



Newer Design Guide Available

Cisco Smart Business Architecture has become part of the Cisco Validated Designs program.

For up-to-date guidance on the designs described in this guide, see <http://cvddocs.com/fw/Aug13-245>

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SBA

BORDERLESS
NETWORKS

DEPLOYMENT
GUIDE

MPLS WAN Deployment Guide

● ● ● SMART BUSINESS ARCHITECTURE

February 2013 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 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.

The Release Notes for a series provides a summary of additions and changes made in the 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 February 2013 is the “February 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 [SBA feedback form](#).

If you would like to be notified when new comments are posted, an RSS feed is available from the SBA customer and partner pages.

Table of Contents

What's In This SBA Guide.....	1	Deploying a WAN Remote-Site Distribution Layer	56
Cisco SBA Borderless Networks	1	Remote-Site Router to Distribution Layer.....	56
Route to Success	1	Remote-Site Router to Distribution Layer (Router 2)	60
About This Guide	1	Deploying WAN Quality of Service	64
Introduction.....	2	Configuring QoS	64
Related Reading	2	Appendix A: Product List	68
Design Goals	2	Appendix B: Changes	71
Architecture Overview.....	5		
WAN Design	5		
Quality of Service.....	12		
Deploying the WAN.....	13		
Overall WAN Architecture Design Goals	13		
Deploying an MPLS WAN.....	15		
Business Overview.....	15		
Technology Overview.....	15		
Deployment Details	19		
MPLS CE Router Configuration.....	19		
Remote-Site MPLS CE Router Configuration	27		
Adding Secondary MPLS Link on Existing MPLS CE Router.....	42		
Remote-Site Router Configuration (Dual-Router - Router 2)	45		

What's In This SBA Guide

Cisco SBA Borderless Networks

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.

Cisco SBA Borderless Networks is a comprehensive network design targeted at organizations with up to 10,000 connected users. The SBA Borderless Network architecture incorporates wired and wireless local area network (LAN) access, wide-area network (WAN) connectivity, WAN application optimization, and Internet edge security infrastructure.

Route to Success

To ensure your success when implementing the designs in this guide, you should first read any guides that this guide depends upon—shown to the left of this guide on the route below. As you read this guide, specific prerequisites are cited where they are applicable.

About This Guide

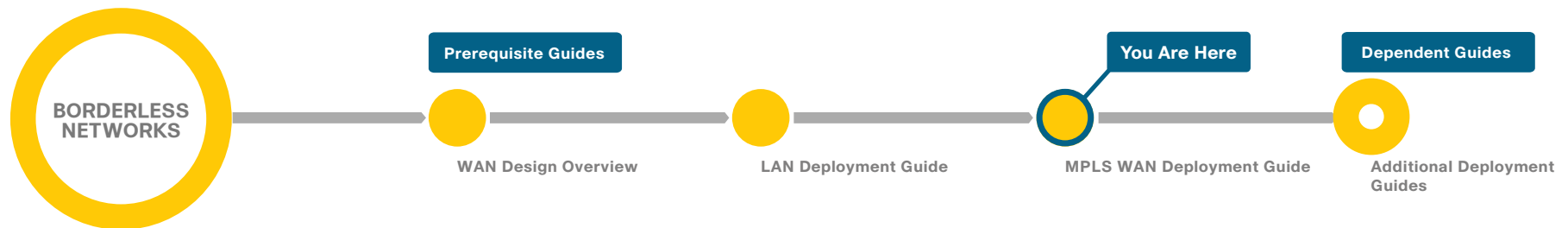
This *deployment guide* contains one or more deployment chapters, which each include the following sections:

- **Business Overview**—Describes the business use case for the design. Business decision makers may find this section especially useful.
- **Technology Overview**—Describes the technical design for the business use case, including an introduction to the Cisco products that make up the design. Technical decision makers can use this section to understand how the design works.
- **Deployment Details**—Provides step-by-step instructions for deploying and configuring the design. Systems engineers can use this section to get the design up and running quickly and reliably.

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

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

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



Introduction

Cisco SBA—Borderless Networks is a solid network foundation designed to provide networks with up 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 overall WAN architecture is described in the *WAN Design Overview*.

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

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

Each of these WAN deployment guides has a complementary WAN configuration guide.

Related Reading

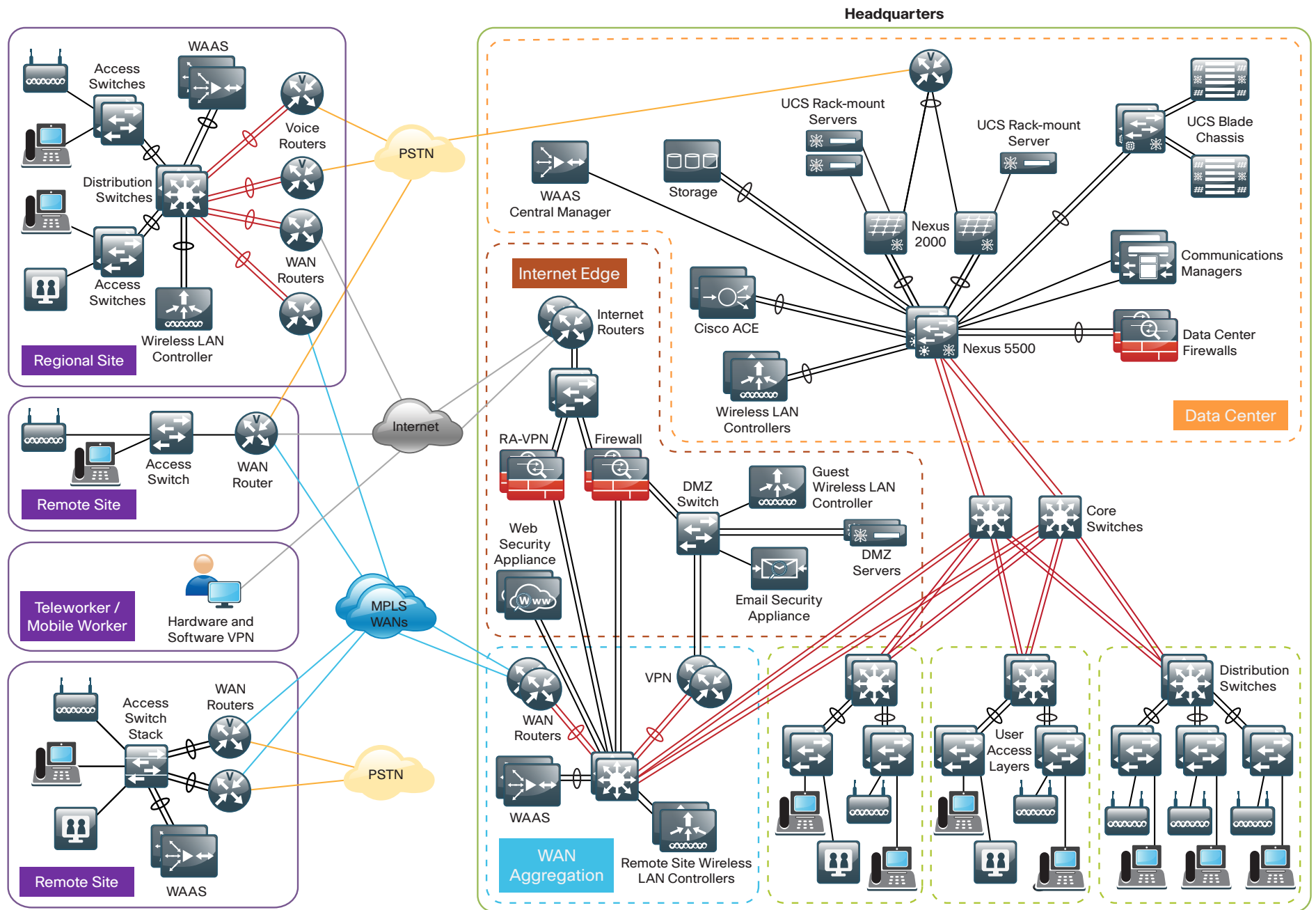
The *LAN Deployment Guide* describes wired network access with ubiquitous capabilities for both the larger campus-size LAN as well as the smaller remote-site LAN. Resiliency, security, and scalability are included to provide a robust communications environment. Quality of service (QoS) is integrated 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.

Design Goals

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

Notes

Figure 1 - Borderless Networks for Enterprise Organizations Overview



Ease of Deployment, Flexibility, and Scalability

Organizations with up 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, video, and collaboration applications.
- 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.
- Video and voice perform better through the use of medianet technologies. Cisco's recommended approach for video and collaboration, which simplifies, lowers the risks, cuts costs, and improves the quality of your video and voice deployments.

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

Architecture Overview

The *Cisco SBA—Borderless Networks MPLS 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:

- MPLS WAN connectivity for up to 500 remote sites
- Primary and secondary links to provide redundant topology options for resiliency
- Wired 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:

- Multiprotocol Label Switching (MPLS) Layer 3 VPN (primary)
- Multiprotocol Label Switching (MPLS) Layer 3 VPN (secondary)
- Internet VPN (secondary)

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.

The usage of an Internet VPN transport to provide a redundant topology option for resiliency is covered in the *VPN WAN Deployment Guide*.

MPLS WAN Transport

Cisco IOS Software Multiprotocol Label Switching (MPLS) enables enterprises and service providers to build next-generation intelligent networks that deliver a wide variety of advanced, value-added services over a single infrastructure. You can integrate this economical solution seamlessly over any existing infrastructure, such as IP, Frame Relay, ATM, or Ethernet.

MPLS Layer 3 VPNs use a peer-to-peer VPN Model that leverages the Border Gateway Protocol (BGP) to distribute VPN-related information. This peer-to-peer model allows enterprise subscribers to outsource routing information to service providers, which can result in significant cost savings and a reduction in operational complexity for enterprises.

Subscribers who need to transport IP multicast traffic can enable Multicast VPNs (MVPNs).

The WAN leverages MPLS VPN as a primary WAN transport or as a backup WAN transport (to an alternate MPLS VPN primary).

Ethernet WAN

Both of the WAN transports mentioned previously use Ethernet as a standard media type. Ethernet is becoming a dominant carrier handoff in many markets and it is relevant to include Ethernet as the primary media in the tested architectures. Much of the discussion in this guide can also be applied to non-Ethernet media (such as T1/E1, DS-3, OC-3, and so on), but they are not explicitly discussed.

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*. All of the WAN edge routers connect into a distribution layer.

The WAN transport options include MPLS VPN used as a primary or secondary transport. Each transport connects to a dedicated CE router. A similar method of connection and configuration is used for both.

Table 1 - WAN-aggregation design models

	MPLS Static	MPLS Dynamic	Dual MPLS
Remote sites	Up to 50	Up to 100	Up to 500
WAN links	Single	Single	Dual
Edge routers	Single	Single	Dual
WAN routing protocol	None (static)	BGP (dynamic)	BGP (dynamic)
Transport 1	MPLS VPN A	MPLS VPN A	MPLS VPN A
Transport 2	—	—	MPLS VPN A

This deployment guide documents multiple WAN-aggregation design models that are statically or dynamically routed with either single or dual MPLS carriers. The primary differences between the various designs are the usage of routing protocols and the overall scale of the architecture. For each design model, you can select several router platforms with differing levels of performance and resiliency capabilities.

Each of the design models is shown with LAN connections into either a collapsed core/distribution layer or a dedicated WAN distribution layer. There are no functional differences between these two methods from the WAN-aggregation perspective.

In all of the WAN-aggregation designs, 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.

Each MPLS carrier terminates to a dedicated WAN router with a primary goal of eliminating any single points of failure. A single VPN hub router is used across both designs. The various design models are contrasted in Table 1.

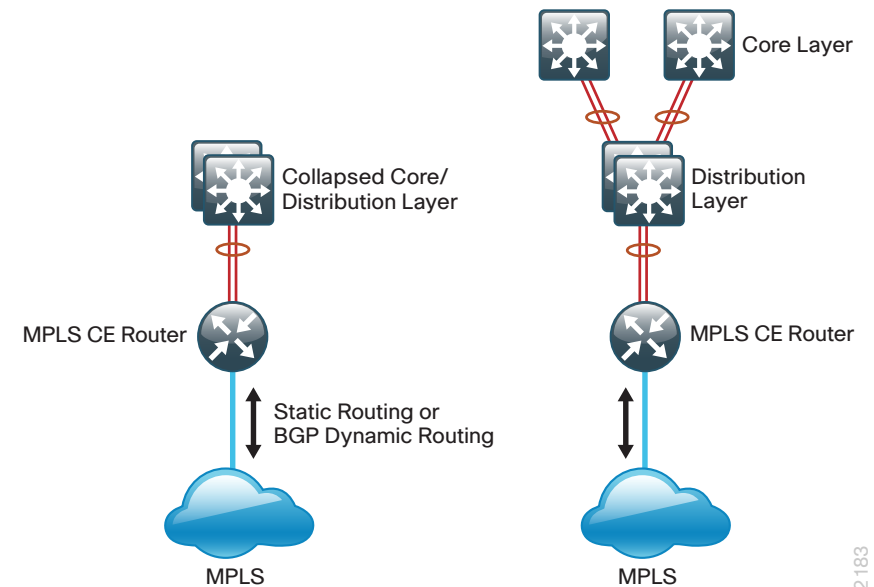
The characteristics of each design are as follows:

MPLS Static Design Model

- Supports up to 50 remote sites
- Has a single MPLS VPN carrier
- Uses static routing with MPLS VPN carrier

The MPLS Static design model is shown in the following figure.

Figure 2 - MPLS Static and MPLS Dynamic design models (single MPLS carrier)



MPLS Dynamic Design Model

- Supports up to 100 remote sites
- Has a single MPLS VPN carrier
- Uses BGP routing with MPLS VPN carrier

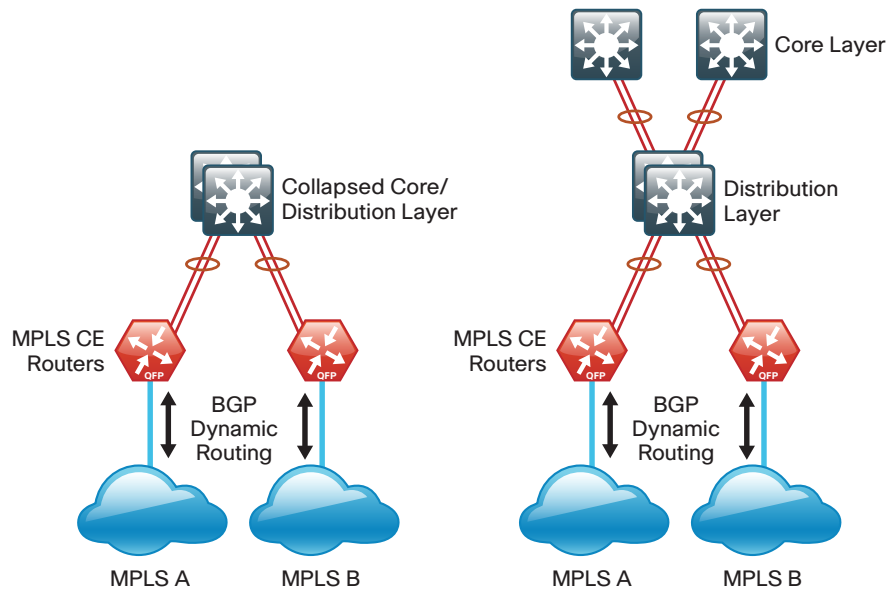
The MPLS Dynamic design model is shown in Figure 2.

Dual MPLS Design Model

- Supports up to 500 remote sites
- Has multiple MPLS VPN carriers
- Uses BGP routing with MPLS VPN carrier
- Typically used with a dedicated WAN distribution layer

The Dual MPLS design model is shown in the following figure.

Figure 3 - Dual MPLS design model

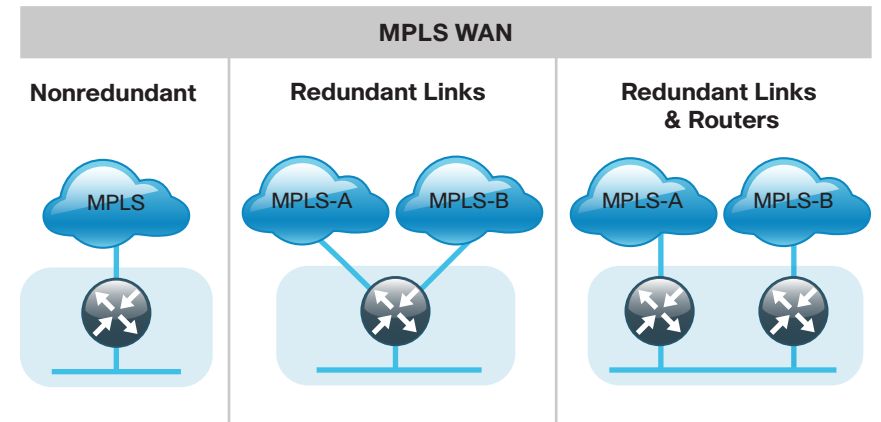


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WAN Remote-Site Designs

This guide documents multiple WAN remote-site 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



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The remote-site designs include single or dual WAN edge routers. These are always MPLS CE routers.

Most remote-site types 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.

Designs which include Internet VPN for additional resiliency are covered in the *VPN Remote Site Deployment Guide*.

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	MPLS VPN A	-
Single	Dual	MPLS VPN A	MPLS VPN B
Dual	Dual	MPLS VPN A	MPLS VPN B

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 *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 64	Data	Yes	-
VLAN 69	Voice	Yes	-
VLAN 99	Transit	Yes (dual router only)	Yes (dual router only)
VLAN 50	Router link (1)	-	Yes
VLAN 54	Router link (2)	-	Yes (dual router only)

Layer 2 Access

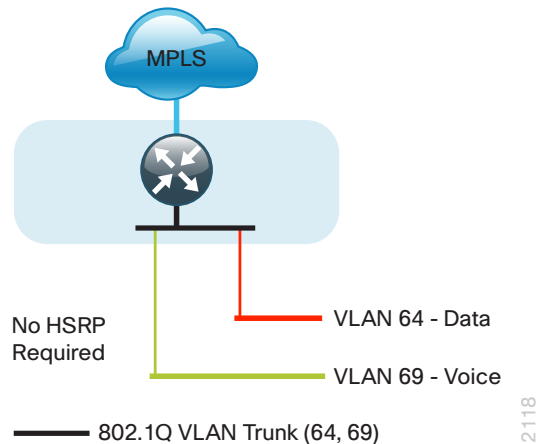
WAN remote sites that do not require additional distribution layer routing devices are considered to be flat or from a LAN perspective they are considered unrouted Layer 2 sites. All Layer 3 services are provided by the attached WAN routers. The access switches, through the use of multiple VLANs, can support services such as data and voice. 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 *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 subinter

faces 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.

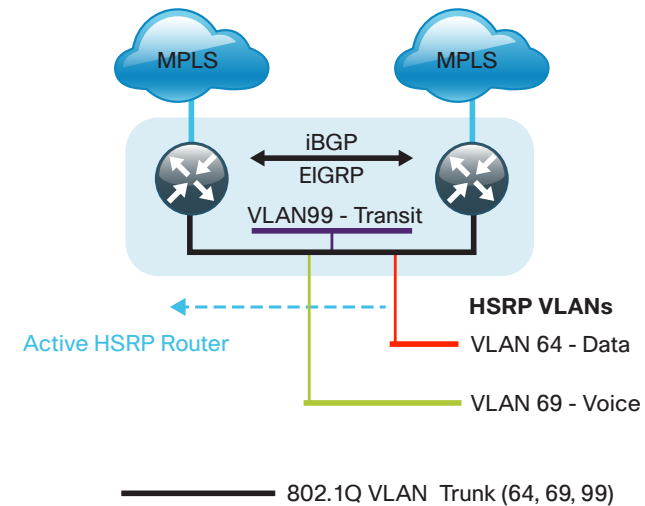
Figure 5 - WAN remote site—Flat Layer 2 LAN (single router)



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 Enhanced Interior Gateway 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)

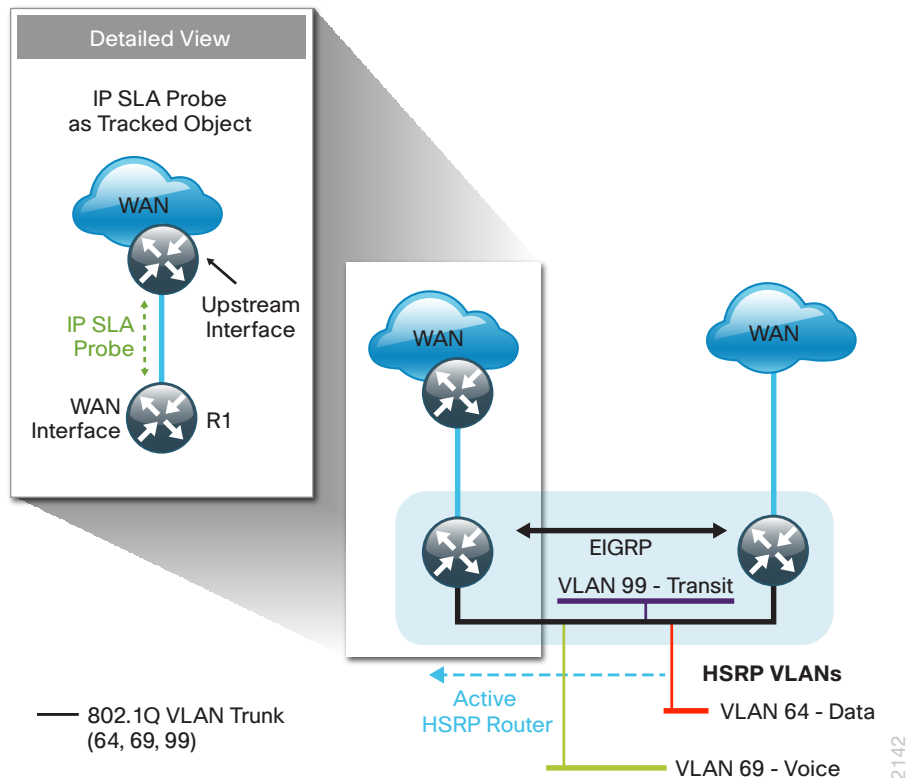


Enhanced Object Tracking (EOT) provides a consistent methodology for various router and switching features to conditionally modify their operation based on information objects available within other processes. The objects that can be tracked include interface line protocol, IP route reachability, and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

Figure 7 - WAN remote-site - IP SLA probe to verify upstream device reachability



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 MPLS CE router to the MPLS Provider Edge (PE) router to ensure reachability of the next hop router. This is more effective than simply monitoring the status of the WAN interface.

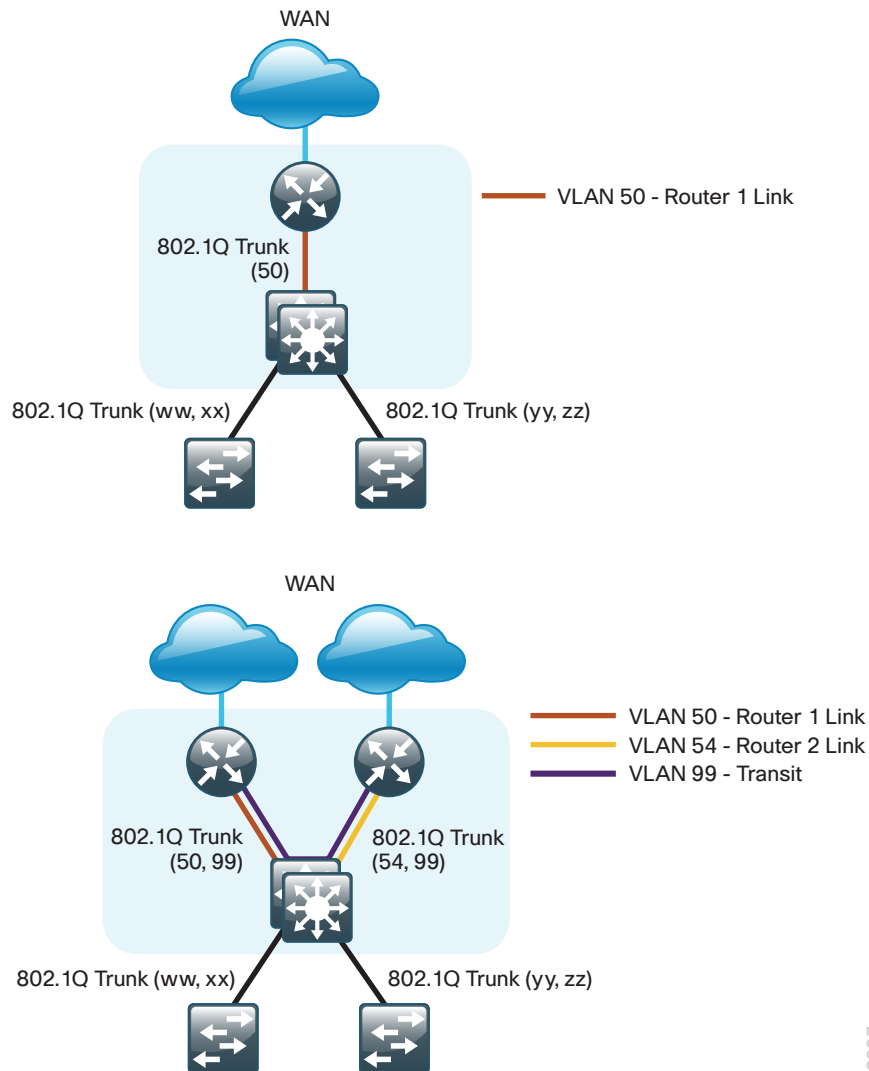
The dual router designs also warrant an additional component that is required for proper routing in certain scenarios. In these cases, a traffic flow from a remote-site host might be sent to a destination reachable via the alternate WAN transport (for example, an MPLS A + MPLS B remote site communicating with a MPLS-B-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

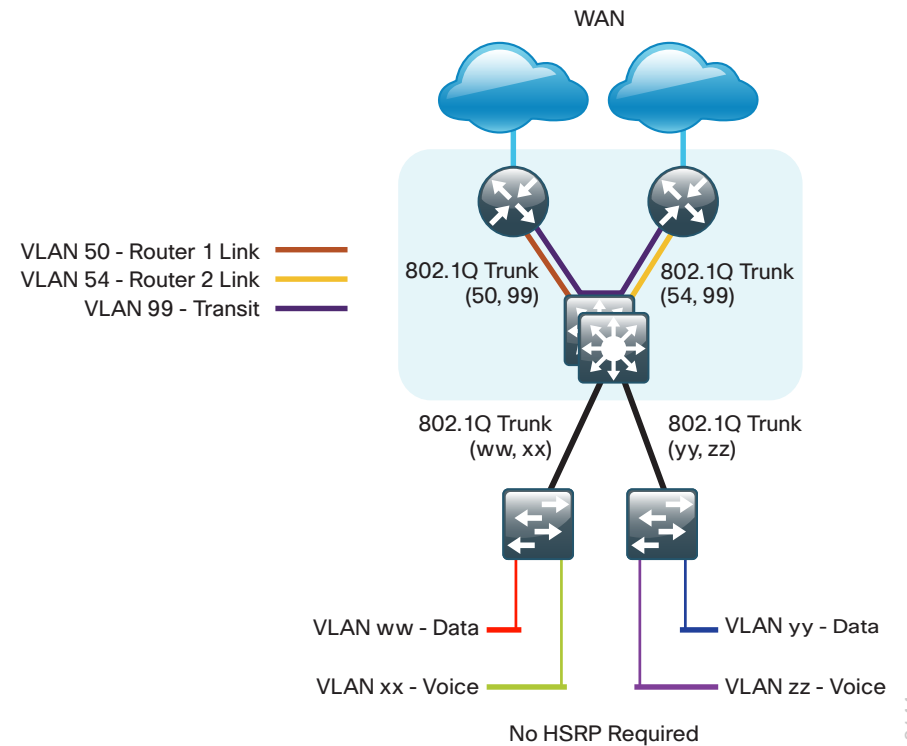
Large remote sites may require a LAN environment similar to that of a small campus LAN that includes a distribution layer and access layer. This topology works well with either a single or dual router WAN edge. To implement this design, the routers should connect via EtherChannel links to the distribution 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 8 - 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 9 - 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 has the appropriate share of the network resources to protect the user experience and ensure the consistent operations 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. In order 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. This table is included as a reference.

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, 33	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

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 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:

MPLS VPN-connected site:

- Connects to a site on the same MPLS VPN; the optimal route is direct within the MPLS VPN (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 one of the MPLS VPN WAN transports is designated as the primary transport, which is the preferred path in most conditions.

MPLS VPN primary + MPLS VPN secondary dual-connected site:

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

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. 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.

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

Notes

Deploying an MPLS 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 a common resource access experience to the workforce regardless of location.

To control operational costs, the WAN must support the convergence of voice, video, and data transport onto a single, centrally managed infrastructure. As organizations move into multinational or global business markets, they require a flexible network design that allows for country-specific access requirements and controls complexity. The ubiquity of carrier-provided MPLS 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 MPLS an effective WAN transport for growing organizations.

Technology Overview

WAN-Aggregation—MPLS CE Routers

The MPLS WAN designs are intended to support up to 500 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. The amount of bandwidth required at the WAN-aggregation site determines which model of router to use. The choice of whether to implement a single router or dual router is determined by the number of carriers that are required in order to provide connections to all of the remote sites.

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 (millions of packets per second) 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.

This design uses the following routers as MPLS CE routers:

- Cisco ASR 1002 Aggregation Services Router configured with an Embedded Service Processor 5 (ESP5)
- Cisco ASR 1001 Aggregation Services Router fixed configuration with a 2.5 Gbps Embedded Service Processor
- Cisco 3945 Integrated Services Router
- Cisco 3925 Integrated Services Router

All of the design models can be constructed using any of the MPLS CE routers listed in Table 7. You should consider the following: the forwarding performance of the router using an Ethernet WAN deployment with broad services enabled, the router's alignment with the suggested design model, and the number of remote sites.

Table 7 - WAN aggregation—MPLS CE router options

Service	Cisco 3925	Cisco 3945	ASR 1001	ASR 1002
Ethernet WAN with services	100 Mbps	150 Mbps	250 Mbps	500 Mbps
Software Redundancy Option	None	None	Yes	Yes
Redundant power supply	Option	Option	Default	Default
Supported Design Models	All	All	All	All
Suggested Design Model	MPLS Static	MPLS Static	MPLS Dynamic	Dual MPLS
Suggested Number of Remote Sites	25	50	100	250

Remote Sites—MPLS 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 multiple integrated service router models as MPLS CE routers, and the expected performance is shown in the following table.

Table 8 - WAN remote-site Cisco Integrated Services Router options

Option	881V ¹	1941 ²	2911	2921	2951	3925	3945
Ethernet WAN with services ³	8 Mbps	25 Mbps	35 Mbps	50 Mbps	75 Mbps	100 Mbps	150 Mbps
On-board FE ports	1 (and 4-port LAN switch)	0	0	0	0	0	0
On-board GE ports ⁴	0	2	3	3	3	3	3
Service module slots ⁵	0	0	1	1	2	2	4
Redundant power supply option	No	No	No	No	No	Yes	Yes

Notes:

1. The Cisco 881 Integrated Services Router is recommended for use at single-router, single-link remote sites with voice over IP requirements.
2. The 1941 is recommended for use at single-router, single-link remote sites.
3. 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.
4. A single-router, dual-link remote-site requires 4 router interfaces when using a port-channel to connect to an access or distribution layer. Add the EHWIC-1GE-SFP-CU to the Cisco 2900 and 3900 Series Integrated Services Routers in order to provide the additional WAN-facing interface.
5. Some service modules are double-wide.

The MPLS CE routers at the WAN remote sites connect in the same manner as the MPLS CE routers at the WAN-aggregation site. The single link MPLS 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 and this approach is used for the MPLS Dynamic and Dual MPLS designs.

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. MPLS VPN-connected sites require static routing to be handled by the carrier, and any changes or modifications require a change request to the carrier.

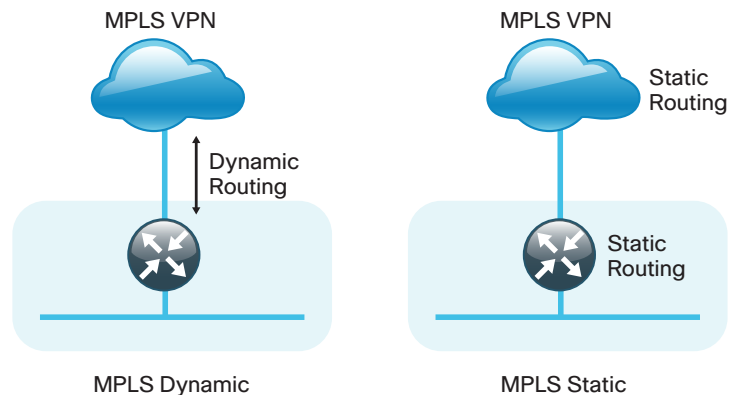
The smaller scale MPLS Static design uses static routing and relies on the carrier to configure the additional required static routes on the PE routers.



Tech Tip

We recommend that you select the Dual MPLS or MPLS Dynamic designs if you intend to use resilient WAN links or want to be able to modify your routing configuration without carrier involvement.

Figure 10 - MPLS WAN remote site (single-router, single-link)

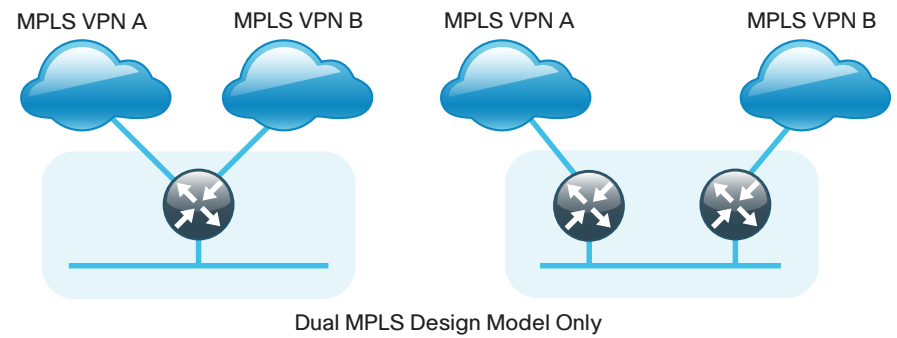


2124

You can augment the basic single-link design by adding an alternate WAN transport that uses a secondary MPLS carrier 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 and the Dual MPLS or MPLS Dynamic design models are used. The routing protocols are tuned to ensure the proper path selection.

Figure 11 - MPLS WAN dual-carrier remote site (dual-link options)



2125

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.

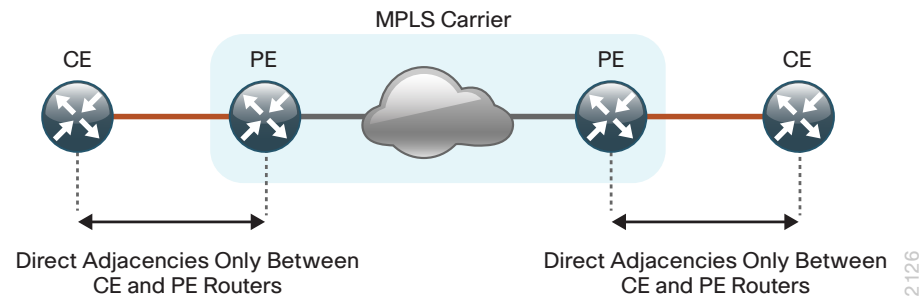
Design Details

All WAN-aggregation MPLS CE routers connect to the same 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.

WAN transport via Ethernet is the only media type tested and included in the configuration section. Other media types are commonly used (such as T1/E1), and these technologies are reliable and well understood. Due to the multiplicity of potential choices for transport, media type, and interface type, we decided to limit the focus of this deployment guide. Documentation of additional variants is available in other guides.

MPLS VPNs require a link between a PE router and a CE router. The PE and CE routers are considered IP neighbors across this link. CE routers are only able to communicate with other CE routers across the WAN via intermediate PE routers.

Figure 12 - MPLS VPN (PE-CE connections)



2126

Both the PE and CE routers are required to have sufficient IP-routing information to provide end-to-end reachability. To maintain this routing information, you typically need to use a routing protocol; BGP is most commonly used for this purpose. The various CE routers advertise their routes to the PE routers. The PE routers propagate the routing information within the carrier network and in turn re-advertise the routes back to other CE routers. This propagation of routing information is known as *dynamic PE-CE routing* and it is essential when any sites have multiple WAN transports (often referred to as dual-homed or multi-homed). Dynamic PE-CE routing with BGP is used in the Dual MPLS and MPLS Dynamic designs.

i

Tech Tip

EIGRP and Open Shortest Path First (OSPF) Protocol are also effective as PE-CE routing protocols, but may not be universally available across all MPLS VPN carriers.

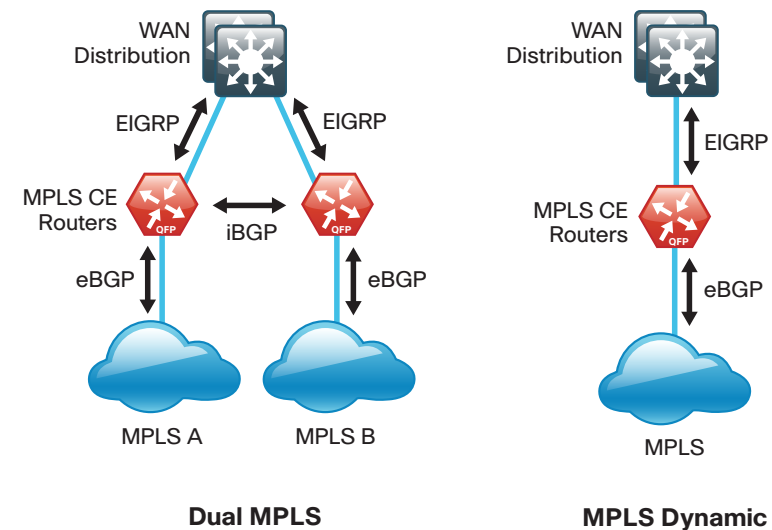
Sites with only a single WAN transport (a single-homed site) do not require dynamic PE-CE routing, and can rely on static routing because there is only a single path to any destination. This design recommends dynamic PE-CE routing to provide consistency with configurations across both single-homed and 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 static routing option is also included to support smaller scale requirements that do not require a dynamic routing protocol. Static routing is used in the MPLS Static design model.

Cisco did not test the PE routers, and their configurations are not included in this guide.

For an MPLS VPN WAN deployment, you need to install and configure MPLS CE routers at every location, including the WAN-aggregation site, and at every MPLS WAN-connected remote site.

At the WAN-aggregation site, an MPLS CE router must be connected both to the distribution layer and to its respective MPLS carrier. Multiple routing protocols (EIGRP and BGP) are 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 IP routing details for the single and dual MPLS carrier WAN-aggregation topology with dynamic routing are shown in the following figure.

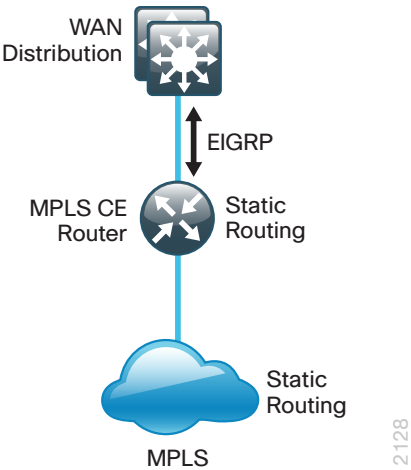
Figure 13 - Dual MPLS and MPLS Dynamic designs—MPLS CE routing detail



2127

The IP routing details for the single MPLS carrier WAN-aggregation topology with static routing are shown in the following figure.

Figure 14 - MPLS Static Design—MPLS CE 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, 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.

BGP

Cisco chose BGP as the routing protocol for PE and CE routers to connect to the MPLS VPNs because it is consistently supported across virtually all MPLS carriers. In this role, BGP is straightforward to configure and requires little or no maintenance. BGP scales well and you can use it to advertise IP aggregate addresses for remote sites.

To use BGP, you must select an Autonomous System Number (ASN). In this design, we use a private ASN (65511) as designated by the Internet Assigned Numbers Authority (IANA). The private ASN range is 64512 to 65534.

A dual-carrier MPLS design requires an iBGP connection between the CE routers to properly retain routing information for the remote sites.

Deployment Details

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 9 - Parameters used in the deployment examples

Hostname	Loopback IP Address	Port Channel IP Address
CE-ASR1002-1	10.4.32.241/32	10.4.32.2/30
CE-ASR1001-2	10.4.32.242/32	10.4.32.6/30

Process

MPLS CE Router Configuration

1. Configure the Distribution Switch
2. Configure the WAN Aggregation Platform
3. Configure Connectivity to the LAN
4. Connect to MPLS PE Router
5. Redistribute WAN routes into EIGRP
6. Configure BGP (recommended)

Procedure 1 Configure the Distribution Switch



Reader Tip

This process assumes that the distribution switch has already been configured following the guidance in the *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-channel1
description CE-ASR1002-1
no switchport
ip address 10.4.32.1 255.255.255.252
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. Not all router platforms can support Link Aggregation Control Protocol (LACP) to negotiate with the switch, so EtherChannel is configured statically.

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 CE-ASR1002-1 Gig0/0/0
!
interface GigabitEthernet2/0/1
description CE-ASR1002-1 Gig0/0/1
!
interface range GigabitEthernet1/0/1, GigabitEthernet2/0/1
no switchport
macro apply EgressQoS
carrier-delay msec 0
channel-group 1 mode on
logging event link-status
logging event trunk-status
logging event bundle-status
no shutdown
```

Step 3: Allow the routing protocol to form neighbor relationships across the port channel interface.

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

Step 4: It is a best practice to summarize IP routes from the WAN distribution layer towards the core. On the distribution layer switch, 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
```

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 CE-ASR1002-1
```

Step 2: Configure local login and password.

The local login account and password provides basic access authentication to a router, which provides only limited operational privileges. The enable password secures access to the device configuration mode. By enabling password encryption, you prevent the disclosure of plain text passwords when viewing configuration files.

```
username admin password clisco123  
enable secret clisco123  
service password-encryption  
aaa new-model
```

Step 3: By default, https access to the router will use the enable password for authentication.

Step 4: (Optional) Configure centralized user authentication.

As networks scale in the number of devices to maintain it poses an operational burden to maintain local user accounts on every device. A centralized Authentication, Authorization and Accounting (AAA) service reduces operational tasks per device and provides an audit log of user access for security compliance and root cause analysis. When AAA is enabled for access control, all management access to the network infrastructure devices (SSH and HTTPS) is controlled by AAA.



Reader Tip

The AAA server used in this architecture is the Cisco Authentication Control System. For details about ACS configuration, see the *Device Management Using ACS 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 in Step 2 on each network infrastructure device to provide a fallback authentication source in case the centralized TACACS+ server is unavailable.

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

Step 5: Configure device management protocols.

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

Specify the transport preferred none on vty lines to prevent errant connection attempts from the CLI prompt. Without this command, if the ip name-server is unreachable, long timeout delays may occur for mistyped commands.

```
ip domain-name cisco.local
ip ssh version 2
no ip http server
ip http secure-server
line vty 0 15
  transport input ssh
  transport preferred none
```

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

```
line con 0
  logging synchronous
```

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 6: (Optional) In networks where network operational support is centralized you can increase network security by using an access list to limit the networks that can access your device. In this example, only devices on the 10.4.48.0/24 network will be able to access the device via SSH or SNMP.

```
access-list 55 permit 10.4.48.0 0.0.0.255
line vty 0 15
  access-class 55 in
!
snmp-server community cisco RO 55
snmp-server community cisco123 RW 55
```



Tech Tip

If you configure an access-list on the vty interface you may lose the ability to use ssh to login from one router to the next for hop-by-hop troubleshooting.

Step 7: Configure a synchronized clock.

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
```

Step 8: Configure an in-band management interface.

The loopback interface is a logical interface that is always reachable as long as the device is powered on and any IP interface is reachable to the network. Because of this capability, the loopback address is the best way to manage the 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 10.4.32.241 255.255.255.255
 ip pim sparse-mode
```

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

Bind the device processes for SNMP, SSH, PIM, TACACS+ and NTP to the loopback interface address for optimal resiliency:

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

Step 9: 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 10: 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 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
```

The Cisco ASR1000 Series router requires the **distributed** keyword.

```
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-channel1
  ip address 10.4.32.2 255.255.255.252
  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. Not all router platforms can support LACP to negotiate with the switch, so EtherChannel is configured statically.

```
interface GigabitEthernet0/0/0
  description WAN-D3750X Gig1/0/1
  !
interface GigabitEthernet0/0/1
  description WAN-D3750X Gig2/0/1
  !
interface range GigabitEthernet0/0/0, GigabitEthernet0/0/1
  no ip address
  channel-group 1
  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-channel1
```

Procedure 4 Connect to MPLS PE Router

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 sub-rate of 300 Mbps.

```
interface GigabitEthernet0/0/3
  bandwidth 300000
```



Tech Tip

Command reference:

bandwidth *kbps*

(300 Mbps = 300,000 kbps)

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

The IP addressing used between CE and PE routers must be negotiated with your MPLS carrier. Typically a point-to-point netmask of 255.255.255.252 is used.

```
interface GigabitEthernet0/0/3
  ip address 192.168.3.1 255.255.255.252
```

Step 3: Administratively enable the interface and disable CDP.

We do not recommend the use of CDP on external interfaces.

```
interface GigabitEthernet0/0/3
  no cdp enable
  no shutdown
```


Procedure 5 Redistribute WAN routes into EIGRP

The WAN-aggregation CE routers are configured either for dynamic routing with BGP or are statically routed. If you have a remote-site design that includes sites with dual WAN links, or do not wish to have your MPLS carrier make changes or modifications, then use the BGP option. This is the recommended approach.

If your remote-site design only uses single WAN links and you don't anticipate adding or modifying IP networks at the remote sites, then you can use the statically routed option. The MPLS carrier is responsible for configuring static IP routing within the MPLS network.



Tech Tip

If you do not use dynamic routing with BGP then the MPLS carrier must configure a set of static routes on its PE routers for the WAN-aggregation site and for each of the remote sites. Site-specific routing details must be shared with your MPLS carrier.

Option 1. BGP dynamic routing with MPLS carrier

Step 1: Redistribute BGP into EIGRP.

The BGP routes are redistributed into EIGRP with a default metric. By default, only the bandwidth and delay values are used for metric calculation.

```
router eigrp [as number]
  default-metric [bandwidth (Kbps)] [delay (usec)] 255 1 1500
  redistribute bgp [BGP ASN]
```

Step 2: Configure route-map and inbound distribute-list for EIGRP.

This design uses mutual route redistribution; BGP routes are distributed into EIGRP and EIGRP routes are distributed into BGP (covered in Procedure 6). It is important to tightly control how routing information is shared between different routing protocols when you use this configuration; 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.

An inbound distribute-list with a route-map is used to limit which routes are accepted for installation into the route table. The WAN-aggregation MPLS CE routers are configured to only accept routes that do not originate from the MPLS or DMVPN WAN sources. To accomplish this task, you must create a route-map that matches any routes originating from the WAN indicated by a specific route tag. This method allows for dynamic identification of the various WAN routes. BGP-learned routes are implicitly tagged with their respective source AS and other WAN routes are explicitly tagged by their WAN-aggregation router (documented in a separate procedure). The specific route tags in use are shown below.



Reader Tip

DMVPN deployment is covered in the *VPN WAN Deployment Guide*.
Layer 2 WAN deployment is covered in the *Layer 2 WAN Deployment Guide*.

Table 10 - Route tag information for WAN-aggregation MPLS CE routers

Tag	Route source	Tag method	action
65401	MPLS VPN A	implicit	block
65402	MPLS VPN B	implicit	block
300	Layer 2 WAN	explicit	accept
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 need to block more tags.

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



Tech Tip

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

```
route-map BLOCK-TAGGED-ROUTES deny 10
  match tag 65401 65402 65512
!
route-map BLOCK-TAGGED-ROUTES permit 20
!
router eigrp 100
  distribute-list route-map BLOCK-TAGGED-ROUTES in
  default-metric 100000 100 255 1 1500
  redistribute bgp 65511
```

Option 2. Static routing with service provider

Step 1: Configure static routes to remote sites' LANs on the WAN-aggregation CE router. It is a best practice to summarize the remote-site network ranges into a single route when possible.

```
ip route 10.5.0.0 255.255.0.0 192.168.3.2
```

Step 2: It is desirable to advertise a route for the MPLS PE-CE links, which includes the CE routers' WAN interfaces, so you can use this to determine router reachability for troubleshooting. It is a best practice to summarize the PE-CE link ranges into a single route when possible.

```
ip route 192.168.3.0 255.255.255.0 192.168.3.2
```

Step 3: You must also configure routes to the remote-site router loopback addresses. A single summary route for the loopback range may be used when possible.

```
ip route 10.255.251.0 255.255.255.0 192.168.3.2
```

Step 4: Configure EIGRP to advertise the remote-site static routes. These routes are redistributed into EIGRP with a default metric. By default, only the bandwidth and delay values are used for metric calculation.

```
router eigrp [as number]
  default-metric [bandwidth (Kbps)] [delay (usec)] 255 1 1500
  redistribute static
```

Procedure 6

Configure BGP (recommended)

This procedure is only used when using BGP dynamic routing with the MPLS carrier.

Step 1: Enable BGP.

To complete this step, you must use a BGP ASN. You can consult with your MPLS carrier on the requirements for the ASN, but you may be permitted to use a private ASN as designated by IANA. The private ASN range is 64512 to 65534.

```
router bgp 65511
  no synchronization
  bgp router-id 10.4.32.241
  bgp log-neighbor-changes
  no auto-summary
```

Step 2: Configure eBGP.

You must configure BGP with the MPLS carrier PE device. The MPLS carrier must provide their ASN (the ASN in Step 1 is the ASN identifying your site). Because the carrier PE router uses a different ASN, this configuration is considered an external BGP (eBGP) connection.

The CE router only advertises network routes to the PE via BGP when:

- The route is specified in network statements and is present in the local routing table.
- The route is redistributed into BGP.

It is desirable to advertise a route for the PE-CE link, so you should include this network in a network statement. You can use this to determine router reachability for troubleshooting.

```
router bgp 65511
  network 192.168.3.0 mask 255.255.255.252
  neighbor 192.168.3.2 remote-as 65401
```

Step 3: Redistribute EIGRP into BGP.

All EIGRP routes learned by the CE router, including routes from the core and for other WAN sites, should be advertised into the WAN. It is most efficient if you summarize these routes before they are advertised to the CE router.

Because BGP does not propagate a default route via redistribution, you must explicitly specify 0.0.0.0 in a network statement.

```
router bgp 65511
 network 0.0.0.0
 redistribute eigrp 100
```

Step 4: Configure iBGP (Optional).

With dual MPLS carriers, a BGP link is configured between the CE routers.

Since the CE routers are using the same ASN, this configuration is considered an internal BGP (iBGP) connection. This design uses iBGP peering using device loopback addresses, which requires the update-source and next-hop-self-configuration options.

```
router bgp 65511
 neighbor 10.4.32.242 remote-as 65511
 neighbor 10.4.32.242 update-source Loopback0
 neighbor 10.4.32.242 next-hop-self
```

Process

Remote-Site MPLS CE Router Configuration

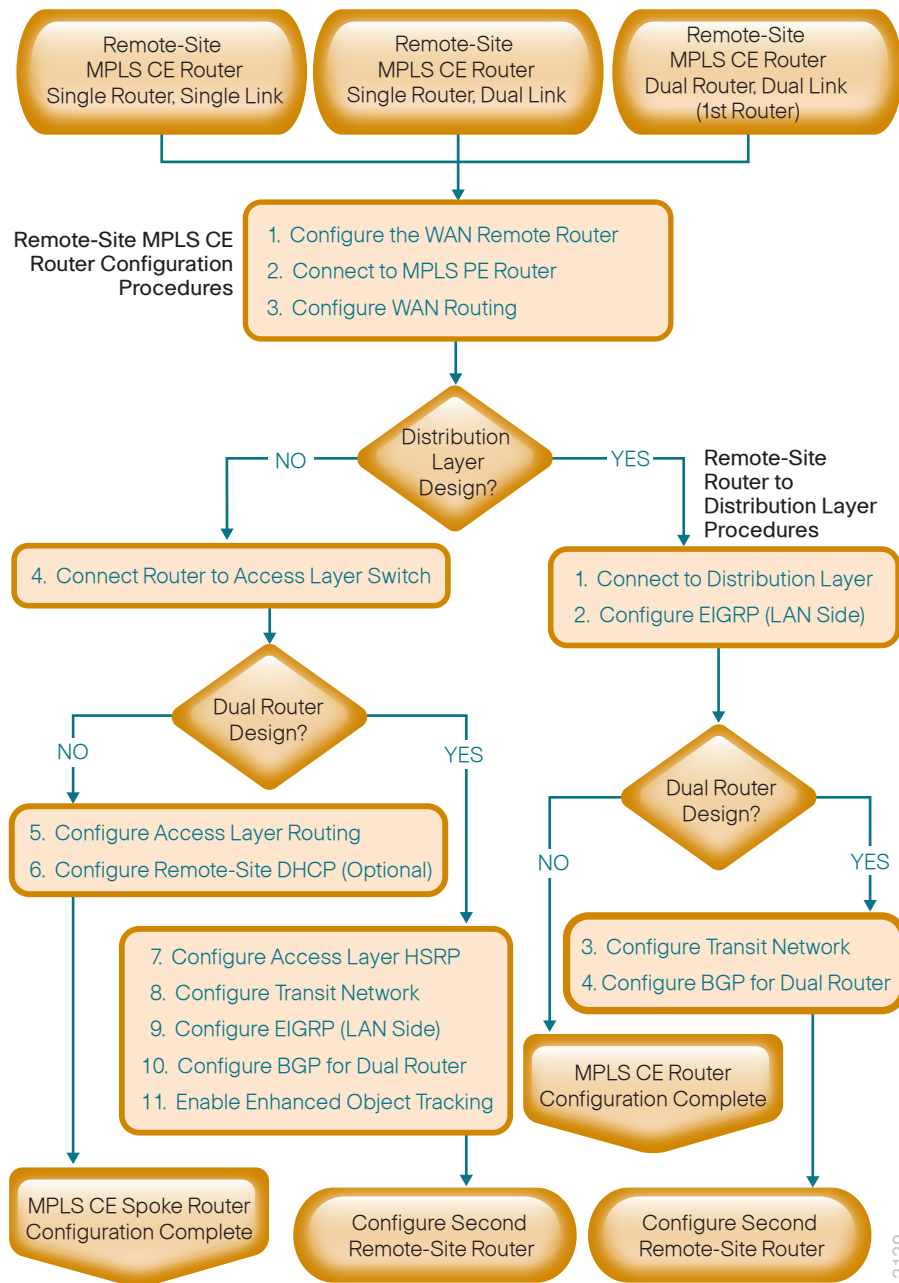
1. Configure the WAN Remote Router
2. Connect to the MPLS PE Router
3. Configure WAN Routing
4. Connect Router to Access Layer Switch
5. Configure Access Layer Routing
6. Configure Remote-Site DHCP
7. Configure Access Layer HSRP
8. Configure Transit Network
9. Configure EIGRP (LAN Side)
10. Configure BGP for Dual Router
11. Enable Enhanced Object Tracking

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

- MPLS CE router for a MPLS WAN remote site (single router, single link).
- MPLS WAN Dual Carrier remote site. Use these procedures when performing the initial configuration of a dual-connected MPLS CE in the single-router, dual-link design or for configuring the first router of the dual-router, dual-link design.

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

Figure 15 - Remote-site MPLS 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.

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

```
hostname [hostname]
```

Step 2: Configure local login and password.

The local login account and password provides basic access authentication to a router which provides only limited operational privileges. The enable password secures access to the device configuration mode. By enabling password encryption, you prevent the disclosure of plain text passwords when viewing configuration files.

```
username admin password c1sco123
enable secret c1sco123
service password-encryption
aaa new-model
```

Step 3: By default, https access to the router will use the enable password for authentication.

Step 4: (Optional) Configure centralized user authentication.

As networks scale in the number of devices to maintain it poses an operational burden to maintain local user accounts on every device. A centralized Authentication, Authorization and Accounting (AAA) service reduces operational tasks per device and provides an audit log of user access for security compliance and root cause analysis. When AAA is enabled for access control, all management access to the network infrastructure devices (SSH and HTTPS) is controlled by AAA.



Reader Tip

The AAA server used in this architecture is the Cisco Authentication Control System. For details about ACS configuration, see the *Device Management Using ACS 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 in Step 2 on each network infrastructure device to provide a fallback authentication source in case the centralized TACACS+ server is unavailable.

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

Step 5: Configure device management protocols.

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

Specify the transport preferred none on vty lines to prevent errant connection attempts from the CLI prompt. Without this command, if the ip name-server is unreachable, long timeout delays may occur for mistyped commands.

```
ip domain-name cisco.local
ip ssh version 2
no ip http server
ip http secure-server
line vty 0 15
  transport input ssh
  transport preferred none
```

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

```
line con 0
  logging synchronous
```

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 6: (Optional) In networks where network operational support is centralized you can increase network security by using an access list to limit the networks that can access your device. In this example, only devices on the 10.4.48.0/24 network will be able to access the device via SSH or SNMP.

```
access-list 55 permit 10.4.48.0 0.0.0.255
line vty 0 15
  access-class 55 in
!
snmp-server community cisco RO 55
snmp-server community cisco123 RW 55
```



Tech Tip

If you configure an access-list on the vty interface you may lose the ability to use ssh to login from one router to the next for hop-by-hop troubleshooting.

Step 7: Configure a synchronized clock.

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

Step 8: Configure an in-band management interface.

The loopback interface is a logical interface that is always reachable as long as the device is powered on and any IP interface is reachable to the network. Because of this capability, the loopback address is the best way to manage the 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 a unique network range that is not part of any other internal network summary range.

```
interface Loopback 0
  ip address [ip address] 255.255.255.255
  ip pim sparse-mode
```

The **ip pim sparse-mode** command will be explained in the next step.

Bind the device processes for SNMP, SSH, PIM, TACACS+ and NTP to the loopback interface address for optimal resiliency:

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

Step 9: 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 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
```

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 MPLS PE Router

Step 1: Assign the interface bandwidth.

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

The example shows a Gigabit interface (1000 Mbps) with a sub-rate of 10 Mbps.

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



Tech Tip

Command Reference:

bandwidth *kbps*

10 Mbps = 10,000 kbps

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

The IP addressing used between CE and PE routers must be negotiated with your MPLS carrier. Typically a point-to-point netmask of 255.255.255.252 is used.

```
interface [interface type] [number]
ip address [IP address] [netmask]
```

Step 3: Administratively enable the interface and disable CDP.

We do not recommend the use of CDP on external interfaces.

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

Example

```
interface GigabitEthernet0/0
bandwidth 10000
ip address 192.168.3.9 255.255.255.252
no cdp enable
no shutdown
```

Procedure 3 Configure WAN Routing

The remote-site CE routers are configured either for dynamic routing with BGP or are statically routed. If you have a remote-site design that includes sites with dual WAN links or you do not want to have your MPLS carrier make changes or modifications, use the BGP option. This is the recommended approach, and assumes that the WAN-aggregation CE router has already been configured for BGP.

If your remote-site design only uses single WAN links and you don't anticipate adding or modifying IP networks at the remote site, then you can use the statically routed option. The MPLS carrier is responsible for configuring static IP routing within the MPLS network.



Tech Tip

If you do not use dynamic routing with BGP then the MPLS carrier must configure a set of static routes on its PE routers for the WAN-aggregation site and for each of the remote sites. Site specific routing details must be shared with your MPLS carrier.

Option 1. BGP dynamic routing with MPLS carrier

Step 1: Enable BGP.

To complete this step, a BGP ASN is required. You might be able to reuse the same value used on the MPLS VPN CE from the WAN-aggregation site. Consult with your MPLS carrier on the requirements for the ASN.

```
router bgp 65511
  no synchronization
  bgp router-id [IP address of Loopback0]
  bgp log-neighbor-changes
  no auto-summary
```

Step 2: Configure eBGP.

You must configure BGP with the MPLS carrier PE device. The MPLS carrier must provide their ASN (the ASN in Step 1 is the ASN identifying your site). Since the carrier PE router will use a different ASN, this configuration is considered an external BGP (eBGP) connection.

The CE router only advertises network routes to the PE via BGP in the following cases:

- The route is specified in network statements and is present in the local routing table.
- The route is redistributed into BGP (not applicable in the remote-site use case).

It is desirable to advertise a route for the PE-CE link, so you should include this network in a network statement. You can use this to determine router reachability for troubleshooting. Similarly, you must configure BGP to advertise the loopback network for the router.

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 aggregate address as configured below suppresses the more specific routes. If any LAN network is present in the route table, the aggregate is advertised to the MPLS PE, which offers a measure of resiliency. If the various LAN networks cannot be summarized, you must list each individually. You must add a separate network statement for the loopback address.

```
router bgp 65511
  network [PE-CE link network] mask [PE-CE link netmask]
  network [Loopback network] mask 255.255.255.255
  network [DATA network] mask [netmask]
  network [VOICE network] mask [netmask]
  aggregate-address [summary IP address] [summary netmask]
summary-only
  neighbor [IP address of PE] remote-as [carrier ASN]
```

Example

```
router bgp 65511
  no synchronization
  bgp router-id 10.255.251.206
  bgp log-neighbor-changes
  network 192.168.3.8 mask 255.255.255.252
  network 10.255.251.206 mask 255.255.255.255
  network 10.5.12.0 mask 255.255.255.0
  network 10.5.13.0 mask 255.255.255.0
  aggregate-address 10.5.8.0 255.255.248.0 summary-only
  neighbor 192.168.3.10 remote-as 65401
  no auto-summary
```

Option 2. Static routing with service provider

Step 1: This option has remote sites using static routing to the MPLS WAN to forward all traffic to the WAN-aggregation site. Only a default route is required.

```
ip route 0.0.0.0 0.0.0.0 192.168.3.10
```

Step 2: Both the remote-site specific IP range and the chosen loopback IP address for the router must be provided to the MPLS carrier for each remote site, so that they can properly configure the static routes to the remote-site.



Tech Tip

For each remote site with static routing, the WAN-aggregation CE router must have a corresponding static host route for that site's loopback address.

Procedure 4

Connect Router to Access Layer Switch



Reader Tip

Please refer to the *LAN Deployment Guide* for complete access layer configuration details. This guide only includes the additional steps to complete the distribution layer configuration.

If you are using a remote-site distribution layer then skip to the “Deploying a WAN Remote-Site Distribution Layer” section of this guide.

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

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

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

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

```
interface Port-channel1
description EtherChannel link to RS206-A2960S
no shutdown
```

Step 2: Configure EtherChannel member interfaces on the router.

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

```
interface GigabitEthernet0/1
description RS206-A2960S Gig1/0/24
!
interface GigabitEthernet0/2
description RS206-A2960S Gig2/0/24
!
interface range GigabitEthernet0/1, GigabitEthernet0/2
no ip address
channel-group 1
no shutdown
```

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

Connect the router EtherChannel uplinks to separate switches in the access layer switch stack, or in the case of the Cisco Catalyst 4507R+E distribution layer, to separate redundant modules for additional resiliency.

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

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

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

```
interface GigabitEthernet1/0/24
  description Link to RS206-3925-1 Gig0/1
interface GigabitEthernet2/0/24
  description Link to RS206-3925-1 Gig0/2
!
interface range GigabitEthernet1/0/24, GigabitEthernet2/0/24
  switchport
  macro apply EgressQoS
  channel-group 1 mode on
  logging event link-status
  logging event trunk-status
  logging event bundle-status
```

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

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

```
interface Port-channel1
  description EtherChannel link to RS206-3925-1
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 64,69
  switchport mode trunk
  ip arp inspection trust
  spanning-tree portfast trunk
  ip dhcp snooping trust
  no shutdown
```

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

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

Step 1: Enable the physical interface on the router.

```
interface GigabitEthernet0/2
  description RS202-A3560X Gig1/0/24
  no ip address
  no shutdown
```

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

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

```
interface GigabitEthernet1/0/24
  description Link to RS201-2911 Gig0/2
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 64,69
  switchport mode trunk
  ip arp inspection trust
  spanning-tree portfast trunk
  macro apply EgressQoS
  logging event link-status
  logging event trunk-status
  ip dhcp snooping trust
  no shutdown
```

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

Option 3. Layer 2 trunk from Cisco 881 router to access layer switch

This option connects the remote-site Cisco 881 Integrated Services Router to a single-member access switch with a single Ethernet connection. This option differs significantly from the previous two options because an embedded Ethernet switch provides the LAN connectivity of the Cisco 881 router.

Step 1: Configure necessary VLANs on the embedded switch of the remote-site router.

```
vlan 64
  name Wired-Data
vlan 69
  name Wired-Voice
vlan 999
  name Native
```

Step 2: Configure the remote-site router's connection to the remote-site Ethernet switch.

```
interface FastEthernet0
  switchport trunk native vlan 999
  switchport trunk allowed vlan 1,2,64,69,1002-1005
  switchport mode trunk
  no ip address
  no shutdown
```



Tech Tip

The embedded switch on the Cisco 881 router requires that the default VLANs be allowed on trunks. To maintain security and configuration consistency, these VLANs (1, 2, 1002, 1003, 1004, and 1005) will be pruned on the access-switch side of the trunk.

Step 3: Configure the trunk on the access layer switch.

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

```
interface GigabitEthernet1/0/24
  description Link to RS4-881 Fast0
  switchport trunk native vlan 999
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 64,69
  switchport mode trunk
  ip arp inspection trust
  macro apply EgressQoS
  logging event link-status
  logging event trunk-status
  ip dhcp snooping trust
  no shutdown
```

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

Procedure 5

Configure Access Layer Routing

Option 1. Layer 2 EtherChannel or Layer 2 trunk

Step 1: Create subinterfaces and assign VLAN tags.

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

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

Step 2: Configure IP settings for each subinterface.

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

When using a centralized DHCP server, routers with LAN interfaces connected to a LAN using DHCP for end-station IP addressing must use an IP helper. This is the preferred method. An alternate option for local DHCP server configuration is shown in the following procedure.

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

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

Option 2. Layer 2 trunk from Cisco 881 router to access layer switch

Step 1: Configure IP settings for each subinterface.

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

When using a centralized DHCP server, routers with LAN interfaces connected to a LAN using DHCP for end-station IP addressing must use an IP helper. This is the preferred method. An alternate option for local DHCP server configuration is shown in the following procedure.

```
interface [Vlan number]
  description [usage]
  ip address [LAN network 1] [LAN network 1 netmask]
  ip helper-address 10.4.48.10
  ip pim sparse-mode
```

Example - Layer 2 EtherChannel

```
interface Port-channel1
  no ip address
  no shutdown
  !
  interface Port-channel1.64
  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 Port-channel1.69
  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
```

Example - Layer 2 Link

```
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 GigabitEthernet0/2.69
  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
```


Example - Layer 2 Link from Cisco 881

```
interface Vlan64
description Data
ip address 10.5.28.1 255.255.255.0
ip helper-address 10.4.48.10
ip pim sparse-mode
!
interface Vlan69
description Voice
ip address 10.5.29.1 255.255.255.0
ip helper-address 10.4.48.10
ip pim sparse-mode
```

Procedure 6 Configure Remote-Site DHCP

(Optional)

This is an optional procedure. The previous procedure assumes the DHCP service has been configured centrally and uses the **ip helper-address** command to forward DHCP requests to the centralized DHCP server.

You may also choose to run a local DHCP server on the remote-site router instead. If so, use the following steps to use local DHCP service on the router to assign basic network configuration for IP phones, wireless access-points, users' laptop and desktop computers, and other endpoint devices. Remove the previously configured **ip helper-address** commands for any interface that is using local DHCP server.



Tech Tip

If you intend to use a dual-router remote-site design, you should use a resilient DHCP solution, such as a centralized DHCP server. Options for resilient DHCP at the remote-site include using IOS on a distribution-layer switch stack or implementing a dedicated DHCP server solution.

Step 1: Configure a DHCP scope for data endpoints, excluding DHCP assignment for the first 19 addresses in the subnet.

```
ip dhcp excluded-address 10.5.4.1 10.11.4.19
ip dhcp pool DHCP-Wired-Data
network 10.5.4.0 255.255.255.0
default-router 10.5.4.1
domain-name cisco.local
dns-server 10.4.48.10
```

Step 2: Configure a DHCP scope for voice endpoints, excluding DHCP assignment for the first 19 addresses in the subnet.

Step 3: Voice endpoints require an option field to tell them where to find their initial configuration. Different vendors use different option fields, so the number may vary based on the voice product you choose (for example, Cisco uses DHCP option 150).

```
ip dhcp excluded-address 10.5.5.1 10.11.5.19
ip dhcp pool DHCP-Wired-Voice
network 10.5.5.0 255.255.255.0
default-router 10.5.5.1
domain-name cisco.local
dns-server 10.4.48.10
```

The following procedures (Procedure 7 through Procedure 11) are only relevant for the dual-router design.

Procedure 7 Configure Access Layer HSRP

Applies to Dual-Router Design Only

You need to configure HSRP to enable the use of a Virtual IP (VIP) as a default gateway that is shared between two routers. The HSRP active router is the MPLS CE router connected to the primary MPLS carrier and the HSRP standby router is the router connected to the secondary MPLS carrier or 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 11 - WAN remote-site HSRP parameters (dual router)

Router	HSRP role	Virtual IP address (VIP)	Real IP address	HSRP priority	PIM DR priority
MPLS CE (primary)	Active	.1	.2	110	110
MPLS CE (secondary) or 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 [type][number].[sub-interface number]
ip address [LAN network 1 address] [LAN network 1 netmask]
ip pim dr-priority 110
standby version 2
standby 1 ip [LAN network 1 gateway address]
standby 1 priority 110
standby 1 preempt
standby 1 authentication md5 key-string c1sco123
```

Example - Layer 2 link

```
interface GigabitEthernet0/2
no ip address
no shutdown
!
interface GigabitEthernet0/2.64
description Data
encapsulation dot1Q 64
ip address 10.5.12.2 255.255.255.0
ip helper-address 10.4.48.10
ip pim dr-priority 110
ip pim sparse-mode
standby version 2
standby 1 ip 10.5.12.1
standby 1 priority 110
standby 1 preempt
standby 1 authentication md5 key-string c1sco123
!
interface GigabitEthernet0/2.69
description Voice
encapsulation dot1Q 69
ip address 10.5.13.2 255.255.255.0
ip helper-address 10.4.48.10
ip pim dr-priority 110
ip pim sparse-mode
standby version 2
standby 1 ip 10.5.13.1
standby 1 priority 110
standby 1 preempt
standby 1 authentication md5 key-string c1sco123
```

Procedure 8 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 hair-pinning. 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.

Step 1: Configure transit network interface on the router.

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

Example—MPLS CE Router (primary)

```
interface GigabitEthernet0/2.99
  description Transit Net
  encapsulation dot1Q 99
  ip address 10.5.8.1 255.255.255.252
  ip pim sparse-mode
```

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

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

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

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

```
interface GigabitEthernet1/0/24
  switchport trunk allowed vlan add 99
```

Procedure 9 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 WAN interface (MPLS PE-CE link interface) as an EIGRP interface.

```
router eigrp 100
  network [network] [inverse mask]
  passive-interface default
  no passive-interface [Transit interface]
  eigrp router-id [IP address of Loopback0]
  no auto-summary
```

Step 2: Redistribute BGP into EIGRP-100.

The BGP routes are redistributed into EIGRP with a default metric. By default, only the WAN bandwidth and delay values are used for metric calculation.

```
router eigrp 100
  default-metric [WAN bandwidth] [WAN delay] 255 1 1500
  redistribute bgp 65511
```



Tech Tip

Command Reference:

default-metric *bandwidth delay reliability loading mtu*

bandwidth—Minimum bandwidth of the route in kilobytes per second

delay—Route delay in tens of microseconds.

Example

```
router eigrp 100
  default-metric 100000 100 255 1 1500
  network 10.4.0.0 0.1.255.255
  network 10.255.0.0 0.0.255.255
  redistribute bgp 65511
  passive-interface default
  no passive-interface GigabitEthernet0/2.99
  eigrp router-id 10.255.251.206
  no auto-summary
```

Procedure 10

Configure BGP for Dual Router

Step 1: Configure iBGP between the remote-site MPLS CE routers.

The dual-carrier MPLS design requires that a BGP link is configured between the CE routers. Since the CE routers are using the same ASN, this configuration is considered an internal BGP (iBGP) connection. This design uses iBGP peering using the transit network, which requires the next-hop-self-configuration option.

You must complete this step on both remote-site MPLS CE routers. Note, the iBGP session will not be established until you complete the transit network and EIGRP (LAN side) steps.

```
router bgp 65511
  neighbor [iBGP neighbor Transit Net IP] remote-as 65511
  neighbor [iBGP neighbor Transit Net IP] next-hop-self
```

Step 2: Configure BGP to prevent the remote site from becoming a transit AS.

By default, BGP readvertises all BGP learned routes. In the dual-MPLS design, this means that MPLS-A routes will be advertised to MPLS-B and vice-versa. In certain cases, when a link to a MPLS hub has failed, remote sites will advertise themselves as a transit autonomous system providing access between the two carriers. Unless the remote site has been specifically designed for this type of routing behavior, with a high bandwidth connection, it is a best practice to disable the site from becoming a transit site. You must use a route-map and an as-path access-list filter. You need to apply this route-map on both remote-site MPLS CE routers. Each router will apply this outbound to the neighbor for its respective MPLS carrier.

```
router bgp 65511
  neighbor [IP address of PE] route-map NO-TRANSIT-AS out
```

The regular expression “^\$” corresponds to routes originated from the remote-site. This type of filter only allows for the locally originated routes to be advertised.

```
ip as-path access-list 10 permit ^$
!
route-map NO-TRANSIT-AS permit 10
  match as-path 10
```

Step 3: Tune BGP routing to prefer the primary MPLS carrier.

BGP uses a well-known rule set to determine the “best path” when the same IP route prefix is reachable via two different paths. The MPLS dual-carrier design in many cases provides two equal cost paths, and it is likely that the first path selected will remain the active path unless the routing protocol detects a failure. To accomplish the design goal of deterministic routing and primary/secondary routing behavior necessitates tuning BGP. This requires the use of a route-map and an as-path access-list filter.

```
router bgp 65511
  neighbor [IP address of PE] route-map PREFER-MPLS-A in
```

The regular expression “_65401\$” corresponds to routes originated from the AS 65401 (MPLS-A). This allows BGP to selectively modify the routing information for routes originated from this AS. In this example, the BGP local preference is 200 for the primary MPLS carrier. Routes originated from the secondary MPLS carrier will continue to use their default local preference of 100. Apply this route-map inbound to the neighbor for the primary MPLS carrier only.

```
ip as-path access-list 1 permit _65401$
!
route-map PREFER-MPLS-A permit 10
  match as-path 1
  set local-preference 200
!
route-map PREFER-MPLS-A permit 20
```

Step 4: Add loopback network for secondary router.

```
router bgp 65511
  network [Secondary router loopback network] mask
 255.255.255.255
```

network to the HSRP standby router and begin to forward traffic across the alternate path. This is sub-optimal routing, and you can address it by using EOT.

The HSRP active router (primary MPLS CE) can use the IP SLA feature to send echo probes to its MPLS PE router and if the PE router becomes unreachable, then 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 primary transport (MPLS VPN).

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 MPLS PE router as the probe destination, the destination address is the same as the BGP neighbor address configured in Procedure 3.

```
ip sla 100
  icmp-echo [probe destination IP address] source-interface
[WAN interface]
  threshold 1000
  timeout 1000
  frequency 15
ip sla schedule 100 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 50 ip sla 100 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]
  standby 1 track 50 decrement 10
```

Procedure 11 Enable Enhanced Object Tracking

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 primary MPLS VPN transport were to fail, the HSRP active router would learn an alternate path through the transit

Example

```
interface GigabitEthernet 0/2.64
 standby 1 track 50 decrement 10
interface GigabitEthernet 0/2.69
 standby 1 track 50 decrement 10
!
track 50 ip sla 100 reachability
!
ip sla 100
 icmp-echo 192.168.3.10 source-interface GigabitEthernet0/0
 timeout 1000
 threshold 1000
 frequency 15
ip sla schedule 100 life forever start-time now
```

Process

Adding Secondary MPLS Link on Existing MPLS CE Router

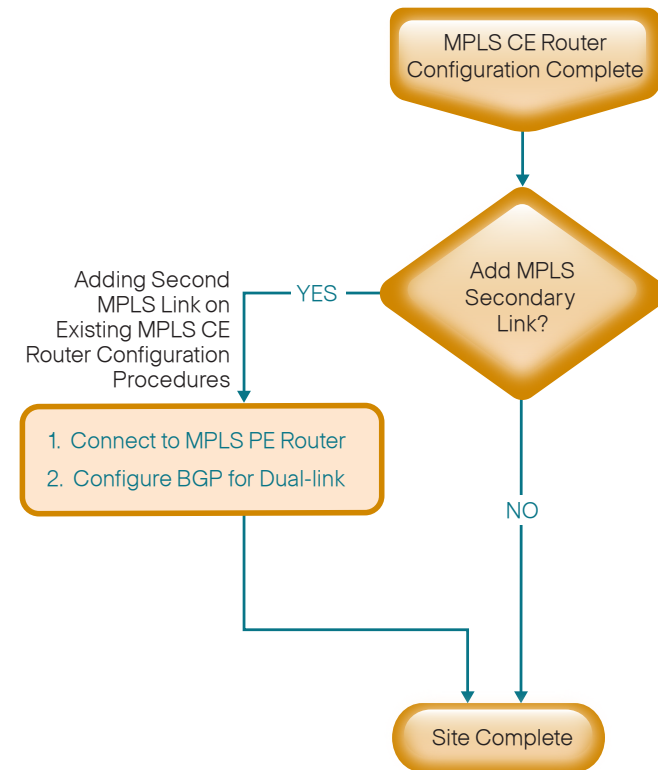
1. Connect to MPLS PE Router
2. Configure BGP for Dual Link

This set of procedures includes the additional steps necessary to complete the configuration of a MPLS CE router for a MPLS WAN dual-carrier remote site (single-router, dual-link).

The following procedures assume that the configuration of a MPLS CE Router for a MPLS WAN remote site (single-router, single-link) has already been completed and BGP dynamic routing has been configured. Only the additional procedures to add an additional MPLS link to the running MPLS CE router are included here.

The following flowchart provides details on how to add a second MPLS backup link on an existing remote-site MPLS CE router.

Figure 16 - Adding MPLS backup configuration flowchart



2130

Procedure 1 Connect to MPLS PE Router

This procedure applies to the interface used to connect the secondary or additional MPLS carrier.

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 10 Mbps.

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



Tech Tip

Command Reference:

bandwidth *kbps*

10 Mbps = 10,000 kbps

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

The IP addressing used between CE and PE routers must be negotiated with your MPLS carrier. Typically, a point-to-point netmask of 255.255.255.252 is used.

```
interface [interface type] [number]
  ip address [IP address] [netmask]
```

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

Cisco does not recommend that you use the Cisco Discovery Protocol on external interfaces.

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

Example

```
interface GigabitEthernet0/1
  bandwidth 10000
  ip address 192.168.4.13 255.255.255.252
  ip pim sparse-mode
  no cdp enable
  no shutdown
```

Procedure 2 Configure BGP for Dual Link

Step 1: Configure eBGP to add an additional eBGP neighbor and advertise the PE-CE link.

BGP must be configured with the MPLS carrier PE device. The MPLS carrier must provide their ASN (the ASN in this step is the ASN identifying your site). Since the carrier PE router will use a different ASN, this configuration is considered an external BGP (eBGP) connection.

It is desirable to advertise a route for the PE-CE link, so you should include this network in a network statement. You can use it to determine router reachability for troubleshooting.

The remote-site LAN networks are already advertised based on the configuration already completed in the Remote-Site MPLS CE Router Configuration procedures.

```
router bgp 65511
  network [PE-CE link 2 network] mask [PE-CE link 2 netmask]
  neighbor [IP address of PE 2] remote-as [carrier ASN]
```

Step 2: Configure BGP to prevent the remote site from becoming a transit AS.

By default, BGP readvertises all BGP learned routes. In the dual-MPLS design, this means that MPLS-A routes are advertised to MPLS-B and vice-versa. In certain cases, when a link to a MPLS hub has failed, remote sites will advertise themselves as a transit autonomous system providing access between the two carriers. Unless the remote site has been specifically designed for this type of routing behavior, with a high bandwidth connection, it is a best practice to disable the site from becoming a transit site. To do this, you need to use a route-map and an as-path access-list filter. Apply this route-map outbound to the neighbors for both MPLS carriers.

```
router bgp 65511
  neighbor [IP address of PE] route-map NO-TRANSIT-AS out
  neighbor [IP address of PE 2] route-map NO-TRANSIT-AS out
```

The regular expression “^\$” corresponds to routes originated from the remote-site. This type of filter only allows for the locally originated routes to be advertised.

```
ip as-path access-list 10 permit ^$
!
route-map NO-TRANSIT-AS permit 10
  match as-path 10
```

Step 3: Tune BGP routing to prefer the primary MPLS carrier.

BGP uses a well-known rule set to determine the “best path” when the same IP route prefix is reachable via two different paths. The MPLS dual-carrier design in many cases provides two equal cost paths, and it is likely that the first path selected will remain the active path unless the routing protocol detects a failure. To accomplish the design goal of deterministic routing and primary/secondary routing behavior necessitates tuning BGP. This requires the use of a route-map and an as-path access-list filter.

```
router bgp 65511
  neighbor [IP address of PE] route-map PREFER-MPLS-A in
```

The regular expression “_65401\$” corresponds to routes originated from the AS 65401 (MPLS-A). This allows BGP to selectively modify the routing information for routes originated from this AS. In this example, the BGP local preference is 200 for the primary MPLS carrier. Routes originated from the secondary MPLS carrier will continue to use their default local preference of 100. Apply this route-map inbound to the neighbor for the primary MPLS carrier only.

```
ip as-path access-list 1 permit _65401$
!
route-map PREFER-MPLS-A permit 10
  match as-path 1
  set local-preference 200
!
route-map PREFER-MPLS-A permit 20
```

Example

```
router bgp 65511
  network 192.168.4.12 mask 255.255.255.252
  neighbor 192.168.3.14 route-map PREFER-MPLS-A in
  neighbor 192.168.3.14 route-map NO-TRANSIT-AS out
  neighbor 192.168.4.14 remote-as 65402
  neighbor 192.168.4.14 route-map NO-TRANSIT-AS out
!
ip as-path access-list 1 permit _65401$
ip as-path access-list 10 permit ^$
!
route-map NO-TRANSIT-AS permit 10
  match as-path 10
!
route-map PREFER-MPLS-A permit 10
  match as-path 1
  set local-preference 200
!
route-map PREFER-MPLS-A permit 20
```

Process

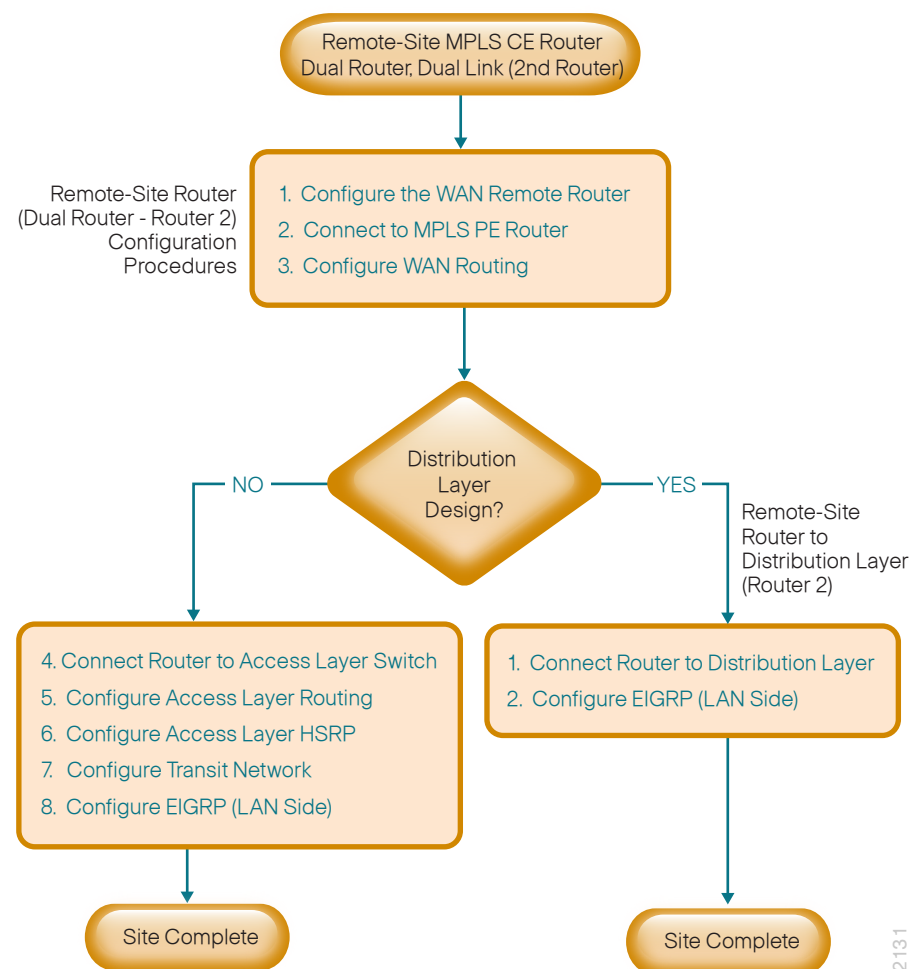
Remote-Site Router Configuration (Dual-Router - Router 2)

1. Configure the WAN Remote Router
2. Connect to the MPLS PE Router
3. Configure WAN Routing
4. Connect Router to Access Layer Switch
5. Configure Access Layer Routing
6. Configure Access Layer HSRP
7. Configure Transit Network
8. Configure EIGRP (LAN Side)

Use this set of procedures when you configure an MPLS WAN dual-carrier remote-site. Use these procedures when you configure the second MPLS CE router of the dual-router, dual-link design.

The following flowchart provides details about how to configure a remote-site MPLS CE router.

Figure 17 - Remote-site MPLS CE router 2 configuration flowchart



2131

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.

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

```
hostname [hostname]
```

Step 2: Configure local login and password.

The local login account and password provides basic access authentication to a router which provides only limited operational privileges. The enable password secures access to the device configuration mode. By enabling password encryption, you prevent the disclosure of plain text passwords when viewing configuration files.

```
username admin password c1sco123
enable secret c1sco123
service password-encryption
aaa new-model
```

Step 3: By default, https access to the router will use the enable password for authentication.

Step 4: (Optional) Configure centralized user authentication.

As networks scale in the number of devices to maintain it poses an operational burden to maintain local user accounts on every device. A centralized Authentication, Authorization and Accounting (AAA) service reduces operational tasks per device and provides an audit log of user access for security compliance and root cause analysis. When AAA is enabled for access control, all management access to the network infrastructure devices (SSH and HTTPS) is controlled by AAA.



Reader Tip

The AAA server used in this architecture is the Cisco Authentication Control System. For details about ACS configuration, see the *Device Management Using ACS 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 in Step 2 on each network infrastructure device to provide a fallback authentication source in case the centralized TACACS+ server is unavailable.

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

Step 5: Configure device management protocols.

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

Specify the transport preferred none on vty lines to prevent errant connection attempts from the CLI prompt. Without this command, if the ip name-server is unreachable, long timeout delays may occur for mistyped commands.

```
ip domain-name cisco.local
ip ssh version 2
no ip http server
ip http secure-server
line vty 0 15
  transport input ssh
  transport preferred none
```

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

```
line con 0
  logging synchronous
```

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 6: (Optional) In networks where network operational support is centralized you can increase network security by using an access list to limit the networks that can access your device. In this example, only devices on the 10.4.48.0/24 network will be able to access the device via SSH or SNMP.

```
access-list 55 permit 10.4.48.0 0.0.0.255
line vty 0 15
  access-class 55 in
!
snmp-server community cisco RO 55
snmp-server community cisco123 RW 55
```



Tech Tip

If you configure an access-list on the vty interface you may lose the ability to use ssh to login from one router to the next for hop-by-hop troubleshooting.

Step 7: Configure a synchronized clock.

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

Step 8: Configure an in-band management interface.

The loopback interface is a logical interface that is always reachable as long as the device is powered on and any IP interface is reachable to the network. Because of this capability, the loopback address is the best way to manage the 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 a unique network range that is not part of any other internal network summary range.

```
interface Loopback 0
  ip address [ip address] 255.255.255.255
  ip pim sparse-mode
```

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

Bind the device processes for SNMP, SSH, PIM, TACACS+ and NTP to the loopback interface address for optimal resiliency.

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

Step 9: 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 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
```

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 MPLS PE Router

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 sub-rate of 10 Mbps.

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



Tech Tip

Command Reference:

bandwidth *kbps*

10 Mbps = 10,000 kbps

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

You must negotiate the IP addressing used between CE and PE routers with your MPLS carrier. Typically, a point-to-point netmask of 255.255.255.252 is used.

```
interface [interface type] [number]
  ip address [IP address] [netmask]
```


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

Cisco does not recommend that you use Cisco Discovery Protocol on external interfaces.

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

Example

```
interface GigabitEthernet0/0
  bandwidth 25000
  ip address 192.168.4.9 255.255.255.252
  no cdp enable
  no shutdown
```

Procedure 3 Configure WAN Routing

Step 1: Enable BGP.

To complete this step, you must use a BGP ASN. You might be able to reuse the same value used on the MPLS VPN CE from the WAN-aggregation site. Consult with your MPLS carrier on the requirements for the ASN.

The CE router only advertises network routes to the PE via BGP in the following cases:

- The route is specified in network statements and is present in the local routing table.
- The route is redistributed into BGP (not applicable in the remote-site use case).

```
router bgp 65511
  no synchronization
  bgp router-id [IP address of Loopback0]
  bgp log-neighbor-changes
  no auto-summary
```

Step 2: Configure eBGP.

You must configure BGP with the MPLS carrier PE device. The MPLS carrier must provide their ASN (the ASN in Step 1 is the ASN identifying your site). Since the carrier PE router will use a different ASN, this configuration is considered an external BGP (eBGP) connection.

It is desirable to advertise a route for the PE-CE link, so you should include this network in a network statement. You can use this to determine router reachability for troubleshooting.

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 aggregate address as configured below suppresses the more specific routes. If any LAN network is present in the route table, the aggregate is advertised to the MPLS PE, which offers a measure of resiliency. If the various LAN networks cannot be summarized, you must list each individually.

The remote-site routers have in-band management configured via the loopback interface. To ensure reachability of the loopback interfaces in a dual-router design, you must list the loopbacks of both the primary and secondary routers as BGP networks.



Tech Tip

On the primary MPLS CE router, you must add a network statement for the loopback address of the secondary MPLS CE router. This is required for loopback resiliency.

```
router bgp 65511
  network [PE-CE link network] mask [PE-CE link netmask]
  network [Primary router loopback network] mask
  255.255.255.255
  network [Secondary router loopback network] mask
  255.255.255.255
  network [DATA network] mask [netmask]
  network [VOICE network] mask [netmask]
  aggregate-address [summary IP address] [summary netmask]
  summary-only
  neighbor [IP address of PE] remote-as [carrier ASN]
```

Step 3: Configure iBGP between the remote-site MPLS CE routers.

The dual-carrier MPLS design requires that a BGP link is configured between the CE routers. Since the CE routers are using the same ASN, this configuration is considered an internal BGP (iBGP) connection.

Note, the iBGP session will not be established until you complete the transit network and EIGRP (LAN side) steps.

```
router bgp 65511
 neighbor [iBGP neighbor Transit Net IP] remote-as 65511
 neighbor [iBGP neighbor Transit Net IP] next-hop-self
```

Step 4: Configure BGP to prevent the remote site from becoming a transit AS.

By default, BGP readvertises all BGP learned routes. In the dual-MPLS design, this means that MPLS-A routes will be advertised to MPLS-B and vice-versa. In certain cases, when a link to a MPLS hub has failed, remote sites will advertise themselves as a transit autonomous system providing access between the two carriers. Unless the remote site has been specifically designed for this type of routing behavior, with a high bandwidth connection, it is a best practice to disable the site from becoming a transit site. You must use a route-map and an as-path access-list filter. You need to apply this route-map on both remote-site MPLS CE routers. Each router will apply this outbound to the neighbor for its respective MPLS carrier.

```
router bgp 65511
 neighbor [IP address of PE 2] route-map NO-TRANSIT-AS out
```

The regular expression “^\$” corresponds to routes originated from the remote-site. This type of filter only allows for the locally originated routes to be advertised.

```
ip as-path access-list 10 permit ^$
!
route-map NO-TRANSIT-AS permit 10
 match as-path 10
```

Example - MPLS CE Router (secondary)

```
router bgp 65511
 no synchronization
 bgp router-id 10.255.252.206
 bgp log-neighbor-changes
 network 192.168.4.8 mask 255.255.255.252
 network 10.255.251.206 mask 255.255.255.255
 network 10.255.252.206 mask 255.255.255.255
 network 10.5.12.0 mask 255.255.255.0
 network 10.5.13.0 mask 255.255.255.0
 aggregate-address 10.5.8.0 255.255.248.0 summary-only
 neighbor 10.5.8.1 remote-as 65511
 neighbor 10.5.8.1 next-hop-self
 neighbor 192.168.4.10 remote-as 65402
 neighbor 192.168.4.10 route-map NO-TRANSIT-AS out
 no auto-summary
!
ip as-path access-list 10 permit ^$
!
route-map NO-TRANSIT-AS permit 10
 match as-path 10
```

Procedure 4

Connect Router to Access Layer Switch



Reader Tip

Please refer to the *LAN Deployment Guide* for complete access layer configuration details. This guide only includes the additional steps to complete the distribution layer configuration.

If you are using a remote-site distribution layer then skip to the “Deploying a WAN Remote-Site Distribution Layer” section of this guide.

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

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

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

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

```
interface Port-channel2
description EtherChannel link to RS206-A2960S
no shutdown
```

Step 2: Configure EtherChannel member interfaces on the router.

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

```
interface GigabitEthernet0/1
description RS206-A2960S Gig1/0/23
!
interface GigabitEthernet0/2
description RS206-A2960S Gig2/0/23
!
interface range GigabitEthernet0/1, GigabitEthernet0/2
no ip address
channel-group 2
no shutdown
```

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

Connect the router EtherChannel uplinks to separate switches in the access layer switch stack, or in the case of the Cisco Catalyst 4507R+E distribution layer, to separate redundant modules for additional resiliency.

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

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

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

```
interface GigabitEthernet1/0/23
description Link to RS206-3925-2 Gig0/1
interface GigabitEthernet2/0/23
description Link to RS206-3925-2 Gig0/2
!
interface range GigabitEthernet1/0/23, GigabitEthernet2/0/23
switchport
macro apply EgressQoS
channel-group 2 mode on
logging event link-status
logging event trunk-status
logging event bundle-status
```

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

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

```
interface Port-channel2
  description EtherChannel link to RS206-3925-2
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 64,69,99
  switchport mode trunk
  ip arp inspection trust
  spanning-tree portfast trunk
  ip dhcp snooping trust
  no shutdown
```

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

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

Step 1: Enable the physical interface on the router.

```
interface GigabitEthernet0/2
  description RS206-A2960S Gig1/0/23
  no ip address
  no shutdown
```

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

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

```
interface GigabitEthernet1/0/23
  description Link to RS206-3925-2 Gig0/2
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 64,69,99
  switchport mode trunk
```

```
ip arp inspection trust
spanning-tree portfast trunk
macro apply EgressQoS
logging event link-status
logging event trunk-status
ip dhcp snooping trust
no shutdown
```

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

Procedure 5 Configure Access Layer Routing

Step 1: Create subinterfaces and assign VLAN tags.

After the physical interface or port-channel 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 making them the same simplifies the overall configuration. The subinterface portion of the configuration should be repeated for all data or voice VLANs.

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

Step 2: Configure IP settings for each subinterface.

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

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

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

```
interface [type] [number]. [sub-interface number]
  description [usage]
  ip helper-address 10.4.48.10
  ip pim sparse-mode
```

Example - Layer 2 EtherChannel

```
interface Port-channel2
  no ip address
  no shutdown
  !
  hold-queue 150 in
  !
interface Port-channel2.64
  description Data
  encapsulation dot1Q 64
  ip helper-address 10.4.48.10
  ip pim sparse-mode
  !
interface Port-channel2.69
  description Voice
  encapsulation dot1Q 69
  ip helper-address 10.4.48.10
  ip pim sparse-mode
```

Example - Layer 2 Link

```
interface GigabitEthernet0/2
  no ip address
  no shutdown
  !
interface GigabitEthernet0/2.64
  description Data
  encapsulation dot1Q 64
  ip helper-address 10.4.48.10
  ip pim sparse-mode
  !
interface GigabitEthernet0/2.69
  description Voice
  encapsulation dot1Q 69
  ip helper-address 10.4.48.10
  ip pim sparse-mode
```

Procedure 6

Configure Access Layer HSRP

Configure HSRP to use a Virtual IP (VIP) as a default gateway that is shared between two routers. The HSRP active router is the MPLS CE router connected to the primary MPLS carrier and the HSRP standby router is the router connected to the secondary MPLS carrier or 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	Virtual IP address (VIP)	Real IP address	HSRP priority	PIM DR priority
MPLS CE (primary)	Active	.1	.2	110	110
MPLS CE (secondary) or DMVPN Spoke	Standby	.1	.3	105	105

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.

Repeat this procedure for all data or voice subinterfaces.

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

Example—MPLS CE Router (secondary) with Layer 2 Ether-Channel

```
interface Port-channel2
no ip address
no shutdown
!
interface Port-channel2.64
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 105
ip pim sparse-mode
standby version 2
standby 1 ip 10.5.12.1
standby 1 priority 105
standby 1 preempt
standby 1 authentication md5 key-string c1sco123
!
interface Port-channel2.69
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 version 2
```

```
standby 1 ip 10.5.13.1
standby 1 priority 105
standby 1 preempt
standby 1 authentication md5 key-string c1sco123
```

Example—MPLS CE Router (secondary) with Layer 2 Link

```
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 105
ip pim sparse-mode
standby version 2
standby 1 ip 10.5.12.1
standby 1 priority 105
standby 1 preempt
standby 1 authentication md5 key-string c1sco123
!
interface GigabitEthernet0/2.69
description Voice
encapsulation dot1Q 69
ip address 10.5.13.3 255.255.255.0
ip helper-address 10.4.48.10
ip pim dr-priority 105
ip pim sparse-mode
standby version 2
standby 1 ip 10.5.13.1
standby 1 priority 105
standby 1 preempt
standby 1 authentication md5 key-string c1sco123
```

Procedure 7 Configure Transit Network

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 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]
  ip pim sparse-mode
```

Example—MPLS CE Router (secondary)

```
interface GigabitEthernet0/2.99
  description Transit Net
  encapsulation dot1q 99
  ip address 10.5.8.2 255.255.255.252
  ip pim sparse-mode
```

Procedure 8 Configure EIGRP (LAN Side)

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 WAN interface (MPLS PE-CE link interface) as an EIGRP interface.

```
router eigrp 100
  network [network] [inverse mask]
  passive-interface default
  no passive-interface [Transit interface]
  eigrp router-id [IP address of Loopback0]
  no auto-summary
```

Step 2: Redistribute BGP into EIGRP-100.

The BGP routes are redistributed into EIGRP with a default metric. By default, only the WAN bandwidth and delay values are used for metric calculation.

```
router eigrp 100
  default-metric [WAN bandwidth] [WAN delay] 255 1 1500
  redistribute bgp 65511
```



Tech Tip

Command Reference:

default-metric *bandwidth delay reliability loading mtu*

bandwidth—Minimum bandwidth of the route in kilobytes per second

delay—Route delay in tens of microseconds.

Example

```
router eigrp 100
  default-metric 100000 100 255 1 1500
  network 10.4.0.0 0.1.255.255
  redistribute bgp 65511
  passive-interface default
  no passive-interface GigabitEthernet0/2.99
  eigrp router-id 10.255.252.206
  no auto-summary
```


Deploying a WAN Remote-Site Distribution Layer

Process

Remote-Site Router to Distribution Layer

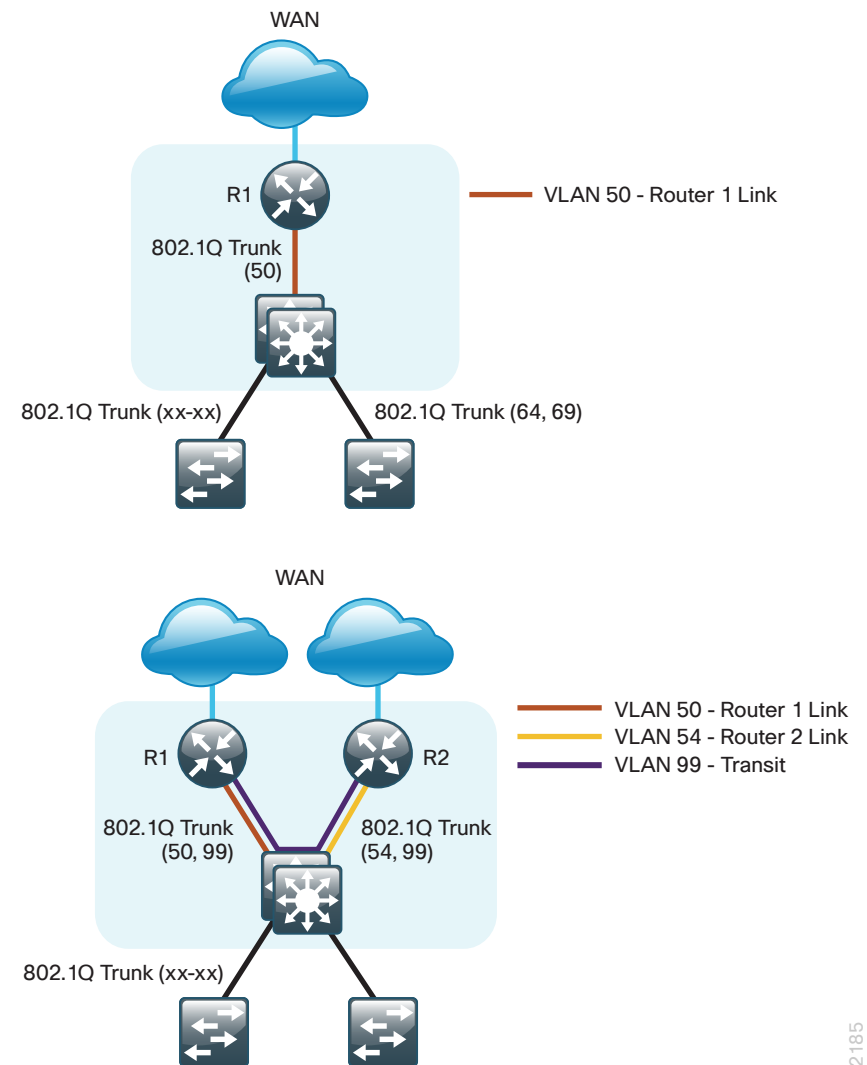
1. Connect Router to Distribution Layer
2. Configure EIGRP (LAN Side)
3. Configure the Transit Network
4. Configure BGP for Dual Router

Use this set of procedures to configure a MPLS CE router for a MPLS WAN remote site (single-router, single-link). This section includes all required procedures to connect to a LAN distribution layer.

Also, use this set of procedures for a dual-carrier MPLS remote site. Use these procedures when you are connecting a distribution layer to the first router of the dual-router, dual-link design.

Both distribution layer remote-site options are shown in the following figure.

Figure 18 - WAN remote site - Connection to distribution layer



Procedure 1 Connect Router to Distribution Layer



Reader Tip

Please refer to the *Cisco SBA—LAN Deployment Guide* for complete distribution layer configuration details. This guide only includes the additional steps to complete the distribution layer configuration.

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

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

```
interface Port-channel1
  description EtherChannel link to RS200-D3750X
  no shutdown
```

Step 2: Configure the port channel subinterfaces and assign IP addresses.

After you have enabled the 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-channel1.50
  description R1 routed link to distribution layer
  encapsulation dot1q 50
  ip address 10.5.0.1 255.255.255.252
  ip pim sparse-mode
```

Step 3: Configure EtherChannel member interfaces on the router.

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

```
interface GigabitEthernet0/1
  description RS200-D3750X Gig1/0/1
  !
interface GigabitEthernet0/2
  description RS200-D3750X Gig2/0/1
  !
interface range GigabitEthernet0/1, GigabitEthernet0/2
  no ip address
  channel-group 1
  no shutdown
```

Step 4: Configure VLAN on the distribution layer switch.

If your VLAN does not already exist on the distribution layer switch configure it now.

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

Step 5: Configure Layer 3 on the distribution layer switch.

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

```
interface Vlan50
  ip address 10.5.0.2 255.255.255.252
  ip pim sparse-mode
  no shutdown
```

Step 6: Configure EtherChannel member interfaces on the distribution layer switch.

Connect the router EtherChannel uplinks to separate switches in the distribution layer switches or stack, and in the case of the Cisco Catalyst 4507R+E distribution layer, to separate redundant modules for additional resiliency.

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

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

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

```
interface GigabitEthernet1/0/1
  description Link to RS200-3925-1 Gig0/1
interface GigabitEthernet2/0/1
  description Link to RS200-3925-1 Gig0/2
!
interface range GigabitEthernet1/0/1, GigabitEthernet2/0/1
  switchport
  macro apply EgressQoS
  channel-group 1 mode on
  logging event link-status
  logging event trunk-status
  logging event bundle-status
```

Step 7: Configure EtherChannel trunk on the distribution layer switch.

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

```
interface Port-channel1
  description EtherChannel link to RS200-3925-1
  switchport trunk encapsulation dot1q
  switchport trunk allowed vlan 50
  switchport mode trunk
  spanning-tree portfast trunk
  no shutdown
```

The Catalyst 4500 does not require the **switchport trunk encapsulation dot1q** command.

Procedure 2

Configure EIGRP (LAN Side)

You must configure a routing protocol between the router and distribution layer.

Step 1: Enable EIGRP-100 on the router.

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 100
  network 10.5.0.0 0.0.255.255
  network 10.255.0.0 0.0.255.255
  passive-interface default
  no passive-interface [interface]
  eigrp router-id [IP address of Loopback0]
  no auto-summary
```

Step 2: Redistribute BGP into EIGRP-100 on the router.

The BGP routes are redistributed into EIGRP with a default metric. By default, only the WAN bandwidth and delay values are used for metric calculation.

```
router eigrp [as number]
  default-metric [WAN bandwidth (Kbps)] [WAN delay (usec)] 255
  1 1500
  redistribute bgp 65511
```

Example

```
router eigrp 100
  default-metric 100000 100 255 1 1500
  network 10.5.0.0 0.0.255.255
  network 10.255.0.0 0.0.255.255
  passive-interface default
  no passive-interface Port-channel1.50
  eigrp router-id 10.255.251.200
  no auto-summary
```

Step 3: Enable EIGRP on distribution layer switch VLAN interface.

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

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

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. The transit network uses Layer 2 pass through on the distribution layer switch, so no SVI is required.

Step 1: Configure the transit net interface on the router.

```
interface Port-channel1.99
  description Transit Net
  encapsulation dot1Q 99
  ip address 10.5.0.9 255.255.255.252
  ip pim sparse-mode
```

Step 2: Enable EIGRP on the transit net interface on the router.

```
router eigrp 100
  no passive-interface Port-channel1.99
```

Step 3: Configure transit network VLAN on the distribution layer switch.

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

Step 4: Add transit network VLAN to existing distribution layer switch EtherChannel trunk.

```
interface Port-channel1
  switchport trunk allowed vlan add 99
```

Procedure 4 Configure BGP for Dual Router

Step 1: Configure iBGP between the remote-site MPLS CE routers.

The dual-carrier MPLS design requires that a BGP link is configured between the CE routers. Since the CE routers are using the same ASN, this configuration is considered an internal BGP (iBGP) connection. This design uses iBGP peering using device loopback addresses, which requires the update-source and next-hop-self configuration options.

You must complete this step on both remote-site MPLS CE routers. Note, the iBGP session will not be established until you complete the transit network and EIGRP (LAN side) steps.

```
router bgp 65511
  neighbor [iBGP neighbor Transit Net IP] remote-as 65511
  neighbor [iBGP neighbor Transit Net IP] next-hop-self
```

Step 2: Configure BGP to prevent the remote site from becoming a transit AS.

By default, BGP readvertises all BGP learned routes. In the dual-MPLS design, this means that MPLS-A routes will be advertised to MPLS-B and vice-versa. In certain cases, when a link to a MPLS hub has failed, remote sites will advertise themselves as a transit autonomous system providing access between the two carriers. Unless the remote site has been specifically designed for this type of routing behavior, with a high bandwidth connection, it is a best practice to disable the site from becoming a transit site. You must use a route-map and an as-path access-list filter. You need to apply this route-map on both remote-site MPLS CE routers. Each router will apply this outbound to the neighbor for its respective MPLS carrier.

```
router bgp 65511
  neighbor [IP address of PE] route-map NO-TRANSIT-AS out
```

The regular expression “^\$” corresponds to routes originated from the remote-site. This type of filter only allows for the locally originated routes to be advertised.

```
ip as-path access-list 10 permit ^$
!
route-map NO-TRANSIT-AS permit 10
  match as-path 10
```

Step 3: Tune BGP routing to prefer the primary MPLS carrier.

BGP uses a well-known rule set to determine the “best path” when the same IP route prefix is reachable via two different paths. The MPLS dual-carrier design in many cases provides two equal cost paths, and it is likely that the first path selected will remain the active path unless the routing protocol detects a failure. To accomplish the design goal of deterministic routing and primary/secondary routing behavior necessitates tuning BGP. This requires the use of a route-map and an as-path access-list filter.

```
router bgp 65511
  neighbor [IP address of PE] route-map PREFER-MPLS-A in
```

The regular expression “_65401\$” corresponds to routes originated from the AS 65401 (MPLS-A). This allows BGP to selectively modify the routing information for routes originated from this AS. In this example, the BGP local preference is 200 for the primary MPLS carrier. Routes originated from the secondary MPLS carrier will continue to use their default local preference of 100. Apply this route-map inbound to the neighbor for the primary MPLS carrier only.

```
ip as-path access-list 1 permit _65401$
!
route-map PREFER-MPLS-A permit 10
  match as-path 1
  set local-preference 200
!
route-map PREFER-MPLS-A permit 20
```

Step 4: Add loopback network for secondary router.

```
router bgp 65511
  network [Secondary router loopback network] mask
  255.255.255.255
```

Process

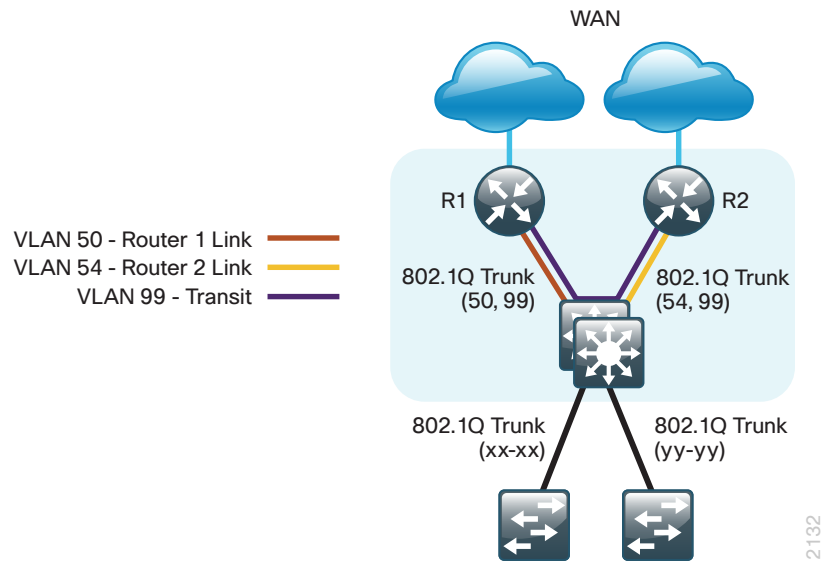
Remote-Site Router to Distribution Layer (Router 2)

1. Connect Router to Distribution Layer
2. Configure EIGRP (LAN Side)

Use this set of procedures for a dual-carrier MPLS WAN remote site. Use these procedures to connect a distribution layer when configuring the second router of the dual-router, dual-link design. This design uses a separate routed link from the second router of the dual-router scenario to the LAN distribution layer switch.

The dual-router distribution layer remote-site option is shown in the following figure.

Figure 19 - WAN remote site - Connection to distribution layer



Step 2: Configure the port channel subinterfaces and assign IP address.

After you have enabled the 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-channel2.54
description R2 routed link to distribution layer
encapsulation dot1Q 54
ip address 10.5.0.5 255.255.255.252
ip pim sparse-mode
```

Step 3: Configure the transit network interface on the router.

```
interface Port-channel2.99
description Transit Net
encapsulation dot1Q 99
ip address 10.5.0.10 255.255.255.252
ip pim sparse-mode
```

Step 4: Configure EtherChannel member interfaces on the router.

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

```
interface GigabitEthernet0/1
description RS200-D3750X Gig1/0/2
!
interface GigabitEthernet0/2
description RS200-D3750X Gig2/0/2
!
interface range GigabitEthernet0/1, GigabitEthernet0/2
no ip address
channel-group 2
no shutdown
```

Procedure 1 Connect Router to Distribution Layer



Reader Tip

Please refer to the *LAN Deployment Guide* for complete distribution layer configuration details. This guide only includes the additional steps to complete the distribution layer configuration.

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

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

```
interface Port-channel2
description EtherChannel link to RS200-D3750X
no shutdown
```

Step 5: Configure VLAN on the distribution layer switch.

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

```
vlan 54
name R2-link
```

Step 6: Configure Layer 3 on the distribution layer switch.

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

```
interface Vlan54
ip address 10.5.0.6 255.255.255.252
ip pim sparse-mode
no shutdown
```

Step 7: Configure EtherChannel member interfaces on the distribution layer switch.

Connect the router EtherChannel uplinks to separate switches in the distribution layer switches or stack, and in the case of the Cisco Catalyst 4507R+E distribution layer, to separate redundant modules for additional resiliency.

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

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

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

```
interface GigabitEthernet1/0/2
description Link to RS200-3925-2 Gig0/1
interface GigabitEthernet2/0/2
description Link to RS200-3925-2 Gig0/2
!
interface range GigabitEthernet1/0/2, GigabitEthernet2/0/2
switchport
macro apply EgressQoS
channel-group 2 mode on
logging event link-status
logging event trunk-status
logging event bundle-status
```

Step 8: Configure EtherChannel trunk on the distribution layer switch.

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

```
interface Port-channel2
description EtherChannel link to RS200-3925-2
switchport trunk encapsulation dot1q
switchport trunk allowed vlan 54,99
switchport mode trunk
spanning-tree portfast trunk
no shutdown
```

The Catalyst 4500 does not require the **switchport trunk encapsulation dot1q** command.

Procedure 2

Configure EIGRP (LAN Side)

You must configure a routing protocol between the router and distribution layer.

Step 1: Enable EIGRP-100 on the router.

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 100
 network 10.5.0.0 0.0.255.255
 network 10.255.0.0 0.0.255.255
 passive-interface default
 no passive-interface [routed link interface]
 no passive-interface [transit net interface]
 eigrp router-id [IP address of Loopback0]
 no auto-summary
```

Step 2: Redistribute BGP into EIGRP-100 on the router.

The BGP routes are redistributed into EIGRP with a default metric. By default, only the WAN bandwidth and delay values are used for metric calculation.

```
router eigrp [as number]
 default-metric [WAN bandwidth (Kbps)] [WAN delay (usec)] 255
 1 1500
 redistribute bgp 65511
```

Example

```
router eigrp 100
 default-metric 500000 100 255 1 1500
 network 10.5.0.0 0.0.255.255
 network 10.255.0.0 0.0.255.255
 passive-interface default
 no passive-interface Port-channel12.54
 no passive-interface Port-channel12.99
 eigrp router-id 10.255.252.200
 no auto-summary
```

Step 3: Enable EIGRP on distribution layer switch VLAN interface.

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

```
router eigrp 100
 no passive-interface Vlan54
```

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

Configuring QoS

1. Create the QoS Maps to Classify Traffic
2. Create the Policy Map to Mark BGP Traffic
3. Define Policy Map to use Queuing Policy
4. Configure Physical Interface S&Q Policy
5. Apply QoS Policy to a 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 wish to take against the traffic type. The **class-map** command sets the match logic. In this case, the **match-any** keyword indicates that the maps match any of the specified criteria. This keyword is followed by the name you want to assign to the class of service. After you have configured the **class-map** command, you 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 13 - QoS classes of service

Class of service	Traffic type	DSCP values	Bandwidth %	Congestion avoidance
VOICE	Voice traffic	ef	10 (PQ)	-
INTERACTIVE-VIDEO	Interactive video (video conferencing)	cs4, af41	23 (PQ)	-
CRITICAL-DATA	Highly interactive (such as Telnet, Citrix, and Oracle thin clients)	af31, cs3	15	DSCP based
DATA	Data	af21	19	DSCP based
SCAVENGER	Scavenger	af11, cs1	5	-
NETWORK-CRITICAL	Routing protocols. Operations, administration and maintenance (OAM) traffic.	cs6, cs2	3	-
default	Best effort	other	25	random

Step 2: Create a class map for BGP protocol matching.

BGP traffic is not explicitly tagged with a DSCP value. Use NBAR to match BGP by protocol.

This step is only required for a WAN-aggregation MPLS CE router or a WAN remote-site MPLS CE router that is using BGP.

```
class-map match-any [class-map name]
  match ip protocol [protocol name]
```

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 4.

Procedure 2

Create the Policy Map to Mark BGP Traffic

This procedure is only required for a WAN-aggregation MPLS CE router or a WAN remote-site MPLS CE router that uses BGP.

To ensure proper treatment of BGP routing traffic in the WAN, you must assign a DSCP value of cs6. Although the class-map you created in the previous step matches all BGP traffic to the class named BGP, you must configure a policy-map to assign the required DSCP value to all BGP traffic.

```
policy-map MARK-BGP
  class BGP-ROUTING
    set dscp cs6
```

Procedure 3

Define Policy Map to use Queuing Policy

This procedure applies to all WAN routers.

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.

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.

Step 1: Create the parent policy map.

```
policy-map [policy-map-name]
```

Steps 2–6 are repeated for each class in Table 13 including class-default.

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.

```
priority percent [percentage]
```

Step 5: (Optional) Apply the child service policy.

This is an optional step only for the NETWORK-CRITICAL class of service with the MARK-BGP child service policy.

```
service-policy [policy-map-name]
```

Step 6: (Optional) Define the congestion mechanism.

```
random-detect [type]
```

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
    service-policy MARK-BGP
  class class-default
    bandwidth percent 25
    random-detect
```



Tech Tip

Although these bandwidth assignments represent a good baseline, it is important to consider your actual traffic requirements per class and adjust the bandwidth settings accordingly.

Procedure 4

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 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 WAN routers. You can repeat this procedure 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 (bps)]
```

Step 3: Apply the child service policy.

```
policy-map [policy-map-name]
```

Example

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 5 Apply QoS Policy to a 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

Appendix A: Product List

WAN Aggregation

Functional Area	Product Description	Part Numbers	Software
WAN-aggregation Router	Aggregation Services 1002 Router	ASR1002-5G-VPN/K9	IOS-XE 15.2(2)S2
	Aggregation Services 1001 Router	ASR1001-2.5G-VPNK9	Advanced Enterprise license

WAN Remote Site

Functional Area	Product Description	Part Numbers	Software
Modular WAN Remote-site Router	Cisco 3945 Voice Sec. Bundle, PVDM3-64, UC and SEC License PAK	C3945-VSEC/K9	15.1(4)M5 securityk9 license datak9 license
	Cisco 3925 Voice Sec. Bundle, PVDM3-64, UC and SEC License PAK	C3925-VSEC/K9	
	Data Paper PAK for Cisco 3900 series	SL-39-DATA-K9	
	Cisco 2951 Voice Sec. Bundle, PVDM3-32, UC and SEC License PAK	C2951-VSEC/K9	
	Cisco 2921 Voice Sec. Bundle, PVDM3-32, UC and SEC License PAK	C2921-VSEC/K9	
	Cisco 2911 Voice Sec. Bundle, PVDM3-32, UC and SEC License PAK	C2911-VSEC/K9	
	Data Paper PAK for Cisco 2900 series	SL-29-DATA-K9	

LAN Access Layer

Functional Area	Product Description	Part Numbers	Software
Modular Access Layer Switch	Cisco Catalyst 4507R+E 7-slot Chassis with 48Gbps per slot	WS-C4507R+E	3.3.0.SG(15.1-1SG) IP Base license
	Cisco Catalyst 4500 E-Series Supervisor Engine 7L-E	WS-X45-SUP7L-E	
	Cisco Catalyst 4500 E-Series 48 Ethernet 10/100/1000 (RJ45) PoE+ ports	WS-X4648-RJ45V+E	
	Cisco Catalyst 4500 E-Series 48 Ethernet 10/100/1000 (RJ45) PoE+,UPoE ports	WS-X4748-UPOE+E	
Stackable Access Layer Switch	Cisco Catalyst 3750-X Series Stackable 48 Ethernet 10/100/1000 PoE+ ports	WS-C3750X-48PF-S	15.0(2)SE IP Base license
	Cisco Catalyst 3750-X Series Stackable 24 Ethernet 10/100/1000 PoE+ ports	WS-C3750X-24P-S	
	Cisco Catalyst 3750-X Series Two 10GbE SFP+ and Two GbE SFP ports network module	C3KX-NM-10G	
	Cisco Catalyst 3750-X Series Four GbE SFP ports network module	C3KX-NM-1G	
Standalone Access Layer Switch	Cisco Catalyst 3560-X Series Standalone 48 Ethernet 10/100/1000 PoE+ ports	WS-C3560X-48PF-S	15.0(2)SE IP Base license
	Cisco Catalyst 3560-X Series Standalone 24 Ethernet 10/100/1000 PoE+ ports	WS-C3560X-24P-S	
	Cisco Catalyst 3750-X Series Two 10GbE SFP+ and Two GbE SFP ports network module	C3KX-NM-10G	
	Cisco Catalyst 3750-X Series Four GbE SFP ports network module	C3KX-NM-1G	
Stackable Access Layer Switch	Cisco Catalyst 2960-S Series 48 Ethernet 10/100/1000 PoE+ ports and Two 10GbE SFP+ Uplink ports	WS-C2960S-48FPD-L	15.0(2)SE LAN Base license
	Cisco Catalyst 2960-S Series 48 Ethernet 10/100/1000 PoE+ ports and Four GbE SFP Uplink ports	WS-C2960S-48FPS-L	
	Cisco Catalyst 2960-S Series 24 Ethernet 10/100/1000 PoE+ ports and Two 10GbE SFP+ Uplink ports	WS-C2960S-24PD-L	
	Cisco Catalyst 2960-S Series 24 Ethernet 10/100/1000 PoE+ ports and Four GbE SFP Uplink ports	WS-C2960S-24PS-L	
	Cisco Catalyst 2960-S Series Flexstack Stack Module	C2960S-STACK	

LAN Distribution Layer

Functional Area	Product Description	Part Numbers	Software
Modular Distribution Layer Virtual Switch Pair	Cisco Catalyst 6500 E-Series 6-Slot Chassis	WS-C6506-E	15.0(1)SY1 IP Services license
	Cisco Catalyst 6500 VSS Supervisor 2T with 2 ports 10GbE and PFC4	VS-S2T-10G	
	Cisco Catalyst 6500 16-port 10GbE Fiber Module w/DFC4	WS-X6816-10G-2T	
	Cisco Catalyst 6500 24-port GbE SFP Fiber Module w/DFC4	WS-X6824-SFP-2T	
	Cisco Catalyst 6500 4-port 40GbE/16-port 10GbE Fiber Module w/DFC4	WS-X6904-40G-2T	
	Cisco Catalyst 6500 4-port 10GbE SFP+ adapter for WX-X6904-40G module	CVR-CFP-4SFP10G	
Modular Distribution Layer Switch	Cisco Catalyst 4507R+E 7-slot Chassis with 48Gbps per slot	WS-C4507R+E	3.3.0.SG(15.1-1SG) Enterprise Services license
	Cisco Catalyst 4500 E-Series Supervisor Engine 7-E, 848Gbps	WS-X45-SUP7-E	
	Cisco Catalyst 4500 E-Series 24-port GbE SFP Fiber Module	WS-X4624-SFP-E	
	Cisco Catalyst 4500 E-Series 12-port 10GbE SFP+ Fiber Module	WS-X4712-SFP+E	
Stackable Distribution Layer Switch	Cisco Catalyst 3750-X Series Stackable 12 GbE SFP ports	WS-C3750X-12S-E	15.0(2)SE IP Services license
	Cisco Catalyst 3750-X Series Two 10GbE SFP+ and Two GbE SFP ports network module	C3KX-NM-10G	
	Cisco Catalyst 3750-X Series Four GbE SFP ports network module	C3KX-NM-1G	

Appendix B: Changes

This appendix summarizes the changes to this guide since the previous Cisco SBA series.

- We made changes to improve the readability and technical accuracy of this guide.
- We updated the code version for the Cisco ASR and ISR platforms.

Notes

Feedback

Please use the [feedback form](#) to send comments and suggestions about this guide.



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