CISCO VALIDATED DESIGN

IWAN Direct Internet Access Design Guide

December 2016

REFERENCE NETWORK ARCHITECTURE

Table of Contents

Introduction 1

Related Reading 1

Technology Use Cases 1

Overview of Cisco IWAN and Secure DIA 4

Direct Internet Access Design 10

Design Detail 10

Deploying Direct Internet Access 28

Using This Section 28

IWAN Single-Router Hybrid Remote Site with DIA 29

Configuring DIA Routing 29

Configuring Single-Router Remote Site with Layer 3 Distribution 34

Configuring Network Address Translation for DIA 37

Configuring Zone-Based Firewall for DIA 40

Configuring Additional Router Security 49

Configuring ISP Black-Hole Routing Detection 53

IWAN Dual-Router Hybrid Remote Site with DIA 59

Configuring DIA Routing 60

Configuring Network Address Translation for DIA 68

Configuring Zone-Based Firewall for DIA 71

Configuring Additional Router Security 80

Configuring ISP Black-Hole Routing Detection 84

IWAN Single-Router Dual-Internet Remote Site with DIA 89

Configuring DIA Routing 90

Configuring Single-Router Remote Site with Layer 3 Distribution 95

Configuring Network Address Translation for DIA 98

Configuring Zone-Based Firewall for DIA 101

Configuring Additional Router Security 113

Configuring ISP Black-Hole Routing Detection 118

IWAN Dual-Router Dual-Internet Remote Site with DIA 123

Configuring DIA Routing 124

Configuring Network Address Translation for DIA 132

Configuring Zone-Based Firewall for DIA 135

Configuring Additional Router Security 144

Configuring ISP Black-Hole Routing Detection 148

Appendix A: Product List 154

Appendix B: Router Configurations 158

Single-Router Hybrid with DIA 159

Dual-Router Hybrid with DIA 159

Single-Router Dual-Internet with DIA 161

Dual-Router Dual-Internet with DIA 162

Appendix C: DIA with PfR Load-Balancing 163

Configuring DIA with PfR Load-Balancing 163

Appendix D: Changes 166

Introduction

Security is an essential component of Cisco Intelligent WAN (IWAN). Cisco IWAN delivers an uncompromised user experience over any connection, allowing an organization to right-size their network with operational simplicity and lower costs while reducing security risks.

This guide describes how to reduce WAN bandwidth and improve user experience by enabling secure direct access to the Internet at each remote site, without routing employee traffic to central network locations.

RELATED READING

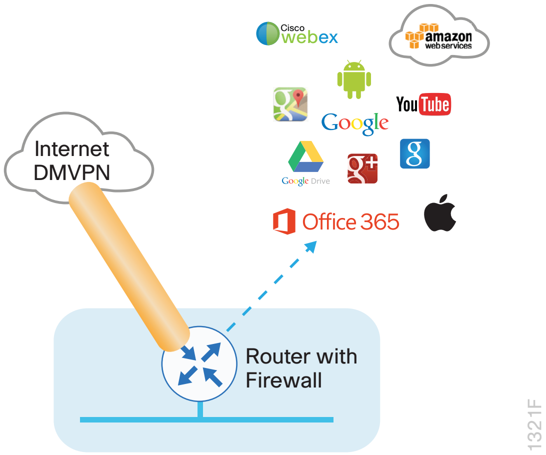
The Intelligent WAN Deployment Guide provides configuration and deployment guidance for IWAN routing with enhanced interior gateway routing protocol (EIGRP) named mode or border gateway protocol (BGP) and open shortest path first (OSPF). It also has guidance for dynamic multipoint virtual private network phase 3 (DMVPNv3), pre-shared key (PSK), public key infrastructure (PKI), and performance routing version 3 (PfRv3) for Cisco IWAN.

TECHNOLOGY USE CASES

For remote-site users to effectively support the business, organizations require that the wide-area network (WAN) provide sufficient performance, reliability, and security.

Although remote-site workers use many centrally located applications and services, there are also benefits in providing direct Internet access (DIA) at each remote-site location. Offloading Internet browsing and providing direct access to public cloud service providers can significantly reduce traffic on the private WAN, saving costs and improving overall survivability. Leveraging the cloud in the remote office can also greatly increase performance and the overall cloud experience.

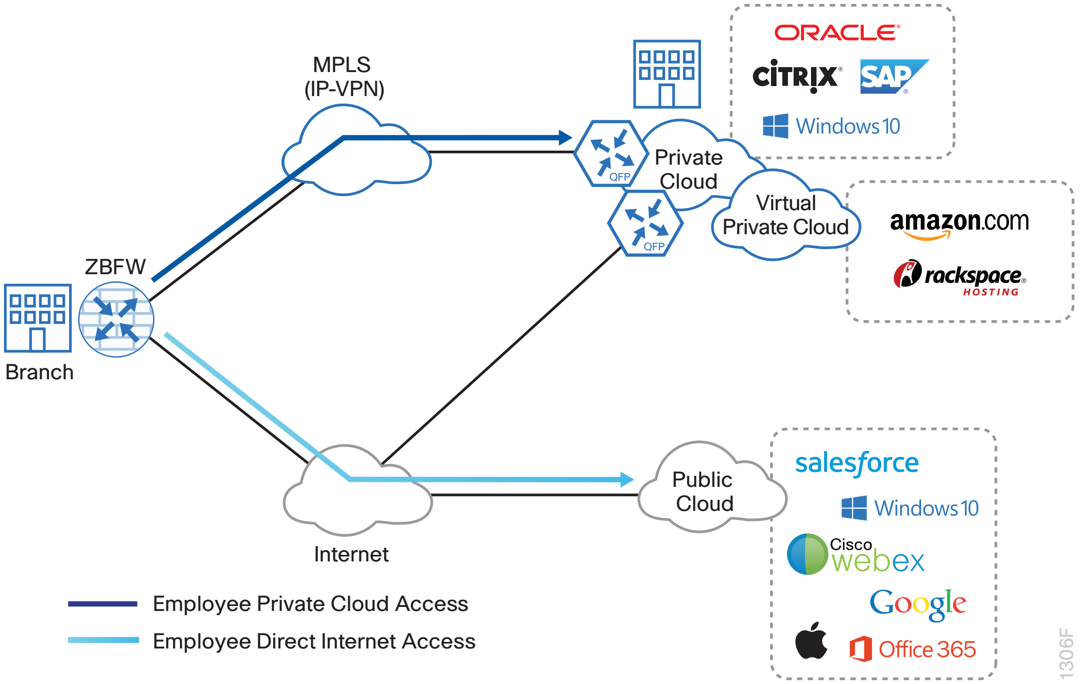
Figure 1 *IWAN remote site with DIA*



Use Case: DIA for Remote-Site Internal Employees

Remote-site users directly access the Internet for cloud-based applications and user web access without having to route their traffic through a central site over the WAN.

Figure 2 *Employee DIA*



This design guide enables the following network capabilities:

- Offloading Internet traffic from the WAN, thereby reducing bandwidth utilization
- Improving user experience by providing DIA for employees at IWAN remote-site locations
- Deploying Cisco IOS security services for remote users and applications that leverage zone-based firewall (ZBFW), network address translation (NAT), and other integrated network security features
- Resilient routing of local Internet, such as rerouting with local fall back or accessing the Internet through the central site during local Internet failure conditions

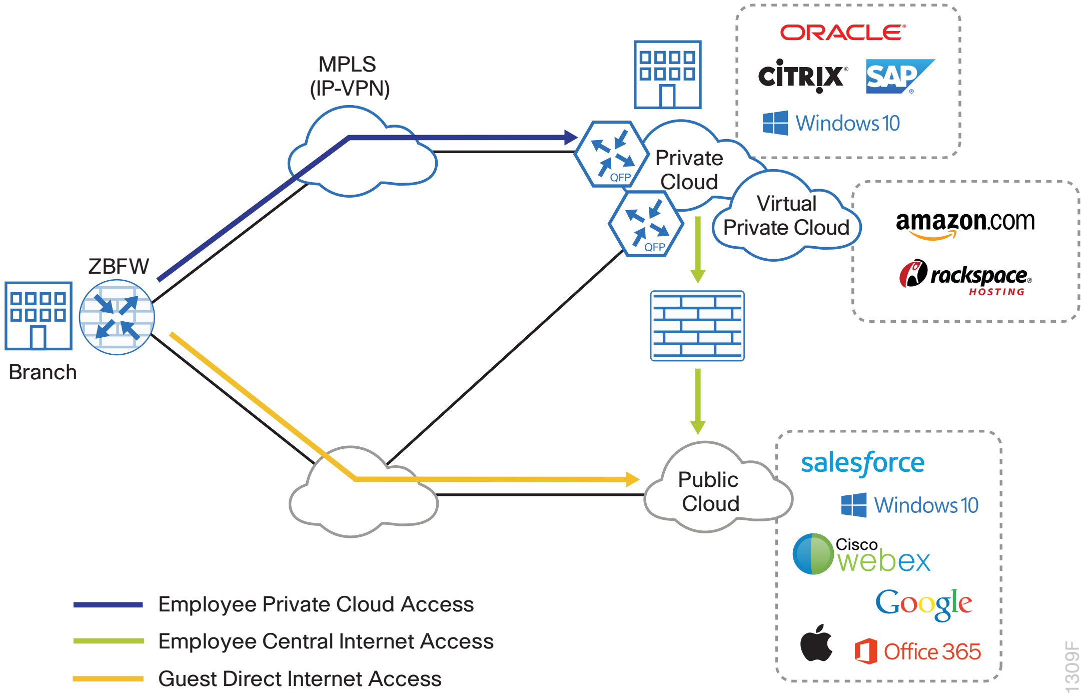
Use Case: DIA from Remote-Site Guest Wireless Users

Reader Tip

This use case is discussed in the previous version of the IWAN DIA CVD. If you are interested in deploying Guest Wireless for DIA, see "Deploying Remote Site Guest Wireless Access" in the previous version.

Remote-site guest users directly access the Internet for cloud-based applications and user web access without having to route their traffic through the central site and traverse the internal network.

Figure 3 *Guest DIA*



This design guide enables the following network capabilities:

- Offloading Internet traffic from the WAN by providing isolated secure direct Internet access for guest network users independent of employee Internet access
- Deploying remote-site wireless guest access with acceptable use policies (AUP) and guest authentication services by using Cisco Identity Services Engine (ISE) and integrated wireless controller functionality with local and central web authentication.
- Deploying Cisco IOS security services for remote guest users by leveraging ZBFW, NAT, and other network security features to isolate and secure guest user traffic
- Integrating with existing central site guest deployment solutions

OVERVIEW OF CISCO IWAN AND SECURE DIA

This guide provides designs that enable highly available and secure local Internet connectivity for Cisco IWAN remote sites. It shows you how to deploy the network and services in order to enable the following IWAN configurations:

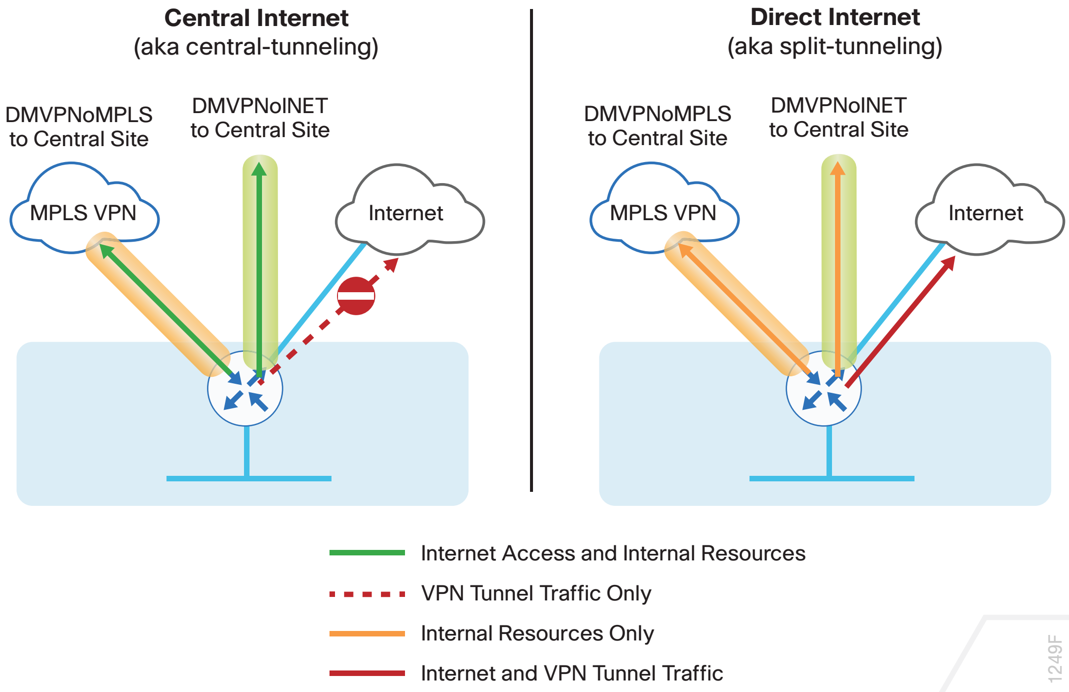
- Secure remote-site direct Internet access for employees

While the Internet is quickly becoming a more stable platform with better price to performance and improved reliability, it can still fall short of meeting standards for many businesses. With Cisco IWAN, network operations has the security and application services to deliver the highest levels of resiliency and reliability over a variety of WAN transports.

IWAN Remote-Site Design with DIA

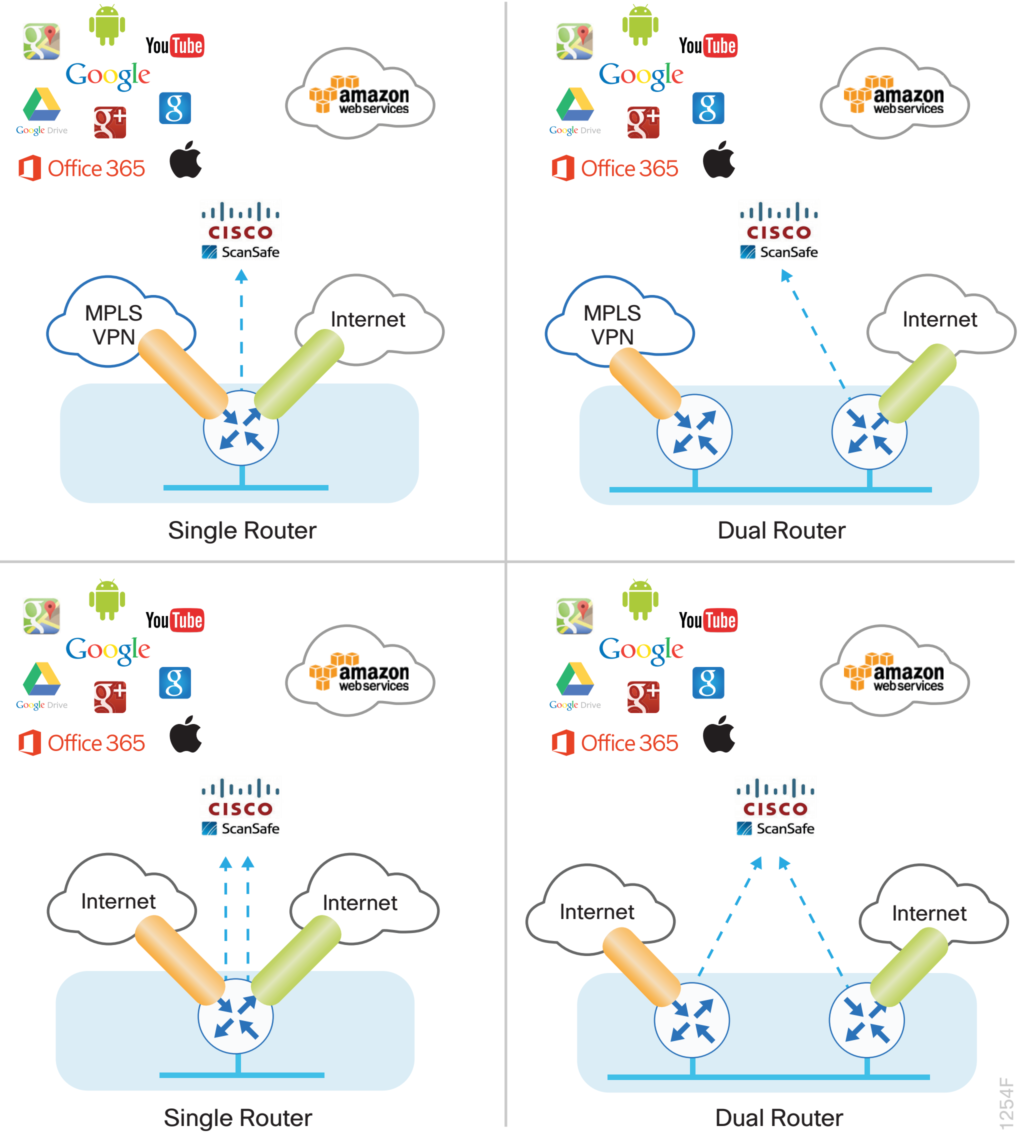
The remote-site design provides the remote office with DIA solutions for web browsing and cloud services. This is commonly referred to as the *local or direct Internet model* where traffic accesses Internet services directly without traversing the WAN. With the direct Internet model, user web traffic and hosted cloud services traffic are permitted to use the local Internet link in a split-tunneling manner. In this model a default route is generated locally, connecting each remote site directly to the Internet provider. Private WAN connections using DMVPN over Internet or MPLS-based WAN services provide a transparent WAN service for internal routes to data center and campus resources.

Figure 4 *Central Internet and local Internet comparison*


Central Internet
(aka central-tunneling)
DMVPNoMPLS to Central Site
DMVPNoINET to Central Site
MPLS VPN
Internet
Direct Internet
(aka split-tunneling)
DMVPNoMPLS to Central Site
DMVPNoINET to Central Site
MPLS VPN
Internet
Internet Access and Internal Resources
VPN Tunnel Traffic Only
Internal Resources Only
Internet and VPN Tunnel Traffic
1249F

This guide documents secure, direct Internet-enabled WAN remote-site designs based upon combinations of IP WAN transports, which are mapped to site-specific requirements around service levels and resiliency. WAN transport is transparent and made uniform by using DMVPN tunnels with front door virtual routing and forwarding (FVRF), irrespective of the service from the provider.

Figure 5 *IWAN direct Internet access models*



The primary focus of the design is to allow usage of the following commonly deployed remote-site IWAN configurations with local Internet access:

- Single-router remote site with MPLS WAN services and Internet connectivity, known as the *IWAN single-router hybrid* design model.
- Dual-router remote site with MPLS WAN services and Internet connectivity, known as the *IWAN dual-router hybrid* design model.
- Single remote site with dual-Internet connections to different Internet service providers (ISPs), known as the *single-router dual-Internet* design model
- Dual-router remote site with dual-Internet connections to different ISPs, known as the *dual-router dual-Internet* design model

Reader Tip

The choice to use locally routed or direct Internet is locally significant to the remote site. No changes are required to the primary site.

The remote-site designs documented in this guide can be deployed in parallel with other remote-site designs that use centralized Internet access.

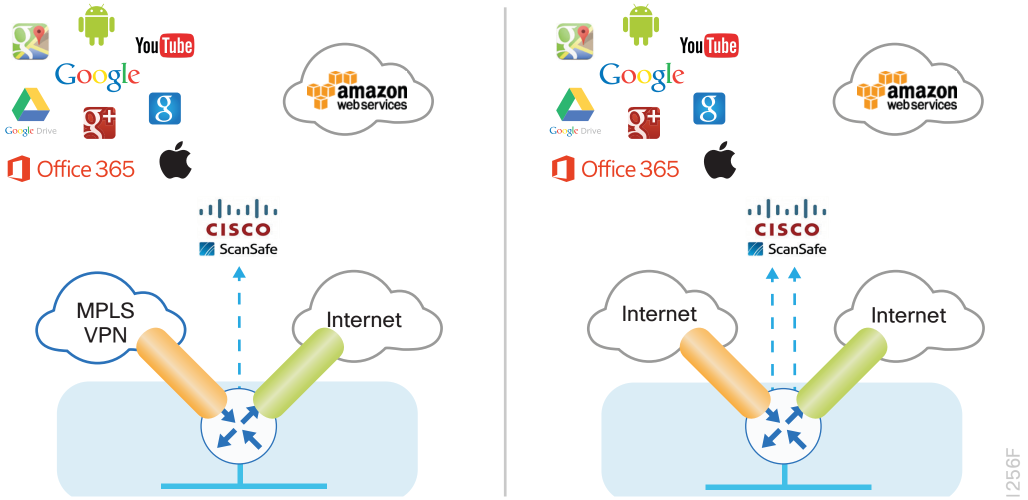
This guide does not address the primary aggregation site design and configuration details. This solution is tested and evaluated to work with the design models and WAN-aggregation site configurations as outlined in the Intelligent WAN Deployment Guide.

IWAN High Availability

The majority of remote sites are designed with a single-router WAN edge; however, certain remote-site types require a dual-router WAN edge. Dual-router candidate sites include regional office or remote campus locations with large user populations, or sites with business critical needs that justify additional redundancy to remove single points of failure.

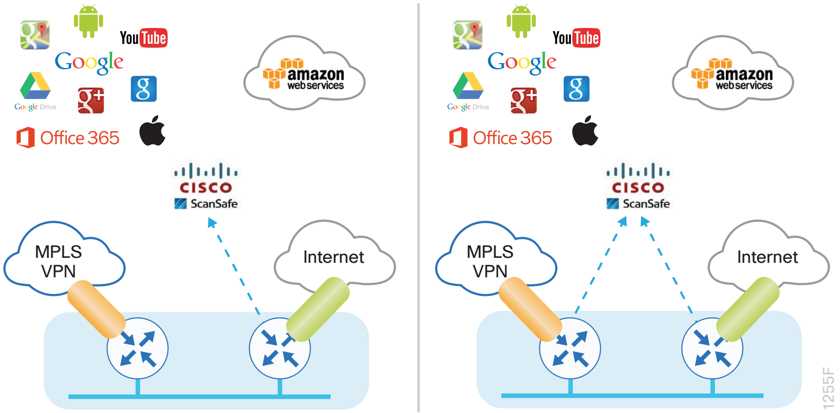
The network must tolerate single failure conditions, including the failure of any single WAN transport link or any single network device at the primary remote site. IWAN remote-site designs provide the following high availability options for direct Internet access.

Figure 6 Single-router IWAN remote sites with DIA



Remote sites classified as single router may provide Internet failover in the event of local Internet link failure. Hybrid IWAN configurations may fail over to the central Internet model. Single-router dual-Internet IWAN configurations provide redundancy for local Internet connectivity by failing over to the secondary local Internet connection.

Figure 7 *Dual-router IWAN remote sites with DIA*



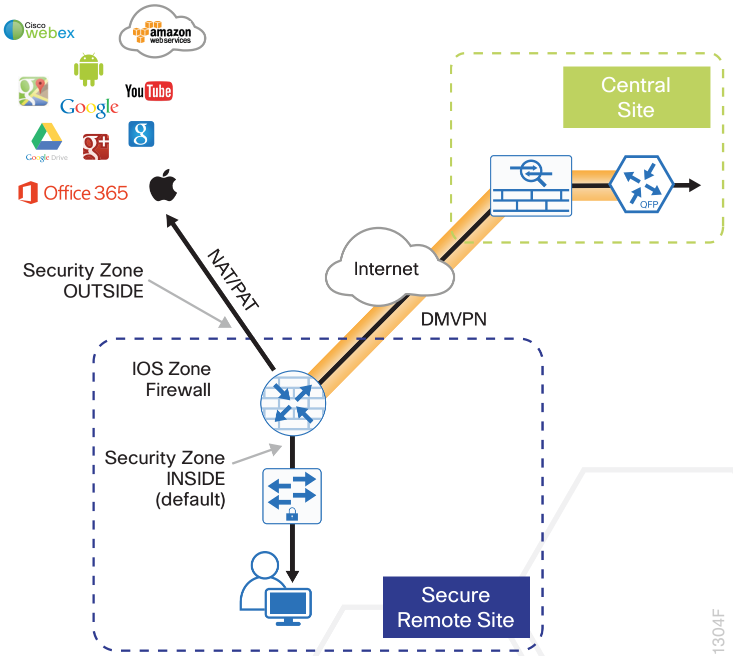
Remote sites classified as dual router may provide Internet failover in the event of local Internet link or router failure. Hybrid IWAN configurations may fail over to the central Internet model. IWAN dual Internet configurations provide redundancy for local Internet connectivity by failing over to the secondary local Internet connection.

Securing DIA

Network security is an essential component of this design. In a large network, there are many entry points and you need to ensure they are as secure as possible without making the network too difficult to use. Securing the network not only helps keep the network safe from attacks but is also a key component to network-wide resiliency.

To help organizations address concerns with cloud security, this guide addresses the implementation of several key integrated security features. As organizations leverage local Internet in the remote site, considerations for securing access at each remote location is necessary. This guide provides general recommendations and guidelines for implementing stateful firewalling, NAT, and basic router security and hardening.

Figure 8 *IWAN secure remote site*



Network Address Translation

With the growing adoption of distributed cloud applications, NAT plays an integral role in enabling organizations to deploy and secure public and private cloud services.

NAT enables private IP networks that use unregistered IP addresses (as specified in RFC 1918) to connect to the Internet. NAT is used to translate the private addresses defined on internal networks into legal routable addresses because ISPs cannot route RFC 1918 addresses.

Although it is possible to use public IP addresses internally at a remote site, NAT will most likely still be required. If there are a large number of branches using public IP addresses, it is not possible or desirable to advertise them using BGP. The additional cost of Internet connections with BGP precludes the use of inexpensive broadband services.

Primarily designed for IP address conservation and network design simplification, NAT can also serve as a security mechanism by hiding a host’s IP address and application ports.

NAT operates on a firewall and routers connecting two network segments and translating the internal private addresses to a public address on the external network. It can be configured to show only one IP address externally. This provides additional security by effectively hiding the entire internal network behind a single IP address. This capability is called port address translation (PAT), also referred to as *NAT overload*.

NAT provides the following benefits:

- Security, providing an added layer of defense from external attackers by hiding IP addresses and application ports
- Scalability through the reuse of IP addresses, and by using IP address overloading capabilities
- Simplified provisioning and troubleshooting by enforcing consistent network design across network locations

NAT is typically implemented at the edge of the network wherever an organization connects to the Internet. Today, this may be in central or large aggregation sites or in remote sites providing localized Internet services.

Cisco IOS Zone-Based Firewall

With the adoption of remote-site local Internet for user web browsing and cloud services, the deployment of firewall services at the remote office Internet edge is critical to maintaining an organization’s security posture.

Zone-based firewall (ZBFW), also called *zone policy firewall*, is a Cisco IOS-integrated stateful firewall implemented on the Cisco Integrated Services Routers (ISR) and Cisco Aggregation Services Routers (ASR) routing platforms.

Firewall zone policies are configured by using the Cisco Common Classification Policy Language (C3PL), which employs a hierarchical structure to define inspection for network protocols and the groups to which the inspection will be applied. Users familiar with the Cisco IOS modular quality of service CLI (MQC) will recognize the use of class maps to specify which traffic will be affected by the action applied in a policy map.

Within this model, router interfaces are assigned to security zones, which establish the security borders of your network. A security zone defines a boundary where traffic is subjected to policy restrictions; this policy is called a *zone policy*. Zone policies define what traffic is allowed to flow between security zones. Zone policies are unidirectional firewall policies applied between two security zones, called a *zone pair*. A zone pair is defined as two security zones between which a zone policy is applied.

Router interfaces assigned to configured security zones are subject to the default policies and rules:

- An interface can be a member of only a single security zone.
- A security zone can contain only member interfaces that are all in the same virtual routing and forwarding (VRF); interfaces in different VRFs may not be part of the same security zone.
- When an interface is placed into a security zone, traffic is implicitly allowed to flow between other interfaces assigned to the same security zone.
- Traffic flow to interfaces in different security zones is denied with an implicit deny all zone policy.
- Traffic cannot flow between an interface that is a member of a security zone and any interface that is not a member of a security zone. Instead, the traffic is dropped. If the default zone configuration is implemented as is described in this guide, traffic can flow between interfaces without security zone configurations because all interfaces automatically become part of the default zone.
- To allow traffic to flow between different security zones, policies must be configured between any two security zones.
- Pass, inspect, and drop actions can only be applied between two zones.
- By default, traffic (for instance, a routing protocol) that flows to and from the router itself is permitted. The router (as a source and destination) is defined as the self-zone by the Cisco IOS firewall. Traffic to and from the self-zone on any interface is allowed until traffic is explicitly denied by a user-defined zone security policy.

Direct Internet Access Design

DESIGN DETAIL

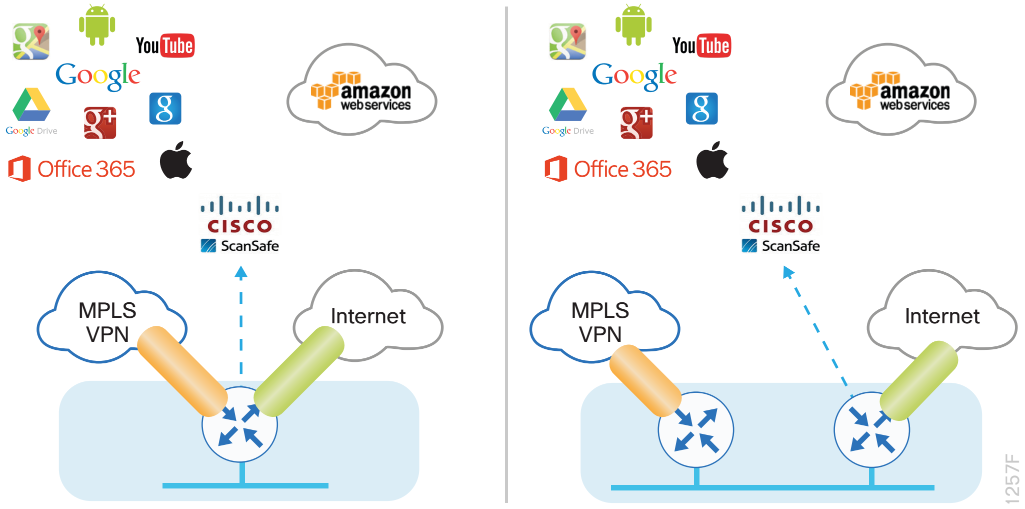
This guide focuses on four remote-site designs with DIA. These designs provide configurations and guidance for enabling secure localized Internet access in remote office locations.

Each of the Cisco IWAN remote-site design options support DIA and internal network communications with the central site. All designs support resilient routing.

The IWAN hybrid direct Internet access designs are:

- Single-router hybrid designs, MPLS and Internet
- Dual-router hybrid designs, MPLS and Internet

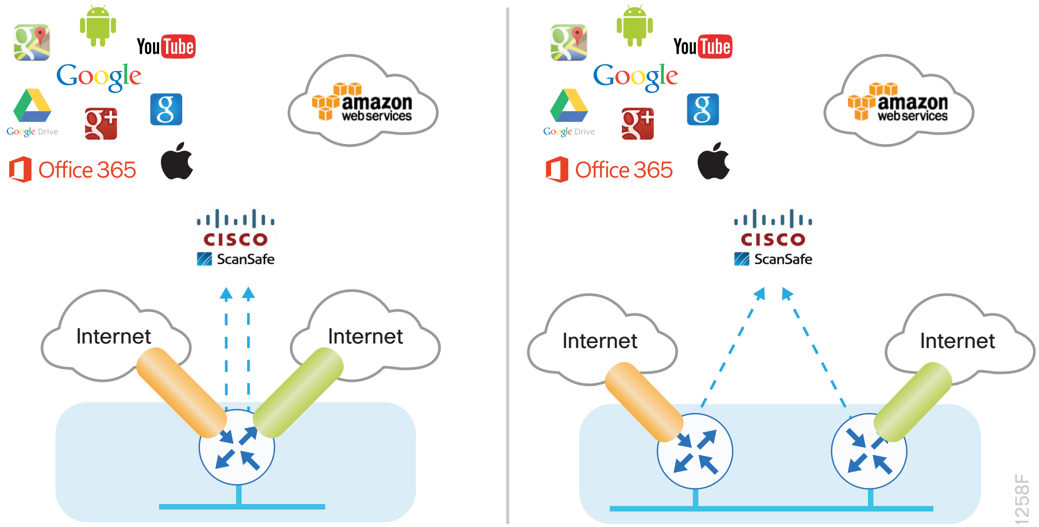
Figure 9 *IWAN hybrid design models with DIA*



The IWAN dual-Internet direct Internet access designs are:

- Single-router, dual-Internet design
- Dual-router, dual-Internet design

Figure 10 *IWAN dual-Internet design models with DIA*



Local Internet traffic is forwarded directly to the Internet by using the default route. This default route is directed at the next-hop router in the ISP's network. Because RFC-1918 addresses are used for internal networks, all Internet-bound traffic is translated to a public address by using PAT on the ISP-connected interface. The ZBFW is enabled to provide stateful inspection and to enforce a policy that only allows return traffic for sessions initiated by internal users and for DMVPN tunnel traffic between the remote-site router and the DMVPN hub router.

Reader Tip

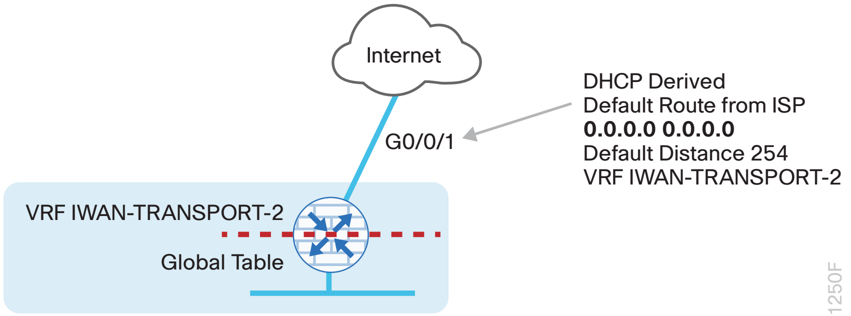
For more information about the different IWAN deployment models, see the Intelligent WAN Deployment Guide.

IWAN DIA Routing with Front Door VRF

All IWAN designs are based on the use of front door virtual routing and forwarding (FVRF) with DMVPN to segment the routing table, thus allowing two default routes to exist on the same router.

With FVRF, the default route from the ISP is contained within the Internet facing VRF and is only used for DMVPN tunnel formation. A default route is obtained from the local ISP by using DHCP and is added to the outside VRF with a default administrative distance (AD) value of 254.

Figure 11 *IWAN FVRF routing–VRF default route*

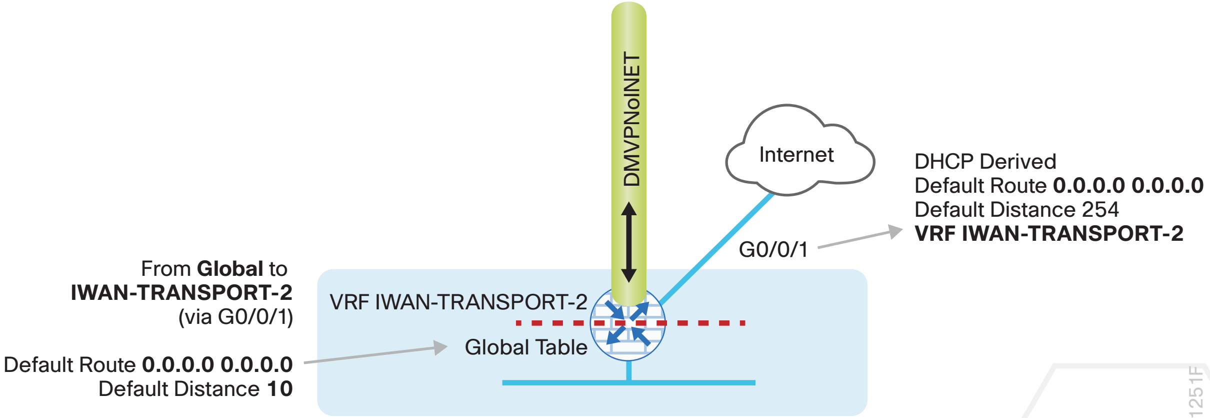


In the base IWAN configuration, a second default route is contained in the global table. In this central Internet model, the global table default route directs traffic over the tunnel interfaces.

When a remote site is converted to use a local or direct Internet model, the global default route needs to direct traffic outside the Internet facing DMVPN tunnel to the Internet.

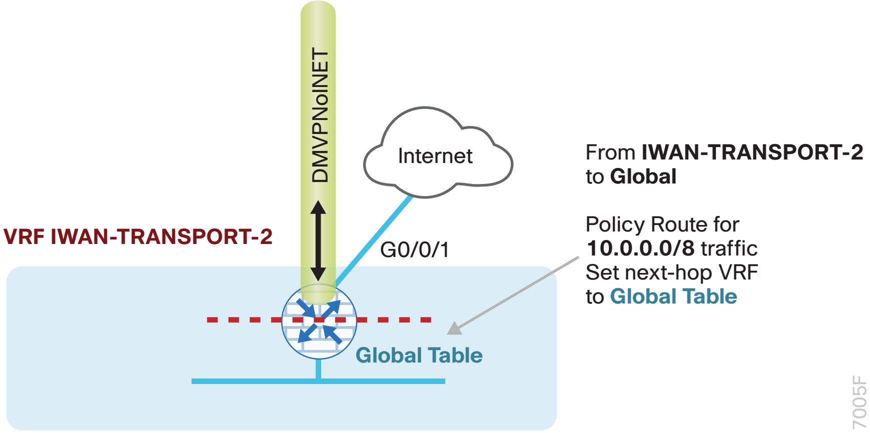
In the direct Internet model, a default route over Internet-based VPN tunnels cannot be allowed. In this case, because backup Internet routing is not possible over these VPN tunnels, the recommended best practice is to filter the central-site default route.

Figure 12 *IWAN FVRF routing–global to VRF outbound*



When FVRF is used, the return traffic from the Internet to the remote site router needs to traverse from the outside facing Internet VRF to the global routing table. In IWAN configurations, a local policy route must be used to move return traffic from the outside VRF into the global table that is destined to the internal remote site network.

Figure 13 IWAN FVRF routing–return VRF to global routing

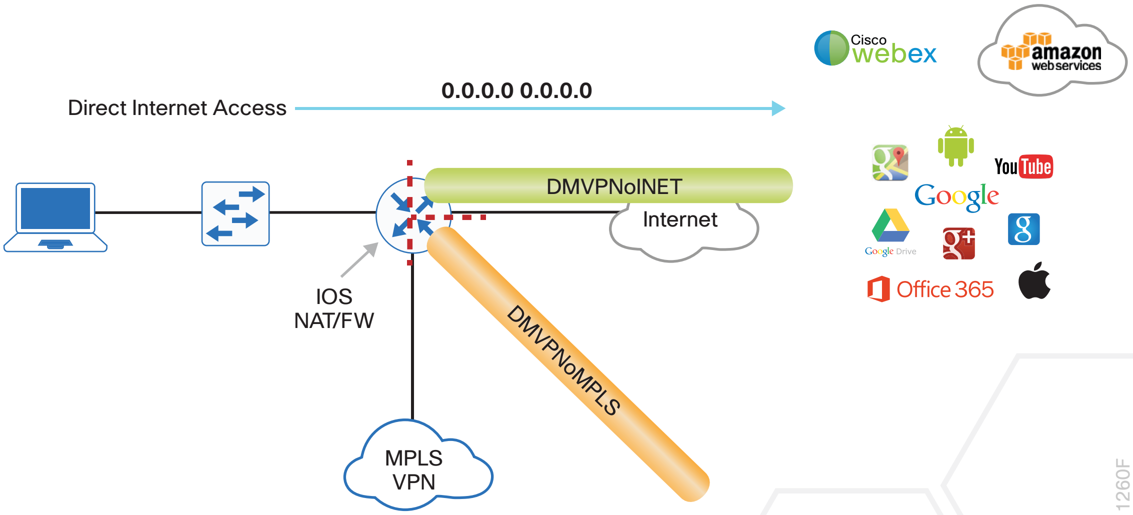

DMVPNoINET
Internet
VRF IWAN-TRANSPORT-2
G0/0/1
Global Table
From **IWAN-TRANSPORT-2** to **Global**
Policy Route for **10.0.0.0/8** traffic
Set next-hop VRF to **Global Table**
7005F

IWAN Single-Router Hybrid Remote-Site Routing

In this design, the remote site is configured with a single router by using DMVPN over MPLS as the primary connectivity for internal traffic. This site also uses an Internet connection on the same router for DMVPN over the Internet as an alternate path.

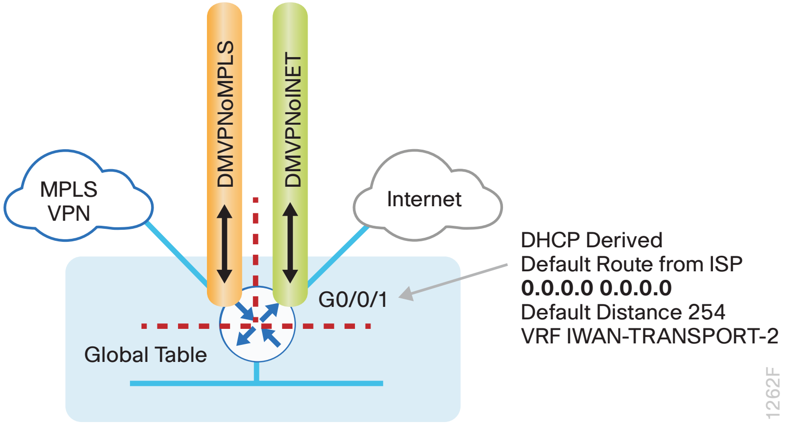
In the hybrid design with DIA, Internet traffic is routed outside the DMVPN tunnel for local Internet access. In this configuration, the local path is primary with failover to the central site Internet connectivity by using the MPLS-based DMVPN tunnel.

Figure 14 IWAN single-router hybrid with DIA



With IWAN, internal networks are advertised using the WAN routing protocol over the DMVPN tunnels, preferring the MPLS-based path. Based on performance routing (PfR) policy, critical internal traffic or traffic that stays within the organization is routed primarily over the MPLS-based WAN tunnel and alternatively over the Internet-based DMVPN tunnel. If the MPLS-based DMVPN tunnel fails, all internal traffic is routed to the central site by using DMVPN over the Internet.

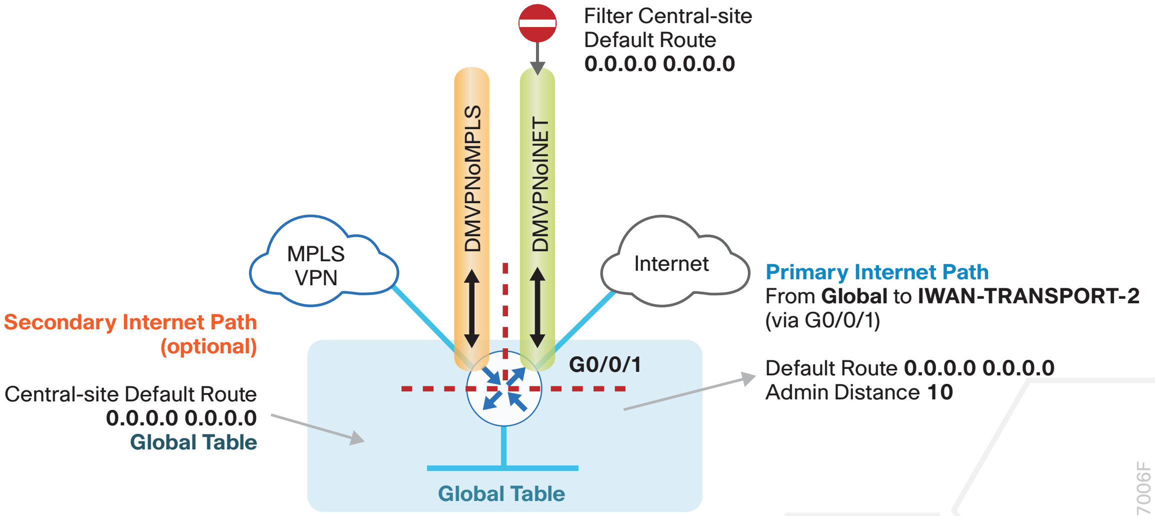
Figure 15 *IWAN single-router hybrid design—routing*



In this example, the Internet facing Ethernet interface on the router is using DHCP to obtain an IP address from the ISP. The router is also using DHCP to install a default route into the outside VRF routing table. By default, this DHCP-installed static route has an AD value of 254.

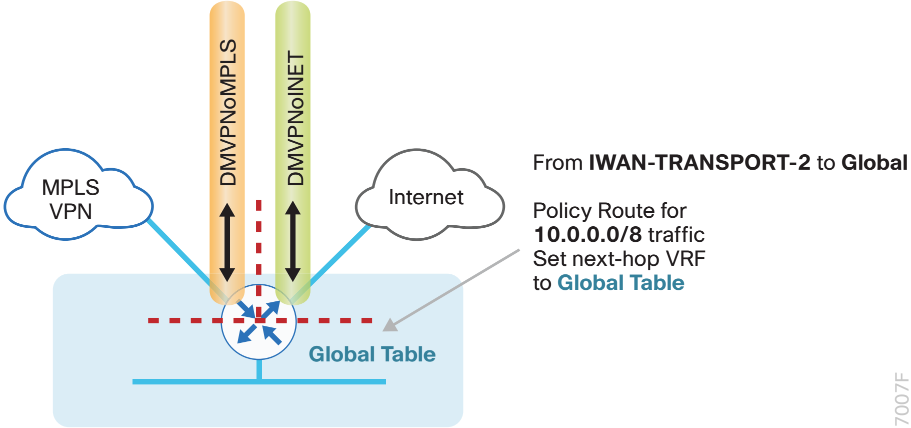
In this case, the default route to the local ISP is isolated in the VRF IWAN-TRANSPORT-2 and used for DMVPN tunnel setup and to route traffic from the outside VRF to the Internet. The default route is used for both Internet protocol service-level agreement (IPSLA) and DIA traffic.

Figure 16 *IWAN single-router hybrid—global default*



For DIA, the central default route must be filtered inbound on the Internet-based DMVPN tunnel interface. A default static route with an AD of 10 is configured in the global table.

Figure 17 *IWAN single-router hybrid—Internet return routing*



From **IWAN-TRANSPORT-2** to **Global**

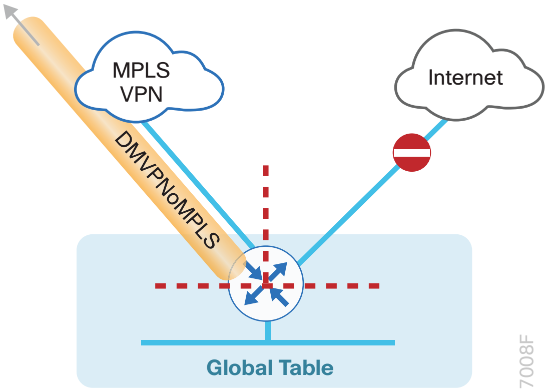
Policy Route for
10.0.0.0/8 traffic
Set next-hop VRF
to **Global Table**

A local policy routing configuration is also added for return traffic from the Internet. In this configuration, a route map is used to move the traffic from the outside facing VRF to the global routing table.

Figure 18 *IWAN single-router hybrid—central failover*

Central Internet Failover

Central-site Default Route
0.0.0.0 0.0.0.0
Global Table



In this configuration, the MPLS-based tunnel can be used as a backup path for Internet if the local Internet connection fails. The central-site default route is advertised over the MPLS-based tunnel and is used only if the local connection fails.

Tech Tip

This configuration requires you to turn off PfR load-balancing on the Hub Master Controller. If PfR load-balancing is not turned off, the traffic will fail over to the central site Internet path, but it will not return to the local DIA interface after the failure condition is resolved.

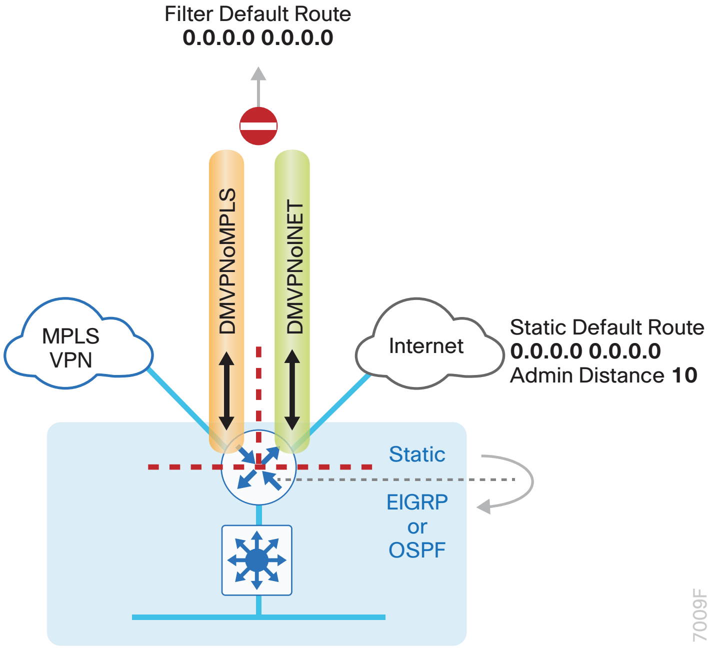
If PfR load-balancing is a requirement for your environment, see "Appendix C: DIA with PfR Load-Balancing" for an alternate way to configure your hybrid remote sites.

If PfR load-balancing is not required, DMVPN tunnel state and IPSLA probes are used to determine the availability of the primary local Internet connection. If a failure is detected, an Embedded Event Manager script removes the default static route. Instead, the central default route via the MPLS-based DMVPN tunnel is used.

Single-Router Layer 3 Distribution Site

When a remote-site IWAN router is connected to a Layer 3 distribution switch, additional configurations are required to advertise the local Internet default route via the LAN routing protocol (example: EIGRP or OSPF).

Figure 19 *IWAN single router hybrid—Layer 3 distribution*



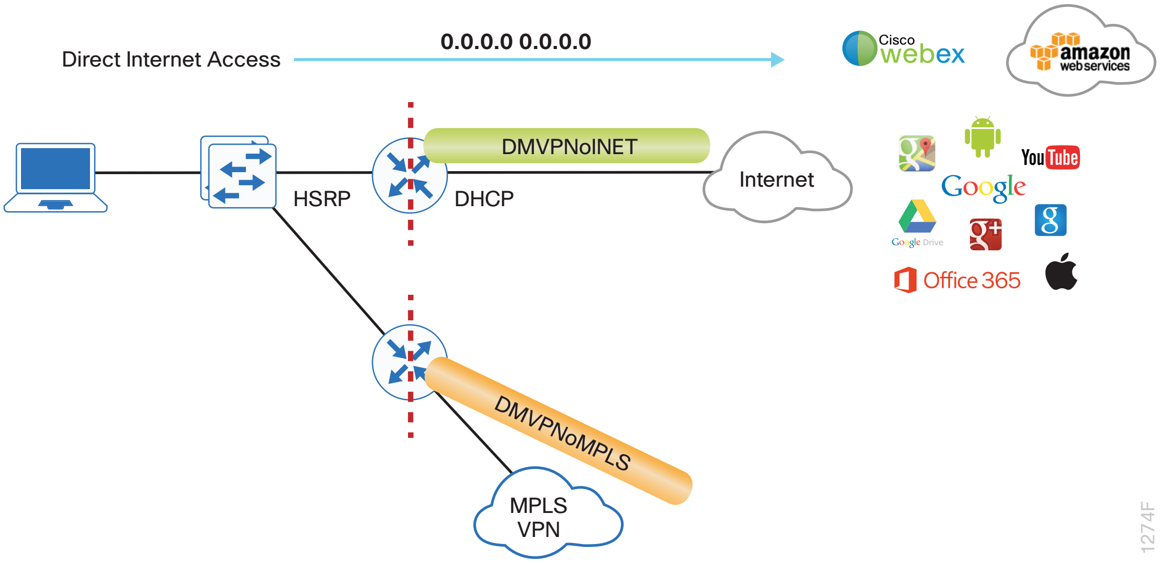
On the IWAN router, two things must be accomplished to correctly advertise the local default route. First, to ensure the local default route is not advertised to the WAN, filter outbound on both DMVPN tunnel interfaces. Second, the static default route must be distributed into the LAN routing protocol so the IWAN router can advertise the default route to the distribution switch.

IWAN Dual-Router Hybrid Remote Site Routing

In this design, the remote site is configured with dual routers. The primary router uses DMVPN over MPLS as the primary connection for internal traffic. This site also uses a secondary router with an Internet connection for DMVPN over the Internet as an alternate path.

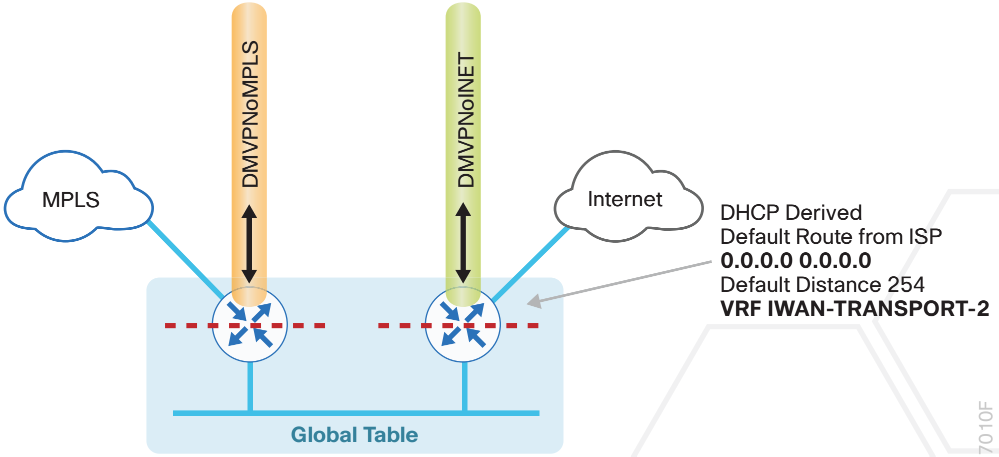
In the hybrid design with DIA the Internet traffic is routed outside the DMVPN tunnel for local Internet access on the secondary router. In this configuration, the local path is primary with failover to the central site Internet connectivity by using the MPLS-based DMVPN tunnel on the primary router.

Figure 20 *IWAN dual-router hybrid with DIA*



With IWAN, internal networks are advertised by the WAN routing protocol over the DMVPN tunnels, preferring the MPLS-based path on the primary router. Based on PfR policy, critical internal traffic or traffic that stays within the organization is routed primarily over the MPLS-based WAN tunnel and alternatively over the Internet-based DMVPN tunnel on the secondary router. In the case of a failure on the primary router, all internal traffic is routed to the central site by using DMVPN over the Internet on the secondary router.

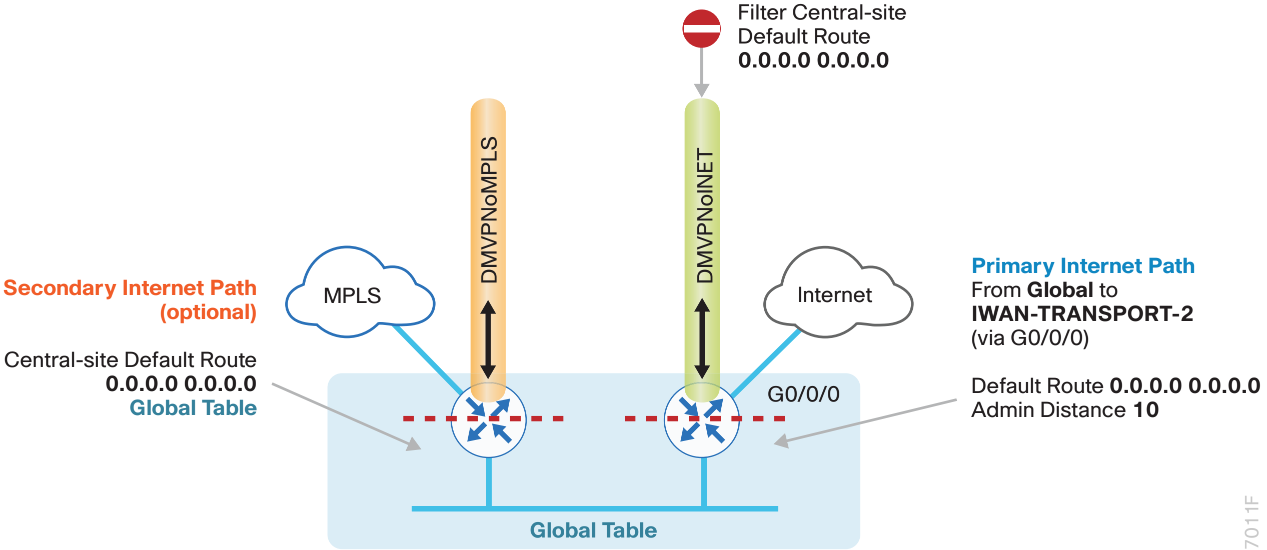
Figure 21 *IWAN dual-router hybrid—VRF routing*



In this example, the Internet-facing Ethernet interface on the secondary router is using DHCP to obtain an IP address from the ISP. The secondary router is also using DHCP to install a default route into the local table. By default, this DHCP installed static route has an AD value of 254.

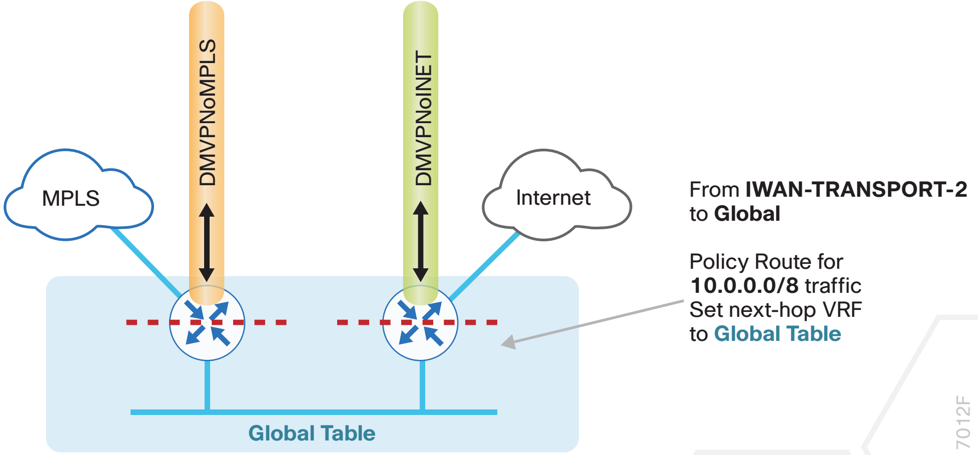
In this case, the default route to the local ISP is isolated in the VRF IWAN-TRANSPORT-2 and used for DMVPN tunnel setup and to route traffic from the outside VRF to the Internet. The default route is used for both IPSLA and DIA traffic.

Figure 22 IWAN dual-router hybrid–global default



For DIA, the central default route must be filtered inbound on the Internet-based DMVPN tunnel interface on the secondary router. A default static route with an administrative distance of 10 is also configured in the global table on the secondary router.

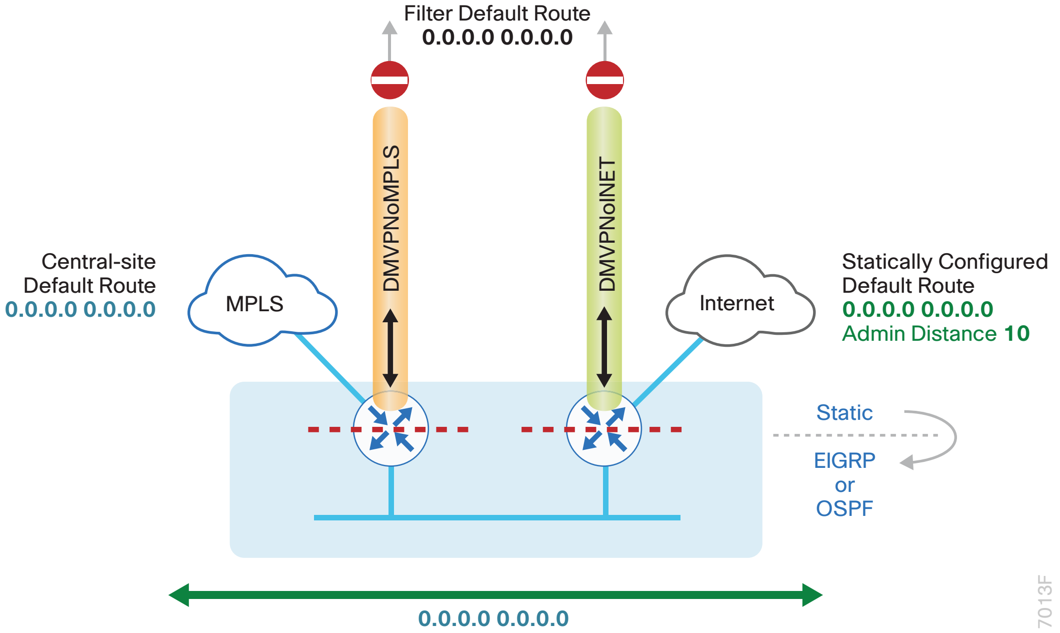
Figure 23 IWAN dual-router hybrid–Internet return routing



A local policy routing configuration is also added to the secondary router for return traffic from the Internet. In this configuration, a route map is used to move the traffic from the outside facing VRF to the global routing table.

With dual-router sites, additional configurations are required to advertise the local Internet default route via the LAN routing protocol from the secondary to the primary IWAN router. This also advertises the route to a Layer 3 distribution switch if needed.

Figure 24 *IWAN dual-router hybrid–routing*

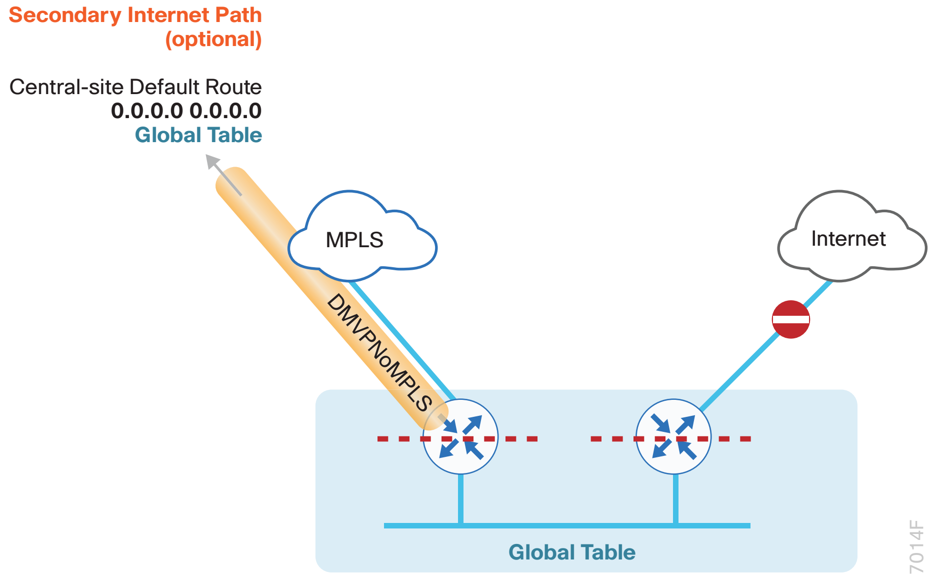


On the IWAN routers, two things must be accomplished in order to correctly advertise the local default route between the WAN edge routers and optionally with a Layer 3 distribution switch.

First, to ensure the local default route is not advertised to the WAN, filter outbound on both routers' DMVPN tunnel interfaces.

Second, the static default route must be redistributed into the LAN routing protocol on the secondary router so it can advertise the default route to the primary router. When the primary router receives the redistributed default route from the secondary IWAN router, it has an administrative distance less than the existing MPLS-based tunnel central route. The redistributed default route is preferred over the MPLS-based tunnel central route.

Figure 25 IWAN dual-router hybrid—central site failover



In this configuration, the MPLS-based tunnel on the primary router can be used as a backup path for Internet if the local Internet connection or the secondary router fails. The central-site default route is advertised over the MPLS-based tunnel via the WAN routing protocol and is used only if the local connection fails. In this condition, the secondary router and Layer 3 distribution switch also receive the central default route from the primary router.

Tech Tip

This configuration requires you to turn off PfR load-balancing on the Hub Master Controller. If PfR load-balancing is not turned off, the traffic will fail over to the central site Internet path, but it will not return to the local DIA interface after the failure condition is resolved.

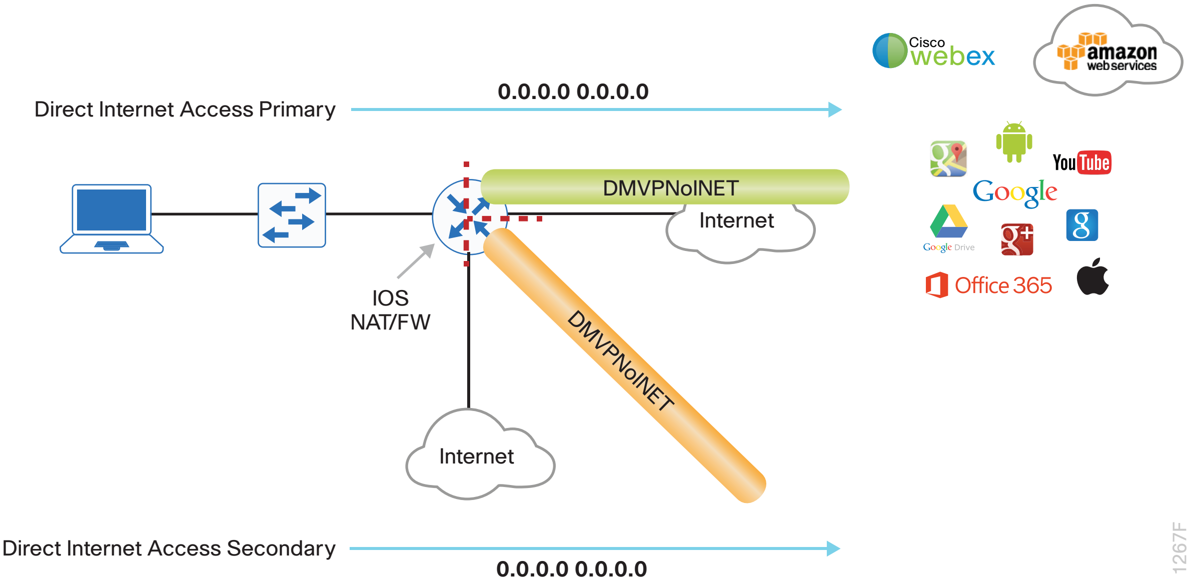
If PfR load-balancing is a requirement for your environment, see "Appendix C: DIA with PfR Load-Balancing" for an alternate way to configure your hybrid remote sites.

If PfR load-balancing is not required, DMVPN tunnel state and IPSLA probes are used to determine the availability of the primary local Internet connection on the secondary router. If a failure is detected, an EEM script removes the default static route from the secondary router and the central default route via the primary router is used.

IWAN Single-Router, Dual-Internet Remote-Site Routing

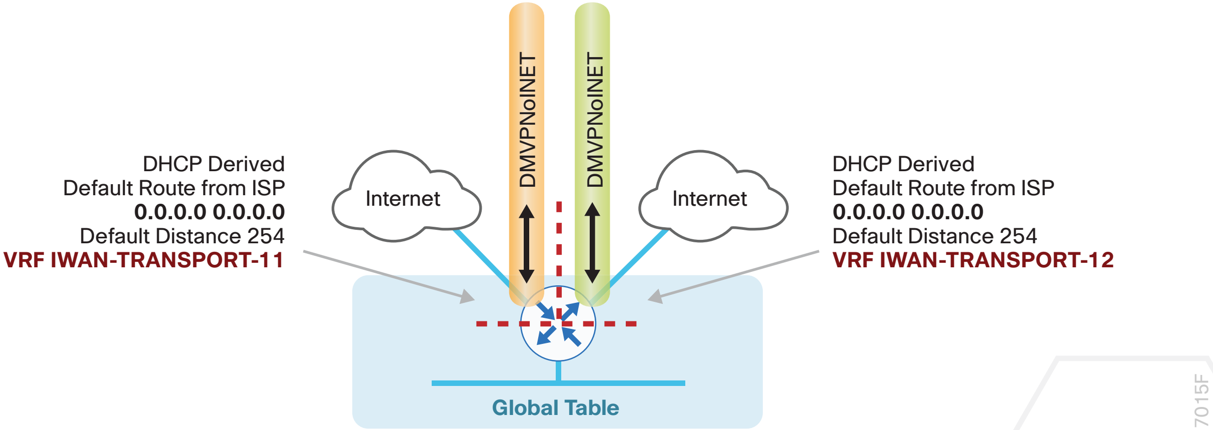
In this design, the remote site is configured with a single router using dual-Internet connections. Traffic is balanced over these connections by using PfR policy.

Figure 26 *IWAN single router, dual-Internet with DIA*



With IWAN, internal networks are advertised using the WAN routing protocol over the DMVPN tunnels, preferring the primary path. Based on PfR policy, critical internal traffic or traffic that stays within the organization is routed over the first ISP and alternatively over the second. In the case of primary tunnel failure, all internal traffic is routed to the central site by using the remaining DMVPN tunnel interface.

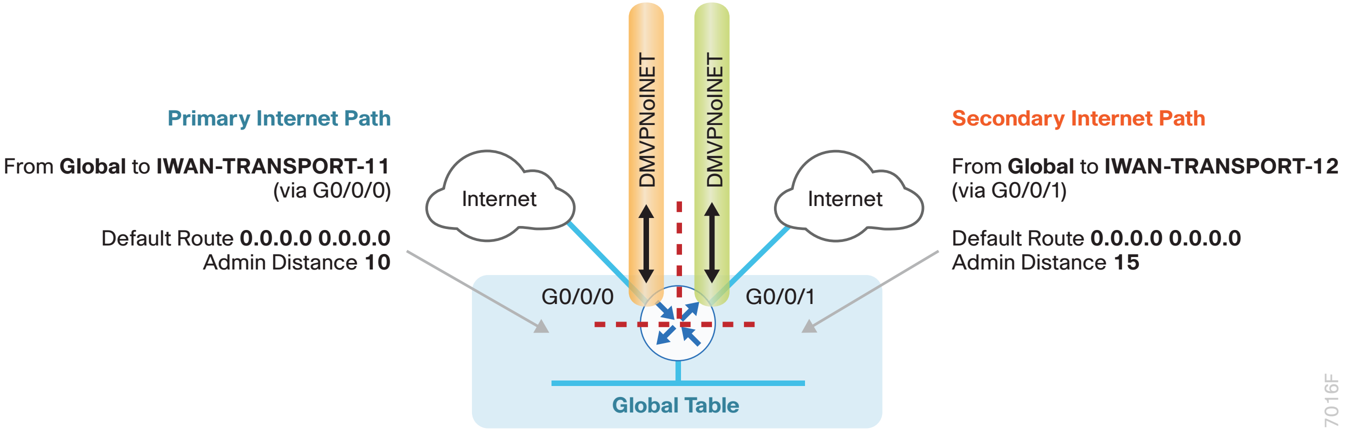
Figure 27 *IWAN single router, dual-Internet–routing*



In this example, the Internet facing Ethernet interfaces on the router are both using dynamic host configuration protocol (DHCP) in order to obtain an IP address from the ISP. The router is also using DHCP to install a default route into each VRF routing table. By default, this DHCP-installed static route has an AD value of 254.

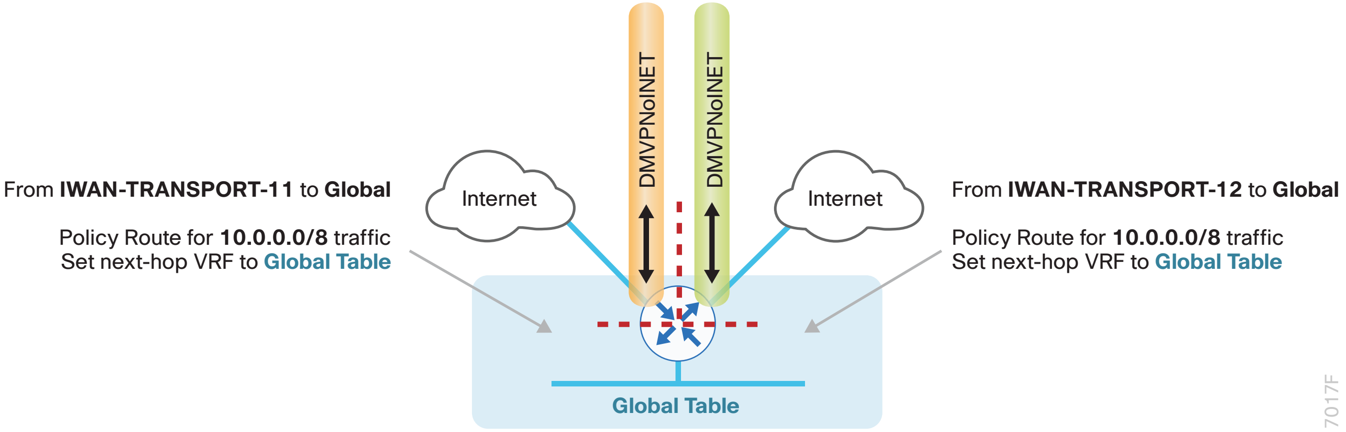
In this case, the default routes to the Internet are isolated in the outside VRFs IWAN-TRANSPORT-11 and IWAN-TRANSPORT-12 and are used for DMVPN tunnel setup and to route traffic from the outside VRF to the Internet. The default routes are used for both IPSLA and DIA traffic.

Figure 28 *IWAN single router, dual-Internet–global default*


Primary Internet Path
From **Global** to **IWAN-TRANSPORT-11** (via G0/0/0)
Default Route **0.0.0.0 0.0.0.0**
Admin Distance **10**
Internet
DMVPNoINET
DMVPNoINET
Internet
Secondary Internet Path
From **Global** to **IWAN-TRANSPORT-12** (via G0/0/1)
Default Route **0.0.0.0 0.0.0.0**
Admin Distance **15**
G0/0/0
G0/0/1
Global Table
7016F

For DIA, the central default route must be filtered inbound on the Internet-based DMVPN tunnel interfaces. A default static route with an administrative distance of 10 is configured in the global table for the primary ISP and a second default static route with a distance of 15 for the secondary ISP connection.

Figure 29 *IWAN single router, dual-Internet–Internet return routing*


From **IWAN-TRANSPORT-11** to **Global**
Policy Route for **10.0.0.0/8** traffic
Set next-hop VRF to **Global Table**
Internet
DMVPNoINET
DMVPNoINET
Internet
From **IWAN-TRANSPORT-12** to **Global**
Policy Route for **10.0.0.0/8** traffic
Set next-hop VRF to **Global Table**
Global Table
7017F

A local policy routing configuration is also added for return traffic from the Internet. In this configuration, a route map is used to move the traffic from the outside facing VRF to the global routing table inbound on both Internet facing interfaces.

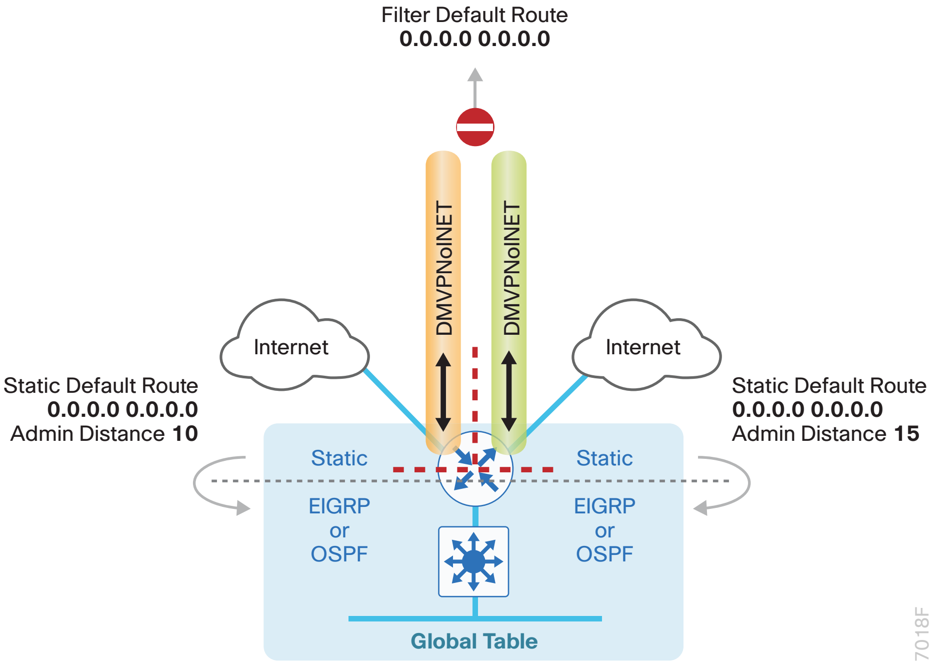
In this configuration, if the primary ISP connection fails, all locally routed Internet traffic is routed to the secondary ISP.

DMVPN tunnel state and IPSLA probes are used to determine the availability of the primary local Internet connection. If a failure is detected, an EEM script removes the primary default static route and the secondary static default route with an administrative distance of 15 is used instead.

Single-Router, Layer 3 Distribution Site

When a remote site IWAN router is connected to a Layer 3 distribution switch, additional configurations are required to advertise the local Internet default route via the LAN routing protocol.

Figure 30 *IWAN single router, dual-Internet–Layer 3 distribution*



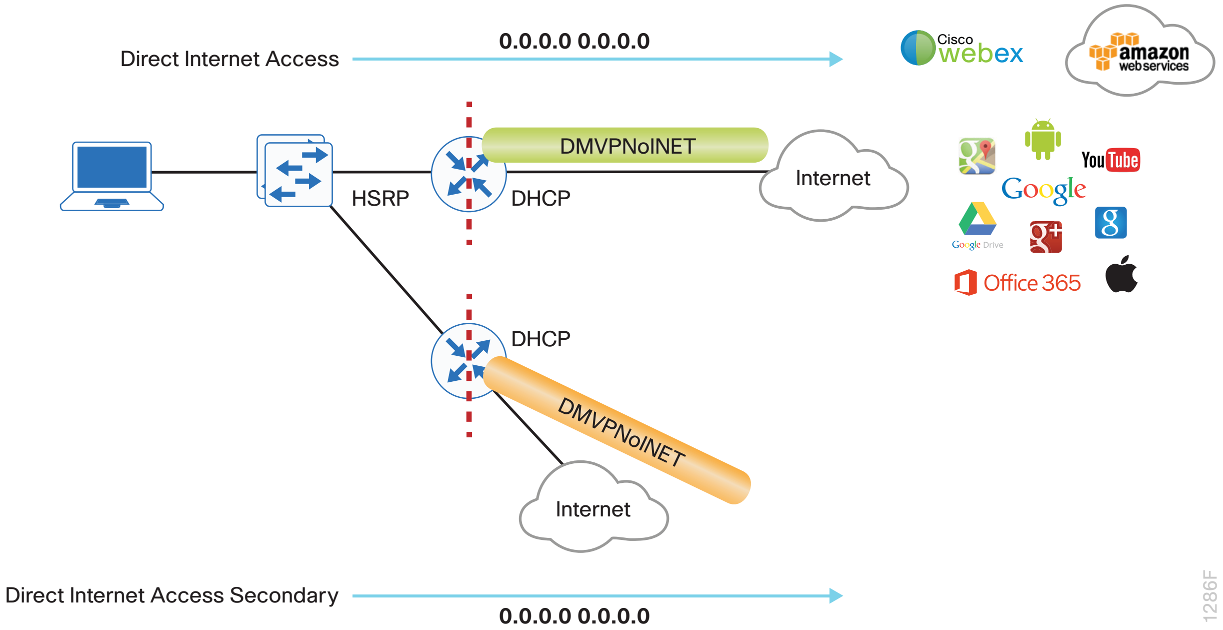
On the IWAN router, two things must be accomplished to correctly advertise the local default route. First, to ensure the local default route is not advertised to the WAN, filter outbound on both DMVPN tunnel interfaces. Second, redistribute the static default routes into the LAN routing protocol so the IWAN router can advertise the default route to the distribution switch.

IWAN Dual-Router, Dual-Internet Remote Site Routing

In this design, the remote site is configured with dual routers. Both routers connect to the Internet. The primary router provides a primary connection for internal traffic. The secondary router provides an alternate path via DM-VPN over the Internet.

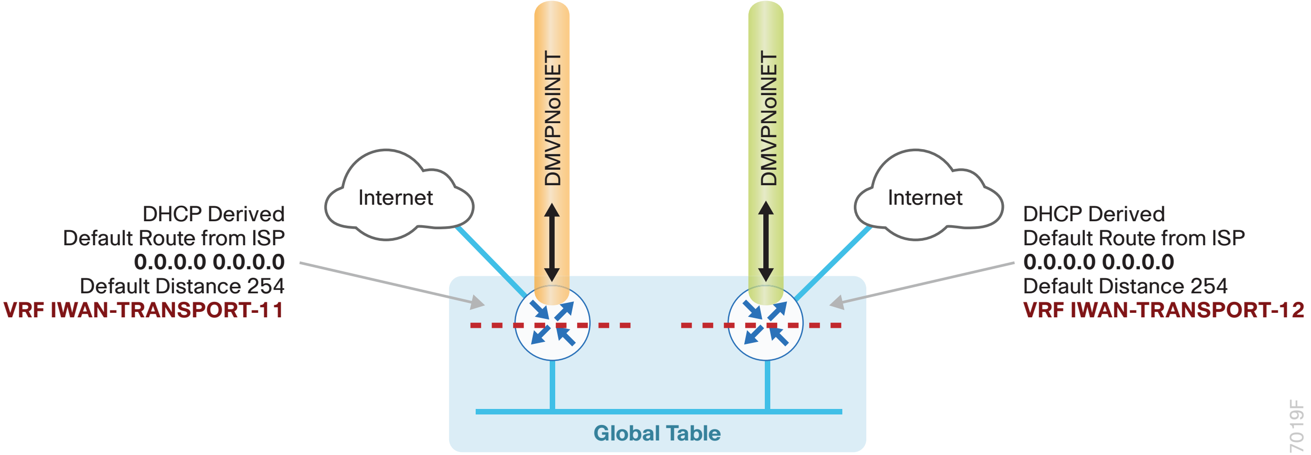
In the dual-Internet design with DIA, Internet traffic is routed outside the DMVPN tunnels for local Internet access on both routers. In this configuration, the local Internet path is primary on the primary router with failover to the secondary router's ISP.

Figure 31 *IWAN dual router, dual-Internet with DIA*



With IWAN, internal networks are advertised by using the WAN routing protocol over the DMVPN tunnels, preferring the path on the primary router. Based on PfR policy, critical internal traffic or traffic that stays within the organization is routed primarily over the primary router's WAN tunnel and alternatively over the DMVPN tunnel on the secondary router. In the case of a failure on the primary router, all internal traffic is routed to the central site by using DMVPN over the Internet on the secondary router.

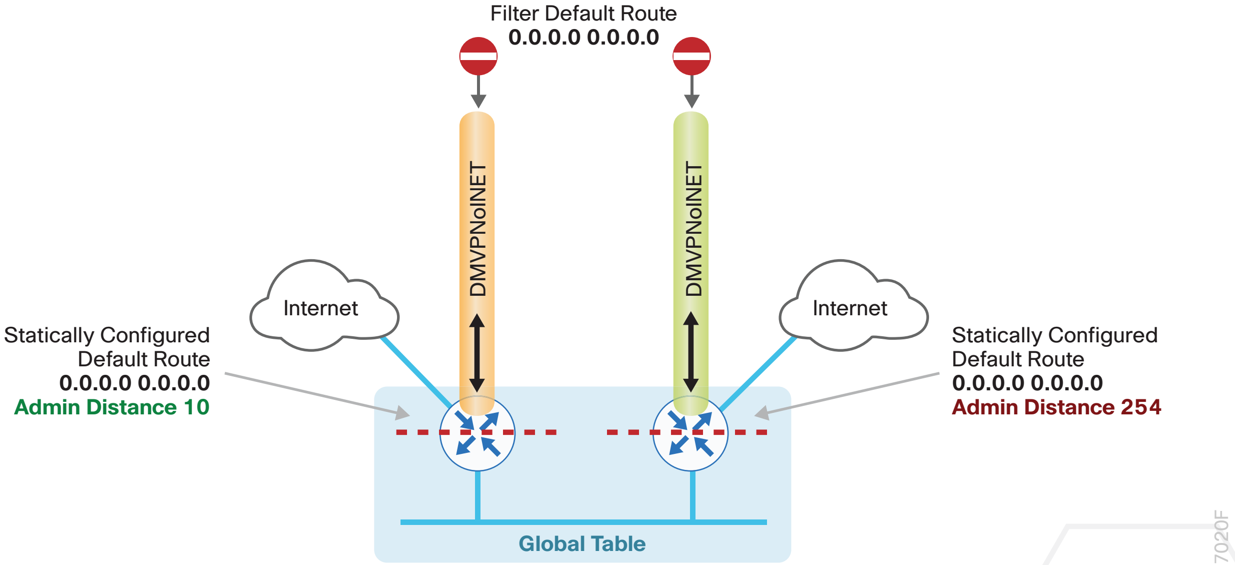
Figure 32 *IWAN dual router, dual-Internet–VRF routing*



In this example, the Internet facing Ethernet interfaces on both routers are using DHCP to obtain an IP address from each ISP. The routers are also using DHCP to install default routes into the outside VRF routing table on each router. By default, this DHCP installed static route has an AD value of 254.

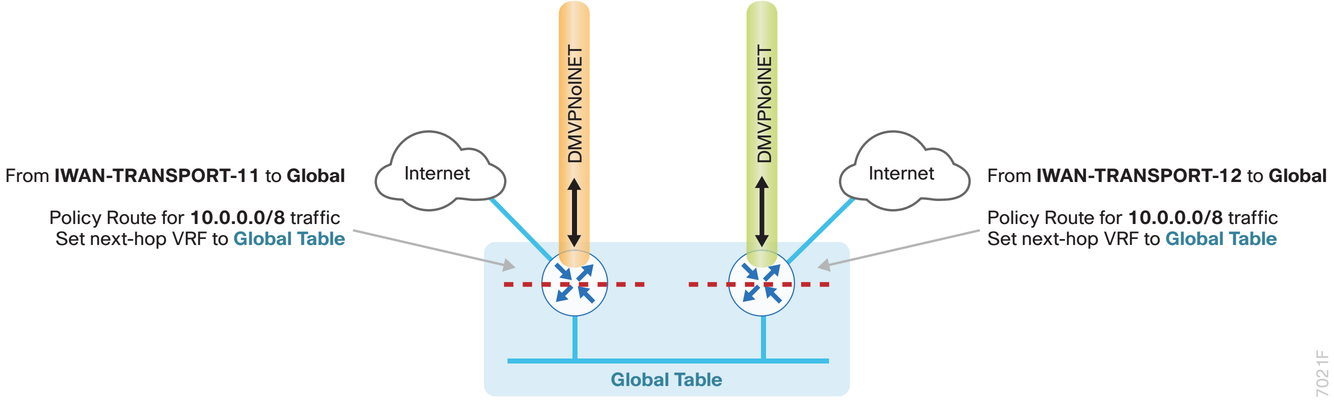
In this case, the default route to the local ISPs are isolated in the VRF IWAN-TRANSPORT-11 on the primary router and IWAN-TRANSPORT-12 on the secondary router. These default routes are used for DMVPN tunnel setup and to route traffic from the outside VRF to the Internet. These default routes are also used for both IPSLA and DIA traffic.

Figure 33 *IWAN dual router, dual-Internet–global default*



For DIA, the central default route must be filtered inbound on the Internet-based DMVPN tunnel interfaces on both the primary and secondary routers. A default static route with an administrative distance of 10 is also configured in the global table on the primary router and a static default with an administrative distance of 254 on the secondary router. The value of 254 is used so the LAN routing protocol is preferred.

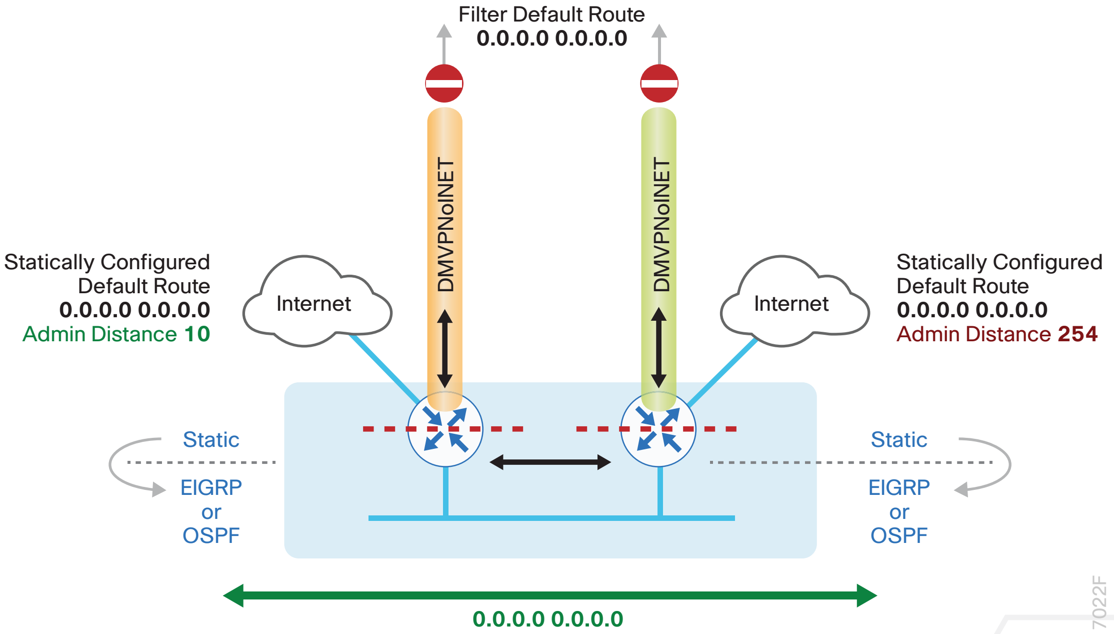
Figure 34 IWAN dual router, dual-Internet–Internet return routing


From **IWAN-TRANSPORT-11** to **Global**
Policy Route for **10.0.0.0/8** traffic
Set next-hop VRF to **Global Table**
Internet
DMVPNoINET
DMVPNoINET
Internet
From **IWAN-TRANSPORT-12** to **Global**
Policy Route for **10.0.0.0/8** traffic
Set next-hop VRF to **Global Table**
Global Table
7021F

A local policy routing configuration is also added to the routers for return traffic from the Internet. In this configuration, a route map is used to move the traffic from the outside facing VRFs to the global routing tables on each router.

With dual-router sites, additional configurations are required to advertise the local Internet default routes via the LAN routing protocol between the primary and secondary IWAN routers. This also advertises the route to a Layer 3 distribution switch if needed.

Figure 35 IWAN dual router, dual-Internet–routing



On the IWAN routers, two things must be accomplished in order to correctly advertise the local default route between the WAN edge routers and optionally with a Layer 3 distribution switch.

First, to ensure the local default route is not advertised to the WAN, filter outbound on both routers' DMVPN tunnel interfaces.

Second, redistribute the static default route into the LAN routing protocol on both the primary and secondary routers so they can advertise the default route between them and with a Layer 3 distribution switch.

The primary router advertises the redistributed static default route to the secondary router and distribution switch with an administrative distance of less than 254; this will be preferred over the static default route configured on the secondary router with a distance of 254. The secondary router also advertises a redistributed default static route to the primary router and distribution switch with the less preferred metric.

In this configuration, the DMVPN tunnel on the secondary router can be used as a backup path for Internet if the local Internet connection or the primary router fails. In the case of a primary ISP failure, the secondary router advertises the secondary ISP default via the LAN routing protocol and becomes the Internet path for the remote site network.

DMVPN tunnel state and IPSLA probes are used to determine the availability of the primary router's local Internet connection. If a failure is detected, an EEM script removes the default static route from the primary router and the redistributed static route on the secondary router is used instead.

Deploying Direct Internet Access

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
```

The successful deployment of secure DIA with IWAN includes a number of components that ensure proper DIA functionality within each remote-site design. All of these tasks are covered in this section:

- Configuration of remote site default routing including any necessary filtering and redistribution
- Configuration of NAT
- Configuration of zone-based firewall
- Configuration of additional router security
- Configuration of ISP black hole routing detection

USING THIS SECTION

This guide is organized into sections focused on each IWAN remote-site design, with detailed procedures for the implementation of direct Internet access. The configurations in each section are specific to each design model. The common technical details are repeated in each section so it is not necessary to read the entire guide to get a full understanding of the solution.

To configure direct Internet access, use the section appropriate for your remote site design requirements:

- “IWAN Single-Router Hybrid Remote Site with DIA”
- “IWAN Dual-Router Hybrid Remote Site with DIA”
- “IWAN Single-Router Dual-Internet Remote Site with DIA “
- “IWAN Dual-Router Dual-Internet Remote Site with DIA”

Reader Tip

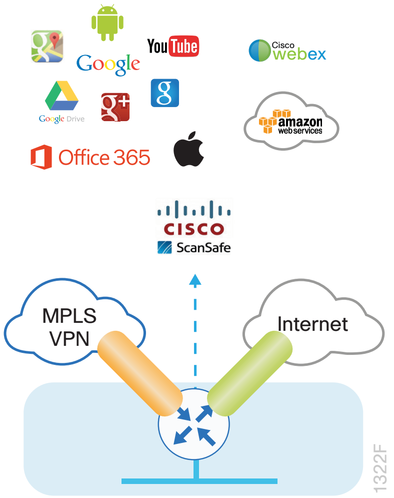
The configurations that follow are remote-site configurations only. These configurations assume each remote site has been configured based on the IWAN foundation. For information about configuring the remote-site routing and primary site WAN-aggregation routers, see the Intelligent WAN Deployment Guide.

IWAN SINGLE-ROUTER HYBRID REMOTE SITE WITH DIA

This section describes configuring DIA for the single-router hybrid IWAN design. These configurations assume the single-router hybrid site with centralized Internet access is configured and functional, as described in the Intelligent WAN Deployment Guide.

In this section, you convert a remote site from centralized Internet access for employees to a secure DIA configuration.

Figure 36 IWAN single-router hybrid design



PROCESS

Configuring DIA Routing

1. Configure Internet interface
2. Filter learned central default route
3. Configure local default routing for outbound local Internet traffic
4. Configure local policy-routing for return Internet traffic

In the following procedures, you enable DIA routing, NAT, and zone-based firewall configurations for the single-router hybrid IWAN design. In this configuration, you route local Internet traffic by using split-tunneling outside the DMVPN tunnel. All configurations are specific to this design model.

Procedure 1 Configure Internet interface

For security, disable the ISP interface before configuring DIA. You will not restore this interface until you complete all of the configurations in this section.

Tech Tip

If you are remotely connected to the remote-site router via SSH, you will be disconnected from the router console. Shutting down the Internet interface will drop the existing DMVPN tunnel.

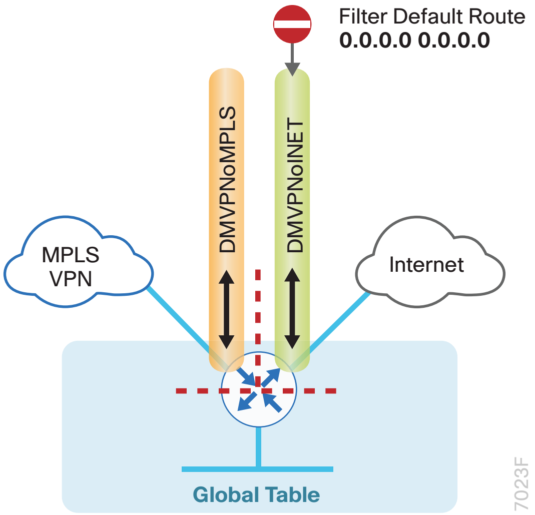
Step 1: Verify that the Internet-facing interface is disabled.

```
interface GigabitEthernet0/0/1
 shutdown
```

Procedure 2 Filter learned central default route

With DIA routing, the default route is locally configured for the global routing table. It is important to filter the default route originating over the Internet-facing DMVPN tunnel from the central site. Failover to the central site is optional over the MPLS-based DMVPN tunnel. In the single-router hybrid design with DIA, all Internet traffic is routed directly to the local ISP interface; it is not feasible to failover to central Internet by using an Internet based DMVPN tunnel.

Figure 37 Filter inbound default route from the central site



If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

Step 1: Create an access list to match the default route and permit all other routes.

```
ip access-list standard ALL-EXCEPT-DEFAULT
 deny 0.0.0.0
 permit any
```

Step 2: Create a route-map to reference the access list.

```
route-map BLOCK-DEFAULT permit 10
 description block only the default route inbound from the WAN
  match ip address ALL-EXCEPT-DEFAULT
```

Step 3: Apply the policy as an inbound distribute list for the Internet-facing DMVPN tunnel interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK-DEFAULT in tunnel11
exit
```

Step 4: (Optional) If you do not want fallback to centralized Internet, also apply the policy as an inbound distribute list for the MPLS-facing DMVPN tunnel interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK-DEFAULT in tunnel10
exit
```

Option 2: BGP on the WAN

Step 1: Create an ip prefix-list to match the default route.

```
ip prefix-list ALL-EXCEPT-DEFAULT seq 10 permit 0.0.0.0/0
```

Step 2: Create a route-map to reference the ip prefix list.

```
route-map BLOCK-DEFAULT deny 10
 description Block only the default route inbound from the WAN
 match ip address prefix-list ALL-EXCEPT-DEFAULT

route-map BLOCK-DEFAULT permit 100
 description Permit all other routes
```

Step 3: Apply the policy as an inbound route-map for the Internet-facing DMVPN tunnel interface.

```
router bgp 65100
 address-family ipv4
  neighbor INET-HUB route-map BLOCK-DEFAULT in
 exit-address-family
```

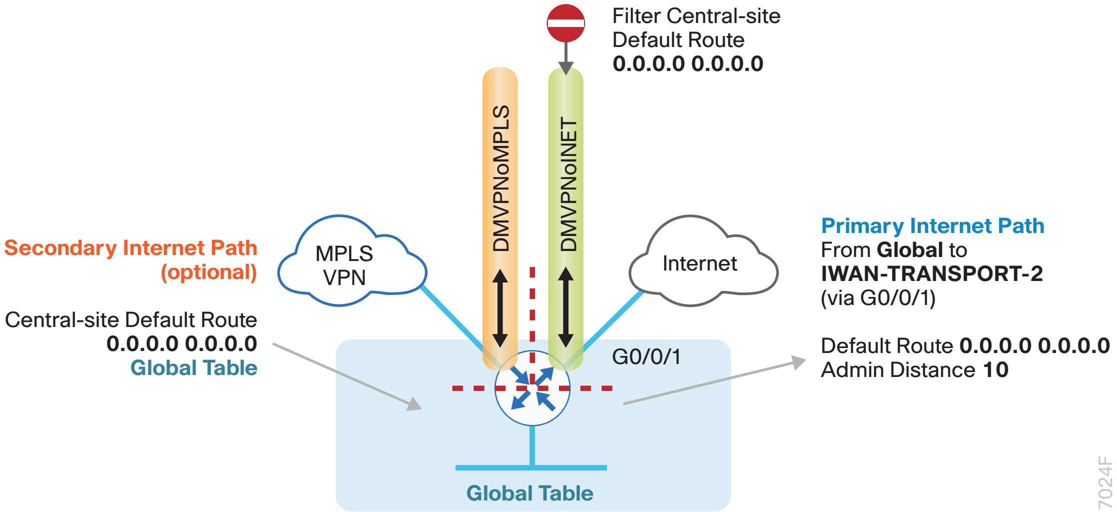
Step 4: (Optional) If you do not want fallback to centralized Internet, also apply the policy as an inbound route-map for the MPLS-facing DMVPN tunnel interface.

```
router bgp 65100
 address-family ipv4
  neighbor MPLS-HUB route-map BLOCK-DEFAULT in
 exit-address-family
```

Procedure 3 Configure local default routing for outbound local Internet traffic

Internal employee traffic is in the global table and needs to route to the Internet via the ISP interface in the IWAN-TRANSPORT-2 VRF. This configuration allows traffic to traverse from the global VRF to the outside VRF in DMVPN F-VRF configurations used for IWAN.

Figure 38 IWAN single-router hybrid—egress default routing



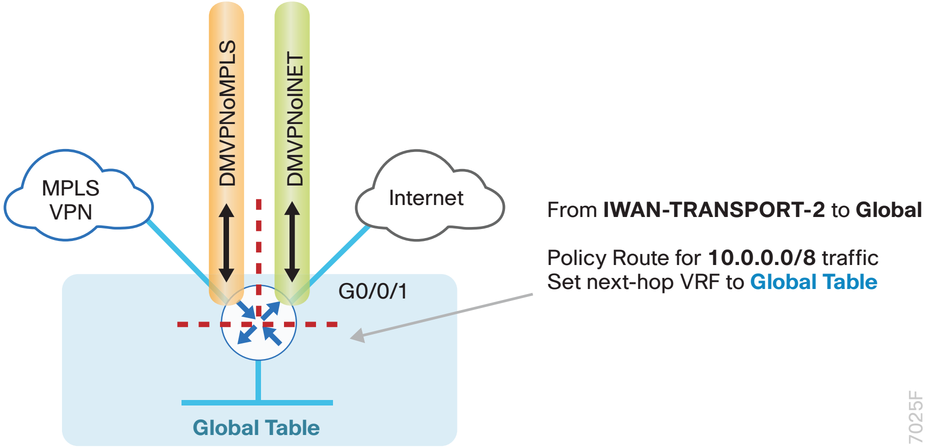
Step 1: Configure a default route in the global table that allows traffic into the outside transit VRF and set the administrative distance to 10.

```
ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/1 dhcp 10
```

Procedure 4 Configure local policy-routing for return Internet traffic

Traffic returning to the outside NAT address of the router ISP interface will be contained inside the IWAN-TRANSPORT-2 VRF. The local policy configuration allows this traffic to be routed back to the global table.

Figure 39 IWAN single-router hybrid–return routing



From **IWAN-TRANSPORT-2** to **Global**

Policy Route for **10.0.0.0/8** traffic
Set next-hop VRF to **Global Table**

Step 1: Configure an ACL that matches the summary range of the internal IP networks.

```
ip access-list extended INTERNAL-NETS
 permit ip any 10.0.0.0 0.255.255.255
```

Step 2: Create a route map that references the ACL and changes the traffic to the global table.

```
route-map INET-INTERNAL permit 10
 description Return routing for Local Internet Access
 match ip address INTERNAL-NETS
 set global
```

Step 3: Apply the local policy routing configuration to the Internet-facing router interface.

```
interface GigabitEthernet0/0/1
 ip policy route-map INET-INTERNAL
```

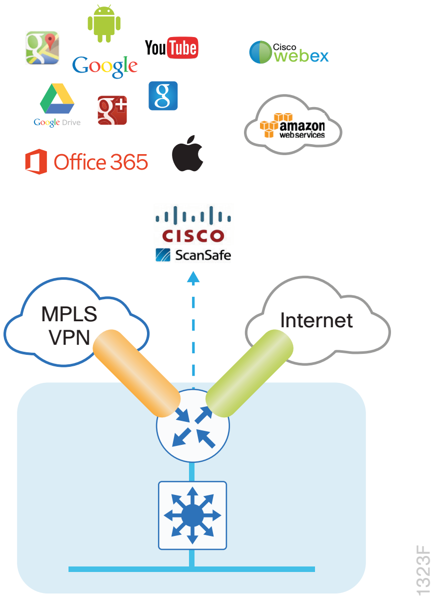
PROCESS

Configuring Single-Router Remote Site with Layer 3 Distribution

1. Configure outbound filtering of the default route to the WAN
2. Configure static default route redistribution into LAN routing protocol

Use this process when a single-router IWAN site requires connectivity to a Layer 3 distribution switch as outlined in the Intelligent WAN Deployment Guide. Here, you need to redistribute the local default route into the LAN routing protocol for advertisement to the Layer 3 switch and filter the default route from being advertised to the WAN.

Figure 40   IWAN single-router hybrid–Layer 3 distribution



Procedure 1   Configure outbound filtering of the default route to the WAN

Perform these steps when connecting a single router to a Layer 3 distribution switch.

If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

Step 1: If you do not already have one, configure an access list to deny the default route and permit all other routes.

```
ip access-list standard ALL-EXCEPT-DEFAULT
 deny 0.0.0.0
 permit any
```

Step 2: Add an instance after the existing route map named "ROUTE-LIST" and reference the access list that denies the default route and permits all other routes. There should be an instance of this route map from the IWAN foundation configuration. This statement is added between the existing statements.

```
route-map ROUTE-LIST permit 20
 description Block Local Internet Default route out to the WAN
 match ip address ALL-EXCEPT-DEFAULT
```

Step 3: Ensure that the route map is applied as an outbound distribution list on the DMVPN tunnel interfaces.

```
router eigrp IWAN-EIGRP

 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map ROUTE-LIST out Tunnel10
   distribute-list route-map ROUTE-LIST out Tunnel11
  exit-af-topology
exit-address-family
```

Option 2: BGP on the WAN

Step 1: If you do not already have one, create an ip prefix-list to match the default.

```
ip prefix-list ALL-EXCEPT-DEFAULT seq 10 permit 0.0.0.0/0
```

Step 2: Add an instance after the existing route map named "SPOKE-OUT" and reference the access list that denies the default route and permits all other routes. There should be an instance of this route map from the IWAN foundation configuration. These statements are added after the existing statements.

```
route-map SPOKE-OUT deny 20
 description Block only the default route outbound from the WAN
 match ip address prefix-list ALL-EXCEPT-DEFAULT

route-map SPOKE-OUT permit 1000
 description Permit all other routes
```

Step 3: Ensure the policy is applied as an outbound route-map for the DMVPN tunnel interfaces.

```
router bgp 65100
 address-family ipv4
  neighbor MPLS-HUB route-map SPOKE-OUT out
  neighbor INET-HUB route-map SPOKE-OUT out
 exit-address-family
```

Procedure 2 Configure static default route redistribution into LAN routing protocol

Perform these steps when connecting a single router to a Layer 3 distribution switch.

If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the LAN

Step 1: Configure an access list to match the default route for redistribution.

```
ip access-list standard DEFAULT-ONLY
 permit 0.0.0.0
```

Step 2: Configure a route map for static redistribution, referencing the access list that matches the static default route.

```
route-map STATIC-IN permit 10
 description Redistribute local default route
 match ip address DEFAULT-ONLY
```

Step 3: Redistribute the static default route installed by DHCP into EIGRP AS400 by using the route map.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   redistribute static route-map STATIC-IN
  exit-af-topology
exit-address-family
```

Option 2: BGP on the WAN and OSPF on the LAN

Step 1: Configure an access list to match the default route for redistribution.

```
ip access-list standard DEFAULT-ONLY
 permit 0.0.0.0
```

Step 2: Create a route-map to reference the ip access-list.

```
route-map STATIC-IN permit 10
 description Redistribute local default route
 match ip address DEFAULT-ONLY
```

Step 3: Redistribute the static default route from BGP to OSPF.

```
router bgp 65100
 address-family ipv4
  redistribute static route-map STATIC-IN
 exit-address-family
```

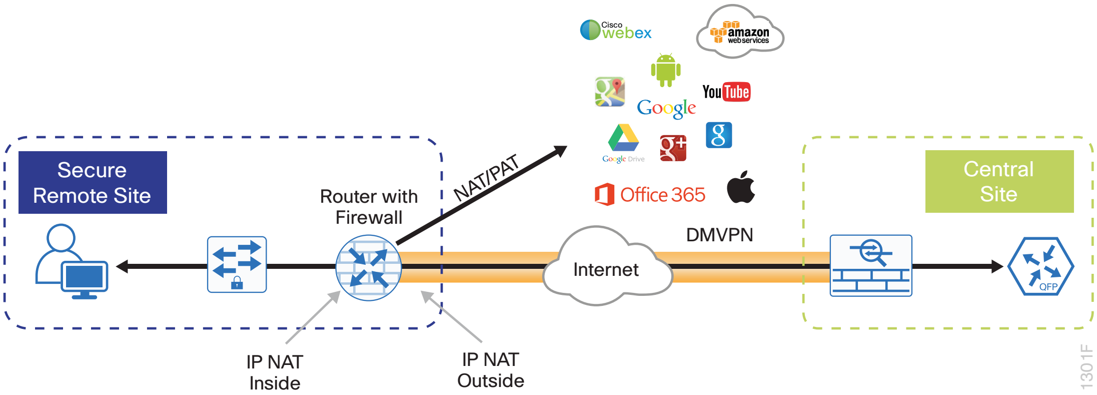
PROCESS

Configuring Network Address Translation for DIA

1. Define and configure Cisco IOS NAT policy

In this design, inside hosts use RFC 1918 addresses, and traffic destined to the Internet from the local site needs to be translated to public IP space. The Internet-facing interface on the remote-site router uses DHCP to acquire a publically routable IP address; the NAT policy here will translate inside private IP addressed hosts to this DHCP address by using PAT.

Figure 41 *NAT for Internet traffic*



Procedure 1 Define and configure Cisco IOS NAT policy

Use this procedure if you want to configure NAT for single-router, hybrid remote-site configurations.

Step 1: Define a policy matching the desired traffic to be translated. Use an ACL and include all remote-site subnets used by employees.

```
ip access-list extended NAT-LOCAL
 permit ip 10.7.128.0 0.0.7.255 any
```

Step 2: Configure route map to reference the ACL and match the outgoing Internet Interface.

```
route-map NAT permit 10
 description Local Internet NAT
 match ip address NAT-LOCAL
 match interface GigabitEthernet0/0/1
```

Step 3: Configure the NAT policy.

```
ip nat inside source route-map NAT interface GigabitEthernet0/0/1 overload
```

Step 4: Enable NAT by applying policy to the inside router interfaces. Apply this configuration, as needed, to internal interfaces or sub-interfaces where traffic matching the ACL may originate, such as the data and transit networks and any service interfaces such as Cisco UCS-E or Cisco Services Ready Engine (SRE) interfaces.

```
interface GigabitEthernet0/0/2.64
 ip nat inside
```

Step 5: Configure the Internet-facing interfaces for NAT.

```
interface GigabitEthernet0/0/1
 description ISP Connection
 ip nat outside
```

Tech Tip

When you configure NAT on IOS router interfaces, you will see **ip virtual-reassembly in** added to the configuration. This is automatically enabled for features that require fragment reassembly, such as NAT, Firewall, and IPS.

Step 6: Verify proper interfaces are configured for NAT.

```
RS31-4451X#sh ip nat statistics
Total active translations: 33 (0 static, 33 dynamic; 33 extended)
Outside interfaces:
  GigabitEthernet0/0/1
Inside interfaces:
  GigabitEthernet0/0/2.64
Hits: 119073  Misses:
Expired translations:
Dynamic mappings:
-- Inside Source
[Id: 1] route-map NAT interface GigabitEthernet0/0/1 refcount 0
nat-limit statistics:
 max entry: max allowed 0, used 0, missed 0
In-to-out drops: 0  Out-to-in drops: 0
Pool stats drop: 0  Mapping stats drop: 0
Port block alloc fail: 0
IP alias add fail: 0
Limit entry add fail: 0
```

Step 7: Verify NAT translations for intended sources that are using local Internet services.

```
RS31-4451X#sh ip nat translations
Pro  Inside global        Inside local         Outside local        Outside global
tcp  172.18.98.205:2223   192.168.192.21:49569 93.184.215.200:443   93.184.215.200:443
tcp  172.18.98.205:2202   192.168.192.21:49548 66.235.132.161:80    66.235.132.161:80
tcp  172.18.98.205:2178   192.168.192.21:49512 74.125.224.114:80    74.125.224.114:80
tcp  172.18.98.205:2181   192.168.192.21:49527 23.203.236.179:80    23.203.236.179:80
```

PROCESS

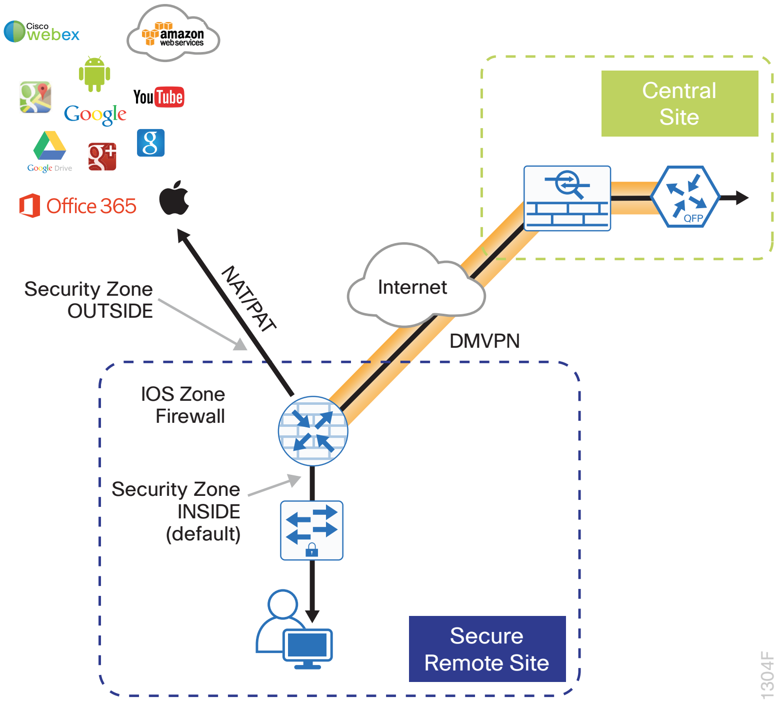
Configuring Zone-Based Firewall for DIA

1. Configure base Cisco IOS zone-based firewall parameters
2. Restrict traffic to the router
3. Enable and verify zone-based firewall configuration

The following Cisco IOS firewall configuration is intended for use on Internet-facing remote-site routers that provide secure local-Internet access. This configuration assumes DHCP and DMVPN are also configured to use the outside interface. To configure the required base firewall policies, complete the following procedures.

Follow these procedures to secure a remote-site router with direct Internet configurations.

Figure 42 Zone-based firewall for DIA



Procedure 1 Configure base Cisco IOS zone-based firewall parameters

Step 1: If it is configured, remove the inbound ACL from the Internet-facing router interfaces, and then shut down the interface before continuing. This prevents unauthorized traffic while the ZBFW is configured.

```
interface GigabitEthernet0/0/1
  shutdown
  no ip access-list extended ACL-INET-PUBLIC in
```

Step 2: Define security zones. A *zone* is a named group of interfaces that have similar functions or security requirements. This example defines the names of the two basic security zones identified. For simplicity this design uses the "default" security zone for inside interfaces. Once the default zone has been defined, all interfaces not explicitly configured as members of a security zone will automatically be part of the default security zone.

```
zone security default
zone security OUTSIDE
```

Tech Tip

This design uses the "default" zone for all inside interfaces; traffic can flow between all interfaces in the default zone.

An interface not defined as part of a security zone is automatically part of the "default" zone. In this configuration, all undefined interface DMVPN tunnels, transit sub-interfaces, and service interfaces such as Cisco UCS-E, and SRE interfaces are included as part of the default zone.

Be aware that any interface that is removed from a defined security zone will be automatically placed into the default zone. In this configuration, that interface will be treated as an "inside" zone and have access to the internal routing domain.

Step 3: Define a class map to match specific protocols. Class-maps apply **match-any** or **match-all** operators in order to determine how to apply the match criteria to the class. If **match-any** is specified, traffic must meet at least one of the match criteria in the class-map to be included in the class. If **match-all** is specified, traffic must meet all of the match criteria to be included in the class.

```
class-map type inspect match-any INSIDE-TO-OUTSIDE-CLASS
 match protocol ftp
 match protocol tcp
 match protocol udp
 match protocol icmp
```

Tech Tip

Protocols that use single ports (such as HTTP, telnet, SSH, etc.) can be statefully allowed with tcp inspection alone by using the **match protocol tcp** command.

Protocols such as **ftp** that use multiple ports (one for control and another for data) require application inspection in order to enable dynamic adjustments to the active firewall policy. The specific TCP ports that are required for the application are allowed for short durations, as necessary.

Step 4: Define policy maps. A policy is an association of traffic classes and actions. It specifies what actions should be performed on defined traffic classes. In this case, you statefully inspect the outbound session so that return traffic is permitted.

```
policy-map type inspect INSIDE-TO-OUTSIDE-POLICY
 class type inspect INSIDE-TO-OUTSIDE-CLASS
  inspect
 class class-default
  drop
```

Tech Tip

An *action* is a specific functionality that is associated with a traffic class. **Inspect**, **drop**, and **pass** are actions.

With the **inspect** action, return traffic is automatically allowed for established connections. The **pass** action permits traffic in one direction only. When using the **pass** action, you must explicitly define rules for return traffic.

Step 5: Define the zone pair and apply the policy map. A zone pair represents two defined zones and identifies the source and destination zones where a unidirectional firewall policy-map is applied. This configuration uses only one zone pair because all traffic is inspected and thus allowed to return.

```
zone-pair security IN_OUT source default destination OUTSIDE
 service-policy type inspect INSIDE-TO-OUTSIDE-POLICY
```

Procedure 2 Restrict traffic to the router

Cisco IOS defines the router by using the fixed-name self as a separate security zone. The self-zone is the exception to the default deny-all policy.

All traffic destined to or originating from the router itself (local traffic) on any interface is allowed until traffic is explicitly denied. In other words, any traffic flowing directly between defined zones and the router's IP interfaces is implicitly allowed and is not initially controlled by zone firewall policies.

This default behavior of the self-zone ensures that connectivity to the router's management interfaces and the function of routing protocols is maintained when an initial zone firewall configuration is applied to the router.

Specific rules that control traffic to the self-zone are required. When you configure a ZBFW rule that includes the self-zone, traffic between the self-zone and the other defined zones is immediately restricted in both directions.

Table 1 Self-zone firewall access list parameters

Protocol	Stateful inspection policy
ISAKMP	Yes
ICMP	Yes
DHCP	No
ESP	No
GRE	No

The following configuration allows the required traffic for proper remote-site router configuration with DMVPN. ESP and DHCP cannot be inspected and need to be configured with a **pass** action in the policy, using separate ACL and class-maps. ISAKMP should be configured with the **inspect** action and thus needs to be broken out with a separate ACL and class-maps for inbound and outbound policies.

Tech Tip

More specific ACLs than are shown here with the "any" keyword are recommended for added security.

Step 1: In the following steps, define access lists.

Step 2: Define an ACL allowing traffic with a destination of the router itself from the OUTSIDE zone. This includes ISAKMP for inbound tunnel initiation. This traffic can be inspected and is identified in the following ACL.

```
ip access-list extended ACL-RTR-IN
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit icmp any any echo
 permit icmp any any echo-reply
 permit icmp any any ttl-exceeded
 permit icmp any any port-unreachable
 permit udp any any gt 1023 ttl eq 1
```

Step 3: Identify traffic for IPSEC tunnel initiation and other traffic that will originate from the router (self-zone) to the OUTSIDE zone. This traffic can be inspected.

```
ip access-list extended ACL-RTR-OUT
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit icmp any any
 permit udp any any eq domain
```

Tech Tip

The Internet control message protocol (ICMP) and domain entries here are for IPSLA probes that originate from the router.

```
 permit icmp any any
 permit udp any any eq domain
```

Step 4: Configure the DHCP ACL to allow the router to acquire a public IP address dynamically from the ISP. This traffic needs to be defined separately for server and client and cannot be inspected.

```
ip access-list extended DHCP-IN
 permit udp any eq bootps any eq bootpc

ip access-list extended DHCP-OUT
 permit udp any eq bootpc any eq bootps
```

Step 5: Configure the ESP ACL to allow the router to establish IPSEC communications for DMVPN. ESP needs to be explicitly allowed inbound and outbound in separate ACLs. ESP cannot be inspected.

```
ip access-list extended ESP-IN
 permit esp any any

ip access-list extended ESP-OUT
 permit esp any any
```

Step 6: Configure the GRE ACL to allow GRE tunnel formation. GRE needs to be explicitly allowed inbound only.

```
ip access-list extended GRE-IN
 permit gre any any
```

Tech Tip

GRE needs to be permitted inbound for GRE on IOS-XE platforms due to a difference in interface order of operations. This is not required on IOS ISRG2 platforms.

Next, you define class maps for traffic to and from the self-zone. Separate class-maps are required for inbound and outbound initiated flows as well as for traffic that can be inspected by the router.

Step 7: Define the class-map matching inbound traffic that can be inspected.

```
class-map type inspect match-any INSPECT-ACL-IN-CLASS
 match access-group name ACL-RTR-IN
```

Step 8: Define the class-map matching outbound traffic that can be inspected.

```
class-map type inspect match-any INSPECT-ACL-OUT-CLASS
 match access-group name ACL-RTR-OUT
```

Step 9: Define the class-map matching inbound traffic that is not able to be inspected.

```
class-map type inspect match-any PASS-ACL-IN-CLASS
 match access-group name ESP-IN
 match access-group name DHCP-IN
 match access-group name GRE-IN
```

Step 10: Define the class-map matching outbound traffic that cannot be inspected.

```
class-map type inspect match-any PASS-ACL-OUT-CLASS
 match access-group name ESP-OUT
 match access-group name DHCP-OUT
```

Next, you define policy maps. Create two separate policies, one for traffic inbound and one for traffic outbound.

Step 11: Define the inbound policy-map that refers to both of the outbound class-maps with actions of **inspect**, **pass**, and **drop** for the appropriate class defined.

```
policy-map type inspect ACL-IN-POLICY
 class type inspect INSPECT-ACL-IN-CLASS
  inspect
 class type inspect PASS-ACL-IN-CLASS
  pass
 class class-default
  drop
```

Step 12: Define the outbound policy-map that refers to both of the outbound class-maps with actions of **inspect**, **pass**, and **drop** for the appropriate class defined.

```
policy-map type inspect ACL-OUT-POLICY
 class type inspect INSPECT-ACL-OUT-CLASS
  inspect
 class type inspect PASS-ACL-OUT-CLASS
  pass
 class class-default
  drop
```

Tech Tip

Inspection for Layer 7 applications is not allowed for traffic going to and from the self-zone to other zones. Cisco IOS firewalls support only inspection of TCP, UDP, and H.323 traffic that terminates on or originates from the router itself.

Traffic such as DHCP and ESP cannot be inspected and must be configured as **Pass** in the associated policy-map.

Next, you define the zone pair and apply policy maps to them.

Step 13: Define the zone pair for traffic destined to the self-zone of the router from the outside and associate the inbound policy-map defined in the previous step.

```
zone-pair security TO-ROUTER source OUTSIDE destination self
 service-policy type inspect ACL-IN-POLICY
```

Step 14: Define the zone pair for traffic destined from the self-zone of the router to the outside and associate the outbound policy-map defined in the previous step.

```
zone-pair security FROM-ROUTER source self destination OUTSIDE
 service-policy type inspect ACL-OUT-POLICY
```

Procedure 3 Enable and verify zone-based firewall configuration

Step 1: Assign the Internet-facing router interface to the outside security zone. All other interfaces are assigned to the default zone and do not need to be defined.

```
interface GigabitEthernet0/0/1
 description Internet Connection
 zone-member security OUTSIDE
```

Tech Tip

By default, traffic is allowed to flow between interfaces that are members of the same zone, while a default “deny-all” policy is applied to traffic moving between zones.

This design uses the “default” zone for all inside interfaces; traffic can flow between all interfaces in the default zone.

An interface not defined as part of a security zone is automatically part of the “default” zone. In this configuration, all undefined interface DMVPN tunnels, transit sub-interfaces, and service interfaces such as Cisco UCS-E, and SRE interfaces are included as part of the default zone.

Loopback interfaces are members of the “self” zone and are not assigned to a defined security zone or the default zone.

Step 2: Verify the interface assignment for the zone firewall and ensure that all required interfaces for the remote site configuration are assigned to the proper zone.

```
RS31-4451X#show zone security
zone self
  Description: System defined zone

zone default
  Description: System level zone. Interface without zone membership is in this zone automatically

zone OUTSIDE
  Member Interfaces:
    GigabitEthernet0/0/1
```

Step 3: Verify firewall operation by reviewing the byte counts for each of the configured policies and classes.

```
RS31-4451X#show policy-map type inspect zone-pair sessions
  Zone-pair: FROM-ROUTER
  Service-policy inspect : ACL-OUT-POLICY
    Class-map: INSPECT-ACL-OUT-CLASS (match-any)
      Match: access-group name ACL-RTR-OUT
        50 packets, 13824 bytes
      Inspect
    Class-map: PASS-ACL-OUT-CLASS (match-any)
      Match: access-group name ESP-OUT
        0 packets, 0 bytes
      Match: access-group name DHCP-OUT
        8 packets, 2680 bytes
      Pass
        8 packets, 2680 bytes
    Class-map: class-default (match-any)
      Match: any
      Drop
        0 packets, 0 bytes
  Zone-pair: IN_OUT
  Service-policy inspect : INSIDE-TO-OUTSIDE-POLICY
    Class-map: INSIDE-TO-OUTSIDE-CLASS (match-any)
      Match: protocol ftp
```

```
          0 packets, 0 bytes
        Match: protocol tcp
          0 packets, 0 bytes
        Match: protocol udp
          0 packets, 0 bytes
        Match: protocol icmp
          0 packets, 0 bytes
        Inspect
      Class-map: class-default (match-any)
        Match: any
        Drop
          0 packets, 0 bytes
    Zone-pair: TO-ROUTER
    Service-policy inspect : ACL-IN-POLICY
      Class-map: INSPECT-ACL-IN-CLASS (match-any)
        Match: access-group name ACL-RTR-IN
          52 packets, 14040 bytes
        Inspect
      Class-map: PASS-ACL-IN-CLASS (match-any)
        Match: access-group name ESP-IN
          0 packets, 0 bytes
        Match: access-group name DHCP-IN
          8 packets, 2736 bytes
        Match: access-group name GRE-IN
          0 packets, 0 bytes
        Pass
          1697 packets, 332091 bytes
      Class-map: class-default (match-any)
        Match: any
        Drop
          0 packets, 0 bytes
```

Step 4: Add the following command to the router configuration in order to identify traffic dropped by the Cisco IOS-XE zone firewall.

```
parameter-map type inspect global
 log dropped-packets
```

Tech Tip

In IOS, when you configure the command **ip inspect drop-pkt**, the following is automatically added to the router configuration:

```
parameter-map type inspect global
 log dropped-packets enable
```

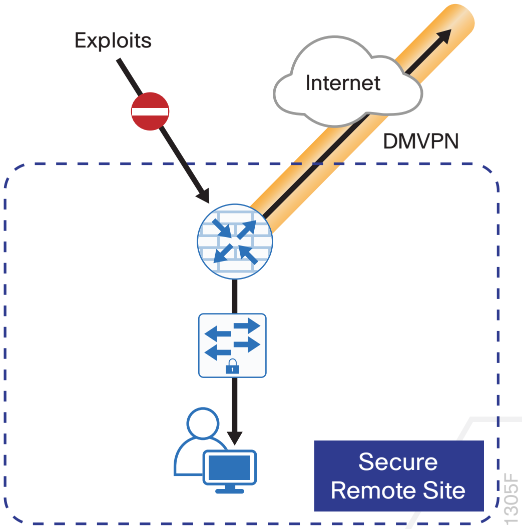
PROCESS

Configuring Additional Router Security

1. Disable IP ICMP redirects
2. Disable ICMP unreachable messages
3. Disable proxy ARP
4. Disable unused router services
5. Disable CDP and LLDP
6. Enable keepalives for TCP sessions
7. Configure internal-network floating static routes
8. Enable Internet interfaces

In addition to the security measures already taken in prior configuration tasks, this section introduces best practices recommendations for securing Internet-facing routers. Disabling unused services and features for networking devices improves the overall security posture by minimizing the amount of information exposed. This practice also minimizes the amount of router CPU and memory load that is required to process unneeded packets.

Figure 43 *Additional router security*



Tech Tip

These are general security guidelines only. You may take additional measures to secure remote-site routers on a case-by-case basis. Take care to ensure that the disabling of certain features does not impact other functions of the network. For added security in hybrid IWAN designs, you can also apply these additional security configurations to MPLS provider interfaces.

Procedure 1 Disable IP ICMP redirects

Routers use ICMP redirect messages to notify that a better route is available for a given destination. In this situation, the router forwards the packet and sends an ICMP redirect message back to the sender advising of an alternative and preferred route to the destination. In many implementations, there is no benefit in permitting this behavior. An attacker can generate traffic, forcing the router to respond with ICMP redirect messages, negatively impacting the CPU and performance of the router. You can prevent this by disabling ICMP redirect messages.

Step 1: Disable ICMP redirect messages on Internet-facing router interface.

```
interface GigabitEthernet0/0/1
 description Internet Connection
 no ip redirects
```

Procedure 2 Disable ICMP unreachable messages

When filtering on router interfaces, routers send ICMP unreachable messages back to the source of blocked traffic. Generating these messages can increase CPU utilization on the router. By default, Cisco IOS ICMP unreachable messages are limited to one every 500 milliseconds. ICMP unreachable messages can be disabled on a per interface basis.

Step 1: Disable ICMP unreachable messages on Internet-facing router interface.

```
interface GigabitEthernet0/0/1
 description Internet Connection
 no ip unreachables
```

Procedure 3 Disable proxy ARP

Proxy address resolution protocol (ARP) allows the router to respond to ARP request for hosts other than itself. Proxy ARP can help machines on a subnet reach remote subnets without configuring routing or a default gateway as defined in RFC 1027. Disadvantages to using proxy ARP:

- An attacker can impact available memory by sending a large number of ARP requests.
- A router is also susceptible to man-in-the-middle attacks where a host on the network could be used to spoof the MAC address of the router, resulting in unsuspecting hosts sending traffic to the attacker.

You can disable proxy ARP by using the **interface** configuration command.

Step 1: Disable proxy ARP on Internet-facing router interface.

```
interface GigabitEthernet0/0/1
 description Internet Connection
 no ip proxy-arp
```

Procedure 4 Disable unused router services

As a security best practice, you should disable all unnecessary services that could be used to launch denial of service (DoS) and other attacks. Many unused services that pose a security threat are disabled by default in current Cisco IOS versions.

Step 1: Disable maintenance operation protocol (MOP) on Internet-facing router interface.

```
interface GigabitEthernet0/0/1
 description Internet Connection
 no mop enabled
```

Step 2: Disable Packet Assembler/Disassembler (PAD) service globally on the router.

```
no service pad
```

Step 3: Prevent the router from attempting to locate a configuration file via trivial file transfer protocol (TFTP) globally on the router.

```
no service config
```

Procedure 5 Disable CDP and LLDP

Attackers can use Cisco Discovery Protocol (CDP) and link layer discovery protocol (LLDP) for reconnaissance and network mapping. CDP is a network protocol that is used to discover other CDP-enabled devices. CDP is often used by network management systems (NMS) and for troubleshooting networking problems. LLDP is an IEEE protocol that is defined in 802.1AB and is very similar to CDP. You should disable CDP and LLDP on router interfaces that connect to untrusted networks.

Step 1: Disable CDP on Internet-facing router interface.

```
interface GigabitEthernet0/0/1
 description Internet Connection
 no cdp enable
```

Step 2: Disable LLDP on Internet-facing router interface.

```
interface GigabitEthernet0/0/1
 description Internet Connection
 no lldp transmit
 no lldp receive
```

Procedure 6 Enable keepalives for TCP sessions

This configuration enables TCP keepalives on inbound connections to the router and outbound connections from the router. This ensures that the device on the remote end of the connection is still accessible and half-open or orphaned connections are removed from the router.

Step 1: Enable the TCP keepalives service for inbound and outbound connections globally on the router.

```
service tcp-keepalives-in
service tcp-keepalives-out
```

Procedure 7 Configure internal-network floating static routes

In the event the DMVPN tunnel to the hub site fails, you will want to ensure traffic destined to internal networks does not follow the local Internet default route. It's best to have the network fail closed to prevent possible security implications and unwanted routing behavior.

Configuring floating static routes to null zero with an AD of 254 ensures that all internal subnets route to null0 in the event of tunnel failure.

Step 1: Configure static route for internal network subnets.

```
ip route 10.0.0.0 255.0.0.0 null0 254
```

Tech Tip

Configure the appropriate number of null 0 routes for internal network ranges, using summaries when possible for your specific network environment. Depending on the networking environment more specific statements may be required.

Procedure 8 Enable Internet interfaces

Now that the security configurations are complete, you can enable the Internet-facing interfaces.

Step 1: Enable the Internet-facing router interface.

```
interface GigabitEthernet0/0/1
 description Internet Connection
 no shutdown
```

PROCESS

Configuring ISP Black-Hole Routing Detection

1. Configure ISP black-hole routing detection

In many cases you will need to ensure connectivity issues with your ISP does not cause black-hole routing conditions. Failure conditions can exist where the DHCP address and routes are not removed from the remote-site router when connectivity issues exist with the broadband service or local premise equipment. There may also be circumstances if certain services are unreachable within via the local ISP connection that you want to reroute to a secondary Internet Service.

Tech Tip

This configuration requires you to turn off PfR load-balancing on the Hub Master Controller. If PfR load-balancing is not turned off, the traffic will fail over to the central site Internet path, but it will not return to the local DIA interface after the failure condition is resolved.

If PfR load-balancing is a requirement for your environment, see “Appendix C: DIA with PfR Load-Balancing” for an alternate way to configure your hybrid remote sites.

If central Internet fallback is required and you do not need PfR load-balancing, configure one or more of the following options.

Procedure 1 Configure ISP black-hole routing detection

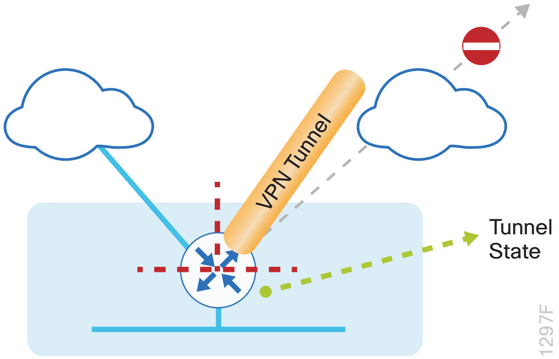
Option 1: DMVPN Tunnel State Tracking

In this solution, the DMVPN tunnel state is used to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, a “down” state of the tunnel interface triggers the removal of the default route via an EEM script. If tunnel state is “up,” the route will remain.

Tech Tip

With this method, a failure or maintenance at the central site can cause a failover event where the route is removed due to tunnel state change and the local Internet connection remains active at the remote site. In hybrid configurations, this can cause failover to Central Internet for multiple sites. It is recommended that you use the other options presented in this guide for hybrid DIA configurations.

Figure 44 *IWAN tunnel tracking with EEM*



Step 1: Ensure that state tracking is configured for the DMVPN tunnel interface.

```
interface Tunnel11
 if-state nhrp
```

Step 2: Configure the tracking parameters and logic for the IPSLA probes.

```
track 80 interface Tunnel10 line-protocol
```

Step 3: Configure the EEM script to remove the route when the tunnel line protocol transitions to a “down” state.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 80 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/1 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/1 DISABLED"
```

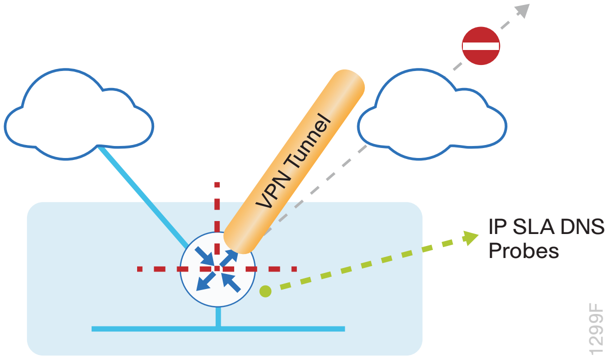
Step 4: Configure the EEM script to restore the local default route when the tunnel line protocol transitions to an “up” state.

```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 80 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/1 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/1 ENABLED"
```

Option 2: DNS-Based IPSLA Probes

In this solution, you use DNS-based IPSLA probes to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, the failure of DNS probes to two or more root DNS servers triggers the removal of the default route via an EEM script. If any DNS probe is active, the route will remain.

Figure 45 *IPSLA with DNS probes*



Tech Tip

For DNS-based IPSLA probes to function, you need to ensure that DNS or “domain” is permitted in the ZBFW outbound ACL, from the self-zone to the OUTSIDE zone. Example:

```
ip access-list extended ACL-RTR-OUT
 permit udp any any eq domain
```

Step 1: Configure the VRF-aware IPSLA DNS probes.

```
ip sla 118
 dns d.root-servers.net name-server 199.7.91.13
 vrf IWAN-TRANSPORT-2
 threshold 1000
 timeout 3000
 frequency 15
ip sla schedule 118 life forever start-time now

ip sla 119
 dns b.root-servers.net name-server 192.228.79.201
 vrf IWAN-TRANSPORT-2
 threshold 1000
 timeout 3000
 frequency 15
ip sla schedule 119 life forever start-time now
```

Tech Tip

When configuring DNS probes, you should specify the hostname of the DNS server itself. That asks the DNS server to resolve for itself, allowing the use of root DNS servers.

Step 2: Configure the tracking parameters and logic for the IPSLA probes.

```
track 73 ip sla 118 reachability
track 74 ip sla 119 reachability

track 100 list boolean or
 object 73
 object 74
```

Step 3: Configure an EEM script to remove the route in the event of DNS probe failure.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 100 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/1 dhcp 
10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/1 DISABLED"
```

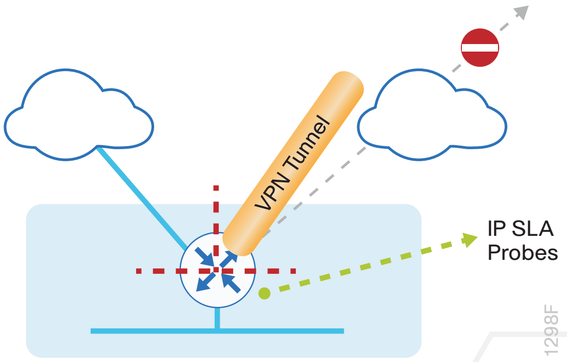
Step 4: Configure an EEM script to also restore the local default route when the DNS probes are active.

```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 100 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/1 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/1 ENABLED"
```

Option 3: IPSLA ICMP Probes

In this solution, you use IPSLA ICMP probes to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, the failure of ICMP probes to two different IP hosts triggers the removal of the default route via an EEM script. If either ICMP probe is active, the route will remain.

Figure 46 *IPSLA with ICMP probes*



Tech Tip

For ICMP-based IPSLA probes to function, you need to ensure ICMP is permitted in the outbound ACL, from the self-zone to the OUTSIDE zone.

Step 1: Configure the VRF-aware IPSLA ICMP probes.

```
ip sla 110
 icmp-echo 172.18.1.253 source-interface GigabitEthernet0/0/1
 vrf IWAN-TRANSPORT-2
 threshold 1000
 frequency 15
ip sla schedule 110 life forever start-time now

ip sla 111
 icmp-echo 172.18.1.254 source-interface GigabitEthernet0/0/1
 vrf IWAN-TRANSPORT-2
 threshold 1000
 frequency 15
ip sla schedule 111 life forever start-time now
```

Step 2: Configure the tracking parameters and logic for the IPSLA ICMP probes.

```
track 60 ip sla 110 reachability
track 61 ip sla 111 reachability
track 62 list boolean or
 object 60
 object 61
```

Step 3: Configure an EEM script to remove the route when the ICMP probes are down.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 62 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/1 dhcp 
10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/1 DISABLED"
```

Step 4: Configure the EEM script to also restore the local default route when the ICMP probes are active.

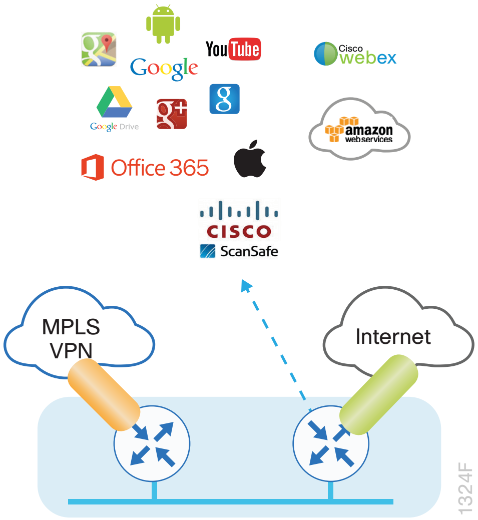
```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 62 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/1 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/1 ENABLED"
```

IWAN DUAL-ROUTER HYBRID REMOTE SITE WITH DIA

This section describes configuring of DIA for the dual-router hybrid IWAN design. These configurations assume the dual-router hybrid site with centralized Internet access is configured and functional, as outlined in the Intelligent WAN Deployment Guide.

In this section, you convert a remote site from centralized Internet access for employees to a secure DIA configuration.

Figure 47 *IWAN dual-router hybrid with DIA*



PROCESS

Configuring DIA Routing

1. Configure Internet interface
2. Filter learned central default route
3. Configure local default routing for outbound local Internet traffic
4. Configure local policy routing for return Internet traffic
5. Filter default route outbound to WAN
6. Redistribute DHCP default route into LAN routing protocol

In the following procedures, you enable DIA routing, NAT and zone-based firewall configurations for the dual-router hybrid IWAN design. In this configuration, you route local Internet traffic by using split-tunneling outside the DMVPN tunnel on the secondary router. All configurations are specific to this design model.

Procedure 1 Configure Internet interface

For security, disable the ISP interface before configuring DIA. You will not restore this interface until you complete all of the configurations in this section.

Tech Tip

If you are remotely connected to the remote-site router via SSH, you will be disconnected from the router console. Shutting down the Internet interface will drop the existing DMVPN tunnel.

Step 1: Verify that the Internet-facing interface is disabled.

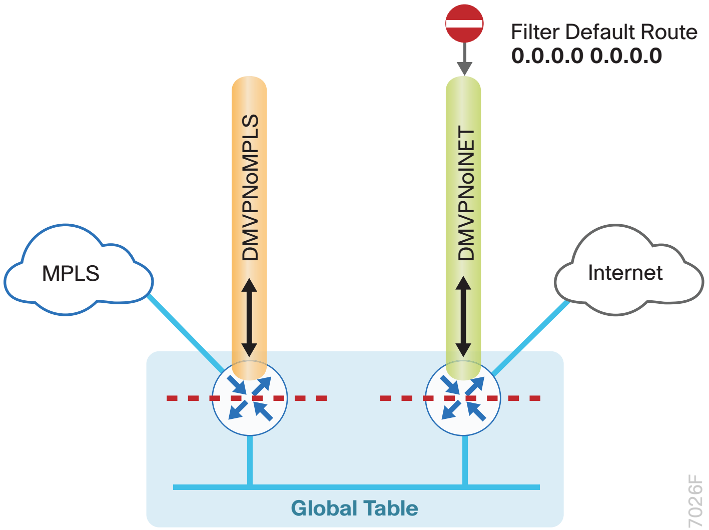
```
interface GigabitEthernet0/0/0
 shutdown
```

Procedure 2 Filter learned central default route

With DIA routing, the default route is locally configured for the global routing table. It is important to filter the default route originating over the Internet-facing DMVPN tunnel from the central site. Failover to the central site is optional over the MPLS-based DMVPN tunnel. In the single-router hybrid design with DIA, all Internet traffic is routed directly to the local ISP interface; it is not feasible to failover to central Internet by using an Internet-based DMVPN tunnel.

The configurations are on the secondary router, unless otherwise stated

Figure 48 *Filter inbound default route from the central site*



If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

Step 1: Create an access list to match the default route and permit all other routes.

```
ip access-list standard ALL-EXCEPT-DEFAULT
 deny 0.0.0.0
 permit any
```

Step 2: Create a route-map to reference the access list.

```
route-map BLOCK-DEFAULT permit 10
 description Block only the default route inbound from the WAN
  match ip address ALL-EXCEPT-DEFAULT
```

Step 3: Apply the policy as an inbound distribute list for the Internet-facing DMVPN tunnel interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK-DEFAULT in tunnel11
exit
```

Step 4: (Optional) If you do not want fallback to centralized Internet, create the same access list and route map on the primary router, and then apply the policy as an inbound distribute list for the MPLS-facing DMVPN tunnel interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK-DEFAULT in tunnel10
exit
```

Option 2: BGP on the WAN

Step 1: Create an ip prefix-list to match the default route.

```
ip prefix-list ALL-EXCEPT-DEFAULT seq 10 permit 0.0.0.0/0
```

Step 2: Create a route-map to reference the ip prefix list.

```
route-map BLOCK-DEFAULT deny 10
 description Block only the default route inbound from the WAN
 match ip address prefix-list ALL-EXCEPT-DEFAULT

route-map BLOCK-DEFAULT permit 100
 description Permit all other routes
```

Step 3: Apply the policy as an inbound route-map for the Internet-facing DMVPN tunnel interface.

```
router bgp 65100
 address-family ipv4
  neighbor INET-HUB route-map BLOCK-DEFAULT in
 exit-address-family
```

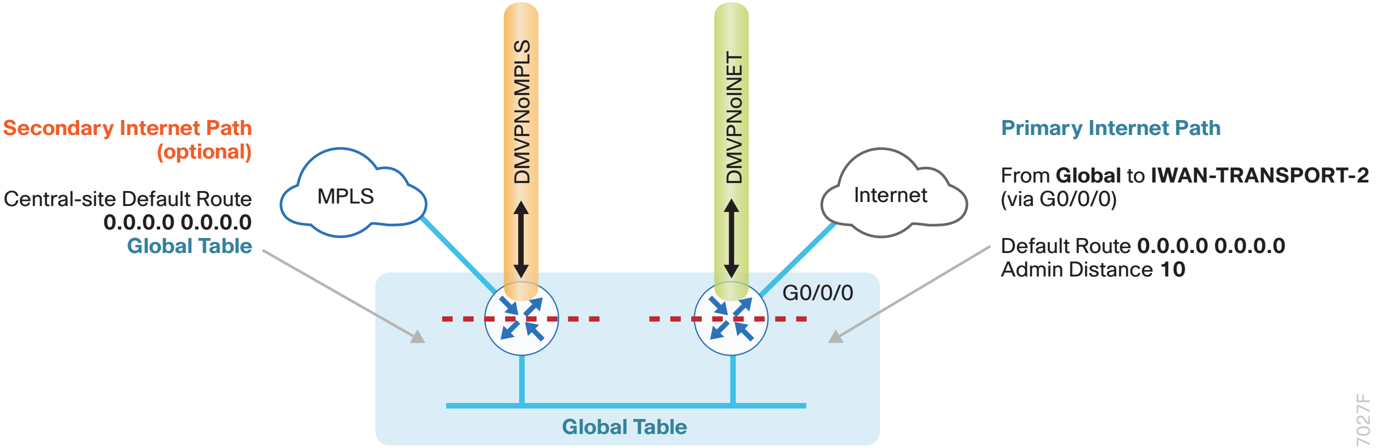
Step 4: (Optional) If you do not want fallback to centralized Internet, create the same ip prefix list and route map on the primary router, and then apply the policy as an inbound route-map for the MPLS-facing DMVPN tunnel interface.

```
router bgp 65100
 address-family ipv4
  neighbor MPLS-HUB route-map BLOCK-DEFAULT in
 exit-address-family
```

Procedure 3 Configure local default routing for outbound local Internet traffic

Internal employee traffic is in the global table and needs to route to the Internet via the ISP interface in the IWAN-TRANSPORT-2 VRF. This configuration allows traffic to traverse from the global to the outside VRF in DMVPN F-VRF configurations used for IWAN.

Figure 49 IWAN dual-router hybrid—egress default routing



Step 1: Configure a default route in the global table that allows traffic into the outside transit VRF and set the administrative distance to 10 on the secondary router

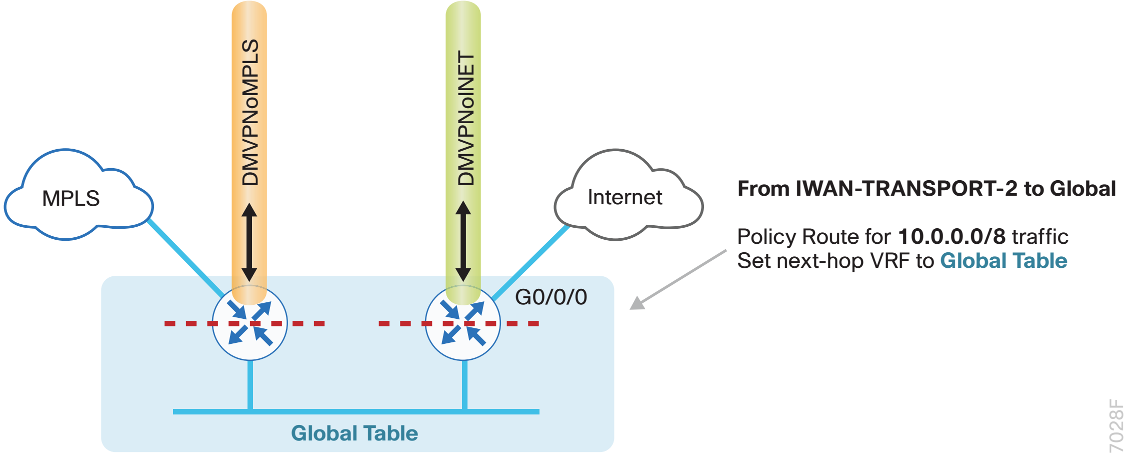
```
ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10
```

Procedure 4 Configure local policy routing for return Internet traffic

Traffic returning to the outside NAT address of the router ISP interface will be contained inside the IWAN-TRANSPORT-2 VRF. The local policy configuration allows this traffic to be routed back to the global table.

The configurations are on the secondary router.

Figure 50 IWAN dual-router hybrid—local policy return routing



From IWAN-TRANSPORT-2 to Global

Policy Route for **10.0.0.0/8** traffic
Set next-hop VRF to **Global Table**

Step 1: Configure an ACL that matches the summary range of the internal IP networks.

```
ip access-list extended INTERNAL-NETS
 permit ip any 10.0.0.0 0.255.255.255
```

Step 2: Create a route map that references the ACL and changes the traffic to the global table.

```
route-map INET-INTERNAL permit 10
 description Return routing for Local Internet Access
 match ip address INTERNAL-NETS
 set global
```

Step 3: Apply the local policy routing configuration to the Internet-facing router interface.

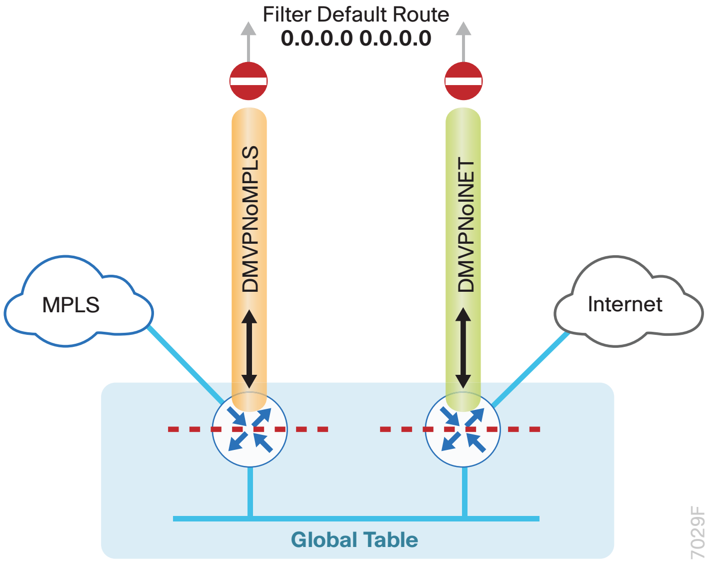
```
interface GigabitEthernet0/0/0
 ip policy route-map INET-INTERNAL
```

Procedure 5 Filter default route outbound to WAN

When you redistribute the default route into the routing protocol in the next procedure, it will be sent out the WAN interfaces to the central site location. This is not the desired behavior, so you must first configure an outbound filter.

The configurations are on both routers.

Figure 51 IWAN dual-router hybrid–egress default route filtering



If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

Step 1: On both routers, configure an access list to deny the default route and permit all other routes.

```
ip access-list standard ALL-EXCEPT-DEFAULT
 deny   0.0.0.0
 permit any
```

Step 2: On both routers, add an instance after the existing route map named "ROUTE-LIST" and reference the access list that denies the default route and permits all other routes. There should be an instance of this route map from the IWAN foundation configuration. This statement should go between the existing statements.

```
route-map ROUTE-LIST permit 20
 description Block Local Internet Default route out to the WAN
 match ip address ALL-EXCEPT-DEFAULT
```

Step 3: On the primary router, ensure that the route map is applied as an outbound distribution list on the DMVPN tunnel interface. Apply this as part of the foundational configuration for dual-router egress filtering.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map ROUTE-LIST out Tunnel10
  exit-af-topology
exit-address-family
```

Step 4: On the secondary router, ensure that the route map is applied as an outbound distribution list on the DMVPN tunnel interface. Apply this as part of the foundational configuration for dual-router egress filtering.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map ROUTE-LIST out Tunnel11
  exit-af-topology
exit-address-family
```

Option 2: BGP on the WAN

Step 1: On both routers, create an ip prefix-list to match the default.

```
ip prefix-list ALL-EXCEPT-DEFAULT seq 10 permit 0.0.0.0/0
```

Step 2: On both routers, add an instance after the existing route map named “SPOKE-OUT” and reference the access list that denies the default route and permits all other routes. There should be an instance of this route map from the IWAN foundation configuration. These statements are added after the existing statements.

```
route-map SPOKE-OUT deny 20
 description Block only the default route outbound from the WAN
 match ip address prefix-list ALL-EXCEPT-DEFAULT

route-map SPOKE-OUT permit 1000
 description Permit all other routes
```

Step 3: On the primary router, ensure the policy is applied as an outbound route-map for the DMVPN tunnel interface. Apply this as part of the foundational configuration for dual-router egress filtering.

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

Step 4: On the secondary router, ensure the policy is applied as an outbound route-map for the DMVPN tunnel interface. Apply this as part of the foundational configuration for dual-router egress filtering.

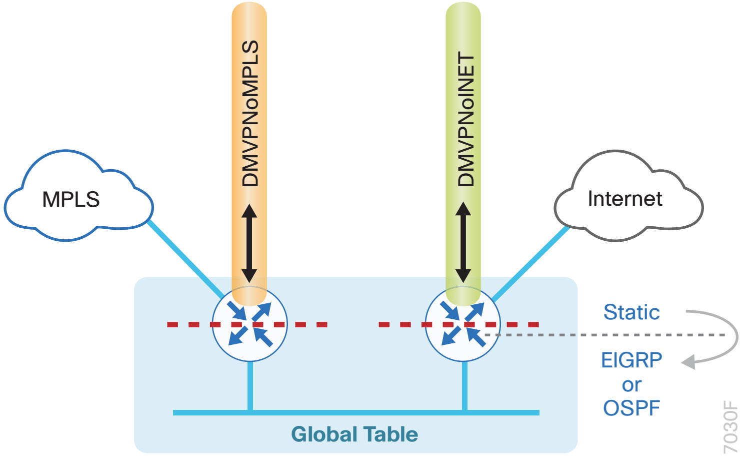
```
router bgp 65100
 address-family ipv4
  neighbor INET-HUB route-map SPOKE-OUT out
 exit-address-family
```

Procedure 6 Redistribute DHCP default route into LAN routing protocol

For dual-router configurations, you need to redistribute the statically configured default route into the LAN routing protocol for reachability on both WAN routers.

The configurations are on the secondary router.

Figure 52 IWAN dual-router hybrid–route redistribution



If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the LAN

Step 1: Configure an access list to match the default route.

```
ip access-list standard DEFAULT-ONLY
 permit 0.0.0.0
```

Step 2: Configure a route-map instance for static redistribution referencing the access list that matches the static default route.

```
route-map STATIC-IN permit 10
 description Redistribute local default route
 match ip address DEFAULT-ONLY
```

Step 3: Redistribute the static default route installed by DHCP into EIGRP AS400 by using the route map.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   redistribute static route-map STATIC-IN
  exit-af-topology
exit-address-family
```

Option 2: BGP on the WAN and OSPF on the LAN

Step 1: Configure an access list to match the default route for redistribution.

```
ip access-list standard DEFAULT-ONLY
 permit 0.0.0.0
```

Step 2: Create a route-map to reference the ip access-list.

```
route-map STATIC-IN permit 10
 description Redistribute local default route
 match ip address DEFAULT-ONLY
```

Step 3: Redistribute the static default route from BGP to OSPF.

```
router bgp 65100
 address-family ipv4
  redistribute static route-map STATIC-IN
 exit-address-family
```

PROCESS

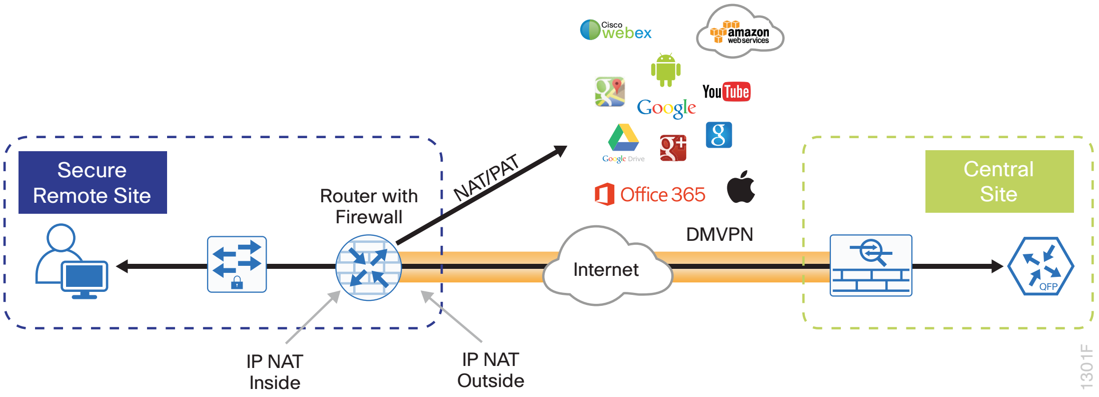
Configuring Network Address Translation for DIA

1. Define and configure Cisco IOS NAT policy

In this design, inside hosts use RFC 1918 addresses, and traffic destined to the Internet from the local site needs to be translated to public IP space. The Internet-facing interface on the remote-site router uses DHCP to acquire a publically routable IP address; the NAT policy here will translate inside private IP addressed hosts to this DHCP address by using PAT.

Perform these configurations on the secondary router.

Figure 53 *NAT for Internet traffic*



Procedure 1 Define and configure Cisco IOS NAT policy

Use this procedure to configure dual-router hybrid remote-site configurations.

Step 1: Define a policy matching the desired traffic to be translated. Use an ACL and include all remote-site subnets used by employees.

```
ip access-list extended NAT-LOCAL
 permit ip 10.7.144.0 0.0.7.255 any
```

Step 2: Configure route map to reference the ACL and match the outgoing Internet Interface.

```
route-map NAT permit 10
 description Local Internet NAT
 match ip address NAT-LOCAL
 match interface GigabitEthernet0/0/0
```

Step 3: Configure the NAT policy.

```
ip nat inside source route-map NAT interface GigabitEthernet0/0/0 overload
```

Step 4: Enable NAT by applying policy to the inside router interfaces. Apply this configuration as needed to internal interfaces or sub-interfaces where traffic matching the ACL may originate, such as the data and transit networks and any service interfaces such as Cisco UCS-E or Cisco SRE interfaces.

```
interface Port-channel 2.64
description data network
 ip nat inside

interface Port-channel 2.99
description transit network
 ip nat inside
```

Step 5: Configure the Internet-facing interfaces for NAT.

```
interface GigabitEthernet0/0/0
 description ISP Connection
 ip nat outside
```

Tech Tip

When you configure NAT on the router interfaces in IOS, you will see **ip virtual-reassembly in** added to the configuration. This is automatically enabled for features that require fragment reassembly, such as NAT, Firewall, and IPS.

Step 6: Verify proper interfaces are configured for NAT.

```
RS32-4451X-2#show ip nat statistics
Total active translations: 33 (0 static, 33 dynamic; 33 extended)
Outside interfaces:
  GigabitEthernet0/0/0
Inside interfaces:
  Port-channel2.64
Hits: 119073  Misses:
Expired translations:
Dynamic mappings:
-- Inside Source
[Id: 1] route-map NAT interface GigabitEthernet0/0/0 refcount 0
nat-limit statistics:
 max entry: max allowed 0, used 0, missed 0
In-to-out drops: 0  Out-to-in drops: 0
Pool stats drop: 0  Mapping stats drop: 0
Port block alloc fail: 0
IP alias add fail: 0
Limit entry add fail: 0
```

Step 7: Verify NAT translations for intended sources that are using local Internet services.

```
RS32-4451X-2#sh ip nat translations
Pro  Inside global        Inside local          Outside local        Outside global
tcp  172.18.98.250:2223   192.168.192.21:49569  93.184.215.200:443   93.184.215.200:443
tcp  172.18.98.250:2202   192.168.192.21:49548  66.235.132.161:80    66.235.132.161:80
tcp  172.18.98.250:2178   192.168.192.21:49512  74.125.224.114:80    74.125.224.114:80
tcp  172.18.98.250:2181   192.168.192.21:49527  23.203.236.179:80    23.203.236.179:80
```

PROCESS

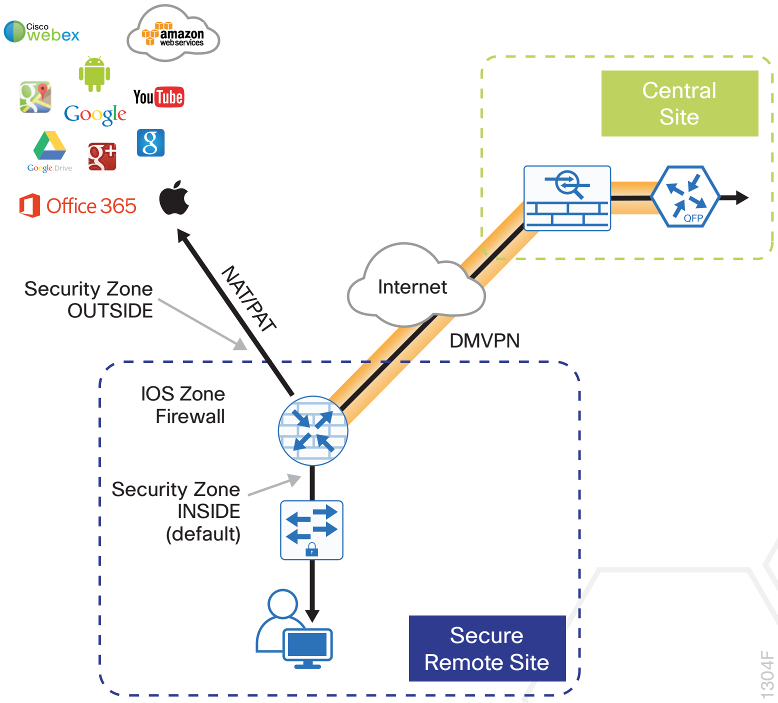
Configuring Zone-Based Firewall for DIA

1. Configure base Cisco IOS Zone-Based Firewall parameters
2. Restrict traffic to the router
3. Enable and verify zone-based firewall configuration

The following Cisco IOS firewall configuration is intended for use on Internet-facing remote site routers providing secure local-Internet access. This configuration assumes DHCP and DMVPN are also configured to use the outside interface. To configure the required base firewall policies, complete the following procedures on the secondary router.

Follow these procedures to secure a dual-router hybrid remote-site router with direct Internet configurations.

Figure 54 Zone-based firewall for DIA



Procedure 1 Configure base Cisco IOS Zone-Based Firewall parameters

Step 1: If it is configured, remove the inbound ACL from the Internet-facing router interfaces, and then shut down the interface before continuing. This prevents unauthorized traffic while the ZBFW is configured.

```
interface GigabitEthernet0/0/0
  shutdown
  no ip access-list extended ACL-INET-PUBLIC in
```

Step 2: Define security zones. A zone is a named group of interfaces that have similar functions or security requirements. This example defines the names of the two basic security zones identified. For simplicity, this design uses the "default" security zone for inside interfaces. Once the default zone has been defined, all interfaces not explicitly configured as members of a security zone will automatically be part of the default security zone.

```
zone security default
zone security OUTSIDE
```

Tech Tip

This design uses the "default" zone for all inside interfaces; traffic can flow between all interfaces in the default zone.

An interface not defined as part of a security zone is automatically part of the "default" zone. In this configuration, all undefined interface DMVPN tunnels, transit sub-interfaces, and service interfaces such as Cisco UCS-E, and SRE interfaces are included as part of the default zone.

Be aware that any interface that is removed from a defined security zone will be automatically placed into the default zone. In this configuration, that interface will be treated as an "inside" zone and have access to the internal routing domain.

Step 3: Define a class map to match specific protocols. Class-maps apply **match-any** or **match-all** operators in order to determine how to apply the match criteria to the class. If **match-any** is specified, traffic must meet at least one of the match criteria in the class-map to be included in the class. If **match-all** is specified, traffic must meet all of the match criteria to be included in the class.

```
class-map type inspect match-any INSIDE-TO-OUTSIDE-CLASS
 match protocol ftp
 match protocol tcp
 match protocol udp
 match protocol icmp
```

Tech Tip

Protocols that use single ports (such as HTTP, telnet, SSH, etc.) can be statefully allowed with tcp inspection alone by using the **match protocol tcp** command.

Protocols such as ftp that use multiple ports (one for control and another for data) require application inspection in order to enable dynamic adjustments to the active firewall policy. The specific TCP ports that are required for the application are allowed for short durations, as necessary.

Step 4: Define policy maps. A policy is an association of traffic classes and actions. It specifies what actions should be performed on defined traffic classes. In this case, you statefully inspect the outbound session so that return traffic is permitted.

```
policy-map type inspect INSIDE-TO-OUTSIDE-POLICY
 class type inspect INSIDE-TO-OUTSIDE-CLASS
  inspect
 class class-default
  drop
```

Tech Tip

An *action* is a specific functionality that is associated with a traffic class. **Inspect**, **drop**, and **pass** are actions.

With the **inspect** action, return traffic is automatically allowed for established connections. The **pass** action permits traffic in one direction only. When using the **pass** action, you must explicitly define rules for return traffic.

Step 5: Define the zone pair and apply the policy map. A zone pair represents two defined zones and identifies the source and destination zones where a unidirectional firewall policy-map is applied. This configuration uses only one zone pair because all traffic is inspected and thus allowed to return.

```
zone-pair security IN_OUT source default destination OUTSIDE
 service-policy type inspect INSIDE-TO-OUTSIDE-POLICY
```

Procedure 2 Restrict traffic to the router

Cisco IOS defines the router by using the fixed name self as a separate security zone. The self-zone is the exception to the default deny-all policy.

All traffic destined to or originating from the router itself (local traffic) on any interface is allowed until traffic is explicitly denied. In other words, any traffic flowing directly between defined zones and the router's IP interfaces is implicitly allowed and is not initially controlled by zone firewall policies.

This default behavior of the self-zone ensures that connectivity to the router's management interfaces and the function of routing protocols is maintained when an initial zone firewall configuration is applied to the router.

Specific rules that control traffic to the self-zone are required. When you configure a ZBFW rule that includes the self-zone, traffic between the self-zone and the other defined zones is immediately restricted in both directions.

Table 2 Self-zone firewall access list parameters

Protocol	Stateful inspection policy
ISAKMP	Yes
ICMP	Yes
DHCP	No
ESP	No
GRE	No

The following configuration allows the required traffic for proper remote-site router configuration with DMVPN. ESP and DHCP cannot be inspected and need to be configured with a **pass** action in the policy, using separate ACL and class-maps. ISAKMP should be configured with the **inspect** action and thus needs to be broken out with a separate ACL and class-maps for inbound and outbound policies.

Tech Tip

More specific ACLs than are shown here with the "any" keyword are recommended for added security.

Step 1: In the following steps, define access lists.

Step 2: Define an ACL allowing traffic with a destination of the router itself from the OUTSIDE zone. This includes ISAKMP for inbound tunnel initiation. This traffic can be inspected and is identified in the following ACL.

```
ip access-list extended ACL-RTR-IN
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit icmp any any echo
 permit icmp any any echo-reply
 permit icmp any any ttl-exceeded
 permit icmp any any port-unreachable
 permit udp any any gt 1023 ttl eq 1
```

Step 3: Identify traffic for IPSEC tunnel initiation and other traffic that will originate from the router (self-zone) to the OUTSIDE zone. This traffic can be inspected.

```
ip access-list extended ACL-RTR-OUT
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit icmp any any
 permit udp any any eq domain
```

Tech Tip

The ICMP and domain entries here are for IPSLA probes that originate from the router.

```
 permit icmp any any
 permit udp any any eq domain
```

Step 4: Configure the DHCP ACL to allow the router to acquire a public IP address dynamically from the ISP. This traffic needs to be defined separately for server and client and cannot be inspected.

```
ip access-list extended DHCP-IN
 permit udp any eq bootps any eq bootpc

ip access-list extended DHCP-OUT
 permit udp any eq bootpc any eq bootps
```

Step 5: Configure the ESP ACL to allow the router to establish IPSEC communications for DMVPN. ESP needs to be explicitly allowed inbound and outbound in separate ACLs. ESP cannot be inspected.

```
ip access-list extended ESP-IN
 permit esp any any

ip access-list extended ESP-OUT
 permit esp any any
```

Step 6: Configure the GRE ACL to allow GRE tunnel formation. GRE needs to be explicitly allowed inbound only.

```
ip access-list extended GRE-IN
 permit gre any any
```

Tech Tip

GRE needs to be permitted inbound for GRE on IOS-XE platforms due to a difference in interface order of operations. This is not required on IOS ISRG2 platforms.

Next, you define class maps for traffic to and from the self-zone. Separate class-maps are required for inbound and outbound initiated flows as well as for traffic that can be inspected by the router.

Step 7: Define the class-map matching inbound traffic that can be inspected.

```
class-map type inspect match-any INSPECT-ACL-IN-CLASS
 match access-group name ACL-RTR-IN
```

Step 8: Define the class-map matching outbound traffic that can be inspected.

```
class-map type inspect match-any INSPECT-ACL-OUT-CLASS
 match access-group name ACL-RTR-OUT
```

Step 9: Define the class-map matching inbound traffic that is not able to be inspected.

```
class-map type inspect match-any PASS-ACL-IN-CLASS
 match access-group name ESP-IN
 match access-group name DHCP-IN
 match access-group name GRE-IN
```

Step 10: Define the class-map matching outbound traffic that cannot be inspected.

```
class-map type inspect match-any PASS-ACL-OUT-CLASS
 match access-group name ESP-OUT
 match access-group name DHCP-OUT
```

Next, you define policy maps. Create two separate policies, one for traffic inbound and one for traffic outbound.

Step 11: Define the inbound policy-map that refers to both of the outbound class-maps with actions of **inspect**, **pass**, and **drop** for the appropriate class defined.

```
policy-map type inspect ACL-IN-POLICY
 class type inspect INSPECT-ACL-IN-CLASS
  inspect
 class type inspect PASS-ACL-IN-CLASS
  pass
 class class-default
  drop
```

Step 12: Define the outbound policy-map that refers to both of the outbound class-maps with actions of **inspect**, **pass**, and **drop** for the appropriate class defined.

```
policy-map type inspect ACL-OUT-POLICY
 class type inspect INSPECT-ACL-OUT-CLASS
  inspect
 class type inspect PASS-ACL-OUT-CLASS
  pass
 class class-default
  drop
```

Tech Tip

Inspection for Layer 7 applications is not allowed for traffic going to and from the self-zone to other zones. Cisco IOS firewalls support only inspection of TCP, UDP, and H.323 traffic that terminates on or originates from the router itself.

Traffic such as DHCP and ESP cannot be inspected and must be configured as **Pass** in the associated policy-map.

Next, you define the zone pair and apply policy maps to them.

Step 13: Define the zone pair for traffic destined to the self-zone of the router from the outside and associate the inbound policy-map defined in the previous step.

```
zone-pair security TO-ROUTER source OUTSIDE destination self
 service-policy type inspect ACL-IN-POLICY
```

Step 14: Define the zone pair for traffic destined from the self-zone of the router to the outside and associate the outbound policy-map defined in the previous step.

```
zone-pair security FROM-ROUTER source self destination OUTSIDE
 service-policy type inspect ACL-OUT-POLICY
```

Procedure 3 Enable and verify zone-based firewall configuration

Step 1: Assign the Internet-facing router interface to the outside security zone. All other interfaces are assigned to the default zone and do not need to be defined.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 zone-member security OUTSIDE
```

Tech Tip

By default, traffic is allowed to flow between interfaces that are members of the same zone, while a default “deny-all” policy is applied to traffic moving between zones.

This design uses the “default” zone for all inside interfaces, traffic can flow between all interfaces in the default zone.

An interface not defined as part of a security zone is automatically part of the “default” zone. In this configuration, all undefined interface DMVPN tunnels, transit sub-interfaces, and service interfaces such as Cisco UCS-E, and SRE interfaces are included as part of the default zone.

Loopback interfaces are members of the “self” zone and are not assigned to a defined security zone or the default zone.

Step 2: Verify the interface assignment for the zone firewall and ensure that all required interfaces for the remote site configuration are assigned to the proper zone.

```
RS32-4451X-2#show zone security
zone self
  Description: System defined zone

zone default
  Description: System level zone. Interface without zone membership is in this 
zone automatically

zone OUTSIDE
  Member Interfaces:
    GigabitEthernet0/0/0
```

Step 3: Verify firewall operation by reviewing the byte counts for each of the configured policies and classes.

```
RS32-4451X-2#show policy-map type inspect zone-pair sessions
  Zone-pair: FROM-ROUTER
  Service-policy inspect : ACL-OUT-POLICY
    Class-map: INSPECT-ACL-OUT-CLASS (match-any)
      Match: access-group name ACL-RTR-OUT
        50 packets, 13824 bytes
      Inspect
    Class-map: PASS-ACL-OUT-CLASS (match-any)
      Match: access-group name ESP-OUT
        0 packets, 0 bytes
      Match: access-group name DHCP-OUT
        8 packets, 2680 bytes
      Pass
        8 packets, 2680 bytes
    Class-map: class-default (match-any)
      Match: any
      Drop
        0 packets, 0 bytes
  Zone-pair: IN_OUT
  Service-policy inspect : INSIDE-TO-OUTSIDE-POLICY
    Class-map: INSIDE-TO-OUTSIDE-CLASS (match-any)
      Match: protocol ftp
```

```
            0 packets, 0 bytes
          Match: protocol tcp
            0 packets, 0 bytes
          Match: protocol udp
            0 packets, 0 bytes
          Match: protocol icmp
            0 packets, 0 bytes
          Inspect
        Class-map: class-default (match-any)
          Match: any
          Drop
            0 packets, 0 bytes
      Zone-pair: TO-ROUTER
      Service-policy inspect : ACL-IN-POLICY
        Class-map: INSPECT-ACL-IN-CLASS (match-any)
          Match: access-group name ACL-RTR-IN
            52 packets, 14040 bytes
          Inspect
        Class-map: PASS-ACL-IN-CLASS (match-any)
          Match: access-group name ESP-IN
            0 packets, 0 bytes
          Match: access-group name DHCP-IN
            8 packets, 2736 bytes
          Match: access-group name GRE-IN
            0 packets, 0 bytes
          Pass
            1697 packets, 332091 bytes
        Class-map: class-default (match-any)
          Match: any
          Drop
            0 packets, 0 bytes
```

Step 4: Add the following command to the router configuration in order to identify traffic dropped by the Cisco IOS-XE zone firewall.

```
parameter-map type inspect global
 log dropped-packets
```

Tech Tip

In IOS, when you configure the command **ip inspect drop-pkt**, the following is automatically added to the router configuration:

```
parameter-map type inspect global
 log dropped-packets enable
```

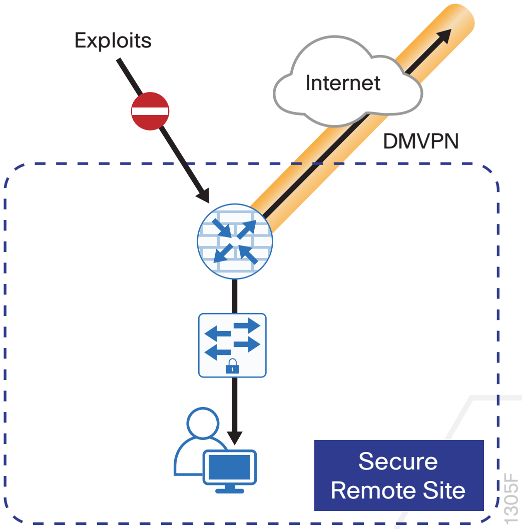
PROCESS

Configuring Additional Router Security

1. Disable IP ICMP redirects
2. Disable ICMP unreachable messages
3. Disable Proxy ARP
4. Disable unused router services
5. Disable CDP and LLDP
6. Enable keepalives for TCP sessions
7. Configure internal-network floating static routes
8. Enable Internet interface

In addition to the security measures already taken in prior configuration tasks, this section introduces best practices recommendations to secure Internet-facing routers. Disabling unused services and features for networking devices improves the overall security posture by minimizing the amount of information exposed. This practice also minimizes the amount of router CPU and memory load that is required to process unneeded packets.

Figure 55 Additional router security



Tech Tip

These are general security guidelines only. You may take additional measures to secure remote-site routers on a case-by-case basis. Take care to ensure that the disabling of certain features does not impact other functions of the network. For added security in hybrid IWAN designs, you can also apply these additional security configurations to MPLS provider interfaces.

Procedure 1 Disable IP ICMP redirects

Routers use ICMP redirect messages to notify that a better route is available for a given destination. In this situation, the router forwards the packet and sends an ICMP redirect message back to the sender advising of an alternative and preferred route to the destination. In many implementations, there is no benefit in permitting this behavior. An attacker can generate traffic, forcing the router to respond with ICMP redirect messages, negatively impacting the CPU and performance of the router. You can prevent this by disabling ICMP redirect messages.

Step 1: Disable ICMP redirect messages on Internet-facing router interface.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no ip redirects
```

Procedure 2 Disable ICMP unreachable messages

When filtering on router interfaces, routers send ICMP unreachable messages back to the source of blocked traffic. Generating these messages can increase CPU utilization on the router. By default, Cisco IOS ICMP unreachable messages are limited to one every 500 milliseconds. ICMP unreachable messages can be disabled on a per interface basis.

Step 1: Disable ICMP unreachable messages on Internet-facing router interface.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no ip unreachables
```

Procedure 3 Disable Proxy ARP

Proxy ARP allows the router to respond to ARP request for hosts other than itself. Proxy ARP can help machines on a subnet reach remote subnets without configuring routing or a default gateway as defined in RFC 1027. Disadvantages to using proxy ARP:

- An attacker can impact available memory by sending a large number of ARP requests.
- A router is also susceptible to man-in-the-middle attacks where a host on the network could be used to spoof the MAC address of the router, resulting in unsuspecting hosts sending traffic to the attacker.

You can disable proxy ARP by using the **interface** configuration command.

Step 1: Disable proxy ARP on Internet-facing router interface.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no ip proxy-arp
```

Procedure 4 Disable unused router services

As a security best practice, you should disable all unnecessary services that could be used to launch DoS and other attacks. Many unused services that pose a security threat are disabled by default in current Cisco IOS versions.

Step 1: Disable MOP on Internet-facing router interface.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no mop enabled
```

Step 2: Disable PAD service globally on the router.

```
no service pad
```

Step 3: Prevent the router from attempting to locate a configuration file via TFTP globally on the router.

```
no service config
```

Procedure 5 Disable CDP and LLDP

Attackers can use CDP and LLDP for reconnaissance and network mapping. CDP is a network protocol that is used to discover other CDP-enabled devices. CDP is often used by NMS and for troubleshooting networking problems. LLDP is an IEEE protocol that is defined in 802.1AB and is very similar to CDP. You should disable CDP and LLDP on router interfaces that connect to untrusted networks.

Step 1: Disable CDP on Internet-facing router interface.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no cdp enable
```

Step 2: Disable LLDP on Internet-facing router interface.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no lldp transmit
 no lldp receive
```

Procedure 6 Enable keepalives for TCP sessions

This configuration enables TCP keepalives on inbound connections to the router and outbound connections from the router. This ensures that the device on the remote end of the connection is still accessible and half-open or orphaned connections are removed from the router.

Step 1: Enable the TCP keepalives service for inbound and outbound connections globally on the router.

```
service tcp-keepalives-in
service tcp-keepalives-out
```

Procedure 7 Configure internal-network floating static routes

In the event the DMVPN tunnel to the hub site fails, you will want to ensure traffic destined to internal networks does not follow the local Internet default route. It's best to have the network fail closed to prevent possible security implications and unwanted routing behavior.

Configuring floating static routes to null zero with an AD of 254 ensures that all internal subnets route to null0 in the event of tunnel failure.

Step 1: Configure static route for internal network subnets.

```
ip route 10.0.0.0 255.0.0.0 null0 254
```

Tech Tip

Configure the appropriate number of null 0 routes for internal network ranges, using summaries when possible for your specific network environment.

Procedure 8 Enable Internet interface

Now that the security configurations are complete, you can enable the Internet-facing interface.

Step 1: Enable the Internet-facing router interface.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no shutdown
```

PROCESS

Configuring ISP Black-Hole Routing Detection

1. Configure ISP black-hole routing detection

In many cases you will need to ensure connectivity issues with your ISP does not cause black-hole routing conditions. Failure conditions can exist where the DHCP address and routes are not removed from the remote-site router when connectivity issues exist with the broadband service or local premise equipment. There may also be circumstances if certain services are unreachable within via the local ISP connection that you want to reroute to a secondary Internet service.

Tech Tip

This configuration requires you to turn off PfR load-balancing on the Hub Master Controller. If PfR load-balancing is not turned off, the traffic will fail over to the central site Internet path, but it will not return to the local DIA interface after the failure condition is resolved.

If PfR load-balancing is a requirement for your environment, see "Appendix C: DIA with PfR Load-Balancing" for an alternate way to configure your hybrid remote sites.

If central Internet fallback is required and you do not need PfR load-balancing, configure one or more of the following options on the secondary router.

Procedure 1 Configure ISP black-hole routing detection

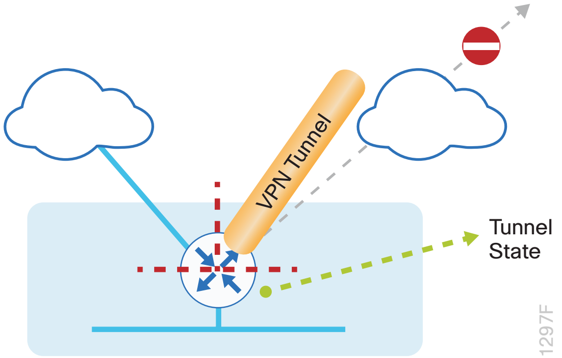
Option 1: DMVPN Tunnel State Tracking

In this solution, the DMVPN tunnel state is used to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, a "down" state of the tunnel interface triggers the removal of the default route via an EEM script. If tunnel state is "up," the route will remain.

Tech Tip

With this method a failure or maintenance at the central site can cause a failover event where the route is removed due to tunnel state change and the local Internet connection remains active at the remote site. In hybrid configurations this can cause failover to Central Internet for multiple sites. It is recommended that you use the other options presented in this guide for hybrid DIA configurations.

Figure 56 *IWAN tunnel tracking with EEM*



Step 1: Ensure that state tracking is configured for the DMVPN tunnel interface on the secondary router.

```
interface Tunnel11
 if-state nhrp
```

Step 2: Configure the tracking parameters and logic for the IPSLA probes on the secondary router.

```
track 80 interface Tunnel10 line-protocol
```

Step 3: On the secondary router, configure an EEM script to remove the local default route when the tunnel line protocol transitions to a “down” state.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 80 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 
10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 DISABLED"
```

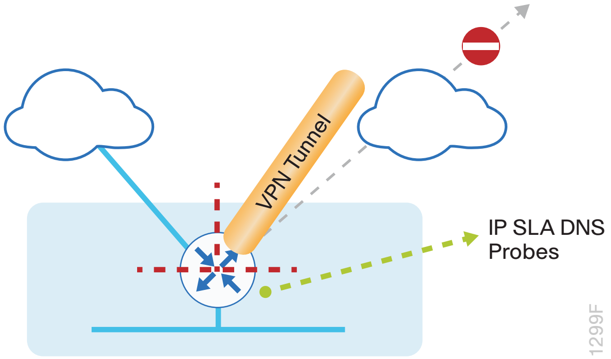
Step 4: On the secondary router, configure an EEM script to also restore the local default route when the tunnel state tracking object is “up”.

```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 80 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 ENABLED"
```

Option 2: DNS-Based IPSLA Probes

In this solution, you use DNS-based IPSLA probes to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, the failure of DNS probes to two or more root DNS servers triggers the removal of the default route via an EEM script. If any DNS probe is active, the route will remain.

Figure 57 *IPSLA with DNS probes*



Tech Tip

For DNS-based IPSLA probes to function, you need to ensure that DNS or "domain" is permitted in the ZBFW outbound ACL, from the self-zone to the OUTSIDE zone. Example:

```
ip access-list extended ACL-RTR-OUT
 permit udp any any eq domain
```

Step 1: On the secondary router, configure the VRF-aware IPSLA DNS probes.

```
ip sla 118
 dns d.root-servers.net name-server 199.7.91.13
 vrf IWAN-TRANSPORT-2
 threshold 1000
 timeout 3000
 frequency 15
ip sla schedule 118 life forever start-time now

ip sla 119
 dns b.root-servers.net name-server 192.228.79.201
 vrf IWAN-TRANSPORT-2
 threshold 1000
 timeout 3000
 frequency 15
ip sla schedule 119 life forever start-time now
```

Tech Tip

When configuring DNS probes, you should specify the hostname of the DNS server itself. That asks the DNS server to resolve for itself, allowing the use of root DNS servers.

Step 2: On the secondary router, configure the tracking parameters and logic for the IPSLA probes.

```
track 73 ip sla 118 reachability
track 74 ip sla 119 reachability
!
track 100 list boolean or
 object 73
 object 74
```

Step 3: On the secondary router, configure an EEM script to remove the route in the event of DNS probe failure.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 100 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 
10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 DISABLED"
```

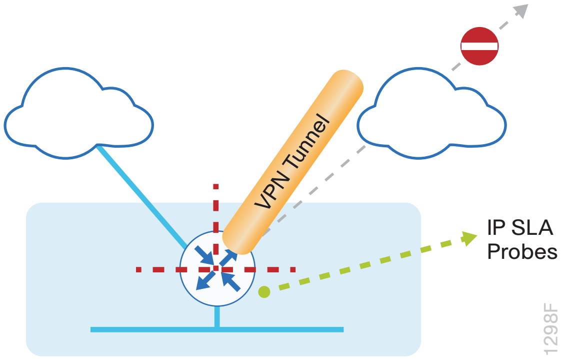
Step 4: On the secondary router, configure an EEM script to also restore the local default route when the DNS probes are active.

```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 100 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 ENABLED"
```

Option 3: IPLSA ICMP Probes

In this solution, you use IPSLA ICMP probes to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, the failure of ICMP probes to two different IP hosts triggers the removal of the default route via an EEM script. If either ICMP probe is active, the route will remain.

Figure 58 *IPSLA with ICMP probes*



Tech Tip

For ICMP-based IPSLA probes to function, you need to ensure ICMP is permitted in the outbound ACL, from the self-zone to the OUTSIDE zone.

Step 1: Configure the VRF-aware IPSLA ICMP probes.

```
ip sla 110
 icmp-echo 172.18.1.253 source-interface GigabitEthernet0/0/0
 vrf IWAN-TRANSPORT-2
 threshold 1000
 frequency 15
ip sla schedule 110 life forever start-time now

ip sla 111
 icmp-echo 172.18.1.254 source-interface GigabitEthernet0/0/0
 vrf IWAN-TRANSPORT-2
 threshold 1000
 frequency 15
ip sla schedule 111 life forever start-time now
```

Step 2: Configure the tracking parameters and logic for the IPSLA ICMP probes.

```
track 60 ip sla 110 reachability
track 61 ip sla 111 reachability
track 62 list boolean or
 object 60
 object 61
```

Step 3: Configure the EEM script to remove the route when the ICMP probes are down.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 62 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 
10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 DISABLED"
```

Step 4: Configure the EEM script to also restore the local default route when the ICMP probes are active.

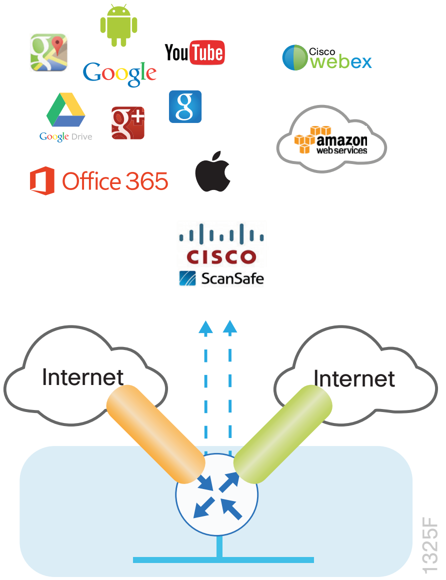
```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 62 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 ENABLED"
```

IWAN SINGLE-ROUTER DUAL-INTERNET REMOTE SITE WITH DIA

This section describes configuring DIA for the single-router dual-Internet IWAN design. . These configurations assume that the single-router dual-Internet site with centralized Internet access is configured and functional, as described in the Intelligent WAN Deployment Guide.

In this section, you convert a remote site from centralized Internet access for employees to a secure DIA configuration.

Figure 59 IWAN single-router dual-Internet with DIA



PROCESS

Configuring DIA Routing

1. Configure Internet interfaces
2. Filter learned central default route
3. Configure local default routing for outbound local Internet traffic
4. Configure local policy routing for return Internet traffic

In the following procedures, you enable DIA routing, NAT and zone-based firewall configurations for the single-router dual-Internet IWAN design. In this configuration, local internet traffic will be routed using split-tunneling outside the DMVPN tunnel. All configurations are specific to this design model.

Procedure 1 Configure Internet interfaces

For security, disable the ISP interface before configuring DIA. You will not restore this interface until you complete all of the configurations in this section.

Tech Tip

If you are remotely connected to the remote-site router via SSH, you will be disconnected from the router console. Shutting down the Internet interfaces will drop the existing DMVPN tunnel.

Step 1: Verify that the Internet-facing interfaces are disabled.

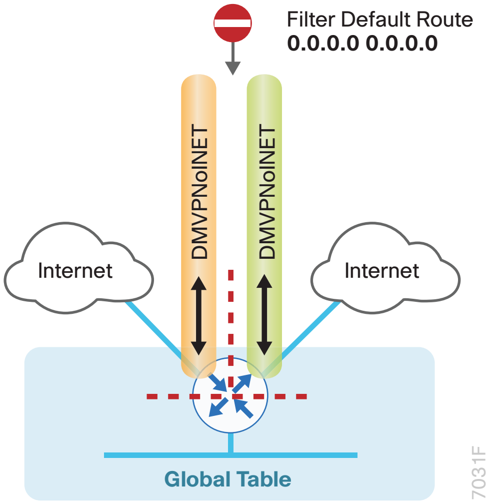
```
interface GigabitEthernet0/0/0
 shutdown

interface GigabitEthernet0/0/1
 shutdown
```

Procedure 2 Filter learned central default route

With DIA routing, the default route is locally configured for the global routing table. It is important to filter the default route originating over both Internet-facing DMVPN tunnels from the central site. In the single-router dual-Internet design with DIA, all Internet traffic is routed directly to the local ISP interface; it is not feasible to failover to central internet using an Internet-based DMVPN tunnel. Internet failover is from the primary to the secondary Internet interface on the router.

Figure 60 Filter inbound default route from the central site



If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

Step 1: Create an access list to match the default route and permit all other routes.

```
ip access-list standard ALL-EXCEPT-DEFAULT
 deny   0.0.0.0
 permit any
```

Step 2: Create a route-map to reference the access list.

```
route-map BLOCK-DEFAULT permit 10
 description block only the default route inbound from the WAN
  match ip address ALL-EXCEPT-DEFAULT
```

Step 3: Apply the policy as an inbound distribute list for the Internet-facing DMVPN tunnel interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK-DEFAULT in tunnel20
   distribute-list route-map BLOCK-DEFAULT in tunnel21
  exit-af-topology
 exit-address-family
```

Option 2: BGP on the WAN

Step 1: Create an ip prefix-list to match the default route.

```
ip prefix-list ALL-EXCEPT-DEFAULT seq 10 permit 0.0.0.0/0
```

Step 2: Create a route-map to reference the ip prefix list.

```
route-map BLOCK-DEFAULT deny 10
 description Block only the default route inbound from the WAN
 match ip address prefix-list ALL-EXCEPT-DEFAULT

route-map BLOCK-DEFAULT permit 100
 description Permit all other routes
```

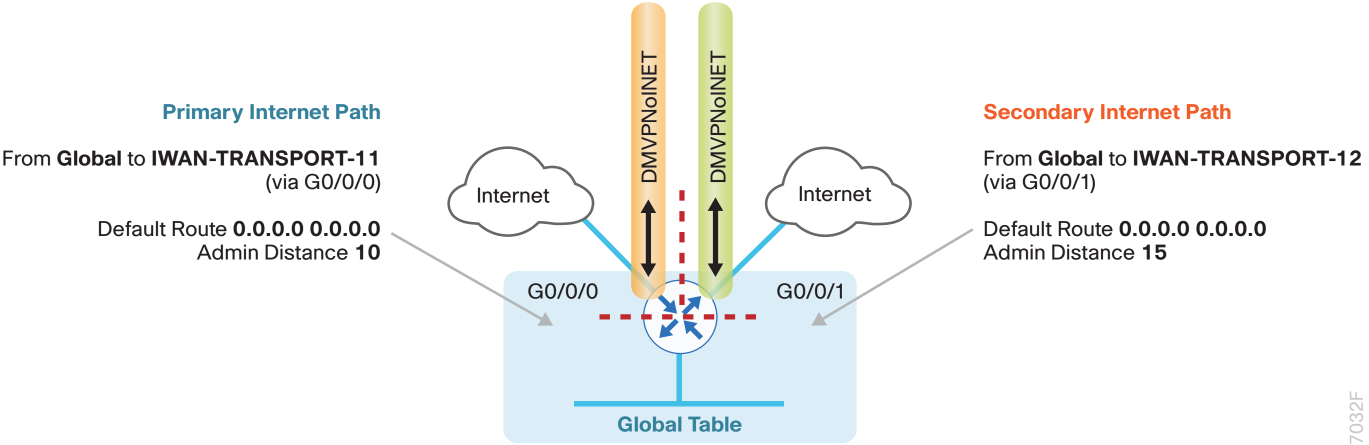
Step 3: Apply the policy as an inbound route-map for the Internet-facing DMVPN tunnel interface.

```
router bgp 65100
 address-family ipv4
  neighbor INET1-HUB route-map BLOCK-DEFAULT in
  neighbor INET2-HUB route-map BLOCK-DEFAULT in
 exit-address-family
```

Procedure 3 Configure local default routing for outbound local Internet traffic

Internal employee traffic is in the global table and needs to route to the Internet via the ISP interface in the IWAN-TRANSPORT-11 VRF. This configuration allows traffic to traverse from the global to the outside VRF in DMVPN F-VRF configurations used for IWAN.

Figure 61 *IWAN single-router dual-Internet–egress default routing*



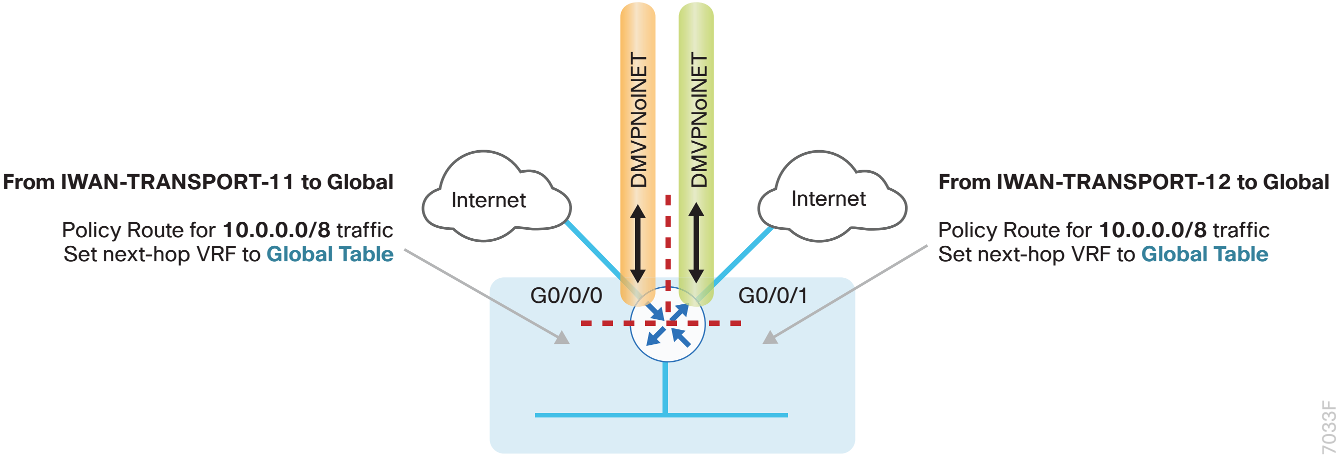
Step 1: Configure a default route in the global table that allows traffic into the outside transit VRF and set the administrative distances.

```
ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10
ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/1 dhcp 15
```

Procedure 4 Configure local policy routing for return Internet traffic

Traffic returning to the outside NAT address of the router ISP interface will be contained inside the IWAN-TRANSPORT-11 and IWAN-TRANSPORT-12 VRFs. The local policy configuration allows this traffic to be routed back to the global table.

Figure 62 *IWAN single-router dual-Internet–local policy return routing*


From IWAN-TRANSPORT-11 to Global
Policy Route for **10.0.0.0/8** traffic
Set next-hop VRF to **Global Table**
Internet
DMVPNoINET
DMVPNoINET
Internet
From IWAN-TRANSPORT-12 to Global
Policy Route for **10.0.0.0/8** traffic
Set next-hop VRF to **Global Table**
G0/0/0
G0/0/1
7033F

Step 1: Configure an ACL that matches the summary range of the internal IP networks.

```
ip access-list extended INTERNAL-NETS
 permit ip any 10.0.0.0 0.255.255.255
```

Step 2: Create a route map that references the ACL and changes the traffic to the global table.

```
route-map INET-INTERNAL permit 10
 description Return routing for Local Internet Access
 match ip address INTERNAL-NETS
 set global
```

Step 3: Apply the local policy routing configuration to the Internet-facing router interfaces.

```
interface GigabitEthernet0/0/0
 ip policy route-map INET-INTERNAL

interface GigabitEthernet0/0/1
 ip policy route-map INET-INTERNAL
```

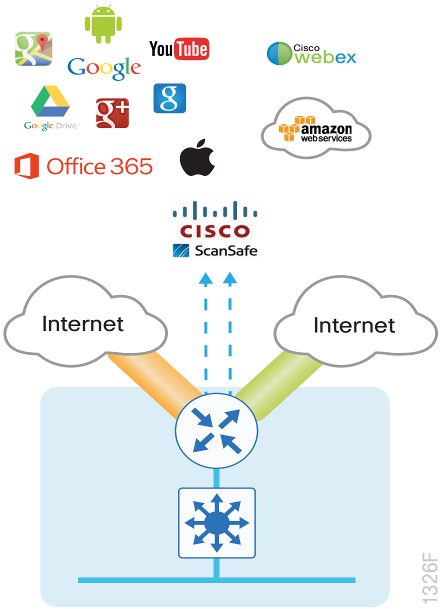
PROCESS

Configuring Single-Router Remote Site with Layer 3 Distribution

1. Configure outbound filtering of the default route to the WAN
2. Configure static default route redistribution into LAN routing protocol

Use this process when a single-router IWAN site requires connectivity to a Layer 3 distribution switch as outlined in the Intelligent WAN Deployment Guide. Here, you need to redistribute the local default route into the LAN routing protocol for advertisement to the Layer 3 switch and filter the default route from being advertised to the WAN.

Figure 63 IWAN single-router dual-Internet–Layer 3 distribution



Procedure 1 Configure outbound filtering of the default route to the WAN

Perform these steps when connecting a single-router to a Layer 3 distribution switch.

If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

Step 1: If you do not already have one, configure an access list to deny the default route and permit all other routes.

```
ip access-list standard ALL-EXCEPT-DEFAULT
 deny   0.0.0.0
 permit any
```

Step 2: Add an instance after the existing route map named “ROUTE-LIST” and reference the access list that denies the default route and permits all other routes. There should be an instance of this route map from the IWAN foundation configuration. This statement should go between the existing statements.

```
route-map ROUTE-LIST permit 20
 description Block Local Internet Default route out to the WAN
 match ip address ALL-EXCEPT-DEFAULT
```

Step 3: Ensure that the route map is applied as an outbound distribution list on the DMVPN tunnel interfaces.

```
router eigrp IWAN-EIGRP
  address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map ROUTE-LIST out Tunnel20
   distribute-list route-map ROUTE-LIST out Tunnel21
  exit-af-topology
 exit-address-family
```

Option 2: BGP on the WAN

Step 1: If you do not already have one, create an ip prefix-list to match the default.

```
ip prefix-list ALL-EXCEPT-DEFAULT seq 10 permit 0.0.0.0/0
```

Step 2: Add an instance after the existing route map named “SPOKE-OUT” and reference the access list that denies the default route and permits all other routes. There should be an instance of this route map from the IWAN foundation configuration. These statements are added after the existing statements.

```
route-map SPOKE-OUT deny 20
 description Block only the default route outbound from the WAN
 match ip address prefix-list ALL-EXCEPT-DEFAULT


route-map SPOKE-OUT permit 1000
 description Permit all other routes
```

Step 3: Ensure the policy is applied as an outbound route-map for the DMVPN tunnel interfaces.

```
router bgp 65100
 address-family ipv4
  neighbor INET1-HUB route-map SPOKE-OUT out
  neighbor INET2-HUB route-map SPOKE-OUT out
 exit-address-family
```

Procedure 2 Configure static default route redistribution into LAN routing protocol

Perform these steps when connecting a single router to a Layer 3 distribution switch.

If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the LAN

Step 1: Configure an access list to match the default route for redistribution.

```
ip access-list standard DEFAULT-ONLY
 permit 0.0.0.0
```

Step 2: Configure a route map for static redistribution, referencing the access list that matches the static default route.

```
route-map STATIC-IN permit 10
 description Redistribute local default route
 match ip address DEFAULT-ONLY
```

Step 3: Redistribute the static default route installed by DHCP into EIGRP AS400 by using the route map.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   redistribute static route-map STATIC-IN
  exit-af-topology
 exit-address-family
```

Option 2: BGP on the WAN and OSPF on the LAN

Step 1: Configure an access list to match the default route for redistribution.

```
ip access-list standard DEFAULT-ONLY
 permit 0.0.0.0
```

Step 2: Create a route-map to reference the ip access-list.

```
route-map STATIC-IN permit 10
 description Redistribute local default route
 match ip address DEFAULT-ONLY
```

Step 3: Redistribute the static default route from BGP to OSPF.

```
router bgp 65100
 address-family ipv4
  redistribute static route-map STATIC-IN
 exit-address-family
```

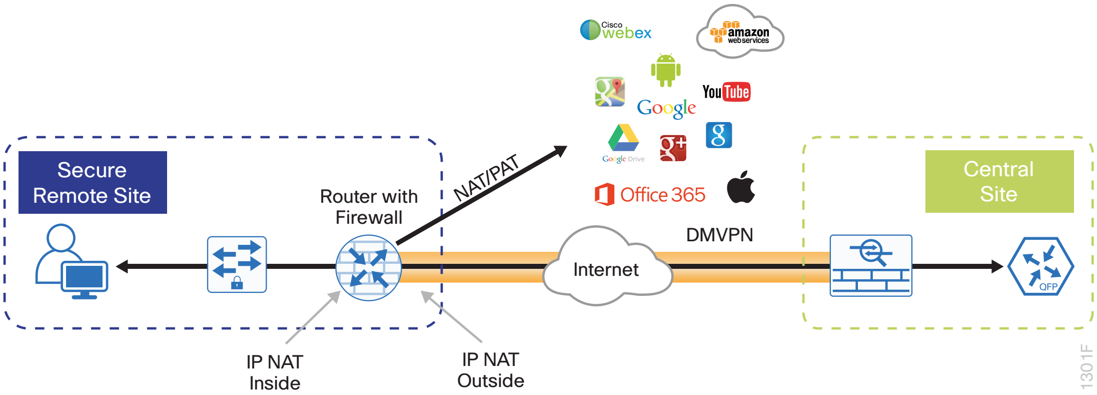
PROCESS

Configuring Network Address Translation for DIA

1. Configure NAT policy on a single router with dual-Internet links

In this design, inside hosts use RFC 1918 addresses, and traffic destined to the Internet from the local site needs to be translated to public IP space. The Internet-facing interface on the remote-site router uses DHCP to acquire a publically routable IP address; the NAT policy here will translate inside private IP addressed hosts to this DHCP address by using PAT.

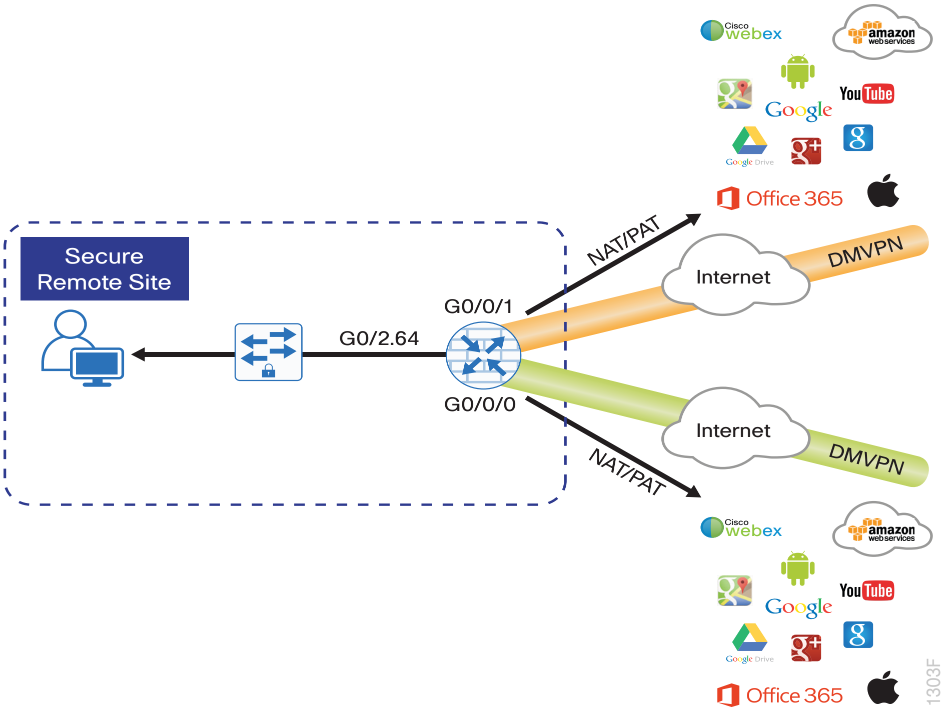
Figure 64 NAT for Internet traffic



Procedure 1 Configure NAT policy on a single router with dual-Internet links

Use this procedure if you want to configure NAT for single-router dual-Internet configurations. This procedure provides the NAT configurations required when connecting a single router to two different ISPs.

Figure 65 IWAN single-router dual-Internet–NAT



Step 1: Define a policy matching the desired traffic to be translated. Use an ACL and include all remote-site subnets.

```
ip access-list extended NAT
 permit ip 10.7.160.0 0.0.7.255 any
```

Step 2: Configure route maps matching the ACL and interfaces where NAT will be applied.

```
route-map ISP-A permit 10
 match ip address NAT
 match interface GigabitEthernet0/0/0

route-map ISP-B permit 10
 match ip address NAT
 match interface GigabitEthernet0/0/1
```

Step 3: Configure the NAT policies for PAT on both Internet interfaces.

```
ip nat inside source route-map ISP-A interface GigabitEthernet0/0/0 overload
ip nat inside source route-map ISP-B interface GigabitEthernet0/0/1 overload
```

Step 4: Enable NAT by applying the policy to the inside router interfaces. Apply this configuration, as needed, to internal interfaces or sub-interfaces where traffic matching the ACL may originate, such as the data network.

```
interface GigabitEthernet0/0/2.64
 ip nat inside
```

Step 5: Configure the Internet-facing interfaces for NAT.

```
interface GigabitEthernet0/0/0
 description Internet Connection (ISP-A)
 ip nat outside

interface GigabitEthernet0/0/1
 description Internet Connection (ISP-B)
 ip nat outside
```

Tech Tip

When you configure NAT on IOS router interfaces, you will see **ip virtual-reassembly in** added to the configuration. This is automatically enabled for features that require fragment reassembly, such as NAT, Firewall, and IPS.

Step 6: Verify proper interfaces are configured for NAT.

```
RS33-4451X#show ip nat statistics
Total active translations: 175 (0 static, 175 dynamic; 175 extended)
Outside interfaces:
  GigabitEthernet0/0/0, GigabitEthernet0/0/1
Inside interfaces:
  GigabitEthernet0/0/2.64
Hits: 587036  Misses: 5285
Expired translations: 5108
Dynamic mappings:
-- Inside Source
[Id: 1] route-map ISP-A interface GigabitEthernet0/0/0 refcount 175
[Id: 2] route-map ISP-B interface GigabitEthernet0/0/1 refcount 0
refcount 0
```

```
        nat-limit statistics:
         max entry: max allowed 0, used 0, missed 0
        In-to-out drops: 0  Out-to-in drops: 11
        Pool stats drop: 0  Mapping stats drop: 0
        Port block alloc fail: 0
        IP alias add fail: 0
        Limit entry add fail: 0
```

Step 7: Verify NAT translations for intended sources that are using local Internet services.

```
RS33-4451X#show ip nat translations
Pro  Inside global        Inside local         Outside local        Outside global
tcp  172.18.99.11:5021    10.7.164.20:49678    69.25.24.26:80       69.25.24.26:80
tcp  172.18.99.11:5108    10.7.164.20:49765    23.203.221.156:443   23.203.221.156:443
tcp  172.18.99.11:4105    10.7.164.20:49786    23.204.109.42:80     23.204.109.42:80
tcp  172.18.99.11:4975    10.7.164.20:49632    23.204.109.48:80     23.204.109.48:80
```

PROCESS

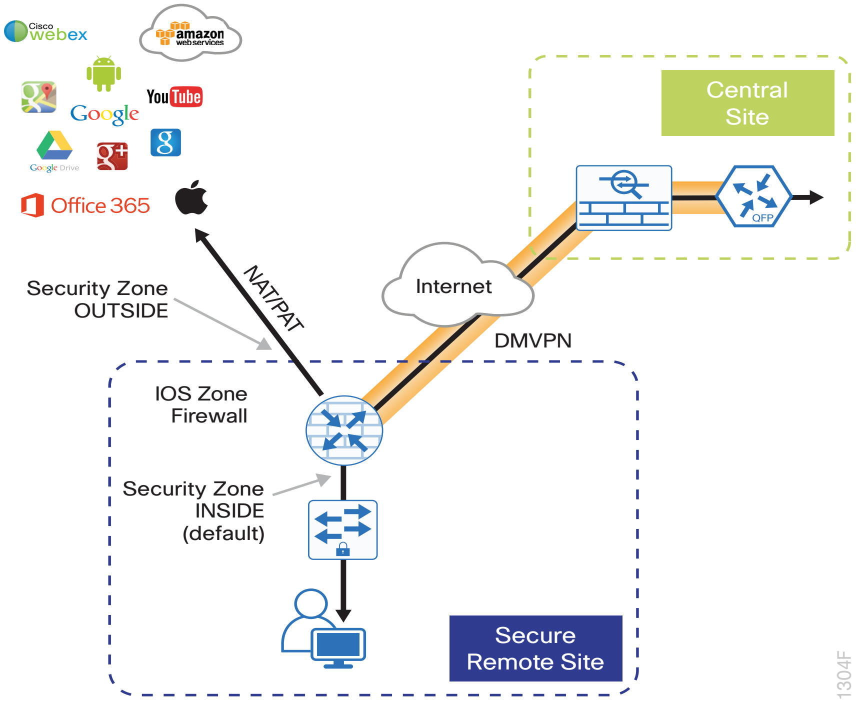
Configuring Zone-Based Firewall for DIA

1. Configure base Cisco IOS Zone-Based Firewall parameters
2. Restrict traffic to the router
3. Enable and verify zone-based firewall configuration

The following Cisco IOS firewall configuration is intended for use on Internet-facing remote site routers that provide secure local Internet access. This configuration assumes DHCP and DMVPN are also configured to use the outside interface. To configure the required base firewall policies, complete the following procedures.

Follow these procedures to secure a single-router dual-Internet remote-site router with direct Internet configurations.

Figure 66 *Zone-based firewall for DIA*



Procedure 1 Configure base Cisco IOS Zone-Based Firewall parameters

Step 1: If it is configured, remove the inbound ACL from the Internet-facing router interfaces, and then shut down the interface before continuing. This prevents unauthorized traffic while the ZBFW is configured.

```
interface GigabitEthernet0/0/0
  shutdown
  no ip access-list extended ACL-INET-PUBLIC in

interface GigabitEthernet0/0/1
  shutdown
  no ip access-list extended ACL-INET-PUBLIC in
```

Step 2: Define security zones. A *zone* is a named group of interfaces that have similar functions or security requirements. This example defines the names of the three basic security zones identified.

Step 3: This example has two outside interfaces that are both in a unique VRF. In this situation, you must define two security zones; you cannot define a single security zones to interfaces in different VRFs.

Step 4: For simplicity, this design uses the “default” security zone for inside interfaces. Once the default zone has been defined, all interfaces not explicitly configured as members of a security zone will automatically be part of the default security zone.

```
zone security default
zone security OUTSIDE-A
zone security OUTSIDE-B
```

Tech Tip

This design uses the “default” zone for all inside interfaces; traffic can flow between all interfaces in the default zone.

An interface not defined as part of a security zone is automatically part of the “default” zone. In this configuration, all undefined interface DMVPN tunnels, transit sub-interfaces, and service interfaces such as Cisco UCS-E, and SRE interfaces are included as part of the default zone.

Be aware that any interface that is removed from a defined security zone will be automatically placed into the default zone. In this configuration, that interface will be treated as an “inside” zone and have access to the internal routing domain.

Step 5: Define a class map to match specific protocols. Class-maps apply **match-any** or **match-all** operators in order to determine how to apply the match criteria to the class. If **match-any** is specified, traffic must meet at least one of the match criteria in the class-map to be included in the class. If **match-all** is specified, traffic must meet all of the match criteria to be included in the class.

```
class-map type inspect match-any INSIDE-TO-OUTSIDE-CLASS
 match protocol ftp
 match protocol tcp
 match protocol udp
 match protocol icmp
```

Tech Tip

Protocols that use single ports (such as HTTP, telnet, SSH, etc.) can be statefully allowed with tcp inspection alone by using the **match protocol tcp** command.

Protocols such as **ftp** that use multiple ports (one for control and another for data) require application inspection in order to enable dynamic adjustments to the active firewall policy. The specific TCP ports that are required for the application are allowed for short durations, as necessary.

Step 6: Define policy maps. A policy is an association of traffic classes and actions. It specifies what actions should be performed on defined traffic classes. In this case, you statefully inspect the outbound session so that return traffic is permitted.

```
policy-map type inspect INSIDE-TO-OUTSIDE-POLICY
 class type inspect INSIDE-TO-OUTSIDE-CLASS
  inspect
 class class-default
  drop
```

Tech Tip

An *action* is a specific functionality that is associated with a traffic class. **Inspect**, **drop**, and **pass** are actions.

With the **inspect** action, return traffic is automatically allowed for established connections. The **pass** action permits traffic in one direction only. When using the **pass** action, you must explicitly define rules for return traffic.

Step 7: Define the zone pair and apply the policy map. A zone pair represents two defined zones and identifies the source and destination zones where a unidirectional firewall policy-map is applied. This configuration uses only one zone pair because all traffic is inspected and thus allowed to return. In this case, you need to define two zone pairs: one for each outside zone and the default zone.

```
zone-pair security IN_OUT-A source default destination OUTSIDE-A
 service-policy type inspect INSIDE-TO-OUTSIDE-POLICY

zone-pair security IN_OUT-B source default destination OUTSIDE-B
 service-policy type inspect INSIDE-TO-OUTSIDE-POLICY
```

Procedure 2 Restrict traffic to the router

Cisco IOS defines the router by using the fixed-name self as a separate security zone. The self-zone is the exception to the default deny-all policy.

All traffic destined to or originating from the router itself (local traffic) on any interface is allowed until traffic is explicitly denied. In other words, any traffic flowing directly between defined zones and the router's IP interfaces is implicitly allowed and is not initially controlled by zone firewall policies.

This default behavior of the self-zone ensures that connectivity to the router's management interfaces and the function of routing protocols is maintained when an initial zone firewall configuration is applied to the router.

Specific rules that control traffic to the self-zone are required. When you configure a ZBFW rule that includes the self-zone, traffic between the self-zone and the other defined zones is immediately restricted in both directions.

Table 3 Self-zone firewall access list parameters

Protocol	Stateful inspection policy
ISAKMP	Yes
ICMP	Yes
DHCP	No
ESP	No
GRE	No

The following configuration allows the required traffic for proper remote-site router configuration with DMVPN. ESP and DHCP cannot be inspected and need to be configured with a **pass** action in the policy, using separate ACL and class-maps. ISAKMP should be configured with the **inspect** action and thus needs to be broken out with a separate ACL and class-maps for inbound and outbound policies.

Tech Tip

More specific ACLs than are shown here with the "any" keyword are recommended for added security.

Step 1: In the following steps, define access lists.

Step 2: Define an ACL allowing traffic with a destination of the router itself from the OUTSIDE zone. This includes ISAKMP for inbound tunnel initiation. This traffic can be inspected and is identified in the following ACL.

```
ip access-list extended ACL-RTR-IN
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit icmp any any echo
 permit icmp any any echo-reply
 permit icmp any any ttl-exceeded
 permit icmp any any port-unreachable
 permit udp any any gt 1023 ttl eq 1
```

Step 3: Identify traffic for IPSEC tunnel initiation and other traffic that will originate from the router (self-zone) to the OUTSIDE zone. This traffic can be inspected.

```
ip access-list extended ACL-RTR-OUT
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit icmp any any
 permit udp any any eq domain
```

Tech Tip

The ICMP and domain entries here are for IPSLA probes that originate from the router.

```
 permit icmp any any
 permit udp any any eq domain
```

Step 4: Configure the DHCP ACL to allow the router to acquire a public IP address dynamically from the ISP. This traffic needs to be defined separately for server and client and cannot be inspected.

```
ip access-list extended DHCP-IN
 permit udp any eq bootps any eq bootpc

ip access-list extended DHCP-OUT
 permit udp any eq bootpc any eq bootps
```

Step 5: Configure the ESP ACL to allow the router to establish IPSEC communications for DMVPN. ESP needs to be explicitly allowed inbound and outbound in separate ACLs. ESP cannot be inspected.

```
ip access-list extended ESP-IN
 permit esp any any

ip access-list extended ESP-OUT
 permit esp any any
```

Step 6: Configure the GRE ACL to allow GRE tunnel formation. GRE needs to be explicitly allowed inbound only.

```
ip access-list extended GRE-IN
 permit gre any any
```

Tech Tip

GRE needs to be permitted inbound for GRE on IOS-XE platforms due to a difference in interface order of operations. This is not required on IOS ISRG2 platforms.

Next, you define class maps for traffic to and from the self-zone. Separate class-maps are required for inbound and outbound initiated flows as well as for traffic that can be inspected by the router.

Step 7: Define the class-map matching inbound traffic that can be inspected.

```
class-map type inspect match-any INSPECT-ACL-IN-CLASS
 match access-group name ACL-RTR-IN
```

Step 8: Define the class-map matching outbound traffic that can be inspected.

```
class-map type inspect match-any INSPECT-ACL-OUT-CLASS
 match access-group name ACL-RTR-OUT
```

Step 9: Define the class-map matching inbound traffic that is not able to be inspected.

```
class-map type inspect match-any PASS-ACL-IN-CLASS
 match access-group name ESP-IN
 match access-group name DHCP-IN
 match access-group name GRE-IN
```

Step 10: Define the class-map matching outbound traffic that cannot be inspected.

```
class-map type inspect match-any PASS-ACL-OUT-CLASS
 match access-group name ESP-OUT
 match access-group name DHCP-OUT
```

Next, you define policy maps. Create two separate policies, one for traffic inbound and one for traffic outbound.

Step 11: Define the inbound policy-map that refers to both of the outbound class-maps with actions of **inspect**, **pass**, and **drop** for the appropriate class defined.

```
policy-map type inspect ACL-IN-POLICY
 class type inspect INSPECT-ACL-IN-CLASS
  inspect
 class type inspect PASS-ACL-IN-CLASS
  pass
 class class-default
  drop
```

Step 12: Define the outbound policy-map that refers to both of the outbound class-maps with actions of **inspect**, **pass**, and **drop** for the appropriate class defined.

```
policy-map type inspect ACL-OUT-POLICY
 class type inspect INSPECT-ACL-OUT-CLASS
  inspect
 class type inspect PASS-ACL-OUT-CLASS
  pass
 class class-default
  drop
```

Tech Tip

Inspection for Layer 7 applications is not allowed for traffic going to and from the self-zone to other zones. Cisco IOS firewalls support only inspection of TCP, UDP, and H.323 traffic that terminates on or originates from the router itself.

Traffic such as DHCP and ESP cannot be inspected and must be configured as **Pass** in the associated policy-map.

Next, you define the zone pair and apply policy maps to them.

Step 13: Define the zone pair for traffic destined to the self-zone of the router from the outside and associate the inbound policy-map defined in the previous step.

```
zone-pair security TO-ROUTER-A source OUTSIDE-A destination self
 service-policy type inspect ACL-IN-POLICY

zone-pair security TO-ROUTER-B source OUTSIDE-B destination self
 service-policy type inspect ACL-IN-POLICY
```

Step 14: Define the zone pair for traffic destined from the self-zone of the router to the outside and associate the outbound policy-map defined in the previous step.

```
zone-pair security FROM-ROUTER-A source self destination OUTSIDE-A
 service-policy type inspect ACL-OUT-POLICY

zone-pair security FROM-ROUTER-B source self destination OUTSIDE-B
 service-policy type inspect ACL-OUT-POLICY
```

Procedure 3 Enable and verify zone-based firewall configuration

Step 1: Assign the Internet-facing router interfaces to the outside security zone. All other interfaces are assigned to the default zone and do not need to be defined.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 zone-member security OUTSIDE-A

interface GigabitEthernet0/0/1
 description Internet Connection
 zone-member security OUTSIDE-B
```

Tech Tip

Interfaces in different VRFs cannot be assigned to the same security zone. In this case, each ISP interface must be in a different security zone.

An interface not defined as part of a security zone is automatically part of the “default” zone. In this configuration, all undefined interface DMVPN tunnels, transit sub-interfaces, and service interfaces such as Cisco UCS-E, and SRE interfaces are included as part of the default zone.

Loopback interfaces are members of the “self” zone and are not assigned to a defined security zone or the default zone.

Step 2: Verify the interface assignment for the zone firewall and ensure that all required interfaces for the remote site configuration are assigned to the proper zone.

```
RS33-4451X#show zone security
zone self
  Description: System defined zone

zone OUTSIDE-A
  Member Interfaces:
    GigabitEthernet0/0/0

zone OUTSIDE-B
  Member Interfaces:
    GigabitEthernet0/0/1

zone default
  Description: System level zone. Interface without zone membership is in this
zone automatically
```

Step 3: Verify firewall operation by reviewing the byte counts for each of the configured policies and classes.

```
RS33-4451X#show policy-map type inspect zone-pair sessions
  Zone-pair: FROM-ROUTER-A
  Service-policy inspect : ACL-OUT-POLICY
    Class-map: INSPECT-ACL-OUT-CLASS (match-any)
      Match: access-group name ACL-RTR-OUT
        1653936 packets, 103139556 bytes
      Inspect
        Established Sessions
         Session ID 0x001955D3 (172.18.99.11:8)=>(172.18.1.253:23626) icmp SIS_
OPEN
          Created 00:00:04, Last heard 00:00:04
          Bytes sent (initiator:responder) [36:36]
         Session ID 0x001955D2 (172.18.99.11:8)=>(172.18.1.254:23625) icmp SIS_
OPEN
          Created 00:00:04, Last heard 00:00:04
          Bytes sent (initiator:responder) [36:36]
    Class-map: PASS-ACL-OUT-CLASS (match-any)
      Match: access-group name ESP-OUT
        0 packets, 0 bytes
      Match: access-group name DHCP-OUT
        82 packets, 27470 bytes
      Pass
        82 packets, 27470 bytes
    Class-map: class-default (match-any)
      Match: any
      Drop
        0 packets, 0 bytes
  Zone-pair: FROM-ROUTER-B
  Service-policy inspect : ACL-OUT-POLICY
    Class-map: INSPECT-ACL-OUT-CLASS (match-any)
      Match: access-group name ACL-RTR-OUT
        676 packets, 169296 bytes
      Inspect
    Class-map: PASS-ACL-OUT-CLASS (match-any)
      Match: access-group name ESP-OUT
        0 packets, 0 bytes
      Match: access-group name DHCP-OUT
        82 packets, 27470 bytes
      Pass
        82 packets, 27470 bytes
    Class-map: class-default (match-any)
      Match: any
      Drop
        0 packets, 0 bytes
  Zone-pair: IN_OUT-A
  Service-policy inspect : INSIDE-TO-OUTSIDE-POLICY
    Class-map: INSIDE-TO-OUTSIDE-CLASS (match-any)
      Match: protocol ftp
        0 packets, 0 bytes
      Match: protocol icmp
        0 packets, 0 bytes
      Match: protocol udp
```

```
        4 packets, 357 bytes
      Match: protocol tcp
        2541 packets, 156894 bytes
      Inspect
        Established Sessions
         Session ID 0x00195303 (10.7.164.20:50159)=>(199.59.148.12:80) tcp SIS_OPEN
          Created 00:12:12, Last heard 00:12:11
          Bytes sent (initiator:responder) [333:748]
         Session ID 0x001955C3 (10.7.164.20:50250)=>(54.235.157.205:80) tcp SIS_OPEN
          Created 00:00:23, Last heard 00:00:23
          Bytes sent (initiator:responder) [0:0]
         Session ID 0x001955C2 (10.7.164.20:50249)=>(54.235.157.205:80) tcp SIS_OPEN
          Created 00:00:23, Last heard 00:00:22
          Bytes sent (initiator:responder) [518:213]
         Session ID 0x001951E5 (10.7.164.20:50062)=>(23.204.109.9:80) tcp SIS_OPEN
          Created 00:15:45, Last heard 00:00:00
          Bytes sent (initiator:responder) [719288:33937120]
    Class-map: class-default (match-any)
      Match: any
      Drop
        0 packets, 0 bytes
  Zone-pair: IN_OUT-B
  Service-policy inspect : INSIDE-TO-OUTSIDE-POLICY
    Class-map: INSIDE-TO-OUTSIDE-CLASS (match-any)
      Match: protocol ftp
        0 packets, 0 bytes
      Match: protocol icmp
        0 packets, 0 bytes
      Match: protocol udp
        0 packets, 0 bytes
      Match: protocol tcp
        0 packets, 0 bytes
      Inspect
    Class-map: class-default (match-any)
      Match: any
      Drop
        0 packets, 0 bytes
  Zone-pair: TO-ROUTER-A
  Service-policy inspect : ACL-IN-POLICY
    Class-map: INSPECT-ACL-IN-CLASS (match-any)
      Match: access-group name ACL-RTR-IN
        520 packets, 140828 bytes
      Inspect
    Class-map: PASS-ACL-IN-CLASS (match-any)
      Match: access-group name ESP-IN
        0 packets, 0 bytes
      Match: access-group name DHCP-IN
        82 packets, 28044 bytes
      Match: access-group name GRE-IN
        0 packets, 0 bytes
      Pass
        17880 packets, 3495146 bytes
    Class-map: class-default (match-any)
      Match: any
      Drop
        0 packets, 0 bytes
  Zone-pair: TO-ROUTER-B
  Service-policy inspect : ACL-IN-POLICY
    Class-map: INSPECT-ACL-IN-CLASS (match-any)
      Match: access-group name ACL-RTR-IN
        522 packets, 142292 bytes
      Inspect
    Class-map: PASS-ACL-IN-CLASS (match-any)
      Match: access-group name ESP-IN
        0 packets, 0 bytes
      Match: access-group name DHCP-IN
        82 packets, 28044 bytes
      Match: access-group name GRE-IN
        0 packets, 0 bytes
```

```
        Pass
          17888 packets, 3496154 bytes
      Class-map: class-default (match-any)
        Match: any
        Drop
          0 packets, 0 bytes
```

Step 4: Add the following command to the router configuration in order to identify traffic dropped by the Cisco IOS-XE zone firewall.

```
parameter-map type inspect global
 log dropped-packets
```

Tech Tip

In IOS, when you configure the command **ip inspect drop-pkt**, the following is automatically added to the router configuration:

```
parameter-map type inspect global
 log dropped-packets enable
```

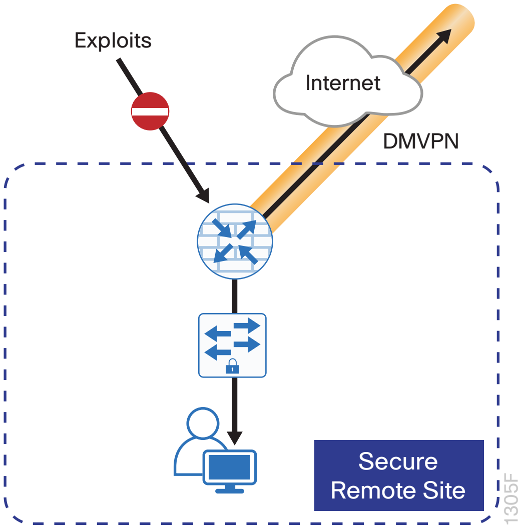
PROCESS

Configuring Additional Router Security

1. Disable IP ICMP redirects
2. Disable ICMP unreachable messages
3. Disable proxy ARP
4. Disable unused router services
5. Disable CDP and LLDP
6. Enable keepalives for TCP sessions
7. Configure internal-network floating static routes
8. Enable Internet interfaces

In addition to the security measures already taken in prior configuration tasks, this section introduces best practices recommendations for securing Internet-facing routers. Disabling unused services and features for networking devices improves the overall security posture by minimizing the amount of information exposed. This practice also minimizes the amount of router CPU and memory load that is required to process unneeded packets.

Figure 67 Additional router security



Tech Tip

These are general security guidelines only. You may take additional measures to secure remote-site routers on a case-by-case basis. Take care to ensure that the disabling of certain features does not impact other functions of the network.

Procedure 1 Disable IP ICMP redirects

Routers use ICMP redirect messages to notify that a better route is available for a given destination. In this situation, the router forwards the packet and sends an ICMP redirect message back to the sender advising of an alternative and preferred route to the destination. In many implementations, there is no benefit in permitting this behavior. An attacker can generate traffic, forcing the router to respond with ICMP redirect messages, negatively impacting the CPU and performance of the router. You can prevent this by disabling ICMP redirect messages.

Step 1: Disable ICMP redirect messages on Internet-facing router interfaces.

```
interface GigabitEthernet0/0/0
 description Internet Connection ISP-A
 no ip redirects

interface GigabitEthernet0/0/1
 description Internet Connection ISP-B
 no ip redirects
```

Procedure 2 Disable ICMP unreachable messages

When filtering on router interfaces, routers send ICMP unreachable messages back to the source of blocked traffic. Generating these messages can increase CPU utilization on the router. By default, Cisco IOS ICMP unreachable messages are limited to one every 500 milliseconds. ICMP unreachable messages can be disabled on a per interface basis.

Step 1: Disable ICMP unreachable messages on Internet-facing router interfaces.

```
interface GigabitEthernet0/0/0
 description Internet Connection ISP-A
 no ip unreachables

interface GigabitEthernet0/0/1
 description Internet Connection ISP-B
 no ip unreachables
```

Procedure 3 Disable proxy ARP

Proxy ARP allows the router to respond to ARP request for hosts other than itself. Proxy ARP can help machines on a subnet reach remote subnets without configuring routing or a default gateway as defined in RFC 1027. Disadvantages to using proxy ARP:

- An attacker can impact available memory by sending a large number of ARP requests.
- A router is also susceptible to man-in-the-middle attacks where a host on the network could be used to spoof the MAC address of the router, resulting in unsuspecting hosts sending traffic to the attacker.

You can disable proxy ARP by using the **interface** configuration command.

Step 1: Disable proxy ARP on Internet-facing router interfaces.

```
interface GigabitEthernet0/0/0
 description Internet Connection ISP-A
 no ip proxy-arp

interface GigabitEthernet0/0/1
 description Internet Connection ISP-B
 no ip proxy-arp
```

Procedure 4 Disable unused router services

As a security best practice, you should disable all unnecessary services that could be used to launch DoS and other attacks. Many unused services that pose a security threat are disabled by default in current Cisco IOS versions.

Step 1: Disable MOP on Internet-facing router interfaces.

```
interface GigabitEthernet0/0/0
 description Internet Connection ISP-A
 no mop enabled

interface GigabitEthernet0/0/1
 description Internet Connection ISP-B
 no mop enabled
```

Step 2: Disable PAD service globally on the router.

```
no service pad
```

Step 3: Prevent the router from attempting to locate a configuration file via TFTP globally on the router.

```
no service config
```

Procedure 5 Disable CDP and LLDP

Attackers can use CDP and LLDP for reconnaissance and network mapping. CDP is a network protocol that is used to discover other CDP-enabled devices. CDP is often used by NMS and for troubleshooting networking problems. LLDP is an IEEE protocol that is defined in 802.1AB and is very similar to CDP. You should disable CDP and LLDP on router interfaces that connect to untrusted networks.

Step 1: Disable CDP on Internet-facing router interfaces.

```
interface GigabitEthernet0/0/0
 description Internet Connection ISP-A
 no cdp enable

interface GigabitEthernet0/0/1
 description Internet Connection ISP-B
 no cdp enable
```

Step 2: Disable LLDP on Internet-facing router interfaces.

```
interface GigabitEthernet0/0/0
 description Internet Connection ISP-A
 no lldp transmit
 no lldp receive

interface GigabitEthernet0/0/1
 description Internet Connection ISP-B
 no lldp transmit
 no lldp receive
```

Procedure 6 Enable keepalives for TCP sessions

This configuration enables TCP keepalives on inbound connections to the router and outbound connections from the router. This ensures that the device on the remote end of the connection is still accessible and half-open or orphaned connections are removed from the router.

Step 1: Enable the TCP keepalives service for inbound and outbound connections globally on the router.

```
service tcp-keepalives-in
service tcp-keepalives-out
```

Procedure 7 Configure internal-network floating static routes

In the event the DMVPN tunnel to the hub site fails, you will want to ensure traffic destined to internal networks does not follow the local Internet default route. It's best to have the network fail closed to prevent possible security implications and unwanted routing behavior.

Configuring floating static routes to null zero with an AD of 254 ensures that all internal subnets route to null0 in the event of tunnel failure.

Step 1: Configure static route for internal network subnets.

```
ip route 10.0.0.0 255.0.0.0 null0 254
```

Tech Tip

Configure the appropriate number of null 0 routes for internal network ranges, using summaries when possible for your specific network environment.

Procedure 8 Enable Internet interfaces

Now that the security configurations are complete, you can enable the Internet-facing interfaces.

Step 1: Enable the Internet-facing router interfaces.

```
interface GigabitEthernet0/0/0
 description Internet Connection ISP-A
 no shutdown

interface GigabitEthernet0/0/1
 description Internet Connection ISP-B
 no shutdown
```

PROCESS

Configuring ISP Black-Hole Routing Detection

1. Configure ISP black-hole routing detection

In many cases you will need to ensure connectivity issues with your ISP does not cause black-hole routing conditions. Failure conditions can exist where the DHCP address and routes are not removed from the remote-site router when connectivity issues exist with the broadband service or local premise equipment. There may also be circumstances if certain services are unreachable within via the local ISP connection that you want to reroute to a secondary Internet service.

If central Internet fallback is required, configure one or more of the following options.

Procedure 1 Configure ISP black-hole routing detection

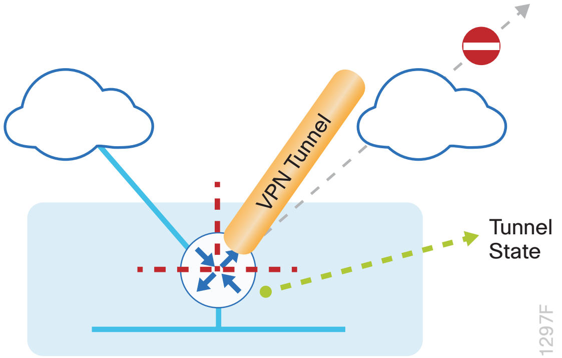
Option 1: DMVPN Tunnel State Tracking

In this solution, the DMVPN tunnel state is used to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, a “down” state of the tunnel interface triggers the removal of the default route via an EEM script. If tunnel state is “up” the route will remain.

Tech Tip

With this method, a failure or maintenance at the central site can cause a failover event where the route is removed due to tunnel state change and the local Internet connection remains active at the remote site.

Figure 68 IWAN tunnel tracking with EEM



Step 1: Ensure that state tracking is configured for the DMVPN tunnel interface.

```
interface Tunnel20
 if-state nhrp
```

Step 2: Configure the tracking parameters and logic for the IPSLA probes.

```
track 80 interface Tunnel20 line-protocol
```

Step 3: Configure an EEM script to remove the local default route when the tunnel line protocol transitions to a "down" state.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 80 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 DISABLED"
```

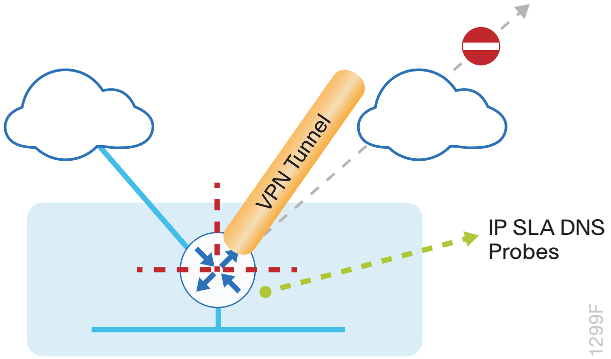
Step 4: Configure an EEM script to restore the local default route when the tunnel line protocol transitions to an "up" state.

```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 80 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 ENABLED"
```

Option 2: DNS-based IPSLA Probes

In this solution, you use DNS-based IPSLA probes to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, the failure of DNS probes to two or more root DNS servers triggers the removal of the default route via an EEM script. If any DNS probe is active, the route will remain.

Figure 69 IPSLA with DNS probes



Tech Tip

For DNS-based IPSLA probes to function, you need to ensure that DNS or “domain” is permitted in the ZBFW outbound ACL, from the self-zone to the OUTSIDE zone. Example:

```
ip access-list extended ACL-RTR-OUT
 permit udp any any eq domain
```

Step 1: Configure the VRF-aware IPSLA DNS probes.

```
ip sla 118
 dns d.root-servers.net name-server 199.7.91.13
 vrf IWAN-TRANSPORT-3
 threshold 1000
 timeout 3000
 frequency 15
ip sla schedule 118 life forever start-time now

ip sla 119
 dns b.root-servers.net name-server 192.228.79.201
 vrf IWAN-TRANSPORT-3
 threshold 1000
 timeout 3000
 frequency 15
ip sla schedule 119 life forever start-time now
```

Tech Tip

When configuring DNS probes, you should specify the hostname of the DNS server itself. That asks the DNS server to resolve for itself, allowing the use of root DNS servers.

Step 2: Configure the tracking parameters and logic for the IPSLA probes.

```
track 73 ip sla 118 reachability
track 74 ip sla 119 reachability

track 100 list boolean or
 object 73
 object 74
```

Step 3: Configure an EEM script to remove the route in the event of DNS probe failure.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 100 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 
10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 DISABLED"
```

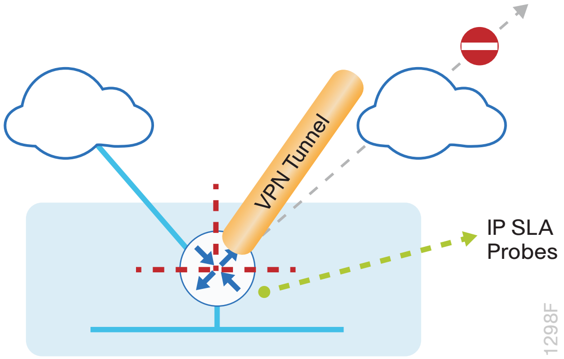
Step 4: Configure an EEM script to also restore the local default route when the DNS probes are active.

```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 100 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 ENABLED"
```

Option 3: IPSLA ICMP Probes

In this solution, you use IPSLA ICMP probes to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, the failure of ICMP probes to two different IP hosts triggers the removal of the default route via an EEM script. If either ICMP probe is active, the route will remain.

Figure 70 *IPSLA with ICMP probes*



Tech Tip

For ICMP-based IPSLA probes to function, you need to ensure ICMP is permitted in the outbound ACL, from the self-zone to the OUTSIDE zone.

Step 1: Configure the VRF-aware IPSLA ICMP probes.

```
ip sla 110
 icmp-echo 172.18.1.253 source-interface GigabitEthernet0/0/0
 vrf IWAN-TRANSPORT-3
 threshold 1000
 frequency 15
ip sla schedule 110 life forever start-time now

ip sla 111
 icmp-echo 172.18.1.254 source-interface GigabitEthernet0/0/0
 vrf IWAN-TRANSPORT-3
 threshold 1000
 frequency 15
ip sla schedule 111 life forever start-time now
```

Step 1: Configure the tracking parameters and logic for the IPSLA ICMP probes.

```
track 60 ip sla 110 reachability
track 61 ip sla 111 reachability
track 62 list boolean or
 object 60
 object 61
```

Step 2: Configure the EEM script to remove the route when the ICMP probes are down.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 62 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 DISABLED"
```

Step 3: Configure an EEM script to also restore the local default route when the ICMP probes are active.

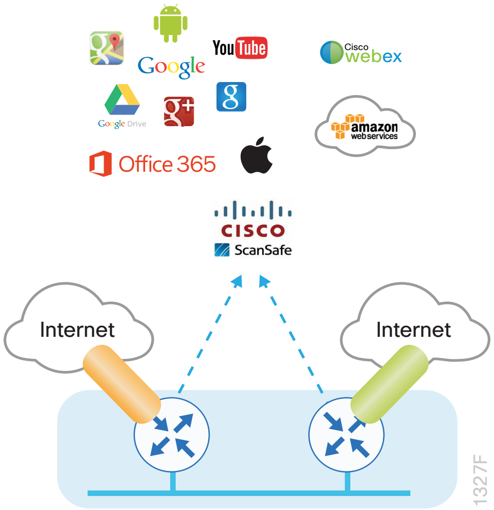
```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 62 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 ENABLED"
```

IWAN DUAL-ROUTER DUAL-INTERNET REMOTE SITE WITH DIA

This process describes configuring DIA for the dual-router dual-Internet IWAN design. These configurations assume the dual-router dual-Internet site with centralized Internet access is configured and functional as outlined in the Intelligent WAN Deployment Guide.

In this section, you convert a remote site from centralized Internet access for employees to a secure DIA configuration.

Figure 71 IWAN dual-router dual-Internet with DIA



PROCESS

Configuring DIA Routing

1. Configure Internet interface
2. Filter learned central default route
3. Configure local default routing for outbound local Internet traffic
4. Configure local policy-routing for return Internet traffic
5. Filter default route outbound to WAN
6. Redistribute DHCP default route into LAN routing protocol

In the following procedures, you enable DIA routing, NAT, and zone-based Firewall configurations for the dual-router dual-Internet IWAN design. In this configuration, you route local Internet traffic by using split-tunneling outside the DMVPN tunnel on the secondary router. All configurations are specific to this design model.

Procedure 1 Configure Internet interface

For security, disable the ISP interface before configuring DIA. You will not restore this interface until you complete all of the configurations in this section.

Tech Tip

If you are remotely connected to the remote-site router via SSH, you will be disconnected from the router console. Shutting down the Internet interface will drop the existing DMVPN tunnel.

Step 1: On both routers, verify that the Internet-facing interface is disabled.

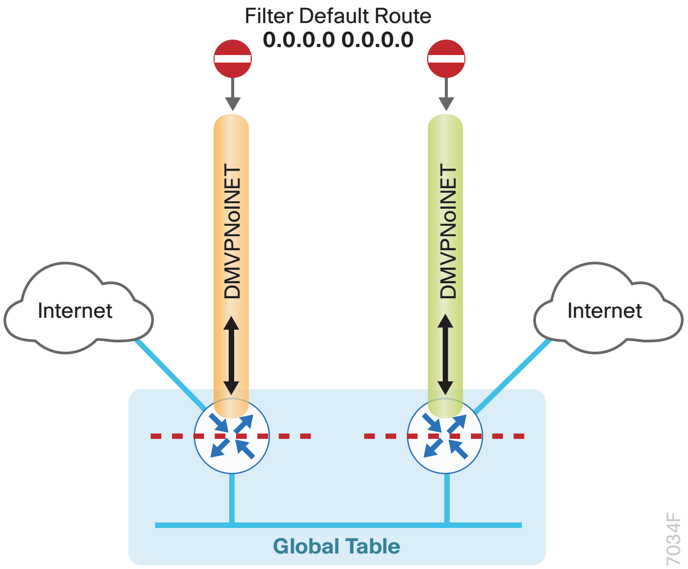
```
interface GigabitEthernet0/0/0
 shutdown
```

Procedure 2 Filter learned central default route

With DIA routing, the default route is locally configured for the global routing table. It is important to filter the default route originating over the Internet-facing DMVPN tunnel from the central site. In the dual-router dual-Internet design with DIA, all Internet traffic is routed directly to the local ISP interface; it is not feasible to failover to central Internet by using an Internet-based DMVPN tunnel.

The configurations are on both routers.

Figure 72 Filter inbound default route from the central site



If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

Step 1: On both routers, create an access list to match the default route and permit all other routes.

```
ip access-list standard ALL-EXCEPT-DEFAULT
 deny   0.0.0.0
 permit any
```

Step 2: On both routers, create a route-map to reference the access list.

```
route-map BLOCK-DEFAULT permit 10
 description Block only the default route inbound from the WAN
  match ip address ALL-EXCEPT-DEFAULT
```

Step 3: On the primary router, apply the policy as an inbound distribute list for the Internet-facing DMVPN tunnel interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK-DEFAULT in tunnel20
  exit-af-interface
 exit-address-family
```

Step 4: On the secondary router, apply the policy as an inbound distribute list for the Internet-facing DMVPN tunnel interface.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map BLOCK-DEFAULT in tunnel21
  exit-af-interface
 exit-address-family
```

Option 2: BGP on the WAN

Step 1: On both routers, create an ip prefix-list to match the default route.

```
ip prefix-list ALL-EXCEPT-DEFAULT seq 10 permit 0.0.0.0/0
```

Step 2: On both routers, create a route-map to reference the ip prefix list.

```
route-map BLOCK-DEFAULT deny 10
 description Block only the default route inbound from the WAN
 match ip address prefix-list ALL-EXCEPT-DEFAULT

route-map BLOCK-DEFAULT permit 100
 description Permit all other routes
```

Step 3: On the primary router, apply the policy as an inbound route-map for the Internet-facing DMVPN tunnel interface.

```
router bgp 65100
 address-family ipv4
  neighbor INET1-HUB route-map BLOCK-DEFAULT in
 exit-address-family
```

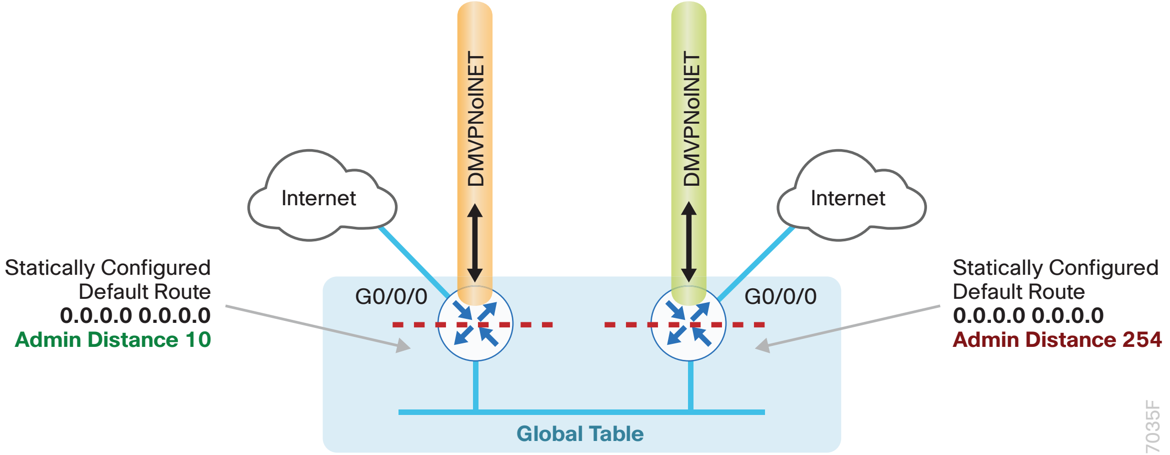
Step 4: On the secondary router, apply the policy as an inbound route-map for the Internet-facing DMVPN tunnel interface.

```
router bgp 65100
 address-family ipv4
  neighbor INET2-HUB route-map BLOCK-DEFAULT in
 exit-address-family
```

Procedure 3 Configure local default routing for outbound local Internet traffic

Internal employee traffic is in the global table and needs to route to the Internet via the ISP interface in the IWAN-TRANSPORT-11 and IWAN-TRANSPORT-12 VRFs. This configuration allows traffic to traverse from the global to the outside VRF in DMVPN F-VRF configurations used for IWAN.

Figure 73 IWAN dual-router dual-Internet–egress default routing



Step 1: On the primary router, configure a default route in the global table that allows traffic into the outside transit VRF and set the administrative distance to 10.

```
ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10
```

Step 2: On the secondary router, configure a default route in the global table that allows traffic into the outside transit VRF and set the administrative distance to 254 so this router prefers the external EIGRP route from the primary router.

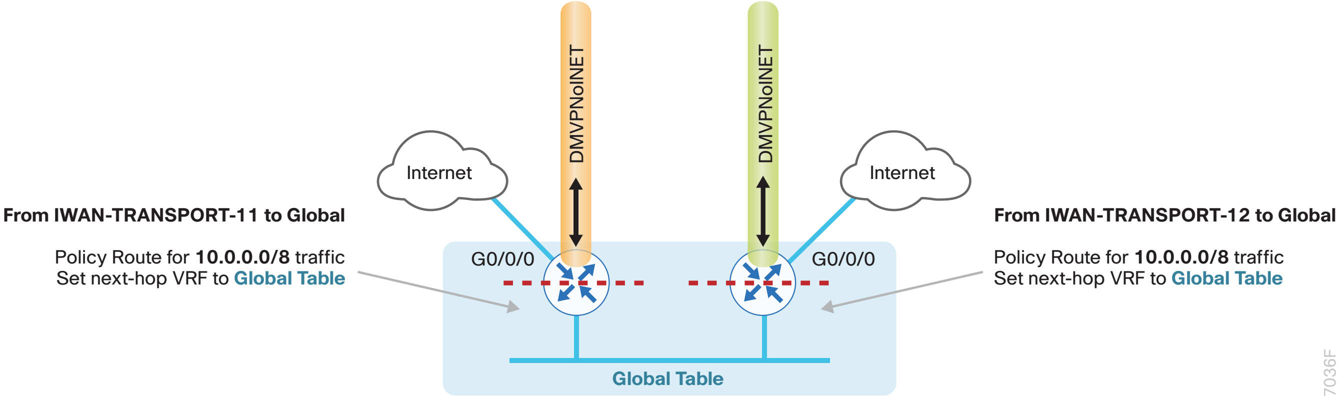
```
ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 254
```

Procedure 4 Configure local policy-routing for return Internet traffic

Traffic returning to the outside NAT address of the router ISP interface will be contained inside the IWAN-TRANSPORT-11 and IWAN-TRANSPORT-12 VRFs. The local policy configuration allows this traffic to be routed back to the global table.

The configurations are on both routers.

Figure 74 IWAN dual-router dual-Internet–local policy return routing


DMVPNoINET
DMVPNoINET
Internet
Internet
From IWAN-TRANSPORT-11 to Global
Policy Route for 10.0.0.0/8 traffic
Set next-hop VRF to Global Table
G0/0/0
G0/0/0
From IWAN-TRANSPORT-12 to Global
Policy Route for 10.0.0.0/8 traffic
Set next-hop VRF to Global Table
Global Table
7036F

Step 1: On both routers, configure an ACL that matches the summary range of the internal IP networks.

```
ip access-list extended INTERNAL-NETS
 permit ip any 10.0.0.0 0.255.255.255
```

Step 2: On both routers, create a route map that references the ACL and changes the traffic to the global table.

```
route-map INET-INTERNAL permit 10
 description Return routing for Local Internet Access
 match ip address INTERNAL-NETS
 set global
```

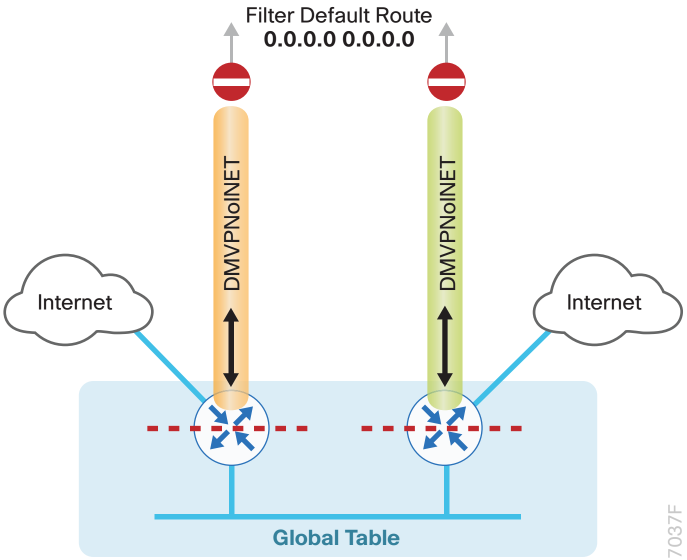
Step 3: On both routers, apply the local policy routing configuration to the Internet-facing router interfaces.

```
interface GigabitEthernet0/0/0
 ip policy route-map INET-INTERNAL
```

Procedure 5 Filter default route outbound to WAN

When you redistribute the default route into the routing protocol in the next procedure, it will be sent out the WAN interfaces to the central site location. This is not the desired behavior, so you must first configure an outbound filter.

Figure 75 IWAN dual-router dual-Internet–egress default route filtering



If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the WAN

Step 1: On both routers, configure an access list to deny the default route and permit all other routes.

```
ip access-list standard ALL-EXCEPT-DEFAULT
 deny   0.0.0.0
 permit any
```

Step 2: On both routers, add an instance after the existing route map named “ROUTE-LIST” and reference the access list that denies the default route and permits all other routes. There should be an instance of this route map from the IWAN foundation configuration. This statement should go between the existing statements.

```
route-map ROUTE-LIST permit 20
 description Block Local Internet Default route out to the WAN
 match ip address ALL-EXCEPT-DEFAULT
```

Step 3: On the primary router, ensure that the route map is applied as an outbound distribution list on the DMVPN tunnel interface. Apply this as part of the foundational configuration for dual-router egress filtering.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map ROUTE-LIST out Tunnel20
  exit-af-topology
 exit-address-family
```

Step 4: On the secondary router, ensure that the route map is applied as an outbound distribution list on the DMVPN tunnel interface. Apply this as part of the foundational configuration for dual-router egress filtering.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   distribute-list route-map ROUTE-LIST out Tunnel21
  exit-af-topology
 exit-address-family
```

Option 2: BGP on the WAN

Step 1: On both routers, create an ip prefix-list to match the default.

```
ip prefix-list ALL-EXCEPT-DEFAULT seq 10 permit 0.0.0.0/0
```

Step 2: On both routers, add an instance after the existing route map named “SPOKE-OUT” and reference the access list that denies the default route and permits all other routes. There should be an instance of this route map from the IWAN foundation configuration. These statements are added after the existing statements.

```
route-map SPOKE-OUT deny 20
 description Block only the default route outbound from the WAN
 match ip address prefix-list ALL-EXCEPT-DEFAULT

route-map SPOKE-OUT permit 1000
 description Permit all other routes
```

Step 3: On the primary router, ensure the policy is applied as an outbound route-map for the DMVPN tunnel interface. Apply this as part of the foundational configuration for dual-router egress filtering.

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

Step 4: On the secondary router, ensure the policy is applied as an outbound route-map for the DMVPN tunnel interface. Apply this as part of the foundational configuration for dual-router egress filtering.

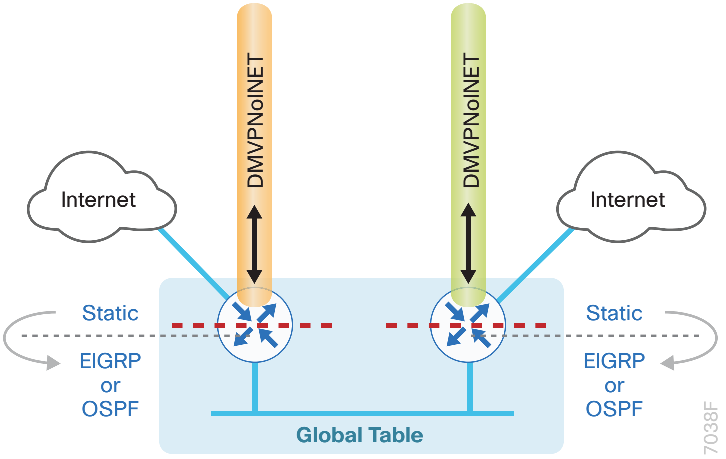
```
router bgp 65100
 address-family ipv4
  neighbor INET2-HUB route-map SPOKE-OUT out
 exit-address-family
```

Procedure 6 Redistribute DHCP default route into LAN routing protocol

For dual-router configurations, you need to redistribute the statically configured default route into the LAN routing protocol for reachability on both WAN routers.

The configurations are on both routers.

Figure 76 *IWAN dual-router dual-Internet—route redistribution*



If you are using EIGRP as your routing protocol, choose option 1. If you are using BGP on the WAN and OSPF on the LAN, choose option 2.

Option 1: EIGRP on the LAN

Step 1: On both routers, configure an access list to match the default route.

```
ip access-list standard DEFAULT-ONLY
 permit 0.0.0.0
```

Step 2: On both routers, configure a route-map instance for static redistribution referencing the access list that matches the static default route.

```
route-map STATIC-IN permit 10
 description Redistribute local default route
 match ip address DEFAULT-ONLY
```

Step 3: On both routers, redistribute the static default route installed by DHCP into EIGRP AS400 by using the route map.

```
router eigrp IWAN-EIGRP
 address-family ipv4 unicast autonomous-system 400
  topology base
   redistribute static route-map STATIC-IN
  exit-af-topology
 exit-address-family
```

Option 2: BGP on the WAN and OSPF on the LAN

Step 1: On both routers, configure an access list to match the default route for redistribution.

```
ip access-list standard DEFAULT-ONLY
 permit 0.0.0.0
```

Step 2: On both routers, create a route-map to reference the ip access-list.

```
route-map STATIC-IN permit 10
 description Redistribute local default route
 match ip address DEFAULT-ONLY
```

Step 3: On both routers, redistribute the static default route from BGP to OSPF.

```
router bgp 65100
 address-family ipv4
  redistribute static route-map STATIC-IN
 exit-address-family
```

PROCESS

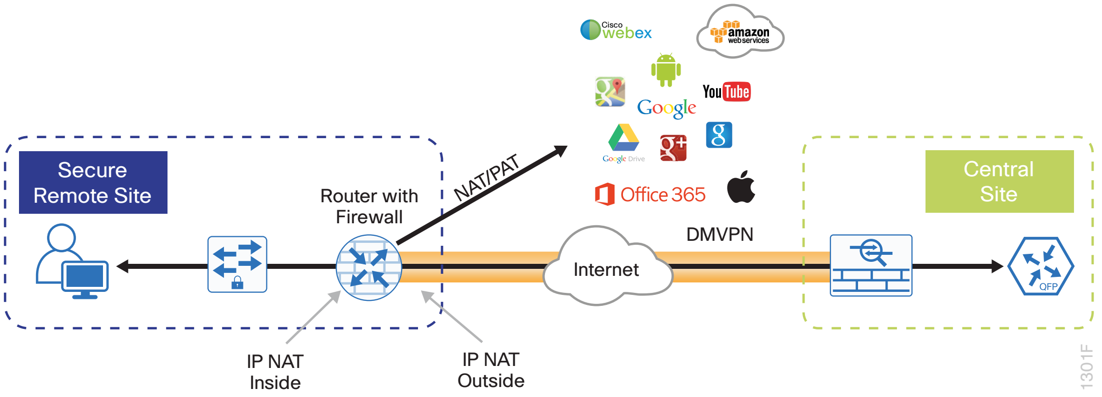
Configuring Network Address Translation for DIA

1. Define and configure Cisco IOS NAT policy

In this design, inside hosts use RFC 1918 addresses, and traffic destined to the Internet from the local site needs to be translated to public IP space. The Internet-facing interface on the remote-site router uses DHCP to acquire a publically routable IP address; the NAT policy here will translate inside private IP addressed hosts to this DHCP address by using PAT.

This configuration is done on both the primary and secondary routers.

Figure 77 *NAT for Internet Traffic*



Procedure 1 Define and configure Cisco IOS NAT policy

Use this procedure to configure NAT for DIA for dual-router dual-Internet remote-site configurations.

Step 1: Define a policy matching the desired traffic to be translated. Use an ACL and include all remote-site subnets used by employees.

```
ip access-list extended NAT-LOCAL
 permit ip 10.7.176.0 0.0.7.255 any
```

Step 2: Configure route map to reference the ACL and match the outgoing Internet Interface.

```
route-map NAT permit 10
 description Local Internet NAT
 match ip address NAT-LOCAL
 match interface GigabitEthernet0/0/0
```

Step 3: Configure the NAT policy.

```
ip nat inside source route-map NAT interface GigabitEthernet0/0/0 overload
```

Step 4: Enable NAT by applying policy to the inside router interfaces. Apply this configuration as needed to internal interfaces or sub-interfaces where traffic matching the ACL may originate, such as the data and transit networks and any service interfaces such as Cisco UCS-E or Cisco SRE interfaces.

```
interface Port-channel 1.64
description Data network
 ip nat inside

interface Port-channel 1.99
description Transit network
 ip nat inside
```

Step 5: Configure the Internet-facing interfaces for NAT.

```
interface GigabitEthernet0/0/0
 description ISP Connection
 ip nat outside
```

Tech Tip

When you configure NAT on an IOS router interfaces, you will see **ip virtual-reassembly in** added to the configuration. This is automatically enabled for features that require fragment reassembly, such as NAT, Firewall, and IPS.

Step 6: Verify proper interfaces are configured for NAT.

```
RS34-4451X-1#show ip nat statistics
Total active translations: 0 (0 static, 0 dynamic; 0 extended)
Outside interfaces:
  GigabitEthernet0/0/0
Inside interfaces:
  Port-channel1.64
Hits: 119073  Misses:
Expired translations:
Dynamic mappings:
-- Inside Source
[Id: 1] route-map NAT interface GigabitEthernet0/0/0 refcount 0
nat-limit statistics:
 max entry: max allowed 0, used 0, missed 0
In-to-out drops: 0  Out-to-in drops: 0
Pool stats drop: 0  Mapping stats drop: 0
Port block alloc fail: 0
IP alias add fail: 0
Limit entry add fail: 0
```

Step 7: Verify NAT translations for intended sources that are using local Internet services.

```
RS34-4451X-1#show ip nat translations
Pro  Inside global        Inside local         Outside local        Outside global
tcp  172.18.99.21:5021    10.7.164.20:49678    69.25.24.26:80       69.25.24.26:80
tcp  172.18.99.21:5108    10.7.164.20:49765    23.203.221.156:443   23.203.221.156:443
tcp  172.18.99.21:4105    10.7.164.20:49786    23.204.109.42:80     23.204.109.42:80
tcp  172.18.99.21:4975    10.7.164.20:49632    23.204.109.48:80     23.204.109.48:80
```

PROCESS

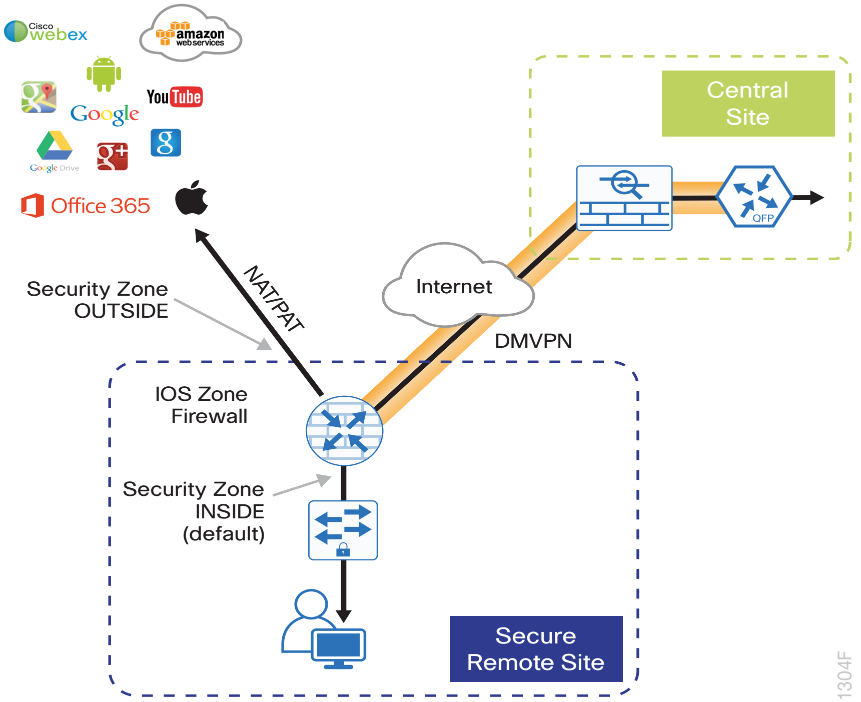
Configuring Zone-Based Firewall for DIA

1. Configure base Cisco IOS Zone-Based Firewall parameters
2. Restrict traffic to the router
3. Enable and verify zone-based firewall configuration

The following Cisco IOS firewall configuration is intended for use on Internet-facing remote site routers providing secure local-Internet access. This configuration assumes DHCP and DMVPN are also configured to use the outside interface. To configure the required base firewall policies, complete the following procedures on both routers.

Follow these procedures to secure a dual-router dual-Internet remote-site router with direct Internet configurations.

Figure 78 Zone-based firewall for DIA



Procedure 1 Configure base Cisco IOS Zone-Based Firewall parameters

Step 1: If it is configured, remove the inbound ACL from the Internet-facing router interfaces, and then shut down the interface before continuing. This prevents unauthorized traffic while the ZBFW is configured.

```
interface GigabitEthernet0/0/0
  shutdown
  no ip access-list extended ACL-INET-PUBLIC in
```

Step 2: Define security zones. A zone is a named group of interfaces that have similar functions or security requirements. This example defines the names of the two basic security zones identified. For simplicity, this design uses the "default" security zone for inside interfaces. Once the default zone has been defined, all interfaces not explicitly configured as members of a security zone will automatically be part of the default security zone.

```
zone security default
zone security OUTSIDE
```

Tech Tip

This design uses the "default" zone for all inside interfaces; traffic can flow between all interfaces in the default zone.

An interface not defined as part of a security zone is automatically part of the "default" zone. In this configuration, all undefined interface DMVPN tunnels, transit sub-interfaces, and service interfaces such as Cisco UCS-E, and SRE interfaces are included as part of the default zone.

Be aware that any interface that is removed from a defined security zone will be automatically placed into the default zone. In this configuration, that interface will be treated as an "inside" zone and have access to the internal routing domain..

Step 3: Define a class map to match specific protocols. Class-maps apply **match-any** or **match-all** operators in order to determine how to apply the match criteria to the class. If **match-any** is specified, traffic must meet at least one of the match criteria in the class-map to be included in the class. If **match-all** is specified, traffic must meet all of the match criteria to be included in the class.

```
class-map type inspect match-any INSIDE-TO-OUTSIDE-CLASS
 match protocol ftp
 match protocol tcp
 match protocol udp
 match protocol icmp
```

Tech Tip

Protocols that use single ports (such as HTTP, telnet, SSH, etc.) can be statefully allowed with tcp inspection alone by using the **match protocol tcp** command.

Protocols such as ftp that use multiple ports (one for control and another for data) require application inspection in order to enable dynamic adjustments to the active firewall policy. The specific TCP ports that are required for the application are allowed for short durations, as necessary.

Step 4: Define policy maps. A policy is an association of traffic classes and actions. It specifies what actions should be performed on defined traffic classes. In this case, you statefully inspect the outbound session so that return traffic is permitted.

```
policy-map type inspect INSIDE-TO-OUTSIDE-POLICY
 class type inspect INSIDE-TO-OUTSIDE-CLASS
  inspect
 class class-default
  drop
```

Tech Tip

An *action* is a specific functionality that is associated with a traffic class. **Inspect**, **drop**, and **pass** are actions.

With the **inspect** action, return traffic is automatically allowed for established connections. The **pass** action permits traffic in one direction only. When using the **pass** action, you must explicitly define rules for return traffic.

Step 5: Define the zone pair and apply the policy map. A zone pair represents two defined zones and identifies the source and destination zones where a unidirectional firewall policy-map is applied. This configuration uses only one zone pair because all traffic is inspected and thus allowed to return.

```
zone-pair security IN_OUT source default destination OUTSIDE
 service-policy type inspect INSIDE-TO-OUTSIDE-POLICY
```

Procedure 2 Restrict traffic to the router

Cisco IOS defines the router by using the fixed name self as a separate security zone. The self-zone is the exception to the default deny-all policy.

All traffic destined to or originating from the router itself (local traffic) on any interface is allowed until traffic is explicitly denied. In other words, any traffic flowing directly between defined zones and the router's IP interfaces is implicitly allowed and is not initially controlled by zone firewall policies.

This default behavior of the self-zone ensures that connectivity to the router's management interfaces and the function of routing protocols is maintained when an initial zone firewall configuration is applied to the router.

Specific rules that control traffic to the self-zone are required. When you configure a ZBFW rule that includes the self-zone, traffic between the self-zone and the other defined zones is immediately restricted in both directions.

Table 4 *Self-zone firewall access list parameters*

Protocol	Stateful inspection policy
ISAKMP	Yes
ICMP	Yes
DHCP	No
ESP	No
GRE	No

The following configuration allows the required traffic for proper remote-site router configuration with DMVPN. ESP and DHCP cannot be inspected and need to be configured with a **pass** action in the policy, using separate ACL and class-maps. ISAKMP should be configured with the **inspect** action and thus needs to be broken out with a separate ACL and class-maps for inbound and outbound policies.

Tech Tip

More specific ACLs than are shown here with the "any" keyword are recommended for added security.

Step 1: In the following steps, define access lists.

Step 2: Define an ACL allowing traffic with a destination of the router itself from the OUTSIDE zone. This includes ISAKMP for inbound tunnel initiation. This traffic can be inspected and is identified in the following ACL.

```
ip access-list extended ACL-RTR-IN
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit icmp any any echo
 permit icmp any any echo-reply
 permit icmp any any ttl-exceeded
 permit icmp any any port-unreachable
 permit udp any any gt 1023 ttl eq 1
```

Step 3: Identify traffic for IPSEC tunnel initiation and other traffic that will originate from the router (self zone) to the OUTSIDE zone. This traffic can be inspected.

```
ip access-list extended ACL-RTR-OUT
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit icmp any any
 permit udp any any eq domain
```

Tech Tip

The ICMP and domain entries here are for IPSLA probes that originate from the router.

```
 permit icmp any any
 permit udp any any eq domain
```

Step 4: Configure the DHCP ACL to allow the router to acquire a public IP address dynamically from the ISP. This traffic needs to be defined separately for server and client and cannot be inspected.

```
ip access-list extended DHCP-IN
 permit udp any eq bootps any eq bootpc

ip access-list extended DHCP-OUT
 permit udp any eq bootpc any eq bootps
```

Step 5: Configure the ESP ACL to allow the router to establish IPSEC communications for DMVPN. ESP needs to be explicitly allowed inbound and outbound in separate ACLs. ESP cannot be inspected.

```
ip access-list extended ESP-IN
 permit esp any any

ip access-list extended ESP-OUT
 permit esp any any
```

Step 6: Configure the GRE ACL to allow GRE tunnel formation. GRE needs to be explicitly allowed inbound only.

```
ip access-list extended GRE-IN
 permit gre any any
```

Tech Tip

GRE needs to be permitted inbound for GRE on IOS-XE platforms due to a difference in interface order of operations. This is not required on IOS ISRG2 platforms.

Next, you define class maps for traffic to and from the self-zone. Separate class-maps are required for inbound and outbound initiated flows as well as for traffic that can be inspected by the router.

Step 7: Define the class-map matching inbound traffic that can be inspected.

```
class-map type inspect match-any INSPECT-ACL-IN-CLASS
 match access-group name ACL-RTR-IN
```

Step 8: Define the class-map matching outbound traffic that can be inspected.

```
class-map type inspect match-any INSPECT-ACL-OUT-CLASS
 match access-group name ACL-RTR-OUT
```

Step 9: Define the class-map matching inbound traffic that is not able to be inspected.

```
class-map type inspect match-any PASS-ACL-IN-CLASS
 match access-group name ESP-IN
 match access-group name DHCP-IN
 match access-group name GRE-IN
```

Step 10: Define the class-map matching outbound traffic that cannot be inspected.

```
class-map type inspect match-any PASS-ACL-OUT-CLASS
 match access-group name ESP-OUT
 match access-group name DHCP-OUT
```

Next, you define policy maps. Create two separate policies, one for traffic inbound and one for traffic outbound.

Step 11: Define the inbound policy-map that refers to both of the outbound class-maps with actions of **inspect**, **pass**, and **drop** for the appropriate class defined.

```
policy-map type inspect ACL-IN-POLICY
 class type inspect INSPECT-ACL-IN-CLASS
  inspect
 class type inspect PASS-ACL-IN-CLASS
  pass
 class class-default
  drop
```

Step 12: Define the outbound policy-map that refers to both of the outbound class-maps with actions of **inspect**, **pass**, and **drop** for the appropriate class defined.

```
policy-map type inspect ACL-OUT-POLICY
 class type inspect INSPECT-ACL-OUT-CLASS
  inspect
 class type inspect PASS-ACL-OUT-CLASS
  pass
 class class-default
  drop
```

Tech Tip

Inspection for Layer 7 applications is not allowed for traffic going to and from the self-zone to other zones. Cisco IOS firewalls support only inspection of TCP, UDP, and H.323 traffic that terminates on or originates from the router itself.

Traffic such as DHCP and ESP cannot be inspected and must be configured as **Pass** in the associated policy-map.

Next, you define the zone pair and apply policy maps to them.

Step 13: Define the zone pair for traffic destined to the self-zone of the router from the outside and associate the inbound policy-map defined in the previous step.

```
zone-pair security TO-ROUTER source OUTSIDE destination self
 service-policy type inspect ACL-IN-POLICY
```

Step 14: Define the zone pair for traffic destined from the self-zone of the router to the outside and associate the outbound policy-map defined in the previous step.

```
zone-pair security FROM-ROUTER source self destination OUTSIDE
 service-policy type inspect ACL-OUT-POLICY
```

Procedure 3 Enable and verify zone-based firewall configuration

Step 1: Assign the Internet-facing router interface to the outside security zone. All other interfaces are assigned to the default zone and do not need to be defined.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 zone-member security OUTSIDE
```

Tech Tip

By default, traffic is allowed to flow between interfaces that are members of the same zone, while a default “deny-all” policy is applied to traffic moving between zones.

This design uses the “default” zone for all inside interfaces, traffic can flow between all interfaces in the default zone.

An interface not defined as part of a security zone is automatically part of the “default” zone. In this configuration, all undefined interface DMVPN tunnels, transit sub-interfaces, and service interfaces such as Cisco UCS-E, and SRE interfaces are included as part of the default zone.

Loopback interfaces are members of the “self” zone and are not assigned to a defined security zone or the default zone.

Step 2: Verify the interface assignment for the zone firewall and ensure that all required interfaces for the remote site configuration are assigned to the proper zone.

```
RS34-4451X-1#show zone security
zone self
  Description: System defined zone

zone default
  Description: System level zone. Interface without zone membership is in this zone automatically

zone OUTSIDE
  Member Interfaces:
    GigabitEthernet0/0/0
```

Step 3: Verify firewall operation by reviewing the byte counts for each of the configured policies and classes.

```
RS32-4451X-2#show policy-map type inspect zone-pair sessions
  Zone-pair: FROM-ROUTER
  Service-policy inspect : ACL-OUT-POLICY
    Class-map: INSPECT-ACL-OUT-CLASS (match-any)
      Match: access-group name ACL-RTR-OUT
        50 packets, 13824 bytes
      Inspect
    Class-map: PASS-ACL-OUT-CLASS (match-any)
      Match: access-group name ESP-OUT
        0 packets, 0 bytes
      Match: access-group name DHCP-OUT
        8 packets, 2680 bytes
      Pass
        8 packets, 2680 bytes
    Class-map: class-default (match-any)
      Match: any
      Drop
        0 packets, 0 bytes
  Zone-pair: IN_OUT
  Service-policy inspect : INSIDE-TO-OUTSIDE-POLICY
    Class-map: INSIDE-TO-OUTSIDE-CLASS (match-any)
      Match: protocol ftp
```

```
          0 packets, 0 bytes
        Match: protocol tcp
          0 packets, 0 bytes
        Match: protocol udp
          0 packets, 0 bytes
        Match: protocol icmp
          0 packets, 0 bytes
        Inspect
      Class-map: class-default (match-any)
        Match: any
        Drop
          0 packets, 0 bytes
    Zone-pair: TO-ROUTER
    Service-policy inspect : ACL-IN-POLICY
      Class-map: INSPECT-ACL-IN-CLASS (match-any)
        Match: access-group name ACL-RTR-IN
          52 packets, 14040 bytes
        Inspect
      Class-map: PASS-ACL-IN-CLASS (match-any)
        Match: access-group name ESP-IN
          0 packets, 0 bytes
        Match: access-group name DHCP-IN
          8 packets, 2736 bytes
        Match: access-group name GRE-IN
          0 packets, 0 bytes
        Pass
          1697 packets, 332091 bytes
      Class-map: class-default (match-any)
        Match: any
        Drop
          0 packets, 0 bytes
```

Step 4: Add the following command to the router configuration in order to identify traffic dropped by the Cisco IOS-XE zone firewall.

```
parameter-map type inspect global
 log dropped-packets
```

Tech Tip

In IOS, when you configure the command **ip inspect drop-pkt**, the following is automatically added to the router configuration:

```
parameter-map type inspect global
 log dropped-packets enable
```

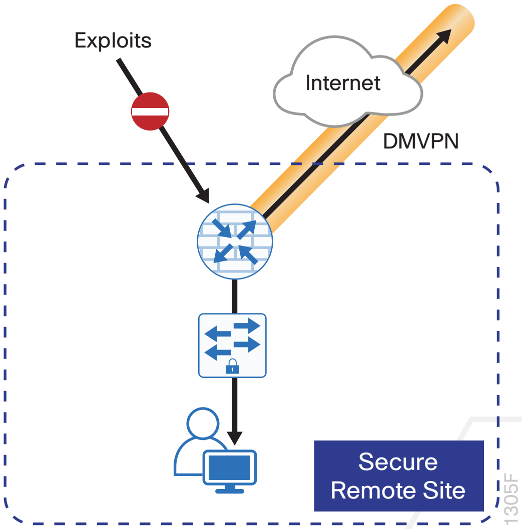
PROCESS

Configuring Additional Router Security

1. Disable IP ICMP redirects
2. Disable ICMP unreachable messages
3. Disable Proxy ARP
4. Disable unused router services
5. Disable CDP and LLDP
6. Enable keepalives for TCP sessions
7. Configure internal-network floating static routes
8. Enable Internet interfaces

In addition to the security measures already taken in prior configuration tasks, this section introduces best practices recommendations to secure Internet-facing routers. Disabling unused services and features for networking devices improves the overall security posture by minimizing the amount of information exposed. This practice also minimizes the amount of router CPU and memory load that is required to process unneeded packets.

Figure 79 *Additional router security*



Tech Tip

These are general security guidelines only. You may take additional measures to secure remote site routers on a case-by-case basis. Take care to ensure that disabling certain features does not impact other functions of the network.

Procedure 1 Disable IP ICMP redirects

Routers use ICMP redirect messages to notify that a better route is available for a given destination. In this situation, the router forwards the packet and sends an ICMP redirect message back to the sender advising of an alternative and preferred route to the destination. In many implementations, there is no benefit in permitting this behavior. An attacker can generate traffic, forcing the router to respond with ICMP redirect messages, negatively impacting the CPU and performance of the router. You can prevent this by disabling ICMP redirect messages.

Step 1: Disable ICMP redirect messages on Internet-facing router interfaces on both routers.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no ip redirects
```

Procedure 2 Disable ICMP unreachable messages

When filtering on router interfaces, routers send ICMP unreachable messages back to the source of blocked traffic. Generating these messages can increase CPU utilization on the router. By default, Cisco IOS ICMP unreachable messages are limited to one every 500 milliseconds. ICMP unreachable messages can be disabled on a per interface basis.

Step 1: Disable ICMP unreachable messages on Internet-facing router interfaces on both routers.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no ip unreachables
```

Procedure 3 Disable Proxy ARP

Proxy ARP allows the router to respond to ARP request for hosts other than itself. Proxy ARP can help machines on a subnet reach remote subnets without configuring routing or a default Disadvantages to using proxy ARP:

- An attacker can impact available memory by sending a large number of ARP requests.
- A router is also susceptible to man-in-the-middle attacks where a host on the network could be used to spoof the MAC address of the router, resulting in unsuspecting hosts sending traffic to the attacker.

You can disable Proxy ARP by using the **interface** configuration command

Step 1: Disable proxy ARP on Internet-facing router interfaces on both routers.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no ip proxy-arp
```

Procedure 4 Disable unused router services

As a security best practice, you should disable all unnecessary services that could be used to launch DoS and other attacks. Many unused services that pose a security threat are disabled by default in current Cisco IOS versions.

Step 1: Disable MOP on Internet-facing router interfaces on both routers.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no mop enabled
```

Step 2: Disable PAD service globally on the router.

```
no service pad
```

Step 3: Prevent the router from attempting to locate a configuration file via TFTP globally on the router.

```
no service config
```

Procedure 5 Disable CDP and LLDP

Attackers can use CDP and LLDP for reconnaissance and network mapping. CDP is a network protocol that is used to discover other CDP-enabled devices. CDP is often used by NMS and for troubleshooting networking problems. LLDP is an IEEE protocol that is defined in 802.1AB and is very similar to CDP. You should disable CDP and LLDP on router interfaces that connect to untrusted networks.

Step 1: Disable CDP on Internet-facing router interfaces on both routers.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no cdp enable
```

Step 2: Disable LLDP on Internet-facing router interfaces on both routers.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no lldp transmit
 no lldp receive
```

Procedure 6 Enable keepalives for TCP sessions

This configuration enables TCP keepalives on inbound connections to the router and outbound connections from the router. This ensures that the device on the remote end of the connection is still accessible and half-open or orphaned connections are removed from the router.

Step 1: Enable the TCP keepalives service for inbound and outbound connections globally on the routers. Configuration commands enable a device

```
service tcp-keepalives-in
service tcp-keepalives-out
```

Procedure 7 Configure internal-network floating static routes

In the event the DMVPN tunnel to the hub site fails, you will want to ensure traffic destined to internal networks does not follow the local Internet default route. It's best to have the network fail closed to prevent possible security implications and unwanted routing behavior.

Configuring floating static routes to null zero with an AD of 254 ensures that all internal subnets route to null0 in the event of tunnel failure.

Step 1: Configure static route for internal network subnets on both routers.

```
ip route 10.0.0.0 255.0.0.0 null0 254
```

Tech Tip

Configure the appropriate number of null 0 routes for internal network ranges, using summaries when possible for your specific network environment.

Procedure 8 Enable Internet interfaces

Now that the security configurations are complete, you can enable the Internet-facing interfaces.

Step 1: Enable the Internet-facing router interfaces on both routers.

```
interface GigabitEthernet0/0/0
 description Internet Connection
 no shutdown
```

PROCESS

Configuring ISP Black-Hole Routing Detection

1. Configure ISP black-hole routing detection

In many cases you will need to ensure connectivity issues with your ISP does not cause black-hole routing conditions. Failure conditions can exist where the DHCP address and routes are not removed from the remote-site router when connectivity issues exist with the broadband service or local premise equipment. There may also be circumstances if certain services are unreachable within via the local ISP connection that you want to reroute to a secondary Internet service.

If Internet fallback is required, configure one or more of the following options on the primary router.

Procedure 1 Configure ISP black-hole routing detection

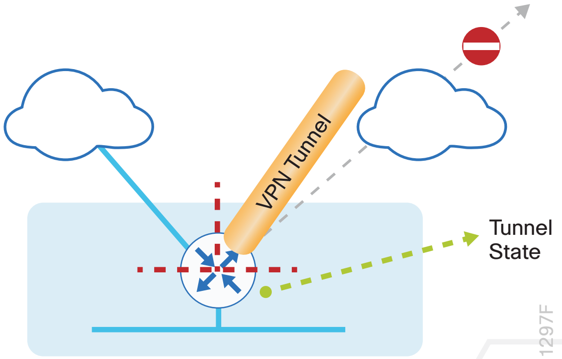
Option 1: DMVPN Tunnel State Tracking

In this solution, the DMVPN tunnel state is used to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, a “down” state of the tunnel interface triggers the removal of the default route via an EEM script. If tunnel state is “up” the route will remain.

Tech Tip

With this method, a failure or maintenance at the central site can cause a failover event where the route is removed due to tunnel state change and the local Internet connection remains active at the remote site.

Figure 80 *IWAN tunnel tracking with EEM*



Step 1: Ensure that state tracking is configured for the DMVPN tunnel interface on the primary router.

```
interface Tunnel20
 if-state nhrp
```

Step 2: Configure the tracking parameters and logic for the IPSLA probes on the primary router.

```
track 80 interface Tunnel20 line-protocol
```

Step 3: On the primary router, configure an EEM script to remove the local default route when the tunnel line protocol transitions to a "down" state.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 80 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 
10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 DISABLED"
```

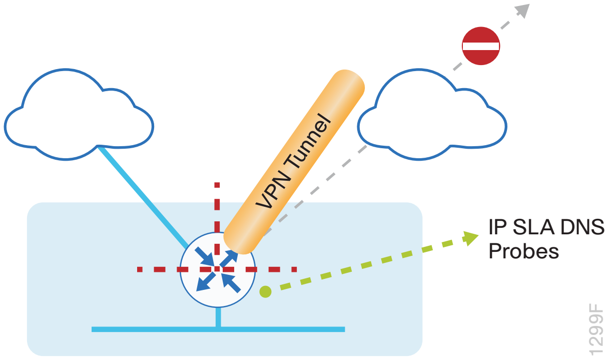
Step 4: On the primary router, configure an EEM script to also restore the local default route when the tunnel line protocol transitions to an "up" state.

```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 80 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 ENABLED"
```

Option 2: DNS-Based IPSLA Probes

In this solution, you use DNS-based IPSLA probes to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, the failure of DNS probes to two or more root DNS servers triggers the removal of the default route via an EEM script. If any DNS probe is active, the route will remain.

Figure 81 *IPSLA with DNS probes*



Tech Tip

For DNS-based IPSLA probes to function, you need to ensure that DNS or "domain" is permitted in the ZBFW outbound ACL, from the self-zone to the OUTSIDE zone. Example:

```
ip access-list extended ACL-RTR-OUT
 permit udp any any eq domain
```

Step 1: On the primary router, configure the VRF-aware IPSLA DNS probes.

```
ip sla 118
 dns d.root-servers.net name-server 199.7.91.13
 vrf IWAN-TRANSPORT-3
 threshold 1000
 timeout 3000
 frequency 15
ip sla schedule 118 life forever start-time now

ip sla 119
 dns b.root-servers.net name-server 192.228.79.201
 vrf IWAN-TRANSPORT-3
 threshold 1000
 timeout 3000
 frequency 15
ip sla schedule 119 life forever start-time now
```

Tech Tip

When configuring DNS probes, you should specify the hostname of the DNS server itself. That asks the DNS server to resolve for itself, allowing the use of root DNS servers.

Step 2: On the primary router, configure the tracking parameters and logic for the IPSLA probes.

```
track 73 ip sla 118 reachability
track 74 ip sla 119 reachability
!
track 100 list boolean or
 object 73
 object 74
```

Step 3: On the primary router, configure an EEM script to remove the local default route in the event of DNS probe failure.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 100 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 
10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 DISABLED"
```

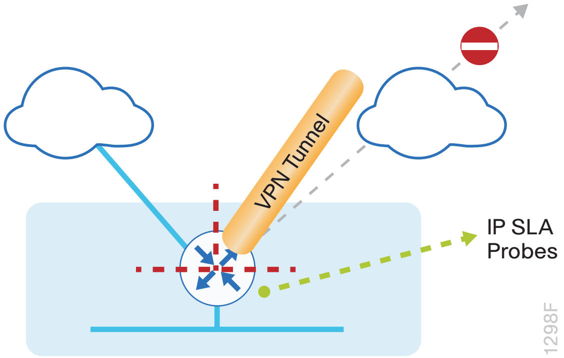
Step 4: On the primary router, configure an EEM script to also restore the local default route when the DNS probes are active.

```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 100 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 ENABLED"
```

Option 3: IPSLA ICMP Probes

In this solution, you use IPSLA ICMP probes to monitor the status of the ISP connection used as the primary path for local Internet traffic. In this example, the failure of ICMP probes to two different IP hosts triggers the removal of the default route via an EEM script. If either ICMP probe is active the route will remain.

Figure 82 IPSLA with ICMP probes



Step 1: On the primary router, configure the VRF-aware IPSLA ICMP probes.

```
ip sla 110
 icmp-echo 172.18.1.253 source-interface GigabitEthernet0/0/0
 vrf IWAN-TRANSPORT-3
 threshold 1000
 frequency 15
ip sla schedule 110 life forever start-time now

ip sla 111
 icmp-echo 172.18.1.254 source-interface GigabitEthernet0/0/0
 vrf IWAN-TRANSPORT-3
 threshold 1000
 frequency 15
ip sla schedule 111 life forever start-time now
```

Step 2: On the primary router, configure the tracking parameters and logic for the IPSLA ICMP probes.

```
track 60 ip sla 110 reachability
track 61 ip sla 111 reachability
track 62 list boolean or
 object 60
 object 61
```

Step 3: On the primary router, configure an EEM script to remove the local default route when the ICMP probes are down.

```
event manager applet DISABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 62 state down
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "no ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 
10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 DISABLED"
```

Step 4: On the primary router, configure an EEM script to also restore the local default route when the ICMP probes are active.

```
event manager applet ENABLE-IWAN-DIA-DEFAULT
 description ISP Black hole Detection - Tunnel state
 event track 62 state up
 action 1  cli command "enable"
 action 2  cli command "configure terminal"
 action 3  cli command "ip route 0.0.0.0 0.0.0.0 GigabitEthernet0/0/0 dhcp 10"
 action 4  cli command "end"
 action 99 syslog msg "IWAN DIA DEFAULT IP ROUTE via GIG0/0/0 ENABLED"
```

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.

WAN AGGREGATION

Place In Network	Product Description	Part Number	SW Version	Feature Set
WAN-aggregation Router	Aggregation Services 1002X Router	ASR1002X-5G-VPNK9	IOS XE 03.16.04b.S	Advanced Enterprise
	Aggregation Services 1001X Router	ASR1001X-5G-VPN	IOS XE 03.16.04b.S	Advanced Enterprise
	Cisco ISR 4451-X Security Bundle with SEC License	ISR4451-X-SEC/K9	IOS XE 03.16.04b.S	securityk9
Hub or Transit MC	Cloud Services Router 1000v	CSR1000v	IOS XE 03.16.04b.S	AX

WAN REMOTE SITE

Place In Network	Product Desccription	Part Number	SW Version	Feature Set
Modular WAN Remote-site Router	Cisco ISR 4451 AX Bundle with APP and SEC License	ISR4451-X-AX/K9	IOS XE 03.16.04b.S	securityk9, appxk9
	Cisco ISR 4431 AX Bundle with APP and SEC License	ISR4431-AX/K9	IOS XE 03.16.04b.S	securityk9, appxk9
	Cisco ISR 4351 AX Bundle with APP and SEC License	ISR4351-AX/K9	IOS XE 03.16.04b.S	securityk9, appxk9
	Cisco ISR 4331 AX Bundle with APP and SEC License	ISR4331-AX/K9	IOS XE 03.16.04b.S	securityk9, appxk9
	Cisco ISR 4321 AX Bundle with APP and SEC License	ISR4321-AX/K9	IOS XE 03.16.04b.S	securityk9, appxk9
	Cisco ISR 3945 AX Bundle with APP and SEC License	C3945-AX/K9	15.5(3)M4a	securityk9, datak9, uck9
	Cisco ISR 3925 AX Bundle with APP and SEC License	C3925-AX/K9	15.5(3)M4a	securityk9, datak9, uck9
	Unified Communications Paper PAK for Cisco 3900 Series	SL-39-UC-K9		
	Cisco ISR 2951 AX Bundle with APP and SEC License	C2951-AX/K9	15.5(3)M4a	securityk9, datak9, uck9
	Cisco ISR 2921 AX Bundle with APP and SEC License	C2921-AX/K9	15.5(3)M4a	securityk9, datak9, uck9
	Cisco ISR 2911 AX Bundle with APP and SEC License	C2911-AX/K9	15.5(3)M4a	securityk9, datak9, uck9
	Unified Communications Paper PAK for Cisco 2900 Series	SL-29-UC-K9		
	Cisco ISR 1941 AX Bundle with APP and SEC License	C1941-AX/K9	15.5(3)M4a	securityk9, datak9

INTERNET EDGE

Place In Network	Product Description	Part Number	SW Version	Feature Set
Firewall	Cisco ASA 5545-X	ASA5545-K9	ASA 9.4(3)	
	Cisco ASA 5525-X	ASA5525-K9	ASA 9.4(3)	
	Cisco ASA 5515-X	ASA5515-K9	ASA 9.4(3)	
	Cisco ASA 5512-X	ASA5512-K9	ASA 9.4(3)	
	Cisco ASA 5512-X Security Plus license	ASA5512-SEC-PL		
	Firewall Management	ASDM	7.6(2)	

INTERNET EDGE LAN

Place In Network	Product Description	Part Number	SW Version	Feature Set
DMZ Switch	Cisco Catalyst 2960-X Series 24 10/100/1000 PoE and 2 SFP+ Uplink	WS-C2960X-24PS	15.2(3)E1	LAN Base
	Cisco Catalyst 2960-X FlexStack-Plus Hot-Swappable Stacking Module	C2960X-STACK		

LAN ACCESS LAYER

Place In Network	Product Description	Part Number	SW Version	Feature Set
Modular Access Layer Switch	Cisco Catalyst 4500E Series 4507R+E 7-slot Chassis with 48Gbps per slot	WS-C4507R+E	3.7.1E(15.2.3E1)	IP Base
	Cisco Catalyst 4500E Supervisor Engine 8-E, Unified Access, 928Gbps	WS-X45-SUP8-E	3.7.1E(15.2.3E1)	IP Base
	Cisco Catalyst 4500E 12-port 10GbE SFP+ Fiber Module	WS-X4712-SFP+E		
	Cisco Catalyst 4500E 48-Port 802.3at PoE+ 10/100/1000 (RJ-45)	WS-X4748-RJ45V+E		
	Cisco Catalyst 4500E Series 4507R+E 7-slot Chassis with 48Gbps per slot	WS-C4507R+E	3.7.1E(15.2.3E1)	IP Base
	Cisco Catalyst 4500E Supervisor Engine 7L-E, 520Gbps	WS-X45-SUP7L-E	3.7.1E(15.2.3E1)	IP Base
	Cisco Catalyst 4500E 48 Ethernet 10/100/1000 (RJ45) PoE+,UPoE ports	WS-X4748-UPOE+E		
	Cisco Catalyst 4500E 48 Ethernet 10/100/1000 (RJ45) PoE+ ports	WS-X4648-RJ45V+E		

Place In Network	Product Description	Part Number	SW Version	Feature Set
Stackable Access Layer Switch	Cisco Catalyst 3850 Series Stackable 48 Ethernet 10/100/1000 PoE+ ports	WS-C3850-48F	3.7.1E(15.2.3E1)	IP Base
	Cisco Catalyst 3850 Series Stackable 24 Ethernet 10/100/1000 PoE+ Ports	WS-C3850-24P	3.7.1E(15.2.3E1)	IP Base
	Cisco Catalyst 3850 Series 2 x 10GE Network Module	C3850-NM-2-10G		
	Cisco Catalyst 3850 Series 4 x 1GE Network Module	C3850-NM-4-1G		
	Cisco Catalyst 3650 Series 24 Ethernet 10/100/1000 PoE+ and 2x10GE or 4x1GE Uplink	WS-C3650-24PD	3.7.1E(15.2.3E1)	IP Base
	Cisco Catalyst 3650 Series 24 Ethernet 10/100/1000 PoE+ and 4x1GE Uplink	WS-C3650-24PS	3.7.1E(15.2.3E1)	IP Base
	Cisco Catalyst 3650 Series Stack Module	C3650-STACK		
	Cisco Catalyst 2960-X Series 24 10/100/1000 Ethernet and 2 SFP+ Uplink	WS-C2960X-24PD	15.2(3)E1	LAN Base
Standalone Access Layer Switch	Cisco Catalyst 3650 Series 24 Ethernet 10/100/1000 PoE+ and 4x1GE Uplink	WS-C3650-24PS	3.7.1E(15.2.3E1)	IP Base

LAN DISTRIBUTION LAYER

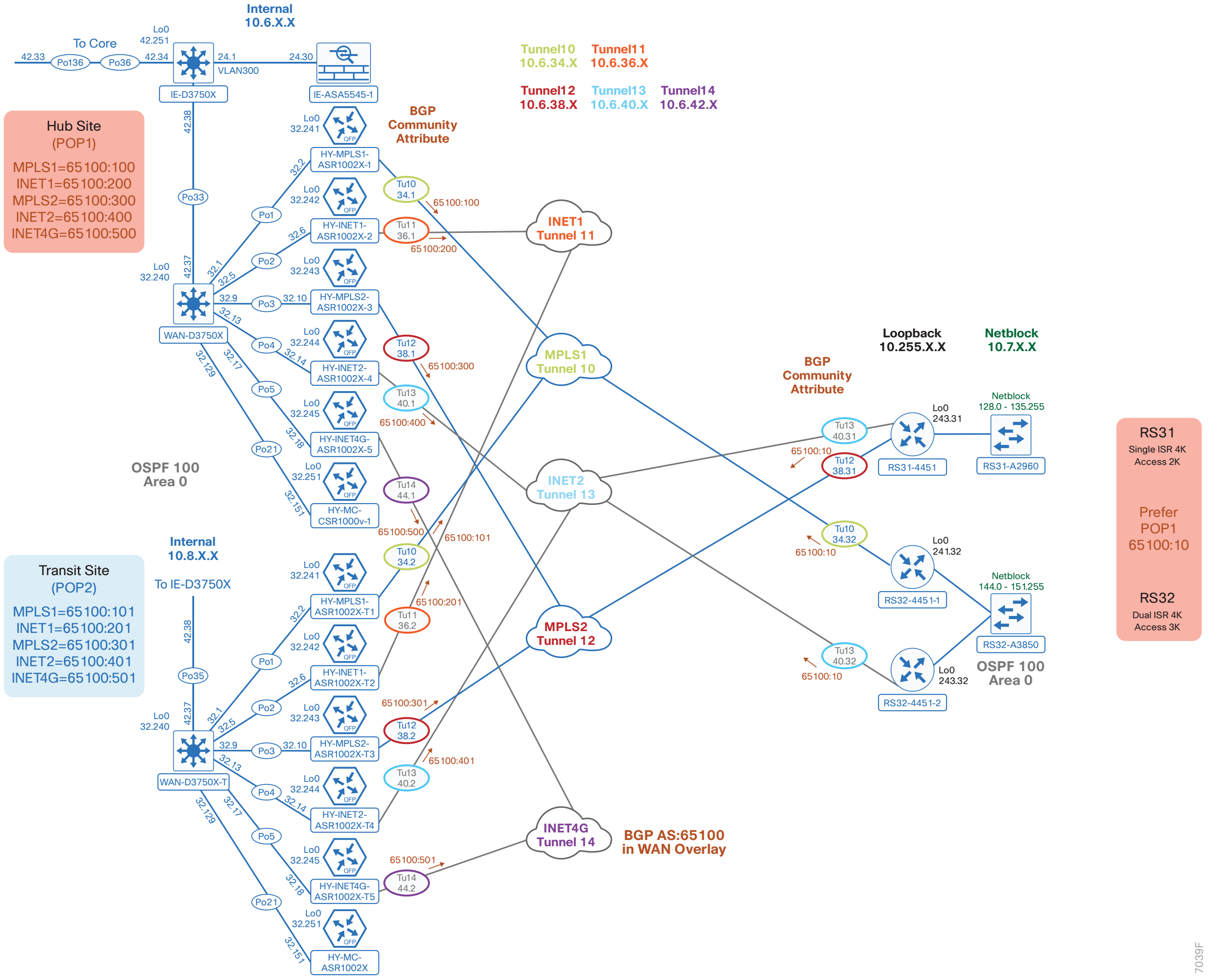
Place In Network	Product Description	Part Number	SW Version	Feature Set
Modular Distribution Layer Virtual Switch Pair	Cisco Catalyst 6500 VSS Supervisor 2T with 2 ports 10GbE and PFC4	VS-S2T-10G	15.2(1)SY1	IP Services
	Cisco Catalyst 6800 Series 6807-XL 7-Slot Modular Chassis	C6807-XL	15.2(1)SY1	IP Services
	Cisco Catalyst 6500 4-port 40GbE/16-port 10GbE Fiber Module w/DFC4	WS-X6904-40G-2T		
	Cisco Catalyst 6500 4-port 10GbE SFP+ adapter for WX-X6904-40G module	CVR-CFP-4SFP10G		
	Cisco Catalyst 6500 CEF720 48 port 10/100/1000mb Ethernet	WS-X6748-GE-TX		
	Cisco Catalyst 6500 Distributed Forwarding Card 4	WS-F6K-DFC4-A		
	Cisco Catalyst 6500 Series 6506-E 6-Slot Chassis	WS-C6506-E	15.2(1)SY1	IP services
	Cisco Catalyst 6500 VSS Supervisor 2T with 2 ports 10GbE and PFC4	VS-S2T-10G	15.2(1)SY1	IP services
	Cisco Catalyst 6500 4-port 40GbE/16-port 10GbE Fiber Module w/DFC4	WS-X6904-40G-2T		
	Cisco Catalyst 6500 4-port 10GbE SFP+ adapter for WX-X6904-40G module	CVR-CFP-4SFP10G		
	Cisco Catalyst 6500 48-port GigE Mod (SFP)	WS-X6748-SFP		
	Cisco Catalyst 6500 Distributed Forwarding Card 4	WS-F6K-DFC4-A		
	Cisco Catalyst 6500 24-port GigE Mod (SFP)	WS-X6724-SFP		
	Cisco Catalyst 6500 Distributed Forwarding Card 4	WS-F6K-DFC4-A		

Place in Network	Product Description	Part Number	SW Version	Feature Set
Extensible Fixed Distribution Layer Virtual Switch Pair	Cisco Catalyst 6800 Series 6880-X Extensible Fixed Aggregation Switch (Standard Tables)	C6880-X-LE	15.2(1)SY1	IP Services
	Cisco Catalyst 6800 Series 6880-X Multi Rate Port Card (Standard Tables)	C6880-X-LE-16P10G		
Modular Distribution Layer Virtual Switch Pair	Cisco Catalyst 4500E Series 4507R+E 7-slot Chassis with 48Gbps per slot	WS-C4507R+E	3.7.1E(15.2.3E1)	Enterprise Services
	Cisco Catalyst 4500E Supervisor Engine 7-E, 848Gbps	WS-X45-SUP7-E	3.7.1E(15.2.3E1)	Enterprise Services
	Cisco Catalyst 4500E 12-port 10GbE SFP+ Fiber Module	WS-X4712-SFP+E		
	Cisco Catalyst 4500E 48-Port 802.3at PoE+ 10/100/1000 (RJ-45)	WS-X4748-RJ45V+E		
Fixed Distribution Layer Virtual Switch Pair	Cisco Catalyst 4500-X Series 32 Port 10GbE IP Base Front-to-Back Cooling WS-C4500X-32SFP+ 3.5.3E(15.2.1E3) Enterprise Services			
Stackable Distribution Layer Switch	Cisco Catalyst 3850 Series Stackable Switch with 12 SFP Ethernet	WS-C3850-12S	3.7.1E(15.2.3E1)	IP Services
	Cisco Catalyst 3850 Series 4 x 1GE Network Module	C3850-NM-4-1G		
	Cisco Catalyst 3850 Series 2 x 10GE Network Module	C3850-NM-2-10G		

Appendix B: Router Configurations

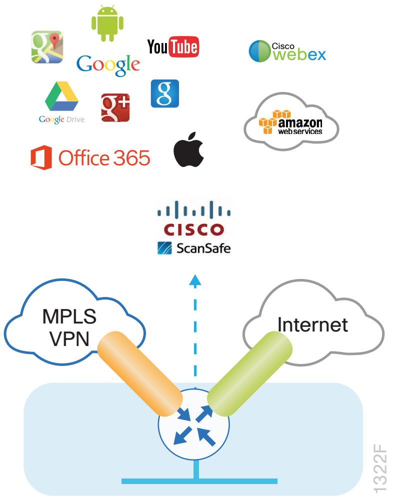
This section includes the remote site configuration files corresponding to the IWAN hybrid model, as referenced in the figure below.

Figure 83 *IWAN hybrid model for BGP*



SINGLE-ROUTER HYBRID WITH DIA

Figure 84 *Single-router hybrid configurations*

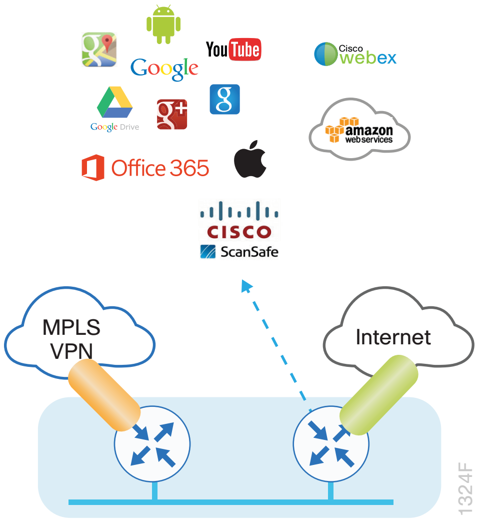


Below is a link to the configuration for the single-router hybrid design for BGP with internal employee DIA:

- RS31—Single-Router, two-Link, Access (MPLS2 and INET2):
    - RS31-4451: MPLS2 and INET2 WAN links

DUAL-ROUTER HYBRID WITH DIA

Figure 85 *Dual-router hybrid configurations*

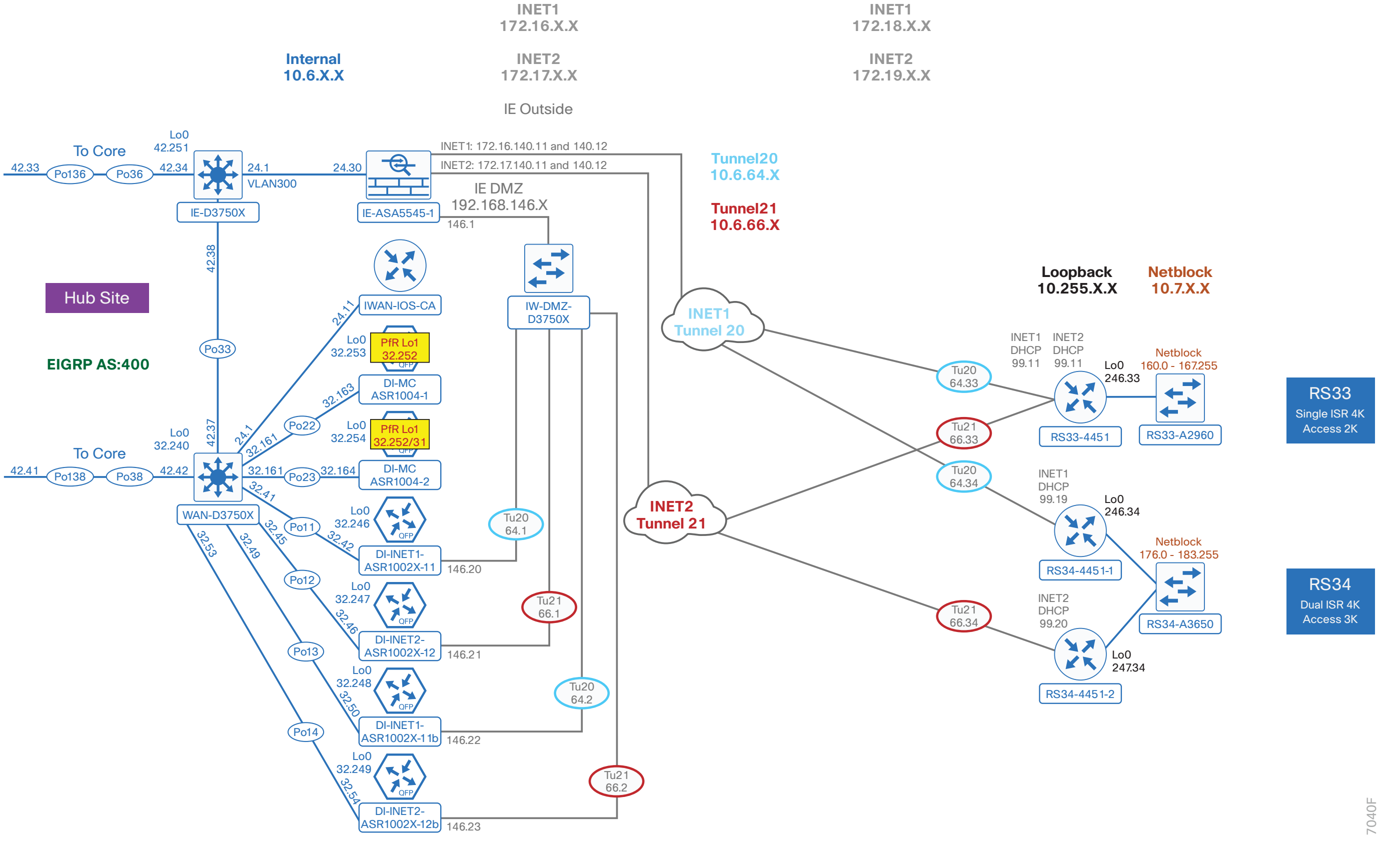


Below are links to the configuration files for both routers in the dual-router hybrid design for BGP with internal employee DIA:

- RS32—Dual-Router, Two-Link, Access (MPLS1, and INET2):
  - RS32-4451-1: MPLS1 WAN link
  - RS32-4451-2: INET2 WAN link

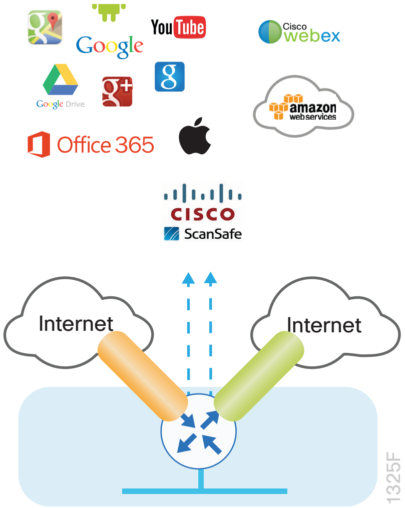
This section includes the remote site configuration files corresponding to the IWAN dual-Internet model, as referenced in the figure below.

Figure 86 *IWAN dual-Internet model for EIGRP*



SINGLE-ROUTER DUAL-INTERNET WITH DIA

Figure 87 Single-router dual-Internet configurations

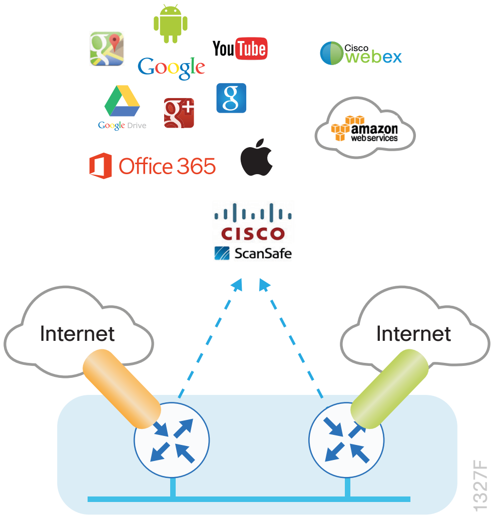


Below is a link to the configuration file for the single-router dual-Internet design for EIGRP with internal employee DIA:

- RS33—Single-Router, Two-Link, Access (INET1 and INET2):
    - RS33-4451: INET1 and INET2 WAN links

DUAL-ROUTER DUAL-INTERNET WITH DIA

Figure 88 Dual-router dual-Internet configurations



Below are links to the configuration files for both routers in the dual-router dual-Internet design for EIGRP with internal employee DIA:

- RS34—Dual-Router, Two-Link, Access (INET1 and INET2):
  - RS34-4451-1: INET1 WAN link
  - RS34-4451-2: INET2 WAN link

Appendix C: DIA with PfR Load-Balancing

Optional

Follow the optional steps in this appendix if your hybrid DIA environment requires PfR load-balancing. The DIA configuration must be completed as specified in the hybrid sections of this guide when implementing the changes listed below.

PROCESS

Configuring DIA with PfR Load-Balancing

1. Configure static IP address, default route and NAT
2. Configure IP next hop tracking
3. Configure policy-based routing

This solution requires policy based routing and a static IP address on the Internet-facing WAN interface.

Procedure 1 Configure static IP address, default route and NAT

Step 1: Configure a static IP address on the Internet-facing WAN interface.

This feature requires a static IP address from your service provider.

```
interface GigabitEthernet0/0/1
 ip address 172.19.98.43 255.255.255.248
```

Step 2: Configure a static default route for the Internet-facing WAN interface.

With a static IP address, you need a static default route in the Internet VRF.

```
ip route vrf IWAN-TRANSPORT-4 0.0.0.0 0.0.0.0 172.19.98.41
```

Step 3: Configure NAT for the Internet-facing WAN interface.

The NAT statement needs to specify the Internet VRF.

```
ip nat inside source route-map NAT interface GigabitEthernet0/0/1 vrf IWAN-
TRANSPORT-4 overload
```

Procedure 2 Configure IP next hop tracking

Step 1: Configure the VRF-aware IPSLA ICMP probe.

Create the ip sla probe using the service providers next-hop gateway IP address and the source interface of the

Internet-facing WAN. Specify the F-VRF for the interface, schedule the sla to start now and run forever.

```
ip sla 13
 icmp-echo 172.19.98.41 source-interface GigabitEthernet0/0/1
 vrf IWAN-TRANSPORT-4
 threshold 500
 frequency 10
ip sla schedule 13 life forever start-time now
```

Step 2: Configure the tracking parameters and logic for the IPSLA ICMP probes..

```
track 13 ip sla 13 reachability
```

Procedure 3 Configure policy-based routing

Step 1: Configure the access list for local LAN to DIA traffic.

Deny traffic to the IP address range defined in your enterprise prefix statement and permit all other traffic destined for the Internet.

```
ip access-list extended LAN-TO-DIA
 deny   ip any 10.4.0.0 0.3.255.255 log
 permit ip any any log
```

Step 2: Configure the route map for LAN to DIA traffic.

Match the traffic using the access list from the previous step. Set the next-hop IP address in the Internet VRF. Verify the next hop IP address is available by using the IPSLA track from the previous procedure.

```
route-map TRAFFIC-TO-PROXY-AND-DIA permit 10
 description Internal PBR-DIA-Fallback
 match ip address LAN-TO-DIA
 set ip vrf IWAN-TRANSPORT-4 next-hop verify-availability 172.19.98.41 1 track 
13
```

Step 3: Apply the route map to the LAN interface.

Apply the route map from the previous step to the LAN-facing interface.

```
interface GigabitEthernet0/0/2.64
 ip policy route-map TRAFFIC-TO-PROXY-AND-DIA
```

The return traffic will follow the same path as the DIA configurations discussed elsewhere in the guide.

Single-Router Hybrid with DIA and PfR Load-balancing

Below is a link to the configuration file for the single-router hybrid design for BGP with internal employee DIA and PfR load-balancing:

- RS31—Single-Router, two-Link, Access (MPLS2 and INET2):
  - RS31-4451: MPLS2 and INET2 WAN links

Appendix D: Changes

This appendix summarizes the changes Cisco made to this guide since its last edition:

- Routing Updates
    - Added iBGP in WAN overlay with OSPF on LAN as an option
- PfR Updates
    - Added a PfR load-balancing example as an optional configuration

Please use the feedback form to send comments and suggestions about this guide.

Americas Headquarters
Cisco Systems, Inc.
San Jose, CA

Asia Pacific Headquarters
Cisco Systems (USA) Pte. Ltd.
Singapore

Europe Headquarters
Cisco Systems International BV Amsterdam,
The Netherlands

Cisco has more than 200 offices worldwide. Addresses, phone numbers, and fax numbers are listed on the Cisco Website at www.cisco.com/go/offices.

ALL DESIGNS, SPECIFICATIONS, STATEMENTS, INFORMATION, AND RECOMMENDATIONS (COLLECTIVELY, “DESIGNS”) IN THIS MANUAL ARE PRESENTED “AS IS,” WITH ALL FAULTS. CISCO AND ITS SUPPLIERS DISCLAIM ALL WARRANTIES, INCLUDING, WITHOUT LIMITATION, THE WARRANTY OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT OR ARISING FROM A COURSE OF DEALING, USAGE, OR TRADE PRACTICE. IN NO EVENT SHALL CISCO OR ITS SUPPLIERS BE LIABLE FOR ANY INDIRECT, SPECIAL, CONSEQUENTIAL, OR INCIDENTAL DAMAGES, INCLUDING, WITHOUT LIMITATION, LOST PROFITS OR LOSS OR DAMAGE TO DATA ARISING OUT OF THE USE OR INABILITY TO USE THE DESIGNS, EVEN IF CISCO OR ITS SUPPLIERS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. THE DESIGNS ARE SUBJECT TO CHANGE WITHOUT NOTICE. USERS ARE SOLELY RESPONSIBLE FOR THEIR APPLICATION OF THE DESIGNS. THE DESIGNS DO NOT CONSTITUTE THE TECHNICAL OR OTHER PROFESSIONAL ADVICE OF CISCO, ITS SUPPLIERS OR PARTNERS. USERS SHOULD CONSULT THEIR OWN TECHNICAL ADVISORS BEFORE IMPLEMENTING THE DESIGNS. RESULTS MAY VARY DEPENDING ON FACTORS NOT TESTED BY CISCO.

Any Internet Protocol (IP) addresses used in this document are not intended to be actual addresses. Any examples, command display output, and figures included in the document are shown for illustrative purposes only. Any use of actual IP addresses in illustrative content is unintentional and coincidental.

© 2016 Cisco Systems, Inc. All rights reserved.

Cisco and the Cisco logo are trademarks or registered trademarks of Cisco and/or its affiliates in the U.S. and other countries. To view a list of Cisco trademarks, go to this URL: www.cisco.com/go/trademarks. Third-party trademarks mentioned are the property of their respective owners. The use of the word partner does not imply a partnership relationship between Cisco and any other company. (1110R)