGRE tunnel interface.

The EIGRP hello interval is increased to 20 seconds and the EIGRP hold time is increased to 60 seconds in order to accommodate up to 2000 remote sites on a single DMVPN cloud. Increasing the EIGRP timers also slows down the routing convergence to improve network stability and the IWAN design allows PfR to initiate the fast failover, so changing the timers is recommended for all IWAN deployments.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel200
   hello-interval 20
   hold-time 60
  exit-af-interface
exit-address-family
```

Step 3: Configure EIGRP neighbor authentication. Neighbor authentication enables the secure establishment of peering adjacencies and exchange route tables over the DMVPN tunnel interface.

```
key chain WAN-KEY
 key 1
  key-string c1sco123


router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel200
   authentication mode md5
   authentication key-chain WAN-KEY
  exit-af-interface
 exit-address-family
```

Step 4: Configure EIGRP network summarization.

The remote-site LAN networks must be advertised. The IP assignment for the remote sites was designed so that all of the networks in use can be summarized within a single aggregate route. As configured below, the **summary-address** command suppresses the more specific routes. If any network within the summary is present in the route table, the summary is advertised to the DMVPN hub, which offers a measure of resiliency. If the various LAN networks cannot be summarized, then EIGRP continues to advertise the specific routes.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel200
   summary-address [summary network] [summary mask]
  exit-af-interface
 exit-address-family
```

Step 5: Configure the throughput delay on the tunnel interface.

Step 6: The tunnel interface throughput delay setting should be set to influence the routing protocol path preference. Set the primary WAN path to 10000 usec and the secondary WAN path to 200000 usec to prefer one over the other. The delay command is entered in 10 usec units.

```
interface Tunnel200
 delay 20000
```

Step 7: Add the stub-site wan-interface.

You add one command to each af-interface tunnel in order to identify it as the stub-site wan-interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Tunnel200
   stub-site wan-interface
  exit-af-interface
 exit-address-family
```

Step 8: Block the tunnel addresses from being advertised on the WAN by using IP prefix lists and a route map.

```
ip prefix-list TUNNEL-ROUTES seq 10 permit 10.6.34.0/23
ip prefix-list TUNNEL-ROUTES seq 20 permit 10.6.36.0/23

route-map BLOCK_TUNNEL_ROUTES deny 10
 description Block the tunnel routes
 match ip address prefix-list TUNNEL-ROUTES

route-map BLOCK_TUNNEL_ROUTES permit 20
 description Permit the rest of the routes
```

Step 9: Apply an outbound distribute list to the tunnel interface.

Use the route map from the previous step to block the routes.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK_TUNNEL_ROUTES out Tunnel200
  exit-af-topology
exit-address-family
```

Step 10: Proceed to Procedure 8 “Configure IP multicast routing for tunnel.”

Option 2: BGP on the WAN

Step 1: Configure BGP values for the mGRE tunnel interface.

Use a private AS number for the BGP process. Assign this router's loopback address as the BGP router-id. Log the neighbor changes. For internal BPG, use the same AS number for the remote sites. Use the tunnel interface as the update source. Adjust the BGP hello and hold timers to 20 seconds and 60 seconds, respectively. Peer to the hub border router.

```
router bgp 65100
 bgp router-id 10.255.243.12
 bgp log-neighbor-changes
 neighbor INET1-HUB peer-group
 neighbor INET1-HUB remote-as 65100
 neighbor INET1-HUB description To IWAN INET1 Hub Router
 neighbor INET1-HUB update-source Tunnel200
 neighbor INET1-HUB timers 20 60
 neighbor 10.6.36.1 peer-group INET1-HUB
```

Step 2: Configure the BGP address family.

Redistribute BGP internal routes and advertise an aggregate address for the site specific super-net prefix. Set next-hop-self, set the weight to 50000, and turn on soft reconfiguration inbound. Activate the BGP connection to the DMVPN hub border router and set the BGP distance.

```
router bgp 65100
 address-family ipv4
  bgp redistribute-internal
  aggregate-address 10.7.16.0 255.255.248.0 summary-only
  neighbor INET1-HUB next-hop-self all
  neighbor INET1-HUB weight 50000
  neighbor INET1-HUB soft-reconfiguration inbound
  neighbor 10.6.36.1 activate
  distance bgp 201 19 200
exit-address-family
```

Step 3: Create the prefix lists for BGP.

Define the prefix-lists for both remote site routers' loopback ip addresses and the site-specific prefixes.

```
ip prefix-list LOCAL-LOOPBACKS seq 10 permit 10.255.241.12/32
ip prefix-list LOCAL-LOOPBACKS seq 20 permit 10.255.243.12/32
ip prefix-list LOCAL-SUBNETS seq 10 permit 10.7.16.0/21
```

Step 4: Create and apply the prefix route maps for BGP.

Define the route map to allow prefixes to go out on the tunnel interface. Apply the route map to the BGP address family for the hub border router.

```
route-map SPOKE-OUT permit 10
 description Match the local networks
 match ip address prefix-list LOCAL-LOOPBACKS LOCAL-SUBNETS

router bgp 65100
 address-family ipv4
  neighbor INET1-HUB route-map SPOKE-OUT out
```

Procedure 8 Configure IP multicast routing for tunnel

Optional

This optional procedure includes additional steps for configuring IP Multicast for a DMVPN tunnel on a router with IP Multicast already enabled. Skip this procedure if you do not want to use IP Multicast in your environment.

Step 1: Configure PIM on the DMVPN tunnel interface.

Enable IP PIM sparse mode on the DMVPN tunnel interface.

```
interface Tunnel200
 ip pim sparse-mode
```

Step 2: Configure the DR priority for the DMVPN spoke router.

Proper multicast operation across a DMVPN cloud requires that the hub router assumes the role of PIM DR. Spoke routers should never become the DR. You can prevent that by setting the DR priority to 0 for the spokes.

```
interface Tunnel200
 ip pim dr-priority 0
```

Procedure 9 Connect router to access layer switch

Optional

If you are using a remote-site distribution layer, skip to the "Configuring Second Router for Remote-Site Distribution Layer" process.

Reader Tip

This guide includes only the additional steps needed to complete the access layer configuration. For complete access layer configuration details, refer to the Campus LAN Layer 2 Access with Simplified Distribution Deployment Guide .

Layer 2 EtherChannels are used to interconnect the router to the access layer in the most resilient method possible, unless the access layer device is a single fixed configuration switch, Otherwise a simple Layer 2 trunk between the router and switch is used.

In the access layer design, the remote sites use collapsed routing, with 802.1Q trunk interfaces to the LAN access layer. The VLAN numbering is locally significant only.

Option 1: Layer 2 EtherChannel from router to access layer switch

Step 1: Configure port-channel interface on the router.

```
interface Port-channel2
 description EtherChannel link to RS12-A2960X
 no shutdown
```

Step 2: Configure EtherChannel member interfaces on the router.

Configure the physical interfaces to tie to the logical port-channel using the channel-group command. The number for the port-channel and channel-group must match. Not all router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet0/1
 description RS12-A2960X Gig1/0/48

interface GigabitEthernet0/2
 description RS12-A2960X Gig2/0/48

interface range GigabitEthernet0/1, GigabitEthernet0/2
  no ip address
  channel-group 2
  no shutdown
```

Step 3: Configure EtherChannel member interfaces on the access layer switch.

Connect the router EtherChannel uplinks to separate switches in the access layer switch stack.

The physical interfaces that are members of a Layer 2 EtherChannel are configured prior to configuring the logical port-channel interface. Doing the configuration in this order allows for minimal configuration and reduces errors because most of the commands entered to a port-channel interface are copied to its members interfaces and do not require manual replication.

Configure two or more physical interfaces to be members of the EtherChannel. It is recommended that they are added in multiples of two. Also, apply the egress QoS macro that was defined in the platform configuration procedure to ensure traffic is prioritized appropriately.

Not all connected router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet1/0/48
 description Link to RS12-2911-2 Gig0/1

interface GigabitEthernet2/0/48
 description Link to RS12-2911-2 Gig0/2

interface range GigabitEthernet1/0/48, GigabitEthernet2/0/48
 switchport
 channel-group 2 mode on
 logging event link-status
 logging event trunk-status
 logging event bundle-status
 load-interval 30
 macro apply EgressQoS
```

Step 4: Configure EtherChannel trunk on the access layer switch.

An 802.1Q trunk is used, which allows the router to provide the Layer 3 services to all the VLANs defined on the access layer switch. The VLANs allowed on the trunk are pruned to only the VLANs that are active on the access layer switch. When using EtherChannel the interface type will be port-channel and the number must match the channel group configured in Step 3. DHCP Snooping and ARP inspection are set to trust.

```
interface Port-channel2
 description EtherChannel link to RS12-2911-2
 switchport trunk allowed vlan 64,69,99
 switchport mode trunk
 ip arp inspection trust
 spanning-tree portfast trunk
 ip dhcp snooping trust
 load-interval 30
 no shutdown
```

The Cisco Catalyst 3750 Series Switch requires the **switchport trunk encapsulation dot1q** command.

Option 2: Layer 2 trunk from router to access layer switch

Step 1: Enable the physical interface on the router.

```
interface GigabitEthernet0/2
 description RS12-A2960X Gig1/0/48
 no ip address
 no shutdown
```

Step 2: Configure the trunk on the access layer switch.

Use an 802.1Q trunk for the connection, which allows the router to provide the Layer 3 services to all the VLANs defined on the access layer switch. The VLANs allowed on the trunk are pruned to only the VLANs that are active on the access switch. DHCP Snooping and ARP inspection are set to trust.

```
interface  GigabitEthernet1/0/48
 description Link to RS12-2911-2 Gig0/2
 switchport trunk allowed vlan 64,69,99
 switchport mode trunk
 ip arp inspection trust
 spanning-tree portfast trunk
 logging event link-status
 logging event trunk-status
 ip dhcp snooping trust
 no shutdown
 load-interval 30
 macro apply EgressQoS
```

The Cisco Catalyst 3750 Series Switch requires the **switchport trunk encapsulation dot1q** command.

Procedure 10 Configure access layer interfaces

Step 1: Create subinterfaces and assign VLAN tags.

After the physical interface or port-channel have been enabled, then the appropriate data or voice subinterfaces can be mapped to the VLANs on the LAN switch. The subinterface number does not need to equate to the 802.1Q tag, but making them the same simplifies the overall configuration. The subinterface portion of the configuration should be repeated for all data or voice VLANs.

```
interface [type][number].[sub-interface number]
 encapsulation dot1Q [dot1q VLAN tag]
```

Step 2: Configure IP settings for each subinterface.

This design uses an IP addressing convention with the default gateway router assigned an IP address and IP mask combination of **N.N.N.1 255.255.255.0** where N.N.N is the IP network and 1 is the IP host.

When you are using a centralized DHCP server, your routers with LAN interfaces connected to a LAN using DHCP for end-station IP addressing must use an IP helper.

This remote-site DMVPN spoke router is the second router of a dual-router design and HSRP is configured at the access layer. The actual interface IP assignments will be configured in the following procedure.

```
interface  [type][number].[sub-interface number]
 description [usage]
 encapsulation dot1Q [dot1q VLAN tag]
 ip helper-address 10.4.48.10
 ip pim sparse-mode
```

Example: Layer 2 port-channel

```
interface Port-channel2
 no ip address
 no shutdown

interface Port-channel2.64
 description Data
 encapsulation dot1Q 64
 ip helper-address 10.4.48.10
 ip pim sparse-mode

interface Port-channel2.69
 description Voice
 encapsulation dot1Q 69
 ip helper-address 10.4.48.10
 ip pim sparse-mode
```

Example: Layer 2 Gigabit Ethernet

```
interface GigabitEthernet0/2
 no ip address
 no shutdown

interface GigabitEthernet0/2.64
 description Data
 encapsulation dot1Q 64
 ip helper-address 10.4.48.10
 ip pim sparse-mode

interface GigabitEthernet0/2.69
 description Voice
 encapsulation dot1Q 69
 ip helper-address 10.4.48.10
 ip pim sparse-mode
```

Procedure 11 Configure access layer HSRP

You configure HSRP to enable a VIP that you use as a default gateway that is shared between two routers. The HSRP active router is the router connected to the primary carrier and the HSRP standby router is the router connected to the secondary carrier or backup link.

Step 1: Configure the HSRP standby router with a standby priority that is lower than the HSRP active router.

The router with the higher standby priority value is elected as the HSRP active router. The preempt option allows a router with a higher priority to become the HSRP active, without waiting for a scenario where there is no router in the HSRP active state. The relevant HSRP parameters for the router configuration are shown in the following table.

Table 30 WAN remote-site HSRP parameters (dual router)

Router	HSRP role	VIP	Real IP address	HSRP priority	PIM DR priority
Primary	Active	.1	.2	110	110
Secondary	Standby	.1	.3	105	105

The dual-router access-layer design requires a modification for resilient multicast. The PIM DR should be on the HSRP active router. The DR is normally elected based on the highest IP address and has no awareness of the HSRP configuration. In this design, the HSRP active router has a lower real IP address than the HSRP standby router, which requires a modification to the PIM configuration. The PIM DR election can be influenced by explicitly setting the DR priority on the LAN-facing subinterfaces for the routers.

Tech Tip

The HSRP priority and PIM DR priority are shown in the previous table to be the same value; however there is no requirement that these values must be identical.

Step 2: Repeat this procedure for all data or voice subinterfaces.

```
interface [interface type][number].[sub-interface number]
 ip address [LAN network 1 address] [LAN network 1 netmask]
 ip pim dr-priority 105
 standby version 2
 standby 1 ip [LAN network 1 gateway address]
 standby 1 priority 105
 standby 1 preempt
 standby 1 authentication md5 key-string c1sco123
```

Example: Layer 2 port-channel

```
interface PortChannel2
 no ip address
 no shutdown

interface PortChannel2.64
 description Data
 encapsulation dot1Q 64
 ip address 10.7.18.3 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim dr-priority 105
 ip pim sparse-mode
 standby version 2
 standby 1 ip 10.7.18.1
 standby 1 priority 105
 standby 1 preempt
 standby 1 authentication md5 key-string c1sco123

interface PortChannel2.69
 description Voice
 encapsulation dot1Q 69
 ip address 10.7.19.3 255.255.255.0
```

```
 ip helper-address 10.4.48.10
 ip pim dr-priority 105
 ip pim sparse-mode
 standby version 2
 standby 1 ip 10.7.19.1
 standby 1 priority 105
 standby 1 preempt
 standby 1 authentication md5 key-string c1sco123
```

Example: Layer 2 Gigabit Ethernet

```
interface GigabitEthernet0/2
 no ip address
 no shutdown

interface GigabitEthernet0/2.64
 description Data
 encapsulation dot1Q 64
 ip address 10.7.18.3 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim dr-priority 105
 ip pim sparse-mode
 standby version 2
 standby 1 ip 10.7.18.1
 standby 1 priority 105
 standby 1 preempt
 standby 1 authentication md5 key-string c1sco123

interface GigabitEthernet0/2.69
 description Voice
 encapsulation dot1Q 69
 ip address 10.7.19.3 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim dr-priority 105
 ip pim sparse-mode
 standby version 2
 standby 1 ip 10.7.19.1
```

```
standby 1 priority 105
standby 1 preempt
standby 1 authentication md5 key-string c1sco123
```

Procedure 12 Configure transit network for dual router design

You use this network for router-router communication and to avoid hairpinning. The transit network should use an additional subinterface on the router interface that is already being used for data or voice.

Step 1: Configure the transit network between the two routers.

There are no end stations connected to this network, so HSRP and DHCP are not required.

```
interface [interface type][number].[sub-interface number]
 encapsulation dot1Q [dot1q VLAN tag]
 ip address [transit net address] [transit net netmask]
 ip pim sparse-mode
```

Example: Layer 2 port-channel

```
interface PortChannel2.99
 description Transit Net
 encapsulation dot1Q 99
 ip address 10.7.16.10 255.255.255.252
 ip pim sparse-mode
```

Example: Layer 2 Gigabit Ethernet

```
interface GigabitEthernet0/2.99
 description Transit Net
 encapsulation dot1Q 99
 ip address 10.7.16.10 255.255.255.252
 ip pim sparse-mode
```

Procedure 13 Configure the routing protocol on the transit network

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the transit network

The following table shows the EIGRP transit network delay in use.

Table 31 EIGRP transit network delay for IWAN remote-site routers

LAN Interface	EIGRP LAN Delay (10 usec)
Transit	24000

A single EIGRP process runs on the DMVPN spoke router, which has already been enabled during the configuration of the DMVPN tunnel. All interfaces on the router are EIGRP interfaces, but only the DMVPN tunnel interface and transit network are non-passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements.

Step 1: Configure the transit network subinterface as non-passive.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
   af-interface GigabitEthernet0/2.99
    no passive-interface
   exit-af-interface
 exit-address-family
```

Step 2: Configure EIGRP neighbor authentication. Neighbor authentication enables the secure establishment of peering adjacencies and exchange route tables over the transit network interface.

```
key chain LAN-KEY
 key 1
  key-string c1sco123

router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface GigabitEthernet0/2.99
   authentication mode md5
   authentication key-chain LAN-KEY
  exit-af-interface
 exit-address-family
```

Step 3: Configure the throughput delay on the transit network interface.

At a remote site location where there are multiple border routers, the interface throughput delay setting should be set to influence the routing protocol path preference. Set the transit network LAN path to 240000 usec. The delay command is entered in 10 usec units.

```
interface GigabitEthernet0/2.99
 delay 24000
```

Option 2: OSPF on the transit network

A single OSPF process runs on the DMVPN spoke router.

Step 1: Configure OSPF Area 0 by using the network summary address and the loopback interface IP address as the router-id. Turn on default information originate in order to advertise a default route into the OSPF domain.

```
router ospf 100
 router-id 10.255.243.12
 network 10.7.16.0 0.0.7.255 area 0
 network 10.255.243.12 0.0.0.0 area 0
 default-information originate
```

Step 2: Turn on passive-interface as the default and remove it for the transit network LAN interface.

```
router ospf 100
 passive-interface default
 no passive-interface GigabitEthernet0/2.99
```

Step 3: Create a route map to block local subnets from OSPF and tag all the rest of the BGP routes coming into OSPF.

Block the local subnets using the **LOCAL-SUBNETS** prefix list created previously. Tag the rest of the routes from BGP with a value of 1.

```
route-map REDIST-BGP-TO-OSPF deny 10
 description Do not redistribute LOCAL SUBNETS into OSPF
 match ip address prefix-list LOCAL-SUBNETS


route-map REDIST-BGP-TO-OSPF permit 20
 description Identify routes redistributed from BGP
 set tag 1
```

Step 4: Redistribute BGP into OSPF using the route map from the previous step.

```
router ospf 100
 redistribute bgp 65100 subnets route-map REDIST-BGP-TO-OSPF
```

Step 5: Create a route map to block the routes with a tag value of 1.

Block routes with a tag of 1, but allow all internal, external type 1 and external type 2.

```
route-map REDIST-OSPF-TO-BGP deny 10
 description Block all routes redistributed from BGP
 match tag 1

route-map REDIST-OSPF-TO-BGP permit 20
 description Redistribute all other routes
 match route-type internal
 match route-type external type-1
 match route-type external type-2
```

Step 6: Redistribute OSPF into BGP by using the route map from the previous step.

```
router bgp 65100
 address-family ipv4
  redistribute ospf 100 route-map REDIST-OSPF-TO-BGP
 exit-address-family
```

Deploying an IWAN Remote-Site Distribution Layer

This process helps you configure a DMVPN spoke router for an IWAN remote site and connect to a distribution layer.

PROCESS

Configuring Remote-Site Router for Distribution Layer

1. Connect router to distribution layer
2. Configure distribution layer switch
3. Configure the routing protocol on the distribution layer link
4. Configure transit network for dual router design
5. Configure the routing protocol on the transit network

Use this process to:

- Connect a distribution layer to a router in the single-router, dual-link design.
- Connect a distribution layer to the first router of the dual-router, dual-link design.

The distribution layer remote-site options are shown in the following figures.

Figure 8 *IWAN single router remote-site: Connection to distribution layer*

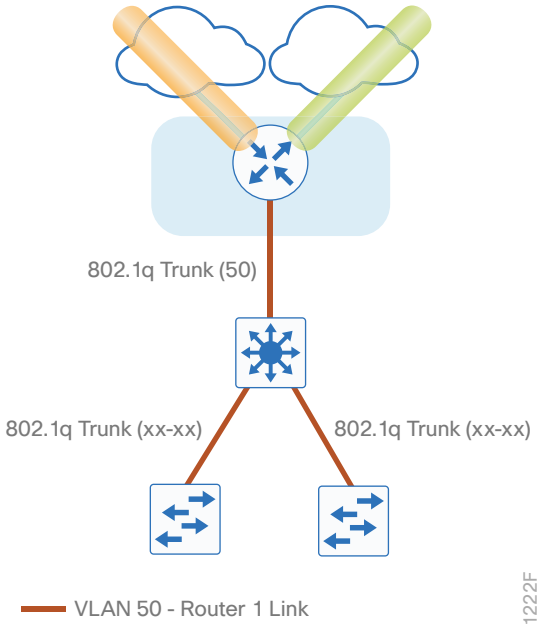
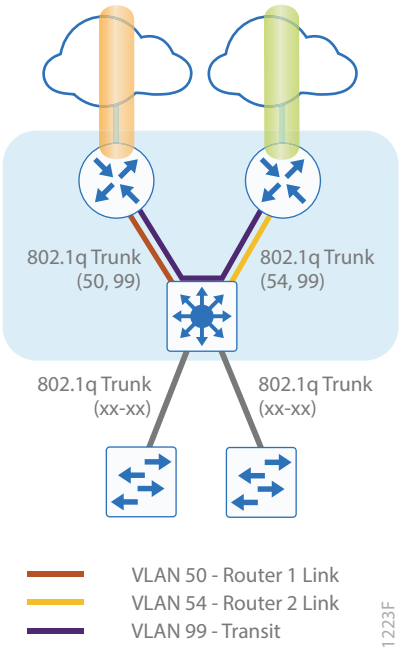


Figure 9 *IWAN dual router remote-site: Connection to distribution layer*



Procedure 1 Connect router to distribution layer

Reader Tip

This guide includes only the additional steps for completing the distribution layer configuration. For complete distribution layer configuration details, see the Campus LAN Layer 2 Access with Simplified Distribution Deployment Guide .

Layer 2 EtherChannels are used to interconnect the remote-site router to the distribution layer in the most resilient method possible. This connection allows for multiple VLANs to be included on the EtherChannel as necessary.

Step 1: Configure port-channel interface on the router.

```
interface Port-channel1
 description EtherChannel link to RS42-D3850
 no shutdown
```

Step 2: Configure the port channel sub-interfaces and assign IP addresses.

After you have enabled the interface, map the appropriate sub-interfaces to the VLANs on the distribution layer switch. The sub-interface number does not need to equate to the 802.1Q tag, but making them the same simplifies the overall configuration.

The sub-interface configured on the router corresponds to a VLAN interface on the distribution-layer switch. Traffic is routed between the devices with the VLAN acting as a point-to-point link.

```
interface Port-channel1.50
 description R1 routed link to distribution layer
 encapsulation dot1Q 50
 ip address 10.7.208.1 255.255.255.252
 ip pim sparse-mode
```

Step 3: Configure EtherChannel member interfaces on the router.

Configure the physical interfaces to tie to the logical port-channel using the channel-group command. The number for the port-channel and channel-group must match. Not all router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet0/0/2
 description RS42-D3850 Gig1/1/1

interface GigabitEthernet0/0/3
 description RS42-D3850 Gig2/1/1

interface range GigabitEthernet0/0/2, GigabitEthernet0/0/3
  no ip address
  channel-group 1
  no shutdown
```

Procedure 2 Configure distribution layer switch

Step 1: Configure VLAN on the distribution layer switch.

```
vlan 50
 name R1-link
```

Step 2: Configure Layer 3 on the distribution layer switch.

Configure a VLAN interface, also known as a switch virtual interface (SVI), for the new VLAN added. The SVI is used for point to point IP routing between the distribution layer and the WAN router.

```
interface Vlan50
 ip address 10.5.208.2 255.255.255.252
 ip pim sparse-mode
 no shutdown
```

Step 3: Configure EtherChannel member interfaces on the distribution layer switch.

Connect the router EtherChannel uplinks to separate switches in the distribution layer switches or stack.

The physical interfaces that are members of a Layer 2 EtherChannel are configured prior to configuring the logical port-channel interface. Doing the configuration in this order allows for minimal configuration and reduces errors because most of the commands entered to a port-channel interface are copied to its members interfaces and do not require manual replication.

Configure two or more physical interfaces to be members of the EtherChannel. It is recommended that they are added in multiples of two. Also, apply the egress QoS macro that was defined in the platform configuration procedure to ensure traffic is prioritized appropriately.

Not all connected router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet1/1/1
 description Link to RS42-4451X-1 Gig0/0/2

interface GigabitEthernet2/1/1
 description Link to RS42-4451X-1 Gig0/0/3

interface range GigabitEthernet1/1/1, GigabitEthernet2/1/1
 switchport
 channel-group 1 mode on
 logging event link-status
 logging event trunk-status
 logging event bundle-status
 load-interval 30
 macro apply EgressQoS
```

Step 4: Configure EtherChannel trunk on the distribution layer switch.

An 802.1Q trunk is used, which allows the router to provide the Layer 3 services to all the VLANs defined on the distribution layer switch. The VLANs allowed on the trunk are pruned to only the VLANs that are active on the distribution layer switch. When using EtherChannel the interface type will be port-channel and the number must match the channel group configured in Step 3. DHCP Snooping and ARP inspection are set to trust.

```
interface Port-channel1
 description EtherChannel link to RS42-4451X-1
 switchport trunk allowed vlan 50
 switchport mode trunk
 spanning-tree portfast trunk
 load-interval 30
 no shutdown
```

The Cisco Catalyst 3750 Series Switch requires the **switchport trunk encapsulation dot1q** command.

Procedure 3 Configure the routing protocol on the distribution layer link

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the distribution layer link

The following table shows the EIGRP LAN delay in use.

Table 32 EIGRP LAN delay for IWAN remote-site routers with distribution links

LAN Interface	EIGRP LAN Delay (10 usec)
All LAN	25000

A single EIGRP process runs on the DMVPN spoke router, which has already been enabled during configuration of the DMVPN tunnel. All interfaces on the router are EIGRP interfaces, but only the DMVPN tunnel interface and the link to the distribution layer are non-passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements.

Step 1: Configure the distribution layer link sub-interface as non-passive.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
   af-interface Port-channel1.50
    no passive-interface
   exit-af-interface
 exit-address-family
```

Step 2: Configure EIGRP neighbor authentication. Neighbor authentication enables the secure establishment of peering adjacencies and exchange route tables over the interface.

```
key chain LAN-KEY
 key 1
  key-string c1sco123

router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Port-channel1.50
   authentication mode md5
   authentication key-chain LAN-KEY
  exit-af-interface
 exit-address-family
```

Step 3: Configure the throughput delay on the LAN interface.

At the remote where there are multiple routers, the interface throughput delay setting should be set to influence the EIGRP routing protocol path preference.

> ***Tech Tip***
>
> If you are using Port-channel interfaces with two Gigabit Ethernet members as recommended in this guide, you will have to double the LAN path delay to 500000 microseconds (usec), instead of the standard IWAN setting of 250000.

Set the internal LAN path to 500000 microseconds (usec). The delay command is entered in 10 usec units.

```
interface Port-channel1.50
 delay 50000
```

Step 4: On the distribution layer switch VLAN interface, enable EIGRP.

EIGRP is already configured on the distribution layer switch. The VLAN interface that connects to the router must be configured for EIGRP neighbor authentication and as a non-passive EIGRP interface.

```
key chain LAN-KEY
 key 1
  key-string c1sco123

router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Vlan50
   authentication mode md5
   authentication key-chain LAN-KEY
   no passive-interface
  exit-af-interface
exit-address-family
```

Option 2: OSPF on the distribution layer link

Step 1: Configure OSPF Area 0 by using the network summary address and the loopback interface IP address as the router-id.

```
router ospf 100
 router-id 10.255.241.42
 passive-interface default
 network 10.7.208.0 0.0.7.255 area 0
 network 10.255.241.42 0.0.0.0 area 0
 default-information originate
```

Step 2: Turn on passive-interface as the default and remove it for the distribution layer link.

```
router ospf 100
 passive-interface default
 no passive-interface Port-channel1.50
```

Step 3: On the distribution layer switch VLAN interface, enable OSPF.

OSPF is already configured on the distribution layer switch. The VLAN interface that connects to the router must be configured as a non-passive OSPF interface.

```
router ospf 100
 no passive-interface Vlan50
```

If this is a dual-router site, skip to the next procedure.

Reader Tip

The next several steps are only needed if you are adding a distibution layer to a single-router site using BGP. If you are adding a distribution layer to a dual-router site, these steps were aready completed when you added the second router to the site.

Step 4: In the BGP process, remove redistribute connected, and then add redistribute internal.

The **redistribute connected** command is needed only for single router sites without a distibution layer. When adding a distribution layer to a single router remote site, remove the **redistribute connected** command and add the **bgp redistribute-internal** command.

```
router bgp 65100
 address-family ipv4
  no redistribute connected
  bgp redistribute-internal
 exit-address-family
```

Step 5: Create a route map to tag the BGP routes coming into OSPF.

Tag the routes from BGP with a value of 1.

```
route-map REDIST-BGP-TO-OSPF permit 10
 description Identify routes redistributed from BGP
 set tag 1
```

Step 6: Redistribute BGP into OSPF by using the route map from the previous step.

```
router ospf 100
 redistribute bgp 65100 subnets route-map REDIST-BGP-TO-OSPF
```

Step 7: Create a route map to block the routes with a tag value of 1.

Block routes with a tag of 1, but allow all internal, external type 1 and external type 2.

```
route-map REDIST-OSPF-TO-BGP deny 10
 description Block all routes redistributed from BGP
 match tag 1

route-map REDIST-OSPF-TO-BGP permit 20
 description Redistribute all other routes
 match route-type internal
 match route-type external type-1
 match route-type external type-2
```

Step 8: Redistribute OSPF into BGP by using the route map from the previous step.

```
router bgp 65100
 address-family ipv4
  redistribute ospf 100 route-map REDIST-OSPF-TO-BGP
 exit-address-family
```

Example: Single-router site with distribution layer—RS41-2921

```
router ospf 100
 router-id 10.255.241.41
 redistribute bgp 65100 subnets route-map REDIST-BGP-TO-OSPF
 passive-interface default
 no passive-interface Port-channel1.50
 network 10.7.192.0 0.0.7.255 area 0
 network 10.255.241.41 0.0.0.0 area 0
 default-information originate

router bgp 65100
 bgp router-id 10.255.241.41
 bgp log-neighbor-changes
 neighbor MPLS1-HUB peer-group
 neighbor MPLS1-HUB remote-as 65100
 neighbor MPLS1-HUB description To IWAN MPLS1 Hub Router
 neighbor MPLS1-HUB update-source Tunnel100
 neighbor MPLS1-HUB timers 20 60
```

```
 neighbor 10.6.34.1 peer-group MPLS1-HUB

 address-family ipv4
  bgp redistribute-internal
  aggregate-address 10.7.192.0 255.255.248.0 summary-only
  redistribute ospf 100 route-map REDIST-OSPF-TO-BGP
  neighbor MPLS1-HUB next-hop-self all
  neighbor MPLS1-HUB weight 50000
  neighbor MPLS1-HUB soft-reconfiguration inbound
  neighbor MPLS1-HUB route-map SPOKE-OUT out
  neighbor 10.6.34.1 activate
  distance bgp 201 19 200
 exit-address-family

ip prefix-list LOCAL-LOOPBACKS seq 10 permit 10.255.241.41/32

ip prefix-list LOCAL-SUBNETS seq 10 permit 10.7.192.0/21

route-map SPOKE-OUT permit 10
 description Match the local networks
 match ip address prefix-list LOCAL-LOOPBACKS LOCAL-SUBNETS

route-map REDIST-BGP-TO-OSPF permit 10
 description Identify routes redistributed from BGP
 set tag 1

route-map REDIST-OSPF-TO-BGP deny 10
 description Block all routes redistributed from BGP
 match tag 1

route-map REDIST-OSPF-TO-BGP permit 20
 description Redistribute all other routes
 match route-type internal
 match route-type external type-1
 match route-type external type-2
```

Procedure 4 Configure transit network for dual router design

This procedure is only for dual-router remote sites.

Step 1: Configure the transit network between the two routers.

You use this network for router-router communication and to avoid hairpinning. The transit network should use an additional sub-interface on the EtherChannel interface that is already used to connect to the distribution layer.

There are no end stations connected to this network so HSRP and DHCP are not required. The transit network uses Layer 2 pass through on the distribution layer switch, so no SVI is required.

```
interface Port-channel1.99
 description Transit Net
 encapsulation dot1Q 99
 ip address 10.7.208.9 255.255.255.252
 ip pim sparse-mode
```

Step 2: Configure transit network VLAN on the distribution layer switch.

```
vlan 99
 name Transit-net
```

Step 3: Add transit network VLAN to the existing distribution layer switch EtherChannel trunk.

```
interface Port-channel1
 switchport trunk allowed vlan add 99
```

Procedure 5 Configure the routing protocol on the transit network

This procedure is only for dual-router remote sites.

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the transit network

The following table shows the EIGRP transit network delay in use.

Table 33 EIGRP transit network delay for IWAN remote-site routers

LAN Interface	EIGRP LAN Delay (10 usec)
Transit	24000

Step 1: Enable EIGRP on the transit net interface on the router.

The transit network must be a non-passive EIGRP interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Port-channel1.99
   authentication mode md5
   authentication key-chain LAN-KEY
   no passive-interface
 exit-af-interface
exit-address-family
```

Step 2: Configure the throughput delay on the transit network interface.

At a remote site location where there are multiple border routers, the interface throughput delay setting should be set to influence the routing protocol path preference. Set the transit network LAN path to 240000 usec. The delay command is entered in 10 usec units.

```
interface Port-channel1.99
 delay 24000
```

Option 2: OSPF on the transit network

Step 1: Remove passive interface for the transit network interface.

```
router ospf 100
 no passive-interface Port-channel1.99
```

PROCESS

Configuring Second Router for Remote-Site Distribution Layer

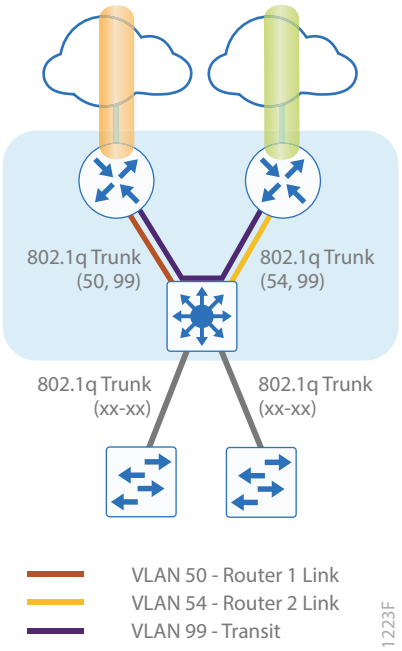
1. Connect router to distribution layer
2. Configure the routing protocol on the distribution layer link

This process helps you configure the second DMVPN spoke router for an IWAN remote site and connect to a distribution layer.

Use this process to connect a distribution layer to the second router of the dual-router, dual-link design.

The dual-router distribution layer remote-site option is shown in the following figure.

Figure 10 *WAN remote-site: Connection to distribution layer*



Procedure 1 Connect router to distribution layer

Reader Tip

Please refer to the Campus Wired LAN Design Guide for complete distribution layer configuration details. This guide only includes the additional steps to complete the distribution layer configuration.

Layer 2 EtherChannels are used to interconnect the remote-site router to the distribution layer in the most resilient method possible. This connection allows for multiple VLANs to be included on the EtherChannel as necessary.

Step 1: Configure port-channel interface on the router.

```
interface Port-channel2
 description EtherChannel link to RS42-D3850
 no shutdown
```

Step 2: Configure the port channel sub-interfaces and assign IP address.

After you have enabled the interface, map the appropriate sub-interfaces to the VLANs on the distribution layer switch. The sub-interface number does not need to equate to the 802.1Q tag, but making them the same simplifies the overall configuration.

The sub-interface configured on the router corresponds to a VLAN interface on the distribution-layer switch. Traffic is routed between the devices with the VLAN acting as a point-to-point link.

```
interface Port-channel2.54
 description R2 routed link to distribution layer
 encapsulation dot1Q 54
 ip address 10.7.208.5 255.255.255.252
 ip pim sparse-mode
```

Step 3: Configure the transit network interface on the router.

```
interface Port-channel2.99
 description Transit Net
 encapsulation dot1Q 99
 ip address 10.7.208.10 255.255.255.252
 ip pim sparse-mode
```

Step 4: Configure EtherChannel member interfaces on the router.

Configure the physical interfaces to tie to the logical port-channel using the channel-group command. The number for the port-channel and channel-group must match. Not all router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet0/0/2
 description RS42-D3850X Gig1/1/2

interface GigabitEthernet0/0/3
 description RS42-D3850X Gig2/1/2

interface range GigabitEthernet0/0/2, GigabitEthernet0/0/3
  no ip address
  channel-group 2
  no shutdown
```

Step 5: Configure VLAN on the distribution layer switch.

```
vlan 54
 name R2-link
```

Step 6: Configure Layer 3 on the distribution layer switch.

Configure a VLAN interface, also known as a SVI, for the new VLAN added. The SVI is used for point to point IP routing between the distribution layer and the WAN router.

```
interface Vlan54
 ip address 10.7.208.6 255.255.255.252
 ip pim sparse-mode
 no shutdown
```

Step 7: Configure EtherChannel member interfaces on the distribution layer switch.

Connect the router EtherChannel uplinks to separate switches in the distribution layer switches or stack.

The physical interfaces that are members of a Layer 2 EtherChannel are configured prior to configuring the logical port-channel interface. Doing the configuration in this order allows for minimal configuration and reduces errors because most of the commands entered to a port-channel interface are copied to its members interfaces and do not require manual replication.

Configure two or more physical interfaces to be members of the EtherChannel. It is recommended that they are added in multiples of two. Also, apply the egress QoS macro that was defined in the platform configuration procedure to ensure traffic is prioritized appropriately.

Not all connected router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet1/1/2
 description Link to RS42-4451X-2 Gig0/0/2
interface GigabitEthernet2/1/2
 description Link to RS42-4451X-2 Gig0/0/3

interface range GigabitEthernet1/1/2, GigabitEthernet2/1/2
 switchport
 channel-group 2 mode on
 logging event link-status
 logging event trunk-status
 logging event bundle-status
 load-interval 30
 macro apply EgressQoS
```

Step 8: Configure EtherChannel trunk on the distribution layer switch.

An 802.1Q trunk is used, which allows the router to provide the Layer 3 services to all the VLANs defined on the distribution layer switch. The VLANs allowed on the trunk are pruned to only the VLANs that are active on the distribution layer switch. When using EtherChannel the interface type will be port-channel and the number must match the channel group configured in Step 3. DHCP Snooping and ARP inspection are set to trust.

```
interface Port-channel2
 description EtherChannel link to RS42-4451X-2
 switchport trunk allowed vlan 54,99
 switchport mode trunk
 spanning-tree portfast trunk
 no shutdown
```

The Cisco Catalyst 3750 Series Switch requires the **switchport trunk encapsulation dot1q** command.

Procedure 2 Configure the routing protocol on the distribution layer link

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the distribution layer link

The following table shows the EIGRP network delay in use.

Table 34 EIGRP delay for IWAN remote-site routers

LAN Interface	EIGRP LAN Delay (10 usec)
LAN	50000
Transit	24000

A single EIGRP process runs on the DMVPN spoke router, which has already been enabled during DMVPN tunnel configuration. All interfaces on the router are EIGRP interfaces, but only the DMVPN tunnel interface, the link to the distribution layer, and the transit network link are non-passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements.

Step 1: Configure the distribution layer link subinterface as non-passive.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
   af-interface Port-channel2.54
    no passive-interface
   exit-af-interface
 exit-address-family
```

Step 2: Configure the transit network link subinterface as non-passive.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
   af-interface Port-channel2.99
    no passive-interface
   exit-af-interface
 exit-address-family
```

Step 3: Configure EIGRP neighbor authentication. Neighbor authentication enables the secure establishment of peering adjacencies and exchange route tables over the interface.

```
key chain LAN-KEY
 key 1
  key-string c1sco123

router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Port-channel2.54
   authentication mode md5
   authentication key-chain LAN-KEY
  exit-af-interface
af-interface Port-channel2.99
   authentication mode md5
   authentication key-chain LAN-KEY
  exit-af-interface
 exit-address-family
```

Step 4: Configure the throughput delay on the LAN interface.

At the remote where there are multiple routers, the interface throughput delay setting should be set to influence the EIGRP routing protocol path preference.

Tech Tip

If you are using Port-channel interfaces with two Gigabit Ethernet members as recommended in this guide, you will have to double the LAN path delay to 500000 microseconds (usec), instead of the standard IWAN setting of 250000.

Set the internal LAN path to 500000 microseconds (usec). The delay command is entered in 10 usec units.

```
interface Port-channel2.54
 delay 50000
```

Step 5: Configure the throughput delay on the transit network interface.

Set the transit network LAN path to 240000 usec. The delay command is entered in 10 usec units.

```
interface Port-channel2.99
 delay 24000
```

Step 6: Enable EIGRP on distribution layer switch VLAN interface.

EIGRP is already configured on the distribution layer switch. The VLAN interface that connects to the router must be configured for EIGRP neighbor authentication and as a non-passive EIGRP interface.

```
key chain LAN-KEY
 key 1
  key-string c1sco123

router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Vlan54
   authentication mode md5
   authentication key-chain LAN-KEY
   no passive-interface
  exit-af-interface
exit-address-family
```

Option 2: OSPF on the distribution layer link

Step 1: Configure OSPF Area 0 by using the network summary address and the loopback interface IP address as the router-id.

```
router ospf 100
 router-id 10.255.243.42
 passive-interface default
 network 10.7.208.0 0.0.7.255 area 0
 network 10.255.243.42 0.0.0.0 area 0
 default-information originate
```

Step 2: Turn on passive-interface as the default and remove it for the distribution layer link and the transit network.

```
router ospf 100
 passive-interface default
 no passive-interface Port-channel2.54
 no passive-interface Port-channel2.99
```

Step 3: On the distribution layer switch VLAN interface, enable OSPF.

OSPF is already configured on the distribution layer switch. The VLAN interface that connects to the router must be configured as a non-passive OSPF interface.

```
router ospf 100
 no passive-interface Vlan350
```

Deploying IWAN Performance Routing

Performance Routing Version 3 (PfRv3) consists of two major Cisco IOS components, an MC and a BR. The MC defines the policies and applies them to various traffic classes that traverse the BR systems. The MC can be configured to learn and control traffic classes on the network.

- The MC is the policy decision-maker. At a large site, such as a data center or campus, the MC is a standalone router. For smaller locations, the MC is typically collocated (configured) on the same platform as the BR. As a general rule, the large locations manage more network prefixes and applications than a remote site deployment so they consume more CPU and memory resources for the MC function. Therefore, Cisco recommends a dedicated router for the MC at large sites.
- The BR is in the data-forwarding path. A BR collects data from its Performance Monitor cache and smart probes, provides a degree of aggregation of this information, and influences the packet-forwarding path as directed by the MC to optimize traffic.

The remote site typically manages fewer active TCs, which are made up of prefixes and applications. In most remote site deployments, it is possible to co-locate the MC and BR on the same hardware platform. CPU and memory utilization should be monitored on MC platforms, and if utilization is high, the network manager should consider an MC platform with a higher capacity CPU and memory. The MC communicates with the border routers over an authenticated TCP socket but has no requirement for populating its own IP routing table with anything more than a route to reach the border routers.

Because PfRv3 is an intelligent path selection technology, there must be at least two external interfaces under the control of PfRv3 and at least one internal interface. IWAN is not limited to two paths. Three paths per preference logic are supported, so you can configure the path-preference as follows:

- **Path-preference**—MPLS1, MPLS2 and MPLS3
- **Fallback**—INET1, INET2 and INET3
- **Next-fallback**—INET4, INET5, INET6

Path-preference can also include fallback to the routing protocol if there is no fallback provider, or the traffic can be dropped if the primary provider is not available.

There must be at least one BR configured. If only one BR is configured, then both external interfaces are attached to the single BR. If more than one BR is configured, then the two or more external interfaces are configured across these BR platforms. External links, or exit points, are therefore owned by the BR; for a supported IWAN solution, the external links must be logical (tunnel) interfaces using a DMVPN overlay.

There are four different roles a device can play in a standard PfRv3 configuration:

- **Hub Master Controller**—The hub MC is the MC at the primary WAN aggregation site. This is the MC device where all PfRv3 policies are configured. It also acts as MC for that site and makes path optimization decision. There is only one hub MC per IWAN domain, and you cannot configure the hub BR on the same router platform as the hub MC.
- **Hub Border Router**—This is a BR at the hub MC site. This is the device where WAN interfaces terminate. There can be one or more hub BRs. On the hub BRs, PfRv3 must be configured with:
  - The address of the local MC
  - The path name on external interfaces
  - The path ID on external interfaces

- **Branch Master Controller**—The branch MC is the MC at the branch-site. There is no policy configuration on this device. It receives policy from the hub MC. This device acts as MC for that site for making path optimization decision. The configuration includes the IP address of the hub MC.
- **Branch Border Router**—This is a BR at the branch-site. The configuration on this device enables BR functionality and includes the IP address of the site local MC. The WAN interface that terminates on the device is detected automatically.

The first design model is the IWAN hybrid, which uses a primary MPLS transport paired with Internet VPN as a secondary transport. In this design model, the MPLS WAN provides SLA class of service guarantees for key applications. The second design model is the IWAN dual Internet, which uses a pair of Internet service providers to further reduce cost while leveraging PfR in order to mitigate network performance problems on a single Internet provider. The third design model is the IWAN dual MPLS, which uses a pair of MPLS transports for additional bandwidth and service provider resiliency. The PfR base configuration is the same for all design models.

The following diagrams show the four different device roles and where they fit into the IWAN hybrid design model.

Figure 11 *IWAN hybrid design model: PfR hub location*

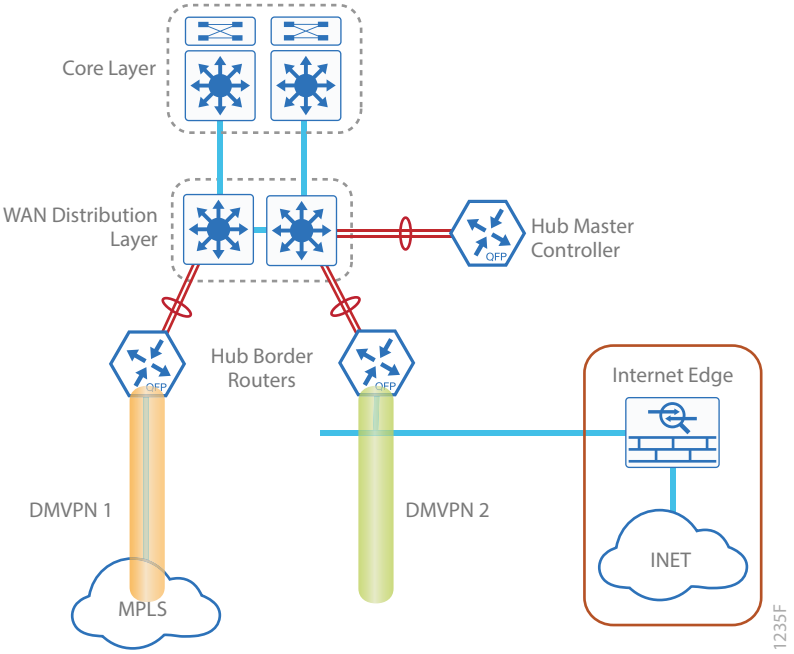
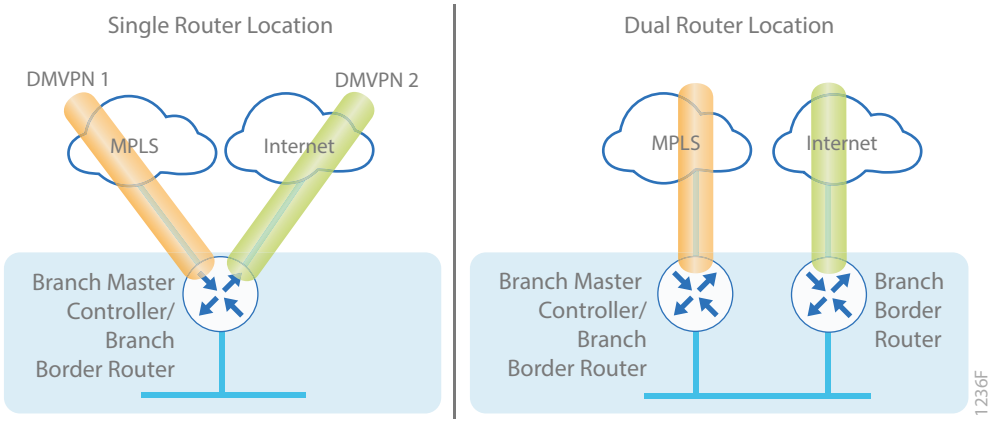


Figure 12 *IWAN hybrid design model: PfR remote-site locations*



PROCESS

Configuring Hub Master Controller

1. Connect router to distribution layer
2. Configure the Hub MC platform
3. Configure connectivity to the LAN
4. Configure the routing protocol on the LAN

This section describes configuring the PfR Hub MC as a new router. Only the core relevant features are included.

Table 35 *Hub MC IP addresses*

IWAN design model	Host name	Loopback IP address	Port-channel IP address
Hybrid	HY-MC-CSR1000v-1	10.6.32.251/32	10.6.32.151/26

Procedure 1 Connect router to distribution layer

Reader Tip

Refer to the Campus Wired LAN Design Guide for complete distribution layer configuration details. This guide only includes the additional steps to complete the distribution layer configuration.

Step 1: If a VLAN does not already exist for the hub MC on the distribution layer switch, configure it now.

```
vlan 350
 name WAN_Service_Net
```

Step 2: If the Layer 3 SVI has not yet been configured, configure it now.

Be sure to configure a VLAN interface (SVI) for every new VLAN you add, so devices in the VLAN can communicate with the rest of the network.

```
interface Vlan350
 ip address 10.6.32.129 255.255.255.192
 no shutdown
```

Next, configure EtherChannel member interfaces.

Tech Tip

EtherChannel is a logical interface that bundles multiple physical LAN links into a single logical link.

Step 3: Connect the hub MC EtherChannel uplinks in order to separate switches in the distribution layer switches or stack, and then configure two physical interfaces to be members of the EtherChannel.

Also, apply the egress QoS macro that was defined in the platform configuration procedure. This ensures traffic is prioritized appropriately. The EtherChannel provides extra resiliency for the hub MC in case there is a link, line card or switch failure.

Tech Tip

Configure the physical interfaces that are members of a Layer 2 EtherChannel prior to configuring the logical port-channel interface. Doing the configuration in this order allows for minimal configuration and reduces errors because most of the commands entered to a port-channel interface are copied to its members interfaces and do not require manual replication.

```
interface GigabitEthernet 1/0/15
 description HY-MC-CSR1000v-1 (WAN-IWAN-C220-1) (vmnic4)

interface GigabitEthernet 2/0/15
 description HY-MC-CSR1000v-1 (WAN-IWAN-C220-1) (vmnic5)

interface range GigabitEthernet 1/0/15, GigabitEthernet 2/0/15
 switchport trunk encapsulation dot1q
 switchport trunk allowed vlan 350
 switchport mode trunk
 logging event trunk-status
 load-interval 30
 macro description EgressQoS
 spanning-tree portfast trunk
 channel-group 21 mode on
```

Next, configure the EtherChannel. Access mode interfaces are used for the connection to the hub MCs.

Step 4: Assign the VLAN created at the beginning of the procedure to the interface. When using EtherChannel, the port-channel number must match the channel group configured in Step 3.

```
interface Port-channel 21
 description HY-MC-CSR1000v-1
 switchport trunk encapsulation dot1q
 switchport trunk allowed vlan 350
 switchport mode trunk
 logging event trunk-status
 logging event bundle-status
 spanning-tree portfast trunk
 no shutdown
```

Step 5: Allow the routing protocol to form neighbor relationships across the vlan interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Vlan350
   no passive-interface
   authentication mode md5
   authentication key-chain LAN-KEY
  exit-af-interface
 exit-address-family
```

Procedure 2 Configure the Hub MC platform

Within this design, there are features and services that are common across all PfR routers. In this procedure, you configure system settings that simplify and secure the management of the solution.

To complete the base configuration for this router, follow the steps in “Configure the platform base features” in Appendix B.

Step 1: Increase the hold-queue on the loopback interface.

Increase the **hold-queue in** and **hold-queue out** to a queue length of 1024 on the loopback interface to allow the RTP application-table to be properly exported using Flexible Net Flow.

```
interface Loopback0
 hold-queue 1024 in
 hold-queue 1024 out
```

Procedure 3 Configure connectivity to the LAN

Any links to adjacent distribution layers should be Layer 3 links or Layer 3 EtherChannels.

Step 1: Configure a Layer 3 interface.

```
interface Port-channel21
  description IW-WAN-D3750X
  ip address 10.6.32.151 255.255.255.192
  no shutdown
```

Step 2: Configure EtherChannel member interfaces.

Configure the physical interfaces to tie to the logical port-channel by using the **channel-group** command. The number for the port-channel and channel-group must match. Not all router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet1
 description IW-WAN-D3750X Gig1/0/15

interface GigabitEthernet2
 description IW-WAN-D3750X Gig2/0/15

interface range GigabitEthernet1, GigabitEthernet2
  no ip address
  cdp enable
  channel-group 21
  no shutdown
```

Procedure 4 Configure the routing protocol on the LAN

If you are planning to use EIGRP, choose option 1. If you are planning to use BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the LAN

Step 1: Configure IP unicast routing authentication key.

```
key chain LAN-KEY
 key 1
   key-string c1sco123
```

Step 2: Configure IP unicast routing using EIGRP named mode.

EIGRP is configured facing the LAN distribution or core layer. In this design, the port-channel interface and the loopback must be EIGRP interfaces. The loopback may remain a passive interface. The network range must include both interface IP addresses, either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface default
   passive-interface
  exit-af-interface
 network 10.6.0.0 0.1.255.255
 eigrp router-id 10.6.32.251
 exit-address-family
```

Step 3: Configure the EIGRP interface.

Allow EIGRP to form neighbor relationships across the interface to establish peering adjacencies and exchange route tables. In this step, you configure EIGRP authentication by using the authentication key specified in the previous procedure.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  af-interface Port-channel21
   no passive-interface
   authentication mode md5
   authentication key-chain LAN-KEY
  exit-af-interface
 exit-address-family
```

Option 2: OSPF on the LAN

Step 1: Configure OSPF Area 0 by using the network summary addresses and the loopback interface IP address as the router-id.

```
router ospf 100
 router-id 10.6.32.251
 network 10.6.32.128 0.0.0.63 area 0
 network 10.6.32.251 0.0.0.0 area 0
```

Step 2: Turn on passive-interface as the default and remove it for the LAN interface.

```
router ospf 100
 passive-interface default
 no passive-interface Port-channel21
```

PROCESS

Configuring PfR for Hub Location

1. Verify IP connectivity to remote site loopback interfaces
2. Configure prefixes for the enterprise and data center
3. Configure PfR domain in the hub MC
4. Configure PfR domain in the hub BR
5. Verify PfR domain is operational on the hub MC

All sites belong to a PfR domain where the remote site MCs are peered together. Peering has been greatly enhanced in PfRv3 which allows site information exchange and single touch provisioning.

PfRv3 has simplified policies with pre-existing templates. The policy configuration for the PfR domain is done in the hub MC and the information is distributed to all sites via MC peering. This not only simplifies provisioning substantially but also makes the policy consistent across the entire IWAN network.

PfRv3 uses Unified Monitor (also called Performance Monitor) to monitor traffic going into WAN links and traffic coming from the WAN links. It monitors performance metrics per differentiated service code point (DSCP) rather than monitoring on per-flow or per-prefix basis. When application-based policies are used, the MC will use a mapping table between the Application Name and the DSCP discovered. This reduces the number of records significantly. PfRv3 relies on performance data measured on the existing data traffic on all paths whenever it can, thereby reducing the need of synthetic traffic. Furthermore, the measurement data is not exported unless there is a violation, which further reduces control traffic and processing of those records.

PfRv3 is also VRF-aware and instances of the MC work under a VRF.

Procedure 1 Verify IP connectivity to remote site loopback interfaces

It is mandatory to use loopback interfaces for the peering traffic between the BR and MC routers. For this design, you put the loopback addresses into a specific subnet range, so they are easily identified in the routing table. The loopback address ranges for the remote sites are as follows:

Table 36 *Remote-site loopback IP address ranges*

IWAN design model	Tunnel type	Loopback 0 address range
Hybrid–Primary Router	MPLS1	10.255.241.0/24
Hybrid–Secondary Router	INET1	10.255.242.0/24

Step 1: Verify that the loopback 0 interfaces on each of your remote sites are reachable from the hub MC by using the **show ip route** command.

This example shows a loopback address range of 10.255.241.0/24 for nine remote site primary routers and an address range of 10.255.242.0/24 for four remote site secondary routers.

```
show ip route | include 10.255.241
D        10.255.241.11/32 [90/25610880] via 10.6.32.129, 1w2d, Port-channel21
D        10.255.241.12/32 [90/25610880] via 10.6.32.129, 1w2d, Port-channel21
D        10.255.241.31/32 [90/25610880] via 10.6.32.129, 1w2d, Port-channel21
D        10.255.241.32/32 [90/25610880] via 10.6.32.129, 1w2d, Port-channel21
D        10.255.241.41/32 [90/25610880] via 10.6.32.129, 1w2d, Port-channel21
D        10.255.241.42/32 [90/25610880] via 10.6.32.129, 1w2d, Port-channel21
D        10.255.241.51/32 [90/25610880] via 10.6.32.129, 1w3d, Port-channel21

show ip route | include 10.255.242
D        10.255.242.12/32 [90/25613440] via 10.6.32.129, 1w1d, Port-channel21
D        10.255.242.32/32 [90/25613440] via 10.6.32.129, 1w2d, Port-channel21
D        10.255.242.42/32 [90/25613440] via 10.6.32.129, 1w2d, Port-channel21
```

Procedure 2 Configure prefixes for the enterprise and data center

Before the configuration of PfRv3 on the hub MC, you must create a prefix list for the enterprise and data center. The enterprise-prefix list covers the range of IP addresses to be controlled and optimized within this IWAN domain. Prefixes outside of the enterprise-prefix list will not be controlled by application policies, but they will be load-balanced.

The site-prefix range includes the prefixes at this specific site, which is normally a WAN aggregation or data center (DC) site. Site-prefixes are typically statically defined at WAN aggregation and DC sites and discovered automatically at remote sites.

Tech Tip

The ip prefix-list options ge and le are not supported by PfR.

Step 1: Create the enterprise prefix list.

```
ip prefix-list [prefix-list-name] seq [value] permit [prefix list]
```

Example

This example shows a contiguous block of private address space from 10.4.0.0 to 10.7.255.255, which covers all the IP addresses within this IWAN PfR domain. It does not include the router loopback address range of 10.255.240.0 to 10.255.247.255 because you do not want PfR controlling those prefixes.

```
ip prefix-list ENTERPRISE-PREFIXES seq 10 permit 10.4.0.0/14
```

Tech Tip

The enterprise prefix list contains the network wide summaries that are advertised from the hub border routers.

Step 2: Create the primary site prefix list.

```
ip prefix-list [prefix-list-name] seq [value] permit [prefix list]
```

Example

This example shows a data center network with two class B private address blocks of 10.4.0.0 and 10.6.0.0.

```
ip prefix-list DC1-PREFIXES seq 10 permit 10.4.0.0/16
ip prefix-list DC1-PREFIXES seq 20 permit 10.6.0.0/16
```

Procedure 3 Configure PfR domain in the hub MC

Domain policies are configured on the hub MC. These policies are distributed to branch MCs by using the peering infrastructure. All sites that are in the same domain will share the same set of PfR policies. Policies can be based on DSCP or on application names.

Policies are created using preexisting templates, or they can be customized with manually defined thresholds for delay, loss and jitter.

PfR policies support the following traffic measurements:

- **Transmission Control Protocol (TCP)**—Latency and loss
- **User Datagram Protocol (UDP)**—No measurements or loss
- **Real-time Transport Protocol (RTP)**—Jitter, latency and loss

Tech Tip

Loss is not calculated for UDP traffic that is not RTP. Traffic loss for RTP voice and video packets is calculated using the sequence numbers in the RTP header.

Table 37 PfR domain pre-defined policy templates

Pre-defined template	Priority	Threshold definition
Voice	1	one-way-delay threshold 150 msec
	2	loss threshold 1.0 percent
	3	jitter threshold 30000 usec
Real-time-video	1	loss threshold 1.0 percent
	2	one-way-delay threshold 150 msec
	3	jitter threshold 20000 usec
Low-latency-data	1	one-way-delay threshold 100 msec
	2	loss threshold 5.0 percent
Bulk-data	1	one-way-delay threshold 300 msec
	2	loss threshold 5.0 percent
Best-effort	1	one-way-delay threshold 500 msec
	2	loss threshold 10.0 percent
Scavenger	1	one-way-delay threshold 500 msec
	2	loss threshold 50.0 percent

The NMS collector IP address and port number are defined in the hub MC. The information is automatically propagated to devices in the IWAN domain. If you do not want to use a single collector for your entire network, you can specify a different IP address and port number in the IWAN domain for each device.

Step 1: Create the hub MC domain.

```
domain [name]
 vrf [name]
  master hub
   source-interface [interface]
   site-prefixes prefix-list [prefixes from previous procedure]
   password [password]
   enterprise-prefix prefix-list [prefixes from previous procedure]
   collector [IP address of NMS] port [NetFlow]
```

The site-prefix splitting feature allows the user to configure a minimum mask length for their enterprise traffic classes. A smaller mask length enables better load-balancing of the traffic classes. By default, the prefixes are split using a mask length of /24.

Tech Tip

If you want to change the minimum mask length for your enterprise or Internet traffic classes, use the following CLI commands:

```
domain iwan
 vrf default
  master hub
   advanced
    minimum-mask-length internet 25
    minimum-mask-length enterprise 25
```

The example above splits the enterprise and Internet traffic classes using a /25 mask, instead of the default /24 mask.

The global probe reduction feature allows you to reduce the probing of traffic on channels that are not carrying traffic. Probing is used to compute important metrics such as reachability, one-way delay, jitter, and loss on channels that don't have user traffic. By default, the general monitor sends 1 packet every 1 second and the quick monitor sends 20 packets every 1 second.

Tech Tip

If you want to reduce the smart-probe bursts for your IWAN domain, use the following CLI commands in the global advanced section:

```
domain iwan
 master hub
  advanced
   smart-probe burst quick 10 packets every 20 seconds
```

The example above sends 10 packets every 20 seconds in the quick monitor when there is no active user traffic in the class. It is applicable to all VRFs in the domain.

Example

```
master hub
 vrf default
  master hub
   source-interface Loopback0
   site-prefixes prefix-list DC1-PREFIXES
   password c1sco123
   enterprise-prefix prefix-list ENTERPRISE-PREFIXES
   collector 10.4.48.36 port 9991
```

Step 2: Create the hub MC policy.

```
domain [name]
 vrf [name]
  master hub (configure the hub MC with additional commands)
   load-balance (load balance the traffic not specified in a class)
   class [name] sequence [value] (repeat for each class)
    match dscp [value] policy [name] (repeat for each dscp value)
    path-preference [primary] fallback [secondary] (path names)
```

Example

The policies use the PfR predefined templates. The path preference for voice, real time video and low latency data is to use MPLS1 unless the delay, jitter, and loss values on the path fall outside the values specified in the templates. The bulk data and default classes use INET1 with fallback to MPLS1 and the scavenger class uses INET1 with fallback to blackhole. The rest of the traffic will be load-balanced between the two paths.

Tech Tip

With this recommended policy, PfR does not manage Internetwork Control (DSCP CS6) traffic. CS6 traffic should always follow the normal routing path.

```
domain iwan
 vrf default
  master hub
   load-balance
   class VOICE sequence 10
    match dscp ef policy voice
    path-preference MPLS1 fallback INET1
   class REAL_TIME_VIDEO sequence 20
    match dscp cs4 policy real-time-video
    match dscp af41 policy real-time-video
    match dscp af42 policy real-time-video
    match dscp af43 policy real-time-video
    path-preference MPLS1 fallback INET1
   class LOW_LATENCY_DATA sequence 30
    match dscp cs2 policy low-latency-data
    match dscp cs3 policy low-latency-data
    match dscp af21 policy low-latency-data
    match dscp af22 policy low-latency-data
    match dscp af23 policy low-latency-data
```

```
 path-preference MPLS1 fallback INET1
class BULK_DATA sequence 40
 match dscp af11 policy bulk-data
 match dscp af12 policy bulk-data
 match dscp af13 policy bulk-data
 path-preference INET1 fallback MPLS1
class SCAVENGER sequence 50
 match dscp cs1 policy scavenger
 path-preference INET1 fallback blackhole
class DEFAULT sequence 60
 match dscp default policy best-effort
 path-preference INET1 fallback MPLS1
```

Procedure 4 Configure PfR domain in the hub BR

The hub BRs are also the DMVPN hub WAN aggregation routers for the network. The PfRv3 configurations for standalone BRs are much simpler because they dynamically learn their policy information from the hub MC. The hub BR routers are also used to advertise the path names and path-ids specified in the hub MC configuration.

There is an optional feature called zero-SLA that reduces the probing to the only default class by muting the other DSCP probes. This feature is useful on Internet connections where nothing is guaranteed. Zero-SLA reduces bandwidth usage on metered interfaces like 4G LTE or other Internet connections with a monthly data cap limit.

Tech Tip

If you want to add the zero-SLA feature to an existing hub BR, you must shutdown the DMVPN tunnel interface before configuring. After the feature is added to the hub BR, bring the tunnel interface back up.

Reader Tip

Whenever IWAN is designed with WAAS leveraging AppNav, please ensure that the Loopback IP address that is being used for PfR is not also used as the AppNav Service Controller address. This is applicable for any Hub IWAN router that is part of an AppNav Cluster.

Table 38 Hub BR path and IP addresses

Host name	Path	Path ID	Loopback IP address	Zero SLA
HY-MPLS1-ASR1002X-1	MPLS1	1	10.6.32.241/32	No
HY-INET1-ASR1002X-2	INET1	2	10.6.32.242/32	Yes (optional)

Step 1: Create the hub BR domain.

```
domain [name]
 vrf [name]
  border (create the BR)
   source-interface [interface]
   master [IP address of local MC]
   password [password of hub MC]
```

Example

```
domain iwan
 vrf default
  border
   source-interface Loopback0
   master 10.6.32.251
   password c1sco123
```

Step 2: Add the path names and path-ids to the tunnel interfaces of the hub BR.

```
interface Tunnel [value]
 domain [name] path [name] path-id [number] zero-sla
```

Example

This example is the primary hub BR using Tunnel 100 with MPLS as the provider.

```
interface Tunnel100
 domain iwan path MPLS1 path-id 1
```

(Optional) This example is the secondary hub BR using Tunnel 200 with INET as the provider and the zero-sla feature. If this is an existing configuration, you shut down the interface, add the zero SLA feature, and then bring the interface back up.

```
interface Tunnel200
 shutdown
 domain iwan path INET1 path-id 2 zero-sla
 no shutdown
```

Step 3: Verify the border is operational by using the **show domain [name] border status** command.

This example shows the primary hub BR of the IWAN hybrid model with MPLS as the provider. There is only one external WAN interface because the second path is on the secondary hub BR, which is reachable via the Tunnel 0 interface at IP address 10.6.32.242.

```
show domain iwan border status
Fri Sep 16 08:10:09.866
------------------------------------------------------------------------
  **** Border Status ****
Instance Status: UP
Present status last updated: 1w0d ago
Loopback: Configured Loopback0 UP (10.6.32.241)
Master: 10.6.32.251
Master version: 2
Connection Status with Master: UP
MC connection info: CONNECTION SUCCESSFUL
Connected for: 3d20h
External Collector: 10.4.48.36  port: 9991
Route-Control: Enabled
Asymmetric Routing: Disabled
Minimum Mask length: 28
Sampling: off
Channel Unreachable Threshold Timer: 4 seconds
Minimum Packet Loss Calculation Threshold: 15 packets
Minimum Byte Loss Calculation Threshold: 1 bytes
Monitor cache usage: 100000 (20%) Auto allocated
Minimum Requirement: Met
External Wan interfaces:
     Name: Tunnel100 Interface Index: 18 SNMP Index: 13 SP: MPLS1 path-id: 1
Status: UP Zero-SLA: NO Path of Last Resort: Disabled


Auto Tunnel information:


   Name:Tunnel1 if_index: 20
   Virtual Template: Not Configured
   Borders reachable via this tunnel:  10.6.32.242
```

Step 4: Repeat this procedure for each hub BR by using the appropriate path name and path-id.

Procedure 5 Verify PfR domain is operational on the hub MC

The PfR path names and path-ids are automatically discovered at the remote site routers from the configuration entered into the tunnel interfaces at the hub site. The hub MC uses the path names and path-ids to determine where traffic should be sent according to its policies.

Step 1: Verify the domain is operational from the hub MC using the **show domain [name] master status** command.

This example shows the hub MC of the IWAN hybrid model in an operational state. The hub BRs are both connected and using their respective Tunnel interfaces as the exits for the hub location.

```
show domain iwan master status
  *** Domain MC Status ***
Master VRF: Global
  Instance Type:    Hub
  Instance id:      0
  Operational status:  Up
  Configured status:  Up
  Loopback IP Address: 10.6.32.251
  Global Config Last Publish status: Peering Success
  Load Balancing:
   Admin Status: Enabled
   Operational Status: Up
   Enterprise top level prefixes configured: 1
   Max Calculated Utilization Variance: 0%
   Last load balance attempt: never
   Last Reason:  Variance less than 20%
   Total unbalanced bandwidth:
         External links: 0 Kbps  Internet links: 0 Kbps
  External Collector: 10.4.48.36 port: 9991
  Route Control: Enabled
  Transit Site Affinity: Enabled
  Load Sharing: Enabled
  Mitigation mode Aggressive: Disabled
  Policy threshold variance: 20
  Minimum Mask Length: 28
  Syslog TCA suppress timer: 180 seconds
```

```
  Traffic-Class Ageout Timer: 5 minutes
  Channel Unreachable Threshold Timer: 4 seconds
  Minimum Packet Loss Calculation Threshold: 15 packets
  Minimum Bytes Loss Calculation Threshold: 1 bytes
  Borders:
    IP address: 10.6.32.241
    Version: 2
    Connection status: CONNECTED (Last Updated 3d20h ago )
    Interfaces configured:
      Name: Tunnel100 | type: external | Service Provider: MPLS1 path-id:1 |
Status: UP | Zero-SLA: NO | Path of Last Resort: Disabled
          Number of default Channels: 0
    Tunnel if: Tunnel1
    IP address: 10.6.32.242
    Version: 2
    Connection status: CONNECTED (Last Updated 3d20h ago )
    Interfaces configured:
      Name: Tunnel200 | type: external | Service Provider: INET1 path-id:2 |
Status: UP | Zero-SLA: YES | Path of Last Resort: Disabled
          Number of default Channels: 0
    Tunnel if: Tunnel0
```

PROCESS

Configuring PfR for Remote Site Locations

1. Verify IP connectivity to hub MC loopback interface
2. Configure PfR in the primary remote site router
3. Configure PfR in the secondary remote site router
4. Verify PfR traffic classes are controlled

Remote sites are discovered using peering. Each remote site MC peers with the hub MC. The remote site MC advertises local site information and learns information about every other site. Prefixes specific to sites are advertised along with the site-id. The site-prefix to site-id mapping is used in monitoring and optimization. This mapping is also used for creating reports for specific sites.

WAN interfaces at each site are discovered using a special probing mechanism referred to as smart probes. This further reduces provisioning on the remote sites. The WAN interface discovery also creates mapping of the interface to a particular service provider. The mapping is used in monitoring and optimization. It can also be used to draw the WAN topology in an NMS GUI like Cisco Prime Infrastructure or LiveAction LiveNX.

Procedure 1 Verify IP connectivity to hub MC loopback interface

PfRv3 requires loopback interfaces for the peering traffic between the BR and MC routers. For this design, you put the hub MC loop back interface into the subnet range of the hub location. The following table shows the loopback addresses for the hub MC.

Table 39 Hub MC loopback IP addresses

IWAN design model	Loopback 0 IP address
Hybrid–Hub MC	10.6.32.251

Each remote site must have a route to the hub MC in the EIGRP topology table over each exit path. You can have more than two paths. You can also have two routes and Equal Cost Multiple Paths.

Step 1: Verify that there are at least two available paths to the loopback 0 interface on the hub MC from each remote site router by using the **show ip eigrp topology** command. This example shows there are two available paths to the hub MC (10.6.32.251) using summarized routes (10.6.0.0/16) from the hub border routers in the IWAN hybrid design model. The first path is the one shown in the IP routing table because the bandwidth is higher than the feasible successor listed second.

```
show ip eigrp topology 10.6.0.0 255.255.0.0
EIGRP-IPv4 VR(IWAN-EIGRP) Topology Entry for AS(400)/ID(10.255.241.11) for
10.6.0.0/16
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 657626453, RIB
is 5137706
  Descriptor Blocks:
  10.6.34.1 (Tunnel100), from 10.6.34.1, Send flag is 0x0
      Composite metric is (657626453/163840), route is Internal
      Vector metric:
        Minimum bandwidth is 200000 Kbit
        Total delay is 10001250000 picoseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1400
        Hop count is 1
        Originating router is 10.6.32.241
        Internal tag is 0
  10.6.36.1 (Tunnel200), from 10.6.36.1, Send flag is 0x0
      Composite metric is (1314078720/163840), route is Internal
      Vector metric:
        Minimum bandwidth is 500000 Kbit
        Total delay is 20001250000 picoseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1400
        Hop count is 1
        Originating router is 10.6.32.242
        Internal tag is 0
```

Procedure 2 Configure PfR in the primary remote site router

Each remote site must have a branch MC and branch BR configured. At dual-router sites it is recommended that you configure the primary router as both an MC and BR and the secondary router as only a BR. The domain name, VRF, and password must match the hub MC configuration. Use the loopback 0 interface as the source. Configure the hub MC IP address.

Reader Tip

Whenever IWAN is designed with WAAS leveraging AppNav/WCCP, please ensure that the Loopback IP address that is being used for PfR is not also used as the AppNav Service Controller address or WCCP router ID. This is applicable for any Branch IWAN router that is part of an AppNav/WCCP Cluster.

Step 1: If you are not on the router console port, turn on terminal monitoring with the **terminal monitor** command from the global command line interface.

```
terminal monitor
```

Step 2: Create the branch MC domain.

```
domain [name]
 vrf [name]
  master branch (create the branch MC)
   source-interface [interface]
   Password [password]
   hub [IP address of hub MC]
```

Example

This example configures the branch MC and points to the IP address of the hub MC in the IWAN hybrid design model.

```
domain iwan
 vrf default
  master branch
   source-interface Loopback0
   password c1sco123
   hub 10.6.32.251
```

Step 3: After approximately two minutes, the console displays an EIGRP SAF message similar to the one below, which indicates the branch MC has created an adjacency with the loopback interface of the hub MC.

```
Sep 16 14:16:00.389: %DUAL-5-NBRCHANGE: EIGRP-SFv4 59501: Neighbor 10.6.32.251
(Loopback0) is up: new adjacency
```

Step 4: Verify the PfR policy from the hub MC has been propagated to the branch MC by using the **show domain [name] master policy** command.

The output from this command should look the same as the output on the hub MC.

Step 5: Enable the BR function.

```
domain [name]
 vrf [name]
  border (create the border)
   source-interface [interface]
   master [local] (local keyword means this router)
   password [password]
```

Example

This example configures the branch BR and points it to the local branch MC, which is running on the same router platform.

```
domain iwan
 vrf default
  border
   source-interface Loopback0
   master local
   password c1sco123
```

Step 6: After approximately thirty seconds, the console displays a line protocol up/down message similar to the one below, which indicates the automatically generated tunnel interface has been created.

```
Sep 16 14:31:26.317: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel200,
changed state to up
```

Step 7: Add the remote prefix tracking feature to the tunnel interfaces of the branch BR.

```
interface Tunnel [value]
 domain [name] dynamic-path
```

Border routers collect local site prefixes from the RIB table and send them to the local master controller. After receiving prefixes from a border router, the local master controller filters prefixes per the following criteria.

- If a prefix is learned on a tunnel interface, the prefix is marked remote and not added to local LAN list.
- If a prefix is learned from NHRP, the prefix is not added to LAN list.
- If a prefix is learned on a physical interface of the tunnel interface, the prefix is not added to LAN list.
- If an enterprise prefix is configured on the hub and the prefix is part of the enterprise prefix list configured on hub, the branch master adds the prefix from the RIB table to the LAN list.

The prefixes in the LAN list are added to the site prefix database as the local site prefix list. In order to learn remote site prefixes, every MC and BR subscribes to the site prefix peering service. MCs publish and receive site prefixes, but BRs only receive site prefixes. The remote site prefixes are added to the site prefix database at each MC and BR.

Example

```
interface Tunnel100
 domain iwan dynamic-path
```

Step 8: Verify that the branch BR is operational by using the **show domain [name] border status** command.

Step 9: Verify that the branch MC is operational by using the **show domain [name] master status** command.

Step 10: Verify the local site prefix list on the branch BR by using the **show domain default border route-import** command.

Procedure 3 Configure PfR in the secondary remote site router

Use this procedure only when there is a secondary remote site router. If you have a single router at a remote location, skip this procedure.

PfRv3 requires loopback interfaces for the peering traffic between the BR and MC routers. For this design, you put the hub MC loop back interface into the subnet range of the hub location.

Each remote site must have a route to the hub MC in the EIGRP topology table over each exit path. You can have more than two paths. You can also have two routes and Equal Cost Multiple Paths.

Step 1: Verify that there are at least two available paths to the loopback 0 interface on the hub MC from each remote site router by using the **show ip eigrp topology** command.

This example shows there are two available paths to the hub MC (10.6.32.251) in the IWAN hybrid design model from the secondary router at a remote site. The first path is through the port-channel2.99 interface, which is the transit network between the primary router and the secondary router in a dual-router configuration.

```
show ip eigrp topology 10.6.32.251 255.255.255.255
EIGRP-IPv4 VR(IWAN-EIGRP) Topology Entry for AS(400)/ID(10.255.242.12) for
10.6.32.251/32
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 3310960640,
RIB is 25866880
  Descriptor Blocks:
  10.7.16.9 (Port-channel2.99), from 10.7.16.9, Send flag is 0x0
      Composite metric is (3310960640/3310632960), route is Internal
      Vector metric:
        Minimum bandwidth is 10000 Kbit
        Total delay is 50021250000 picoseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1400
        Hop count is 4
        Originating router is 10.6.32.251
        Internal tag is 0
  10.6.36.1 (Tunnel200), from 10.6.36.1, Send flag is 0x0
      Composite metric is (3343400960/1720320), route is Internal
      Vector metric:
        Minimum bandwidth is 30000 Kbit
        Total delay is 50016250000 picoseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1400
        Hop count is 3
        Originating router is 10.6.32.251
        Internal tag is 0
```

Step 2: Enable the BR function.

```
domain [name]
 vrf [name]
  border (create the border)
   source-interface [interface]
   master [IP address of branch MC]
   Password [password]
```

Example

This example configures the branch BR and points it to the branch MC, which is running on the primary remote site router.

```
domain iwan
 vrf default
  border
   source-interface Loopback0
   master 10.255.241.12
   password c1sco123
```

Step 3: After approximately thirty seconds, the console displays several EIGRP messages and a line protocol up/down message similar to the ones below. These messages indicate the branch BR has neighbored with the branch MC and automatically generated the tunnel interface from the loopback of the branch BR to the loopback of the branch MC.

```
Sep 16 16:09:11.202: %DUAL-5-NBRCHANGE: EIGRP-SFv4 59501: Neighbor 10.7.18.2
(Port-channel2.64) is up: new adjacency

Sep 16 16:09:11.202: %DUAL-5-NBRCHANGE: EIGRP-SFv4 59501: Neighbor 10.7.19.2
(Port-channel2.69) is up: new adjacency

Sep 16 16:09:11.202: %DUAL-5-NBRCHANGE: EIGRP-SFv4 59501: Neighbor 10.255.241.12
(Loopback0) is up: new adjacency

Sep 16 16:09:11.690: %DUAL-5-NBRCHANGE: EIGRP-SFv4 59501: Neighbor 10.7.16.9
(Port-channel2.99) is up: new adjacency

Sep 16 16:09:12.174: %LINEPROTO-5-UPDOWN: Line protocol on Interface Tunnel0,
changed state to up
```

Step 4: Add the remote prefix tracking feature to the tunnel interfaces of the branch BR.

```
interface Tunnel [value]
 domain [name] dynamic-path
```

Example

```
interface Tunnel200
 domain iwan dynamic-path
```

Step 5: Verify that the branch BR is operational by using the **show domain [name] border status** command.

Step 6: Verify the local site prefix list on the branch BR by using the **show domain default border route-import** command.

Step 7: Repeat Procedure 1 through Procedure 3 for each remote site in your network.

Procedure 4 Verify PfR traffic classes are controlled

The final procedure is to verify that the configured and default traffic classes are controlled by the MC at the hub and branch locations.

Tech Tip

Event tracing is mostly used for debugging purposes and is enabled by default. To see PfRv3 events on your router, use the following show command:

```
show monitor event-trace pfrv3 all
```

With traffic flowing over the WAN, verify that the PfR traffic classes are controlled in the outbound direction on the hub MC by using the **show domain [name] master traffic-classes summary** command.

This example shows the traffic classes are controlled as signified by the CN in the State column. The default class is load-balanced between the MPLS and INET paths across the network. This example is truncated due to the overall length.

```
show domain iwan master traffic-classes summary
```

```
APP - APPLICATION, TC-ID - TRAFFIC-CLASS-ID, APP-ID - APPLICATION-ID
SP - SERVICE PROVIDER, PC = PRIMARY CHANNEL ID,
BC - BACKUP CHANNEL ID, BR - BORDER, EXIT - WAN INTERFACE
UC - UNCONTROLLED, PE - PICK-EXIT, CN - CONTROLLED, UK - UNKNOWN

Dst-Site-Pfx      Dst-Site-Id APP             DSCP    TC-ID APP-ID    State  SP
PC/BC       BR/EXIT

10.7.83.0/24      10.255.241.2N/A           cs3     7632  N/A       CN
INET1    10131/NA    10.6.32.242/Tunnel200
10.255.241.21/32  10.255.241.2N/A           default 12063 N/A       CN
MPLS1    3643/10128  10.6.32.241/Tunnel100
10.7.82.0/24      10.255.241.2N/A           default 7656  N/A       CN
INET1    10130/NA    10.6.32.242/Tunnel200
10.7.18.13/32     10.255.241.1N/A           default 7646  N/A       CN
INET1    10126/NA    10.6.32.242/Tunnel200
10.255.241.12/32  10.255.241.1N/A           default 7651  N/A       CN
INET1    10126/NA    10.6.32.242/Tunnel200
10.7.2.0/24       10.255.241.1N/A           default 7636  N/A       CN
MPLS1    3638/NA     10.6.32.241/Tunnel100
10.7.2.0/24       10.255.241.1N/A           42      7633  N/A       CN
MPLS1    3650/10125  10.6.32.241/Tunnel100
```

```
10.255.242.42/32  10.255.241.4N/A            default 7653  N/A       CN
INET1     10140/NA    10.6.32.242/Tunnel200

10.7.195.0/24     10.255.241.4N/A            default 15340 N/A       CN
INET1     10138/NA    10.6.32.242/Tunnel200

10.7.195.0/24     10.255.241.4N/A            cs3     7640  N/A       CN
MPLS1     3654/NA     10.6.32.241/Tunnel100

10.7.18.0/24      10.255.241.1N/A            default 7638  N/A       CN
INET1     10126/NA    10.6.32.242/Tunnel200

10.255.242.12/32  10.255.241.1N/A            default 17896 N/A       CN
INET1     10126/NA    10.6.32.242/Tunnel200

10.255.241.41/32  10.255.241.4N/A            default 7623  N/A       CN
INET1     10138/NA    10.6.32.242/Tunnel200
```

Step 1: With traffic flowing over the WAN, verify that the PfR traffic classes are controlled in the outbound direction on one of the branch MC routers by using the **show domain [name] master traffic-classes dscp** command.

This example shows a video call is taking place from remote site RS11 to the HQ location. The traffic class is controlled, as signified by the Present State row. The INTERACTIVE-VIDEO, with a DSCP of AF41 (34), is in-policy and using the MPLS path. The traffic class has a valid backup channel, which means the INET path is available if the primary path falls out of policy.

```
show domain iwan master traffic-classes dscp af41
```

```
 Dst-Site-Prefix: 10.4.0.0/16          DSCP: af41 [34] Traffic class id:304
  TC Learned:                  00:00:31 ago
  Present State:               CONTROLLED
  Current Performance Status:  in-policy
  Current Service Provider:    MPLS1 since 00:00:01 (hold until 88 sec)
  Previous Service Provider:   Unknown
  BW Used:                     416 Kbps
  Present WAN interface:       Tunnel100 in Border 10.255.241.11
  Present Channel (primary):   312
  Backup Channel:              313
  Destination Site ID:         10.6.32.251
  Class-Sequence in use:       20
  Class Name:                  INTERACTIVE-VIDEO using policy real-time-video
  BW Updated:                  00:00:01 ago
  Reason for Route Change:     Uncontrolled to Controlled Transition
--------------------------------------------------------------------
```

Step 2: After introducing loss into the MPLS path, verify that the protected traffic class is moved to the backup INET path by using the **show domain [name] master traffic-classes dscp** command.

This example shows the INTERACTIVE-VIDEO class, with a DSCP of AF41 (34), using the backup INET path. The branch MC has moved the traffic due to packet loss of greater than 1%. The traffic is considered in-policy because it has already been moved to the INET path where there is no loss occurring.

```
show domain iwan master traffic-classes dscp af41


 Dst-Site-Prefix: 10.4.0.0/16          DSCP: af41 [34] Traffic class id:303
  TC Learned:                  00:25:40 ago
  Present State:               CONTROLLED
  Current Performance Status: in-policy
  Current Service Provider:    INET1 since 00:01:09
  Previous Service Provider:   INET1 for 180 sec
  (A fallback provider. Primary provider will be re-evaluated 00:02:53 later)
  BW Used:                     414 Kbps
  Present WAN interface:       Tunnel200 in Border 10.255.241.11
  Present Channel (primary):   311
  Backup Channel:              310
  Destination Site ID:         10.6.32.251
  Class-Sequence in use:       10
  Class Name:                  INTERACTIVE-VIDEO using policy real-time-video
  BW Updated:                  00:00:10 ago
  Reason for Route Change:     Loss
-------------------------------------------------------------------
```

Deploying IWAN Quality of Service

QoS has already proven itself as the enabling technology for the convergence of voice, video and data networks. As business needs evolve, so do demands on QoS technologies. The need to protect voice, video and critical data with QoS mechanisms is extremely important on the WAN because access speeds are much lower than the LAN networks that feed them.

PROCESS

Configuring QoS for DMVPN Routers

1. Create the class maps in order to classify traffic
2. Create policy map with queuing policy

When configuring WAN-edge QoS, you are defining how traffic egresses your network. It is critical that the classification, marking, and bandwidth allocations align to the service provider, offering to ensure consistent QoS treatment end to end.

The DMVPN per-tunnel QoS feature on the hub router allows the configuration of the child queuing policy and the parent shaping policy to be signaled from the remote site router. With this type of simplified configuration, the hub site is prevented from sending more traffic than any single remote-site can handle.

You can also mark the header of the GRE tunneled packets by using the QoS policy map classes. There are two methods for marking the DSCP of the tunnel headers in order to influence per-hop treatment within the service provider network. One method applies the policy to a virtual tunnel interface and the second method applies the policy to a physical interface.

The following table shows an example of how to mark the tunnel headers when using a 12- or 8-class model in the enterprise, while combining the traffic classes into a smaller 6-, 5- or 4-class model in the service provider network. The tunnel markings must match the service provider offering, so you will have to adjust the table below according to your specific service level agreement.

Figure 13 *QoS class model mapping: Tunnel mappings must match provider*

Application Class	Per-Hop Behavior	Queuing & Dropping	12-Class	8-Class for IWAN Router	6-Class for Tunnel	5-Class for Tunnel	4-Class for Tunnel
Internetwork Control	CS6	BR Queue	Net-Ctrl	NET-CTRL	~~CS6~~	~~CS6~~	~~CS6~~
VoIP Telephony	EF	Priority Queue (PQ)	Voice	VOICE	EF	EF	EF
Multimedia Conferencing	AF4	BR Queue + DSCP WRED	Interactive-Video	INTERACTIVE-VIDEO	AF41	AF31	AF31
Real-Time Interactive	CS4	BR Queue + DSCP WRED	Real-Time	INTERACTIVE-VIDEO	AF41	AF31	AF31
Broadcast Video	CS5	BR Queue + DSCP WRED	Broadcast-Video	STREAMING-VIDEO	AF31	AF31	AF31
Multimedia Streaming	AF3	BR Queue + DSCP WRED	Streaming-Video	STREAMING-VIDEO	AF31	AF31	AF31
Signaling	CS3	BR Queue	Call-Signaling	CALL-SIGNALING	AF21	AF21	AF21
Ops / Admin / Mgmt	CS2	BR Queue + DSCP WRED	Net-Mgmt	CRITICAL-DATA	AF21	AF21	AF21
Transactional Data	AF2	BR Queue + DSCP WRED	Transactional-Data	CRITICAL-DATA	AF21	AF21	AF21
Bulk Data	AF1	BR Queue + DSCP WRED	Bulk-Data	CRITICAL-DATA	AF21	AF21	AF21
Best Effort	DF	BR Queue + RED	Default	DEFAULT	Default	Default	Default
Scavenger	CS1	Min BR Queue	Scavenger	SCAVENGER	AF11	AF11	Default

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Tech Tip

Because the provider will generally have a network control queue that they do not declare as part of their customer-facing model, the traffic in the NET-CTRL queue will be marked as CS6 on the tunnel header. Because the network elements use this traffic to ensure stability under congestion and when a device is oversubscribed, CS6 traffic should be preserved.

Traffic is regulated from the central site (hub) routers to the remote-site routers on a per-tunnel (spoke) basis. The hub site is unable to send more traffic than a single remote-site can handle, and this ensures that high bandwidth hub sites do not overrun lower bandwidth remote-sites.

The following two procedures apply to all DMVPN WAN hub and spoke routers.

Procedure 1 Create the class maps in order to classify traffic

This number of classes in an egress policy should be chosen based on interface speed, available queues, and device capabilities. This design guide uses an 8-class model in the enterprise and the examples will have to be modified for other models, as required.

Use the **class-map** command to define a traffic class and identify traffic to associate with the class name. You use these class names when configuring policy maps that define actions you want to take against the traffic type. The **class-map** command sets the match logic. In this case, the match-any keyword indicates that the maps match any of the specified criteria. This keyword is followed by the name you want to assign to the class of ser-

vice. After you have configured the **class-map** command, you define specific values, such as DSCP and protocols to match with the match command.

Step 1: Create the class maps for DSCP matching.

You do not need to explicitly configure the default class.

```
class-map match-any [class-map name]
 match dscp [dcsp value] [optional additional dscp value(s)]
```

Table 40 Class of service for 8-class model

Class Name	Traffic type	DSCP values
VOICE	Voice traffic	ef
INTERACTIVE-VIDEO	Interactive video (video conferencing)	cs4, af4
STREAMING-VIDEO	Video streaming	cs5, af3
NET-CTRL	Routing protocols	cs6
CALL-SIGNALING	Voice and video call signaling	cs3
CRITICAL-DATA	Network management, highly interactive	cs2, af1, af2
default	Best effort	all others
SCAVENGER	Scavenger	cs1

Step 2: Repeat this step to create a class-map for each of the seven non-default WAN classes of service listed in the table above.

Example: Class Maps for 8-class QoS model

```
class-map match-any VOICE
 match dscp ef
class-map match-any INTERACTIVE-VIDEO
 match dscp cs4 af41 af42 af43
class-map match-any STREAMING-VIDEO
 match dscp cs5 af31 af32 af33
class-map match-any NET-CTRL
 match dscp cs6
class-map match-any CALL-SIGNALING
 match dscp cs3
class-map match-any CRITICAL-DATA
 match dscp cs2 af11 af12 af13 af21 af22 af23
class-map match-any SCAVENGER
 match dscp cs1
```

Tech Tip

You do not need to configure a Best-Effort class-map. This is implicitly included within class-default as shown in Procedure 2.

To provide unique DSCP counters for packet count, byte count and packet rate in **the show policy-map interface** command and CBQoS-MIB output, put each **match dscp** statement on its own line, such as in the example below.

Example: Class maps with additional DSCP granularity

```
class-map match-any STREAMING-VIDEO
 match dscp af31
 match dscp af32
 match dscp af33
 match dscp cs5
class-map match-any INTERACTIVE-VIDEO
 match dscp cs4
 match dscp af41
 match dscp af42
 match dscp af43
class-map match-any CRITICAL-DATA
 match dscp af11
 match dscp af12
 match dscp af13
 match dscp cs2
 match dscp af21
 match dscp af22
 match dscp af23
class-map match-any VOICE
 match dscp ef
class-map match-any SCAVENGER
 match dscp cs1
class-map match-any CALL-SIGNALING
 match dscp cs3
class-map match-any NET-CTRL
 match dscp cs6
```

Procedure 2 Create policy map with queuing policy

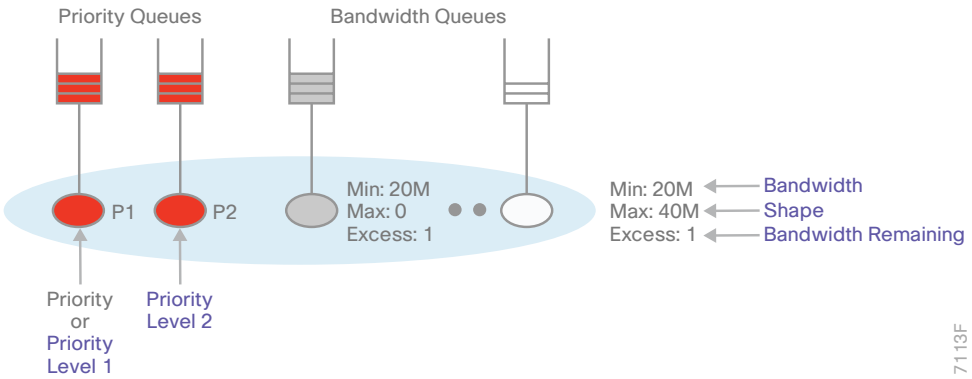
A QoS scheduling entry is configured with either a priority entry or a bandwidth entry. Priority entries can be further divided into P1 or P2 entries by using the **level** keyword. The two levels of priority are only locally significant.

A priority entry can be configured with a conditional (implicit) policer or an always-on (explicit) policer. A conditional policer only polices the traffic when there is congestion on the interface. An always-on policer polices the traffic with or without congestion on the interface. To avoid aggregate priority load issues, the IWAN QoS design requires the use of an always-on policer, rather than a conditional policer.

A bandwidth entry has three distinct parameters: minimum rate, maximum rate and excess weight. The minimum guarantee entry is configured using the **bandwidth** command. The maximum entry is configured using the **shape** command and excess weight is configured using the **bandwidth remaining** command. The excess weight dictates how queues compete for any bandwidth available after priority and minimum guarantees have been met. The **bandwidth remaining percent** command specifies the bandwidth allocation as a percentage of the visible bandwidth that has not been allocated to priority classes.

Visible bandwidth is determined from the configuration to be a reasonable representation of the service rate of a queue, without taking offered load into account. If a class is configured with the **bandwidth remaining** command, the visible bandwidth is inherited directly from the parent. If the **policy-map** is attached to a physical interface the value inherited is the interface speed or the value of the bandwidth statement placed on the interface. If the policy is a child policy with a parent shaper, the visible bandwidth is the parent shape rate. The following figure depicts which commands are used to set each schedule entry.

Figure 14 QoS schedule entries



The order of queuing with a given child policy map is as follows:

- Service P1 until empty
- If P1 is empty, service P2 until empty
- If P1 and P2 are empty, service minimum bandwidth guarantees
- Scheduler picks between the minimum bandwidth queues by selecting the queue that has been waiting the longest
- If P1, P2 and Min are empty, service excess weight until all bandwidth is exhausted or until a given queue has reached a max
- After each packet is sent, return to top

The WAN policy map references the class names you created in the previous procedures and defines the queuing behavior, along with the **bandwidth remaining percent** allocated to each class. Then each class within the policy map invokes an egress queue and a percentage of visible bandwidth is allocated using excess weight. One additional default class defines the bandwidth available for best effort traffic.

There are two methods for marking the tunnel headers. The method you use depends on whether you apply the policy to a virtual tunnel interface or a physical interface. Use the **set dscp tunnel** command when applying the policy-map to a tunnel interface to change the outer header, while leaving the original 12-class marking on the inner header unchanged. Use the **set dscp** command when applying the policy-map to a physical interface because in the order of operations, the outer header has already been imposed and the inner header will not be modified.

Tech Tip

The local router policy maps define eight classes, while most service providers offer only six classes of service. The NET-CTRL class is defined to ensure the correct classification, marking, and queuing of network-critical traffic on egress to the WAN. After the traffic has been transmitted to the service provider, it is put into a queue that is not part of the customer-facing class model.

Step 1: Create the policy map.

```
policy-map [policy-map-name]
```

Step 2: Apply the previously created class-map.

```
class [class-name]
```

Step 3: (Optional) Define what proportion of available bandwidth should be reserved for this class of traffic under congestion.

```
bandwidth remaining percent [percentage]
```

Step 4: (Optional) Define the congestion avoidance mechanism.

```
random-detect [type]
```

Step 5: (Optional) If random-detect is used on an ISR 4K platform, change the value of exponential weighting constant.

```
random-detect exponential-weighting-constant 9
```

Tech Tip

The previous command is only needed in WRED classes for ISR 4K platforms. The default value was inadvertently lowered in IOS XE and a higher value of 9 is better suited for software scheduling platforms, like the ISR 4K. This command is not needed for the ISR G2 or ASR 1K platforms.

Step 6: (Optional) For explicit priority queues, define the priority level for the class.

```
priority level [value]
```

Step 7: (Optional) For explicit priority queues, define the amount of bandwidth that may be consumed by priority traffic.

```
police cir [percentage]
```

Step 8: (Optional) For QOS policies that will be attached to tunnel interfaces (hub router configuration), mark the DSCP in the tunnel header.

```
set dscp tunnel [dscp value]
```

Step 9: (Optional) For QOS policies that will be attached to physical interface (remote-site router configuration), mark the DSCP in the tunnel header.

```
set dscp [dscp value]
```

Tech Tip

Fair queuing should not be used in a policy map for encrypted flows, such as IWAN. The outer tunnel header with a non-changing IP address is used for individual flow queue selection. This results in the same queue being selected for all traffic flowing through the class with fair queuing and reduces the overall queue size to 1/4 of its original size.

Table 41 Bandwidth, congestion avoidance and outbound tunnel values

Class of service for 8-class model	Bandwidth %	Congestion avoidance	Tunnel DSCP values for 6-class model
VOICE	10 (PQ)	–	ef
INTERACTIVE-VIDEO	30 remaining	DSCP based WRED	af41
STREAMING-VIDEO	10 remaining	DSCP based WRED	af31
NET-CTRL	5 remaining	–	cs6 (pass through)
CALL-SIGNALING	4 remaining	–	af21
CRITICAL-DATA	25 remaining	DSCP based WRED	af21
default	25 remaining	random	(pass through)
SCAVENGER	1 remaining	–	af11

Step 10: Repeat Step 2 through Step 8 for each class in the previous table, including the default class.

Tech Tip

The default class does not set the DSCP value, which allows traffic to pass through with markings that do not fit into the values specified by the match statements used above.

Example: WAN aggregation policy map for 6-class service provider offering

This example uses the **set dscp tunnel** command in each class because the policy is applied to the tunnel interfaces on the WAN aggregation routers.

```
policy-map WAN
 class INTERACTIVE-VIDEO
  bandwidth remaining percent 30
  random-detect dscp-based
  random-detect exponential-weighting-constant 9 ! ISR 4K platforms
  set dscp tunnel af41
 class STREAMING-VIDEO
  bandwidth remaining percent 10
  random-detect dscp-based
  random-detect exponential-weighting-constant 9 ! ISR 4K platforms
  set dscp tunnel af31
 class NET-CTRL
  bandwidth remaining percent 5
  set dscp tunnel cs6
 class CALL-SIGNALING
  bandwidth remaining percent 4
  set dscp tunnel af21
  class CRITICAL-DATA
  bandwidth remaining percent 25
  random-detect dscp-based
  random-detect exponential-weighting-constant 9 ! ISR 4K platforms
  set dscp tunnel af21
 class SCAVENGER
  bandwidth remaining percent 1
  set dscp tunnel af11
 class VOICE
  priority level 1
  police cir percent 10
  set dscp tunnel ef
 class class-default
  bandwidth remaining percent 25
  random-detect
  random-detect exponential-weighting-constant 9 ! ISR 4K platforms
```

Example: Remote site policy map for 6-class service provider offering

This example uses the **set dscp** command in each class, because the policy is applied to the physical interfaces on the remote site routers.

```
policy-map WAN
 class INTERACTIVE-VIDEO
  bandwidth remaining percent 30
  random-detect dscp-based
  random-detect exponential-weighting-constant 9 ! ISR 4K platforms
  set dscp af41
 class STREAMING-VIDEO
  bandwidth remaining percent 10
  random-detect dscp-based
  random-detect exponential-weighting-constant 9 ! ISR 4K platforms
  set dscp af31
 class NET-CTRL
  bandwidth remaining percent 5
  set dscp cs6
 class CALL-SIGNALING
  bandwidth remaining percent 4
  set dscp af21
  class CRITICAL-DATA
  bandwidth remaining percent 25
  random-detect dscp-based
  random-detect exponential-weighting-constant 9 ! ISR 4K platforms
  set dscp af21
 class SCAVENGER
  bandwidth remaining percent 1
  set dscp af11
 class VOICE
  priority level 1
  police cir percent 10
  set dscp ef
 class class-default
  bandwidth remaining percent 25
  random-detect
  random-detect exponential-weighting-constant 9 ! ISR 4K platforms
```

Tech Tip

Although these bandwidth assignments represent a good baseline, it is important to consider your actual traffic requirements per class and adjust the bandwidth settings accordingly.

PROCESS

Applying DMVPN QoS Policy to DMVPN Hub Routers

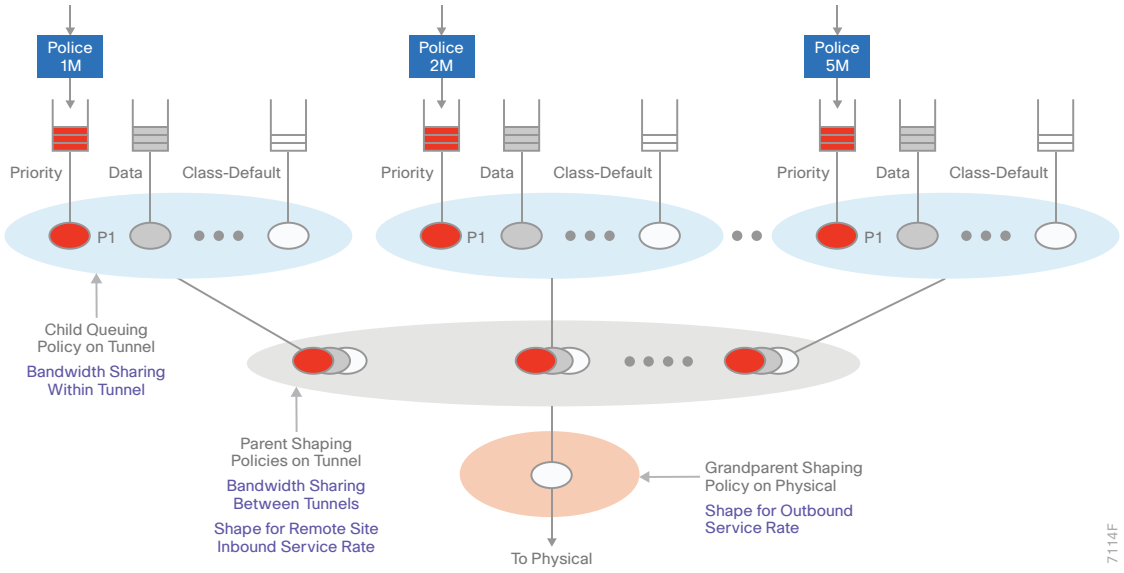
1. Configure shaping policy for hub router
2. Configure per-tunnel QoS policies for DMVPN hub router
3. Configure per-tunnel QoS NHRP policies on DMVPN hub router

This process applies only to DMVPN WAN Aggregation routers.

The hub router uses a three-tier QoS scheduling hierarchy which consists of a child queuing policy and a parent shaping policy on the tunnel, along with a grandparent shaping policy on the physical interface. The child queuing policy provides bandwidth sharing within the tunnel, while the parent shaping policy provides bandwidth sharing between the tunnels and shaping for the remote sites inbound service rate. The grandparent shaping policy prevents the hub router from overrunning the outbound service rate purchased from the provider.

A three-tier hierarchy can lead to aggregate priority load issues if the sum of all the priority traffic from each child queuing policy exceeds the outbound service rate of the hub router. Traffic entering the priority queue should always be protected by a call admission control function running on your call agents. However, to avoid aggregate priority load problems, an explicit policer is recommended for priority traffic, rather than an implicit policer. The explicit policer is an always-on policer that does not require congestion for it to police the traffic to the defined value. The figure below shows the three levels of QoS scheduling hierarchy for a hub router.

Figure 15 *Hub router three-tier QoS scheduling hierarchy*



Procedure 1 Configure shaping policy for hub router

With WAN interfaces using Ethernet as an access technology, the demarcation point between the enterprise and service provider may no longer have a physical-interface bandwidth constraint. Instead, a specified amount of access bandwidth is contracted with the service provider. To ensure the offered load to the service provider does not exceed the contracted rate that results in the carrier discarding traffic, you need to configure shaping on the physical interface. When you configure the **shape average** command, ensure that the value matches the contracted bandwidth rate from your service provider.

Tech Tip

QoS on a physical interface is limited only to the class default shaper. Other QoS configurations on the physical interface are not supported.

You must apply the class default shaper policy map on the main interface before applying the tunnel policy map.

The class default shaper policy map must contain only the class class-default and shape commands.

Create the policy map and configure the shaper for the default class.

As a best practice, embed the transport number within the name of the policy map.

```
policy-map [policy-map-name]
  class class-default
    shape average [bandwidth (kbps)]
```

Step 1: Apply the shaper to the WAN interface.

You must apply the service policy needs to be applied in the outbound direction.

```
interface [interface type] [number]
    service-policy output [policy-map-name]
```

Example: Physical interface

This example shows a router with a 600 Mbps service rate configured on a 1 Gbps physical interface.

```
policy-map TRANSPORT-1-SHAPE-ONLY
 class class-default
  shape average 600000000

interface GigabitEthernet0/0/3
 bandwidth 600000
 service-policy output TRANSPORT-1-SHAPE-ONLY
```

Procedure 2 Configure per-tunnel QoS policies for DMVPN hub router

The QoS policy on a tunnel instance allows you to shape the tunnel traffic to individual spokes and to differentiate between traffic classes within the tunnel for appropriate treatment.

The QoS policy on the tunnel instance is defined and applied only to the DMVPN hub routers at the central site. The remote-site router signals the QoS group policy information to the hub router with a command in the NHRP configuration, which greatly reduces QoS configuration and complexity. The hub router applies the signaled policy in the egress direction for each remote site.

The **bandwidth remaining ratio** command is used to provide each site with their fair share of the remaining bandwidth when the outbound interface is experiencing congestion. The command sets the excess weight, just like the **bandwidth remaining percentage** command. If you do not use this command, the lower bandwidth sites will get all of their assigned bandwidth, while the higher bandwidth sites will get less than their fair share.

In the example below, divide the shape average bandwidth by 1 Mbps to come up with the value for the ratio. If you have sites with less than 5 Mbps of shape average bandwidth, you should divide the shape average for all of your sites by 100 Kbps to ensure they all get a reasonable ratio greater than 1.

Tech Tip

With Per-Tunnel QoS for DMVPN, the queuing and shaping is performed at the outbound physical interface for the GRE/IPsec tunnel packets. This means that the GRE header, the IPsec header and the layer2 (for the physical interface) header are included in the packet-size calculations for shaping and bandwidth queuing of packets under QoS.

The values in the table are examples; make sure to adjust these values for your specific needs and remote-site bandwidth provisioned with your ISP.

Table 42 Per-tunnel QoS policies

Policy name	Class	Bandwidth bps	Bandwidth remaining ratio
RS-GROUP-300MBPS-POLICY	class-default	**300000000**	**300**
RS-GROUP-200MBPS-POLICY	class-default	**200000000**	**200**
RS-GROUP-100MBPS-POLICY	class-default	**100000000**	**100**
RS-GROUP-50MBPS-POLICY	class-default	**50000000**	**50**
RS-GROUP-30MBPS-POLICY	class-default	**30000000**	**30**
RS-GROUP-20MBPS-POLICY	class-default	**20000000**	**20**
RS-GROUP-10MBPS-POLICY	class-default	**10000000**	**10**
RS-GROUP-4G-POLICY	class-default	**8000000**	**8**

Step 1: Create a policy.

```
policy-map [policy-map-name]
```

Step 2: Define a shaper and bandwidth remaining ratio for the default-class and apply the **WAN** QoS queuing child service policy created in Procedure 2, "Create policy map with queuing policy."

The shape average value is entered in bits per second (bps). If all of your bandwidth values are greater than 5 Mbps, enter the bandwidth remaining ratio as shape average bandwidth/1 Mbps. If any of your bandwidth values are 5 Mbps or less, enter the bandwidth remaining ratio as shape average bandwidth/100 Kbps.

```
policy-map [policy-map-name]
   class class-default
    shape average [bandwidth (bps)]
    bandwidth remaining ratio [shape average bandwidth/1 Mbps]
      service-policy [policy-map name]
```

Step 3: For each remote-site type, repeat steps 1 and 2.

Example: Hub border router

```
policy-map RS-GROUP-300MBPS-POLICY
 class class-default
  shape average 300000000
  bandwidth remaining ratio 300
   service-policy WAN
policy-map RS-GROUP-200MBPS-POLICY
 class class-default
  shape average 200000000
  bandwidth remaining ratio 200
   service-policy WAN
policy-map RS-GROUP-100MBPS-POLICY
 class class-default
  shape average 100000000
  bandwidth remaining ratio 100
   service-policy WAN
policy-map RS-GROUP-50MBPS-POLICY
 class class-default
  shape average 50000000
  bandwidth remaining ratio 50
   service-policy WAN
policy-map RS-GROUP-30MBPS-POLICY
 class class-default
  shape average 30000000
```

```
  bandwidth remaining ratio 30
   service-policy WAN
policy-map RS-GROUP-20MBPS-POLICY
 class class-default
  shape average 20000000
  bandwidth remaining ratio 20
   service-policy WAN
policy-map RS-GROUP-10MBPS-POLICY
 class class-default
  shape average 10000000
  bandwidth remaining ratio 10
   service-policy WAN
policy-map RS-GROUP-4G-POLICY
 class class-default
  shape average 8000000
  bandwidth remaining ratio 8
   service-policy WAN
```

Procedure 3 Configure per-tunnel QoS NHRP policies on DMVPN hub router

The QoS policy that the hub uses for a particular endpoint or spoke is selected by the NHRP group in which the spoke is configured.

Prerequisites and important caveats:

- DMVPN must be fully configured and operational before you can configure an NHRP group on a spoke or map the NHRP group to a QoS policy on a hub.
- Although you may configure multiple spokes as part of the same NHRP group, the tunnel traffic for each spoke is measured individually for shaping and policing.
- Only output NHRP policies are supported. These apply to per-site traffic egressing the router towards the WAN.

Step 1: Create NHRP group policy name mapping and apply the policies configured in the previous procedure to the DMVPN tunnel interface on the hub router.

```
interface tunnel[number]
 nhrp map group [NHRP GROUP Policy Name] service-policy output [policy-map name]
```

Example: Hub border router

```
interface tunnel100
 nhrp map group RS-GROUP-300MBPS service-policy output RS-GROUP-300MBPS-POLICY
```

```
nhrp map group RS-GROUP-200MBPS service-policy output RS-GROUP-200MBPS-POLICY
nhrp map group RS-GROUP-100MBPS service-policy output RS-GROUP-100MBPS-POLICY
nhrp map group RS-GROUP-50MBPS service-policy output RS-GROUP-50MBPS-POLICY
nhrp map group RS-GROUP-30MBPS service-policy output RS-GROUP-30MBPS-POLICY
nhrp map group RS-GROUP-20MBPS service-policy output RS-GROUP-20MBPS-POLICY
nhrp map group RS-GROUP-10MBPS service-policy output RS-GROUP-10MBPS-POLICY
nhrp map group RS-GROUP-4G service-policy output RS-GROUP-4G-POLICY
```

PROCESS

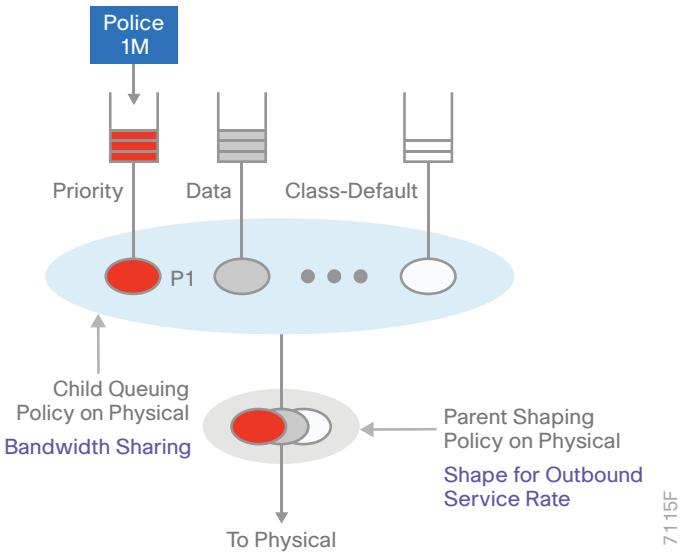
Applying QoS Configurations to Remote Site Routers

1. Configure per-tunnel QoS NHRP policy on remote-site routers
2. Configure physical interface QoS policy on remote-site routers
3. Apply QoS policy to the physical interface on remote-site routers
4. Verify QoS policy on physical interfaces of remote site router
5. Verify DMVPN per-tunnel QoS from hub routers

This process applies only to DMVPN remote site routers.

The remote site router uses a two-tier QoS scheduling hierarchy that consists of a child queuing policy and a parent shaping policy on the physical interface. The child queuing policy provides bandwidth sharing, while the parent shaping policy shapes traffic to the remote sites' outbound service rate. The figure below shows the two levels of QoS scheduling hierarchy for a remote site router.

Figure 16 *Remote site router two-tier QoS scheduling hierarchy*



Procedure 1 Configure per-tunnel QoS NHRP policy on remote-site routers

This procedure configures the remote-site router to reference the QoS policy configured on the hub site routers.

The inbound and outbound service rates do not have to match. In the examples given below, the first interface has 20/20 Mbps symmetrical bandwidth, while the second interface has 50/30 Mbps asymmetrical bandwidth.

Step 1: Apply the NHRP group policy to the DMVPN tunnel interface on the corresponding remote-site router. Use the NHRP group name as defined on the hub router in Procedure 2, "Configure per tunnel QoS policies for DMVPN hub router," above. Configure the **bandwidth receive** command on the interface to match the NHRP group policy chosen and the inbound service rate. The bandwidth value is entered in kilobits per second (Kbps)

```
interface Tunnel[value]
 bandwidth receive [value in Kbps]
 nhrp group [NHRP GROUP Policy Name]
```

Example: Remote site router with dual-link for hybrid

This example shows a remote-site using 20 Mbps and 50 Mbps inbound service rate policies.

```
interface Tunnel100
 bandwidth receive 20000
 nhrp group RS-GROUP-20MBPS

interface Tunnel200
 bandwidth receive 50000
 nhrp group RS-GROUP-50MBPS
```

Procedure 2 Configure physical interface QoS policy on remote-site routers

Repeat this procedure in order to support remote-site routers that have multiple WAN connections attached to different interfaces.

With WAN interfaces using Ethernet as an access technology, the demarcation point between the enterprise and service provider may no longer have a physical-interface bandwidth constraint. Instead, a specified amount of inbound and outbound bandwidth is contracted with the service provider. To ensure the offered load to the service provider does not exceed the outbound service rate that results in the carrier discarding traffic, configure shaping on the physical interface.

This shaping is accomplished with a QoS service policy. You configure a QoS service policy on the outside Ethernet interface, and this parent policy includes a shaper that then references a nested child policy that enables queuing within the shaped rate. When you configure the **shape average** command, ensure that the value matches the outbound service rate bandwidth from your service provider. The shape average value is entered in bits per second (bps).

Step 1: Create the parent policy map.

As a best practice, embed the transport number within the name of the parent policy map.

```
policy-map [policy-map-name]
```

Step 2: Configure the shaper.

```
class [class-name]
  shape average [bandwidth (bps)]
```

Step 3: Apply the child service policy as defined in Procedure 2, "Create policy map with queuing policy," above.

```
service-policy WAN
```

Example: Remote site router with dual-link for hybrid

This example shows a router with a 10-Mbps outbound service rate on interface GigabitEthernet0/0 for transport 1 and a 30-Mbps outbound service rate on interface GigabitEthernet0/1 for transport 2.

```
policy-map POLICY-TRANSPORT-1
 class class-default
  shape average 10000000
   service-policy WAN

policy-map POLICY-TRANSPORT-2
 class class-default
  shape average 30000000
   service-policy WAN
```

Procedure 3 Apply QoS policy to the physical interface on remote-site routers

Repeat this procedure in order to support remote-site routers that have multiple WAN connections attached to different interfaces.

To invoke shaping and queuing on a physical interface, you must apply the parent policy that you configured in the previous procedure.

Step 1: Select the WAN interface and apply the WAN QoS policy

The service policy needs to be applied in the outbound direction. Configure the **bandwidth** statement on the interface to match the shape average statement from the outbound service policy in the previous procedure. Configure the **bandwidth receive** statement on the interface to match the NHRP group policy chosen and the inbound service rate. The bandwidth values are entered in kilobits per second (Kbps)

```
interface [interface type] [number]
 bandwidth [value in Kbps]
 bandwidth receive [value in Kbps] ; only needed if different
 service-policy output [policy-map-name]
```

Example: Remote site router with dual-link for hybrid

This example shows a remote-site using 10 Mbps and 30 Mbps outbound service rate policies with 20 Mbps and 50 Mbps inbound service rate policies.

```
interface GigabitEthernet0/0
 bandwidth 10000 ; outbound service rate
 bandwidth receive 20000 ; inbound service rate
 service-policy output POLICY-TRANSPORT-1

interface GigabitEthernet0/1
 bandwidth 30000 ; outbound service rate
 bandwidth receive 50000 ; inbound service rate
 service-policy output POLICY-TRANSPORT-2
```

Procedure 4 Verify QoS policy on physical interfaces of remote site router

After all of the physical interfaces on a router are configured, you can verify each one before moving to the next remote site.

Step 1: Verify the QoS output policy on each interface is correct by using the **show policy-map interface** command.

Step 2: Repeat the previous step for each interface configured with QoS.

Tech Tip

If you experience tail-drops in your class class-default, a potential work-around is to increase the size of the queue-limit.

On an interface with bandwidth of less than 15 Mbps, the default queue-limit is 64 packets. Increasing this value will add latency to the traffic in the default-class but will also reduce the number of tail-drops.

```
policy-map WAN
 class class-default
  queue-limit 512 packets
```

Procedure 5 Verify DMVPN per-tunnel QoS from hub routers

After the all of the DMVPN routers are configured for Per-Tunnel QoS, you can verify the configurations from the hub router.

Step 1: Verify the Per-Tunnel QoS output policy to each remote-site is correct by using the **show dmvpn detail** command.

Step 2: Repeat the previous step for each DMVPN hub router.

Appendix A: Product List

To view the full list of IWAN-supported routers for this version of the CVD, see Supported Cisco Platforms and Software Releases. All master controllers and border router devices at a common site must use the same version of software.

This guide was validated using the software shown in this appendix. When deploying, you should always use the Cisco IOS Software Checker tool to see if there are software vulnerabilities applicable for your environment. This tool is available at the following location:

https://tools.cisco.com/security/center/selectIOSVersion.x

Appendix B: Common Sections

This steps in this appendix are common for different router types. Please confirm each section matches the router type you are deploying before proceeding.

CONFIGURING THE PLATFORM BASE FEATURES

This section is for all routers.

Step 1: Configure the device host name. Make it easy to identify the device.

```
hostname [Hostname]
```

Step 2: Configure local login and password.

The local login account and password provide basic access authentication to a router, which provides only limited operational privileges. The enable password secures access to the device configuration mode. By enabling password encryption, you prevent the disclosure of plain text passwords when viewing configuration files.

```
username admin secret c1sco123
enable secret c1sco123
service password-encryption
aaa new-model
```

By default, https access to the router will use the enable password for authentication.

Step 3: Increase the buffer logging size to 1 MB.

The default buffer size of 4KB doesn't provide enough room for logging historical events when troubleshooting or investigating problems. Increasing the buffer size provides more flexibility for analysis, especially in instances were syslog is not enabled.

```
logging buffered 1000000
```

Tech Tip

The logging level is set to debugging by default so all debug messages are captured. If this is not desirable, the level can be changed to something lower. However, it is recommended to set it to "informational" (level 6) at a minimum to ensure all other log messages are captured.

Step 4: (Optional) Configure centralized user authentication.

As networks scale in the number of devices to maintain, it poses an operational burden to maintain local user accounts on every device. A centralized AAA service reduces operational tasks per device and provides an audit log of user access for security compliance and root cause analysis. When AAA is enabled for access control, AAA controls all management access to the network infrastructure devices (SSH and HTTPS).

TACACS+ is the primary protocol used to authenticate management logins on the infrastructure devices to the AAA server. A local AAA user database is also defined (in Step 2) on each network infrastructure device in order to provide a fallback authentication source in case the centralized TACACS+ server is unavailable.

```
tacacs server TACACS-SERVER-1
 address ipv4 10.4.48.15
 key SecretKey

aaa group server tacacs+ TACACS-SERVERS
 server name TACACS-SERVER-1

aaa authentication login default group TACACS-SERVERS local
aaa authorization exec default group TACACS-SERVERS local
aaa authorization console
ip http authentication aaa
```

Step 5: Configure device management protocols.

Secure HTTPS and SSH are secure replacements for the HTTP and Telnet protocols. They use SSL and TLS in order to provide device authentication and data encryption.

Secure management of the network device is enabled through the use of the SSH and HTTPS protocols. Both protocols are encrypted for privacy and the nonsecure protocols, Telnet and HTTP, are turned off. SCP is enabled, which allows the use of code upgrades using Prime Infrastructure via SSH-based SCP protocol.

Specify the transport **preferred none** on vty lines in order to prevent errant connection attempts from the CLI prompt. Without this command, if the ip name-server is unreachable, long timeout delays may occur for mistyped commands.

```
ip domain-name cisco.local
ip ssh version 2
no ip http server
ip http secure-server
ip scp server enable
line vty 0 15
 transport input ssh
 transport preferred none
```

When synchronous logging of unsolicited messages and debug output is turned on, console log messages are displayed on the console after interactive CLI output is displayed or printed. With this command, you can continue typing at the device console when debugging is enabled.

```
line con 0
 transport preferred none
 logging synchronous
```

Enable SNMP in order to allow the network infrastructure devices to be managed by an NMS. SNMPv2c is configured both for a read-only and a read-write community string.

```
snmp-server community cisco RO
snmp-server community cisco123 RW
snmp-server ifindex persist ! IOS Classic Only
snmp ifmib ifindex persist  ! IOS XE Only
```

Step 6: (Optional) In networks where network operational support is centralized, you can increase network security by using an access list to limit the networks that can access your device. In this example, only devices on the 10.4.48.0/24 network will be able to access the device via SSH or SNMP.

```
access-list 55 permit 10.4.48.0 0.0.0.255
line vty 0 15
 access-class 55 in

snmp-server community cisco RO 55
snmp-server community cisco123 RW 55
```

Tech Tip

If you configure an access-list on the vty interface you may lose the ability to use ssh to login from one router to the next for hop-by-hop troubleshooting.

Step 7: Configure a synchronized clock.

NTP is designed to synchronize a network of devices. An NTP network usually gets its time from an authoritative time source, such as a radio clock or an atomic clock attached to a time server. NTP then distributes this time across the organizations network.

You should program network devices to synchronize to a local NTP server in the network. The local NTP server typically references a more accurate clock feed from an outside source. By configuring console messages, logs, and debug output to provide time stamps on output, you can cross-reference events in a network.

```
ntp server 10.4.48.17


clock timezone PST -8
clock summer-time PDT recurring


service timestamps debug datetime msec localtime
service timestamps log datetime msec localtime
```

Step 8: Configure an in-band management interface.

The *loopback interface* is a logical interface that is always reachable as long as the device is powered on and any IP interface is reachable to the network. Because of this capability, the loopback address is the best way to manage the router in-band. Layer 3 process and features are also bound to the loopback interface to ensure process resiliency.

The loopback address is commonly a host address with a 32-bit address mask. Allocate the loopback address from the IP address block that the router summarizes to the rest of the network.

```
interface Loopback 0
  ip address [ip address] 255.255.255.255
  ip pim sparse-mode
```

Bind the device processes for SNMP, SSH, PIM, TACACS+ and NTP to the loopback interface address for optimal resiliency:

```
snmp-server trap-source Loopback0
ip ssh source-interface Loopback0
ip pim register-source Loopback0
ip tacacs source-interface Loopback0
ntp source Loopback0
```

Step 9: Return to the previous place in the guide.

CONFIGURING IKEV2 AND IPSEC FOR A DMVPN BORDER ROUTER

This section is for DMVPN border routers only.

The parameters in the table below are used in this section. The crypto configurations have been simplified in this version of the guide in order to minimize the variations from previous guides.

Table 43 Crypto parameters

Parameter	Pre-Shared Keys
crypto ikev2 keyring	DMVPN-KEYRING
crypto ikev2 profile	DMVPN-IKEv2-PROFILE
crypto ipsec profile	DMVPN-IPSEC-PROFILE

IPsec uses a key exchange between the routers in order to encrypt/decrypt the traffic. These keys can be exchanged using pre-shared keys or PKI certificates with a certificate authority. It is also possible to use a combination of the two, which is useful during a migration from one method to the other. **Configuring IKEv2 and IPsec with pre-shared keys**

Step 1: Configure the crypto keyring for pre-shared keys.

The crypto keyring defines a pre-shared key (or password) valid for IP sources that are reachable within a particular VRF. This key is a wildcard pre-shared key if it applies to any IP source. A wildcard key is configured using the 0.0.0.0 0.0.0.0 as the network/mask combination.

```
crypto ikev2 keyring [keyring name]
 peer ANY
  address 0.0.0.0 0.0.0.0
  pre-shared-key [password]
```

Example

```
crypto ikev2 keyring DMVPN-KEYRING
 peer ANY
  address 0.0.0.0 0.0.0.0
  pre-shared-key c1sco123
```

Step 2: Configure the IKEv2 proposal.

The user-defined IKEv2 proposal includes only the following:

- Encryption with AES cipher and a 256-bit key
- Pseudo-random function with SHA and a 512-bit digest
- Diffie-Hellman group: 19

```
crypto ikev2 proposal [proposal name]
 encryption [encryption algorithm]
 prf [pseudo-random function algorithm]
 group [Diffie-Hellman group]
```

Example

```
crypto ikev2 proposal AES/GCM/256
 encryption aes-gcm-256
 prf sha512
 group 19
```

The default IKEv2 proposal is also used.

A **show crypto ikev2 proposal** displays the details of the two proposals.

```
show crypto ikev2 proposal
 IKEv2 proposal: AES/GCM/256
      Encryption : AES-GCM-256
      Integrity  : none
      PRF        : SHA512
      DH Group   : DH_GROUP_256_ECP/Group 19
 IKEv2 proposal: default
      Encryption : AES-CBC-256 AES-CBC-192 AES-CBC-128
      Integrity  : SHA512 SHA384 SHA256 SHA96 MD596
      PRF        : SHA512 SHA384 SHA256 SHA1 MD5
      DH Group : DH_GROUP_1536_MODP/Group 5 DH_GROUP_1024_MODP/Group 2
```

Step 3: Configure the IKEv2 policy.

The crypto policy includes the proposal you created in the previous step. This policy will match any FVRF defined on the router.

```
crypto ikev2 policy [policy name]
 match fvrf any
 proposal [proposal name]
```

Example

```
crypto ikev2 policy AES/GCM/256
 match fvrf any
 proposal AES/GCM/256
```

The default IKEv2 policy is also used.

A **show crypto ikev2 policy** displays the details of the two policies.

```
show crypto ikev2 policy
 IKEv2 policy : AES/GCM/256
      Match fvrf : any
      Match address local : any
      Proposal    : AES/GCM/256

 IKEv2 policy : default
      Match fvrf : any
      Match address local : any
      Proposal    : default
```

Step 4: Configure the IKEv2 profile.

The IKEv2 profile creates an association between an identity address, a VRF, and a crypto keyring. A wildcard address within a VRF is referenced with 0.0.0.0. The **identity local address** must match the loopback address of this router.

> ***Tech Tip***
>
> **Identity local address** is needed for customers who use Carrier Grade NAT (CGN) which requires a unique identity per remote site router even if the same pre-NAT IP address is used for other locations. The command does not affect customers who are not using CGN, so it is a recommended best practice to use the command all of the time.

The profile also defines what method of key sharing will be used on this router with **authentication local** and what methods will be accepted from remote locations with **authentication remote**. The **pre-share** keyword is used with the keyring defined above.

```
crypto ikev2 profile [profile name]
 description [profile description]
 match fvrf [vrf name]
 match identity remote address [IP address]
 identity local address [Loopback IP address of this router]
 authentication remote pre-share
 authentication local pre-share
 keyring local [keyring name]
```

Example: MPLS1 hub border router–HY-MPLS1-ASR1002X-1

```
crypto ikev2 profile DMVPN-IKEv2-PROFILE
 description PSK Profile
 match fvrf any
 match identity remote address 0.0.0.0
 identity local address 10.6.32.241
 authentication local pre-share
 authentication remote pre-share
 keyring local DMVPN-KEYRING
```

Step 5: Define the IPsec transform set.

A transform set is an acceptable combination of security protocols, algorithms, and other settings to apply to IPsec-protected traffic. Peers agree to use a particular transform set when protecting a particular data flow.

The IPsec transform set for DMVPN uses the following:

- ESP with the 256-bit GCM encryption algorithm

Because the DMVPN hub router is behind a NAT device, the IPsec transform must be configured for transport mode.

```
crypto ipsec transform-set [transform set] esp-gcm 256
 mode transport
```

Example

```
crypto ipsec transform-set AES256/GCM/TRANSFORM esp-gcm 256
 mode transport
```

Step 6: Configure the IPsec profile.

The IPsec profile creates an association between an IKEv2 profile and an IPsec transform-set.

```
crypto ipsec profile [profile name]
 set transform-set [transform set]
 set ikev2-profile [ikev2 profile name]
```

Example

```
crypto ipsec profile DMVPN-IPSEC-PROFILE
 set transform-set AES256/GCM/TRANSFORM
 set ikev2-profile DMVPN-IKEv2-PROFILE
```

Step 7: Increase the IPsec anti-replay window size.

```
crypto ipsec security-association replay window-size [value]
```

Example

```
crypto ipsec security-association replay window-size 1024
```

Tech Tip

QoS queuing delays can cause anti-replay packet drops, so it is important to extend the window size in order to prevent the drops from occurring.

Increasing the anti-replay window size has no impact on throughput and security. The impact on memory is insignificant because only an extra 128 bytes per incoming IPsec SA is needed.

It is recommended that you use the maximum window size in order to minimize future anti-replay problems. On the ASR1K, ISR4K and ISRG2 router platforms, the maximum replay window size is 1024.

If you do not increase the window size, the router may drop packets and you may see the following error messages on the router CLI and in the log:

%CRYPTO-4-PKT_REPLAY_ERR: decrypt: replay check failed

A **show crypto ipsec sa** displays the transform and anti-replay window size.

```
show crypto ipsec sa

interface: Tunnel100
    Crypto map tag: Tunnel100-head-0, local addr 192.168.6.1

   protected vrf: (none)
   local  ident (addr/mask/prot/port): (192.168.6.1/255.255.255.255/47/0)
   remote ident (addr/mask/prot/port): (192.168.6.37/255.255.255.255/47/0)
   current_peer 192.168.6.37 port 500
     PERMIT, flags={origin_is_acl,}
    #pkts encaps: 54930270, #pkts encrypt: 54930270, #pkts digest: 54930270
    #pkts decaps: 56137986, #pkts decrypt: 56137986, #pkts verify: 56137986
    #pkts compressed: 0, #pkts decompressed: 0
    #pkts not compressed: 0, #pkts compr. failed: 0
    #pkts not decompressed: 0, #pkts decompress failed: 0
    #send errors 0, #recv errors 0

     local crypto endpt.: 192.168.6.1, remote crypto endpt.: 192.168.6.37
     plaintext mtu 1366, path mtu 1400, ip mtu 1400, ip mtu idb Tunnel100
     current outbound spi: 0xB4CB483E(3033221182)
     PFS (Y/N): N, DH group: none
```

```
        inbound esp sas:
         spi: 0x416B8951(1097566545)
           transform: esp-gcm 256 ,
           in use settings ={Transport, }
           conn id: 5392, flow_id: HW:3392, sibling_flags FFFFFFFF80000008, crypto
map: Tunnel100-head-0
           sa timing: remaining key lifetime (k/sec): (4591555/1700)
           IV size: 8 bytes
           replay detection support: Y  replay window size: 1024
           Status: ACTIVE(ACTIVE)
```

Step 8: Return to the previous place in the guide.

CONFIGURING IKEV2 AND IPSEC FOR A REMOTE SITE ROUTER

This section is for remote site routers only.

The parameters in the table below are used in this section. The crypto configurations have been simplified in this version of the guide in order to minimize the variations from previous guides. Use the values in the table that represent the design you are configuring.

Table 44 Crypto parameters

Parameter	Pre-Shared Keys	Public Key Infrastructure
crypto ikev2 keyring	DMVPN-KEYRING	DMVPN-KEYRING
crypto ikev2 profile	DMVPN-IKEv2-PROFILE	DMVPN-PKI-IKEv2-PROFILE
crypto ipsec profile	DMVPN-IPSEC-PROFILE	DMVPN-PKI-IPSEC-PROFILE

IPsec uses a key exchange between the routers in order to encrypt/decrypt the traffic. These keys can be exchanged using pre-shared keys or PKI certificates with a certificate authority. It is also possible to use a combination of the two, which is useful during a migration from one method to the other.

Configuring IKEv2 and IPsec with Pre-Shared Keys

Step 1: Configure the crypto keyring for pre-shared keys.

The crypto keyring defines a pre-shared key (or password) valid for IP sources that are reachable within a particular VRF. This key is a wildcard pre-shared key if it applies to any IP source. A wildcard key is configured using the 0.0.0.0 0.0.0.0 network/mask combination.

```
crypto ikev2 keyring [keyring name]
 peer ANY
  address 0.0.0.0 0.0.0.0
  pre-shared-key [password]
```

Example

```
crypto ikev2 keyring DMVPN-KEYRING
 peer ANY
  address 0.0.0.0 0.0.0.0
  pre-shared-key c1sco123
```

Step 2: Configure the IKEv2 proposal.

The user-defined IKEv2 proposal includes only the following:

- Encryption with AES cipher and a 256-bit key
- Pseudo-random function with SHA and a 512-bit digest
- Diffie-Hellman group: 19

```
crypto ikev2 proposal [proposal name]
 encryption [encryption algorithm]
 prf [pseudo-random function algorithm]
 group [Diffie-Hellman group]
```

Example

```
crypto ikev2 proposal AES/GCM/256
 encryption aes-gcm-256
 prf sha512
 group 19
```

The default IKEv2 proposal is also used.

A **show crypto ikev2 proposal** displays the details of the two proposals.

```
show crypto ikev2 proposal
 IKEv2 proposal: AES/GCM/256
      Encryption : AES-GCM-256
      Integrity  : none
      PRF        : SHA512
      DH Group   : DH_GROUP_256_ECP/Group 19
 IKEv2 proposal: default
      Encryption : AES-CBC-256 AES-CBC-192 AES-CBC-128
      Integrity  : SHA512 SHA384 SHA256 SHA96 MD596
      PRF        : SHA512 SHA384 SHA256 SHA1 MD5
      DH Group : DH_GROUP_1536_MODP/Group 5 DH_GROUP_1024_MODP/Group 2
```

Step 3: Configure the IKEv2 policy.

The crypto policy includes the proposal you created in the previous step. This policy will match any FVRF defined on the router.

```
crypto ikev2 policy [policy name]
 match fvrf any
 proposal [proposal name]
```

Example

```
crypto ikev2 policy AES/GCM/256
 match fvrf any
 proposal AES/GCM/256
```

The default IKEv2 policy is also used.

A **show crypto ikev2 policy** displays the details of the two policies.

```
show crypto ikev2 policy

 IKEv2 policy : AES/GCM/256
      Match fvrf : any
      Match address local : any
      Proposal    : AES/GCM/256

 IKEv2 policy : default
      Match fvrf : any
      Match address local : any
      Proposal    : default
```

Step 4: Configure the IKEv2 profile.

The IKEv2 profile creates an association between an identity address, a VRF, and a crypto keyring. A wildcard address within a VRF is referenced with 0.0.0.0. The **identity local address** must match the loopback address of this router.

> ***Tech Tip***
>
> **Identity local address** is needed for customers who use Carrier Grade NAT (CGN), which requires a unique identity per remote site router even if the same pre-NAT IP address is used for other locations. The command does not affect customers who are not using CGN, so it is a recommended best practice to use the command all of the time.

The profile also defines what method of key sharing will be used on this router with **authentication local** and what methods will be accepted from remote locations with **authentication remote**. The **pre-share** keyword is used with the keyring defined above.

DPD is essential in order to facilitate fast re-convergence and for spoke registration to function properly in case a DMVPN hub is restarted. The IWAN design recommends you set the remote site DPD timer to 40 seconds with a 5 second retry. Moving the DPD timer into the **crypto ikev2 profile** ensures the command will be used immediately, rather than waiting for the first 24 hour refresh cycle if the command is entered in the global configuration.

```
crypto ikev2 profile [profile name]
 description [profile description]
 match fvrf [vrf name]
 match identity remote address [IP address]
 identity local address [Loopback IP address of this router]
 authentication remote pre-share
 authentication local pre-share
 keyring local [keyring name]
```

Example: Single-router remote site for hybrid–RS11-2921

```
crypto ikev2 profile DMVPN-IKEv2-PROFILE
 description PSK Profile
 match fvrf any
 match identity remote address 0.0.0.0
 identity local address 10.255.241.11
 authentication local pre-share
 authentication remote pre-share
 keyring local DMVPN-KEYRING
 dpd 40 5 on-demand
```

Step 5: Define the IPsec transform set.

A transform set is an acceptable combination of security protocols, algorithms, and other settings to apply to IPsec-protected traffic. Peers agree to use a particular transform set when protecting a particular data flow.

The IPsec transform set for DMVPN uses ESP with the 256-bit GCM encryption algorithm.

Because the DMVPN hub router is behind a NAT device, the IPsec transform must be configured for transport mode.

```
crypto ipsec transform-set [transform set] esp-gcm 256
 mode transport
```

Example

```
crypto ipsec transform-set AES256/GCM/TRANSFORM esp-gcm 256
 mode transport
```

Step 6: Configure the IPsec profile.

The IPsec profile creates an association between an IKEv2 profile and an IPsec transform-set.

```
crypto ipsec profile [profile name]
 set transform-set [transform set]
 set ikev2-profile [ikev2 profile name]
```

Example

```
crypto ipsec profile DMVPN-IPSEC-PROFILE
 set transform-set AES256/GCM/TRANSFORM
 set ikev2-profile DMVPN-IKEv2-PROFILE
```

Step 7: Increase the IPsec anti-replay window size.

```
crypto ipsec security-association replay window-size [value]
```

Example

```
crypto ipsec security-association replay window-size 1024
```

Tech Tip

QoS queuing delays can cause anti-replay packet drops, so it is important to extend the window size in order to prevent the drops from occurring.

Increasing the anti-replay window size has no impact on throughput and security. The impact on memory is insignificant because only an extra 128 bytes per incoming IPsec SA is needed.

It is recommended that you use the maximum window size in order to minimize future anti-replay problems. On the ASR1K, ISR4K and ISRG2 router platforms, the maximum replay window size is 1024.

If you do not increase the window size, the router may drop packets and you may see the following error messages on the router CLI and in the log:

```
%CRYPTO-4-PKT_REPLAY_ERR: decrypt: replay check failed
```

Step 8: Return to the previous place in the guide.

Appendix C: Changes

This appendix summarizes the changes Cisco made to this guide since its last edition.

- Routing updates:
  - Updated the tunnel interface and tunnel ID numbering to match other guides
  - Updated the EIGRP tag numbering to match other guides
- PfR updates:
  - Added probe reduction feature details
  - Added remote prefix tracking feature details
  - Added tech tip for event tracing feature
- QoS updates:
  - Added schedule entry details
  - Added three-tier scheduling hierarchy for hub site details
  - Added two-tier scheduling hierarchy for remote site details
  - Changed ip nhrp map group to nhrp map group to be consistent with later IOS versions
  - Changed ip nhrp group to nhrp group to be consistent with later IOS versions
- Platform update:
  - Increased logging buffer size to 1MB

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