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SBA

ENTERPRISE

BORDERLESS  
NETWORKS

# Layer 2 WAN Deployment Guide

● ● ● SMART BUSINESS ARCHITECTURE

February 2012 Series

# Preface

## Who Should Read This Guide

This Cisco® Smart Business Architecture (SBA) guide is for people who fill a variety of roles:

- Systems engineers who need standard procedures for implementing solutions
- Project managers who create statements of work for Cisco SBA implementations
- Sales partners who sell new technology or who create implementation documentation
- Trainers who need material for classroom instruction or on-the-job training

In general, you can also use Cisco SBA guides to improve consistency among engineers and deployments, as well as to improve scoping and costing of deployment jobs.

## Release Series

Cisco strives to update and enhance SBA guides on a regular basis. As we develop a new series of SBA guides, we test them together, as a complete system. To ensure the mutual compatibility of designs in Cisco SBA guides, you should use guides that belong to the same series.

All Cisco SBA guides include the series name on the cover and at the bottom left of each page. We name the series for the month and year that we release them, as follows:

**month year** Series

For example, the series of guides that we released in August 2011 are the “August 2011 Series”.

You can find the most recent series of SBA guides at the following sites:

Customer access: <http://www.cisco.com/go/sba>

Partner access: <http://www.cisco.com/go/sbachannel>

## How to Read Commands

Many Cisco SBA guides provide specific details about how to configure Cisco network devices that run Cisco IOS, Cisco NX-OS, or other operating systems that you configure at a command-line interface (CLI). This section describes the conventions used to specify commands that you must enter.

Commands to enter at a CLI appear as follows:

```
configure terminal
```

Commands that specify a value for a variable appear as follows:

```
ntp server 10.10.48.17
```

Commands with variables that you must define appear as follows:

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

Commands shown in an interactive example, such as a script or when the command prompt is included, appear as follows:

```
Router# enable
```

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

```
wrr-queue random-detect max-threshold 1 100 100 100 100 100  
100 100 100
```

Noteworthy parts of system output or device configuration files appear highlighted, as follows:

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

## Comments and Questions

If you would like to comment on a guide or ask questions, please use the forum at the bottom of one of the following sites:

Customer access: <http://www.cisco.com/go/sba>

Partner access: <http://www.cisco.com/go/sbachannel>

An RSS feed is available if you would like to be notified when new comments are posted.

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# What's In This SBA Guide

## About SBA

Cisco SBA helps you design and quickly deploy a full-service business network. A Cisco SBA deployment is prescriptive, out-of-the-box, scalable, and flexible.

Cisco SBA incorporates LAN, WAN, wireless, security, data center, application optimization, and unified communication technologies—tested together as a complete system. This component-level approach simplifies system integration of multiple technologies, allowing you to select solutions that solve your organization's problems—without worrying about the technical complexity.

For more information, see the *How to Get Started with Cisco SBA* document:

[http://www.cisco.com/en/US/docs/solutions/Enterprise/Borderless\\_Networks/Smart\\_Business\\_Architecture/SBA\\_Getting\\_Started.pdf](http://www.cisco.com/en/US/docs/solutions/Enterprise/Borderless_Networks/Smart_Business_Architecture/SBA_Getting_Started.pdf)

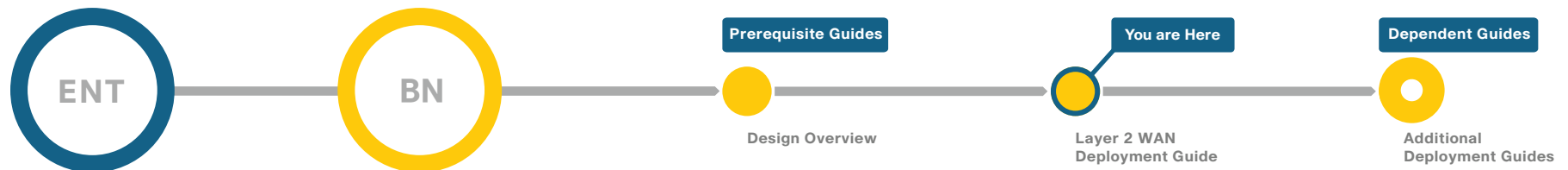
## About This Guide

This *foundation deployment guide* is organized in sections, which each include the following parts:

- **Business Overview**—The challenge your organization faces. Business decision makers can use this part to understand the relevance of the solution to their organizations' operations.
- **Technology Overview**—How Cisco solves the challenge. Technical decision makers can use this part to understand how the solution works.
- **Deployment Details**—Step-by-step instructions for implementing the solution. Systems engineers can use this part to get the solution up and running quickly and reliably.

To learn what changed in this guide between the previous series and the current series, see [Appendix C: Changes](#).

This guide presumes that you have read the prerequisite foundation design overview, as shown on the Route to Success below.



## Route to Success

To ensure your success when implementing the designs in this guide, you should read any guides that this guide depends upon—shown to the left of this guide on the route above. Any guides that depend upon this guide are shown to the right of this guide.

For customer access to all SBA guides: <http://www.cisco.com/go/sba>  
For partner access: <http://www.cisco.com/go/sbachannel>

# Introduction

Cisco SBA for Enterprise Organizations—Borderless Networks is a solid network foundation designed to provide networks with 2,000 to 10,000 connected users the flexibility to support new users or network services without re-engineering the network. We created a prescriptive, out-of-the-box deployment guide that is based on best-practice design principles and that delivers flexibility and scalability.

The foundation architecture is described in a single *Design Guide*, as well as several deployment and configuration guides for each of the three parts of the foundation: LAN, WAN, and Internet Edge.

To help focus on specific elements of the architecture, there are three WAN deployment guides:

- This *Layer 2 WAN Deployment Guide* provides guidance and configuration for a VPLS or Metro Ethernet transport as well as a broadband or Internet transport in a backup role.
- *WAN Deployment Guide* provides flexible guidance and configuration for Multiprotocol Label Switching (MPLS) transport as well as broadband or Internet transport in a backup role.
- *VPN Remote Site Deployment Guide* provides guidance and configuration for broadband or Internet transport in a both a primary or backup role

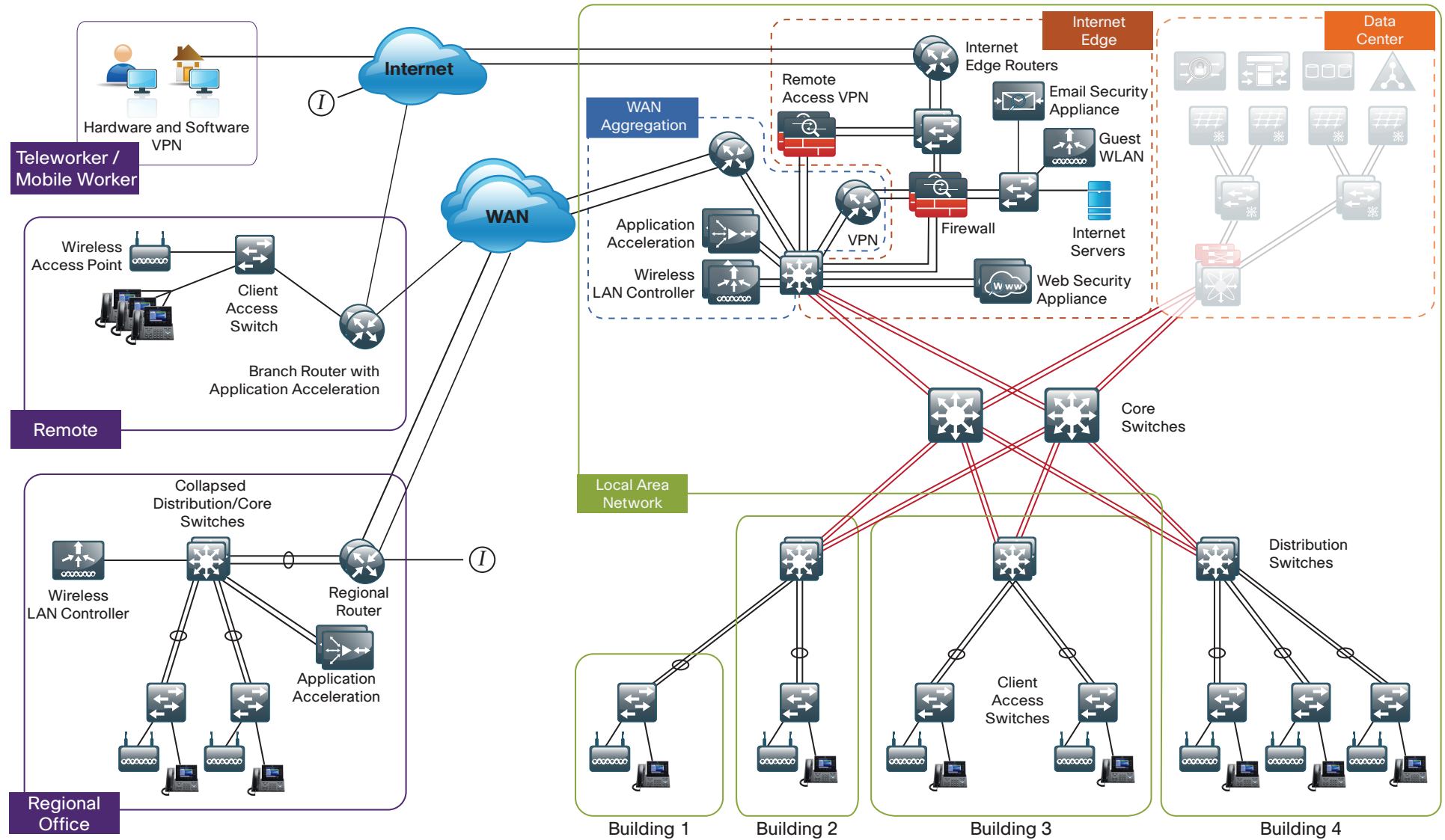
## Related Reading

The *Design Guide* orients you to the overall Cisco SBA design and explains the requirements that were considered when selecting specific products.

The *Local Area Network Deployment Guide* describes wired and wireless network access with ubiquitous capabilities for both the larger campus-size LAN as well as the smaller remote-site LAN. Resiliency, security, and scalability are included to provide a robust communications environment. Quality of service (QoS) is integrated to ensure that the base architecture can support a multitude of applications including low latency, drop-sensitive multimedia applications coexisting with data applications on a single network. The guide also provides a guest and partner access solution that is secured from accessing internal confidential information while using the same wireless infrastructure that employees use.

The *Internet Edge Deployment Guide* focuses on security services, such as firewalls and intrusion prevention systems, that protect your organization's gateway to the Internet. Internet service-provider connectivity and routing options, combined with server load balancing, provide resiliency to the design. This guide's "E-Mail Security" section covers protecting email from spam and malware. The "Web Security" section provides acceptable-use control and monitoring as well as guidance on managing the increasing risk associated with clients browsing the Internet. The Remote Access VPN design supports the teleworker and mobile user with secure remote access. All of these elements are covered in separate sections, yet are designed to work together to provide a secure Internet Edge solution.

Figure 1 - Borderless Networks for Enterprise Organizations Overview





## Design Goals

This architecture is based on requirements gathered from customers, partners, and Cisco field personnel for organizations with 2000 to 10,000 connected users. When designing the architecture, we considered the gathered requirements and the following design goals.

### Ease of Deployment, Flexibility, and Scalability

Organizations with 2000 to 10,000 users are often spread out among different geographical locations, making flexibility and scalability a critical requirement of the network. This design uses several methods to create and maintain a scalable network:

- By keeping a small number of standard designs for common portions of the network, support staff is able to design services for, implement, and support the network more effectively.
- Our modular design approach enhances scalability. Beginning with a set of standard, global building blocks, we can assemble a scalable network to meet requirements.
- Many of the plug-in modules look identical for several service areas; this common look provides consistency and scalability in that the same support methods can be used to maintain multiple areas of the network. These modules follow standard core-distribution-access network design models and use layer separation to ensure that interfaces between the plug-ins are well defined.

### Resiliency and Security

One of the keys to maintaining a highly available network is building appropriate redundancy to guard against failure in the network. The redundancy in our architecture is carefully balanced with the complexity inherent in redundant systems.

With the addition of a significant amount of delay-sensitive and drop-sensitive traffic such as voice and video conferencing, we also place a strong emphasis on recovery times. Choosing designs that reduce the time between failure detection and recovery is important for ensuring that the network stays available even in the face of a minor component failure.

Network security is also a strong component of the architecture. In a large network, there are many entry points and we ensure that 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.

### Ease of Management

While this guide focuses on the deployment of the network foundation, the design takes next phase management and operation into consideration. The configurations in the deployment guides are designed to allow the devices to be managed via normal device management connections, such as SSH and HTTPS, as well as via NMS. The configuration of the NMS is not covered in this guide.

### Advanced Technology–Ready

Flexibility, scalability, resiliency, and security all are characteristics of an advanced technology-ready network. The modular design of the architecture means that technologies can be added when the organization is ready to deploy them. However, the deployment of advanced technologies, such as collaboration, is eased because the architecture includes products and configurations that are ready to support collaboration from day one. For example:

- Access switches provide Power over Ethernet (PoE) for phone deployments without the need for a local power outlet
- The entire network is preconfigured with QoS to support high-quality voice.
- Multicast is configured in the network to support efficient voice and broadcast-video delivery.
- The wireless network is preconfigured for devices that send voice over the wireless LAN, providing IP telephony over 802.11 Wi-Fi (referred to as mobility) at all locations.

The Internet Edge is ready to provide soft phones via VPN, as well as traditional hard or desk phones.

# Architecture Overview

The *Cisco SBA for Enterprise Organizations—Borderless Networks Layer 2 WAN Deployment Guide* provides a design that enables highly available, secure, and optimized connectivity for multiple remote-site LANs.

The WAN is the networking infrastructure that provides an IP-based inter-connection between remote sites that are separated by large geographic distances.

This document shows you how to deploy the network foundation and services to enable the following:

- WAN connectivity for 25 to 100 remote sites
- Primary and secondary links to provide redundant topology options for resiliency
- Data privacy via encryption
- WAN optimization and application acceleration
- Wired and wireless LAN access at all remote sites

## WAN Design

The primary focus of the design is to allow usage of the following commonly deployed WAN transports:

- Layer 2 WAN
- Internet VPN

At a high level, the WAN is an IP network, and these transports can be easily integrated to the design. The chosen architecture designates a primary WAN-aggregation site that is analogous to the hub site in a traditional hub-and-spoke design. This site has direct connections to both WAN transports and high-speed connections to the selected service providers. In addition, the site uses network equipment scaled for high performance and redundancy. The primary WAN-aggregation site is coresident with the data center and usually the primary campus or LAN as well.

## Layer 2 WAN Transport

Ethernet has traditionally been a LAN technology primarily due to the distance limitations of the available media and the requirement for dedicated copper or fiber links.

Layer 2 WAN transports are now widely available from service providers and are able to extend various Layer 2 traffic types (Frame Relay, PPP, ATM, or Ethernet) over a WAN. The most common implementations of Layer 2 WAN are used to provide Ethernet over the WAN using either a point-to-point or point-to-multipoint service.

Service providers implement these Ethernet services by using a variety of methods. MPLS networks support both Ethernet over MPLS (EoMPLS) and Virtual Private LAN Service (VPLS). You can use other network technologies, such as Ethernet switches in various topologies, to provide Ethernet Layer 2 WAN services. These offerings are also referred to as Carrier Ethernet or Metro Ethernet, and they are typically limited to a relatively small geographic area. This guide describes how to use a Layer 2 WAN to interconnect multiple sites independent of the various underlying technologies that are being used by the service providers.

Layer 2 WAN supports an enterprise subscriber model in which the service provider is transparent and the enterprise implements all Layer 3 routing. This allows for flexibility in the WAN design and interconnection of the remote sites.

Point-to-point service allows for the interconnection of two LANs. Point-to-multipoint (multipoint) transparent LAN service allows for the interconnection of more than two LANS. Other service variants include simple and trunked demarcations. By using trunk mode, you can interconnect LANs using 802.1Q VLAN tagging. Service providers often refer to a trunked service as Q-in-Q tunneling (QinQ).

Subscribers who need to transport IP multicast traffic are supported with no additional configuration required by the service provider.

The WAN uses Layer 2 WAN as a primary WAN transport.

Internet as WAN Transport

The Internet is essentially a large-scale public WAN composed of multiple interconnected service providers. The Internet can provide reliable high-performance connectivity between various locations, although it lacks any explicit guarantees for these connections. Despite its “best effort” nature, the Internet is a sensible choice for an alternate WAN transport, or for a primary transport when it is not feasible to connect with another transport option.

Internet connections are typically included in discussions relevant to the Internet edge, specifically for the primary site. Remote-site routers also commonly have Internet connections, but do not provide the same breadth of services using the Internet. For security and other reasons, Internet access at remote sites is often routed through the primary site.

The WAN uses the Internet for VPN site-to-site connections as a backup WAN transport (to Layer 2 WAN).

Dynamic Multipoint VPN

Dynamic Multipoint VPN (DMVPN) is a solution for building scalable site-to-site VPNs that support a variety of applications. DMVPN is widely used for encrypted site-to-site connectivity over public or private IP networks and can be implemented on all WAN routers used in this deployment guide.

DMVPN was selected for the encryption solution for the Internet transport because it supports on-demand full mesh connectivity with a simple hub-and-spoke configuration and a zero-touch hub deployment model for adding remote sites. DMVPN also supports spoke routers that have dynamically assigned IP addresses.

DMVPN makes use of multipoint generic routing encapsulation (mGRE) tunnels to interconnect the hub to all of the spoke routers. These mGRE tunnels are also sometimes referred to as DMVPN clouds in this context. This technology combination supports unicast, multicast, and broadcast IP, including the ability to run routing protocols within the tunnels.

WAN-Aggregation Designs

The WAN-aggregation (hub) designs include two or more WAN edge routers. When WAN edge routers are referred to in the context of the connection to a carrier or service provider, they are typically known as *customer edge (CE) routers*. WAN edge routers that terminate VPN traffic are referred to as VPN hub routers. All of the WAN edge routers connect into a distribution layer.

The WAN transport options include Layer 2 WAN and traditional Internet access. Both transport types connect to either a CE router or a VPN hub router, respectively. Interfacing with each of these transports requires a different connection method and configuration.

There are two WAN-aggregation designs that are documented in this deployment guide: Metro 25 and Metro 100. The primary difference between the Metro 25 and Metro 100 designs is the overall scale of the architecture and the number of broadcast domains or VLANs that are used to communicate with a subset of remote-site routers.

In the WAN-aggregation design, tasks such as IP route summarization are performed at the distribution layer. There are other various devices supporting WAN edge services, and these devices should also connect into the distribution layer.

The Layer 2 WAN service terminates to a dedicated WAN router and a single VPN hub router is used. The various design models are shown in the following table.

Table 1 - WAN-aggregation designs

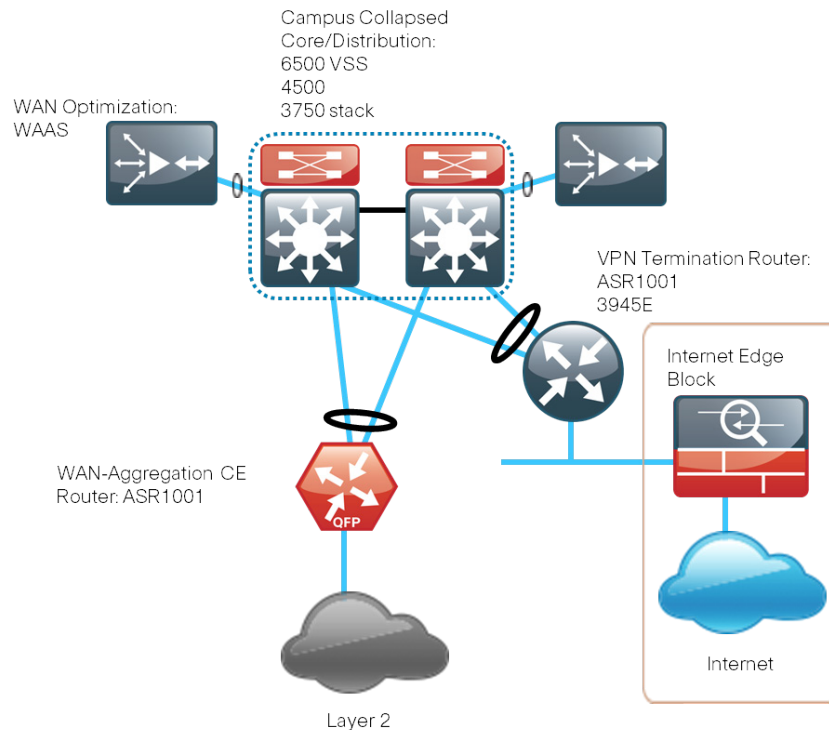
Model	WAN links	Edge routers	Transport 1		Transport 2
			Type	Demarcation	
Metro 25	Dual	Dual	MetroE	simple	Internet VPN
Metro 100	Dual	Dual	MetroE	trunked	Internet VPN

The characteristics of each design are as follows:

### Metro 25 Design

- Has up to 250 Mbps aggregate bandwidth
- Uses a multipoint service
- Connects to a simple demarcation
- Supports up to 25 remote sites
- Uses a single Internet link

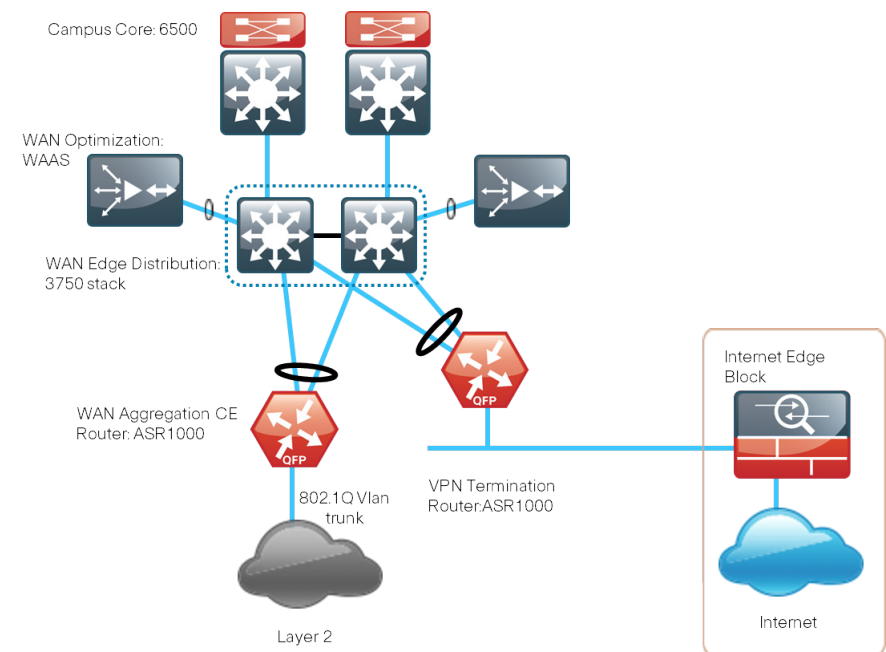
Figure 2 - Metro 25 design



### Metro 100 Design

- Has up to 1 Gbps aggregate bandwidth
- Uses a multipoint service
- Connects to a trunked demarcation
- Supports up to 100 remote sites
- Logically separates the remote-site peering. Distributes router peers across multiple VLANs with maximum of 25 remote-site router peers per VLAN.
- Uses a single Internet link

Figure 3 - Metro 100 design

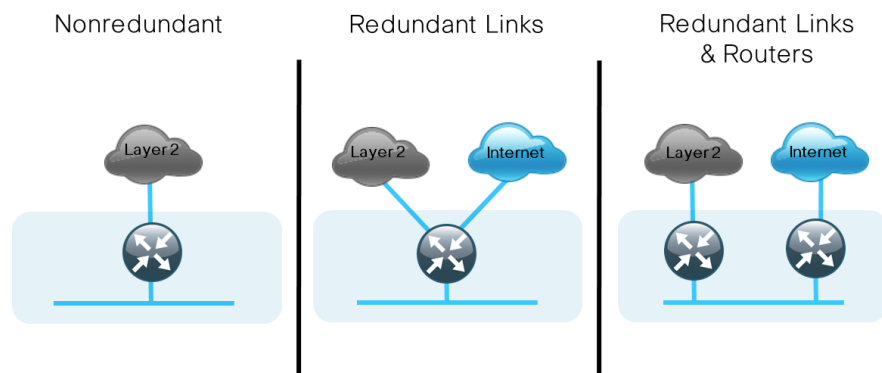




## WAN Remote-Site Designs

This guide documents multiple remote-site WAN designs, and they are based on various combinations of WAN transports mapped to the site specific requirements for service levels and redundancy.

**Figure 4 - WAN remote-site designs**



The remote-site designs include single or dual WAN edge routers. These can be either a CE router or a VPN spoke router. In some cases, a single WAN edge router can perform the role of both a CE router and VPN-spoke router. Most 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 overall WAN design methodology is based on a primary WAN-aggregation site design that can accommodate all of the remote-site types that map to the various link combinations listed in the following table.

**Table 2 - WAN remote-site transport options**

WAN remote-site routers	WAN transports	Primary transport	Secondary transport
Single	Single	MetroE (simple)	-
Single	Single	MetroE (trunked)	-
Single	Dual	MetroE (simple)	Internet
Single	Dual	MetroE (trunked)	Internet
Dual	Dual	MetroE (simple)	Internet
Dual	Dual	MetroE (trunked)	Internet

The modular nature of the network design enables you to create design elements that you can replicate throughout the network.

Both WAN-aggregation designs and all of the WAN remote-site designs are standard building blocks in the overall design. Replication of the individual building blocks provides an easy way to scale the network and allows for a consistent deployment method.

## WAN/LAN Interconnection

The primary role of the WAN is to interconnect primary site and remote-site LANs. The LAN discussion within this guide is limited to how the WAN aggregation site LAN connects to the WAN aggregation devices and how the remote-site LANs connect to the remote-site WAN devices. Specific details regarding the LAN components of the design are covered in the *Cisco SBA for Enterprise Organizations—Borderless Networks LAN Deployment Guide*.

At remote sites, the LAN topology depends on the number of connected users and physical geography of the site. Large sites may require the use of a distribution layer to support multiple access layer switches. Other sites may only require an access layer switch directly connected to the WAN remote-site routers. The variants that are tested and documented in this guide are shown in the following table.

**Table 3 - WAN remote-site LAN options**

WAN remote-site routers	WAN transports	LAN topology
Single	Single	Access only Distribution/access
Single	Dual	Access only Distribution/access
Dual	Dual	Access only Distribution/access

## WAN Remote Sites—LAN Topology

For consistency and modularity, all WAN remote sites use the same VLAN assignment scheme, which is shown in the following table. This deployment guide uses a convention that is relevant to any location that has a single access switch and this model can also be easily scaled to additional access closets through the addition of a distribution layer.

**Table 4 - WAN remote-sites—VLAN assignment**

VLAN	Usage	Layer 2 access	Layer 3 distribution/ access
VLAN 100	Data (primary)	Unused	Yes
VLAN 65	Wireless data	Yes	Yes
VLAN 70	Wireless voice	Yes	Yes
VLAN 64	Data 1	Yes	Yes
VLAN 69	Voice 1	Yes	Yes
Unassigned	Data 2	Unused	Yes
Unassigned	Voice 2	Unused	Yes
VLAN99	Transit	Yes (dual router only)	Yes (dual router only)
VLAN50	Router link (1)	Unused	Yes
VLAN54	Router link (2)	Unused	Yes (dual router only)

## Layer 2 Access

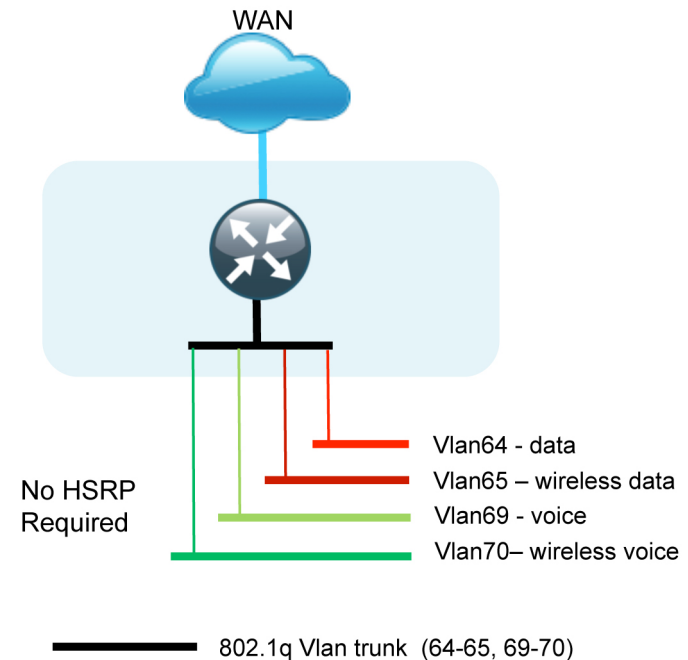
WAN remote sites that do not require additional distribution layer routing devices are considered to be flat, or from a LAN perspective they are considered unrouted Layer 2 sites. All Layer 3 services are provided by the attached WAN routers. The access switches, through the use of multiple VLANs, can support services such as data (wired and wireless) and voice (wired and wireless). The design shown in the following figure illustrates the standardized VLAN assignment scheme. The benefits of this design are clear: all of the access switches can be configured identically, regardless of the number of sites in this configuration.

Access switches and their configuration are not included in this guide. The *Cisco SBA for Enterprise Organizations—Borderless Networks LAN Deployment Guide* provides configuration details on the various access switching platforms.

IP subnets are assigned on a per-VLAN basis. This design only allocates subnets with a 255.255.255.0 netmask for the access layer, even if less than 254 IP addresses are required. (This model can be adjusted as necessary to other IP address schemes.) The connection between the router and the access switch must be configured for 802.1Q VLAN trunking with

subinterfaces on the router that map to the respective VLANs on the switch. The various router subinterfaces act as the IP default gateways for each of the IP subnet and VLAN combinations.

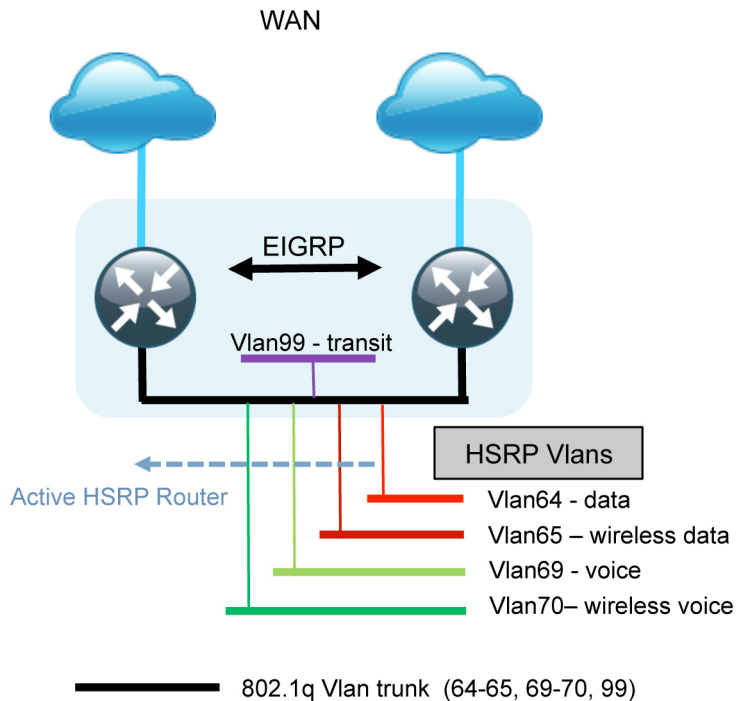
**Figure 5 - WAN remote site flat Layer 2 LAN (single router)**



A similar LAN design can be extended to a dual-router edge as shown in the following figure. This design change introduces some additional complexity. The first requirement is to run a routing protocol. You need to configure the Enhanced Interior Gateway Routing Protocol (EIGRP) between the routers. For consistency with the primary site LAN, use EIGRP process 100.

Because there are now two routers per subnet, a First Hop Redundancy Protocol (FHRP) must be implemented. For this design, Cisco selected Hot Standby Router Protocol (HSRP) as the FHRP. HSRP is designed to allow for transparent failover of the first-hop IP router. HSRP provides high network availability by providing first-hop routing redundancy for IP hosts configured with a default gateway IP address. HSRP is used in a group of routers for selecting an active router and a standby router. When there are multiple routers on a LAN, the active router is the router of choice for routing packets; the standby router is the router that takes over when the active router fails or when preset conditions are met.

Figure 6 - WAN remote site—Flat Layer 2 LAN (dual router)



Enhanced Object Tracking (EOT) provides a consistent methodology for various router and switching features to conditionally modify their operation based on information objects available within other processes. The objects that can be tracked include interface line protocol, IP route reachability, and IP service-level agreement (SLA) reachability as well as several others.

The IP SLA feature provides a capability for a router to generate synthetic network traffic that can be sent to a remote responder. The responder can be a generic IP endpoint that can respond to an Internet Control Message Protocol (ICMP) echo (ping) request, or can be a Cisco router running an IP SLA responder process, that can respond to more complex traffic such as jitter probes. The use of IP SLA allows the router to determine end-to-end reachability to a destination and also the roundtrip delay. More complex probe types can also permit the calculation of loss and jitter along the path. IP SLA is used in tandem with EOT within this design.

To improve convergence times after a Layer 2 WAN failure, HSRP has the capability to monitor the reachability of a next-hop IP neighbor through the use of EOT and IP SLA. This combination allows for a router to give up its

HSRP Active role if its upstream neighbor becomes unresponsive and that provides additional network resiliency.

HSRP is configured to be active on the router with the highest priority WAN transport. EOT of IP SLA probes is implemented in conjunction with HSRP so that in the case of WAN transport failure, the standby HSRP router associated with the lower priority (alternate) WAN transport becomes the active HSRP router. The IP SLA probes are sent from the remote-site CE router to the WAN-aggregation CE router to ensure reachability of the next hop router. This is more effective than simply monitoring the status of the WAN interface.

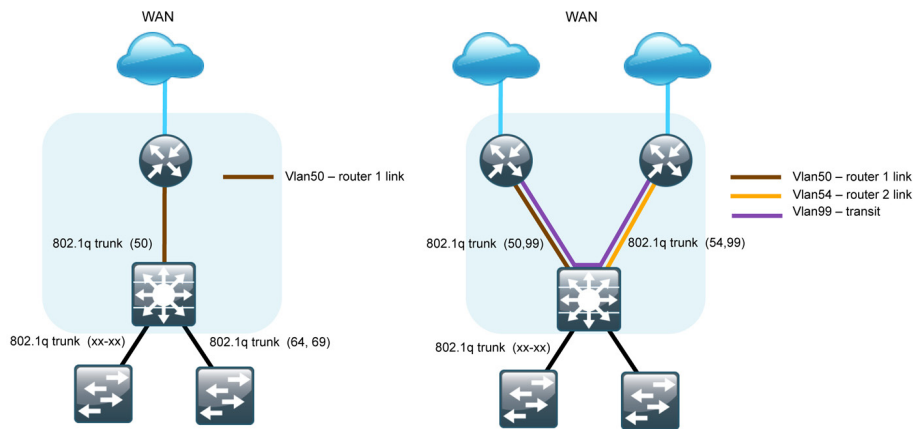
The dual router designs also warrant an additional component that is required for proper routing in certain scenarios. In these cases, a traffic flow from a remote-site host might be sent to a destination reachable via the alternate WAN transport (for example, a Layer 2 + DMVPN remote site communicating with a DMVPN-only remote site). The primary WAN transport router then forwards the traffic out the same data interface to send it to the alternate WAN transport router, which then forwards the traffic to the proper destination. This is referred to as hair-pinning.

The appropriate method to avoid sending the traffic out the same interface is to introduce an additional link between the routers and designate the link as a transit network (VLAN 99). There are no hosts connected to the transit network, and it is only used for router-router communication. The routing protocol runs between router subinterfaces assigned to the transit network. No additional router interfaces are required with this design modification because the 802.1Q VLAN trunk configuration can easily accommodate an additional subinterface.

## Distribution and Access Layer

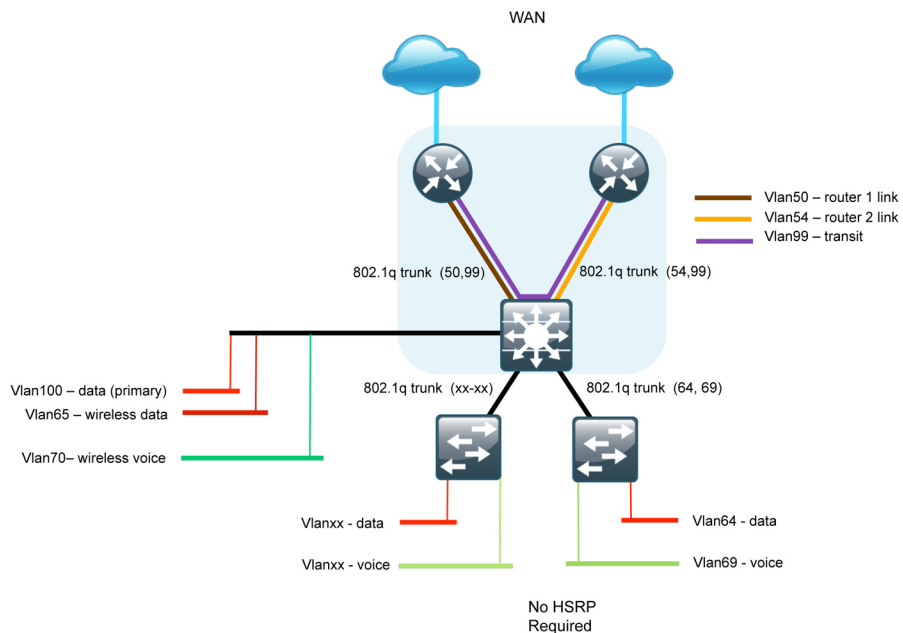
Large remote sites may require a LAN environment similar to that of a small campus LAN that includes a distribution layer and access layer. This topology works well with either a single or dual router WAN edge. To implement this design, the routers should connect via EtherChannel links to the distribution switch. These EtherChannel links are configured as 802.1Q VLAN trunks, to support both a routed point-to-point link to allow EIGRP routing with the distribution switch, and in the dual router design, to provide a transit network for direct communication between the WAN routers.

Figure 7 - WAN remote site—Connection to Distribution Layer



The distribution switch handles all access layer routing, with VLANs trunked to access switches. No HSRP is required when the design includes a distribution layer. A full distribution and access layer design is shown in the following figure.

Figure 8 - WAN remote site—Distribution and access layer (dual router)



## IP Multicast

IP Multicast allows a single IP data stream to be replicated by the infrastructure (routers and switches) and sent from a single source to multiple receivers. IP Multicast is much more efficient than multiple individual unicast streams or a broadcast stream that would propagate everywhere. IP telephony Music On Hold (MOH) and IP video broadcast streaming are two examples of IP Multicast applications.

To receive a particular IP Multicast data stream, end hosts must join a multicast group by sending an Internet Group Management Protocol (IGMP) message to their local multicast router. In a traditional IP multicast design, the local router consults another router in the network that is acting as a rendezvous point (RP) to map the receivers to active sources so that they can join their streams.

The RP is a control-plane operation that should be placed in the core of the network or close to the IP Multicast sources on a pair of Layer 3 switches or routers. IP Multicast routing begins at the distribution layer if the access layer is Layer 2 and provides connectivity to the IP Multicast RP. In designs without a core layer, the distribution layer performs the RP function.

This design is fully enabled for a single global scope deployment of IP Multicast. The design uses an Anycast RP implementation strategy. This strategy provides load sharing and redundancy in Protocol Independent Multicast sparse mode (PIM SM) networks. Two RPs share the load for source registration and the ability to act as hot backup routers for each other.

The benefit of this strategy from the WAN perspective is that all IP routing devices within the WAN use an identical configuration referencing the Anycast RPs. IP PIM SM is enabled on all interfaces including loopbacks, VLANs, and subinterfaces.



## Quality of Service

Most users perceive the network as just a transport utility mechanism to shift data from point A to point B as fast as it can. Many sum this up as just “speeds and feeds.” While it is true that IP networks forward traffic on a best-effort basis by default, this type of routing only works well for applications that adapt gracefully to variations in latency, jitter, and loss. However networks are multiservice by design and support real-time voice and video as well as data traffic. The difference is that real-time applications require packets to be delivered within specified loss, delay, and jitter parameters.

In reality, the network affects all traffic flows and must be aware of end-user requirements and services being offered. Even with unlimited bandwidth, time-sensitive applications are affected by jitter, delay, and packet loss. Quality of service (QoS) enables a multitude of user services and applications to coexist on the same network.

Within the architecture, there are wired and wireless connectivity options that provide advanced classification, prioritizing, queuing and congestion mechanisms as part of the integrated QoS to help ensure optimal use of network resources. This functionality allows for the differentiation of applications, ensuring that each application has an appropriate share of the network resources to protect the user experience and ensure the consistent operation of business critical applications.

QoS is an essential function of the network infrastructure devices used throughout this architecture. QoS enables a multitude of user services and applications, including real-time voice, high-quality video, and delay-sensitive data to coexist on the same network. For the network to provide predictable, measurable, and sometimes guaranteed services, it must manage bandwidth, delay, jitter, and loss parameters. Even if you do not require QoS for your current applications, you can use QoS for management and network protocols to protect the network functionality and manageability under normal and congested traffic conditions.

The goal of this design is to provide sufficient classes of service to allow you to add voice, interactive video, critical data applications, and management traffic to the network, either during the initial deployment or later with minimum system impact and engineering effort.

The QoS classifications in the following table are applied throughout this design.

*Table 5 - QoS service class mappings*

Service class	Per-hop behavior (PHB)	Differentiated services code point (DSCP)	IP Precedence (IPP)	Class of service (CoS)
Network layer	Layer 3	Layer 3	Layer 3	Layer 2
Network control	CS6	48	6	6
Telephony	EF	46	5	5
Signaling	CS3	24	3	3
Multimedia conferencing	AF41, 42, 43	34, 36, 38	4	4
Real-time interactive	CS4	32	4	4
Multimedia streaming	AF31, 32, 34	26, 28, 30	3	3
Broadcast video	CS5	40	4	4
Low-latency data	AF21, 22, 23	18, 20, 22	2	2
Operation, administration, and maintenance (OAM)	CS2	16	2	2
Bulk data	AF11, 12, 13	10, 12, 14	1	1
Scavenger	CS1	8	1	1
Default “best effort”	DF	0	0	0

## WAN Optimization

Cisco Wide Area Application Services (WAAS) is a comprehensive WAN optimization solution that accelerates applications over the WAN, delivers video to a remote office, and provides local hosting of remote-site IT services. Cisco WAAS allows applications to be centralized and to use storage in the data center while maintaining LAN-like application performance.

WAAS accelerates applications and data over the WAN, optimizes bandwidth, empowers cloud computing, and provides local hosting of remote-site IT services, all with industry-leading network integration. Cisco WAAS allows IT organizations to centralize applications and storage while maintaining productivity for remote-site and mobile users.

WAAS is centrally managed and requires one or more Cisco WAAS Central Manager devices that are physically located within the data center but are accessible via a web interface.

The design for optimizing WAN traffic requires the deployment of Cisco Wide Area Application Engine (WAE) appliances or modules at both the WAN aggregation site and at the WAN remote sites. The WAEs run WAAS software that provides the WAN optimization services. The design requires one or more WAE devices at every location, with multiple devices located at a site to provide resiliency. The Cisco WAAS solution operates as a TCP proxy that integrates transparently with other services in the network and provides WAN optimization benefits to the end users, without creating optimization tunnels across the WAN.

The WAN optimization solution is tightly integrated with the WAN routers, with the routers controlling the interception and redirection of traffic to be optimized with WAAS. The design places the WAE appliances on existing network segments, which removes the need for significant network modifications.

A successful WAAS implementation requires the following:

- A method for intercepting chosen traffic to or from the WAN
- The ability to direct the chosen traffic to the WAE devices for proper optimization
- The ability for the WAE to reinject optimized traffic into the network after optimization

Web Cache Communication Protocol (WCCP) is used on the routers to intercept traffic entering the router from the LAN (sourced from the client or the data center) or entering the router from the WAN (from a remote WAE). As part of the WCCP redirection, traffic is forwarded to a chosen WAE via a generic routing encapsulation (GRE) tunnel.

Multiple WAE devices at one location can operate as a cluster. The routers performing the WCCP redirection are responsible for load sharing across the various WAE devices within a cluster. WAAS high availability uses what is referred to as an N+1 model. This name means that if N equivalent devices are required to support the required performance, one additional device is required to provide redundancy.

Traffic to be reinjected into the network uses a negotiated return WCCP GRE tunnel egress method back to the originating router. This method is preferred because it allows the WAE appliances to be located one or more routed hops away from the WCCP router. There are several benefits associated with this method, which are covered in more detail in the following sections.

# Deploying the WAN

## Overall WAN Architecture Design Goals

### IP Routing

The design has the following IP routing goals:

- Provide optimal routing connectivity from primary WAN aggregation sites to all remote locations
- Isolate WAN routing topology changes from other portions of the network
- Ensure active/standby symmetric routing when multiple paths exist, for ease of troubleshooting and to prevent oversubscription of IP telephony Call Admission Control (CAC) limits
- Provide site-site remote routing via the primary WAN aggregation site (hub-and-spoke model)
- Permit optimal direct site-site remote routing when carrier services allow (spoke-to-spoke model)
- Support IP Multicast sourced from the primary WAN aggregation site

At the WAN remote sites, there is no local Internet access for web browsing or cloud services. This model is referred to as a centralized Internet model. It is worth noting that sites with Internet/DMVPN for backup transport could potentially provide local Internet capability; however, for this design, only encrypted traffic to other DMVPN sites is permitted to use the Internet link. In the centralized Internet model, a default route is advertised to the WAN remote sites in addition to the internal routes from the data center and campus.

### LAN Access

All remote sites are to support both wired and wireless LAN access.

### High Availability

The network must tolerate single failure conditions including the failure of any single WAN transport link or any single network device at the primary WAN aggregation site.

- Remote sites classified as single-router, dual-link must be able to tolerate the loss of either WAN transport.
- Remote sites classified as dual-router, dual-link must be able to tolerate the loss of either an edge router or a WAN transport.

### Path Selection Preferences

There are many potential traffic flows based on which WAN transports are in use and whether or not a remote site is using a dual WAN transport. The single WAN transport routing functions as follows.

The Layer 2 WAN-connected site:

- Connects to a site on the Layer 2 WAN (same VLAN); the optimal route is direct within the Layer 2 WAN (traffic is not sent to the primary site).
- Connects to any other site; the route is through the primary site.

The use of the dual WAN transports is specifically tuned to behave in an active/standby manner. This type of configuration provides symmetric routing, with traffic flowing along the same path in both directions. Symmetric routing simplifies troubleshooting because bidirectional traffic flows always traverse the same links.

The design assumes that the Layer 2 WAN transport is designated as the primary transport, which is the preferred path in most conditions.

Layer 2 WAN + DMVPN dual-connected site:

- Connects to a site on the Layer 2 WAN (same VLAN); the optimal route is direct within the Layer 2 WAN (traffic is not sent to the primary site).
- Connects to any DMVPN single-connected site; the optimal route is direct within the DMVPN (only initial traffic is sent to the DMVPN hub, and then it is cut through via spoke-spoke tunnel).
- Connects to any other site; the route is through the primary site

## Data Privacy (Encryption)

All remote-site traffic must be encrypted when transported over public IP networks such as the Internet.

The use of encryption should not limit the performance or availability of a remote-site application, and should be transparent to end users.

## Quality of Service (QoS)

The network must ensure that business applications perform across the WAN during times of network congestion. Traffic must be classified and queued and the WAN connection must be shaped to operate within the capabilities of the connection. This is referred to as hierarchical QoS (HQoS). When the WAN design uses a service provider offering with QoS, the WAN edge QoS classification and treatment must align to the service provider offering to ensure consistent end-to-end QoS treatment of traffic.

Any multipoint WAN service that supports differing access speeds is susceptible to traffic overruns. Layer 2 WAN transports may be implemented with inherent QoS capabilities by the service provider, but this design assumes that the responsibility for implementing QoS falls on the subscriber and must be configured on all WAN Layer 2 CE devices.

The primary difference between the Layer 2 WAN transport QoS model and other SBA WAN QoS is specific to the WAN-aggregation CE router only. This router performs traffic-shaping both at the physical interface level and on a per-remote-site basis. This is referred to as HQoS with nested traffic-shaping.

## Application Optimization

Most business application traffic from the WAN-aggregation site to any remote site, or any traffic from a remote site to any other remote site, should be optimized.

The use of application optimization should be transparent to end users. The application optimization design should include high-availability components to complement other high-availability components of the WAN design.

## Design Parameters

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

*Table 6 - Universal design parameters*

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



# Deploying a Layer 2 WAN

## Business Overview

For remote-site users to effectively support the business, organizations require that the WAN provide sufficient performance and reliability. Although most of the applications and services that the remote-site worker uses are centrally located, the WAN design must provide the workforce with a common resource-access experience, regardless of location.

Major market drivers for Layer 2 WAN services include surging bandwidth requirements and the increased availability of Ethernet building terminations. Carriers have the flexibility to provision bandwidth in flexible increments and deploy these services over their existing infrastructure.

To control operational costs, the WAN must support the convergence of voice, video, and data transport onto a single, centrally managed infrastructure. Layer 2 WAN services provide high-performance, cost-effective, and reliable services within metropolitan areas and, in some cases, for broader geographic areas. The ubiquity of carrier-provided Layer 2 WAN networks makes it a required consideration for an organization building a WAN.

To reduce the time needed to deploy new technologies that support emerging business applications and communications, the WAN architecture requires a flexible design. The ability to easily scale bandwidth or to add additional sites or resilient links makes Layer 2 WAN an effective WAN transport for growing organizations.

## Technology Overview

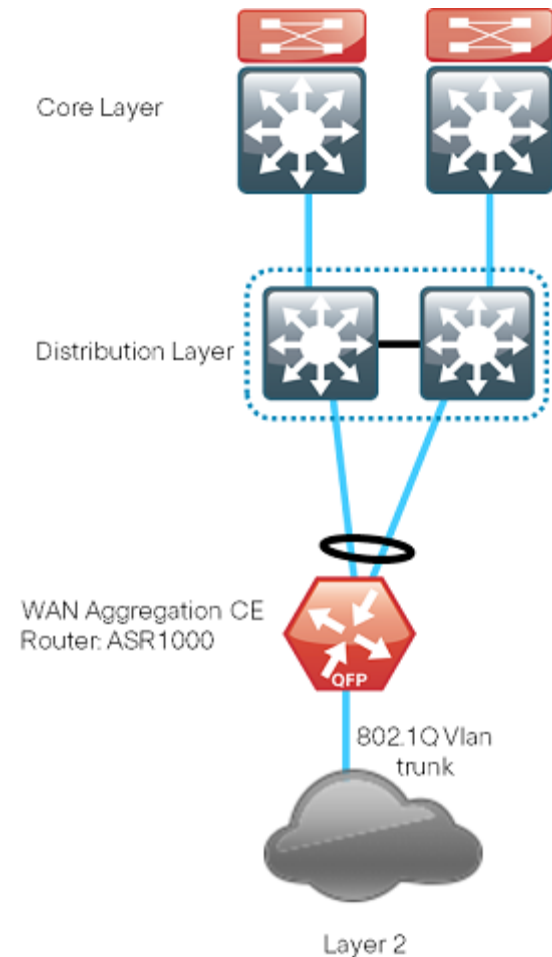
### Metro 100 Design

The Metro 100 design is intended to support up to 100 remote sites with a combined aggregate WAN bandwidth of up to 1.0 Gbps. The most critical devices are the WAN routers that are responsible for reliable IP forwarding and QoS. This design uses the Cisco ASR1002 Aggregation Services Router configured with an Embedded Service Processor 5 (ESP5) for the WAN-aggregation Layer 2 WAN CE router.

The Metro 100 design uses a single Layer 2 WAN carrier and WAN-aggregation CE router. The demarcation uses an 802.1Q encapsulation to provide multiple VLAN support.

The Cisco ASR 1000 Series Aggregation Services Routers represent the next-generation, modular, services-integrated Cisco routing platform. They are specifically designed for WAN aggregation, with the flexibility to support a wide range of 3- to 16-mpps packet-forwarding capabilities, 2.5- to 40-Gbps system bandwidth performance, and scaling. The Cisco ASR 1000 Series is fully modular from both hardware and software perspectives, and the routers have all the elements of a true carrier-class routing product that serves both enterprise and service provider networks.

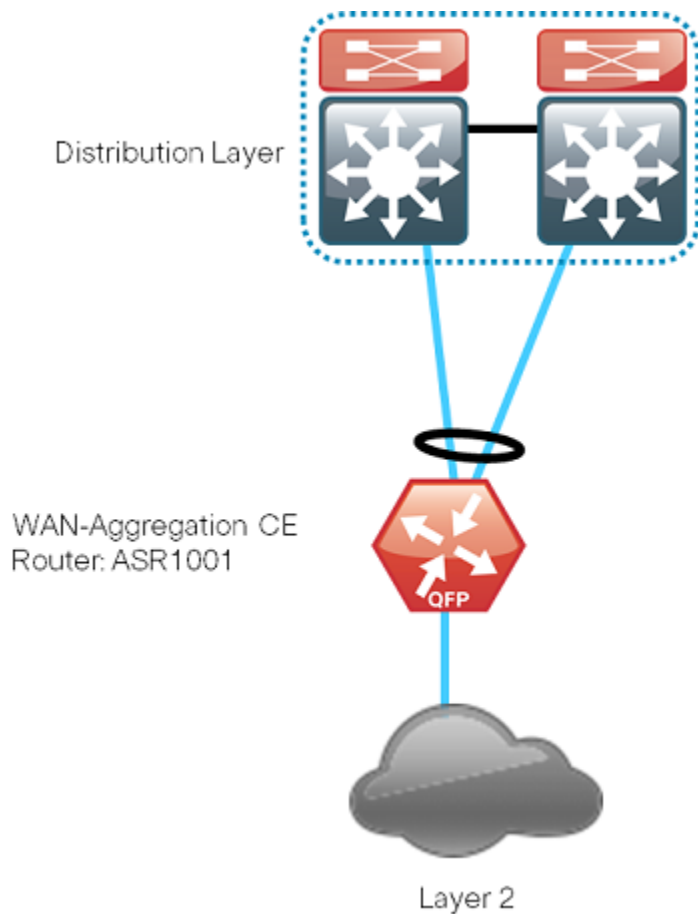
*Figure 9 - Metro 100 design—Layer 2 WAN connection*



### Metro 25 Design

The Metro 25 design is intended to support up to 25 remote sites with a combined aggregate WAN bandwidth of up to 250 Mbps. The Metro 25 design is essentially a smaller version of the Metro 100 design. This variant is included to provide a limited scale option. If further growth in bandwidth or an increase in the number of sites is expected, you should use the Metro 100 design. Using the larger design can prevent unnecessary downtime associated with a change to the primary site demarcation or a device upgrade. This design uses the ASR 1001 for the WAN-aggregation Layer 2 WAN CE router. The Metro 25 design uses a single Layer 2 WAN carrier and a single WAN-aggregation CE router. The demarcation uses simple access mode.

Figure 10 - Metro 25 design—Layer 2 WAN connection



### Remote Sites—CE Router Selection

The actual WAN remote-site routing platforms remain unspecified because the specification is tied closely to the bandwidth required for a location and the potential requirement for the use of service module slots. The ability to implement this solution with a variety of potential router choices is one of the benefits of a modular design approach.

There are many factors to consider in the selection of the WAN remote-site routers. Among those, and key to the initial deployment, is the ability to process the expected amount and type of traffic. You also need to make sure that you have enough interfaces, enough module slots, and a properly licensed Cisco IOS® Software image that supports the set of features that is required by the topology. Cisco tested four integrated service router models as Layer 2 WAN CE routers and the expected performance is shown in the following table.

Table 7 - WAN remote-site integrated service router options

Option	2911	2921	3925	3945
Ethernet WAN with services <sup>1</sup>	35 Mbps	50 Mbps	100 Mbps	150 Mbps
On-board GE ports	3	3	3	3
Service module slots <sup>2</sup>	1	1	2	4
Redundant power supply option	No	No	Yes	Yes

#### Notes:

1. The performance numbers are conservative numbers obtained when the router is passing IMIX traffic with heavy services configured and the CPU utilization is under 75 percent.
2. Some service modules are double-wide.

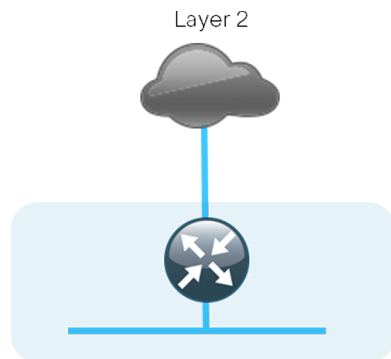
The CE routers at the WAN remote sites connect in the same manner as the WAN aggregation CE router at the WAN-aggregation site. Depending on the service provider, the demarcation may be simple access mode or 802.1Q trunk mode. It is not necessary to use multiple VLANs for connecting the remote-site routers, so if you are using a trunked demarcation, only a single VLAN should be necessary.

The single link Layer 2 WAN remote site is the most basic of building blocks for any remote location. You can use this design with the CE router connected directly to the access layer, or you can use it to support a more complex LAN topology by connecting the CE router directly to a distribution layer.

The IP routing is straightforward and can be handled entirely by using static routes at the WAN-aggregation site and static default routes at the remote site. However, there is significant value to configuring this type of site with dynamic routing.

Dynamic routing makes it easy to add or modify IP networks at the remote site because any changes are immediately propagated to the rest of the network. No configuration changes are required on the WAN-aggregation CE router or on other remote-site CE routers when you use dynamic routing.

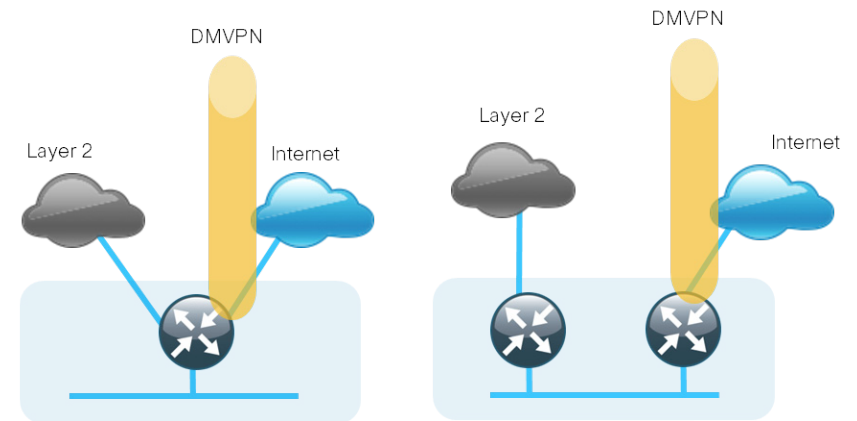
*Figure 11 - Layer 2 WAN remote site (single-router, single-link)*



You can augment the basic single-link design by adding an alternate WAN transport that uses DMVPN over Internet and either connects on the same router or on an additional router. By adding an additional link, you provide the first level of high availability for the remote site. The router can automatically detect failure of the primary link and reroute traffic to the secondary path. It is mandatory to run dynamic routing when there are multiple paths. The routing protocols are tuned to ensure that the desired traffic flows.

The dual-router, dual-link design continues to improve upon the level of high availability for the site. This design can tolerate the loss of the primary router because the secondary router reroutes traffic via the alternate path.

*Figure 12 - Layer 2 WAN + DMVPN remote site (dual-link options)*



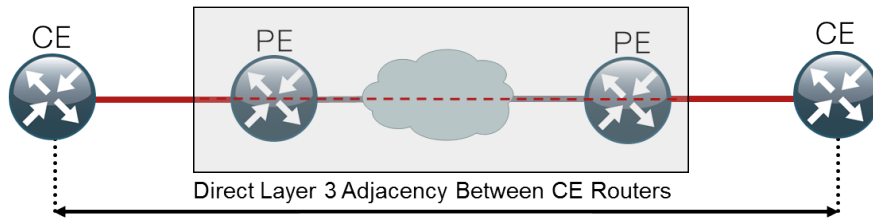
### Design Details

The WAN-aggregation CE router connects to a resilient switching device in the distribution layer. All devices use EtherChannel connections consisting of two port bundles. This design provides both resiliency and additional forwarding performance. You can accomplish additional forwarding performance by increasing the number of physical links within an EtherChannel.

The Layer 2 WAN transport is explicitly focused on providing an Ethernet WAN service, so it is not relevant to document media types other than Ethernet.

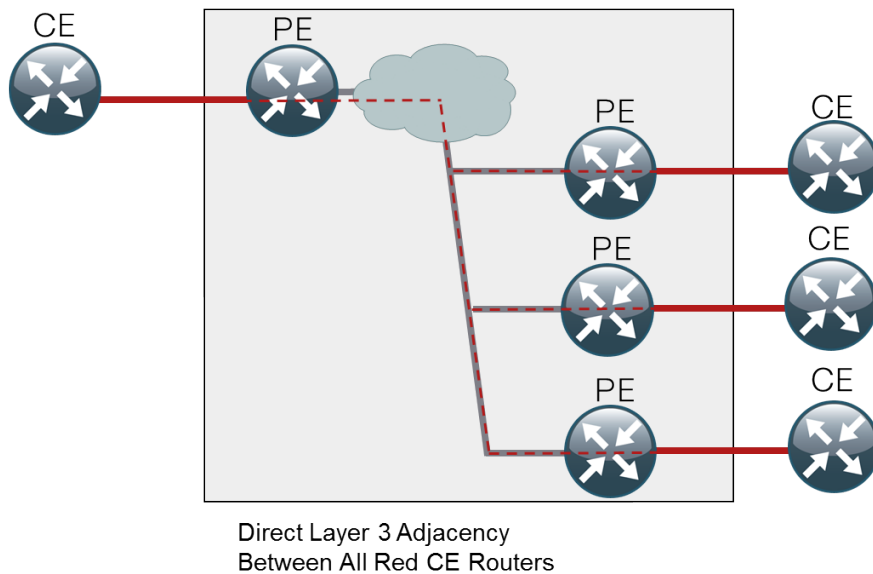
A Layer 2 WAN requires a link between a provider edge (PE) router and a CE router. However, the Layer 2 WAN PE routers are transparent from a Layer 3 perspective so the WAN-aggregation and remote-site CE routers are considered IP neighbors across the WAN link. CE routers are able to directly communicate with other CE routers across the Layer 2 WAN (CE-CE connections).

Figure 13 - Layer 2 WAN simple point-to-point



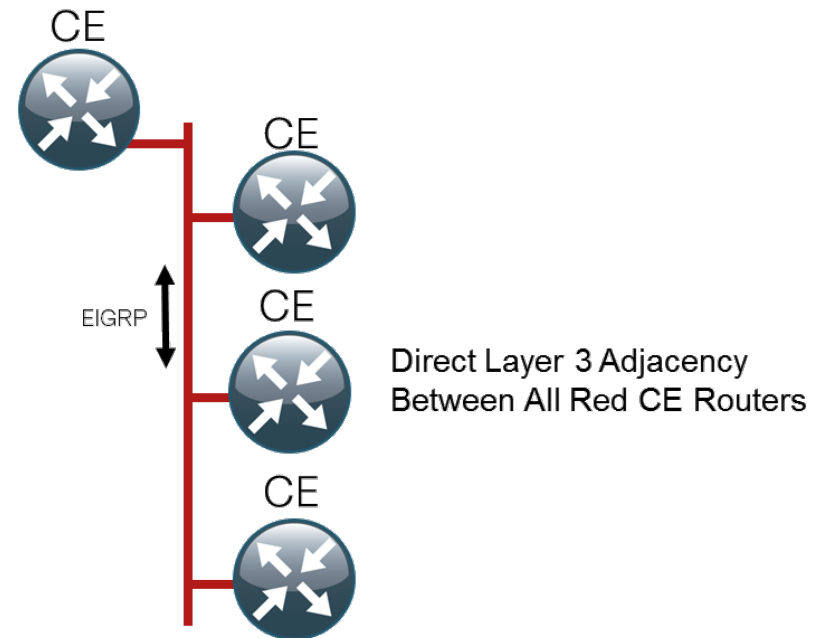
A service provider implements a multipoint Layer 2 WAN by extending the broadcast domain to multiple locations each with a corresponding PE router and attached CE router. A discussion of the underlying technologies used by the service provider to provision this service is beyond the scope of this guide. Cisco did not test the PE routers and their configurations are not included in this guide.

Figure 14 - Layer 2 WAN simple point-to-multipoint



The device connections to a multipoint Layer 2 WAN transport are logically equivalent to the connections to a shared Ethernet segment. The service provider devices are transparent to the subscriber's CE routers. All CE routers are able to directly communicate with each other as if they were on the same LAN.

Figure 15 - Layer 2 WAN simple point-to-multipoint (logical view)



The CE routers are the only devices required to have IP-routing information to provide end-to-end reachability. No IP-routing information is required to be shared with the service provider. Maintaining this routing information typically requires a routing protocol, and we chose EIGRP for this purpose. The various CE routers advertise their routes to other CE router peers.

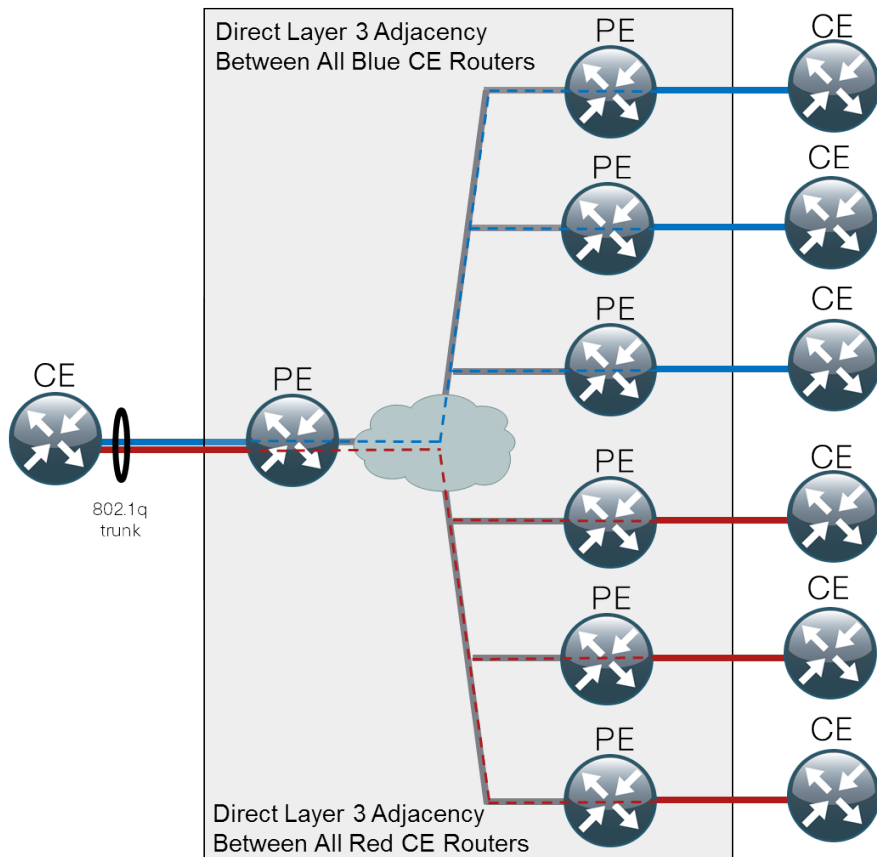
As the number of CE devices increases, there is a corresponding increase in the number of routing protocol neighbors sending and receiving updates to each other. There is a performance impact on the routers' CPU associated with the processing of the updates from the additional neighbors. This impact is most significant on the remote-site Layer 2 WAN CE routers, which are not designed to accommodate large numbers of routing protocol neighbors.

The limiting factor in the number of routing protocol neighbors on a broadcast media is the processing capability of the smallest router's CPU.

There are a variety of methods that can be used to limit the number of neighbors. It is straightforward to use VLANs in the Layer 2 WAN to isolate the remote-site Layer 2 WAN CE routers from each other. The primary difference is the use of a trunked demarcation which allows the use of 802.1Q

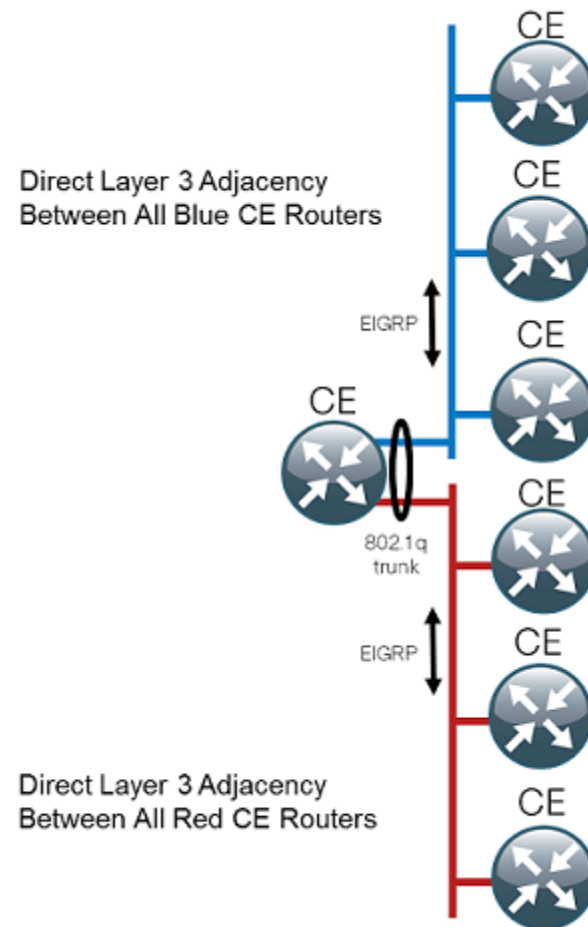
tagged Ethernet frames. The service provider can provide this additional capability over the same infrastructure through a change in the edge configuration and by propagating VLAN tagged frames to other PE devices.

*Figure 16 - Layer 2 WAN trunked point-to-multipoint*



The device connections to a trunked multipoint Layer 2 WAN transport are logically equivalent to the connections to a common Ethernet that has implemented VLANs. The service provider devices are transparent to the subscriber's CE routers. All CE routers attached to a particular VLAN are able to directly communicate with each other. Devices connected to multiple VLANs, such as the WAN-aggregation Layer 2 WAN CE router, are able to communicate with multiple sets of CE routers.

*Figure 17 - Layer 2 WAN trunked point-to-multipoint (logical view)*



Two separate EIGRP processes are used, one for internal routing on the LAN (EIGRP-100) and one for the Layer 2 WAN (EIGRP-300). The primary reason for the separate EIGRP processes is to simplify the route selection at the WAN-aggregation site when connecting multiple remote-site types, potentially including MPLS WAN as used in other SBA WAN guides. This method ensures that all WAN learned routes appear as EIGRP external routes after they are redistributed into the EIGRP-100 process used on the campus LAN.

The Metro 25 design assumes a simple demarcation for both the WAN-aggregation and remote-site routers. Therefore, in this design the WAN-aggregation CE router and all of the remote-site CE routers are EIGRP neighbors. The Metro 100 design assumes a trunked demarcation for both



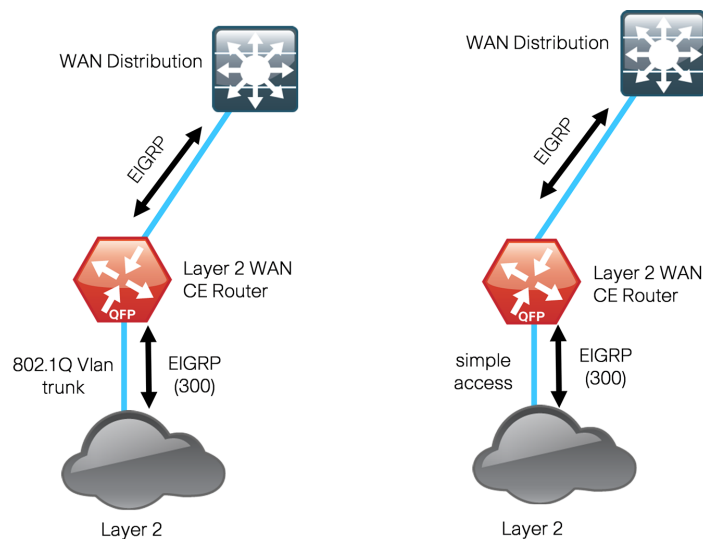
the WAN-aggregation and remote-site routers. Therefore, in this design the WAN-aggregation CE router and sets of remote-site CE routers are EIGRP neighbors. Only remote-site CE routers connected to the same VLAN are EIGRP neighbors.

Sites with only a single WAN transport (a single-homed site) do not require dynamic routing and can rely on static routing because there is only a single path to any destination. This design only includes dynamic WAN routing to provide consistency with configurations across both single-homed and dual-homed sites. This also allows for easy transition from a single-homed to a dual-homed remote-site design by adding an additional link to an existing remote site.

A Layer 2 WAN deployment requires the installation and configuration of CE routers at every location, including the WAN-aggregation site and every Layer 2 WAN-connected remote site.

At the WAN-aggregation site, a Layer 2 WAN CE router must be connected both to the distribution layer and to the Layer 2 WAN service provider. A single routing protocol (EIGRP with multiple instances) is used to exchange routing information, and the routing protocol configurations are tuned from their default settings to influence traffic flows to their desired behavior. The router interface for the Metro 100 design uses multiple subinterfaces which map to the various VLANs in use whereas the Metro 25 design uses only the single physical interface to connect to all of the remote sites. The IP routing details for both WAN-aggregation topologies are shown in the following figure.

**Figure 18 - Metro 100/Metro 25 designs—Layer 2 WAN routing detail**



## EIGRP

Cisco chose EIGRP as the primary routing protocol because it is easy to configure, does not require a large amount of planning, has flexible summarization and filtering, and can scale to large networks. As networks grow, the number of IP prefixes or routes in the routing tables grows as well. You should program IP summarization on links where logical boundaries exist, such as distribution layer links to the wide area or to a core. By performing IP summarization, you can reduce the amount of bandwidth, processor utilization, and memory necessary to carry large route tables, as well as reduce convergence time associated with a link failure.

In this design, EIGRP process 100 is the primary EIGRP process and is referred to as EIGRP-100.

EIGRP-100 is used at the WAN-aggregation site to connect to the primary site LAN distribution layer and at WAN remote sites with dual WAN routers or with distribution-layer LAN topologies.

EIGRP process 300 is the Layer 2 WAN EIGRP process and is referred to as EIGRP-300.

EIGRP-300 is used to exchange routing information between the WAN-aggregation site Layer 2 WAN CE router and the remote-site Layer 2 WAN CE routers. You should configure EIGRP-300 for stub routing on all remote-site routers to improve network stability and reduce resource utilization.

## Deployment Details

### Process

#### Aggregation Router Configuration

1. Configure the Distribution Switch
2. Configure the WAN Aggregation Platform
3. Configure Connectivity to the LAN
4. Connect to Layer 2 WAN
5. Configure EIGRP

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

*Table 8 - Common network services used in the deployment examples*

Service	Address
Hostname	METRO-ASR1000-1
Router loopback IP address	10.4.32.245/32
Router port channel IP address	10.4.32.34/30

### Procedure 1

### Configure the Distribution Switch



#### Reader Tip

This process assumes that the distribution switch has already been configured following the guidance in the *Cisco SBA for Enterprise Organizations—Borderless Networks LAN Deployment Guide*. Only the procedures required to support the integration of the WAN-aggregation router into the deployment are included.

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



#### Tech Tip

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

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

```
interface Port-channel5
description METRO-ASR1000-1
no switchport
ip address 10.4.32.33 255.255.255.252
ip pim sparse-mode
logging event link-status
carrier-delay msec 0
no shutdown
```

## Step 2: Configure EtherChannel member interfaces.

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

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

```
interface GigabitEthernet1/0/1
  description METRO-ASR1000-1 Gig0/0/0
!
interface GigabitEthernet2/0/1
  description METRO-ASR1000-1 Gig0/0/1
!
interface range GigabitEthernet1/0/1, GigabitEthernet2/0/1
  no switchport
  macro apply EgressQoS
  carrier-delay msec 0
  channel-protocol lacp
  channel-group 5 mode active
  logging event link-status
  logging event trunk-status
  logging event bundle-status
  no shutdown
```

## Step 3: Configure the interfaces that are connected to the LAN core to summarize the WAN network range.

```
interface range TenGigabitEthernet1/1/1,
TenGigabitEthernet2/1/1
  ip summary-address eigrp 100 10.4.32.0 255.255.248.0
  ip summary-address eigrp 100 10.5.0.0 255.255.0.0
```

## Step 4: Allow the routing protocol to form neighbor relationships across the port channel interface.

```
router eigrp 100
  no passive-interface Port-channel1
```

## Procedure 2

## Configure the WAN Aggregation Platform

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

### Step 1: Configure the device host name.

Configure the device host name to make it easy to identify the device.

```
hostname METRO-ASR1000-1
```

### Step 2: Configure device management protocols.

Secure HTTP (HTTPS) and Secure Shell (SSH) are secure replacements for the HTTP and Telnet protocols. They use Secure Sockets Layer (SSL) and Transport Layer Security (TLS) to provide device authentication and data encryption.

Secure management of the LAN device is enabled through the use of the SSH and HTTPS protocols. Both protocols are encrypted for privacy and the nonsecure protocols, Telnet and HTTP, are turned off.

```
ip domain-name cisco.local
ip ssh version 2
no ip http server
ip http secure-server
line vty 0 15
  transport input ssh
```

Enable Simple Network Management Protocol (SNMP) to allow the network infrastructure devices to be managed by a Network Management System (NMS). SNMPv2c is configured both for a read-only and a read-write community string.

```
snmp-server community cisco RO
snmp-server community cisco123 RW
```

### Step 3: Configure secure user authentication.

Enable authentication, authorization, and accounting (AAA) for access control. AAA controls all management access to the network infrastructure devices (SSH and HTTPS).



## Reader Tip

The AAA server used in this architecture is the Cisco ACS. For more information about ACS configuration, see the *Cisco SBA for Enterprise Organizations—Borderless Networks Network Device Authentication and Authorization Deployment Guide*.

TACACS+ is the primary protocol used to authenticate management logins on the infrastructure devices to the AAA server. A local AAA user database is also defined on each network infrastructure device to provide a fallback authentication source in case the centralized TACACS+ server is unavailable.

```
enable secret c1sco123
service password-encryption
!
username admin password c1sco123
aaa new-model
!
tacacs server TACACS-SERVER-1
  address ipv4 10.4.48.15
  key SecretKey
!
aaa group server tacacs+ TACACS-SERVERS
  server name TACACS-SERVER-1
!
aaa authentication login default group TACACS-SERVERS local
aaa authorization exec default group TACACS-SERVERS local
aaa authorization console
ip http authentication aaa
```

### Step 4: Configure a synchronized clock.

The Network Time Protocol (NTP) is designed to synchronize a network of devices. An NTP network usually gets its time from an authoritative time source, such as a radio clock or an atomic clock attached to a time server. NTP then distributes this time across the organizations network.

You should program network devices to synchronize to a local NTP server in the network. The local NTP server typically references a more accurate clock feed from an outside source. By configuring console messages, logs, and debug output to provide time stamps on output, you can cross-reference events in a network.

```
ntp server 10.4.48.17
!
clock timezone PST -8
clock summer-time PDT recurring
!
service timestamps debug datetime msec localtime
service timestamps log datetime msec localtime
```

When synchronous logging of unsolicited messages and debug output is turned on, console log messages are displayed on the console after interactive CLI output is displayed or printed. With this command, you can continue typing at the device console when debugging is enabled.

```
line con 0
  logging synchronous
```

### Step 5: Configure an in-band management interface.

The loopback interface is a logical interface that is always reachable as long as the device is powered on and any IP interface is reachable to the network. Because of this capability, the loopback address is the best way to manage the switch in-band. Layer 3 process and features are also bound to the loopback interface to ensure process resiliency.

The loopback address is commonly a host address with a 32-bit address mask. Allocate the loopback address from the IP address block that the distribution switch summarizes to the rest of the network.

```
interface loopback 0
  ip address 10.4.32.245 255.255.255.255
  ip pim sparse-mode
```

The **ip pim sparse-mode** command will be explained further in the procedure.

Bind the SNMP and SSH processes to the loopback interface address for optimal resiliency:

```
snmp-server trap-source Loopback0
ip ssh source-interface Loopback0
ip pim register-source Loopback0
ip tacacs source-interface Loopback0
ntp source Loopback0
```

#### Step 6: Configure IP unicast routing.

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

```
router eigrp 100
 network 10.4.0.0 0.1.255.255
 no auto-summary
 passive-interface default
 eigrp router-id 10.4.32.241
```

#### Step 7: Configure IP Multicast routing.

IP Multicast allows a single IP data stream to be replicated by the infrastructure (routers and switches) and sent from a single source to multiple receivers. Using IP Multicast is much more efficient than multiple individual unicast streams or a broadcast stream that would propagate everywhere. IP Telephony Music on Hold (MOH) and IP Video Broadcast Streaming are two examples of IP Multicast applications.

To receive a particular IP Multicast data stream, end hosts must join a multicast group by sending an IGMP message to their local multicast router. In a traditional IP Multicast design, the local router consults another router in the network that is acting as an RP to map the receivers to active sources so they can join their streams.

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

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

```
ip multicast-routing distributed
```

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

```
ip pim autorp listener
```

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

```
ip pim sparse-mode
```

### Procedure 3

### Configure Connectivity to the LAN

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

#### Step 1: Configure Layer 3 Interface

```
interface Port-channel5
 ip address 10.4.32.34 255.255.255.252
 ip pim sparse-mode
 no shutdown
```

#### Step 2: Configure EtherChannel member interfaces.

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

```
interface GigabitEthernet0/0/0
 description WAN-D3750X Gig1/0/6
!
interface GigabitEthernet0/0/1
 description WAN-D3750X Gig2/0/6
!
interface range GigabitEthernet0/0/0, GigabitEthernet0/0/1
 no ip address
 channel-group 5 mode active
 no shutdown
```

### Step 3: Configure the EIGRP interface.

Allow EIGRP to form neighbor relationships across the interface to establish peering adjacencies and exchange route tables.

```
router eigrp 100
  no passive-interface Port-channel 5
```

## Procedure 4 Connect to Layer 2 WAN

### Step 1: Assign the interface bandwidth.

The bandwidth value should correspond to the actual interface speed, or if you are using a subrate service, use the policed rate from the carrier.

The example shows a Gigabit interface (1000 Mbps) with a subrate of 500 Mbps.

```
interface [interface type] [number]
  bandwidth [bandwidth (kbps)]
```



### Tech Tip

Command reference:

```
bandwidth kbps
```

500 Mbps = 500000 kbps

### Step 2: Assign the IP address and netmask of the WAN interface.

The IP addressing used between CE routers must allow for sufficient host addresses to support a WAN-aggregation CE router, plus up to 25 remote-site CE routers. This design uses a netmask of 255.255.255.0, which is commonly used for LAN addressing. It may be more efficient to use a different netmask to conserve IP addresses. As a best practice, the VLAN number and the subinterface number should match.

Table 9 - Layer 2 WAN transport IP address information

Layer 2 WAN	Interface	VLAN	Subinterface	Network	CE router address
Metro 25	gig0/0/3	none	none	10.4.38.0/24	.1
Metro 100	gig0/0/3	38	gig0/0/3.38	10.4.38.0/24	.1
		39	gig0/0/3.39	10.4.39.0/24	.1

If connected to a simple demarcation for the Metro 25, use the following configuration.

```
interface [interface type] [number]
  ip address [IP address] [netmask]
  ip pim sparse-mode
```

Use the following configuration for each of the VLANs on a trunked demarcation for the Metro 100.

```
interface [interface type] [number].[subinterface number]
  encapsulation dot1Q [Vlan number]
  ip address [IP address] [netmask]
  ip pim sparse-mode
```

**Step 3:** Administratively enable the interface and disable Cisco Discovery Protocol.

Cisco does not recommend the use of Cisco Discovery Protocol external interfaces.

```
interface [interface type] [number]
  no cdp enable
  no shutdown
```

### Example (Metro 25)

```
interface GigabitEthernet0/0/4
  bandwidth 500000
  ip address 10.4.38.1 255.255.255.0
  ip pim sparse-mode
  no cdp enable
  no shutdown
```



## Example (Metro 100)

```
interface GigabitEthernet0/0/4
  bandwidth 500000
  no cdp enable
  no shutdown
!
interface GigabitEthernet0/0/4.38
  encapsulation dot1Q 38
  ip address 10.4.38.1 255.255.255.0
  ip pim sparse-mode
!
interface GigabitEthernet0/0/4.39
  encapsulation dot1Q 39
  ip address 10.4.39.1 255.255.255.0
  ip pim sparse-mode
```

### Procedure 5 Configure EIGRP

The WAN aggregation Layer 2 WAN CE router uses two EIGRP processes. The primary reason for the additional process is to ensure that routes learned from the WAN remote sites appear as EIGRP external routes on the WAN distribution switch. If only a single process was used, then the remote-site routes would appear as EIGRP internal routes on the WAN distribution switch, which would be inconsistent with other SBA WAN deployment guides.

**Step 1:** Enable an additional process, EIGRP-300, for the Layer 2 WAN.

EIGRP-300 is configured for the Layer 2 WAN interface or subinterfaces. The Layer 2 WAN interface or subinterfaces are the only EIGRP-300 interfaces, and their network ranges should be explicitly listed. Repeat for all Layer 2 WAN interfaces as required.

```
router eigrp 300
  network [L2 WAN network 1] [inverse mask]
  network [L2 WAN network 2] [inverse mask] ! if necessary
  passive-interface default
  no passive-interface [L2 WAN interface 1]
  no passive-interface [L2 WAN interface 2] ! if necessary
  eigrp router-id [IP address of Loopback0]
  no auto-summary
```

**Step 2:** Configure route-maps for tagging routes and blocking routes.

This design uses mutual route redistribution; Layer 2 WAN routes from the EIGRP-300 process are distributed into EIGRP-100 and other learned routes from EIGRP-100 are distributed into EIGRP-300. Because the routing protocol is the same, no default metric is required.

It is important to tightly control how routing information is shared between different routing protocols when you use this mutual route redistribution; otherwise, you might experience route flapping, where certain routes are repeatedly installed and withdrawn from the device routing tables. Proper route control ensures the stability of the routing table.



### Tech Tip

If you configure mutual route redistribution without proper matching, tagging, and filtering, route-flapping may occur, which can cause instability.

This router and other WAN routers in other SBA deployments use an inbound distribute list with a route map to limit which routes are accepted for installation into the route table. These routers are configured to block routes from certain other WAN sources. To accomplish this task, you must create a route map that matches any routes originating from the WAN as indicated by a specific route tag. This method allows for dynamic identification of the various WAN routes. The specific route tags in use are shown below.

This task also requires that the Layer 2 WAN learned WAN routes are explicitly tagged by the WAN aggregation CE router during the route redistribution process. To do this, you must create an additional route map to match the source interface of the routes.

**Table 10 - Route tag information for WAN aggregation Layer 2 WAN CE router**

Tag	Route source	Tag method	Action
65401	MPLS VPN A	implicit	accept
65402	MPLS VPN B	implicit	accept
300	Layer 2 WAN	explicit	tag
65512	DMVPN hub routers	explicit	block

This example includes all WAN route sources in the reference design. Depending on the actual design of your network, you may use more or fewer tags.

It is important when creating the blocking route-map that you include a permit statement at the end to permit the installation of routes with non-matching tags.

```
route-map BLOCK-TAGGED-ROUTES deny 10
  match tag 65512
!
route-map BLOCK-TAGGED-ROUTES permit 20
```

You need to appropriately tag the Layer 2 WAN routes to be consistent with other SBA deployments.

The Metro 25 design requires a single interface in the match statement, whereas the Metro 100 design requires multiple subinterfaces.

```
route-map SET-ROUTE-TAG-METROE permit 10
  match interface GigabitEthernet0/0/3.38
  GigabitEthernet0/0/3.39
  set tag 300
```

**Step 3:** Configure the EIGRP mutual route redistribution.

```
router eigrp 100
  distribute-list route-map BLOCK-TAGGED-ROUTES in
  redistribute eigrp 300 route-map SET-ROUTE-TAG-METROE
!
router eigrp 300
  redistribute eigrp 100
```

## Example

```
route-map BLOCK-TAGGED-ROUTES deny 10
  match tag 65512
!
route-map BLOCK-TAGGED-ROUTES permit 20
!
route-map SET-ROUTE-TAG-METROE permit 10
  match interface GigabitEthernet0/0/3.38
  GigabitEthernet0/0/3.39
  set tag 300
!
router eigrp 100
  distribute-list route-map BLOCK-TAGGED-ROUTES in
  redistribute eigrp 300 route-map SET-ROUTE-TAG-METROE
!
router eigrp 300
  network 10.4.38.0 0.0.0.255
  network 10.4.39.0 0.0.0.255
  redistribute eigrp 100
  passive-interface default
  no passive-interface GigabitEthernet0/0/3.38
  no passive-interface GigabitEthernet0/0/3.39
  eigrp router-id 10.4.32.245
```

## Process

### Remote-Site Layer 2 WAN CE Router Configuration

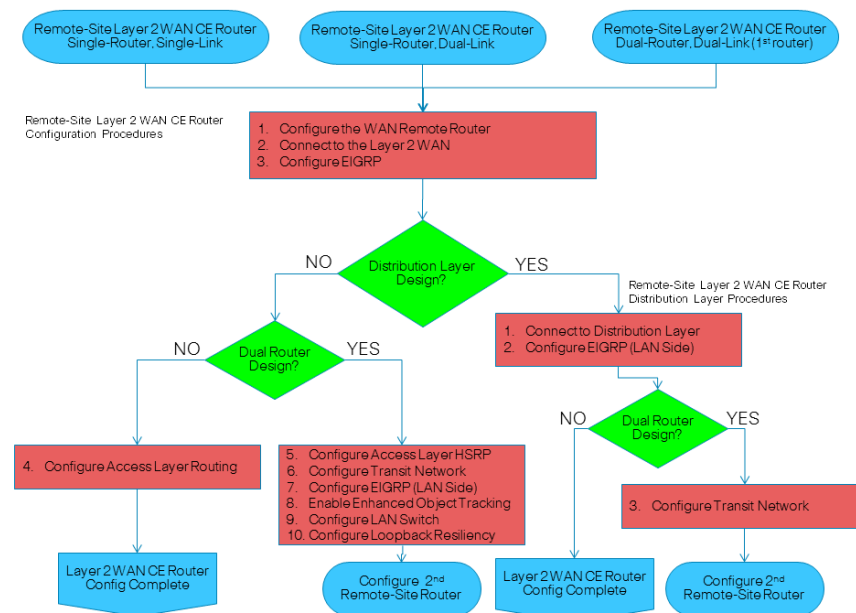
1. Configure the WAN Remote Router
2. Connect to the Layer 2 WAN
3. Configure EIGRP
4. Configure Access Layer Routing
5. Configure Access Layer HSRP
6. Configure Transit Network
7. Configure EIGRP (LAN Side)
8. Enable Enhanced Object Tracking
9. Configure LAN Switch
10. Configure Loopback Resiliency

Use this process for the configuration of any of the following:

- Layer 2 WAN CE router for a Layer 2 WAN remote site (single router, single link).
- Layer 2 WAN + DMVPN remote site. Use these procedures when performing the initial configuration of a dual-role Layer 2 WAN CE and DMVPN spoke router in the single-router, dual-link design or the first router of the dual-router, dual-link design.

The following flowchart provides details about the configuration process for a remote-site Layer 2 WAN CE router.

**Figure 19 - Remote-site Layer 2 WAN CE router configuration flowchart**



## Procedure 1

### Configure the WAN Remote Router

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

**Step 1:** Configure the device host name to make it easy to identify the device.

hostname **[hostname]**

**Step 2:** Configure device management protocols.

Secure HTTP (HTTPS) and Secure Shell (SSH) are secure replacements for the HTTP and Telnet protocols. They use Secure Sockets Layer (SSL) and Transport Layer Security (TLS) to provide device authentication and data encryption.

Secure management of the LAN device is enabled through the use of the SSH and HTTPS protocols. Both protocols are encrypted for privacy and the nonsecure protocols, Telnet and HTTP, are turned off.

```
ip domain-name cisco.local
ip ssh version 2
no ip http server
ip http secure-server
line vty 0 15
    transport input ssh
```

Enable Simple Network Management Protocol (SNMP) to allow the network infrastructure devices to be managed by a Network Management System (NMS). SNMPv2c is configured both for a read-only and a read-write community string.

```
snmp-server community cisco RO
snmp-server community cisco123 RW
```

### Step 3: Configure secure user authentication.

Enable authentication, authorization, and accounting (AAA) for access control. AAA controls all management access to the network infrastructure devices (SSH and HTTPS).



#### Reader Tip

The AAA server used in this architecture is the Cisco Authentication Control System (ACS). For details about ACS configuration, see the *Cisco SBA for Enterprise Organizations—Borderless Networks Network Device Authentication and Authorization Deployment Guide*.

TACACS+ is the primary protocol used to authenticate management logins on the infrastructure devices to the AAA server. A local AAA user database is also defined on each network infrastructure device to provide a fallback authentication source in case the centralized TACACS+ server is unavailable.

```
enable secret cisco123
service password-encryption
!
username admin password cisco123
aaa new-model
!
tacacs server TACACS-SERVER-1
    address ipv4 10.4.48.15
    key SecretKey
!
aaa group server tacacs+ TACACS-SERVERS
    server name TACACS-SERVER-1
!
aaa authentication login default group TACACS-SERVERS local
aaa authorization exec default group TACACS-SERVERS local
aaa authorization console
ip http authentication aaa
```

### Step 4: Configure a synchronized clock.

The Network Time Protocol (NTP) is designed to synchronize a network of devices. An NTP network usually gets its time from an authoritative time source, such as a radio clock or an atomic clock attached to a time server. NTP then distributes this time across the organization's network.

You should program network devices to synchronize to a local NTP server in the network. The local NTP server typically references a more accurate clock feed from an outside source. By configuring console messages, logs, and debug output to provide time stamps on output, you can cross-reference events in a network.

```
ntp server 10.4.48.17
ntp update-calendar
!
clock timezone PST -8
clock summer-time PDT recurring
!
service timestamps debug datetime msec localtime
service timestamps log datetime msec localtime
```

When synchronous logging of unsolicited messages and debug output is turned on, console log messages are displayed on the console after interactive CLI output is displayed or printed. With this command, you can continue typing at the device console when debugging is enabled.

```
line con 0
logging synchronous
```

#### Step 5: Configure an in-band management interface.

The loopback interface is a logical interface that is always reachable as long as the device is powered on and any IP interface is reachable to the network. Because of this capability, the loopback address is the best way to manage the switch in-band. Layer 3 process and features are also bound to the loopback interface to ensure process resiliency.

The loopback address is commonly a host address with a 32-bit address mask. Allocate the remote site router loopback IP address from a unique network range that is not part of any other internal network summary range.

```
interface Loopback0
ip address [ip address] 255.255.255.255
ip pim sparse-mode
```

The **ip pim sparse-mode** command will be explained further in the procedure.

Bind the SNMP and SSH processes to the loopback interface address for optimal resiliency:

```
snmp-server trap-source Loopback 0
ip ssh source-interface Loopback 0
ip pim register-source Loopback0
ip tacacs source-interface Loopback0
ntp source Loopback0
```

#### Step 6: Configure IP Multicast routing.

IP Multicast allows a single IP data stream to be replicated by the infrastructure (that is, routers and switches) and sent from a single source to multiple receivers. Using IP Multicast is much more efficient than multiple individual unicast streams or a broadcast stream that would propagate everywhere. IP Telephony MOH and IP Video Broadcast Streaming are two examples of IP Multicast applications.

To receive a particular IP Multicast data stream, end hosts must join a multicast group by sending an IGMP message to their local multicast router. In a traditional IP Multicast design, the local router consults another router in the network that is acting as an RP to map the receivers to active sources so they can join their streams.

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

Enable IP multicast routing on the platforms in the global configuration mode.

```
ip multicast-routing
```

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

```
ip pim autorp listener
```

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

```
ip pim sparse-mode
```

## Procedure 2

### Connect to the Layer 2 WAN

#### Step 1: Assign the interface bandwidth.

The bandwidth value should correspond to the actual interface speed, or if you are using a substrate service, use the policed rate from the carrier.

The example shows a Gigabit interface (1000 Mbps) with a substrate of 10 Mbps.

```
interface [interface type] [number]
bandwidth [bandwidth (kbps)]
```



## Tech Tip

Command reference:

bandwidth *kbps*

10 Mbps = 10000 kbps

**Step 2:** Assign the IP address and netmask of the WAN interface.

The IP addressing used between CE routers must allow for sufficient host addresses to support a WAN aggregation CE router plus up to 25 remote-site CE routers. This design uses a netmask of 255.255.255.0, which is commonly used for LAN addressing. It may be more efficient to use a different netmask to conserve IP addresses. As a best practice, the VLAN number and the subinterface number should match.

*Table 11 - Layer 2 WAN transport IP address information*

Layer 2 WAN	Interface	VLAN	Subinterface	Network	CE router address
Metro 25	gig0/0/4	none	none	10.4.38.0/24	.1
Metro 100	gig0/0/4	38	gig0/0/3.38	10.4.38.0/24	.1
		39	gig0/0/3.39	10.4.39.0/24	.1

The configuration of the remote-site Layer 2 WAN CE router depends on whether the service provider has implemented a simple or trunked demarcation.

Use the following configuration for a simple demarcation. This connection type may be used even when the WAN aggregation Layer 2 WAN CE router is using a trunked demarcation. However, this requires that the service provider configures the proper VLAN assignment for the remote site connection.

```
interface [interface type] [number]
  ip address [IP address] [netmask]
  ip pim sparse-mode
```

Use the following configuration for a trunked demarcation. The VLAN number and IP network must match those chosen on the WAN aggregation Layer 2 WAN CE router.

```
interface [interface type] [number].[subinterface number]
  encapsulation dot1Q [Vlan number]
  ip address [IP address] [netmask]
  ip pim sparse-mode
```

**Step 3:** Administratively enable the interface and disable Cisco Discovery Protocol. Cisco does not recommend the use of Cisco Discovery Protocol on external interfaces.

```
interface [interface type] [number]
  no cdp enable
  no shutdown
```

**Step 4:** Configure EIGRP.

The remote-site LAN networks must be advertised. The IP assignment for the remote sites was designed so that all of the networks in use can be summarized within a single aggregate route. The summary address as configured below suppresses the more specific routes. If any network within the summary is present in the route table, the summary is advertised to the Layer 2 WAN, which offers a measure of resiliency. If the various LAN networks cannot be summarized, EIGRP continues to advertise the specific routes.

```
interface [interface type] [number].[subinterface number]
  ip summary-address eigrp [as number (Layer 2 WAN)] [summary network] [summary mask]
```

### Example (Simple Demarcation)

```
interface GigabitEthernet0/0
  bandwidth 10000
  ip address 10.4.38.210 255.255.255.0
  ip summary-address eigrp 300 10.5.144.0 255.255.248.0
  no cdp enable
  no shutdown
```



### Example (Trunked Demarcation)

```
interface GigabitEthernet0/0
  bandwidth 10000
  no cdp enable
  no shutdown
!
interface GigabitEthernet0/0.38
  encapsulation dot1q 38
  ip address 10.4.38.210 255.255.255.0
  ip summary-address eigrp 300 10.5.144.0 255.255.248.0
```

### Procedure 3 Configure EIGRP

A single EIGRP-300 process runs on the remote-site Layer 2 WAN CE router. All interfaces on the router are EIGRP interfaces, but only the Layer 2 WAN interface is non-passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address. All remote-site Layer 2 WAN CE routers should run EIGRP stub routing to improve network stability and reduce resource utilization.

```
router eigrp 300
  network [L2 WAN network] [inverse mask]
  network [WAN remote range] [inverse mask]
  passive-interface default
  no passive-interface [L2 WAN interface]
  eigrp router-id [IP address of Loopback0]
  eigrp stub connected summary
  no auto-summary
```

### Example (Trunked Demarcation)

```
router eigrp 300
  network 10.4.38.0 0.0.0.255
  network 10.5.0.0 0.0.255.255
  passive-interface default
  no passive-interface GigabitEthernet0/0.38
  eigrp router-id 10.5.144.254
  eigrp stub connected summary
  no auto-summary
```

### Procedure 4 Configure Access Layer Routing

In the access layer design, the remote sites use collapsed routing, with 802.1Q trunk interfaces to the LAN access layer. The VLAN numbering is locally significant only. The access switches are Layer 2 only.

**Step 1:** Enable the physical interface.

```
interface GigabitEthernet [number]
  no ip address
  no shutdown
```

**Step 2:** Create subinterfaces and assign VLAN tags.

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

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

**Step 3:** Configure IP settings for each subinterface.

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

All router LAN interfaces that use DHCP for end-station IP assignment must use an IP helper to reach a centralized DHCP server in this design.

If the remote-site router is the first router of a dual-router design, then HSRP is configured at the access layer

```
interface GigabitEthernet [number].[sub-interface number]
  encapsulation dot1q [dot1q VLAN tag]
  ip address [LAN network 1] [LAN network 1 netmask]
  ip helper-address 10.4.48.10
  ip pim sparse-mode
```

## Example

```
interface GigabitEthernet0/2
  no ip address
  no shutdown
!
interface GigabitEthernet0/2.64
  description Data
  encapsulation dot1q 64
  ip address 10.5.12.1 255.255.255.0
  ip helper-address 10.4.48.10
  ip pim sparse-mode
!
interface GigabitEthernet0/2.65
  description WirelessData
  encapsulation dot1q 65
  ip address 10.5.10.1 255.255.255.0
  ip helper-address 10.4.48.10
  ip pim sparse-mode
!
interface GigabitEthernet0/2.69
  description Voice
  encapsulation dot1q 69
  ip address 10.5.13.1 255.255.255.0
  ip helper-address 10.4.48.10
  ip pim sparse-mode
!
interface GigabitEthernet0/2.70
  description WirelessVoice
  encapsulation dot1q 70
  ip address 10.5.11.1 255.255.255.0
  ip helper-address 10.4.48.10
  ip pim sparse-mode
```

## Step 4: Configure the trunk on the LAN switch.

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

```
interface GigabitEthernet [number]
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 64,65,69,70
  switchport mode trunk
  macro apply EgressQoS
  ip arp inspection trust
  ip dhcp snooping trust
  logging event link-status
  no shutdown
```

The Catalyst 2960-S and 4500 do not require the **switchport trunk encapsulation dot1q** command.

The following procedures (Procedure 5 through Procedure 8) are only relevant for the dual-router design.

### Procedure 5

### Configure Access Layer HSRP

## Applies to Dual-Router Design Only

You need to configure HSRP enable the use of a Virtual IP (VIP) as a default gateway that is shared between two routers. The HSRP active router is the Layer 2 WAN CE router connected to the Layer 2 WAN and the HSRP standby router is the router connected to the backup link. Configure the HSRP active router with a standby priority that is higher than the HSRP standby router.

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

Table 12 - WAN remote-site HSRP parameters (dual router)

Router	HSRP role	VIP address	Real IP address	HSRP priority	PIM DR priority
Layer 2 WAN CE (primary)	Active	.1	.2	110	110
DMVPN spoke	Standby	.1	.3	105	105

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

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



### Tech Tip

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

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

```
interface [interface type] [number].[sub-interface number]
 encapsulation dot1Q [dot1q VLAN tag]
 ip address [LAN network 1 address] [LAN network 1 netmask]
 ip helper-address [IP address of DHCP server]
 ip pim sparse-mode
 ip pim dr-priority [PIM DR priority]
 standby [number] ip [LAN network 1 gateway address]
 standby [number] priority [priority]
 standby [number] preempt
```

### Example—Layer 2 WAN CE Router (primary)

```
interface GigabitEthernet0/2
 no ip address
 no shutdown
!
interface GigabitEthernet0/2.64
 description Data
 encapsulation dot1Q 64
 ip address 10.5.12.2 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim dr-priority 110
 ip pim sparse-mode
 standby 1 ip 10.5.12.1
 standby 1 priority 110
 standby 1 preempt
!
interface GigabitEthernet0/2.65
 description WirelessData
 encapsulation dot1Q 65
 ip address 10.5.10.2 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim dr-priority 110
 ip pim sparse-mode
 standby 1 ip 10.5.10.1
 standby 1 priority 110
 standby 1 preempt
!
interface GigabitEthernet0/2.69
 description Voice
 encapsulation dot1Q 69
 ip address 10.5.13.2 255.255.255.0
 ip helper-address 10.4.48.10
 ip pim dr-priority 110
 ip pim sparse-mode
 standby 1 ip 10.5.13.1
 standby 1 priority 110
 standby 1 preempt
```

```

!
interface GigabitEthernet0/2.70
  description WirelessVoice
  encapsulation dot1Q 70
  ip address 10.5.11.2 255.255.255.0
  ip helper-address 10.4.48.10
  ip pim dr-priority 110
  ip pim sparse-mode
  standby 1 ip 10.5.11.1
  standby 1 priority 110
  standby 1 preempt

```

## Procedure 6 Configure Transit Network

### Applies to Dual-Router Design Only

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

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

```

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

```

### Example—Layer 2 WAN CE Router (primary)

```

interface GigabitEthernet0/2.99
  description Transit Net
  encapsulation dot1Q 99
  ip address 10.5.152.1 255.255.255.252

```

## Procedure 7 Configure EIGRP (LAN Side)

### Applies to Dual-Router Design Only

You must configure a routing protocol between the two routers. This ensures that the HSRP active router has full reachability information for all WAN remote sites.

**Step 1:** Enable EIGRP-100.

Configure EIGRP-100 facing the access layer. In this design, all LAN-facing interfaces and the loopback must be EIGRP interfaces. All interfaces except the transit-network subinterface should remain passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address. Do not include the Layer 2 WAN interface as an EIGRP interface.

```

router eigrp [as number]
  network [network] [inverse mask]
  passive-interface default
  no passive-interface [interface]
  eigrp router-id [IP address of Loopback0]
  no auto-summary

```

**Step 2:** Redistribute EIGRP-300 into EIGRP-100.

EIGRP-300 is already configured for the Layer 2 WAN interface. Routes from this EIGRP process are redistributed. Since the routing protocol is the same, no default metric is required.

```

router eigrp [as number]
  redistribute eigrp [as number (Layer 2 WAN)]

```

### Example -Remote Site Layer 2 WAN CE Router

```

router eigrp 100
  network 10.5.0.0 0.0.255.255
  redistribute eigrp 300
  passive-interface default
  no passive-interface GigabitEthernet0/2.99
  eigrp router-id 10.5.152.254
  no auto-summary

```

### Applies to Dual-Router Design Only

The HSRP active router remains the active router unless the router is reloaded or fails. Having the HSRP router remain as the active router can lead to undesired behavior. If the Layer 2 WAN transport were to fail, the HSRP active router would learn an alternate path through the transit network to the HSRP standby router and begin to forward traffic across the alternate path. This is suboptimal routing, and you can address it by using EOT.

The HSRP active router (remote-site Layer 2 WAN CE) can use the IP SLA feature to send echo probes to the WAN-aggregation Layer 2 WAN CE router, and if this WAN aggregation router becomes unreachable, the router can lower its HSRP priority, so that the HSRP standby router can preempt and become the HSRP active router.

This procedure is valid only on the router connected to the Layer 2 WAN transport.

#### Step 1: Enable the IP SLA probe.

Use standard ICMP echo (ping) probes, and send them at 15 second intervals. Responses must be received before the timeout of 1000 ms expires. If using the WAN-aggregation Layer 2 WAN CE router as the probe destination, the destination address should match the value assigned in Table 11 that maps to the respective VLAN used by the remote-site Layer WAN CE.

```
ip sla [probe number]
icmp-echo [probe destination IP address] source-interface
[WAN interface]
timeout 1000
threshold 1000
frequency 15
ip sla schedule [probe number] life forever start-time now
```

#### Step 2: Configure EOT.

A tracked object is created based on the IP SLA probe. The object being tracked is the reachability success or failure of the probe. If the probe is successful, the tracked object status is Up; if it fails, the tracked object status is Down.

```
track [tracked obj number] ip sla [probe number] reachability
```

#### Step 3: Link HSRP with the tracked object.

All data or voice subinterfaces should enable HSRP tracking.

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

```
interface [interface type] [number].[sub-interface number]
encapsulation dot1q [dot1q VLAN tag]
ip address [LAN network 1 address] [LAN network 1 netmask]
standby [number] ip [LAN network 1 gateway address]
standby [number] priority [priority]
standby [number] preempt
standby [number] track [tracked obj number] decrement
[priority]
```

#### Example (Trunked Demarcation)

```
interface GigabitEthernet0/2.64
description Data
encapsulation dot1q 64
ip address 10.5.156.2 255.255.255.0
ip helper-address 10.4.48.10
standby 1 ip 10.5.156.1
standby 1 priority 110
standby 1 preempt
standby 1 track 50 decrement 10
!
track 50 ip sla 100 reachability
!
ip sla 100
icmp-echo 10.4.38.1 source-interface GigabitEthernet0/0.38
timeout 1000
threshold 1000
frequency 15
ip sla schedule 100 life forever start-time now
```

## Procedure 9 Configure LAN Switch

### Step 1: Trunk Configuration on the LAN switch

An 802.1Q trunk is used for the connection to this upstream device, which allows it to provide the Layer 3 services to all the VLANs defined on the access layer switch. The VLANs allowed on the trunk are pruned to only the VLANs that are active on the access switch. DHCP Snooping and ARP Inspection are set to trust.

```
default interface GigabitEthernet [number]
!
interface GigabitEthernet [number]
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 64,65,69,70,99
  switchport mode trunk
  macro apply EgressQoS
  ip arp inspection trust
  ip dhcp snooping trust
  logging event link-status
  no shutdown
```

The Catalyst 2960-S and 4500 do not require the **switchport trunk encapsulation dot1q** command.

## Procedure 10 Configure Loopback Resiliency

### Applies to Dual-Router Design Only

The remote-site routers have in-band management configured via the loopback interface. To ensure reachability of the loopback interface in a dual-router design, redistribute the loopback of the adjacent router into the WAN routing protocol.

If the WAN protocol is EIGRP

**Step 1:** Configure an access list to limit the redistribution to only the adjacent router's loopback IP address.

```
ip access-list standard R[number]-LOOPBACK
permit [IP Address of Adjacent Router Loopback]
!
route-map LOOPBACK-ONLY permit 10
match ip address R[number]-LOOPBACK
```

**Step 2:** Configure EIGRP to redistribute the adjacent router's loopback IP address. The EIGRP stub routing must be adjusted to permit redistributed routes.

```
router eigrp [as]
  redistribute eigrp 100 route-map LOOPBACK-ONLY
  eigrp stub connected summary redistributed
```

If the WAN protocol is BGP

**Step 3:** Configure BGP to advertise the adjacent router's loopback network

```
router bgp 65511
  network 10.5.12.0 mask 255.255.255.0
  network 10.5.13.0 mask 255.255.255.0
```



# Deploying a Dynamic Multipoint Virtual Private Network (DMVPN) WAN

## Business Overview

Organizations require the WAN to provide sufficient performance and reliability for the remote-site users to be effective in supporting the business. Although most of the applications and services that the remote-site worker uses are centrally located, the WAN design must provide the workforce with a common resource-access experience, regardless of location.

Carrier-based MPLS service and Layer 2 WAN services are not always available or cost-effective for an organization to use for WAN transport to support remote-site connectivity. Internet-based IP VPNs provide an optional transport that you can use as a resilient backup to a primary network transport or may be adequate to provide the primary network transport for a remote site. Flexible network architecture should include Internet VPN as a transport option without significantly increasing the complexity of the overall design.

While Internet IP VPN networks present an attractive option for effective WAN connectivity, anytime an organization sends data across a public network there is risk that the data will be compromised. Loss or corruption of data can result in a regulatory violation and can present a negative public image, either of which can have significant financial impact on an organization. Secure data transport over public networks like the Internet requires adequate encryption to protect business information.

## Technology Overview

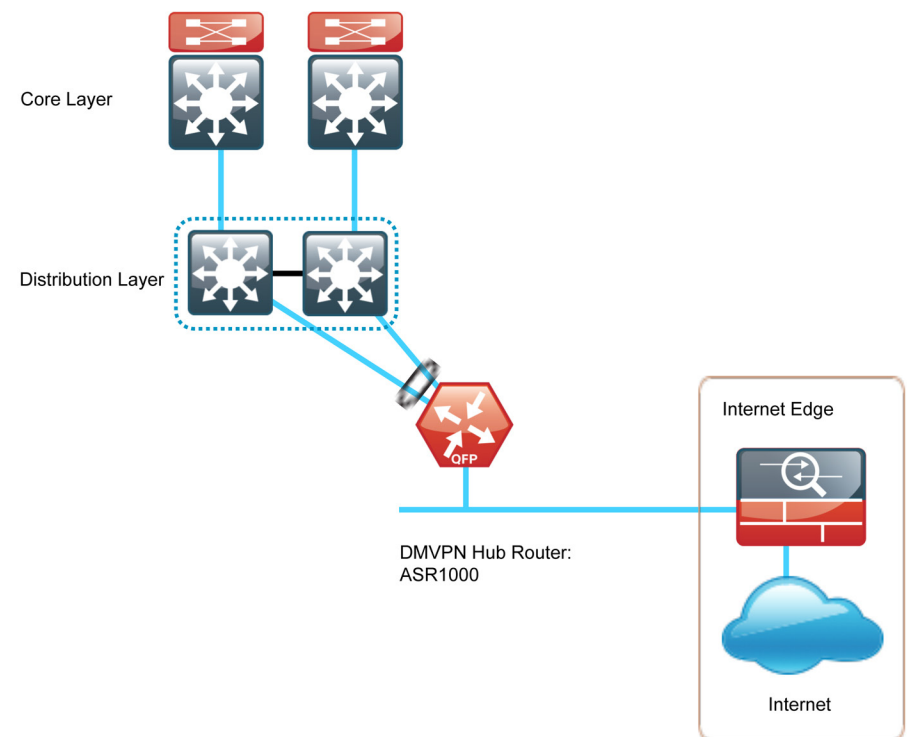
### Metro 100 Design

The Metro 100 design is intended to support up to 100 remote sites with a combined aggregate WAN bandwidth of up to 1.0 Gbps. The most critical devices are the WAN routers that are responsible for reliable IP forwarding and QoS. This design uses the Cisco ASR1002 Aggregation Services Router configured with an ESP5 for the DMVPN hub router.

The Metro 100 design uses a single Internet service provider and a single DMVPN hub router.

The DMVPN VPN router connects to the Internet indirectly through a firewall demilitarized zone (DMZ) interface contained within the Internet edge. Further details of the primary site Internet connection are referenced in the *Cisco SBA for Enterprise Organizations—Borderless Networks Internet Edge Deployment Guide*. The VPN hub router is connected into the firewall DMZ interface, rather than connected directly with an Internet service provider router.

Figure 20 - Metro 100 design—DMVPN connection



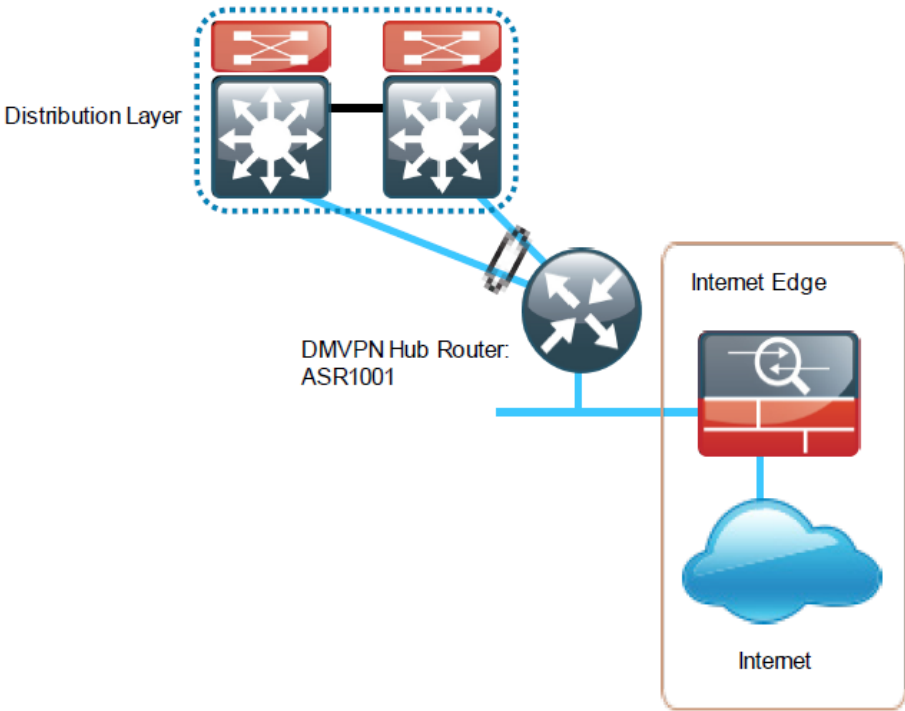
The Cisco ASR1000 Series Aggregation Services Routers represent the next-generation, modular, services-integrated Cisco routing platform. They are specifically designed for WAN aggregation, with the flexibility to support a wide range of 3- to 16-mpps packet-forwarding capabilities, 2.5- to 40-Gbps system bandwidth performance, and scaling.

The Cisco ASR 1000 Series is fully modular, from both hardware and software perspectives, and the routers have all the elements of a true carrier-class routing product that serves both enterprise and service provider networks.

**Metro 25 Design**

The Metro 25 design is intended to support up to 25 remote sites with a combined aggregate WAN bandwidth of up to 250 Mbps. The Metro 25 design is essentially a smaller scale version of the Metro 100 design. This variant is included to provide a limited scale option. If you expect further growth in bandwidth or an increase in the number of sites, use the Metro 100 design. By using the larger design, you can prevent unnecessary downtime associated with device upgrades. This design uses the Cisco ASR1001 for the DMVPN hub router. The Metro 25 design uses a single Internet service provider and a single DMVPN hub router.

*Figure 21 - Metro 25 design—DMVPN connection*



**Remote Sites—DMVPN Spoke Router Selection**

The actual WAN remote-site routing platforms remain unspecified because the specification is tied closely to the bandwidth required for a location and the potential requirement for the use of service module slots. The ability to implement this solution with a variety of potential router choices is one of the benefits of a modular design approach.

There are many factors to consider in the selection of the WAN remote-site routers. Among those, and key to the initial deployment, is the ability to process the expected amount and type of traffic. Also, you need to make sure that you have enough interfaces, enough module slots, and a properly licensed Cisco IOS image that supports the set of features that is required by the topology. Cisco tested four integrated service router models as DMVPN spoke routers and the expected performance is shown in the following table.

*Table 13 - WAN remote-site router options*

Option	2911	2921	3925	3945
Ethernet WAN with Services <sup>1</sup>	35 Mbps	50 Mbps	100 Mbps	150 Mbps
On-board GE ports	3	3	3	3
Service Module Slots <sup>2</sup>	1	1	2	4
Redundant Power Supply	No	No	Yes	Yes

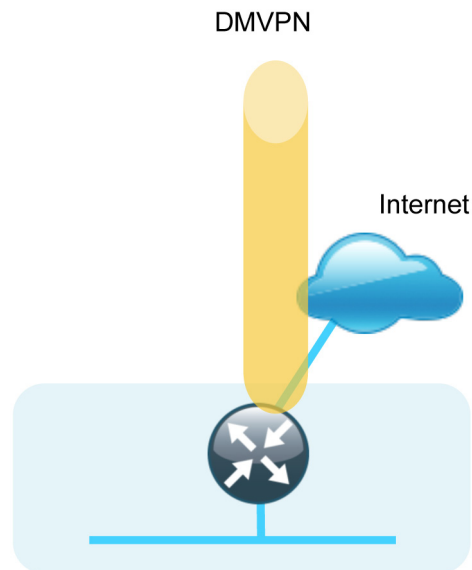
Notes:

- 1. The performance numbers are conservative numbers obtained when the router is passing Internet mix (IMIX) traffic with heavy services configured and the CPU utilization is under 75 percent.
- 2. Some service modules are double-wide.

The DMVPN spoke routers at the WAN remote sites connect to the Internet directly through a router interface. More details about the security configuration of the remote-site routers connected to the Internet are discussed later in this guide. The single link DMVPN remote site is the most basic of building blocks for any remote location. You can use this design with the CE router connected directly to the access layer, or you use it to support a more complex LAN topology by connecting the CE router directly to a distribution layer.

The IP routing is straightforward and can be handled entirely by static routing; using static routes at the WAN aggregation site and static default routes at the remote site. However, there is significant value to configuring this type of site with dynamic routing. It is easy to add or modify IP networks at the remote site when you use dynamic routing because any changes are immediately propagated to the rest of the network.

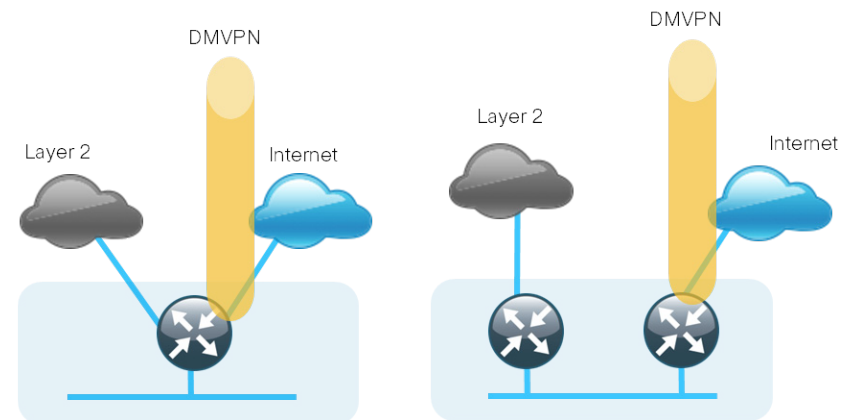
Figure 22 - DMVPN remote site (single link—single router)



The DMVPN connection can be the primary WAN transport, or it can also be the alternate to a Layer 2 WAN transport. You can add the DMVPN single-link design to an existing Layer 2 WAN design to provide additional resiliency by either connecting on the same router or on an additional router. Adding an additional link provides the first level of high availability for the remote site. A failure in the primary link can be automatically detected by the router and traffic can be rerouted to the secondary path. It is mandatory that you run dynamic routing when there are multiple paths. The routing protocols are tuned to ensure the desired traffic flows.

The dual-router, dual-link design continues to improve upon the level of high availability for the site. This design can tolerate the loss of the primary router and traffic can be rerouted via the secondary router (through the alternate path).

Figure 23 - Layer 2 WAN + DMVPN remote site (dual link options)



### VRFs and Front-Door vREF (FVRF)

Virtual Route Forwarding (VRF) is a technology used in computer networks that allows multiple instances of a routing table to co-exist within the same router at the same time. Because the routing instances are independent, you can use the same or overlapping IP Addresses without conflicting with each other. Often in a MPLS context, VRF is also defined as VPN Route Forwarding.

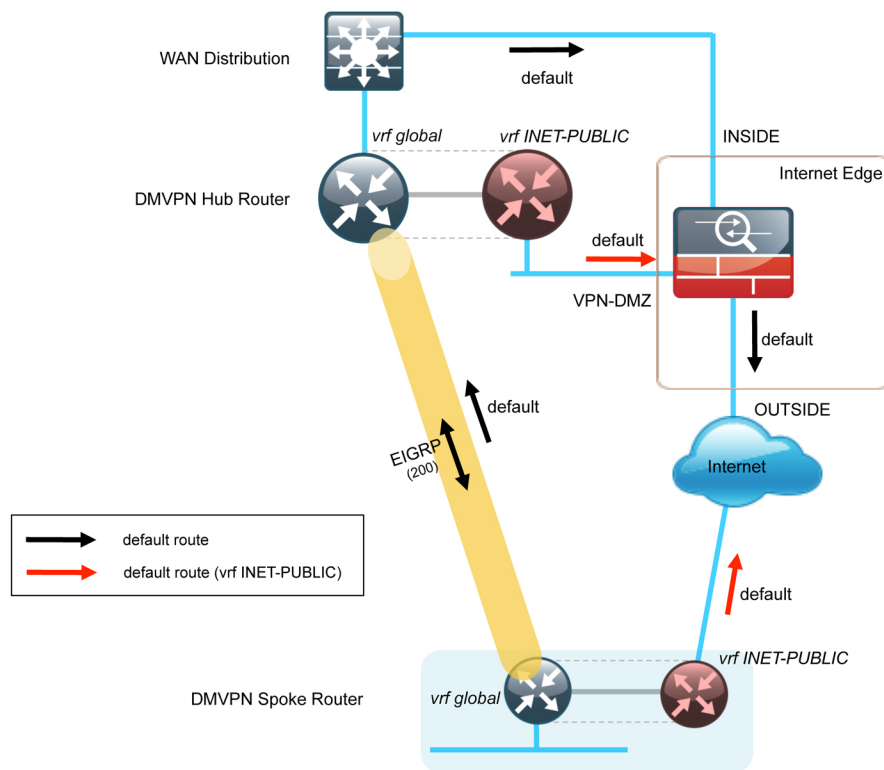
You can implement VRF in a network device by having distinct routing tables, also known as Forwarding Information Bases (FIBs), one per VRF. Alternatively, a network device may have the ability to configure different virtual routers, where each one has its own FIB that is not accessible to any other virtual router instance on the same device.

The simplest form of VRF implementation is VRF Lite. In this implementation, each router within the network participates in the virtual routing environment on a peer-by-peer basis. VRF Lite configurations are only locally significant.

The IP routing policy used in this design for the WAN remote sites does not allow direct Internet access for web browsing or other uses; any remote-site hosts that access the Internet must do so via the Internet edge at the primary site. The end hosts require a default route for all Internet destinations; however, this route must force traffic across the primary or secondary WAN transports (Layer 2 WAN or DMVPN tunnel). This requirement conflicts with the more general VPN spoke router requirement for an Internet-facing default route to bring up the VPN tunnel.

The multiple default route conundrum is solved through the use of VRFs on the router. A router can have multiple routing tables that are kept logically separate on the device. This separation is similar to a virtual router from the forwarding plane perspective. The global VRF corresponds to the traditional routing table, and additional VRFs are given names and route descriptors (RDs). Certain features on the router are VRF aware, including static routing and routing protocols, interface forwarding and IPsec tunneling. This set of features is used in conjunction with DMVPN to permit the use of multiple default routes for both the DMVPN hub routers and DMVPN spoke routers. This combination of features is referred to as front-door vREF (FVRF), because the VRF faces the Internet and the router internal interfaces and the mGRE tunnel all remain in the global VRF. More technical details regarding FVRF can be found in the Technical Feature Supplement appendix.

**Figure 24 - Front-door vREF (FVRF)**



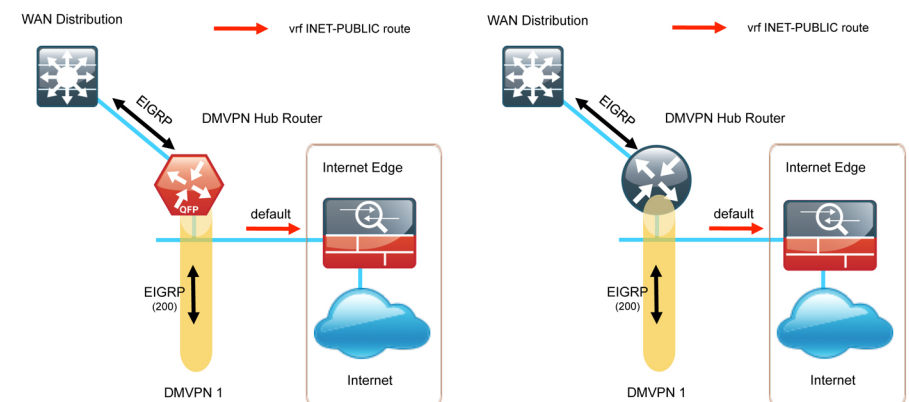
## Design Details

The DMVPN hub router connects to a resilient switching device in the distribution layer and in the DMZ. The DMVPN router uses EtherChannel connections consisting of two port bundles. This design provides both resiliency and additional forwarding performance. Additional forwarding performance can be accomplished by increasing the number of physical links within an EtherChannel.

The DMVPN hub routers must have sufficient IP-routing information to provide end-to-end reachability. Maintaining this routing information typically requires a routing protocol, EIGRP is used for this purpose. Two separate EIGRP processes are used, one for internal routing on the LAN (EIGRP-100) and one for the DMVPN (EIGRP-200). The primary reason for the separate EIGRP processes is to simplify the route selection at the WAN-aggregation site when connecting multiple remote-site types, potentially including MPLS WAN as used in other Smart Business Architecture WAN guides. This method ensures that all WAN learned routes appear as EIGRP external routes after they are redistributed into the EIGRP-100 process used on the campus LAN.

At the WAN aggregation site, you must connect the DMVPN router to the distribution layer and to the DMZ-VPN that provides Internet connectivity. The DMVPN hub routers use FVRF and have a static default route with the INET-PUBLIC VRF pointing to the firewall DMZ interface.

**Figure 25 - Metro 100/25 designs—DMVPN routing details**



## EIGRP

Cisco uses Enhanced IGRP (EIGRP) as the primary routing protocol because it is easy to configure, does not require a large amount of planning, has flexible summarization and filtering, and can scale to large networks. As networks grow, the number of IP prefixes or routes in the routing tables grows as well. You should program IP summarization on links where logical boundaries exist, like distribution layer links to the wide area or to a core. By performing IP summarization, you can reduce the amount of bandwidth, processor, and memory necessary to carry large route tables, and reduce convergence time associated with a link failure.

In this design, EIGRP process 100 is the primary EIGRP process and is referred to as EIGRP-100.

EIGRP-100 is used at the WAN-aggregation site to connect to the primary site LAN distribution layer and at WAN remote sites with dual WAN routers or with distribution-layer LAN topologies. EIGRP-200 is used for the DMVPN tunnels. You should configure EIGRP-200 for stub routing on all remote-site routers to improve network stability and reduce resource utilization.

## Encryption

The primary goal of encryption is to provide data confidentiality, integrity, and authenticity by encrypting IP packets as the data travels across a network.

The encrypted payloads are then encapsulated with a new header (or multiple headers) and transmitted across the network. The additional headers introduce a certain amount of overhead to the overall packet length. The following table highlights the packet overhead associated with encryption based on the additional headers required for various combinations of IPsec and GRE.

*Table 14 - Overhead associated with IPsec and GRE*

Encapsulation	Overhead
GRE only	24 bytes
IPsec (Transport Mode)	36 bytes
IPsec (Tunnel Mode)	52 bytes
IPsec (Transport Mode) + GRE	60 bytes
IPsec (Tunnel Mode) + GRE	76 bytes

There is a maximum transmission unit (MTU) parameter for every link in an IP network and typically the MTU is 1500 bytes. IP packets larger than 1500 bytes must be fragmented when transmitted across these links. Fragmentation is not desirable and can impact network performance. To avoid fragmentation, the original packet size plus overhead must be 1500 bytes or less, which means that the sender must reduce the original packet size. To account for other potential overhead, Cisco recommends that you configure tunnel interfaces with a 1400 byte MTU.

There are dynamic methods for network clients to discover the path MTU, which allow the clients to reduce the size of packets they transmit. However, in many cases, these dynamic methods are unsuccessful, typically because security devices filter the necessary discovery traffic. This failure to discover the path MTU drives the need for a method that can reliably inform network clients of the appropriate packet size. The solution is to implement the **ip tcp adjust mss [size]** command on the WAN routers, which influences the TCP maximum segment size (MSS) value reported by end hosts.

The MSS defines the maximum amount of data that a host is willing to accept in a single TCP/IP datagram. The MSS value is sent as a TCP header option only in TCP SYN segments. Each side of a TCP connection reports its MSS value to the other side. The sending host is required to limit the size of data in a single TCP segment to a value less than or equal to the MSS reported by the receiving host.

The IP and TCP headers combine for 40 bytes of overhead, so the typical MSS value reported by network clients will be 1460. This design includes encrypted tunnels with a 1400 byte MTU, so the MSS used by endpoints should be configured to be 1360 to minimize any impact of fragmentation. In this solution, you implement the **ip tcp adjust mss 1360** command on all WAN facing router interfaces.

## DMVPN

This solution uses the Internet for WAN transport. For data security and privacy concerns any site-to-site traffic that traverses the Internet must be encrypted. Multiple technologies can provide encryption, but the method that provides the best combination of performance, scale, application support, and ease of deployment is DMVPN.

Most use cases in this design guide use Internet/DMVPN as a secondary WAN transport that requires a DMVPN single-cloud, single-hub design. The DMVPN routers use tunnel interfaces that support IP unicast as well as IP multicast and broadcast traffic, including the use of dynamic routing protocols. After the initial spoke-to-hub tunnel is active, it is possible to create dynamic spoke-to-spoke tunnels when site-to-site IP traffic flows require it.



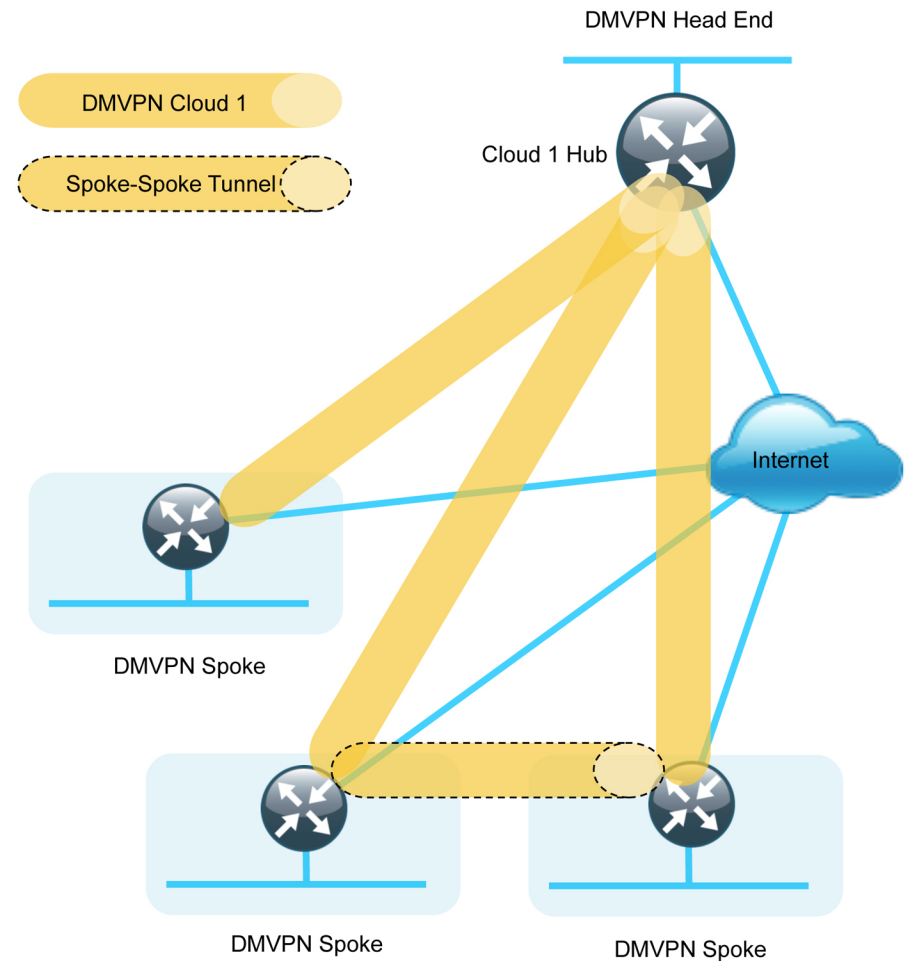
The information required by a spoke to set up dynamic spoke-to-spoke tunnels and properly resolve other spokes is provided through the Next Hop Resolution Protocol (NHRP). Spoke-to-spoke tunnels allow for the optimal routing of traffic between locations without indirect forwarding through the hub. Idle spoke-to-spoke tunnels gracefully time out after a period of inactivity.

It is common for a firewall to be placed between the DMVPN hub router and the Internet. In many cases, the firewall may provide Network Address Translation (NAT) from an internal RFC-1918 IP address (such as 10.4.128.33) to an Internet-routable IP address. The DMVPN solution works well with NAT but requires the use of IPsec transport mode to support a DMVPN hub behind static NAT.

DMVPN requires the use of Internet Security Association and Key Management Protocol (ISAKMP) keepalive intervals for Dead Peer Detection (DPD), which is essential to facilitate fast reconvergence and for spoke registration to function properly in case a DMVPN hub is reloaded. This design enables a spoke to detect that an encryption peer has failed and that the ISAKMP session with that peer is stale, which then allows a new one to be created. Without DPD, the IPsec security association (SA) must time out (the default is 60 minutes) and when the router cannot renegotiate a new SA, a new ISAKMP session is initiated. The maximum wait time is approximately 60 minutes.

One of the key benefits of the DMVPN solution is that the spoke routers can use dynamically assigned addresses, often using DHCP from an Internet provider. The spoke routers can use an Internet default route for reachability to the hub routers and also other spoke addresses.

*Figure 26 - DMVPN single-cloud*



The DMVPN hub router has a static IP address assigned to its public-facing interface. This configuration is essential for proper operation as each of the spoke routers has this IP address embedded in their configurations.



## Deployment Details

### Process

#### DMVPN Hub Router Configuration

1. Configure the Distribution Switch
2. Configure the WAN Aggregation Platform
3. Configure Connectivity to the LAN
4. Configure VRF Lite
5. Connect to Internet DMZ
6. Configure ISAKMP and IPsec
7. Configure the mGRE Tunnel
8. Configure EIGRP

### Procedure 1 **Configure the Distribution Switch**



#### Reader Tip

This process assumes that the distribution switch has already been configured following the guidance in the *Cisco SBA for Enterprise Organizations—Borderless Networks LAN Deployment Guide*. Only the procedures required to support the integration of the WAN aggregation router into the deployment are included.

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



#### Tech Tip

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

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

```
interface Port-channel3
description VPN-ASR1002-1
no switchport
ip address 10.4.32.17 255.255.255.252
ip pim sparse-mode
logging event link-status
carrier-delay msec 0
no shutdown
```

**Step 2:** Configure EtherChannel member interfaces.

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

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

```
interface GigabitEthernet1/0/3
description VPN-ASR1002-1 Gig0/0/0
!
interface GigabitEthernet2/0/3
description VPN-ASR1002-1 Gig0/0/1
!
interface range GigabitEthernet1/0/3, GigabitEthernet2/0/3
no switchport
macro apply EgressQoS
carrier-delay msec 0
channel-protocol lacp
channel-group 3 mode active
logging event link-status
```

```
logging event trunk-status
logging event bundle-status
no shutdown
```

**Step 3:** Configure the interfaces that are connected to the LAN core to summarize the WAN network range.

```
interface range TenGigabitEthernet1/1/1,
TenGigabitEthernet2/1/1
ip summary-address eigrp 100 10.4.32.0 255.255.248.0
ip summary-address eigrp 100 10.5.0.0 255.255.0.0
```

**Step 4:** Allow the routing protocol to form neighbor relationships across the port channel interface.

```
router eigrp 100
no passive-interface Port-channel3
```

## Procedure 2 Configure the WAN Aggregation Platform

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

**Step 1:** Configure the device host name.

Configure the device hostname to make it easy to identify the device.

```
hostname VPN-ASR1000-1
```

**Step 2:** Configure device management protocols.

Secure HTTP (HTTPS) and Secure Shell (SSH) are secure replacements for the HTTP and Telnet protocols. They use Secure Sockets Layer (SSL) and Transport Layer Security (TLS) to provide device authentication and data encryption.

Secure management of the LAN device is enabled through the use of the SSH and HTTPS protocols. Both protocols are encrypted for privacy and the nonsecure protocols, Telnet and HTTP, are turned off.

```
cdp run
ip domain-name cisco.local
ip ssh version 2
no ip http server
```

```
ip http secure-server
line vty 0 15
transport input ssh
```

Enable Simple Network Management Protocol (SNMP) to allow the network infrastructure devices to be managed by a Network Management System (NMS). SNMPv2c is configured both for a read-only and a read-write community string.

```
snmp-server community cisco RO
snmp-server community cisco123 RW
```

**Step 3:** Configure secure user authentication.

Enable authentication, authorization, and accounting (AAA) for access control. AAA controls all management access to the network infrastructure devices (SSH and HTTPS).



### Reader Tip

The AAA server used in this architecture is the Cisco ACS. For more information about ACS configuration, see the *Cisco SBA for Enterprise Organizations—Borderless Networks Network Device Authentication and Authorization Deployment Guide*.

TACACS+ is the primary protocol used to authenticate management logins on the infrastructure devices to the AAA server. A local AAA user database is also defined on each network infrastructure device to provide a fallback authentication source in case the centralized TACACS+ server is unavailable.

```
enable secret cisco123
service password-encryption
!
username admin password cisco123
aaa new-model
!
tacacs server TACACS-SERVER-1
address ipv4 10.4.48.15
key SecretKey
!
```

```

aaa group server tacacs+ TACACS-SERVERS
  server name TACACS-SERVER-1
!
aaa authentication login default group TACACS-SERVERS local
aaa authorization exec default group TACACS-SERVERS local
aaa authorization console
ip http authentication aaa

```

#### Step 4: Configure a synchronized clock.

The Network Time Protocol (NTP) is designed to synchronize a network of devices. An NTP network usually gets its time from an authoritative time source, such as a radio clock or an atomic clock attached to a time server. NTP then distributes this time across the organizations network.

You should program network devices to synchronize to a local NTP server in the network. The local NTP server typically references a more accurate clock feed from an outside source. By configuring console messages, logs, and debug output to provide time stamps on output, you can cross-reference events in a network.

```

ntp server 10.4.48.17
!
clock timezone PST -8
clock summer-time PDT recurring
!
service timestamps debug datetime msec localtime
service timestamps log datetime msec localtime

```

When synchronous logging of unsolicited messages and debug output is turned on, console log messages are displayed on the console after interactive CLI output is displayed or printed. With this command, you can continue typing at the device console when debugging is enabled.

```

line con 0
  logging synchronous

```

#### Step 5: Configure an in-band management interface.

The loopback interface is a logical interface that is always reachable as long as the device is powered on and any IP interface is reachable to the network. Because of this capability, the loopback address is the best way to manage the switch in-band. Layer 3 process and features are also bound to the loopback interface to ensure process resiliency.

The loopback address is commonly a host address with a 32-bit address mask. Allocate the loopback address from the IP address block that the distribution switch summarizes to the rest of the network.

```

interface Loopback 0
  ip address 10.4.32.243 255.255.255.255
  ip pim sparse-mode

```

The ip pim sparse-mode command will be explained further in the process.

Bind the SNMP and SSH processes to the loopback interface address for optimal resiliency:

```

snmp-server trap-source Loopback0
ip ssh source-interface Loopback0
ip pim register-source Loopback0
ip tacacs source-interface Loopback0
ntp source Loopback0

```

#### Step 6: Configure IP unicast routing.

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

```

router eigrp 100
  network 10.4.0.0 0.1.255.255
  no auto-summary
  passive-interface default
  eigrp router-id 10.4.32.243

```

#### Step 7: Configure IP Multicast Routing

IP Multicast allows a single IP data stream to be replicated by the infrastructure (routers and switches) and sent from a single source to multiple receivers. Using IP Multicast is much more efficient than multiple individual unicast streams or a Broadcast stream that would propagate everywhere. IP Telephony Music On Hold (MOH) and IP Video Broadcast Streaming are two examples of IP Multicast applications.

To receive a particular IP Multicast data stream, end hosts must join a multicast group by sending an IGMP message to their local multicast router. In a traditional IP Multicast design, the local router consults another router in the network that is acting as a RP to map the receivers to active sources so they can join their streams.

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

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

```
ip multicast-routing distributed
```

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

```
ip pim autorp listener
```

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

```
ip pim sparse-mode
```

### Procedure 3 Configure Connectivity to the LAN

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

**Step 1:** Configure Layer 3 interface.

```
interface Port-channel3
  ip address 10.4.32.18 255.255.255.252
  ip pim sparse-mode
  no shutdown
```

**Step 2:** Configure EtherChannel member interfaces.

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

```
interface GigabitEthernet0/0/0
  description WAN-D3750X Gig1/0/3
!
interface GigabitEthernet0/0/1
  description WAN-D3750X Gig2/0/3
!
```

```
interface range GigabitEthernet0/0/0, GigabitEthernet0/0/1
  no ip address
  channel-group 3 mode active
  cdp enable
  no shutdown
```

**Step 3:** Configure the EIGRP interface.

Allow EIGRP to form neighbor relationships across the interface to establish peering adjacencies and exchange route tables.

```
router eigrp 100
  no passive-interface Port-channel 3
```

### Procedure 4 Configure VRF Lite

An Internet-facing VRF is created to support FVRF for DMVPN. The VRF name is arbitrary but it is useful to select a name that describes the VRF. An associated route descriptor (RD) must also be configured to make the VRF functional. The RD configuration also creates the routing and forwarding tables and associates the RD with the VRF instance.

This design uses VRF Lite so that the RD value can be chosen arbitrarily. It is a best practice to use the same VRF/RD combination across multiple devices when using VRFs in a similar manner. However, this convention is not strictly required.

```
ip vrf INET-PUBLIC
  rd 65512:1
```



## Reader Tip

### Command Reference:

An RD is either ASN-related (composed of an ASN and an arbitrary number) or IP-address-related (composed of an IP address and an arbitrary number).

You can enter an RD in either of these formats:

*16-bit autonomous-system-number:your 32-bit number*

For example, 65512:1.

*32-bit IP address: your 16-bit number*

For example, 192.168.122.15:1.

This design assumes that the Cisco ASA5500 is configured for static NAT for the DMVPN hub router.

The DMVPN design is using FVRF, so this interface must be placed into the VRF configured in the previous procedure.

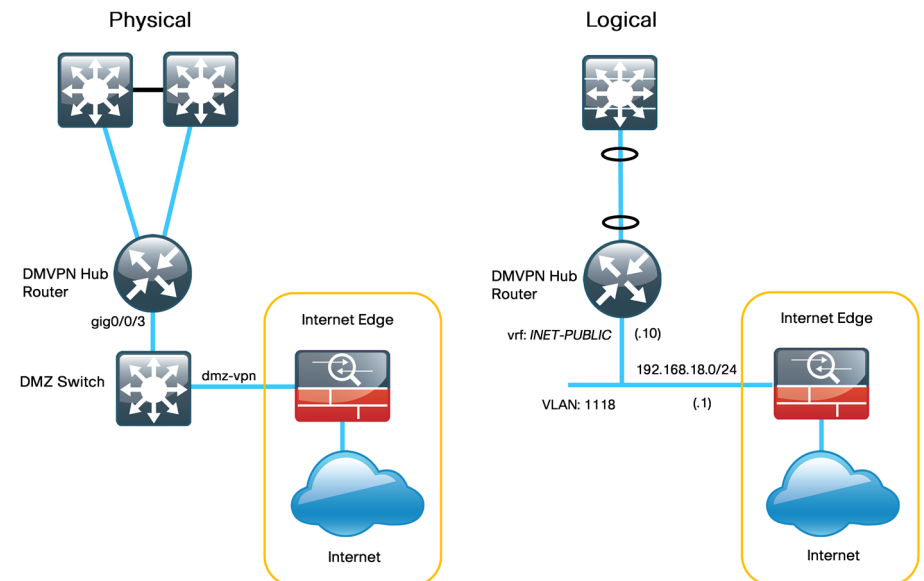
```
interface GigabitEthernet0/0/3
ip vrf forwarding INET-PUBLIC
ip address 192.168.18.10 255.255.255.0
no shutdown
```

### Step 2: Configure the VRF specific default routing.

The VRF created for FVRF must have its own default route to the Internet. This default route points to the ASA5500 DMZ interface IP address.

```
ip route vrf INET-PUBLIC 0.0.0.0 0.0.0.0 192.168.18.1
```

Figure 27 - Physical and logical views for DMZ connection



## Procedure 5

### Connect to Internet DMZ

The DMVPN hub requires a connection to the Internet, and in this design the DMVPN hub is connected through a Cisco ASA5500 Adaptive Security Appliance using a DMZ interface specifically created and configured for a VPN termination router.

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

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

- Assign a routable IP address directly to the router
- Assign a non-routable RFC-1918 address directly to the router and use a static NAT on the Cisco ASA5500 to translate the router IP address to a routable IP address.

## Procedure 6 Configure ISAKMP and IPsec

### Step 1: Configure the crypto keyring.

The crypto keyring defines a pre-shared key (or password) valid for IP sources that are reachable within a particular VRF. This key is a wildcard pre-shared key if it applies to any IP source. A wildcard key is configured using the 0.0.0.0 0.0.0.0 network/mask combination.

```
crypto keyring DMVPN-KEYRING vrf INET-PUBLIC
pre-shared-key address 0.0.0.0 0.0.0.0 key cisco123
```

### Step 2: Configure the ISAKMP policy.

The ISAKMP policy for DMVPN uses the following:

- Advanced Encryption Standard (AES) with a 256-bit key
- Secure Hash Standard (SHA)
- Authentication by Pre-Shared Key (PSK)
- Diffie-Hellman group: 2

```
crypto isakmp policy 10
encr aes 256
hash sha
authentication pre-share
group 2
```

### Step 3: Create the ISAKMP Profile

The ISAKMP profile creates an association between an identity address, a VRF, and a crypto keyring. A wildcard address within a VRF is referenced with 0.0.0.0.

```
crypto isakmp profile FVRF-ISAKMP-INET-PUBLIC
keyring DMVPN-KEYRING
match identity address 0.0.0.0 INET-PUBLIC
```

### Step 4: Define the IPsec transform set.

A transform set is an acceptable combination of security protocols, algorithms, and other settings to apply to IPsec-protected traffic. Peers agree to use a particular transform set when protecting a particular data flow.

The IPsec transform set for DMVPN uses the following:

- ESP with the 256-bit AES encryption algorithm
- ESP with the SHA (HMAC variant) authentication algorithm

Because the DMVPN hub router is behind a NAT device, the IPsec transform must be configured for transport mode.

```
crypto ipsec transform-set AES256/SHA/TRANSPORT esp-aes 256
esp-sha-hmac
mode transport
```

### Step 5: Create the IPsec profile.

The IPsec profile creates an association between an ISAKMP profile and an IPsec transform-set.

```
crypto ipsec profile DMVPN-PROFILE
set transform-set AES256/SHA/TRANSPORT
set isakmp-profile FVRF-ISAKMP-INET-PUBLIC
```

## Procedure 7 Configure the mGRE Tunnel

Table 15 - DMVPN Tunnel Parameters

DMVPN cloud	Tunnel IP address	EIGRP AS	NHRP network ID
Primary	10.4.34.1/23	200	101
Secondary	10.4.36.1/23	201	102

### Step 1: Configure basic interface settings.

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

The bandwidth setting should be set to match the Internet bandwidth of the respective primary or secondary carrier.

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

```
interface Tunnel10
bandwidth 10000
ip address 10.4.34.1 255.255.254.0
no ip redirects
ip mtu 1400
ip tcp adjust-mss 1360
```



## Step 2: Configure the tunnel.

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

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

```
interface Tunnel10
 tunnel source GigabitEthernet0/0/3
 tunnel mode gre multipoint
 tunnel vrf INET-PUBLIC
 tunnel protection ipsec profile DMVPN-PROFILE
```

## Step 3: Configure NHRP.

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

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

EIGRP (configured in the following procedure) relies on a multicast transport and requires NHRP to automatically add routers to the multicast NHRP mappings.

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

```
interface Tunnel10
 ip nhrp authentication cisco123
 ip nhrp map multicast dynamic
 ip nhrp network-id 101
 ip nhrp holdtime 600
 ip nhrp redirect
```

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

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

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



### Reader Tip

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

```
interface Tunnel10
 ip pim sparse-mode
 ip pim nbma-mode
```

## Step 5: Configure EIGRP.

You configure EIGRP in the following Procedure 8, but there are some specific requirements for the mGRE tunnel interface that you need to configure first.

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

The EIGRP hello interval is increased to 20 seconds and the EIGRP hold time is increased to 60 seconds to accommodate up to 500 remote sites on a single DMVPN cloud.

```
interface Tunnel10
 ip hello-interval eigrp 200 20
 ip hold-time eigrp 200 60
 no ip split-horizon eigrp 200
```

## Procedure 8

## Configure EIGRP

You use two EIGRP processes on the DMVPN hub routers. The primary reason for the additional process is to ensure that routes learned from the WAN remotes appear as EIGRP external routes on the WAN distribution switch. If you used only a single process, the remote-site routes would appear as EIGRP internal routes on the WAN distribution switch, which would be preferred to any MPLS VPN learned routes.

**Step 1:** Enable an additional EIGRP process for DMVPN.

Configure EIGRP-200 for the DMVPN mGRE interface. Routes from the other EIGRP process are redistributed. Because the routing protocol is the same, no default metric is required.

The tunnel interface is the only EIGRP interface, and you need to explicitly list its network range.

```
router eigrp 200
 network 10.4.34.0 0.0.1.255
 passive-interface default
 no passive-interface Tunnel10
 eigrp router-id 10.4.32.243
 no auto-summary
```

**Step 2:** Tag and redistribute the routes.

This design uses mutual route redistribution. DMVPN Routes from the EIGRP-200 process are redistributed into EIGRP-100 and other learned routes from EIGRP-100 are redistributed into EIGRP-200. Because the routing protocol is the same, no default metric is required.

It is important to tightly control how routing information is shared between different routing protocols when this mutual route redistribution is used; otherwise, it is possible to experience route flapping, where certain routes are repeatedly installed and with-drawn from the device routing tables. Proper route control ensures the stability of the routing table.

An inbound distribute-list is used on the WAN-aggregation routers to limit which routes are accepted for installation into the route table. These routers are configured to only accept routes which do not originate from the MPLS and DMVPN WAN sources. To accomplish this task, the DMVPN learned WAN routes must be explicitly tagged by their DMVPN hub router during the route redistribution process. The specific route tags in use are shown in the following table.

*Table 16 - Route tag information for DMVPN hub router*

Tag	Route source	Tag method	Action
65401	MPLS A	implicit	accept
65402	MPLS B	implicit	accept
300	Layer 2 WAN	explicit	accept
65512	DMVPN hub routers	explicit	tag

This example includes all WAN route sources in the reference design. Depending on the actual design of your network, you might need to use more tags.

```
router eigrp 100
 redistribute eigrp 200 route-map SET-ROUTE-TAG-DMVPN
!
router eigrp 200
 redistribute eigrp 100
!
route-map SET-ROUTE-TAG-DMVPN permit 10
 match interface Tunnel10
 set tag 65512
```

## Process

### Firewall and DMZ Switch Configuration

1. Configure the DMZ Switch
2. Configure Demilitarized Zone Interface
3. Configure Network Address Translation
4. Configure Security Policy

## Procedure 1 Configure the DMZ Switch



### Reader Tip

This procedure assumes that the switch has already been configured following the guidance in the *Cisco SBA for Enterprise Organizations—Borderless Networks LAN Deployment Guide*. Only the procedures required to support the integration of the firewall into the deployment are included in this guide.

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

```
vlan 1118
spanning-tree vlan 1118 root primary
```

**Step 2:** Configure the interfaces that are connected to the appliances as a trunk.

```
interface GigabitEthernet1/0/24
description IE-ASA5540a Gig0/1
!
interface GigabitEthernet1/0/24
description IE-ASA5540b Gig0/1
```

```
!
interface range GigabitEthernet1/0/24, GigabitEthernet2/0/24
switchport trunk encapsulation dot1q
switchport trunk allowed vlan add 1118
switchport mode trunk
macro apply EgressQoS
logging event link-status
logging event trunk-status
no shutdown
```

**Step 3:** Configure the interfaces that are connected to the DMVPN-aggregation router.

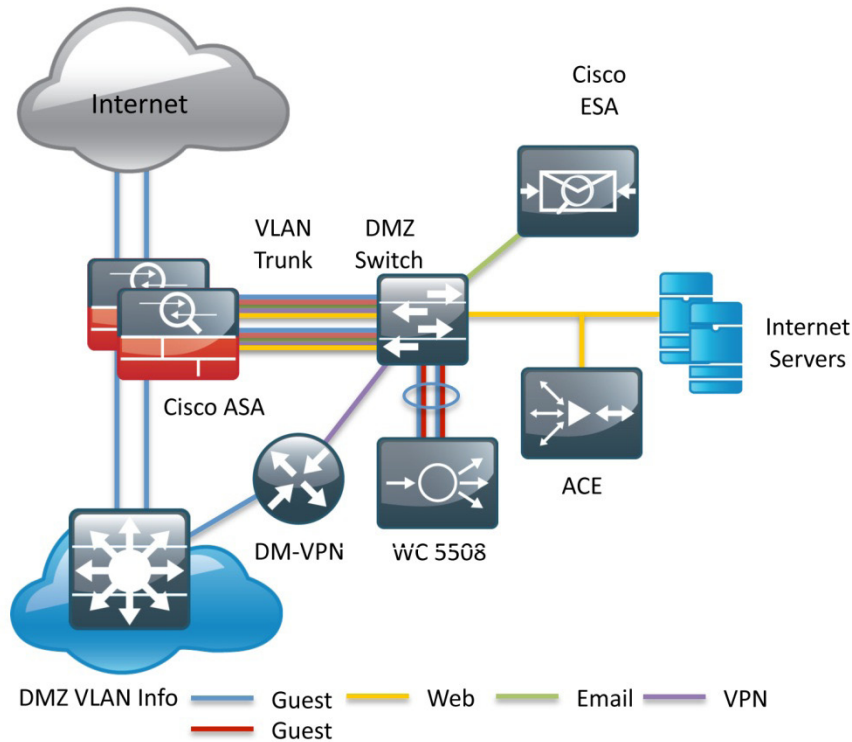
```
interface GigabitEthernet1/0/7
description VPN-ASR1002-1
switchport access vlan 1118
switchport host
macro apply EgressQoS
logging event link-status
no shutdown
```

## Procedure 2 Configure Demilitarized Zone Interface

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

The DMZ network is connected to the appliances on the appliances' GigabitEthernet interface via a VLAN trunk to allow the greatest flexibility if new VLANs must be added to connect additional DMZs. The trunk connects the appliances to a 3750x access-switch stack to provide resiliency. The DMZ VLAN interfaces on the Cisco ASA are each assigned an IP address, which will be the default gateway for each of the VLAN subnets. The DMZ switch only offers Layer 2 switching capability; the DMZ switch's VLAN interfaces do not have an IP address assigned, save for one VLAN interface with an IP address for management of the switch.

Figure 28 - DMZ VLAN topology and services



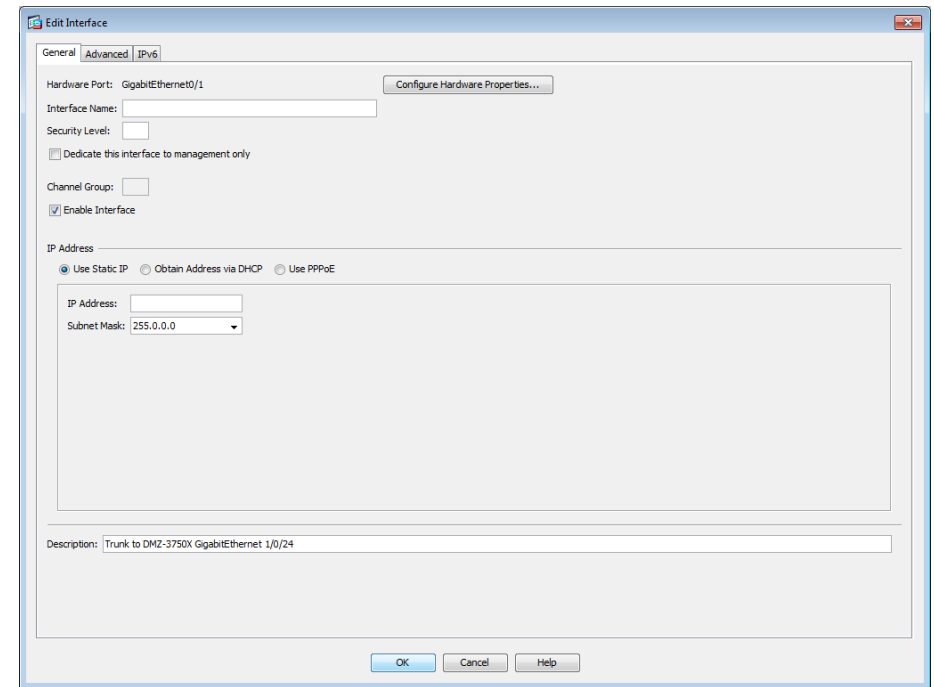
### Tech Tip

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

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

**Step 2:** Click **Edit**.

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



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

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

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

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

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

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

**Step 10:** Enter the interface **IP Address**. (Example: 192.168.18.1)

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

Step 12: Click Apply.

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

Step 14: On the Interfaces tab, for the interface that you created in Step 4, in the Standby IP address column enter the IP address of the standby unit. (Example: 192.168.18.2)

Step 15: Select Monitored.

Step 16: Click Apply.

**Procedure 3**      **Configure Network Address Translation**

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

The example DMZ address to public IP address mapping is shown in the following table.

DMVPN aggregation router DMZ address	DMVPN aggregation router public address (externally routable after NAT)
192.168.18.10	172.16.130.1 (ISP-A)

**Step 1:** In **Configuration > Firewall > Objects > click Network Objects/Groups**.

First, add a network object for the public address of the DMVPN aggregation router on the primary internet connection.

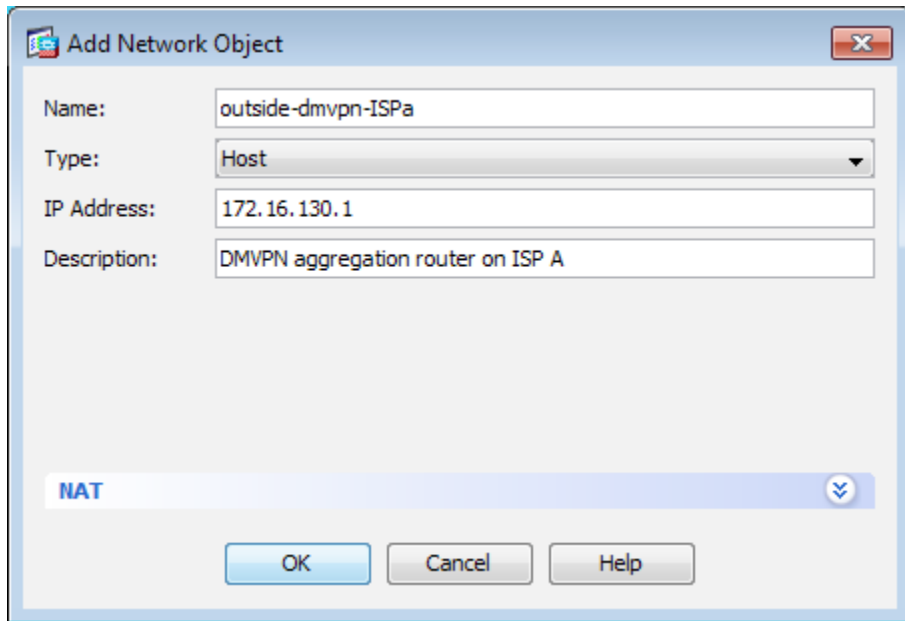
**Step 2:** Click **Add > Network Object**.

**Step 3:** On the Add Network Object dialog box, in the **Name box**, enter a description for the DMVPN aggregation router's public IP address. (Example: outside-dmvpn-ISPa)

**Step 4:** In the **Type** list, choose **Host**.

**Step 5:** In the **IP Address** box, enter the DMVPN aggregation router's public IP address, and then click **OK**. (Example: 172.16.130.1)

**Step 6:** Click **Apply**.



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

**Step 7:** Click **Add > Network Object**.

**Step 8:** In the **Add Network Object** dialog box, in the **Name box**, enter a description for the DMVPN aggregation router's private DMZ IP address. (Example: dmz-dmvpn-1)

**Step 9:** In the **Type** list, choose **Host**.

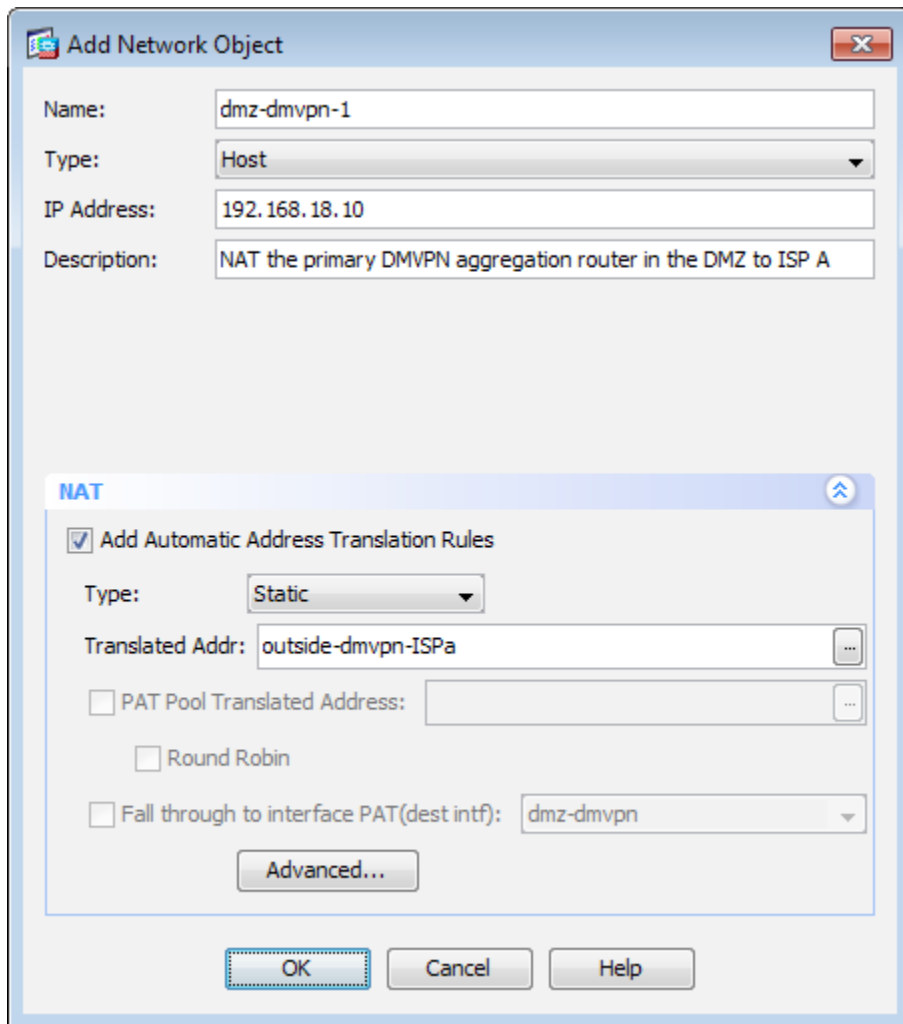
**Step 10:** In the **IP Address** box, enter the router's private DMZ IP address. (Example: 192.168.18.10)

**Step 11:** Click the two down arrows. The NAT pane expands.

**Step 12:** Select **Add Automatic Address Translation Rules**.



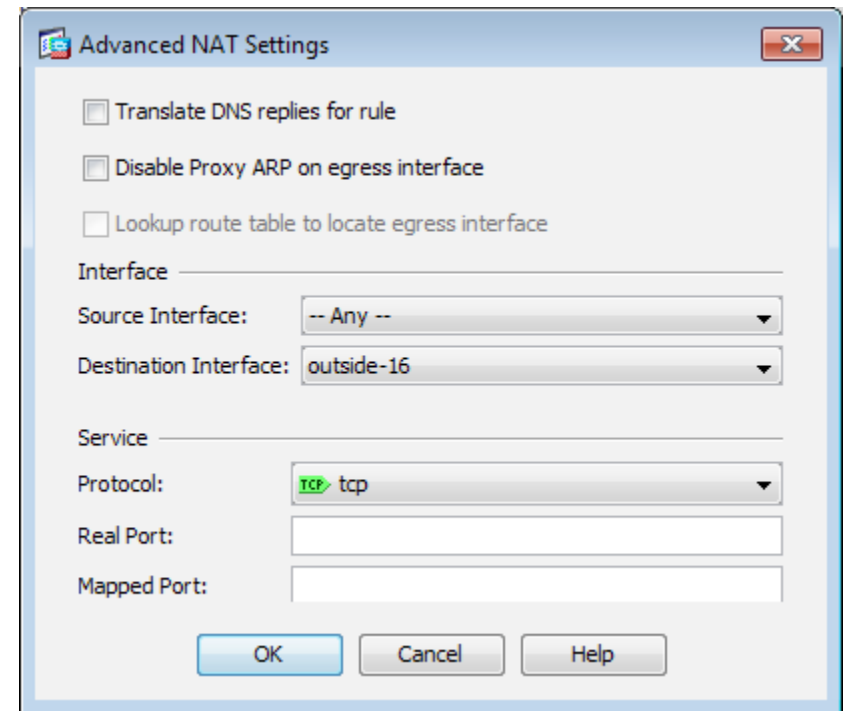
**Step 13:** In the **Translated Addr** list, choose the network object created in Step 2.



The **Add Network Object** dialog box is shown. The **Name** field contains "dmz-dmvpn-1", **Type** is set to "Host", **IP Address** is "192.168.18.10", and **Description** is "NAT the primary DMVPN aggregation router in the DMZ to ISP A". Below these fields is a **NAT** section with a blue header and an expand/collapse icon. The **Add Automatic Address Translation Rules** checkbox is checked. The **Type** dropdown is set to "Static". The **Translated Addr** field contains "outside-dmvpn-ISPa" and has a browse button (...). Below this are two unchecked checkboxes: **PAT Pool Translated Address:** (with a browse button) and **Round Robin**. The **Fall through to interface PAT(dest intf):** dropdown is set to "dmz-dmvpn". An **Advanced...** button is at the bottom of the NAT section. At the bottom of the main dialog are **OK**, **Cancel**, and **Help** buttons.

**Step 14:** Click **Advanced**.

**Step 15:** In the **Destination Interface** list choose the interface name for the primary internet connection, and then click **OK**. (Example: outside-16)



The **Advanced NAT Settings** dialog box is shown. It contains three unchecked checkboxes: **Translate DNS replies for rule**, **Disable Proxy ARP on egress interface**, and **Lookup route table to locate egress interface**. Below these is the **Interface** section with **Source Interface:** set to "-- Any --" and **Destination Interface:** set to "outside-16". The **Service** section has **Protocol:** set to "TCP" (with a green icon) and "tcp" in the dropdown. The **Real Port:** and **Mapped Port:** fields are empty. At the bottom are **OK**, **Cancel**, and **Help** buttons.

**Step 16:** Click **OK**.

**Step 17:** Click **Apply**.

## Procedure 4 Configure Security Policy

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

**Table 17 - Required DMVPN protocols (aggregation router)**

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

**Table 18 - Optional protocols—DMVPN-aggregation router**

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

**Step 1:** In **Configuration > Firewall >** click **Access Rules**.

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



Next, you must insert a new rule above the rule you selected.

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

You must enable the DMVPN remote routers to communicate with the DMVPN aggregation routers in the DMZ.

**Step 4:** In the **Destination** list, choose the network object group created in Procedure 3. (Example: dmz-dmvpn-network/24)

**Step 5:** In the **Service** list box, enter **esp, udp/4500, udp/isakmp**, and then click **OK**.

The screenshot shows the 'Insert Access Rule' dialog box. The 'Interface' is set to '-- Any --'. The 'Action' is 'Permit'. The 'Source' is 'any'. The 'User' is empty. The 'Destination' is 'dmz-dmvpn-network/24'. The 'Service' is 'esp, udp/4500, udp/isakmp'. The 'Description' is 'Allow traffic to the DMVPN aggregation routers'. The 'Enable Logging' checkbox is checked. The 'Logging Level' is 'Default'. There are 'OK', 'Cancel', and 'Help' buttons at the bottom.

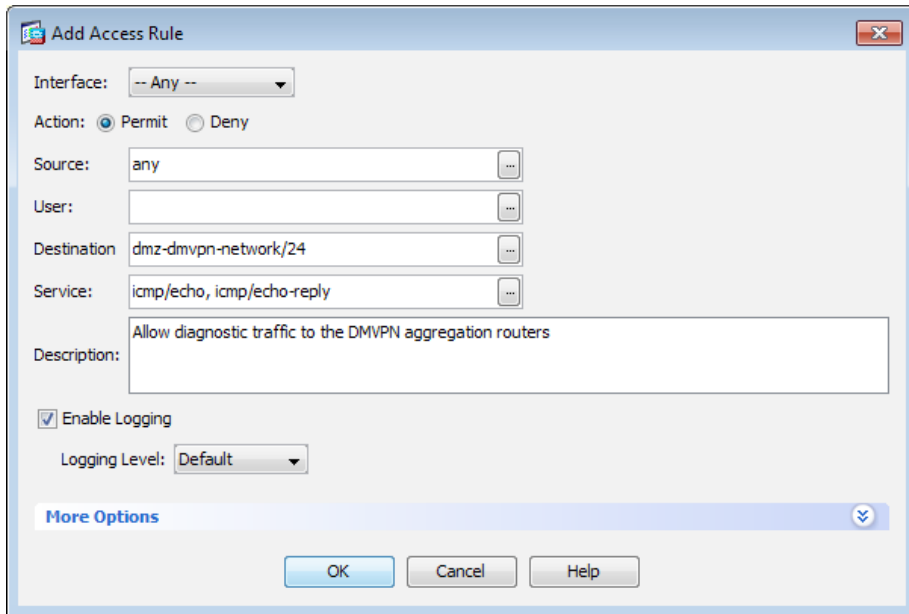
Next, you must insert a new rule to allow diagnostic traffic to the DMVPN aggregation routers.

**Step 6:** Click **Add > Insert**.

You must enable the DMVPN remote routers to communicate with the DMVPN aggregation routers in the DMZ.

**Step 7:** In the **Destination** list, choose the automatically created network object for the DMVPN DMZ. (Example: dmz-dmvpn-network/24)

**Step 8:** In the **Service** list box, enter **icmp/echo, icmp/echo-reply**, and then click **OK**.



The screenshot shows the 'Add Access Rule' dialog box. The 'Interface' is set to '-- Any --'. The 'Action' is set to 'Permit'. The 'Source' is 'any'. The 'User' is empty. The 'Destination' is 'dmz-dmvpn-network/24'. The 'Service' is 'icmp/echo, icmp/echo-reply'. The 'Description' is 'Allow diagnostic traffic to the DMVPN aggregation routers'. The 'Enable Logging' checkbox is checked, and the 'Logging Level' is 'Default'. There are 'OK', 'Cancel', and 'Help' buttons at the bottom.

Interface:	-- Any --
Action:	<input checked="" type="radio"/> Permit <input type="radio"/> Deny
Source:	any
User:	
Destination:	dmz-dmvpn-network/24
Service:	icmp/echo, icmp/echo-reply
Description:	Allow diagnostic traffic to the DMVPN aggregation routers
Enable Logging:	<input checked="" type="checkbox"/>
Logging Level:	Default

**Step 9:** Click **Apply**.

## Notes

## Process

### Enabling DMVPN Backup on Existing Layer 2 WAN CE Router

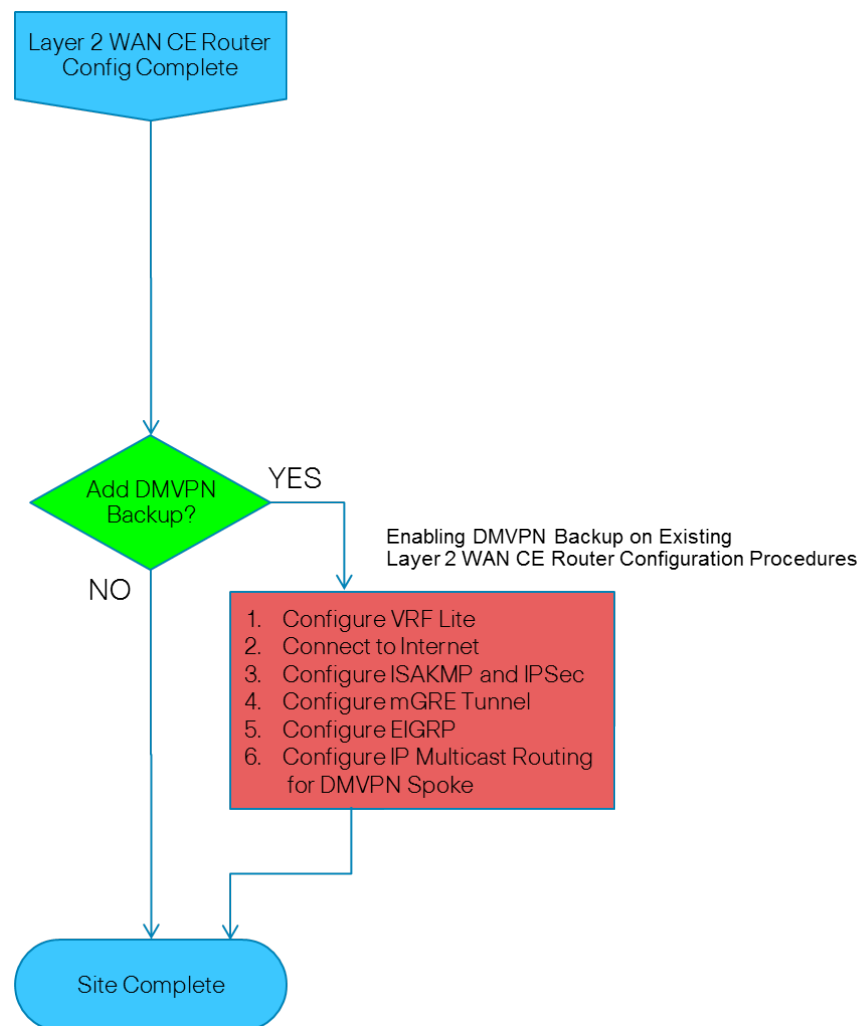
1. Configure VRF Lite
2. Connect to the Internet
3. Configure ISAKMP and IPsec
4. Configure the mGRE Tunnel
5. Configure EIGRP
6. Configure IP Multicast Routing

This set of procedures includes the additional steps necessary to complete the configuration of a dual-role Layer 2 WAN CE and DMVPN spoke router for a Layer 2 WAN + DMVPN remote site (single-router, dual-link).

The following procedures assume that the configuration of a Layer 2 WAN CE Router for a Layer 2 WAN remote site (single-router, single-link) has already been completed. Only the additional procedures to add the DMVPN backup to the running Layer 2 WAN CE router are included here.

The following flowchart provides details about how to add DMVPN backup on an existing remote-site Layer 2 WAN CE router.

Figure 29 - Adding DMVPN backup configuration flowchart



## Procedure 1

### Configure VRF Lite

An Internet-facing VRF is created to support FVRF for DMVPN. The VRF name is arbitrary, but it is useful to select a name that describes the VRF. An associated RD must also be configured to make the VRF functional. The RD configuration also creates the routing and forwarding tables and associates the RD with the VRF instance.

This design uses VRF Lite so the RD value can be chosen arbitrarily. It is a best practice to use the same VRF/RD combination across multiple devices when using VRFs in a similar manner. However, this convention is not strictly required.

```
ip vrf [vrf-name]
rd [ASN:number]
```



### Tech Tip

#### Command Reference:

An RD is either ASN-related (composed of an ASN and an arbitrary number) or IP-address-related (composed of an IP address and an arbitrary number).

You can enter an RD in either of these formats:

*16-bit autonomous-system-number: your 32-bit number*

For example, 65512:1

*32-bit IP address: your 16-bit number*

For example, 192.168.122.15:1.

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

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

```
interface GigabitEthernet 0/1
ip vrf forwarding INET-PUBLIC
ip address dhcp
no shutdown
```

**Step 2:** Configure and apply the access list.

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

**Table 19 - Required DMVPN protocols**

Name	Protocol	Usage
non500-isakmp	UDP 4500	IPsec via NAT-T
Isakmp	UDP 500	ISAKMP
Esp	IP 50	IPsec
Bootpc	UDP 68	DHCP

Example access list:

```
interface GigabitEthernet 0/1
ip access-group ACL-INET-PUBLIC in
ip access-list extended ACL-INET-PUBLIC
permit udp any any eq non500-isakmp
permit udp any any eq isakmp
permit esp any any
permit udp any any eq bootpc
```

## Procedure 2

### Connect to the Internet

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

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

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

*Table 20 - Optional protocols for DMVPN spoke router*

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

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

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

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

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

## Step 2: Configure the ISAKMP Policy and Dead Peer Detection.

The ISAKMP policy for DMVPN uses the following:

- Advanced Encryption Standard (AES) with a 256-bit key
- Secure Hash Standard (SHA)
- Authentication by PSK
- Diffie-Hellman group: 2

DPD is enabled with keepalive intervals sent at 30-second intervals with a 5-second retry interval, which is considered to be a reasonable setting to detect a failed hub.

```
crypto isakmp policy 10
  encr aes 256
  hash sha
  authentication pre-share
  group 2
!
crypto isakmp keepalive 30 5
```

## Step 3: Create the ISAKMP profile.

The ISAKMP profile creates an association between an identity address, a VRF and a crypto keyring. A wildcard address within a VRF is referenced with 0.0.0.0.

```
crypto isakmp profile FVRF-ISAKMP-INET-PUBLIC
  keyring DMVPN-KEYRING
  match identity address 0.0.0.0 INET-PUBLIC
```

## Step 4: Define the IPsec transform set.

A transform set is an acceptable combination of security protocols, algorithms, and other settings to apply to IPsec-protected traffic. Peers agree to use a particular transform set when protecting a particular data flow.

The IPsec transform set for DMVPN uses the following:

- ESP with the 256-bit AES encryption algorithm
- ESP with the SHA (HMAC variant) authentication algorithm

## Procedure 3 Configure ISAKMP and IPsec

### Step 1: Configure the crypto keyring.

The crypto keyring defines a Pre-Shared Key (PSK) (or password) valid for IP sources reachable within a particular VRF. This key is a wildcard PSK if it applies to any IP source. A wildcard key is configured using the 0.0.0.0 0.0.0.0 network/mask combination.

```
crypto keyring DMVPN-KEYRING vrf INET-PUBLIC
  pre-shared-key address 0.0.0.0 0.0.0.0 key cisco123
```



Since the DMVPN hub router is behind a NAT device, the IPsec transform must be configured for transport mode.

```
crypto ipsec transform-set AES256/SHA/TRANSPORT esp-aes 256
esp-sha-hmac
mode transport
```

**Step 5:** Create the IPsec profile.

The IPsec profile creates an association between an ISAKMP profile and an IPsec transform-set.

```
crypto ipsec profile DMVPN-PROFILE
set transform-set AES256/SHA/TRANSPORT
set isakmp-profile FVRF-ISAKMP-INET-PUBLIC
```

## Procedure 4 Configure the mGRE Tunnel

**Step 1:** Configure basic interface settings.

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

The bandwidth setting should be set to match the Internet bandwidth.

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

```
interface Tunnel 10
bandwidth [bandwidth (kbps)]
ip address [IP address] [netmask]
no ip redirects
ip mtu 1400
ip tcp adjust-mss 1360
```

**Step 2:** Configure the tunnel.

DMVPN uses multipoint GRE (mGRE) tunnels. This type of tunnel requires a source interface only. The source interface should be the same interface used in Procedure 6 to connect to the Internet. The **tunnel vrf** command should be set to the VRF defined previously for FVRF.

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

```
interface Tunnel10
tunnel source GigabitEthernet 0/1
tunnel mode gre multipoint
tunnel vrf INET-PUBLIC
tunnel protection ipsec profile DMVPN-PROFILE
```

**Step 3:** Configure NHRP.

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

The spoke router requires several additional configuration statements to define the NHRP server (NHS) and NHRP map statements for the DMVPN hub router mGRE tunnel IP address. EIGRP (configured in the following Procedure 9) relies on a multicast transport. Spoke routers require the NHRP static multicast mapping.

The value that you use for the NHS is the mGRE tunnel address for the DMVPN hub router. The map entries must be set to the outside NAT value of the DMVPN hub, as configured on the Cisco ASA5500. This design uses the values shown in the following table.

**Table 21 - DMVPN hub IP address information**

<b>DMVPN hub DMZ address (actual)</b>	<b>DMVPN hub external address</b>	<b>NHS (DMVPN hub mGRE tunnel address)</b>
192.168.18.10	172.16.130.1	10.4.34.1

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

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

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

```
interface Tunnel10
 ip nhrp authentication cisco123
 ip nhrp map 10.4.34.1 172.16.130.1
 ip nhrp map multicast 172.16.130.1
 ip nhrp network-id 101
 ip nhrp holdtime 600
 ip nhrp nhs 10.4.34.1
 ip nhrp registration no-unique
 ip nhrp shortcut
 ip nhrp redirect
```

#### Step 4: Configure EIGRP.

You configure EIGRP in the following Procedure 5, but you need to configure some specific requirements for the mGRE tunnel interface first.

The EIGRP hello interval is increased to 20 seconds and the EIGRP hold time is increased to 60 seconds to accommodate up to 500 remote sites on a single DMVPN cloud.

```
interface Tunnel10
 ip hello-interval eigrp 200 20
 ip hold-time eigrp 200 60
```

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

```
interface Tunnel10
 ip summary-address eigrp 200 [summary network] [summary mask]
```

### Procedure 5

### Configure EIGRP

A single EIGRP-200 process runs on the DMVPN spoke router. All interfaces on the router are EIGRP interfaces, but only the DMVPN tunnel interface is non-passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address. All DMVPN spoke routers should run EIGRP stub routing to improve network stability and reduce resource utilization.

```
router eigrp 200
 network 10.4.34.0 0.0.1.255
 network 10.5.0.0 0.0.255.255
 passive-interface default
 no passive-interface Tunnel10
 eigrp router-id [IP address of Loopback0]
 eigrp stub connected summary
 no auto-summary
```

### Procedure 6

### Configure IP Multicast Routing

This procedure includes additional steps for completing the IP Multicast configuration when adding DMVPN backup capability to a router with IP multicast already enabled.

#### Step 1: Configure PIM on the DMVPN tunnel interface.

Use sparse-mode for the IP Multicast interface operation mode and enable it on all Layer 3 interfaces, including DMVPN tunnel interfaces.

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

```
interface Tunnel10
 ip pim sparse-mode
```

#### Step 2: Enable PIM NBMA for the DMVPN tunnel.

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

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

```
interface Tunnel10
 ip pim nbma-mode
```

**Step 3:** Configure the DR priority for the DMVPN spoke router.

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

```
interface Tunnel10
 ip pim dr-priority 0
```

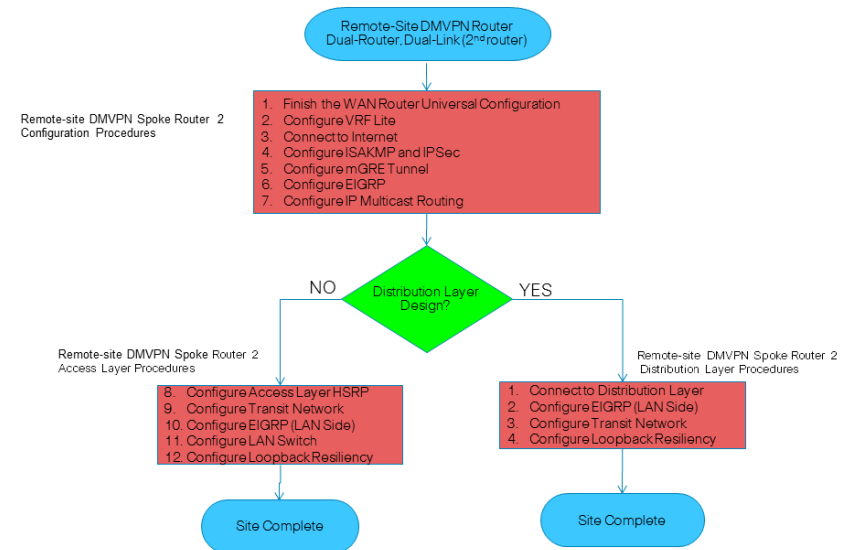
## Process

### Remote-Site DMVPN Spoke Router Configuration

1. Finish WAN Router Universal Configuration
2. Configure VRF Lite
3. Connect to the Internet
4. Configure ISAKMP and IPsec
5. Configure the mGRE Tunnel
6. Configure EIGRP
7. Configure IP Multicast Routing
8. Configure Access Layer HSRP
9. Configure Transit Network
10. Configure EIGRP (LAN Side)
11. Configure LAN Switch
12. Configure Loopback Resiliency

Use this set of procedures when you configure a Layer 2 WAN + DMVPN remote site. Use these procedures when you configure the second router of the dual-router, dual-link design.

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



## Procedure 1

### Finish WAN Router Universal Configuration

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

**Step 1:** Configure the device host name to make it easy to identify the device.

```
hostname [hostname]
```

**Step 2:** Configure device management protocols.

Secure HTTP (HTTPS) and Secure Shell (SSH) are secure replacements for the HTTP and Telnet protocols. They use Secure Sockets Layer (SSL) and Transport Layer Security (TLS) to provide device authentication and data encryption.

You enable secure management of the LAN device through the use of the SSH and HTTPS protocols. Both protocols are encrypted for privacy and the nonsecure protocols, Telnet and HTTP, are turned off.

```
ip domain-name cisco.local
ip ssh version 2
no ip http server
ip http secure-server
line vty 0 15
    transport input ssh
```

Simple Network Management Protocol (SNMP) is enabled to allow the network infrastructure devices to be managed by a Network Management System (NMS). SNMPv2c is configured both for a read-only and a read-write community string.

```
snmp-server community cisco RO
snmp-server community cisco123 RW
```

### Step 3: Configure secure user authentication.

Enable authentication, authorization, and accounting (AAA) for access control. AAA controls all management access to the network infrastructure devices (SSH and HTTPS).



#### Reader Tip

The AAA server used in this architecture is the Cisco Authentication Control System. For details about configuring ACS, see the *Cisco SBA for Enterprise Organizations—Borderless Networks Network Device Authentication and Authorization Deployment Guide*.

TACACS+ is the primary protocol used to authenticate management logins on the infrastructure devices to the AAA server. A local AAA user database is also defined on each network infrastructure device to provide a fallback authentication source in case the centralized TACACS+ server is unavailable.

```
enable secret cisco123
service password-encryption
!
```

```
username admin password cisco123
aaa new-model
!
tacacs server TACACS-SERVER-1
    address ipv4 10.4.48.15
    key SecretKey
!
aaa group server tacacs+ TACACS-SERVERS
    server name TACACS-SERVER-1
!
aaa authentication login default group TACACS-SERVERS local
aaa authorization exec default group TACACS-SERVERS local
aaa authorization console
ip http authentication aaa
```

### Step 4: Configure a synchronized clock.

The Network Time Protocol (NTP) is designed to synchronize a network of devices. An NTP network usually gets its time from an authoritative time source, such as a radio clock or an atomic clock attached to a time server. NTP then distributes this time across the organization's network.

You should program network devices to synchronize to a local NTP server in the network. The local NTP server typically references a more accurate clock feed from an outside source. By configuring console messages, logs, and debug output to provide time stamps on output, you can cross-reference events in a network.

```
ntp server 10.4.48.17
ntp update-calendar
!
clock timezone PST -8
clock summer-time PDT recurring
!
service timestamps debug datetime msec localtime
service timestamps log datetime msec localtime
```

When synchronous logging of unsolicited messages and debug output is turned on, console log messages appear in the console after interactive CLI output is displayed or printed. With this command, you can continue typing at the device console when debugging is enabled.

```
line con 0
    logging synchronous
```

### Step 5: Configure an in-band management interface.

The loopback interface is a logical interface that is always reachable as long as the device is powered on and any IP interface is reachable to the network. Because of this capability, the loopback address is the best way to manage the switch in-band. Layer 3 process and features are also bound to the loopback interface to ensure process resiliency.

The loopback address is commonly a host address with a 32-bit address mask. Allocate the remote site router loopback IP address from a unique network range that is not part of any other internal network summary range.

```
interface Loopback0
 ip address [ip address] 255.255.255.255
 ip pim sparse-mode
```

The **ip pim sparse-mode** command is explained further in the procedure.

Bind the SNMP and SSH processes to the loopback interface address for optimal resiliency:

```
snmp-server trap-source Loopback0
 ip ssh source-interface Loopback0
 ip pim register-source Loopback0
 ip tacacs source-interface Loopback0
 ntp source Loopback0
```

### Step 6: Configure IP Multicast routing.

IP Multicast allows a single IP data stream to be replicated by the infrastructure (that is, routers and switches) and sent from a single source to multiple receivers. Using IP Multicast is much more efficient than multiple individual unicast streams or a broadcast stream that would propagate everywhere. IP Telephony MOH and IP Video Broadcast Streaming are two examples of IP Multicast applications.

To receive a particular IP Multicast data stream, end hosts must join a multicast group by sending an IGMP message to their local multicast router. In a traditional IP Multicast design, the local router consults another router in the network that is acting as an RP to map the receivers to active sources so they can join their streams.

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

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

```
ip multicast-routing
```

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

```
ip pim autorp listener
```

You must enable all Layer 3 interfaces in the network for sparse mode multicast operation.

```
ip pim sparse-mode
```

## Procedure 2

## Configure VRF Lite

An Internet-facing VRF is created to support FVRF for DMVPN. The VRF name is arbitrary but it is useful to select a name that describes the VRF. You must also configure an associated RD to make the VRF functional. The RD configuration creates the routing and forwarding tables and associates the RD with the VRF instance.

This design uses VRF Lite so that the RD value can be chosen arbitrarily. It is a best practice to use the same VRF/RD combination across multiple devices when using VRFs in a similar manner. However, this convention is not strictly required.

```
ip vrf INET-PUBLIC
 rd 65512:1
```



## Reader Tip

### Command Reference:

An RD is either ASN-related (composed of an ASN and an arbitrary number) or IP-address-related (composed of an IP address and an arbitrary number).

You can enter an RD in either of these formats:

*16-bit autonomous-system-number:your 32-bit number*

For example, 65512:1.

*32-bit IP address: your 16-bit number*

For example, 192.168.122.15:1.

## Step 2: Configure and apply the access list.

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

**Table 22 - Required DMVPN protocols**

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

Example access list:

```
interface GigabitEthernet0/1
 ip access-group ACL-INET-PUBLIC in
 ip access-list extended ACL-INET-PUBLIC
 permit udp any any eq non500-isakmp
 permit udp any any eq isakmp
 permit esp any any
 permit udp any any eq bootpc
```

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

**Table 23 - Optional protocols—DMVPN spoke router**

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

## Procedure 3

### Connect to the Internet

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

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

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

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

```
interface [interface type] [number]
 ip vrf forwarding [vrf name]
 ip address dhcp
 no shutdown
```



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

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

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

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

## Procedure 4 Configure ISAKMP and IPsec

**Step 1:** Configure the crypto keyring.

The crypto keyring defines a Pre-Shared Key (PSK) (or password) valid for IP sources reachable within a particular VRF. This key is a wildcard pre-shared key if it applies to any IP source. A wildcard key is configured using the 0.0.0.0 0.0.0.0 network/mask combination.

```
crypto keyring DMVPN-KEYRING vrf INET-PUBLIC
pre-shared-key address 0.0.0.0 0.0.0.0 key cisco123
```

**Step 2:** Configure the ISAKMP policy and Dead Peer Detection (DPD).

The ISAKMP policy for DMVPN uses the following:

- Advanced Encryption Standard (AES) with a 256-bit key
- Secure Hash Standard (SHA)
- Authentication by PSK
- Diffie-Hellman group: 2

DPD is enabled with keepalive intervals sent at 30-second intervals with a 5-second retry interval, which is considered to be a reasonable setting to detect a failed hub.

```
crypto isakmp policy 10
encr aes 256
```

```
hash sha
authentication pre-share
group 2
!
crypto isakmp keepalive 30 5
```

**Step 3:** Create the ISAKMP profile.

The ISAKMP profile creates an association between an identity address, a VRF and a crypto keyring. A wildcard address within a VRF is referenced with 0.0.0.0.

```
crypto isakmp profile [ISAKMP profile name]
keyring [keyring name]
match identity address 0.0.0.0 [vrf name]
```

**Step 4:** Define the IPsec transform set.

A transform set is an acceptable combination of security protocols, algorithms, and other settings to apply to IPsec-protected traffic. Peers agree to use a particular transform set when protecting a particular data flow.

The IPsec transform set for DMVPN uses the following:

- ESP with the 256-bit AES encryption algorithm
- ESP with the SHA (HMAC variant) authentication algorithm

Since the DMVPN hub router is behind a NAT device, you must configure the IPsec transform for transport mode.

```
crypto ipsec transform-set AES256/SHA/TRANSPORT esp-aes 256
esp-sha-hmac
mode transport
```

**Step 5:** Create the IPsec profile.

The IPsec profile creates an association between an ISAKMP profile and an IPsec transform-set.

```
crypto ipsec profile DMVPN-PROFILE
set transform-set AES256/SHA/TRANSPORT
set isakmp-profile FVRF-ISAKMP-INET-PUBLIC
```

## Procedure 5 Configure the mGRE Tunnel

### Step 1: Configure basic interface settings.

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

The bandwidth setting should be set to match the Internet bandwidth.

The IP MTU should be configured to 1400 and the **ip tcp adjust-mss** should be configured to 1360. There is a 40 byte difference which corresponds to the combined IP and TCP header length.

```
interface Tunnel [number]
  bandwidth [bandwidth (kbps)]
  ip address [IP address] [netmask]
  no ip redirects
  ip mtu 1400
  ip tcp adjust-mss 1360
```

### Step 2: Configure the tunnel.

DMVPN uses multipoint GRE (mGRE) tunnels. This type of tunnel requires a source interface only. The source interface should be the same interface used in Procedure 13 to connect to the Internet. You should set the **tunnel vrf** command to the VRF defined previously for FVRF.

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

```
interface Tunnel10
  tunnel source GigabitEthernet0/1
  tunnel mode gre multipoint
  tunnel vrf INET-PUBLIC
  tunnel protection ipsec profile DMVPN-PROFILE
```

### Step 3: Configure NHRP.

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

The spoke router requires several additional configuration statements to define the NHRP server (NHS) and NHRP map statements for the DMVPN hub router mGRE tunnel IP address. EIGRP (configured in the following Procedure 16) relies on a multicast transport. Spoke routers require the NHRP static multicast mapping.

For the NHS value, use the mGRE tunnel address for the DMVPN hub router. The map entries must be set to the outside NAT value of the DMVPN hub, as configured on the Cisco ASA5500. This design uses the values shown in the following table.

Table 24 - DMVPN hub IP address information

DMVPN hub DMZ address	DMVPN hub external address	NHS (DMVPN hub mGRE tunnel address)
10.4.32.33	172.16.130.1	10.4.34.1

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

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

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

```
interface Tunnel10
 ip nhrp authentication cisco123
 ip nhrp map 10.4.34.1 172.16.130.1
 ip nhrp map multicast 172.16.130.1
 ip nhrp network-id 101
 ip nhrp holdtime 600
 ip nhrp nhs 10.4.34.1
 ip nhrp registration no-unique
 ip nhrp shortcut
 ip nhrp redirect
```

#### Step 4: Configure EIGRP.

You configure EIGRP in the following Procedure 6, but you need to configure some specific requirements for the mGRE tunnel interface first.

Increase the EIGRP hello interval to 20 seconds and the EIGRP hold time to 60 seconds to accommodate up to 500 remote sites on a single DMVPN cloud.

```
interface Tunnel10
 ip hello-interval eigrp 200 20
 ip hold-time eigrp 200 60
```

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

```
interface Tunnel10
 ip summary-address eigrp 200 [summary network] [summary mask]
```

### Procedure 6

### Configure EIGRP

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

```
router eigrp 200
 network 10.4.34.0 0.0.1.255
 network 10.5.0.0 0.0.255.255
 passive-interface default
 no passive-interface Tunnel10
 eigrp router-id [IP address of Loopback0]
 eigrp stub connected summary
 no auto-summary
```

### Procedure 7

### Configure IP Multicast Routing

This procedure includes additional steps for completing the IP multicast configuration when adding DMVPN backup capability to a router with IP multicast already enabled.

#### Step 1: Configure PIM on the DMVPN tunnel interface.

Cisco recommends that you use sparse-mode for IP Multicast interface operation mode and to enable it on all Layer 3 interfaces, including DMVPN tunnel interfaces.

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

```
interface Tunnel10
 ip pim sparse-mode
```

**Step 2:** Enable PIM NBMA mode for the DMVPN tunnel.

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

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

```
interface Tunnel10
 ip pim nbma-mode
```

**Step 3:** Configure the DR priority for the DMVPN spoke router.

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

```
interface Tunnel10
 ip pim dr-priority 0
```

## Procedure 8 Configure Access Layer HSRP

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

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

*Table 25 - WAN remote-site HSRP parameters (dual router)*

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

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



### Tech Tip

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

Repeat this procedure for all data or voice subinterfaces.

```
interface [interface type] [number].[sub-interface number]
 encapsulation dot1q [dot1q VLAN tag]
 ip address [LAN network 1 address] [LAN network 1 netmask]
 ip helper-address 10.4.48.10
 ip pim sparse-mode
 ip pim dr-priority 105
 standby 1 ip [LAN network 1 gateway address]
 standby 1 priority 105
 standby 1 preempt
```

## Example

```
interface GigabitEthernet0/2
  no ip address
  no shutdown
!
interface GigabitEthernet0/2.64
  description Data
  encapsulation dot1Q 64
  ip address 10.5.12.3 255.255.255.0
  ip helper-address 10.4.48.10
  ip pim dr-priority 110
  ip pim sparse-mode
  standby 1 ip 10.5.12.1
  standby 1 priority 105
  standby 1 preempt
!
interface GigabitEthernet0/2.65
  description WirelessData
  encapsulation dot1Q 65
  ip address 10.5.10.3 255.255.255.0
  ip helper-address 10.4.48.10
  ip pim dr-priority 110
  ip pim sparse-mode
  standby 1 ip 10.5.10.1
  standby 1 priority 105
  standby 1 preempt
!
interface GigabitEthernet0/2.69
  description Voice
  encapsulation dot1Q 69
  ip address 10.5.13.3 255.255.255.0
  ip helper-address 10.4.48.10
  ip pim dr-priority 105
  ip pim sparse-mode
  standby 1 ip 10.5.13.1
  standby 1 priority 105
  standby 1 preempt
```

```
!
interface GigabitEthernet0/2.70
  description WirelessVoice
  encapsulation dot1Q 70
  ip address 10.5.11.3 255.255.255.0
  ip helper-address 10.4.48.10
  ip pim dr-priority 105
  ip pim sparse-mode
  standby 1 ip 10.5.11.1
  standby 1 priority 105
  standby 1 preempt
```

## Procedure 9

## Configure Transit Network

### Applies to Dual-Router Design Only

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

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

```
interface GigabitEthernet0/2.99
  description Transit Net
  encapsulation dot1Q 99
  ip address 10.5.48.2 255.255.255.252
  ip pim sparse-mode
```

## Procedure 10 Configure EIGRP (LAN Side)

### Applies to Dual-Router Design Only

A routing protocol must be configured between the two routers. This ensures that the HSRP active router has full reachability information for all WAN remote sites.

#### Step 1: Enable EIGRP-100.

You configure EIGRP-100 facing the access layer. In this design, all LAN-facing interfaces and the loopback must be EIGRP interfaces. All interfaces except the transit-network subinterface should remain passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address. Do not include the DMVPN mGRE interface as an EIGRP interface.

```
router eigrp 100
 network 10.5.0.0 0.0.255.255
 passive-interface default
 no passive-interface GigabitEthernet0/2.99
 eigrp router-id [IP address of Loopback0]
 no auto-summary
```

#### Step 2: Redistribute EIGRP-200 (DMVPN) into EIGRP-100.

This step should only be completed on the DMVPN spoke router.

EIGRP-200 is already configured for the DMVPN mGRE interface. Routes from this EIGRP process are redistributed. Since the routing protocol is the same, no default metric is required.

```
router eigrp 100
 redistribute eigrp 200
```

## Procedure 11 Configure LAN Switch

### Applies to Dual-Router Design Only

#### Step 1: Trunk Configuration on the LAN switch

An 802.1Q trunk is used for the connection to this upstream device, which allows it to provide the Layer 3 services to all the VLANs defined on the access layer switch. The VLANs allowed on the trunk are pruned to only the VLANs that are active on the access switch. DHCP Snooping and ARP Inspection are set to trust.

```
default interface GigabitEthernet [number]
!
interface GigabitEthernet [number]
 switchport trunk encapsulation dot1q
 switchport trunk allowed vlan 64,65,69,70,99
 switchport mode trunk
 macro apply EgressQoS
 ip arp inspection trust
 ip dhcp snooping trust
 logging event link-status
 no shutdown
```

The Catalyst 2960-S and 4500 do not require the **switchport trunk encapsulation dot1q** command.



**Applies to Dual-Router Design Only**

The remote-site routers have in-band management configured via the loopback interface. To ensure reachability of the loopback interface in a dual-router design, redistribute the loopback of the adjacent router into the WAN routing protocol.

**Option 1. The WAN protocol is EIGRP**

**Step 1:** Configure an access list to limit the redistribution to only the adjacent router's loopback IP address.

```
ip access-list standard R[number]-LOOPBACK
permit [IP Address of Adjacent Router Loopback]
!
route-map LOOPBACK-ONLY permit 10
match ip address R[number]-LOOPBACK
```

**Step 2:** Configure EIGRP to redistribute the adjacent router's loopback IP address. The EIGRP stub routing must be adjusted to permit redistributed routes.

```
router eigrp [as]
redistribute eigrp 100 route-map LOOPBACK-ONLY
eigrp stub connected summary redistributed
```

**Option 2. The WAN protocol is BGP**

**Step 1:** Configure BGP to advertise the adjacent router's loopback network

```
router bgp 65511
network 10.5.12.0 mask 255.255.255.0
network 10.5.13.0 mask 255.255.255.0
```

# Deploying a WAN Remote-Site Distribution Layer

Use this set of procedures to configure a Layer 2 WAN CE router for a Layer 2 WAN remote site (single-router, single-link). This section includes all required procedures to connect to a distribution layer.

Also, use this set of procedures for a Layer 2 WAN + DMVPN remote site. Use these procedures to connect a distribution layer to a dual-role Layer 2 WAN CE and DMVPN spoke router in the single-router, dual-link design. Use these procedures when you are connecting a distribution layer to the first router of the dual-router, dual-link design.

## Process

Remote-Site Layer 2 WAN CE Router Distribution Layer

1. Connect CE Router to Distribution Layer
2. Configure EIGRP (LAN Side)
3. Configure the Transit Network

## Procedure 1

### Connect CE Router to Distribution Layer

A Layer 2 port-channel interface connects to the WAN distribution switch. This connection allows for multiple VLANs to be included on the EtherChannel if necessary.

The following configuration creates an EtherChannel link between the router and switch, with two channel-group members.

**Step 1:** Configure the port-channel interface.

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

```
interface Port-channel [number]
no ip address
```

**Step 2:** Configure the port channel subinterfaces and assign IP addresses.

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

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

```
interface Port-channel [number].[sub-interface number]
encapsulation dot1Q [dot1q VLAN tag]
ip address [IP address] [netmask]
```

**Step 3:** Administratively enable the port channel group members and assign the appropriate channel group.

Not all router platforms can support LACP to negotiate with the switch, so you configure EtherChannel statically.

```
interface [interface type] [number]
no ip address
channel-group [number]
no shutdown
```

## Example

```
interface Port-channel1
no ip address
!
interface Port-channel1.50
encapsulation dot1Q 50
ip address 10.5.168.1 255.255.255.252
ip pim sparse-mode
!
interface GigabitEthernet0/1
no ip address
```

```

channel-group 1
no shutdown
!
interface GigabitEthernet0/2
no ip address
channel-group 1
no shutdown

```

## Procedure 2 Configure EIGRP (LAN Side)

You must configure a routing protocol between the router and distribution layer.

### Step 1: Enable EIGRP-100.

Configure EIGRP-100 facing the distribution layer. In this design, all distribution-layer-facing subinterfaces and the loopback must be EIGRP interfaces. All other interfaces should remain passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address.

```

router eigrp [as number]
network [network] [inverse mask]
passive-interface default
no passive-interface [interface]
eigrp router-id [IP address of Loopback0]
no auto-summary

```

### Step 2: Redistribute EIGRP-300 (Layer 2 WAN) into EIGRP-100.

Complete this step on the remote-site Layer 2 WAN CE router only.

EIGRP-300 is already configured for the Layer 2 WAN interface. Routes from this EIGRP process are redistributed. Because the routing protocol is the same, no default metric is required.

```

router eigrp [as number]
redistribute eigrp [as number (Layer 2 WAN)]

```

## Example

```

router eigrp 100
network 10.5.0.0 0.0.255.255
redistribute eigrp 300
passive-interface default
no passive-interface Port-channel1.50
eigrp router-id 10.5.168.254
no auto-summary

```

## Procedure 3 Configure the Transit Network

### Applies to Dual-Router Design Only

Configure the transit network between the two routers. You use this network for router-router communication and to avoid hairpinning. The transit network should use an additional subinterface on the EtherChannel interface that is already used to connect to the distribution layer.

The transit network must be a non-passive EIGRP interface.

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

```

interface Port-channel1.99
description Transit Net
encapsulation dot1Q 99
ip address 10.5.168.9 255.255.255.252
ip pim sparse-mode
!
router eigrp 100
no passive-interface Port-channel1.99

```

## Process

### Remote-Site Second Router Distribution Layer

1. Connect Router to Distribution Layer
2. Configure EIGRP (LAN Side)
3. Configure the Transit Network
4. Configure Loopback Resiliency

Use this set of procedures for a Layer 2 WAN + DMVPN remote site. Use these procedures to connect a distribution layer when configuring the second router of the dual-router, dual-link design.

### Procedure 1 Connect Router to Distribution Layer

A Layer 2 port-channel interface connects the DMVPN spoke router to the WAN distribution switch. This connection allows for multiple VLANs to be included on the EtherChannel if necessary.

The following configuration creates an EtherChannel link between the router and switch, with two channel-group members.

**Step 1:** Configure the port-channel interface.

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

```
interface Port-channel [number]
no ip address
```

**Step 2:** Configure the port-channel subinterfaces and assign IP addresses.

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

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

```
interface Port-channel [number].[sub-interface number]
encapsulation dot1Q [dot1q VLAN tag]
ip address [IP address] [netmask]
```

**Step 3:** Enable the port-channel group members and assign the appropriate channel group.

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

```
interface [interface type] [number]
no ip address
channel-group [number]
no shutdown
```

### Example

```
interface Port-channel2
no ip address
!
interface Port-channel2.54
encapsulation dot1Q 54
ip address 10.5.168.5 255.255.255.252
ip pim sparse-mode
!
interface GigabitEthernet0/1
no ip address
channel-group 2
no shutdown
!
interface GigabitEthernet0/2
no ip address
channel-group 2
no shutdown
```

## Procedure 2 Configure EIGRP (LAN Side)

You must configure a routing protocol between the router and distribution layer.

### Step 1: Enable EIGRP-100.

EIGRP-100 is configured facing the distribution layer. In this design, all distribution-layer-facing subinterfaces and the loopback must be EIGRP interfaces. All other interfaces should remain passive. The network range must include all interface IP addresses either in a single network statement or in multiple network statements. This design uses a best practice of assigning the router ID to a loopback address.

```
router eigrp [as number]
 network [network] [inverse mask]
 passive-interface default
 no passive-interface [interface]
 eigrp router-id [IP address of Loopback0]
 no auto-summary
```

### Step 2: Redistribute EIGRP-200 (DMVPN) into EIGRP-100.

This step should only be completed on the DMVPN spoke router.

EIGRP-200 is already configured for the DMVPN mGRE interface. Routes from this EIGRP process are redistributed. Because the routing protocol is the same, no default metric is required.

```
router eigrp [as number]
 redistribute eigrp [as number (DMVPN)]
```

### Example

```
router eigrp 100
 network 10.5.0.0 0.0.255.255
 redistribute eigrp 200
 passive-interface default
 no passive-interface Port-channel2.54
 eigrp router-id 10.5.168.253
 no auto-summary
```

## Procedure 3 Configure the Transit Network

### Applies to Dual-Router Design Only

Configure the transit network between the two routers. You use this network for router-router communication and to avoid hairpinning. The transit network should use an additional subinterface on the EtherChannel interface that is already used to connect to the distribution layer.

The transit network must be a non-passive EIGRP interface.

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

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

### Example

```
interface Port-channel2.99
 description Transit Net
 encapsulation dot1Q 99
 ip address 10.5.168.10 255.255.255.252
 ip pim sparse-mode
 !
router eigrp 100
 no passive-interface Port-channel2.99
```

## Procedure 4 Configure Loopback Resiliency

### Applies to Dual-Router Design Only

The remote-site routers have in-band management configured via the loopback interface. To ensure reachability of the loopback interface in a dual-router design, redistribute the loopback of the adjacent router into the WAN routing protocol.

## Option 1. The WAN protocol is EIGRP

**Step 1:** Configure an access list to limit the redistribution to only the adjacent router's loopback IP address.

```
ip access-list standard R[number]-LOOPBACK
permit [IP Address of Adjacent Router Loopback]
!
route-map LOOPBACK-ONLY permit 10
match ip address R[number]-LOOPBACK
```

**Step 2:** Configure EIGRP to redistribute the adjacent router's loopback IP address. The EIGRP stub routing must be adjusted to permit redistributed routes.

```
router eigrp [as]
redistribute eigrp 100 route-map LOOPBACK-ONLY
eigrp stub connected summary redistributed
```

## Option 2. The WAN protocol is BGP

**Step 1:** Configure BGP to advertise the adjacent router's loopback network

```
router bgp 65511
network 10.5.12.0 mask 255.255.255.0
network 10.5.13.0 mask 255.255.255.0
```

### Process

Remote-Site WAN Distribution Layer Switch Configuration

1. Finish the Switch Universal Config
2. Connect to the WAN Routers
3. Configure EIGRP
4. Configure Transit Network VLAN

### Procedure 1

### Finish the Switch Universal Config

This guide assumes that the distribution layer switch has already been configured. Only the procedures required to complete the connection of the switch to the WAN edge routers are included. For details about distribution layer switch configuration, see the *Cisco SBA for Enterprise Organizations—Borderless Networks LAN Deployment Guide*.

### Procedure 2

### Connect to the WAN Routers

The port-channel interfaces connect to either single or dual WAN routers, and these connections are Layer 2 port channels. The following configuration creates an EtherChannel link between the switch and a router, with two channel-group members. This procedure is repeated for an additional WAN router if necessary.

**Step 1:** Create the VLAN for the router link on the switch, create the VLAN interface and assign the IP address.

Create the point-to-point VLAN for the router link.

```
vlan [VLAN number]
```

Create the VLAN interface and assign the IP address for the point-to-point link.

```
interface Vlan [VLAN number]
ip address [IP address] [netmask]
no shutdown
```

**Step 2:** Configure the port-channel interface and configure for 802.1q VLAN trunking.

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

```
interface Port-channel [number]
switchport trunk encapsulation dot1q
switchport trunk allowed vlan [VLAN number]
switchport mode trunk
```

**Step 3:** Administratively enable the port-channel group members and assign the appropriate channel group. Configure for 802.1 VLAN trunking.



Not all router platforms can support LACP to negotiate with the switch, so you configure EtherChannel statically.

```
interface [interface type] [number]
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan [VLAN number]
  switchport mode trunk
  channel-group [number] mode on
  no shutdown
```

### Example

```
vlan 50
!
interface Port-channel1
  description Layer 2 WAN CE router
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 50
  switchport mode trunk
!
interface GigabitEthernet1/0/1
  description Layer 2 WAN CE router port 1
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 50
  switchport mode trunk
  channel-group 1 mode on
  no shutdown
!
interface GigabitEthernet2/0/1
  description Layer 2 WAN CE router port 2
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 50
  switchport mode trunk
  channel-group 1 mode on
  no shutdown
!
interface Vlan50
  ip address 10.5.168.2 255.255.255.252
  no shutdown
```

### Procedure 3

### Configure EIGRP

Enable EIGRP for the IP address space that the network will be using. If needed for your network, you can enter multiple network statements. Disable autosummarization of the IP networks and enable all routed links to be passive by default. The Loopback 0 IP address is used for the EIGRP router ID to ensure maximum resiliency.

The single logical distribution layer design uses stateful switchover and nonstop forwarding to provide subsecond failover in the event of a supervisor data or control plane failure. This ability reduces packet loss in switchover to redundant logic and keeps packets flowing when the data plane is still intact to adjacent nodes. In the stack-based distribution layer approach, a single logical control point still exists and the master control plane in a stack can failover to another member in the stack providing near-second or subsecond resiliency. When the supervisor or master switch of a distribution platform switches over from the Active to the Hot-Standby supervisor, it will continue switching IP data traffic flows in hardware. However, the supervisor requires time to reestablish control plane two-way peering with EIGRP routing neighbors and avoid the peer router from tearing down adjacencies due to missed hellos that would cause a reroute and disruption of traffic. To allow this time for the supervisor to recover, there is a Nonstop Forwarding (NSF) setting for the routing protocol to wait for the dual supervisor peer switch to recover. The neighboring router is said to be NSF aware if it has a release of IOS that recognizes an NSF peer. All of the platforms used in this design are NSF aware for the routing protocols in use.

You must configure the distribution layer switch to enable NSF for the protocol in use so that it can signal a peer when it switches over to a Hot-Standby supervisor for the peering neighbor to allow it time to reestablish EIGRP protocol to that node. No tuning of the default NSF timers is needed in this network. Nothing has to be configured for an NSF-aware peer router.

```
router eigrp [as number]
  network [network] [inverse mask]
  passive-interface default
  no passive-interface [interface]
  eigrp router-id [IP address of Loopback0]
  no auto-summary
  nsf
```

## Example

```
router eigrp 100
 network 10.5.0.0 0.0.255.255
 passive-interface default
 no passive-interface Vlan50
 eigrp router-id 10.5.168.252
 no auto-summary
 nsf
```

## Example

```
vlan 99
!
interface Port-channel1
 switchport trunk allowed vlan add 99
!
interface GigabitEthernet1/0/1
 switchport trunk allowed vlan add 99
!
interface GigabitEthernet2/0/1
 switchport trunk allowed vlan add 99
```

### Procedure 4 Configure Transit Network VLAN

#### Applies to Dual-Router Design Only

You configure the transit network between the two routers; however, a physical link between the routers is not required. Instead, use a transit VLAN. The distribution layer extends the VLAN across the two existing Layer 2 EtherChannels. The distribution layer does not participate in any routing on the transit network so a VLAN interface is not required for the transit VLAN.

**Step 1:** Create the transit VLAN on the switch.

Create the transit VLAN.

```
vlan [VLAN number]
```

**Step 2:** Add the transit VLAN to the existing port-channel trunk interface and channel group members.

```
interface Port-channel [number]
 switchport trunk allowed vlan add [VLAN number]
!
interface [interface type] [number]
 switchport trunk allowed vlan add [VLAN number]
```

# Deploying WAN Quality of Service

When configuring the WAN-edge QoS, you are defining how traffic egresses your network. It is critical that the classification, marking, and bandwidth allocations align to the service provider offering to ensure consistent QoS treatment end to end.

## Process

### QoS Configuration

1. Create the QoS Maps to Classify Traffic
2. Add ISAKMP Traffic to Network-Critical
3. Implement the Queuing Policy
4. Configure Per-Site Shapers
5. Configure Physical Interface S&Q Policy
6. Apply WAN QoS Policy to Physical Interface

## Procedure 1 Create the QoS Maps to Classify Traffic

Use the **class-map** command to define a traffic class and identify traffic to associate with the class name. These class names are used when configuring policy maps that define actions you want to take against the traffic type. The **class-map** command sets the match logic. In this case, the match-any keyword indicates that the maps matches any of the specified criteria. This keyword is followed by the name you wish to assign to the class of service. After you have configured the **class-map** command,

define specific values, such as DSCP and protocols to match with the **match** command. You use the following two forms of the **match** command: **match dscp** and **match protocol**.

Use the following steps to configure the required WAN class-maps and matching criteria.

**Step 1:** Create the class maps for DSCP matching.

Repeat this step to create a class-map for each of the six WAN classes of service listed in the following table.

You do not need to explicitly configure the default class.

```
class-map match-any [class-map name]
  match dscp [dscp value] [optional additional dscp value(s)]
```

Table 26 - QoS classes of service

Class of service	Traffic type	DSCP values	Bandwidth %	Congestion avoidance
VOICE	Voice traffic	ef	10 (PQ)	-
INTERACTIVE-VIDEO	Interactive video	cs4, af41	23 (PQ)	-
CRITICAL-DATA	Highly interactive	af31, cs3	15	DSCP based
DATA	Data	af21	19	DSCP based
SCAVENGER	Scavenger	af11, cs1	5	
NETWORK-CRITICAL	Routing protocols	cs6, cs2	3	
default	Best effort	other	25	random

## Example

```
class-map match-any VOICE
  match dscp ef
!
class-map match-any INTERACTIVE-VIDEO
  match dscp cs4 af41
!
class-map match-any CRITICAL-DATA
  match dscp af31 cs3
```

```

!
class-map match-any DATA
  match dscp af21
!
class-map match-any SCAVENGER
  match dscp af11 cs1
!
class-map match-any NETWORK-CRITICAL
  match dscp cs6 cs2
!
class-map match-any BGP-ROUTING
  match protocol bgp

```



### Tech Tip

You do not need to configure a Best-Effort Class. This is implicitly included within class-default as shown in Procedure 5.

## Procedure 2

### Add ISAKMP Traffic to Network-Critical

For a WAN connection using DMVPN, you need to ensure proper treatment of ISAKMP traffic in the WAN. To classify this traffic requires the creation of an access-list and the addition of the access-list name to the NETWORK-CRITICAL class-map created in Procedure 1.

This procedure is only required for a WAN-aggregation DMVPN hub router or a WAN remote-site DMVPN spoke router.

**Step 1:** Create the access-list.

```

ip access-list extended ISAKMP
  permit udp any eq isakmp any eq isakmp

```

**Step 2:** Add the match criteria to the existing NETWORK-CRITICAL class-map.

```

class-map match-any NETWORK-CRITICAL
  match access-group name ISAKMP

```



### Tech Tip

The local router policy maps define seven classes while most service providers offer only six classes of service. The NETWORK-CRITICAL policy map is defined to ensure the correct classification, marking, and queuing of network-critical traffic on egress to the WAN. After the traffic has been transmitted to the service provider, the network-critical traffic is typically remapped by the service provider into the critical data class. Most providers perform this remapping by matching on DSCP values cs6 and cs2.

## Procedure 3

### Implement the Queuing Policy

The WAN policy map references the class names you created in the previous procedures and defines the queuing behavior, along with the maximum guaranteed bandwidth allocated to each class. This specification is accomplished with the use of a policy-map. Then, each class within the policy map invokes an egress queue, assigns a percentage of bandwidth, and associates a specific traffic class to that queue. One additional default class defines the minimum allowed bandwidth available for best effort traffic.

### Option 1. Defining Per-Remote-Site Policy Maps

This procedure applies to the WAN aggregation Layer 2 WAN CE router only. This procedure will be repeated multiple times—once for each Layer 2 WAN connected remote site.

**Step 1:** Create a remote-site specific policy map for all Layer 2 WAN connected remote sites.

```

policy-map [policy-map-name]

```

**Step 2:** Apply the previously created class-map.

```

  class [class-name]

```

**Step 3:** Assign the maximum guaranteed bandwidth for the class (Optional).

```

    bandwidth percent [percentage]

```

**Step 4:** (Optional) Define the priority queue for the class. Note, when using a priority queue an implicit policer for this traffic type is applied.

```
priority percent [percentage]
```

**Step 5:** (Optional) Define the congestion mechanism.

```
random-detect [type]
```

**Step 6:** Repeat Step 2 through Step 5 for each class in Table 26, including class-default.

### Option 1 Example (partial policy, showing sites 210 and 211)

```
policy-map POLICY-MAP-Br210
  class VOICE
    priority percent 10
  class INTERACTIVE-VIDEO
    priority percent 23
  class CRITICAL-DATA
    bandwidth percent 15
    random-detect dscp-based
  class DATA
    bandwidth percent 19
    random-detect dscp-based
  class SCAVENGER
    bandwidth percent 5
  class NETWORK-CRITICAL
    bandwidth percent 3
  class class-default
    bandwidth percent 25
    random-detect
```

```
policy-map POLICY-MAP-Br211
  class VOICE
    priority percent 10
  class INTERACTIVE-VIDEO
    priority percent 23
  class CRITICAL-DATA
    bandwidth percent 15
    random-detect dscp-based
```

```
class DATA
  bandwidth percent 19
  random-detect dscp-based
class SCAVENGER
  bandwidth percent 5
class NETWORK-CRITICAL
  bandwidth percent 3
class class-default
  bandwidth percent 25
  random-detect
```

### Option 2. Defining Single Global Policy Map

This procedure applies to the DMVPN hub router and all remote-site WAN routers only.

**Step 1:** Create the parent policy map.

```
policy-map [policy-map-name]
```

**Step 2:** Apply the previously created class-map.

```
class [class-name]
```

**Step 3:** (Optional) Assign the maximum guaranteed bandwidth for the class.

```
bandwidth percent [percentage]
```

**Step 4:** (Optional) Define the priority queue for the class. Note, when using a priority queue an implicit policer for this traffic type is applied.

```
priority percent [percentage]
```

**Step 5:** (Optional) Define the congestion mechanism.

```
random-detect [type]
```

**Step 6:** Repeat Step 3 through Step 5 for each class in Table 26, including class-default.

### Option 2 Example

```
policy-map WAN
  class VOICE
    priority percent 10
  class INTERACTIVE-VIDEO
```

```

priority percent 23
class CRITICAL-DATA
  bandwidth percent 15
  random-detect dscp-based
class DATA
  bandwidth percent 19
  random-detect dscp-based
class SCAVENGER
  bandwidth percent 5
class NETWORK-CRITICAL
  bandwidth percent 3
class class-default
  bandwidth percent 25
  random-detect

```



### Tech Tip

Although these bandwidth assignments represent a good base-line, it is important to consider your actual traffic requirements per class and adjust the bandwidth settings accordingly.

## Procedure 4 Configure Per-Site Shapers

This procedure applies to the WAN-aggregation Layer 2 WAN CE router only.

An additional set of shaping policies is applied at the child level to avoid traffic overruns that may occur if a service provider has smaller contracted rates for remote sites than the primary site. The shaping policies apply uniquely to each remote site depending on the destination network addresses and the contracted bandwidth rate for the remote site.

**Step 1:** Create an IP extended access list to match the destination network range for each remote site.

```

ip access-list extended [ACL name site 1]
  permit ip any [site 1 network] [site 1 inverse mask]

```

**Step 2:** Create a class map for each remote site. Associate the destination network access list with the class map.

```

class-map match-all [Class map name site 1]
  match access-group [ACL name site 1]

```

**Step 3:** Repeat steps 1-2 for each remote site.

**Step 4:** Create a child policy map to reserve bandwidth for NETWORK-CRITICAL traffic and enable traffic shaping to the remote sites.

```

policy-map [child policy-map-name]
  class [class-name]
    bandwidth percent [percentage]

```

*Table 27 - Layer 2 WAN remote-site network and bandwidth parameters*

Site	Network	Contracted rate (Mbps)
210	10.5.144.0/21	10
211	10.5.152.0/21	10
212	10.5.168.0/21	20
213	10.5.176.0/21	20

**Step 5:** Configure the shapers for each remote site using the parameters in the previous table.

```

class [class-name]
  shape [average | peak] [bandwidth (kbps)]

```

**Step 6:** Apply the child service policy.

```

service-policy [policy-map-name]

```

**Step 7:** Repeat steps 5-6 for each remote site.

### Example

```

ip access-list extended Br210-10.5.144.0
  permit ip any 10.5.144.0 0.0.7.255
ip access-list extended Br212-10.5.168.0
  permit ip any 10.5.168.0 0.0.7.255

```



```

class-map match-all CLASS-MAP-Br210
  match access-group name Br210-10.5.144.0
class-map match-all CLASS-MAP-Br212
  match access-group name Br212-10.5.168.0
policy-map POLICY-MAP-L2-WAN-BACKBONE-WITH-PER-SITE-SHAPERS
  class NETWORK-CRITICAL
    bandwidth percent 3
  class CLASS-MAP-Br210
    shape average 10000000
    service-policy POLICY-MAP-Br210
  class CLASS-MAP-Br212
    shape average 20000000
    service-policy POLICY-MAP-Br212

```

## Procedure 5 Configure Physical Interface S&Q Policy

With WAN interfaces using Ethernet as an access technology, the demarcation point between the enterprise and service provider may no longer have a physical-interface bandwidth constraint. Instead, a specified amount of access bandwidth is contracted with the service provider. To ensure the offered load to the service provider does not exceed the contracted rate that results in the carrier discarding traffic, you need to configure shaping needs on the physical interface. This shaping is accomplished with a QoS service policy. You configure a QoS service policy on the outside Ethernet interface, and this parent policy includes a shaper that then references a second or subordinate (child) policy that enables queuing within the shaped rate. This is called a hierarchical Class-Based Weighted Fair Queuing (HCBWFQ) configuration. When you configure the **shape average** command, ensure that the value matches the contracted bandwidth rate from your service provider.

This procedure applies to all remote site WAN routers. This procedure may be repeated multiple times to support devices that have multiple WAN connections attached to different interfaces.

**Step 1:** Create the parent policy map.

As a best practice, embed the interface name within the name of the parent policy map.

```

policy-map [policy-map-name]

```

**Step 2:** Configure the shaper.

```

class [class-name]
  shape [average | peak] [bandwidth (kbps)]

```

**Step 3:** Apply the child service policy.

```

service-policy [policy-map-name]

```

## Example (WAN aggregation Layer 2 WAN CE Router)

This example shows a router with a 500-Mbps link on interface GigabitEthernet0/0/4 and a child shaper policy.

```

policy-map WAN-INTERFACE-G0/0/4
  class class-default
    shape average 500000000
    service-policy POLICY-MAP-L2-WAN-BACKBONE-WITH-PER-SITE-SHAPERS

```

## Example (DMVPN Hub Router)

This example shows a router with a 100-Mbps link on interface GigabitEthernet0/0/3.

```

policy-map WAN-INTERFACE-G0/0/3
  class class-default
    shape average 100000000
    service-policy WAN

```

## Example (Remote-site CE Router)

This example shows a router with a 20-Mbps link on interface GigabitEthernet0/0 and a 10-Mbps link on interface GigabitEthernet0/1.

```

policy-map WAN-INTERFACE-G0/0
  class class-default
    shape average 20000000
    service-policy WAN
!
policy-map WAN-INTERFACE-G0/1
  class class-default
    shape average 10000000
    service-policy WAN

```

## Procedure 6

### Apply WAN QoS Policy to Physical Interface

To invoke shaping and queuing on a physical interface, you must apply the parent policy that you configured in the previous procedure.

This procedure applies to all WAN routers. You can repeat this procedure multiple times to support devices that have multiple WAN connections attached to different interfaces.

**Step 1:** Select the WAN interface.

```
interface [interface type] [number]
```

**Step 2:** Apply the WAN QoS policy.

The service policy needs to be applied in the outbound direction.

```
service-policy output [policy-map-name]
```

#### Example

```
interface GigabitEthernet0/0
  service-policy output WAN-INTERFACE-G0/0
!
interface GigabitEthernet0/1
  service-policy output WAN-INTERFACE-G0/1
```

## Notes

# Deploying Application Optimization with WAAS

## Business Overview

The number of remote work sites is increasing, so network administrators need tools to help them ensure solid application performance in remote locations. Recent trends show that the number of remote sites is increasing and that a majority of new hires are located at remote sites. These trends are tied to global expansion, employee attraction and retention, mergers and acquisitions, cost savings, and environmental concerns.

In the meantime, remote-site communications requirements are evolving to embrace collaborative applications, video, and Web 2.0 technologies. These developments are also placing greater performance demands on the remote sites and the WAN.

The enterprise trend toward data-center consolidation also continues. The consolidation efforts move most remote-site assets into data centers, largely to comply with regulatory mandates for centralized security and stronger control over corporate data assets.

Consolidating data centers while growing the remote-site population means that increasing numbers of remote employees access LAN-based business applications across comparatively slow WANs. With these applications growing increasingly multimedia-centric and latency-sensitive, IT and networking staffs are further challenged to keep remote-application response times on par with the experiences of users situated locally to the company's application servers in the data center. These local users enjoy multimegabit LAN speeds and are not affected by any distance-induced delay, unlike their counterparts at the other end of a WAN connection.

Application optimization can boost network performance along with enhancing security and improving application delivery. Cisco WAN Optimization is an architectural solution comprising a set of tools and techniques that work together in a strategic systems approach to provide best-in-class WAN optimization performance while minimizing its total cost of ownership.

## Technology Overview

### WAN Aggregation

The WAN aggregation site uses a cluster of two or more WAE devices to provide WAAS capabilities. The WAE appliances connect to the distribution-layer switch. The connections use EtherChannel both for increased throughput and for resiliency. The WAEs connect to the WAN services network that is configured on the distribution switch.

The Metro 100 design uses a cluster of WAE-7371 devices. The total number of devices required is a minimum of 2 (for N+1 redundancy). Similarly, the Metro 25 design uses a cluster of WAE-7341 devices and the total number of devices required is a minimum of 2 (for N+1 redundancy). Additional detail on the WAE sizing is provided in the following table. The fan-out numbers correspond to the total number of remote-peer WAE devices.

*Table 28 - WAN aggregation WAE options*

Device	Max optimized TCP connections	Max recommended WAN link [Mbps]	Max optimized throughput [Mbps]	Max core fan-out [Peers]
WAVE-574-3GB	750	8	100	35
WAVE-574-6GB	1300	20	150	70
WAVE-594-8GB	750	50	250	50
WAVE-594-12GB	1300	100	300	100
WAE-674-4GB	2000	45	250	100
WAE-674-8GB	6000	90	350	200
WAE-674-8GB-VB	4000	90	350	200
WAE-694-16GB	2500	200	450	150
WAE-694-24GB	6000	200	500	300
WAE-7341	12000	310	1000	1400
WAE-7371	50000	1000	2500	2800
WAVE-7541	18000	500	1000	700
WAVE-7571	60000	1000	2000	1400
WAVE-8541	150000	2000	4000	2800

A more comprehensive, interactive WAAS sizing tool is available for registered users of cisco.com:

<http://tools.cisco.com/WAAS/sizing>

The WCCP is a protocol developed by Cisco. Its purpose is to transparently intercept and redirect traffic from a network device to a WCCP appliance such as a WAE running WAAS (discussed below).

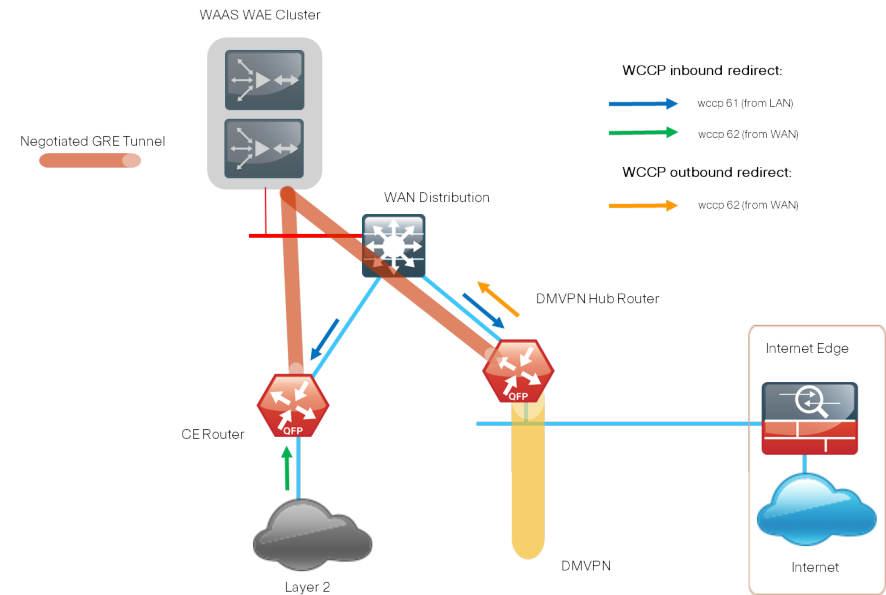
WCCP is enabled on the Layer 2 WAN CE and DMVPN routers. The WCCP redirect uses service groups 61 and 62 to match traffic for redirection. These service groups must be used in pairs:

- Service group 61 uses the source address to redirect traffic
- Service group 62 uses the destination address to redirect traffic

This design uses WCCP 61 inbound on LAN-facing interfaces to match unoptimized data sourced from the data center that is destined for clients at the WAN remote sites. WCCP 62 is used inbound on WAN-facing interfaces, matching optimized data sourced from the WAN remote sites. WCCP 62 is used outbound on LAN interfaces for DMVPN hub routers.

The connections from the switch to the Layer 2 WAN CE and DMVPN routers are all routed point-to-point links. This design mandates the use of a negotiated-return GRE tunnel from WAE to router. When a design uses a GRE negotiated return, it is not required to extend the WAN services VLAN to include the Layer 2 WAN CE and DMVPN routers.

*Figure 30 - WAN aggregation—WAAS topology*



## Remote Sites

The WAN Optimization design for the remote sites can vary somewhat based on site-specific characteristics. Single router sites use a single (non-redundant) WAE. Similarly, all dual-router sites use dual WAEs. The specifics of the WAE sizing and form-factor primarily depend on the number of end users and bandwidth of the WAN links. There are many factors to consider in the selection of the WAN remote-site WAN Optimization platform. The primary parameter of interest is the bandwidth of the WAN link. After the bandwidth requirement has been met, the next item under consideration is the maximum number of concurrent, optimized TCP connections. Additional detail on the WAE sizing is provided in the following table. The optimized throughput numbers correspond to the apparent bandwidth available after successfully optimization by WAAS.

Table 29 - WAN Remote-Site WAE Options

Device	Max optimized TCP connections	Max recommended WAN link [Mbps]	Max optimized throughput [Mbps]
SRE-700-S	200	20	200
SRE-700-M	500	20	200
SRE-900-S	200	50	300
SRE-900-M	500	50	300
SRE-900-L	1000	50	300
WAVE-274	200	2	90
WAVE-294-4GB	200	10	100
WAVE-294-8GB	500	20	150
WAVE-474	400	4	90
WAVE-574-3GB	750	8	100
WAVE-574-6GB	1300	20	150
WAVE-594-8GB	750	50	250
WAVE-594-12GB	1300	100	300
WAE-674-4GB	2000	45	250
WAE-674-8GB	6000	90	350
WAE-674-8GB-VB	4000	90	350
WAE-694-16GB	2500	200	450
WAE-694-24GB	6000	200	500
WAE-7341	12000	310	1000
WAE-7371	50000	1000	2500
WAVE-7541	18000	500	1000
WAVE-7571	60000	1000	2000
WAVE-8541	150000	2000	4000

A more comprehensive, interactive WAAS sizing tool is available for registered users of cisco.com: <http://tools.cisco.com/WAAS/sizing>

The WAE form factors previously discussed include a router Service Ready Engine (SRE) and an external appliance. These variants all run the same WAAS software and are functionally equivalent. The primary difference is the method of LAN attachment for these devices:

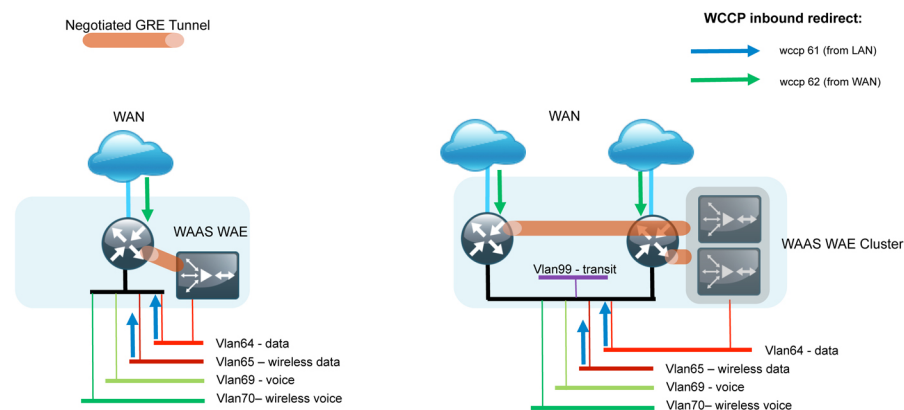
- SRE: One internal interface (router connect only), one external interface
- Appliance: Two interfaces (both external)

The approach for connecting the WAE devices to the LAN is to be consistent regardless of the chosen hardware form-factor. All WAE connections are made using the external interfaces. The benefit of this method is that it is not necessary to create a dedicated network specifically to attach the WAE devices, and the SRE and appliance devices can use an identical design. The internal interface of the SRE is not used for this design, except for the initial bootstrapping of the device configurations.

You must connect an external Ethernet cable from each SRE module for this solution.

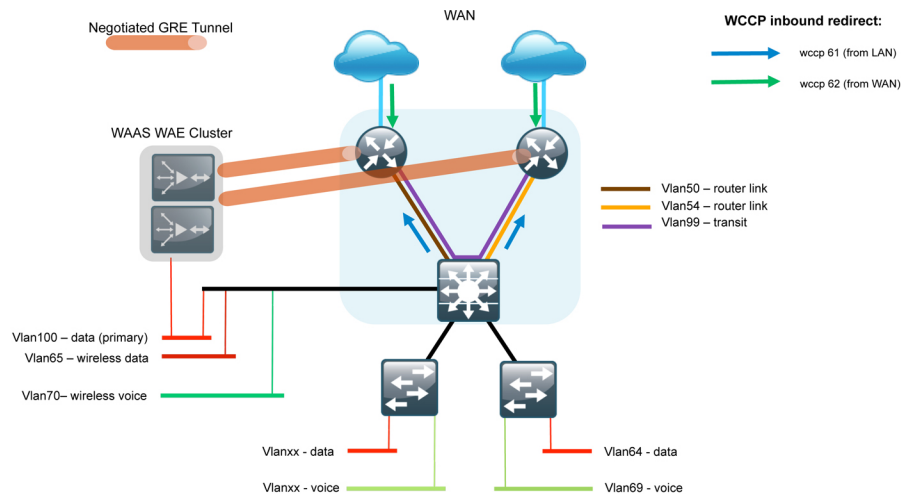
You should connect the WAE devices to the data VLAN of the access switch in all flat Layer 2 designs.

Figure 31 - WAN remote-site—WAAS topology (access layer connection)



When the deployment uses a distribution-layer design, the WAE devices should connect to the primary data VLAN on the distribution switch.

**Figure 32 - WAN remote-site—WAAS topology (distribution layer connection)**



Where possible, connect the WAE appliances through both interfaces using EtherChannel for performance and resiliency.

WCCP Version 2 is enabled on the WAN routers to redirect traffic to the WAAS appliances.

The WCCP redirect uses service groups 61 and 62 to match traffic for redirection. These services groups must be used in pairs:

- Service group 61 uses the source address to redirect traffic
- Service group 62 uses the destination address to redirect traffic

This design uses WCCP 61 inbound on LAN-facing VLAN subinterfaces to match unoptimized data sourced from the clients destined for the data center (or other remote sites). In all cases, WCCP 62 is used inbound on WAN-facing interfaces to match optimized data sourced from the data center (or other remote sites).

Because the WAE is connected to the data VLAN, this design requires the use of a negotiated-return GRE tunnel from the WAE to the router. When using a GRE-negotiated return, you are not required to create a new network on the routers specifically to attach the WAEs.

The following steps provide an overview of the tasks required to configure a basic WAAS environment.

## Process

### WAAS/WAE Configuration

1. Install the vWAAS Virtual Machine
2. Configure the WAAS Central Manager
3. Configure Switch for WAE Appliances
4. Configure the WAE Appliance Devices
5. Configure the WAE SRE and NME Devices
6. Configure Remote Switch for WAE Devices
7. Configure WCCPv2 on Routers

## Procedure 1

### Install the vWAAS Virtual Machine

This procedure is optional and only required if you are using a Virtual WAAS (vWAAS).

vWAAS is provided as an Open Virtual Appliance (OVA). The OVA is pre-packaged with disk, memory, CPU, NICs and other virtual machine related configuration parameters. This is an industry standard and many virtual appliances are available in this format. A different OVA file is provided for each vWAAS model.



### Tech Tip

The OVA files are only available in DVD media format and are not available for download on [www.cisco.com](http://www.cisco.com) at this time.

**Step 1:** Deploy OVF Template with VMWare vSphere client.

You must first install the vWAAS OVA on the VMware ESX/ESXi server using vSphere before configuring vWAAS.

**Step 2:** Configure the device using the VMware console.

The procedures and steps for configuring the vWAAS Central Manager and vWAAS Application Accelerator devices are identical to those for the WAE appliance and SRE form factors. Select the appropriate following procedure to complete the vWAAS configuration.

## Procedure 2 Configure the WAAS Central Manager

Use a Cisco WAVE-574 device for the Central Manager function at the primary location to provide graphical management, configuration, and reporting for the WAAS network. This device resides in the server farm because it is not directly in the forwarding path of the WAN optimization, but provides management and monitoring services. Initial configuration of the Central Manager requires terminal access to the console port for basic configuration options and IP address assignment. For all WAE devices, the factory default username is admin and the factory default password is default.

You can start the initial setup utility from the command line by entering the setup command.

**Step 1:** Run setup.

Parameter	Default Value
1. Device Mode	Application Accelerator
2. Interception Method	WCCP
3. Time Zone	UTC 0 0
4. Management Interface	GigabitEthernet 1/0
5. Autosense	Enabled
6. DHCP	Enabled
ESC Quit ? Help	WAAS Default Configuration

Press 'y' to select above defaults, 'n' to configure all, <1-6> to change specific default [y]: **n**

**Step 2:** Configure as Central Manager.

1. Application Accelerator
  2. Central Manager
- Select device mode [1]: **2**

**Step 3:** Configure time zone.

Enter Time Zone <Time Zone Hours(-23 to 23) Minutes(0-59)>  
[UTC 0 0]: **PST -8 0**

**Step 4:** Configure management interface, IP address, and default gateway.

No.	Interface Name	IP Address	Network Mask
1.	GigabitEthernet	1/0	dhcp
2.	GigabitEthernet	2/0	dhcp

Select Management Interface [1]: **1**  
Enable Autosense for Management Interface? (y/n) [y]: **y**  
Enable DHCP for Management Interface? (y/n) [y]: **n**  
Enter Management Interface IP Address  
<a.b.c.d or a.b.c.d/X(optional mask bits)> [Not configured]:  
**10.4.48.100/24**  
Enter Default Gateway IP Address [Not configured]: **10.4.48.1**

**Step 5:** Configure DNS, host, and NTP settings.

Enter Domain Name Server IP Address [Not configured]:  
**10.4.48.10**  
Enter Domain Name(s) (Not configured): **cisco.local**  
Enter Host Name (None): **WAAS-WCM-1**  
Enter NTP Server IP Address [None]: **10.4.48.17**

**Step 6:** Select appropriate license.

The product supports the following licenses:  
1. Enterprise  
Enter the license(s) you purchased [1]: **1**



**Step 7:** Verify configuration settings and initiate reload.

Parameter	Configured Value
1. Device Mode	Central Manager
2. Time Zone	PST -8 0
3. Management Interface	GigabitEthernet 1/0
4. Autosense	Enabled
5. DHCP	Disabled
6. IP Address	10.4.48.100
7. IP Network Mask	255.255.255.0
8. IP Default Gateway	10.4.48.1
9. DNS IP Address	10.4.48.10
10. Domain Name(s)	cisco.local
11. Host Name	WAAS-WCM-1
12. NTP Server Address	10.4.48.17
13. License	Enterprise

ESC Quit ? Help ! CLI ————— WAAS Final Configuration

Press 'y' to select configuration, 'd' to toggle defaults display, <1-13> to change specific parameter [y]: **y**  
 Apply WAAS Configuration: Device Mode changed in SETUP; New configuration takes effect after a reload. If applicable, registration with CM, CM IP address, WAAS WCCP configuration etc, are applied after the reboot. Initiate system reload?  
 <y/n> [n] **y**  
 Are you sure? <y/n> [n]: **y**

**Step 8:** After the reboot, login to the WAAS Central Manager and enable SSH.

To enable SSH, you need to generate the RSA key and enable the sshd service.

```
ssh-key-generate key-length 2048
sshd version 2
sshd enable
```

**Step 9:** Disable telnet.

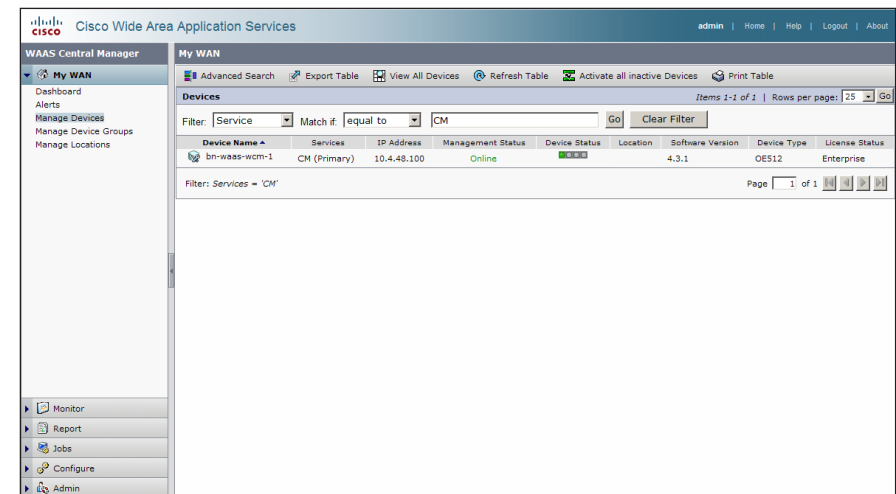
```
no telnet enable
```

**Step 10:** Access the WAAS Central Manager through the web interface.

The Central Manager device should now be up and running after the reload completes, and be accessible to a web browser at the IP address assigned during Step 6 of the setup utility, or at the associated host name if it has been configured in DNS. Specify secure HTTP and the port number 8443 to access the Central Manager, for example https://10.4.48.100:8443. Login using the default administrator user name and password.

**Step 11:** Click **My WAN > Manage Devices**. The Central Manager appears in the My WAN window as the only managed device.

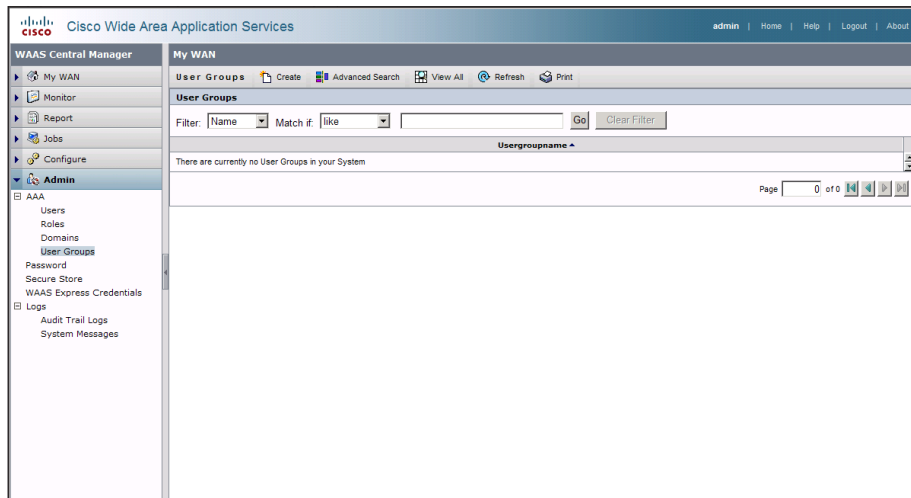
*Figure 33 - WAAS Central Manager-Managed device list*



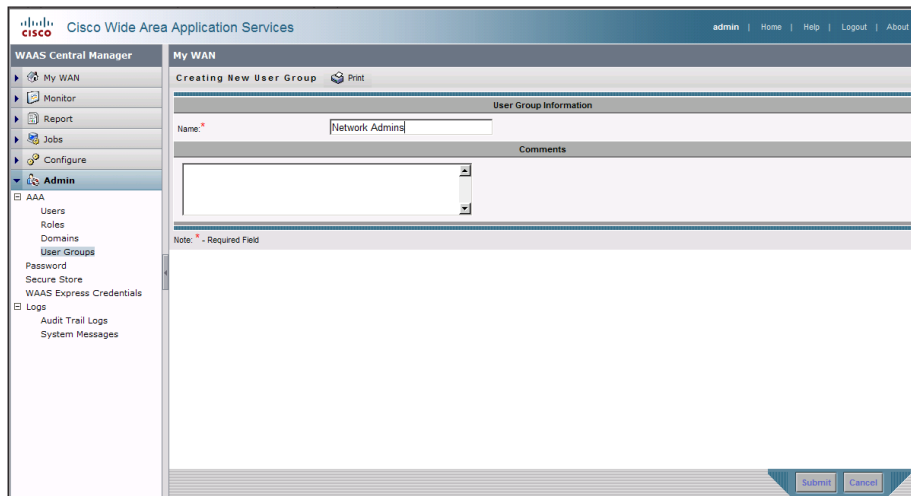
**Step 12:** Configure Network-Admins user group.

The web interface for the Central Manager requires a user group with the proper role assigned to properly authorize users from an external AAA database. This step must be completed before enabling AAA in the following step and can only be performed using the web interface.

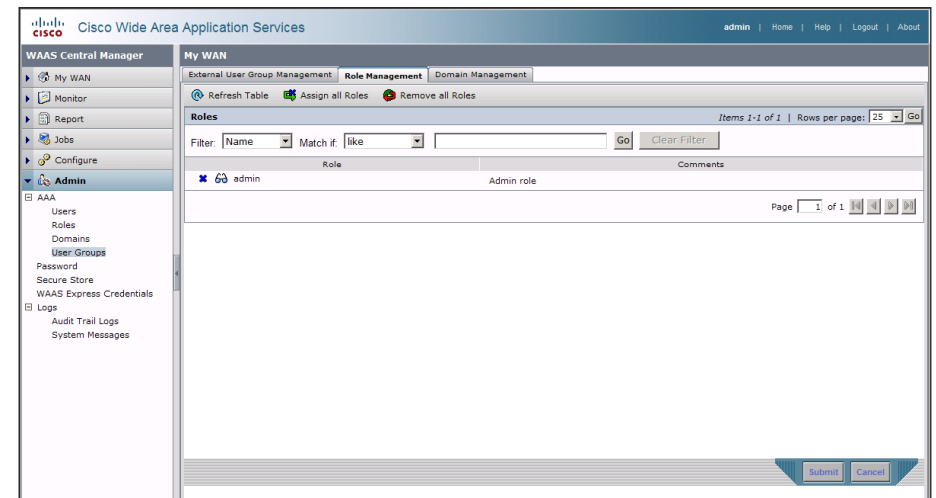
In **Admin > AAA > click User Groups**.



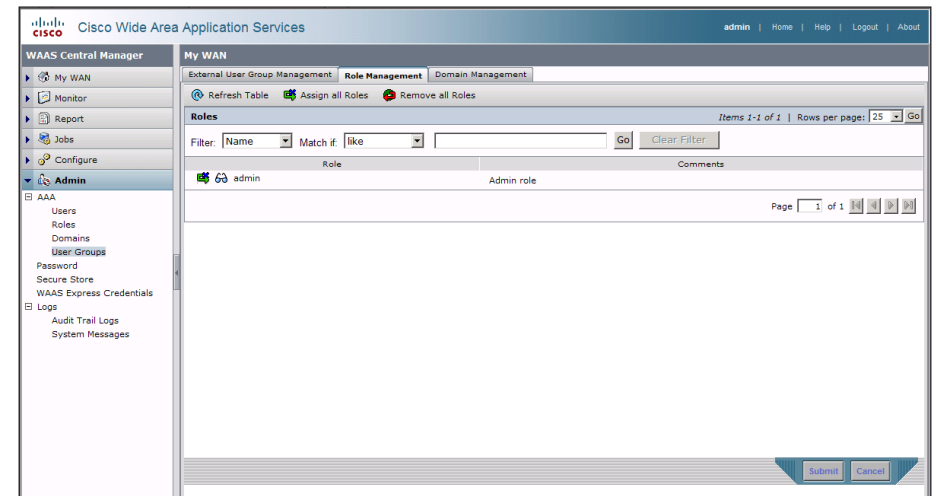
Click **Create** and then in the Name field, type a name. This name must match exactly (case sensitive) the group name used on the AAA server. For example, "Network Admins" in this implementation.



After you create the group, click the **Role Management** tab and then click the **X** to assign the role.



After you properly assign the role, a large green check marks appears next to the icon.



### Step 13: Configure secure user authentication.

Enable AAA authentication access control. AAA controls all management access to the WAAS/WAE devices (SSH and HTTPS).

A local admin user was created on the WAAS/WAE during setup. This user account provides the ability to manage the device in case the centralized TACACS+ server is unavailable or in case you do not have a TACACS+ server in your organization.



#### Tech Tip

The AAA configuration details shown are for the WAAS devices only. Additional configuration is required on the AAA server for successful user authorization. Do not proceed with configuring secure user authentication until you have completed the relevant steps in the *Cisco SBA for Enterprise Organizations—Borderless Networks Network Device Authentication and Authorization Deployment Guide*.

The following configures TACACS+ as the primary method for user authentication (login) and user authorization (configuration).

```
tacacs key SecretKey
tacacs password ascii
tacacs host 10.4.48.15 primary
!
authentication login local enable secondary
authentication login tacacs enable primary
authentication configuration local enable secondary
authentication configuration tacacs enable primary
authentication fail-over server-unreachable
```

### Step 14: After you make configuration changes, save the configuration.

```
copy running-config startup-config
```

### Procedure 3

### Configure Switch for WAE Appliances

The WAN distribution switch is the appropriate location to physically connect devices at the WAN-aggregation site such as WAE appliances that support WAN optimization. This device type requires a resilient connection but does not require a routing protocol. This type of connection can use a Layer 2 EtherChannel link.

This guide assumes that the distribution layer switch has already been configured. Only the procedures required to complete the connection of the switch to the WAE appliances are included. Full details on distribution layer switch configuration are included in the *Cisco SBA for Enterprise Organizations—Borderless Networks LAN Deployment Guide*.

You must create a VLAN and SVI for this and other devices with similar connectivity requirements. This VLAN is referred to as the WAN service network.

#### Step 1: Create the VLAN and SVI.

```
vlan [VLAN number]
 name [VLAN name]
!
interface Vlan [VLAN number]
 ip address [IP address] [netmask]
 no shutdown
```

#### Step 2: Configure Layer 2 EtherChannel links for the devices and associate them with the VLAN.

```
interface Port-channel [number]
 switchport access vlan [VLAN number]
!
interface [type] [number]
 switchport access vlan [VLAN number]
 channel-group [number] mode on
 no shutdown
```

## Example

```
vlan 350
 name WAN_Service_Net-10.4.32.128
!
interface Port-channel17
 description bn-wae-1 EtherChannel
 switchport access vlan 350
!
interface GigabitEthernet1/0/2
 description bn-wae-1 port 1
 switchport access vlan 350
 channel-group 7 mode on
 no shutdown
!
interface GigabitEthernet2/0/2
 description bn-wae-1 port 2
 switchport access vlan 350
 channel-group 7 mode on
 no shutdown
!
interface Vlan350
 ip address 10.4.32.129 255.255.255.192
 no shutdown
```

## Procedure 4 Configure the WAE Appliance Devices

A cluster of Cisco WAE-7341 appliances is deployed at the WAN-aggregation site to provide the headend termination for WAAS traffic to and from the remote sites across the WAN. You connect these devices directly to the WAN distribution-layer switch, using GRE-negotiated return to communicate with the WCCP routers.

You can also deploy WAE appliances at WAN remote sites, either individually or as part of a WAE cluster. You should use this procedure to configure WAN remote-site WAE appliances. You use the same setup utility that you used in the initial configuration of the WAAS Central Manager to set up WAE appliance devices. These devices only require basic setup through their

console port to assign initial settings. After you complete this setup, you can perform all management of the WAAS network through the WAAS Central Manager console.

Initial configuration of the WAE application accelerators requires terminal access to the console port for basic configuration options and IP address assignment. For all WAE devices, the factory default user name is admin and the factory default password is default.

The setup utility configuration steps for the application accelerator WAEs are similar to the setup of the Central Manager, but the steps begin to differ after you choose application-accelerator as the device mode in Step 2. After you choose this mode, the setup script changes to allow you to register the WAE with the existing Central Manager, and to define the traffic interception method as WCCP.

### Step 1: Run setup.

You can start the initial setup utility from the command line by entering the **setup** command.

Parameter	Default Value
1. Device Mode	Application Accelerator
2. Interception Method	WCCP
3. Time Zone	UTC 0 0
4. Management Interface	GigabitEthernet 1/0
5. Autosense	Enabled
6. DHCP	Enabled
ESC Quit ? Help	WAAS Default Configuration

Press 'y' to select above defaults, 'n' to configure all, <1-6> to change specific default [y]: **n**

### Step 2: Configure as application accelerator.

1. Application Accelerator
  2. Central Manager
- Select device mode [1]: **1**

### Step 3: Configure interception method.

1. WCCP
  2. Other
- Select Interception Method [1]: **1**

#### Step 4: Configure time zone.

```
Enter Time Zone <Time Zone Hours(-23 to 23) Minutes(0-59)>
[UTC 0 0]: PST -8 0
```

#### Step 5: Configure management interface, IP address, and default gateway.

```
No. Interface Name      IP Address      Network Mask
  1. GigabitEthernet    1/0             dhcp
  2. GigabitEthernet    2/0             dhcp

Select Management Interface [1]: 1
Enable Autosense for Management Interface? (y/n) [y]: y
Enable DHCP for Management Interface? (y/n) [y]: n
Enter Management Interface IP Address
<a.b.c.d or a.b.c.d/X(optional mask bits)> [Not configured]:
10.4.32.161/26
Enter Default Gateway IP Address [Not configured]: 10.4.32.129
Enter Central Manager IP Address (WARNING: An invalid entry
will cause SETUP to take a long time when applying WAAS
configuration) [None]: 10.4.48.100
```

#### Step 6: Configure DNS, host, and NTP settings.

```
Enter Domain Name Server IP Address [Not configured]:
10.4.48.10
Enter Domain Name(s) (Not configured): cisco.local
Enter Host Name (None): WAE7341-1
Enter NTP Server IP Address [None]: 10.4.48.17
```

#### Step 7: Configure WCCP router list.

```
Enter WCCP Router (max 4) IP Address list (ip1 ip2 ...) []:
10.4.32.243 10.4.32.245
```

#### Step 8: Select appropriate license.

The product supports the following licenses:

1. Transport
2. Enterprise
3. Enterprise & Video
4. Enterprise & Virtual-Blade
5. Enterprise, Video & Virtual-Blade

```
Enter the license(s) you purchased [2]: 2
```

#### Step 9: Verify configuration settings.

Parameter	Configured Value
2. Interception Method	WCCP
3. Time Zone	PST -8 0
4. Management Interface	GigabitEthernet 1/0
5. Autosense	Enabled
6. DHCP	Disabled
7. IP Address	10.4.32.161
8. IP Network Mask	255.255.255.192
9. IP Default Gateway	10.4.32.129
10. CM IP Address	10.4.48.100
11. DNS IP Address	10.4.48.10
12. Domain Name(s)	cisco.local
13. Host Name	WAE7341-1
14. NTP Server Address	10.4.48.17
15. WCCP Router List	10.4.32.243 10.4.32.245
16. License	Enterprise

```
ESC Quit ? Help ! CLI _____ WAAS Final Configuration
```

Press 'y' to select configuration, <F2> to see all configuration, 'd' to toggle defaults display, <1-16> to change specific parameter [y]: **y**  
Applying WAAS configuration on WAE ...  
May take a few seconds to complete ...

If the switch connection to the WAE is configured as a port-channel, this procedure will fail, because the WAE setup script does not enable the port-channel. If so, the registration with the WAAS Central Manager is completed manually in Step 11.

#### Step 10: (Optional) Configure port-channel connection for WAE to connect to the distribution switch stack.

This is an optional step that is only required when connecting the WAE using a port channel for a resilient connection.

```
interface GigabitEthernet 1/0
  no ip address 10.4.32.161 255.255.255.192
  exit
!
primary-interface PortChannel 1
```

```

!
interface PortChannel 1
 ip address 10.4.32.161 255.255.255.192
 exit
!
interface GigabitEthernet 1/0
 channel-group 1
 exit
interface GigabitEthernet 2/0
 channel-group 1
 exit

```

### Step 11: (Optional) Complete registration with WAAS Central Manager.

After the port-channel has been configured, the WAE can reach the WAAS Central Manager. Run the **cms enable** command to force a manual registration.

This is an optional step only required when connecting the initial attempt to register in Step 9 has failed.

```

cms enable
Registering WAAS Application Engine...
Sending device registration request to Central Manager with
address 10.4.48.100
Please wait, initializing CMS tables
Successfully initialized CMS tables
Registration complete.
Please preserve running configuration using 'copy running-
config startup-config'.
Otherwise management service will not be started on reload and
node will be shown 'offline' in WAAS Central Manager UI.
management services enabled

```

There are several additional non-default settings that are enabled on the WAE devices to complete the configuration. These settings are configured in Steps 13 through 15.

### Step 12: Configure GRE negotiated return.

All WAE devices use GRE-negotiated return with their respective WCCP routers:

```
egress-method negotiated-return intercept-method wccp
```

### Step 13: Configure WCCP router list.

The setup script generated a router-list based on the information provided. To view the device configuration, enter the following command:

```

WAE7341-1# show running-config | include wccp router-list
wccp router-list 8 10.4.32.243 10.4.32.245

```

Router list 8 is specifically for use with WCCP configured on a default gateway router. This design uses GRE-negotiated return and router loopback addresses so we need to create a new router list and delete router list 8.

All WAE configurations in this design use router list 1.

```

no wccp router-list 8 10.4.32.243 10.4.32.245
wccp router-list 1 10.4.32.243 10.4.32.245

```

This design uses authentication between the routers and WAE.



### Tech Tip

ASR1000 series routers must use WCCP mask-assign mode for WCCP to operate properly.

If any of the WCCP routers are Cisco ASR1000 Series routers, then change the default setting of hash-source-ip to mask-assign. This change is made on the WAEs, not on the routers.

```

wccp tcp-promiscuous service-pair 61 62 router-list-num 1
password cisco123 mask-assign

```

All other router platforms can use the default setting:

```

wccp tcp-promiscuous service-pair 61 62 router-list-num 1
password cisco123

```

### Step 14: Enable SSH.

To enable SSH, you must generate the RSA key and enable the sshd service.

```

ssh-key-generate key-length 2048
sshd version 2
sshd enable

```

### Step 15: Disable telnet.

```
no telnet enable
```

### Step 16: Configure secure user authentication.

Enable AAA authentication for access control. AAA controls all management access to the WAAS/WAE devices (SSH and HTTPS).

A local admin user was created on the WAAS/WAE during setup. This user account provides the ability to manage the device in case the centralized TACACS+ server is unavailable or in case you do not have a TACACS+ server in your organization.

The following configures TACACS+ as the primary method for user authentication (login) and user authorization (configuration).

```
tacacs key SecretKey
tacacs password ascii
tacacs host 10.4.48.15 primary
!
authentication login local enable secondary
authentication login tacacs enable primary
authentication configuration local enable secondary
authentication configuration tacacs enable primary
authentication fail-over server-unreachable
```

### Step 17: Save the configuration.

After you make configuration changes, save the configuration.

```
copy running-config startup-config
```

## Procedure 5 Configure the WAE SRE and NME Devices

A variety of WAE appliances or SRE form-factors for the remote-site WAAS equipment in this design, depending on the performance requirements.

You can insert the SRE modules directly into a corresponding module slot in the remote-site router and configure them somewhat differently from the appliances. If you are using an appliance, you can follow the WAN Aggregation WAE Device set of procedures with remote-site addressing parameters.

Although the remote-site router can potentially communicate directly with the SRE by using the router backplane, this design uses the external interfaces on the modules, which allows for a consistent design implementation regardless of the chosen WAE device. The SM interface must be enabled

and have an arbitrary (locally significant only) IP address assigned in order to be accessed through a console session from the host router.

You must connect the external interface to the data network on the access or distribution switch for this configuration to work properly.

### Step 1: Configure console access and SRE IP address on the host router.

To permit console access to the SRE modules, you must enter the following commands on the host router.

```
interface SM1/0
ip address 1.1.1.1 255.255.255.252
service-module external ip address 10.5.52.8 255.255.255.0
service-module ip default-gateway 10.5.52.1
no shutdown
```



#### Tech Tip

The IP address assigned 1.1.1.1 to SM/0 is arbitrary in this design and only locally significant to the host router.

### Step 2: (Optional) Configure a AAA exemption for SRE devices.

If AAA has been enabled on the router, you will be prompted for both a router login and a WAAS login; this can be confusing. Disabling the initial router authentication requires the creation of a AAA method, which then is applied to the specific line configuration on the router associated with the SRE.

Create the AAA login method:

```
aaa authentication login MODULE none
```

Determine which line number is assigned to SRE. The example output below shows line 67.

```
Br203-2921-1# show run | begin line con 0
line con 0
logging synchronous
line aux 0
line 67
no activation-character
```



```

no exec
transport preferred none
transport input all
transport output pad telnet rlogin lapb-ta mop udptn v120 ssh
stopbits 1
flowcontrol software
line vty 0 4
password 7 04585A150C2E1D1C5A
transport input ssh

```

Restrict access to the SRE console by creating an access-list. The access-list number is arbitrary, but the IP address must match the address assigned to the SM interface.

```
access-list 67 permit 1.1.1.1
```

Assign the method to the appropriate line:

```

line 67
login authentication MODULE
access-class 67 in
transport output none

```

**Step 3:** Connect to the WAE console using a session from the host router.

After the IP address is assigned, and the interface is enabled, it is possible to open a session on the WAE and run the setup script. For all WAE devices, the factory default username is admin and the factory default password is default.

NOTE: If you are using secure user authentication on the router and have not created a AAA exemption, you must first authenticate with a valid router login credential before logging into the WAE console session.

```
Br203-2921-1# service-module sm 1/0 session
```

**Step 4:** Run setup.

You can start the initial setup utility from the command line by entering the **setup** command.

Parameter	Default Value
Device Mode	Application Accelerator
1. Interception Method	WCCP
2. Time Zone	UTC 0 0
3. Management Interface	GigabitEthernet 1/0 (internal)
Autosense	Disabled
DHCP	Disabled
ESC Quit ? Help	WAAS Default Configuration

Press 'y' to select above defaults, 'n' to configure all, <1-3> to change specific default [y]: **n**

**Step 5:** Configure interception method.

```

1. WCCP
2. Other
Select Interception Method [1]: 1

```

**Step 6:** Configure time zone.

```

Enter Time Zone <Time Zone Hours(-23 to 23) Minutes(0-59)>
[UTC 0 0]: PST -8 0

```

**Step 7:** Configure management interface, IP address, and default gateway. This design uses the external interface as the management interface.

No.	Interface Name	IP Address	Network Mask
1.	GigabitEthernet 1/0 (internal)	unassigned	unassigned
2.	GigabitEthernet 2/0 (external)	dhcp	

```

Select Management Interface [1]: 2
Enable Autosense for Management Interface? (y/n) [y]: y
Enable DHCP for Management Interface? (y/n) [y]: n

```



## Tech Tip

You may receive the following warning. This warning may be disregarded as the IP address configuration was provided previously.

```
*** You have chosen to disable DHCP! Any network
configuration learnt from DHCPserver will be
unlearnt! SETUP will indicate failure as the
managementinterface cannot be brought up - Please
make sure WAE Management Interface IPaddress and
Default Gateway are configured from the Router;
Press ENTER to continue:
```

### Step 8: Configure Central Manager address.

```
Enter Central Manager IP Address (WARNING: An invalid entry
will cause SETUP to take a long time when applying WAAS
configuration) [None]: 10.4.48.100
```

### Step 9: Configure DNS, host, and NTP settings.

```
Enter Domain Name Server IP Address [Not configured]:
10.4.48.10
Enter Domain Name(s) (Not configured): cisco.local
Enter Host Name (None): Br203-WAE-SRE700-1
Enter NTP Server IP Address [None]: 10.4.48.17
```

### Step 10: Configure WCCP router list.

```
Enter WCCP Router (max 4) IP Address list (ip1 ip2 ...) []:
10.5.48.253 10.5.48.254
```

### Step 11: Select appropriate license.

The product supports the following licenses:

1. Transport
2. Enterprise
3. Enterprise & Video

```
Enter the license(s) you purchased [2]: 2
```

### Step 12: Verify configuration settings.

Parameter	Configured Value
1. Interception Method	WCCP
2. Time Zone	PST -8 0
3. Management Interface	GigabitEthernet 2/0 (external)
4. Autosense	Enabled
5. DHCP	Disabled
IP Address	10.5.52.8
IP Network Mask	255.255.255.0
IP Default Gateway	10.5.52.1
6. CM IP Address	10.4.48.100
7. DNS IP Address	10.4.48.10
8. Domain Name(s)	cisco.local
9. Host Name	Br203-WAE-SRE700-1
10. NTP Server Address	10.4.48.17
11. WCCP Router List	10.5.48.253 10.5.48.254
12. License	Enterprise
ESC Quit ? Help ! CLI _____ WAAS Final Configuration	

Press 'y' to select configuration, <F2> to see all configuration, 'd' to toggle defaults display, <1-12> to change specific parameter [y]: **y**

#### Router WCCP configuration

First WCCP router IP in the WCCP router list seems to be an external address; WCCP configuration on external routers is not allowed through SETUP. Please press ENTER to apply WAAS configuration on WAE ...

Applying WAAS configuration on WAE ...

May take a few seconds to complete ...

WAAS configuration applied successfully!!

Saved configuration to memory.

Press ENTER to continue ...

You will be prompted with a recommended router WCCP configuration template. This router configuration is covered in depth in a following procedure, so you do not need to retain this information.

**Step 13:** Configure GRE negotiated return.

All WAE devices use GRE-negotiated return with their respective WCCP routers:

```
egress-method negotiated-return intercept-method wccp
```

**Step 14:** Configure WCCP router list.

The setup script generated a router-list based on the information provided. To view the device configuration, enter the following command:

```
Br203-WAE-SRE700-1# show running-config | include wccp router-  
list
```

```
wccp router-list 8 10.5.48.253 10.5.48.254
```

Router list 8 is specifically for use with WCCP configured on a default gateway router. This design uses GRE-negotiated return and router loopback addresses so we need to create a new router list and delete router list 8.

All WAE configurations in this design use router list 1.

```
no wccp router-list 8 10.5.48.253 10.5.48.254
```

```
wccp router-list 1 10.5.48.253 10.5.48.254
```

This design uses authentication between the routers and the WAEs.

```
wccp tcp-promiscuous router-list-num 1 password cisco123
```

**Step 15:** Enable SSH.

Enabling SSH requires the generation of the RSA key and enabling of the sshd service.

```
ssh-key-generate key-length 2048
```

```
sshd version 2
```

```
sshd enable
```

**Step 16:** Disable telnet.

```
no telnet enable
```

**Step 17:** Configure secure user authentication.

Enable AAA authentication for access control. AAA controls all management access to the WAAS/WAE devices (SSH and HTTPS).

A local admin user was created on the WAAS/WAE during setup. This user account provides the ability to manage the device in case the centralized TACACS+ server is unavailable or in case you do not have a TACACS+ server in your organization.

The following configures TACACS+ as the primary method for user authentication (login) and user authorization (configuration).

```
tacacs key SecretKey
```

```
tacacs password ascii
```

```
tacacs host 10.4.48.15 primary
```

```
!
```

```
authentication login local enable secondary
```

```
authentication login tacacs enable primary
```

```
authentication configuration local enable secondary
```

```
authentication configuration tacacs enable primary
```

```
authentication fail-over server-unreachable
```

**Step 18:** Save the configuration.

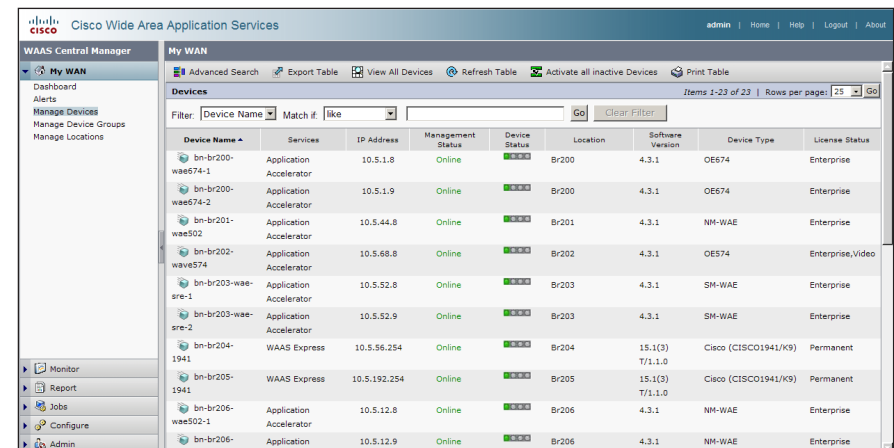
After you make configuration changes, save the configuration.

```
copy running-config startup-config
```

Each WAE registers with the WAAS Central Manager as they become active on the network. You can verify this registration using the show cms info command on the respective WAE or via the web interface to the WCM.

When this configuration is complete, you can return the session to the command line of the host router by entering the escape sequence Ctrl-Shift-6 x.

*Figure 34 - WAAS Central Manager-Populated managed device list*



The screenshot displays the Cisco Wide Area Application Services (WAAS) Central Manager web interface. The main section shows a table of managed devices. The table has columns for Device Name, Services, IP Address, Management Status, Device Status, Location, Software Version, Device Type, and License Status. The devices listed include various Application Accelerators and WAAS Express devices, all showing 'Online' management and device status. The interface also includes a sidebar with navigation options like Dashboard, Alerts, Manage Devices, and a top navigation bar with user information and links.

Device Name	Services	IP Address	Management Status	Device Status	Location	Software Version	Device Type	License Status
bn-br200-wae574-1	Application Accelerator	10.5.1.8	Online	Online	Br200	4.3.1	OE574	Enterprise
bn-br200-wae574-3	Application Accelerator	10.5.1.9	Online	Online	Br200	4.3.1	OE574	Enterprise
bn-br201-wae502	Application Accelerator	10.5.44.8	Online	Online	Br201	4.3.1	NM-WAE	Enterprise
bn-br202-wae574	Application Accelerator	10.5.68.8	Online	Online	Br202	4.3.1	OE574	Enterprise, Video
bn-br203-wae-sre-1	Application Accelerator	10.5.52.8	Online	Online	Br203	4.3.1	SM-WAE	Enterprise
bn-br203-wae-sre-2	Application Accelerator	10.5.52.9	Online	Online	Br203	4.3.1	SM-WAE	Enterprise
bn-br204-1941	WAAS Express	10.5.56.254	Online	Online	Br204	15.1(3) T/1.0	Cisco (CISCO1941/K9)	Permanent
bn-br205-1941	WAAS Express	10.5.192.254	Online	Online	Br205	15.1(3) T/1.0	Cisco (CISCO1941/K9)	Permanent
bn-br206-wae502-1	Application Accelerator	10.5.12.8	Online	Online	Br206	4.3.1	NM-WAE	Enterprise
bn-br206-wae502-2	Application Accelerator	10.5.12.9	Online	Online	Br206	4.3.1	NM-WAE	Enterprise

## Procedure 6 Configure Remote Switch for WAE Devices

If you are using a remote-site distribution-layer design, the distribution switch is the appropriate location to physically connect the WAE devices. This device type requires a resilient connection, but does not require a routing protocol. This type of connection can use a Layer 2 EtherChannel link.

This guide assumes that the distribution layer switch has already been configured. Only the procedures required to complete the connection of the switch to the WAE appliances are included. Full details on distribution layer switch configuration are included in the *Cisco SBA for Enterprise Organizations—Borderless Networks LAN Deployment Guide*.

This design locates the WAE devices on the data (primary) VLAN. It is required to create a VLAN and SVI for this VLAN if it does not already exist.

**Step 1:** Create the VLAN and SVI (if necessary).

```
vlan [VLAN number]
  name [VLAN name]
!
interface Vlan [VLAN number]
  ip address [IP address] [netmask]
  no shutdown
```

**Step 2:** Configure Layer 2 EtherChannel links for the devices and associate them with the VLAN.

```
interface Port-channel [number]
  switchport access vlan [VLAN number]
!
interface [type] [number]
  switchport access vlan [VLAN number]
  channel-group [number] mode on
  no shutdown
!
interface [type] [number]
  switchport access vlan [VLAN number]
  channel-group [number] mode on
  no shutdown
```

## Example

```
vlan 100
  name Data
!
interface Port-channel7
  description bn-wae-1 EtherChannel
  switchport access vlan 100
!
interface GigabitEthernet1/0/3
  description bn-wae-1 port 1
  switchport access vlan 100
  channel-group 7 mode on
  no shutdown
!
interface GigabitEthernet2/0/3
  description bn-wae-1 port 2
  switchport access vlan 100
  channel-group 7 mode on
  no shutdown
!
interface Vlan100
  ip address 10.5.1.1 255.255.255.0
  no shutdown
```

## Procedure 7 Configure WCCPv2 on Routers

In this design, WCCP diverts network traffic destined for the WAN to the WAAS system for optimization. This method provides for a clean deployment with minimal additional cabling, and requires both the WAN-aggregation and remote-site routers to be configured for WCCP.

**Step 1:** Configure global WCCP parameters and enable services 61 and 62.

You must enable services 61 and 62 for WCCP redirect for WAAS. These services should be using WCCP Version 2. As a best practice, exempt certain critical traffic types from WCCP redirect by using a redirect list.

To prevent unauthorized WAE devices from joining the WAAS cluster, you should configure a group-list and password.

```

ip wccp version 2
ip wccp 61 redirect-list [redirect ACL] group-list [group ACL]
password [password]
ip wccp 62 redirect-list [redirect ACL] group-list [group ACL]
password [password]
!
ip access-list standard [group ACL]
  permit [WAAS cluster member IP]
  permit [WAAS cluster member IP]
!
ip access-list extended [redirect ACL]
  deny tcp [src IP address] [dest IP address] any eq [TCP
port]
  deny tcp [src IP address] [dest IP address] any eq [TCP
port]
! Additional lines as necessary
  deny tcp [src IP address] [dest IP address] any eq [TCP
port]
  permit tcp any any

```

**Step 2:** Configure WCCP redirect on the LAN and WAN interfaces.

#### Option 1: All WAAS routers except for DMVPN hub routers

Specific interfaces must be identified where traffic to and from the WAN are intercepted.

Traffic from the LAN is intercepted with service 61 inbound on all LAN interfaces. It is not necessary to configure WCCP interception on voice interfaces and voice VLANs.

```

interface [interface type] [number]
  ip wccp 61 redirect in

```

Traffic from the WAN is intercepted with service 62 inbound on all WAN interfaces, including DMVPN tunnel interfaces (but not their underlying physical interfaces).

```

interface [interface type] [number]
  ip wccp 62 redirect in

```

#### Example—Option 1

```

ip wccp version 2
ip wccp 61 redirect-list WAAS-REDIRECT-LIST group-list BN-WAE
password cisco123
ip wccp 62 redirect-list WAAS-REDIRECT-LIST group-list BN-WAE
password cisco123
!
interface Port-channel1
  ip wccp 61 redirect in
!
interface GigabitEthernet0/0/4
  ip wccp 62 redirect in
!
ip access-list standard BN-WAE
  permit 10.4.32.161
  permit 10.4.32.162
ip access-list extended WAAS-REDIRECT-LIST
  remark WAAS WCCP Redirect List
  deny tcp any any eq 22
  deny tcp any eq 22 any
  deny tcp any eq telnet any
  deny tcp any any eq telnet
  deny tcp any eq bgp any
  deny tcp any any eq bgp
  deny tcp any any eq 123
  deny tcp any eq 123 any
  permit tcp any any

```

#### Option 2: Only for DMVPN hub routers

Specific interfaces must be identified where traffic to and from the WAN are intercepted.

Traffic from the LAN is intercepted with service 61 inbound on the LAN interfaces.

```

interface [interface type] [number]
  ip wccp 61 redirect in

```



## Tech Tip

DMVPN hub routers require WCCP 62 outbound on the LAN interface to support dynamic creation of spoke to spoke tunnels.

Traffic from the WAN is intercepted with service 62 outbound on the LAN interfaces.

```
interface [interface type] [number]
ip wccp 62 redirect out
```

### Example—Option 2

```
ip wccp version 2
ip wccp 61 redirect-list WAAS-REDIRECT-LIST group-list BN-WAE
password c1sco123
ip wccp 62 redirect-list WAAS-REDIRECT-LIST group-list BN-WAE
password c1sco123
!
interface Port-channel3
ip wccp 61 redirect in
ip wccp 62 redirect out
!
ip access-list standard BN-WAE
permit 10.4.32.161
permit 10.4.32.162
ip access-list extended WAAS-REDIRECT-LIST
remark WAAS WCCP Redirect List
deny tcp any any eq 22
deny tcp any eq 22 any
deny tcp any eq telnet any
deny tcp any any eq telnet
deny tcp any eq bgp any
deny tcp any any eq bgp
deny tcp any any eq 123
deny tcp any eq 123 any
permit tcp any any
```

## Notes

# Appendix A: Enterprise Organizations Layer 2 WAN Deployment Product List

The following products and software versions have been validated for Cisco SBA.

Functional Area	Product	Part Numbers	Software Version
WAN 500 Design			
WAN Aggregation	ASR1002	ASR1002-5G-VPN/K9 ASR1002-PWR-AC	IOS-XE 15.1(3)S0a
WAN Aggregation: WAAS Central Manager	WAVE-594 WAAS Appliance	WAVE-594-K9 WAAS-ENT-APL	4.4.1 (WAAS-UNIVERSAL-K9)
WAN Aggregation: WAAS Application Accelerator	WAE-7571-K9 WAAS Appliance	WAE-7571-K9 WAAS-ENT-APL	4.4.1 (WAAS-UNIVERSAL-K9)
WAN 100 Design			
WAN Aggregation:	ASR1001	ASR1001-2.5G-VPNK9 ASR1001-PWR-AC	IOS-XE 15.1(3)S0a
WAN Aggregation: WAAS Central Manager	WAVE-594 WAAS Appliance	WAVE-594-K9 WAAS-ENT-APL	4.4.1 (WAAS-UNIVERSAL-K9)
WAN Aggregation: WAAS Application Accelerator	WAE-7541-K9 WAAS Appliance	WAE-7541-K9 WAAS-ENT-APL	4.4.1 (WAAS-UNIVERSAL-K9)
WAN Remote Site Routers			
WAN Remote Site Router	Cisco2911	C2911-VSEC/K9 SL-29-DATA-K9	15.1(4)M2
WAN Remote Site Router	Cisco2921	C2921-VSEC/K9 SL-29-DATA-K9	15.1(4)M2
WAN Remote Site Router	Cisco3925	C3925-VSEC/K9 SL-39-DATA-K9	15.1(4)M2
WAN Remote Site Router	Cisco3945	C3945-VSEC/K9 SL-39-DATA-K9	15.1(4)M2



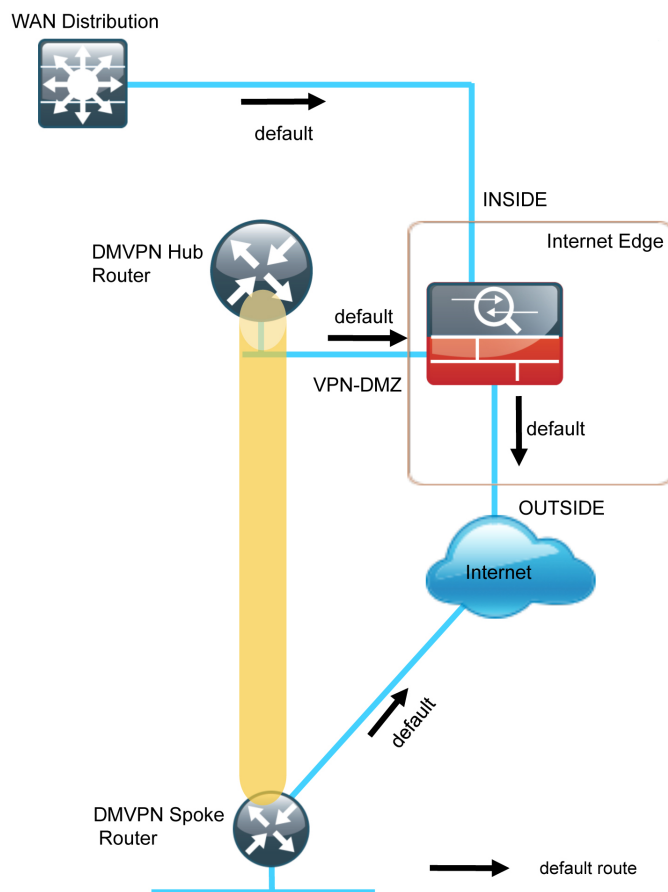
Functional Area	Product	Part Numbers	Software Version
WAN Remote Site WAAS			
Application Accelerator	SM-SRE-700-K9	SM-SRE-700-K9 WAAS-ENT-SM	4.4.1 (WAAS-UNIVERSAL-K9)
Application Accelerator	SM-SRE-900-K9	SM-SRE-900-K9 WAAS-ENT-SM	4.4.1 (WAAS-UNIVERSAL-K9)
Application Accelerator	WAVE-294	WAVE-294-K9 WAAS-ENT-APL	4.4.1 (WAAS-UNIVERSAL-K9)
Application Accelerator	WAVE-594	WAVE-594-K9 WAAS-ENT-APL	4.4.1 (WAAS-UNIVERSAL-K9)
Application Accelerator	WAVE-694	WAVE-694-K9 WAAS-ENT-APL	4.4.1 (WAAS-UNIVERSAL-K9)

# Appendix B: Technical Feature Supplement

## Front Door vREF (FVRF) for DMVPN

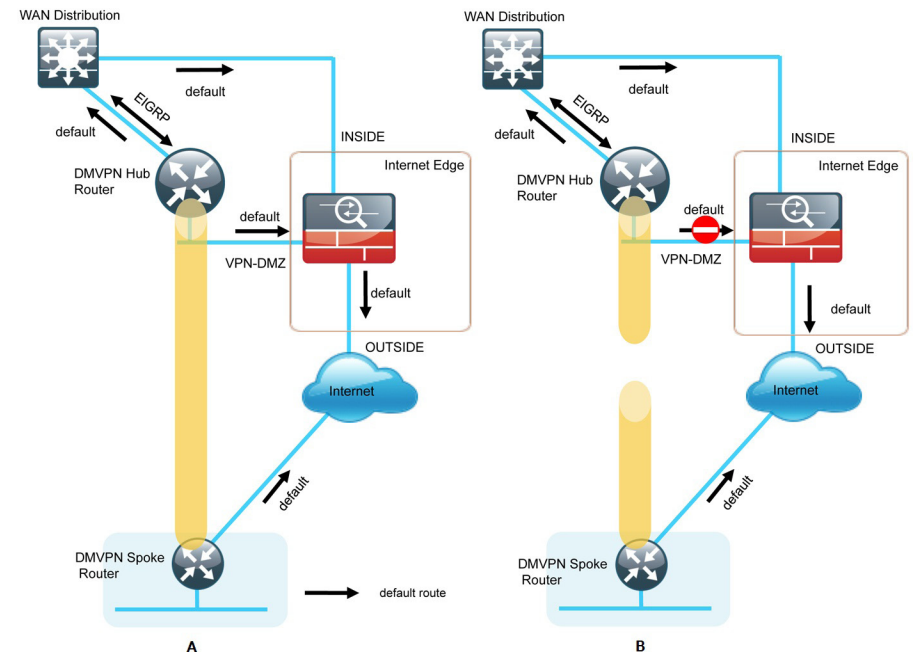
Building an IPsec tunnel requires reachability between the crypto routers. When you use the Internet, routers use a default route to contact their peers.

Figure 35 - IPsec tunnel



If you need to extend the internal network (and the same default routing options that are available to internal users), you must advertise a default route to the VPN hub router. For details, see section A in the following figure.

Figure 36 - IPsec tunnel before/after default route injection



The advertisement of a default route to the hub router (with an existing default route) is problematic. This route requires a better administrative distance to become the active default, which then overrides the default route that is supporting the peer-peer IPsec tunnel connection. This routing advertisement breaks the tunnel as shown in section B in the previous figure.

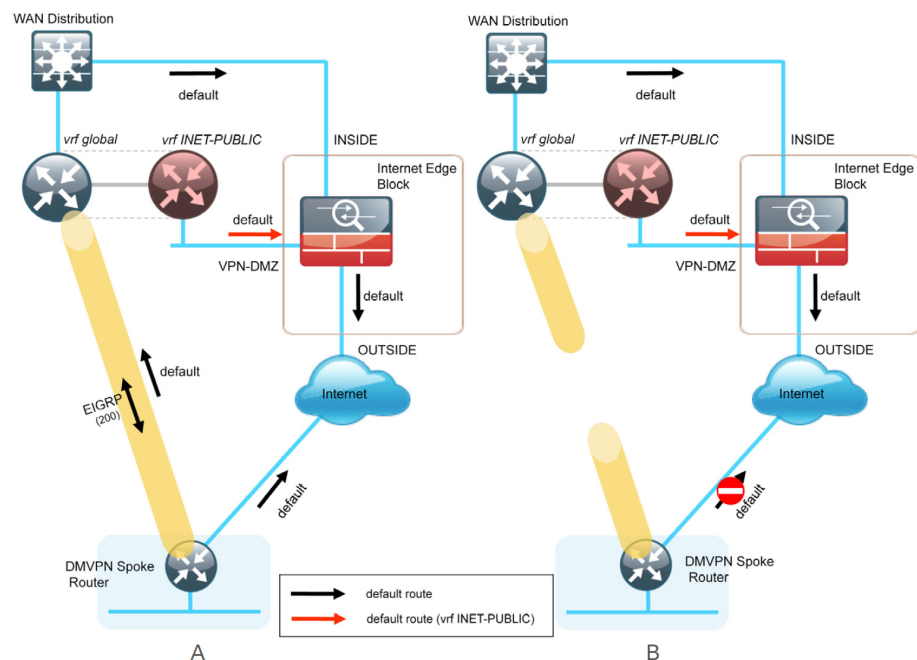
Through the introduction of an external VRF INET-PUBLIC (shown in red), the hub router can support multiple default routes. The internal network remains in the global VRF. This is shown in section A of the following figure.



## Tech Tip

Most additional features on the hub router do not require VRF-awareness.

Figure 37 - IPsec tunnel with FVRF aggregation



This configuration is referred to as FVRF, because the Internet is contained in a VRF. The alternative to this design is inside VRF (IVRF), where the internal network is in a VRF on the VPN hub and the Internet remains in the global VRF. This method is not documented in this guide.

It is now possible to reestablish the IPsec tunnel to the remote peer router. As the remote-site policy requires central Internet access for end users, a default route is advertised through the tunnel. This advertisement causes a similar default routing issue on the remote router; the tunnel default overrides the Internet-pointing default and the tunnel connection breaks as shown in section B in the previous figure.

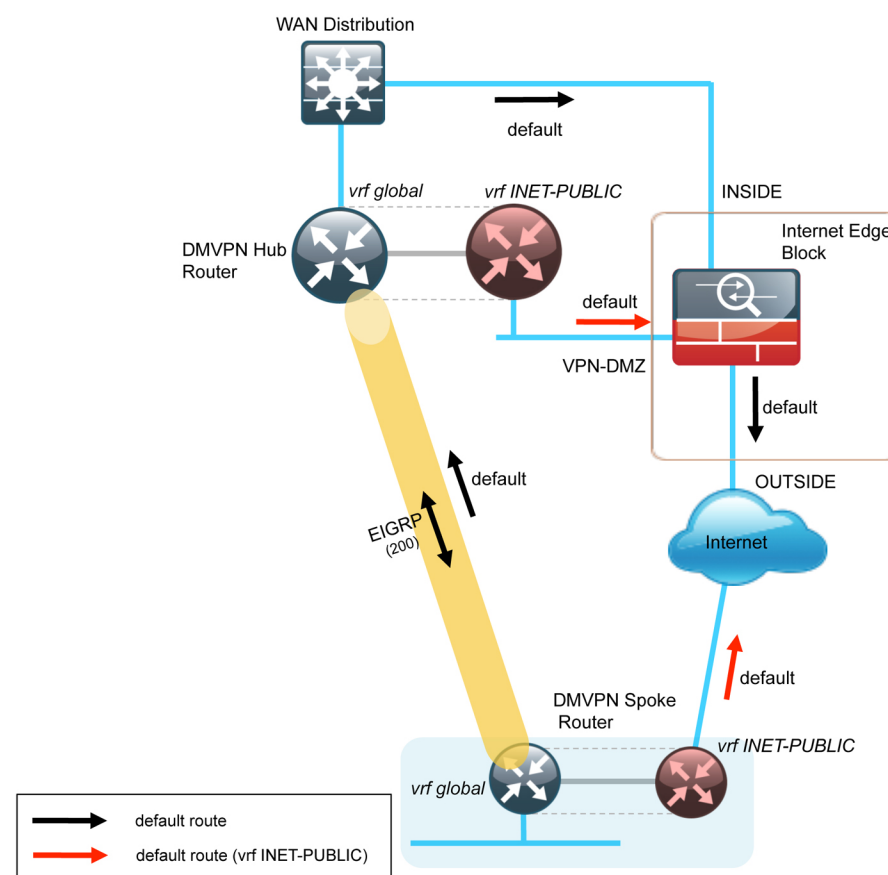
This configuration requires using F-VRF on the remote-site router as well.

The primary benefits of using this solution are as follows:

- Simplified default routing and static default routes in the INET-PUBLIC VRFs
- Ability to support default routing for end-users traffic through VPN tunnels
- Ability to use dynamic default routing for sites with multiple WAN transports
- Ability to build spoke-to-spoke tunnels with DMVPN with end-user traffic routed by default through VPN tunnels

The final design that uses FVRF at both the WAN-aggregation site and a WAN remote-site is shown in the following figure.

Figure 38 - FVRF—Final configuration



# Appendix C: Changes

This appendix summarizes the changes to this guide since the previous Cisco SBA series.

- For IP multicast, we enabled Cisco Auto RP, to simplify deployment.
- For remote site router loopback interfaces, we suggest using an IP address range not in the summary range of any other part of the network.
- For AAA, we updated the commands to a new syntax.
- For the application acceleration platform options, we removed the previous generation appliances.

## Notes



## SMART BUSINESS ARCHITECTURE



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