ROUTE

# Implementing Cisco IP Routing

## Volume 3

**Version 1.0**

## Student Guide

Text Part Number: 97-2816-02

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# Module 5

# Implementing Path Control

## Overview

If you implement redundancy in a network, then multiple paths exist, and the network administrator can manipulate or control the path across the network. Path control is not the same as quality of service (QoS) or Multiprotocol Label Switching traffic engineering (MPLS TE). Path control is a way to change the default packet forwarding across the network. This module explains why it is necessary to manipulate routing information to obtain better resiliency, performance, and availability.

Path control involves the use of a collection of tools, or set of commands, to manipulate the routing protocol forwarding table and bypass the default packet forwarding. This module will provide an overview of these tools, configuration examples of policy-based routing (PBR), and performance issues that are related to path control.

## Module Objectives

Upon completing this module, you will be able to evaluate common network performance issues and identify the tools that are needed to provide Layer 3 path control that uses Cisco IOS Software features to control the path. This ability includes being able to meet these objectives:

- Evaluate common network performance issues that are caused by inefficient path control selection
- Identify the resources that are necessary to develop a Layer 3 solution that uses Cisco IOS Software features to control path selection with a given a set of network requirements, and implement path control between multiple IP routing protocols
- Discuss the lab results for configuring and verifying path control between multiple IP routing protocols
- Preview the e-learning products to teach the use of path control through additional methods
- Preview the available e-learning training on implementing route control by other methods

Lesson 1

# Assessing Path Control Network Performance Issues

## Overview

This lesson evaluates common network performance factors such as redundancy, resiliency, performance, availability, and adaptability. Issues that are related to these factors occur when control of path selection is inefficient. Several solutions exist to avoid these issues. This lesson identifies what resources are needed to provide a Layer 3 solution that uses Cisco IOS Software features to control path selection under a given set of network requirements.

This lesson discusses the use of policy-based routing (PBR), filters (prefix lists, distribute lists, offset lists, and so on), Cisco IOS IP Service Level Agreements (SLAs), and route tags as tools for implementing path control in large networks.

PBR is described in detail, because it allows administrators to route traffic along specific paths according to their needs. PBR gives network designers greater flexibility in determining traffic patterns and best routes. Sometimes, simple destination-based routing is not sufficient. In these cases, network designers may route packets that are based on source address, protocol type, or application type so that they can optimally shape traffic patterns. This lesson discusses how to configure PBR on a Cisco router.

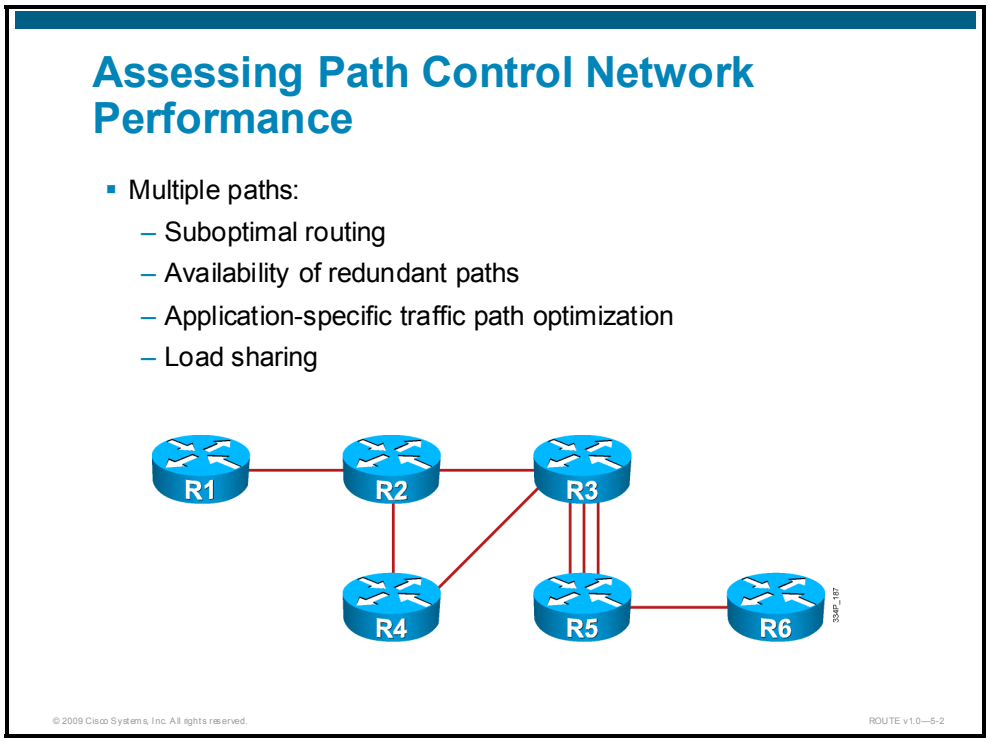
## Objectives

Upon completing this lesson, you will be able to explain common network performance issues that are caused by inefficient path control selection. You will also be able to identify the resources that you need to best provide path control, as well as implementation and verification of PBR. This ability includes being able to meet these objectives:

- Assess path control network performance
- Use filters to determine path selection
- Use PBR to determine path selection
- Configure and verify PBR
- Configure and verify PBR operations on a Cisco router

# Assessing Path Control Network Performance

This topic describes how to assess path control network performance.




Networks are designed to provide high availability and redundancy. The use of different routing protocols and different connectivity options may result in inefficient paths for forwarding packets to their destinations. Not only is redundancy implemented, but each routing protocol has a different administrative distance, metric, and convergence time.

When more than one routing protocol is implemented, there is high probability of inefficient routing. One major mistake is to implement incorrectly configured two-way multipoint redistribution. Two-way redistribution requires careful planning, as well as multipoint redistribution, which is highly problematic.

Convergence is also important. First, protocols converge in different ways from each other and in different ways for different network designs. Second, slow convergence can result in an application sending traffic timeouts before a backup path is found to a destination. Path control is required to avoid performance issues and to optimize paths.

Backup is a high priority in modern networks. However, having redundancy does not guarantee resiliency. For redundancy to be effective, you must configure the network properly; this is true even if you are only fine-tuning a routing protocol or managing path-by-path control tools.

Network engineers should also distinguish between switching all traffic to the backup link if there is a primary link failure, and switching some traffic to back up the link if the primary link is congested. Path control mechanisms can improve performance in such a situation as well. Similarly, load balancing can divide traffic among parallel paths.

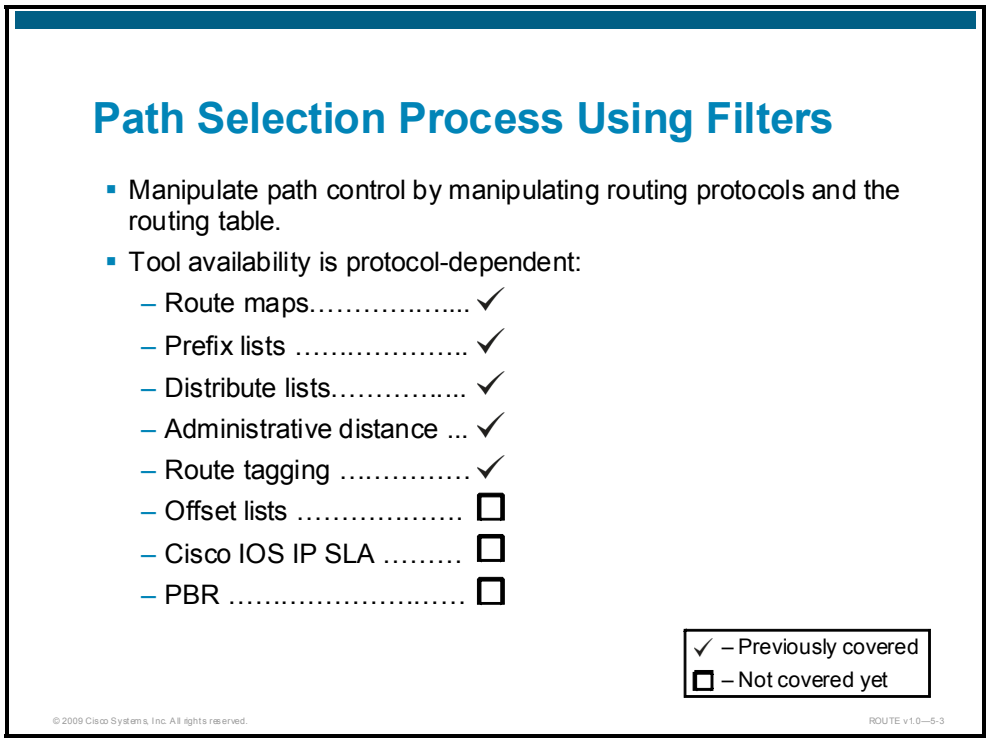
 

Suboptimal routing can occur after redistribution or simply because different routing protocols use different metrics. Redistribution between two routing protocols, if done based on administrative distance, is likely to result in a suboptimal path. A routing protocol with a lower administrative distance likes its own routes more than routes that are coming from another routing protocol with a higher administrative distance value. The situation is similar for metrics. Redistribution resets the metric, and the original metric might not be translated correctly. You can use path control tools to change the default destination forwarding and optimize the path of the packets.

There is no easy way to solve all the issues with path control. It is important to establish a global strategy for path control that provides predictable and deterministic control over traffic patterns, taking into account the physical connectivity as well as the services that are running over the network infrastructure.

# Using Filters to Determine Path Selection

This topic describes how to adjust the path selection process using filters.



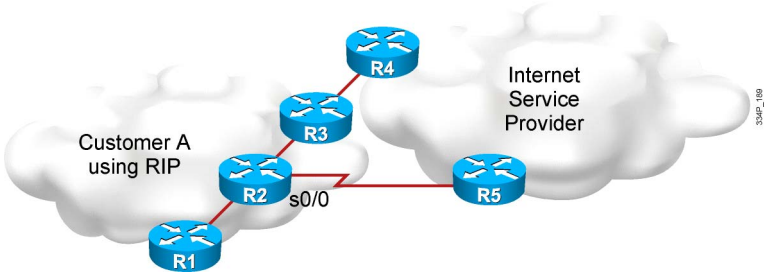

Paths are selected using the IP routing table. The contents of the IP routing table are provided by either a routing protocol or static route entries. The forwarding engine uses these contents to switch the packets from the incoming interface to the outgoing interface. You use filters to manipulate the routing protocols and routing table, to influence the desired path.

Several filters or tools can be used to manipulate the routing table:

- Route maps
- Prefix lists
- Distribute lists
- Administrative distance
- Route tagging
- Offset lists
- Cisco IOS IP SLA
- PBR

## Path Control Tools: Offset List

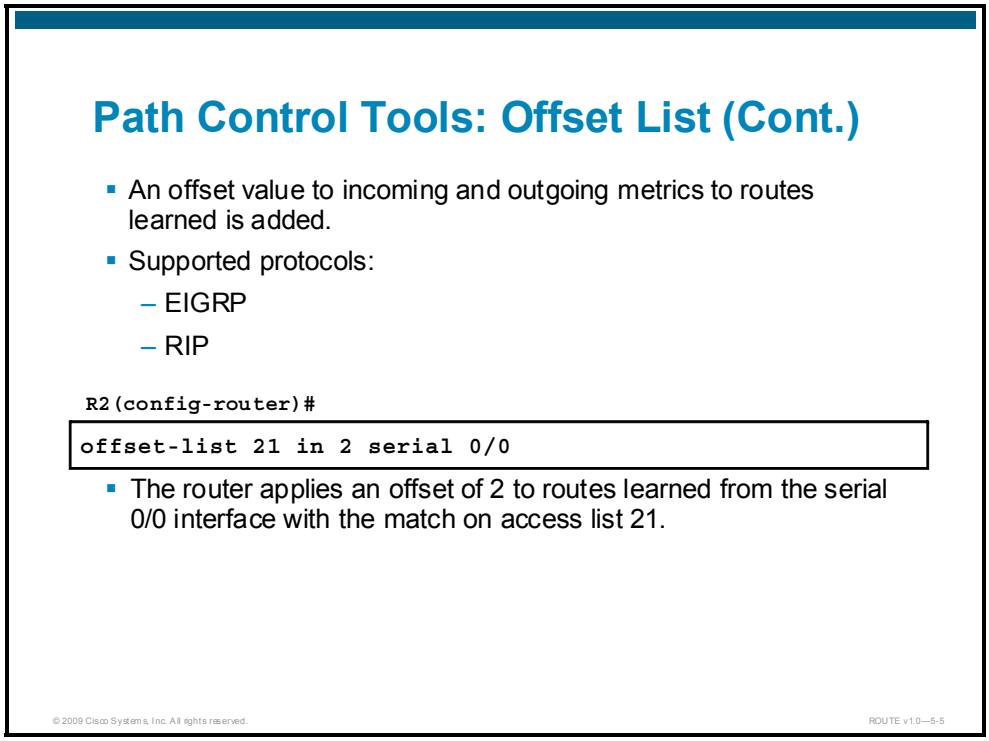
- Routers R4 and R5 receive a subset of routes from the ISP.
- The link between R2 and R5 is slow.
- How do you make the path toward R4 the primary way out of the RIP network for a set of destinations?







In the figure, the customer is using Routing Information Protocol (RIP) and is connected to the ISP via edge routers R4 and R5. A subset of routes is received from each of the edge routers, and RIP increases the cost at every new hop. The cost between R2 and R5 is smaller than that between R4 and R5, because there is only one hop, even though this is a very slow link. Which configuration should be applied to R2 to prefer the path toward R4, which is must faster? The configuration should take into account that this rule is only valid for a set of destinations.




To configure a route to avoid a slow link on R2, use an offset list on the router.

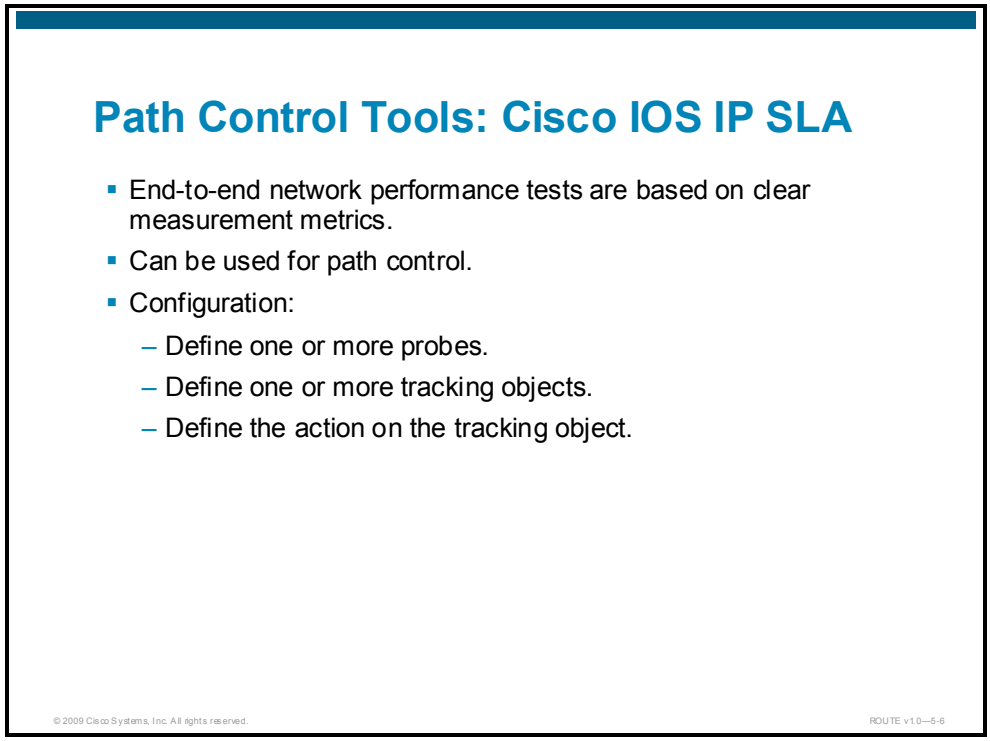
The **offset-list** command adds an offset to incoming and outgoing metrics to routes that are learned via Enhanced Interior Gateway Routing Protocol (EIGRP) or RIP. The offset value is added to the routing metric. An offset list with an interface type and interface number is considered extended and takes precedence over an offset list that is not extended. Therefore, if an entry passes an extended offset list and a normal offset list, the offset of the extended offset list is added to the metric.

In the figure, the **offset-list 21 in 2 serial 0/0** command is used to apply an offset of 2 to routes that are learned from serial interface 0/0 with the match on access list 21. The command is entered into the RIP process configuration mode on R2. With this command, the cost of a selection of routes coming from the serial 0/0 interface is increased, effectively making it worse than the path toward R4. Therefore, for a selection of routes, R4 becomes the way out from the customer network.

For more details about the **offset-list** (EIGRP) command, go to the Cisco IOS IP Routing: EIGRP Command Reference via the following link:
http://www.cisco.com/en/US/docs/ios/iproute_eigrp/command/reference/ire_book.html

For more details about the **offset-list** (RIP) command, go to the Cisco IOS IP Routing: RIP Command Reference via the following link:
http://www.cisco.com/en/US/docs/ios/iproute_rip/command/reference/irr_book.html




Cisco IOS IP SLAs perform network performance measurement within Cisco devices. They use active traffic monitoring (the generation of traffic in a continuous, reliable, and predictable manner) for measuring network performance. Cisco IOS IP SLAs actively send data across the network to measure performance between multiple network locations or across multiple network paths. They use time-stamp information to calculate performance metrics, such as jitter, latency, network and server response times, packet loss, and mean opinion score.

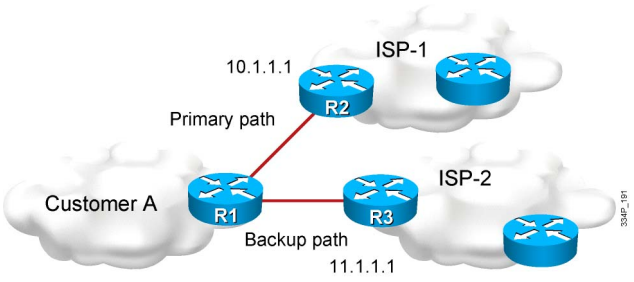
The following steps are required to configure Cisco IOS IP SLA functionality:

- Define one or more probes.
- Define one or more tracking objects.
- Define the action for each tracking object.

| | |
|---|---|
| **Note** | E-learning training is available for path control topics that provide more information about Cisco IOS IP SLAs. |

## Cisco IOS IP SLA Example

- Customer A is multihoming to ISP-1 and ISP-2.
- The link to ISP-1 is the primary link for all traffic.
- Customer A is using the default routes to the ISPs.
- A Cisco IOS IP SLA is used to conditionally announce the default route.





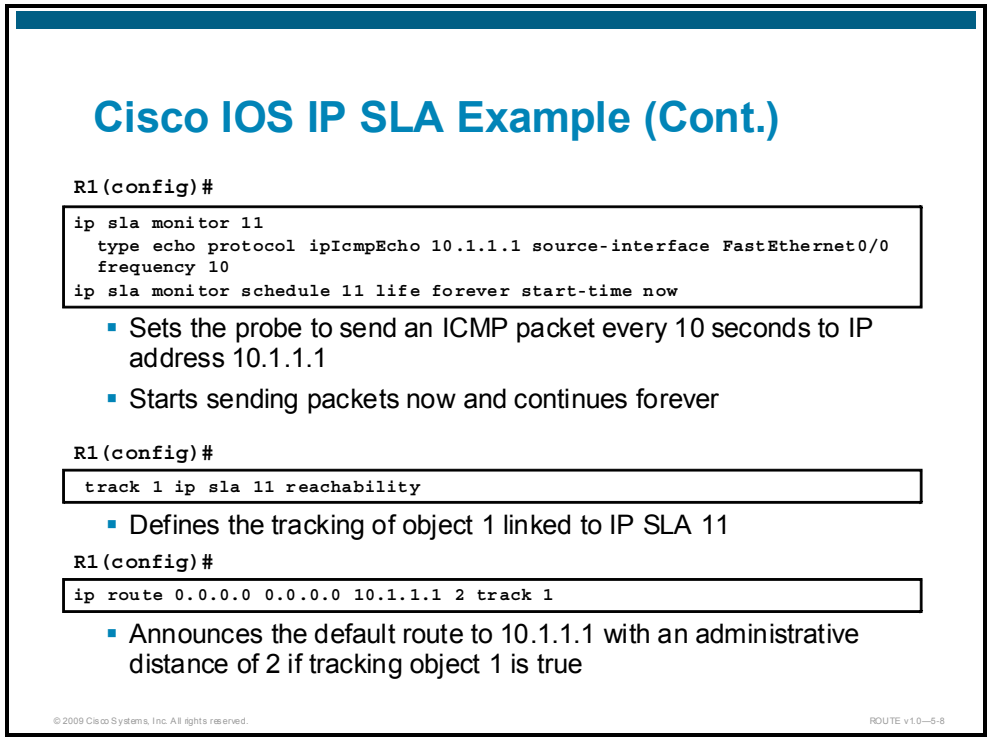


The following example describes the use of Cisco IOS IP SLA functionality for path control.

Customer A is multihoming to two service providers and is not using Border Gateway Protocol (BGP) as the routing protocol. Default routes are configured instead.

To make one link a primary link and the second one a backup link, two static routes with different administrative distances can be configured. The static default route with a lower administrative distance will be preferred and inserted into the IP routing table. However, it is possible that the interface is up and the ISP has problems with the provider edge (PE) router or with the uplink connectivity toward the Internet. In such a case, the active default route sends traffic to the selected ISP, but all traffic is lost. The solution to this issue is to use Cisco IOS IP SLA functionality, which can be used to continuously check the reachability of a specific destination (PE interface, ISP, Domain Name System [DNS] server, or any other trusted destination) and conditionally announce the default route if the connectivity is verified.

The configuration that is required is shown in the next figure.




The figure shows three steps to configure Cisco IOS IP SLA functionality.

The first step is needed to define the probe. The probe number 11 is defined by issuing the **ip sla monitor 11** command. The test that is defined with the **type echo protocol ipIcmpEcho 10.1.1.1 source-interface FastEthernet0/0** command specifies to send the Internet Control Message Protocol (ICMP) echoes to destination 10.1.1.1 to check the connectivity. The FastEthernet0/0 interface is used as a source. The **frequency 10** command schedules the connectivity test to repeat every 10 seconds. Finally, the **ip sla monitor schedule 11 life forever start-time now** command defines the start and end times of the connectivity test for probe 11. The start time is now, and the end time is forever.

The second step requires the tracking object, which is linked to the probe from the first step. The **track 1 ip sla 11 reachability** command defines the tracking of object 1, which is linked to probe 11, and the reachability of 10.1.1.1 is tracked.

The last step is an action that is based on the status of the tracking object. The **ip route 0.0.0.0 0.0.0.0 10.1.1.1 2 track 1** command conditionally announces the default route to 10.1.1.1 with an administrative distance of 2 if the result of tracking object 1 is true.

For more details about the Cisco IOS IP SLA commands, go to the Cisco IOS IP SLAs Command Reference via the following link:
http://www.cisco.com/en/US/docs/ios/ipsla/command/reference/sla_01.html

## Cisco IOS IP SLA Example (Cont.)

```
R1(config)#
ip sla monitor 22
  type echo protocol ipIcmpEcho 11.1.1.1 source-interface FastEthernet0/1
  frequency 10
ip sla monitor schedule 22 life forever start-time now
```

- Sets the probe to send an ICMP packet every 10 seconds to IP address 11.1.1.1
- Starts sending packets now and continues forever

```
R1(config)#
 track 2 ip sla 22 reachability
```

- Defines the tracking of object 2 linked to IP SLA 22

```
R1(config)#
ip route 0.0.0.0 0.0.0.0 11.1.1.1 3 track 2
```

- Announces the default route to 11.1.1.1 with an administrative distance of 3 if tracking object 2 is true

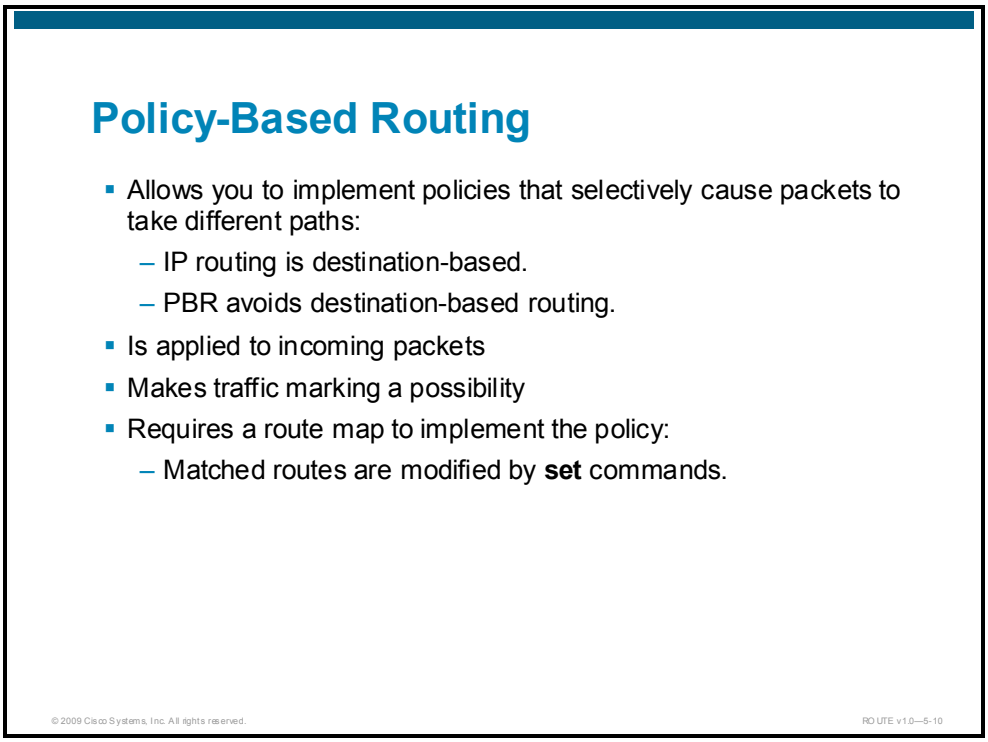



This is an example in which Customer A is multihoming to two ISPs. It requires the configuration of two probes, two tracking objects, and two conditionally announced default routes.

The configuration in the figure is almost the same as the configuration in the previous figure. The probe number is different, because the second test condition tests the reachability of the backup ISP destination address. The tracking object number is different as well, because it is related to the second probe. Finally, the announced default route uses a higher administrative distance (an administrative distance number of 3 is configured in the figure) as the backup. The ISP is used only if the primary is not available. Of course, the second tracking object is used as a reference for a conditional announcement for this default route.

# Using PBR to Determine Path Selection

This topic describes how PBR is used to implement path control.

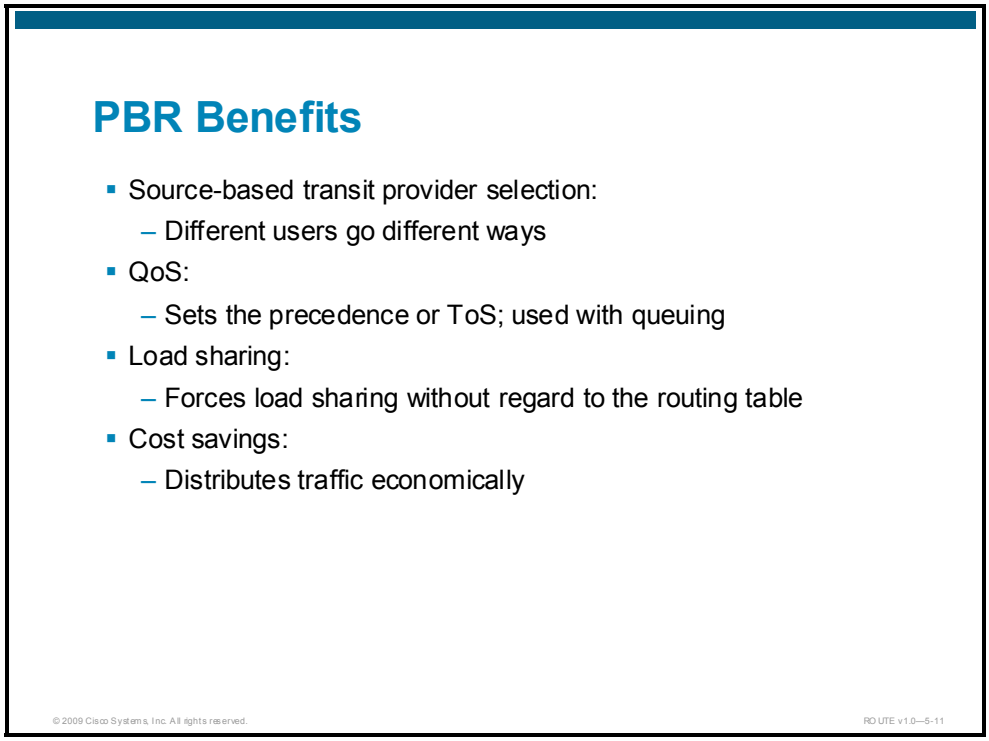



PBR offers significant benefits in terms of implementing user-defined policies to control traffic in the internetwork. It provides solutions in cases where legal, contractual, or political constraints dictate that traffic be routed through specific paths.

PBR adds flexibility in a difficult-to-manage environment by giving the network administrator the ability to route traffic that is based on network needs. For network managers who implement routing policies in their networks, PBR provides an extremely powerful, simple, and flexible tool.

PBR also provides a mechanism for marking packets. As a result, differentiated preferential service can be provided to different types of traffic in combination with queuing techniques that are available in Cisco IOS Software.

PBR is used to bypass the routing table. It allows the network administrator to configure different routing rules beyond the original IP routing table. One of the ways that it can be used is to route packets that are based on the source IP address instead of the destination IP address. PBR is applied to incoming packets and is implemented using route maps, for which **match** commands are used to match the incoming packets and a subset of the **set** commands is used to change the default destination-based routing.



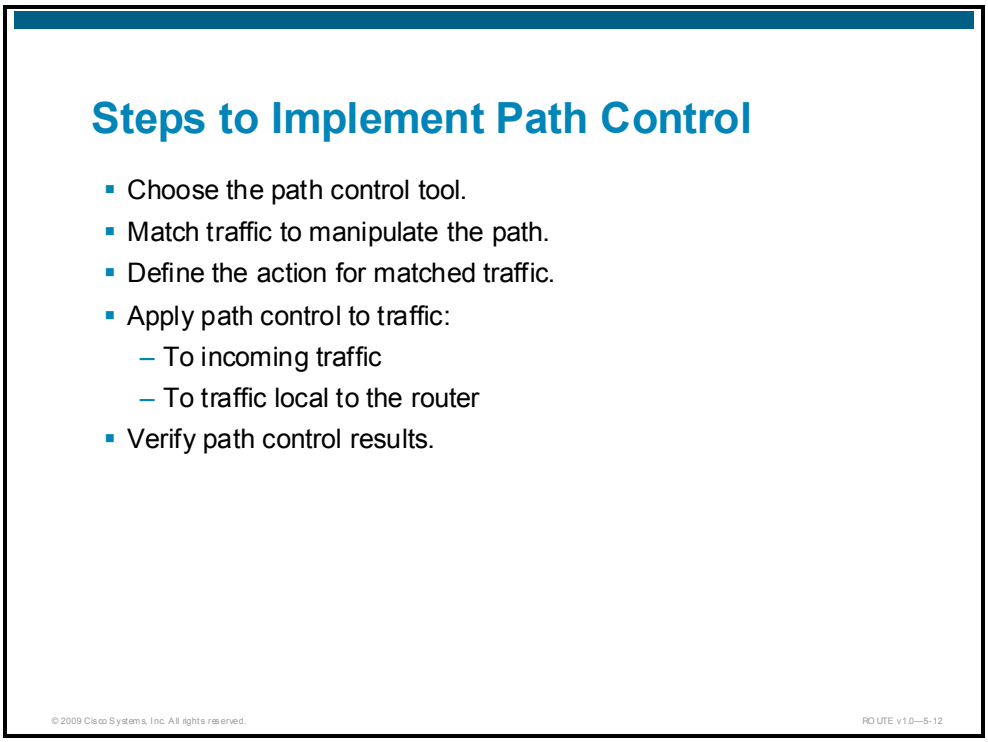

These benefits are achieved by implementing PBR in a network:

- **Source-based transit-provider selection:** ISPs and other organizations use PBR to route traffic that is originating from different sets of users through different Internet connections across the policy routers.
- **Quality of service (QoS):** Organizations provide QoS to differentiated traffic using the following two methods:
  - Set the precedence or type of service (ToS) value in each IP packet header at the periphery of the network.
  - Leverage queuing mechanisms to prioritize traffic in the core or backbone of the network.
- **Cost savings:** Organizations achieve cost savings by distributing interactive and batch traffic among low-bandwidth, low-cost, permanent paths and high-bandwidth, high-cost, switched paths.
- **Load sharing:** In addition to the dynamic load-sharing capabilities that are offered by destination-based routing that is supported by Cisco IOS Software, network managers can implement policies to distribute traffic among multiple paths that are based on the traffic characteristics.

# Configuring and Verifying PBR

This topic describes how to configure and verify PBR.

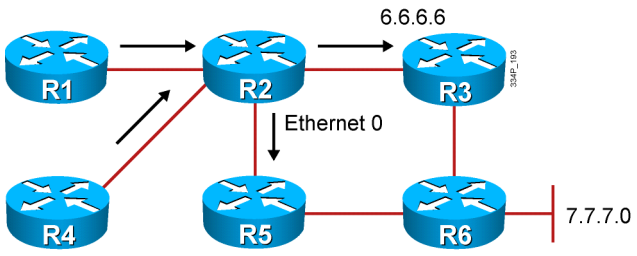



The figure shows the steps that are required to implement path control:

- Choose the path control tool. Path control tools can manipulate the IP routing table or bypass it. You must select the correct tool to fulfill the requirements.
- When you select the path control tool, implement a traffic-matching configuration to specify which traffic will be manipulated.
- When traffic is classified and matched, define the action for a specific class of traffic, to efficiently control the path of packets.
- After a successful configuration of path control, apply statements to manipulate the packets for incoming traffic or traffic that is local to the router.
- Verify path control. You can use simple connectivity commands and several **show** commands.

## Requirements for PBR

- Match packets with the destination network 7.7.7.0 and forward them to the next-hop address 6.6.6.6.
- Match packets between 3 and 200 bytes in size and forward them to the Ethernet 0 interface.
- Apply the route map to the incoming interfaces.
- Verify the configuration.

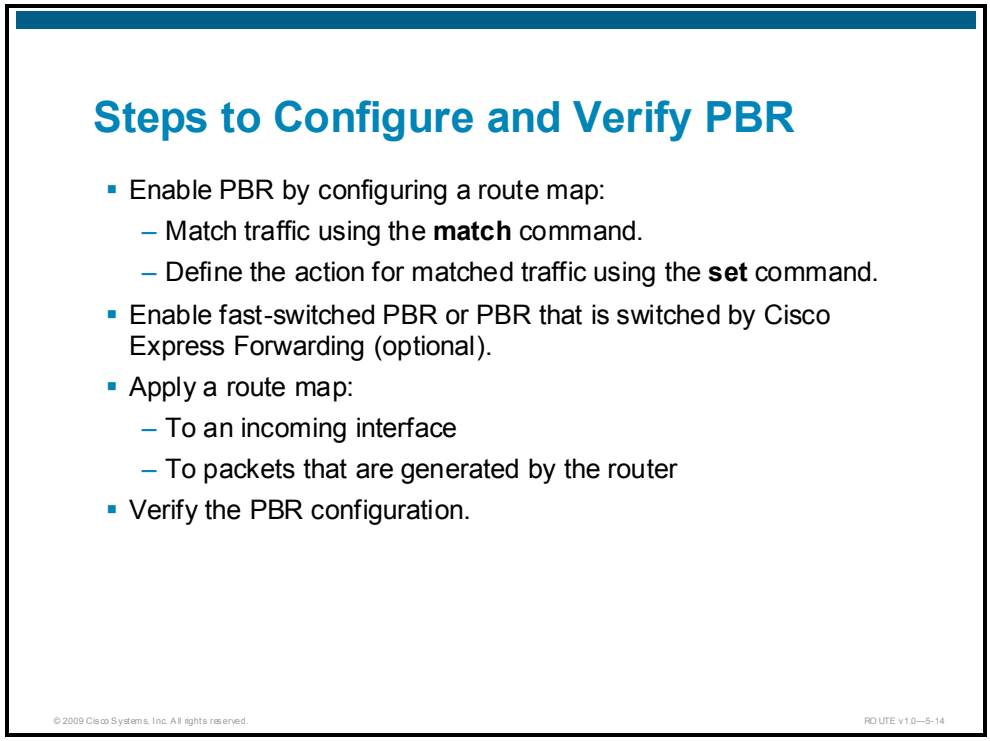






The figure shows the requirements for PBR implementation. PBR is implemented by using the route maps, for which **match** commands are used to match the traffic and **set** commands are used to set desired action to control the path. In the figure, configuration is required to match packets that are going to the destination network 7.7.7.0 and forward them to the next-hop address 6.6.6.6 to avoid suboptimal routing. At the same time, packets with sizes between 3 and 200 bytes must be matched and forwarded to the Ethernet 0 interface. The route map must be applied to the incoming interfaces. Finally, the configuration must be verified.

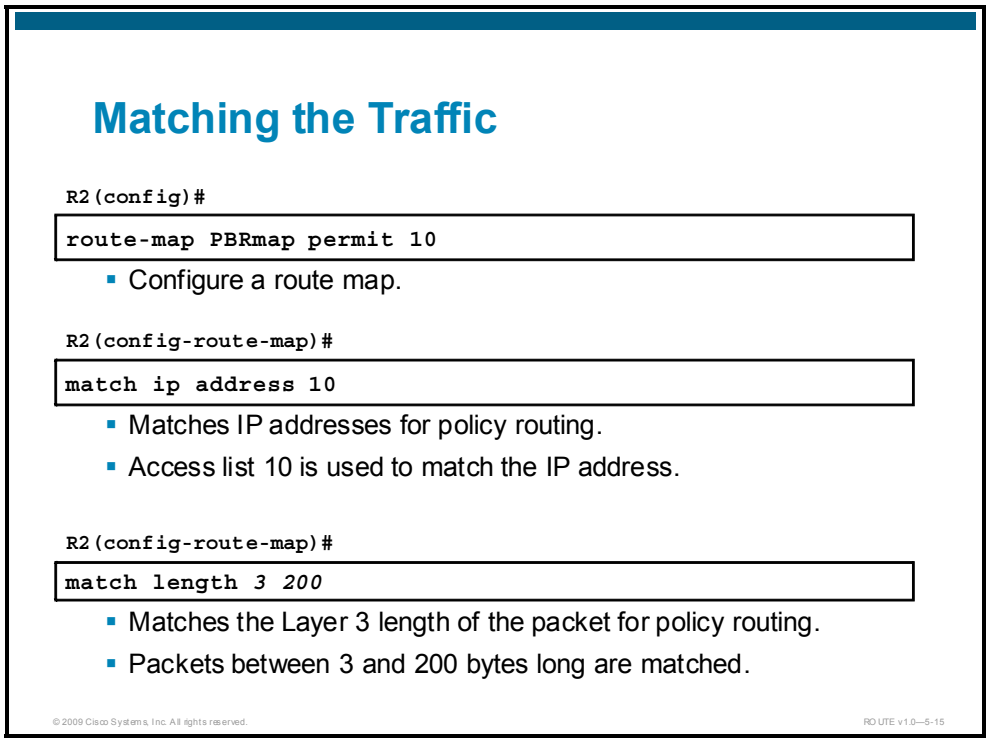



The requirements from the previous figure are used to create the implementation plan for PBR configuration. The implementation plan includes the following steps to configure and verify PBR on Cisco routers:

- Enable PBR by configuring the route map. Traffic is matched using the **match** command. Actions for manipulating path control are defined using **set** commands.
- If desired, enable fast-switched PBR or PBR that is switched by Cisco Express Forwarding. Fast-switched PBR must be enabled manually. In contrast, PBR that is switched by Cisco Express Forwarding is enabled automatically once Cisco Express Forwarding is enabled.
- Apply the route map that is created to an incoming interface or to locally generated packets in the router.
- Verify PBR configuration with basic connectivity and path verification commands as well as policy routing **show** commands.

# Configuring and Verifying PBR Operations on a Cisco Router

This topic describes how to configure and verify PBR on a Cisco router.




Use the **route-map** command to enable policy routing in the router and to enter the **match** and **set** commands that are required. IP standard or extended access lists are used to establish the PBR match criteria using the **match ip address** command. The **match ip address 10** command matches traffic that is based on standard IP access list number 10. A standard IP access list is used to specify the match criteria for the source address of a packet. One example of a standard access list would be:

```
access-list 10 permit 10.0.8.0 0.0.0.255
```

With this access list, any packet coming from subnet 10.0.8.0/24 would trigger the route map.

Extended access lists are used to specify the match criteria that are based on source and destination addresses, application, protocol type, ToS, and precedence. One example of an extended access list would be:

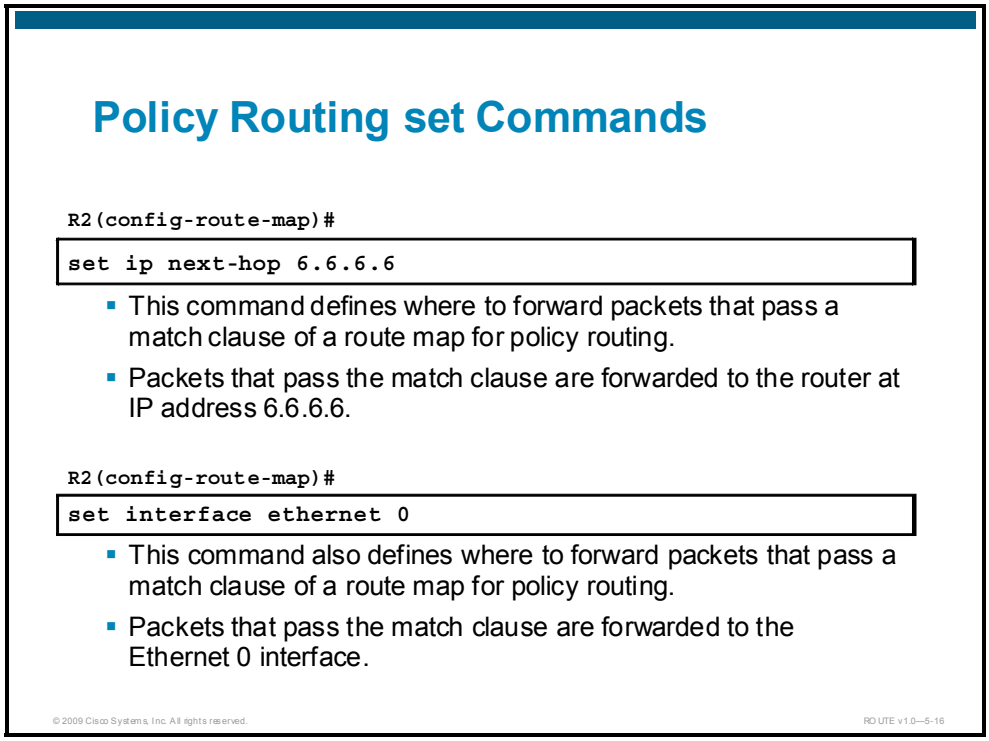
```
access-list 100 permit tcp 10.0.8.0 0.0.0.255 host
172.29.129.131 eq 2000
```

With this access list, any packet coming from subnet 10.0.8.0/24 and sent to 172.29.129.131 on destination port TCP 2000 (which is Skinny, a voice control protocol) would trigger the route map.

The **match length** command matches packets that are based on packet length, and can be configured with a minimum and maximum value. For example, a network administrator can use the **match length** command to distinguish between interactive traffic and file transfer (bulk) traffic, because file transfer traffic typically has larger packet sizes. The **match length 3 200** command matches packets between 3 and 200 bytes long.

For more details about the **route-map** and **match** commands, go to the Cisco IOS IP Routing: Protocol-Independent Command Reference via the following link:
http://www.cisco.com/en/US/docs/ios/iproute_pi/command/reference/iri_book.html




If the match statements are satisfied, one or more of the following set statements are used to specify the criteria for forwarding packets. The router evaluates the four **set** commands for PBR that are shown in this figure and the following figure, in the order that is listed.

Once you choose a destination address or interface, other **set** commands for changing the destination address or interface are ignored. Some of these commands affect only packets for which there is an explicit route in the routing table, and others affect only packets for which there is *no* explicit route in the routing table.

A packet that is not affected by any of the **set** commands in a route map statement is not policy-routed; it is forwarded normally. In other words, destination-based routing is performed. The router uses the four **set** commands for PBR in the following order:

1. The **set ip next-hop** command configures a list of IP addresses. The list specifies the adjacent next-hop router in the path toward the destination to which the packets are forwarded. If more than one IP address is specified, the first IP address that is associated with a currently active interface is used to route the packets.

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**Note** With the **set ip next-hop** command, the policy routing is applied even if the destination network is not present in the routing table. The routing table is checked, but only to determine if the next hop is reachable. It is not checked to determine if there is a route for the destination address of the packet.

This **set** command affects all packet types and is always used if it is configured.

---

The **set ip next-hop 6.6.6.6** command from the figure shows that packets that pass a match clause of a route map for policy routing are forwarded to 6.6.6.6.

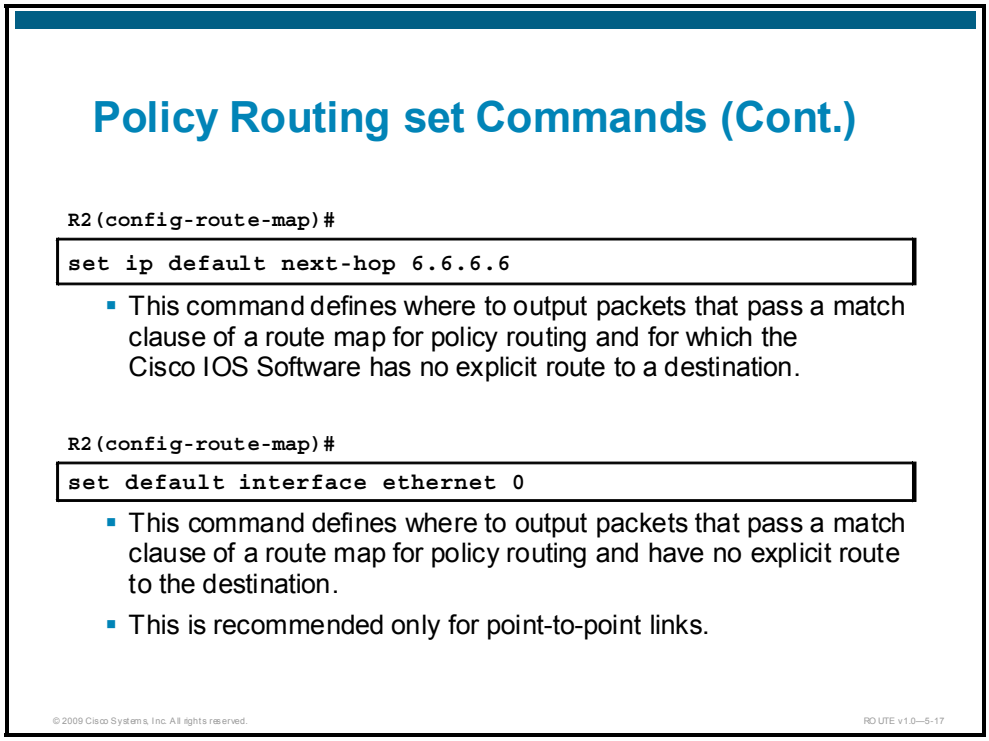
2. The **set interface** command configures a list of interfaces through which the packets are routed. If more than one interface is specified, the first active interface in the list is used for forwarding the packets.

| | |
|---|---|
| **Note** | If there is no explicit route in the routing table for the destination network address of the packet (for example, if the packet is a broadcast packet or is destined to an unknown address), the **set interface** command has no effect and is ignored.<br><br>A default route in the routing table will not be considered an explicit route for an unknown destination address. |

The **set interface ethernet 0** command from the figure defines that packets that pass a match clause of a route map for policy routing are forwarded to interface Ethernet 0.

For more details about the **set** command, go to the Cisco IOS IP Routing: Protocol-Independent Command Reference via the following link:
http://www.cisco.com/en/US/docs/ios/iproute_pi/command/reference/iri_book.html




3. The **set ip default next-hop** command configures a list of default next-hop IP addresses if there is no explicit route that is available to the destination address of the packet that is being considered for PBR. If more than one IP address is specified, the first specified next hop that appears to be next to the router is used. The optional specified IP addresses are tried in sequential order.

| | |
|---|---|
| **Note** | A packet is routed to the next hop that is specified by the **set ip default next-hop** command if there is no explicit route for the destination address of the packet in the routing table. In other words, the routing table is used first. If there is no route in the routing table for the destination address of the packet, the next hop that is specified by the **set ip default-next-hop** command is used.<br><br>A default route in the routing table will not be considered an explicit route for an unknown destination address. |

The **set ip default next-hop 6.6.6.6** command from the figure defines that packets that pass a match clause of a route map for policy routing, and for which the Cisco IOS Software has no explicit route, are forwarded to 6.6.6.6.

4. The **set default interface** command configures a list of default interfaces. If there is no explicit route that is available to the destination address of the packet that is being considered for PBR, it is routed to the first active interface in the list of specified default interfaces.

| | |
|---|---|
| **Note** | A packet is routed out of the interface that is specified by the **set default interface** command only if there is no explicit route for the destination address of the packet in the routing table.<br><br>A default route in the routing table will not be considered an explicit route for an unknown destination address. |

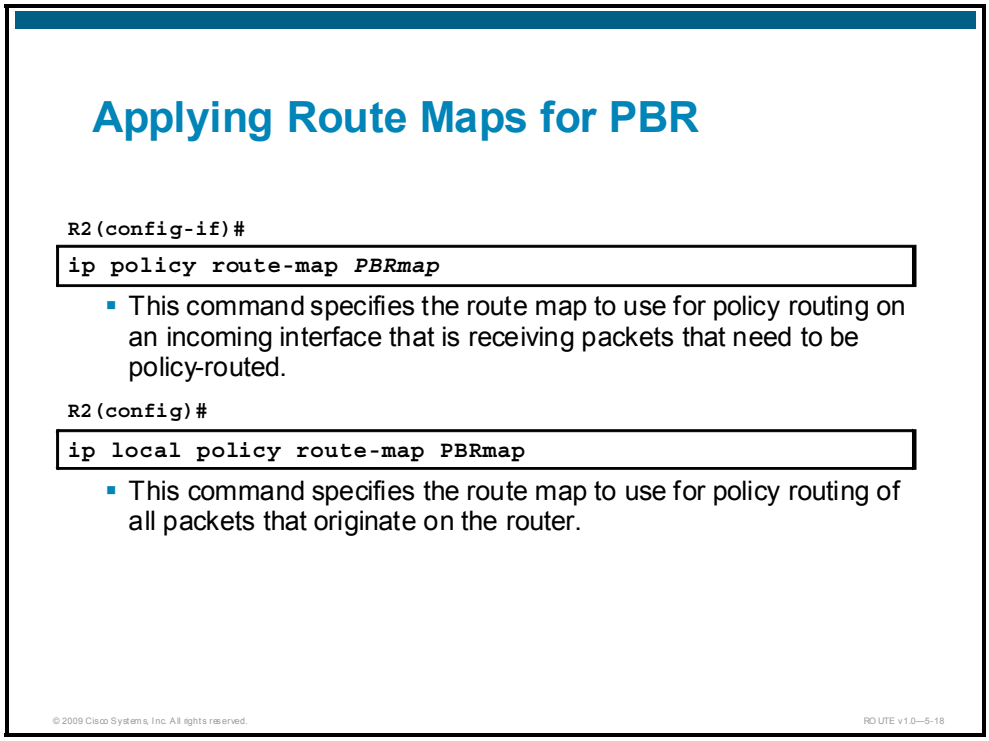
The **set default interface ethernet 0** command from the figure defines that packets that pass a match clause of a route map for policy routing, and for which the Cisco IOS Software has no explicit route, are forwarded to interface Ethernet 0.

PBR also provides a mechanism to mark packets using the **set ip tos** and **set ip precedence** commands:

- The **set ip tos** command is used to set the IP ToS value in the IP packets.
- The **set ip precedence** command is used to set the IP precedence in the IP packets. You must specify either the precedence number or name.

| | |
|---|---|
| **Note** | The **set** commands can be used with each other. |

For more details about the **set** command, go to the Cisco IOS IP Routing: Protocol-Independent Command Reference via the following link:
http://www.cisco.com/en/US/docs/ios/iproute_pi/command/reference/iri_book.html




To identify a route map to use for PBR on an interface, use the **ip policy route-map** interface configuration command. In the figure, the **ip policy route-map PBRmap** command applies the route map named "PBRmap" to the incoming traffic on the interface.

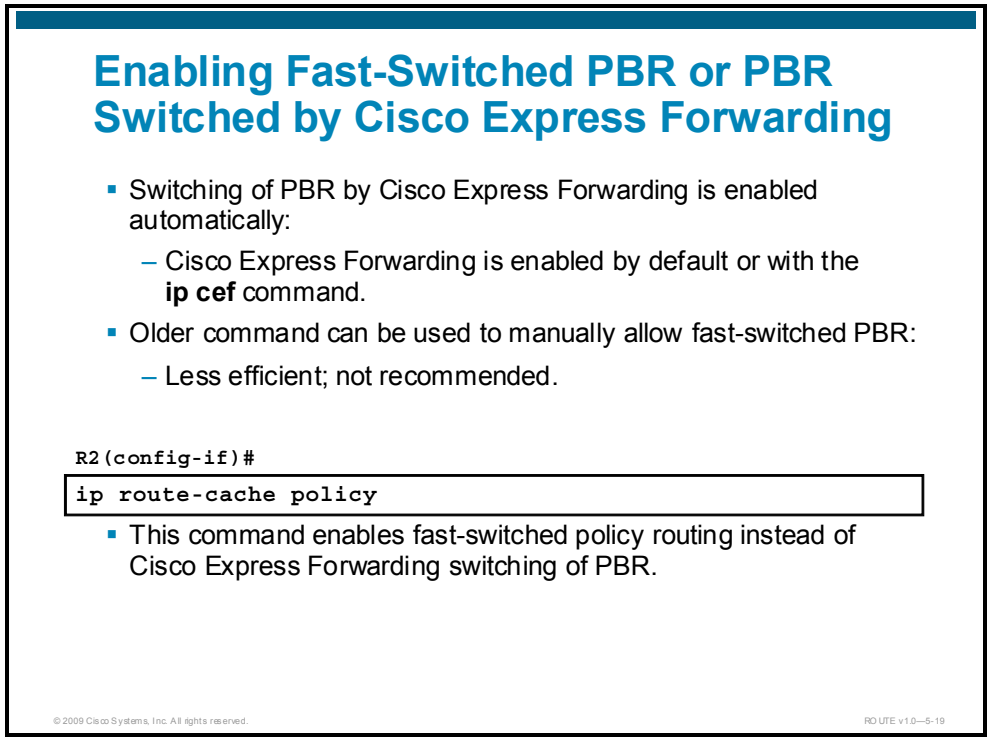
| **Note** | PBR is specified on the incoming interface that receives the packets that need to be policy-routed, not on the interface from which the packets are sent. |
|---|---|

To identify a route map to use for local policy routing, use the **ip local policy route-map** global configuration command. In the figure, the **ip local policy route-map PBRmap** command applies the route map named PBRmap to packets that originate on the router.

Packets that are generated by the router are not normally policy-routed. However, you can use this command to policy-route such packets. You might enable local policy routing if you want packets that originate at the router to take a route other than the obvious shortest path.

For more details about the **ip policy route-map** and **ip local policy route-map** commands, go to the Cisco IOS IP Routing: Protocol-Independent Command Reference via the following link:
http://www.cisco.com/en/US/docs/ios/iproute_pi/command/reference/iri_book.html




Since the release of Cisco IOS Release 12.0, IP PBR can now be fast-switched. Before this feature, PBR was process-switched, which meant that on most platforms, the switching rate was approximately 1000 to 10,000 p/s. This rate was not fast enough for many applications. With Cisco IOS Release 12.0 and later, you can now implement PBR without slowing down the router.

Beginning with Cisco IOS Release 12.0, PBR is also supported in the Cisco Express Forwarding switching path. PBR that is switched by Cisco Express Forwarding has better performance than fast-switched PBR and, therefore, is the optimal way to perform PBR on a router. No special configuration is required to enable PBR to be switched by Cisco Express Forwarding. It is on by default as soon as you enable Cisco Express Forwarding and PBR on the router.

If you decide to use fast switching instead of Cisco Express Forwarding PBR switching (because Cisco Express Forwarding is not enabled on your routers), you must first configure PBR before PBR fast switching can be enabled. Fast switching of PBR is disabled by default. To configure a fast-switched PBR, use the **ip route-cache policy** command in interface configuration mode.

A fast-switched PBR supports all the **match** commands and most of the **set** commands, except for these restrictions:

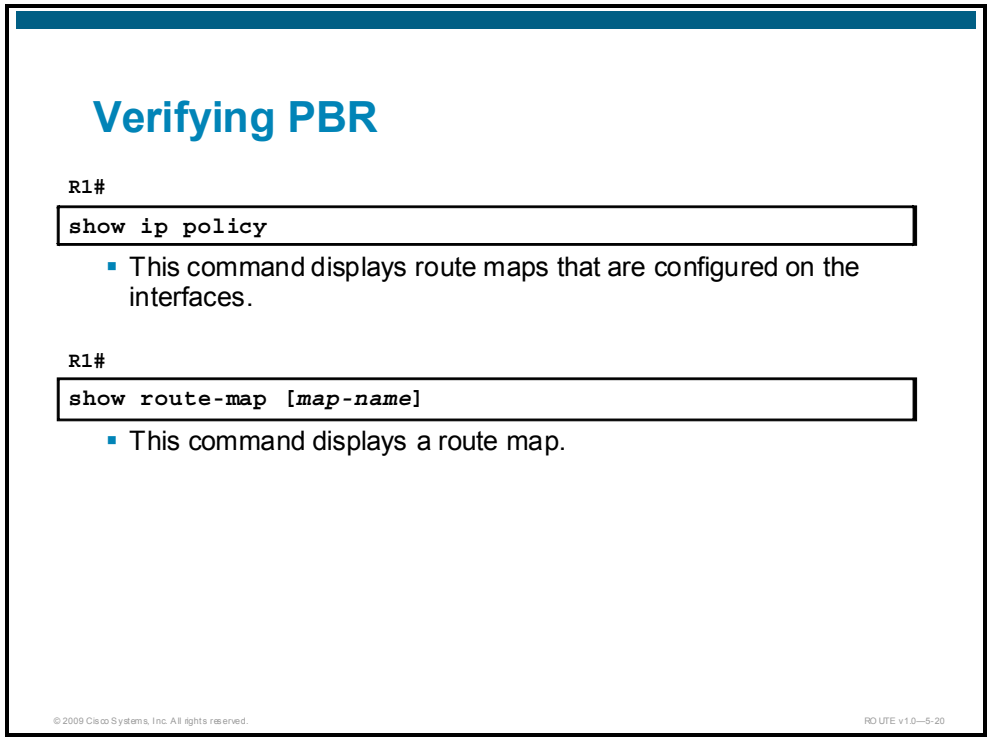
- The **set ip default next-hop** command is not supported.
- The **set interface** command is supported over point-to-point links, unless a route cache entry exists that uses the same interface that is specified in the **set interface** command in the route map. Also, at the process level, usually the routing table is checked to determine if the interface is on an appropriate path to the destination.

  During fast switching, the software does not make this check. Instead, if the packet matches, the software automatically forwards the packet to the specified interface.

| | |
|---|---|
| **Note** | The **ip route-cache policy** command is strictly for fast-switched PBR; it is not required for a PBR that is switched by Cisco Express Forwarding. |

For more details about the **ip route-cache policy** command, go to the Cisco IOS Switching Services Command Reference via the following link:
http://www.ciscosystems.org.ro/en/US/docs/ios/12_3/switch/command/reference/swi_i1.html

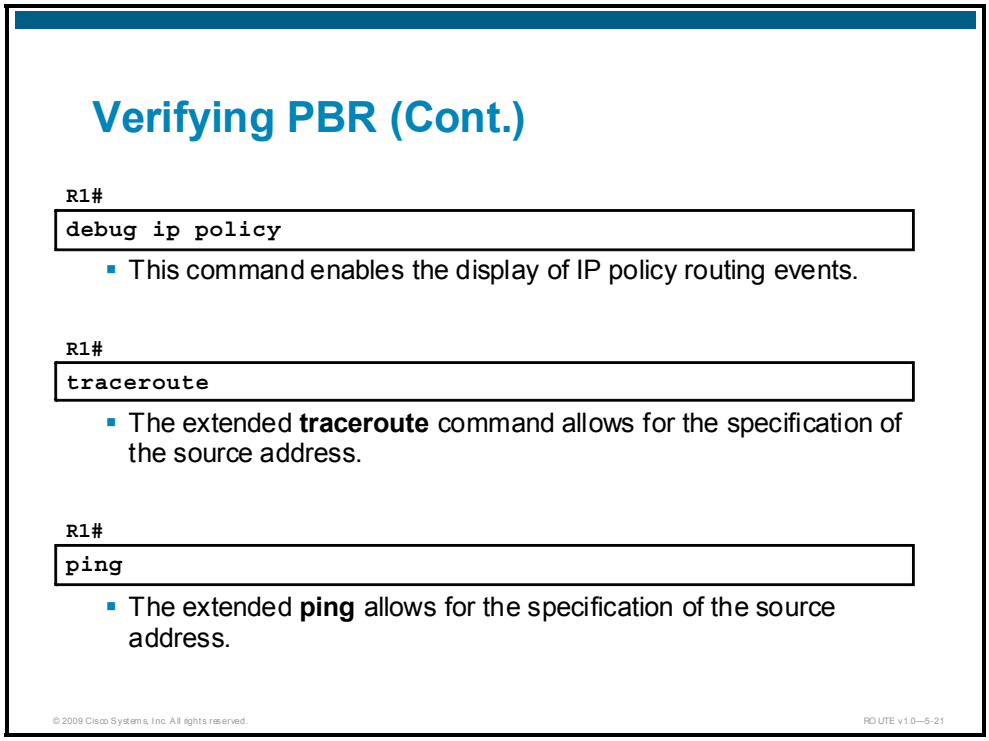
 




To display the route maps that are used for PBR on the interfaces of the router, use the **show ip policy** EXEC command.

To display configured route maps, use the **show route-map** EXEC command.

For more details about the **show ip policy** and **show route-map** commands, go to the Cisco IOS IP Routing: Protocol-Independent Command Reference via the following link: http://www.cisco.com/en/US/docs/ios/iproute_pi/command/reference/iri_book.html




Use the **debug ip policy** EXEC command to display the IP PBR packet activity. This command shows, in detail, the activities that PBR is performing. It also displays information that indicates whether a packet matches the criteria. If the criteria match, the resulting routing information for the packet is displayed as well.

| | |
|---|---|
| **Note** | Because the **debug ip policy** command generates a significant amount of output, use it only when traffic on the IP network is low, so that other activity on the system is not adversely affected. |

To discover the routes that packets follow when traveling to their destination from the router, use the **traceroute** privileged EXEC command. To change the default parameters and invoke an extended traceroute test, enter the command without a destination argument. You will be guided through a dialog to select the required parameters.

To check host reachability and network connectivity, use the **ping** privileged EXEC command. You can use the extended command mode of the **ping** command to specify the supported header options by entering the command without any arguments.

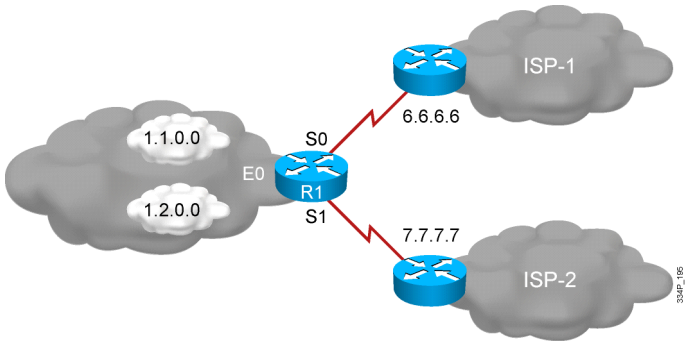
For more details about the **debug ip policy** command, go to the Cisco IOS Debug Command Reference via the following link:
http://www.cisco.com/en/US/docs/ios/debug/command/reference/db_book.html

For more details about the **ping** and **traceroute** commands, go to the Cisco IOS Configuration Fundamentals Command Reference via the following link:
http://www.cisco.com/en/US/docs/ios/fundamentals/command/reference/cf_book.html

## Example: PBR Equal Access

- All traffic that uses a default route and is sourced from subnet 1.1.0.0 should go through ISP-1.
- All traffic that uses a default route and is sourced from subnet 1.2.0.0 should go through ISP-2.







The figure describes a common scenario in which a private company that is attached to more than one ISP must build a traffic policy.

R1 provides Internet access for a private enterprise and is connected to two different ISPs. This router advertises a 0.0.0.0 default route into the enterprise network to avoid a large Internet routing table.

The problem is that when traffic from the enterprise networks 1.1.0.0 and 1.2.0.0 reaches R1, the traffic can go to ISP-1 or ISP-2. The company prefers to have ISP-1 and ISP-2 receive approximately equal amounts of traffic. PBR is used to shape or load-balance traffic from R1 to each of the ISPs.

PBR is implemented at R1. All traffic that is sourced from the 1.1.0.0 subnet is forwarded to ISP-1 if there is no specific route to the destination in the routing table (the default route is not used). All traffic that is sourced from the 1.2.0.0 subnet is forwarded to ISP-2 if there is no specific route to the destination in the routing table.

| | |
|---|---|
| **Note** | This policy provides for an outbound traffic policy from the enterprise to its ISPs only. It does not determine the inbound traffic policy for R1. It is possible that traffic from 1.1.0.0 that is going out to ISP-1 will receive responses from ISP-2. |

## Example: PBR Equal Access (Cont.)

```
R1(config)# access-list 1 permit 1.1.0.0 0.0.255.255
R1(config)# access-list 2 permit 1.2.0.0 0.0.255.255

R1(config)# route-map equal-access permit 10
R1(config-route-map)# match ip address 1
R1(config-route-map)# set ip default next-hop 6.6.6.6
R1(config-route-map)# route-map equal-access permit 20
R1(config-route-map)# match ip address 2
R1(config-route-map)# set ip default next-hop 7.7.7.7
R1(config-route-map)# route-map equal-access permit 30
R1(config-route-map)# set default interface null0

R1(config)# interface ethernet 0
R1(config-if)# ip address 1.1.1.1 255.255.255.0
R1(config-if)# ip policy route-map equal-access

R1(config)# interface serial 0
R1(config-if)# ip address 6.6.6.5 255.255.255.0

R1(config)# interface serial 1
R1(config-if)# ip address 7.7.7.6 255.255.255.0
```




The configuration that is shown in the figure has been set in R1. The name of the route map is "equal-access."

The **ip policy route-map equal-access** command has been applied to the Ethernet 0 interface, which is the incoming interface that receives the packets to be policy-routed.

Sequence number 10 in the route map equal-access is used to match all packets that are sourced from any host in subnet 1.1.0.0. If a packet matches, and if the router has no explicit route for its destination, the packet is sent to the next-hop address 6.6.6.6 (ISP-1 router).

Sequence number 20 in the route map equal-access is used to match all packets that are sourced from any host in subnet 1.2.0.0. If a packet matches, and if the router has no explicit route for its destination, the packet is sent to the next-hop address 7.7.7.7 (ISP-2 router).

Sequence number 30 in the route map equal-access is used to drop all traffic that is not sourced from subnet 1.1.0.0 or 1.2.0.0. The Null0 interface is a route to nowhere (thus, the traffic is dropped). In normal conditions, this sequence 30 policy should not apply to any packet. Traffic that is coming from networks 1.1.0.0 or 1.2.0.0 that have a destination present in the routing table will use the routing table next-hop value. If a destination is not present in the routing table, sequence number 10 or 20 will be applied. Only those packets that are coming from a network other than 1.1.0.0 or 1.2.0.0 and not having a destination address present in the routing table will be redirected to sequence number 30 and dropped.

## Verifying PBR: Examples

```
R1#show ip policy

Interface      Route map
Ethernet0      equal-access


R1#show route-map
route-map equal-access, permit, sequence 10
  Match clauses:
    ip address (access-lists): 1
  Set clauses:
    ip default next-hop 6.6.6.6
Policy routing matches: 3 packets, 168 bytes
route-map equal-access, permit, sequence 20
  Match clauses:
    ip address (access-lists): 2
  Set clauses:
    ip default next-hop 7.7.7.7
route-map equal-access, permit, sequence 30
Set clauses:
    default interface null0
```




In the figure, the output provides examples of two **show** commands that are issued on R1. The **show ip policy** command output indicates that the route map called equal-access is used for PBR on the Ethernet 0 interface of the router. The **show route-map** command output indicates that three packets have matched sequence 10 of the route map equal-access.

## Verifying PBR: Examples (Cont.)

```
R1# debug ip policy
Policy routing debugging is on

11:51:25: IP: s=1.1.1.1 (Ethernet0), d=190.168.1.1, len 100,
policy match
11:51:25: IP: route map equal-access, item 10, permit
11:51:25: IP: s=1.1.1.1 (Ethernet0), d=190.168.1.1
(Serial0), len 100, policy routed
11:51:25: IP: Ethernet0 to Serial0 6.6.6.6
```




The figure provides an example of the **debug ip policy** command output. The **show logging** command shows the logging buffer, including the output of the **debug** command.

The output indicates that a packet from 1.1.1.1 that is destined for 190.168.1.1 has been received on interface Ethernet 0 and that it is policy-routed on the serial 0 interface to the next-hop address 6.6.6.6. The source address of 1.1.1.1 matches line 10 of the route map equal-access.

# Summary

This topic summarizes the key points that were discussed in this lesson.

## Summary

- Redundant paths (multiple paths), redistribution, and the selected routing protocol all affect network performance. Path control must be enabled to improve performance and avoid suboptimal routing.
- A route map with a group of **match** and **set** commands is one of the tools that can be used for path control.
- The path selection process can be accomplished using filters such as route tagging, prefix lists, distribute lists, administrative distance, offset lists, and Cisco IOS IP SLAs.
- To bypass the routing table destination-based forwarding, PBR is used to determine path selection.




## Summary (Cont.)

- PBR uses route maps for configuration. It can be fast-switched or switched by Cisco Express Forwarding.
- Path control **match** commands match incoming traffic. Path control **set** commands manipulate the path; manipulation can be applied to incoming traffic or to traffic that is generated by the router.

Lesson 2

# Lab 5-1 Debrief

## Overview

In Lab 5-1, you manipulated the path for a selection of the packets that are traveling across the network. First, you configured the routing protocol to ensure reachability and to establish the base for destination-based forwarding. Next, you implemented path control to manipulate the path for a set of packets.

You defined several groups of packets and used PBR to manipulate the path across the network. Finally, you verified the configuration.

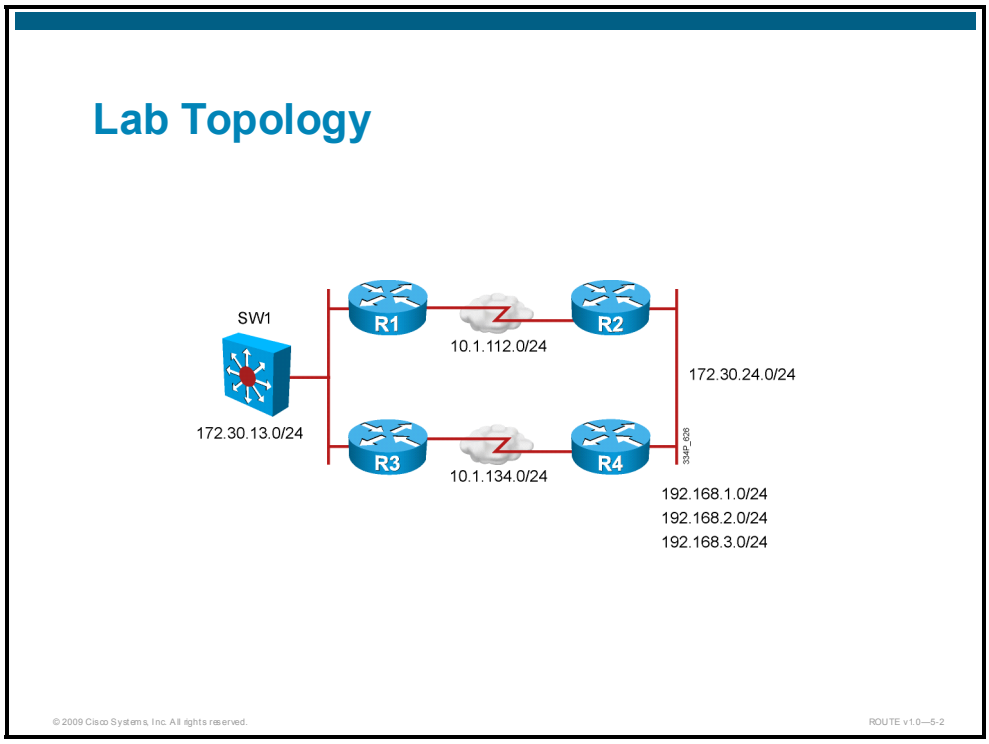
## Objectives

Upon completing this lesson, you will be able to explain destination-based forwarding and configure path control using a PBR tool. This ability includes being able to meet these objectives:

- Identify the implementation and verification tasks for manipulating the path for a selection of the packets that are traveling across the network
- Present a sample solution and identify possible alternative solutions

# Lab Overview and Verification

This topic describes the lab topology and key checkpoints that are used to create a solution and start verification.




The figure presents the physical lab topology that is used for Lab 5-1: “Configure and Verify Path Control Between Multiple IP Routing Protocols.” The topology uses four pod routers and one switch. Routers R1 to R4 build the network where path manipulation is required. Switch SW1 is one source of packets; the other source is locally originated traffic on R1.

Based on this topology, you need to identify the required parameters and configure EIGRP to establish Layer 3 reachability in the network. Because some packets use suboptimal paths, you need to use PBR as a path-control mechanism to manipulate the path of the packets.

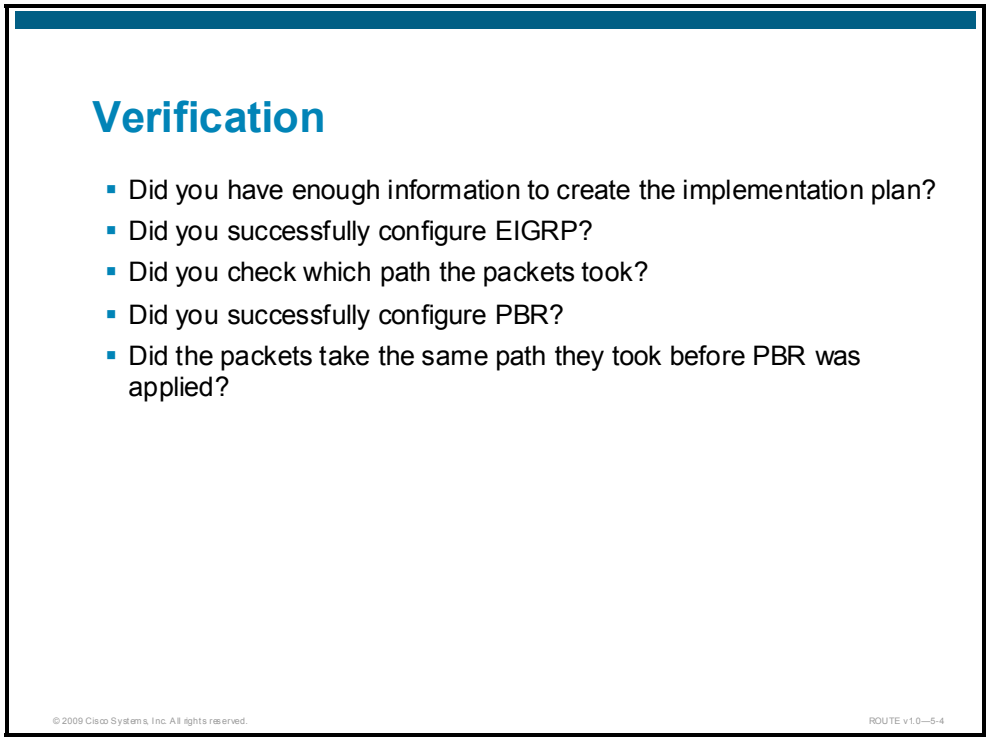
## Lab Review: What Did You Accomplish?

- **Task 1:** Implement EIGRP.
  - What were the steps that you took to configure EIGRP?
- **Task 2:** Implement PBR.
  - Which tools did you use to configure PBR?
  - Where did you apply the PBR configuration for the traffic passing through the router?
  - Where did you apply the PBR configuration for the traffic locally originated in the router?




In the first task, you implemented EIGRP on all routers in the lab (from R1 to R4). You established basic reachability and used verification steps to prove that all the EIGRP networks are in the IP routing table. Once you finished the configuration, you could identify the path that is used for forwarding packets.

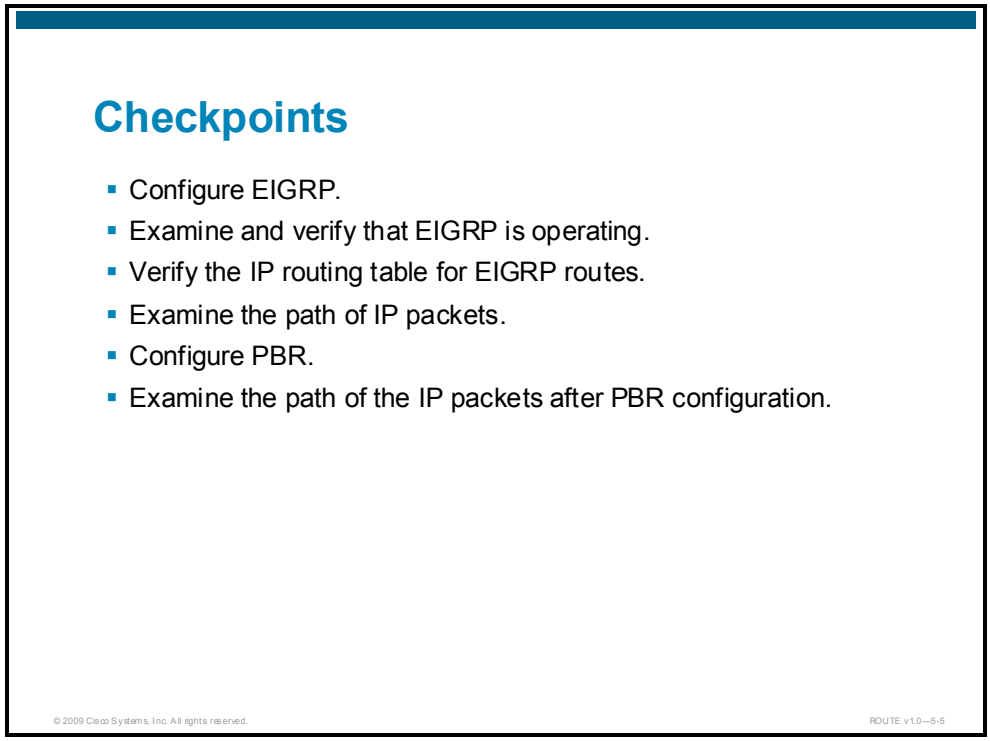
In the second task, you identified the suboptimal path that is used for a group of packets and used PBR as a path-control tool to manipulate packet forwarding. You used route maps to match the packets and set the output parameters. Then, you applied the route maps to traffic on the incoming interface (for packets passing the router) or to locally generated traffic on R1 and R3.




A common approach to verifying the implementation process for a routing protocol is as follows:

- Evaluate if enough information was gathered to create a good implementation plan.
- Check that routes exist in their local IP tables; they will be in the tables after any successful EIGRP configuration.
- Check the IP routing table for the routes to the destinations. The IP routing table provides all the information that is needed to forward incoming packets toward their destinations. Based on the routing protocol that is used, the path for a packet is defined as the route to its destination, provided that it exists in the IP routing table.
- To meet the requirements for path manipulation, configure the PBR path-control tool. You must specify a path for the selected group of packets within the requirements for path manipulation. You can also perform verification.
- If PBR is configured, the path for the selection of packets is different.




With different checkpoints, you can verify for proper configuration. The following checkpoints are used for verification:

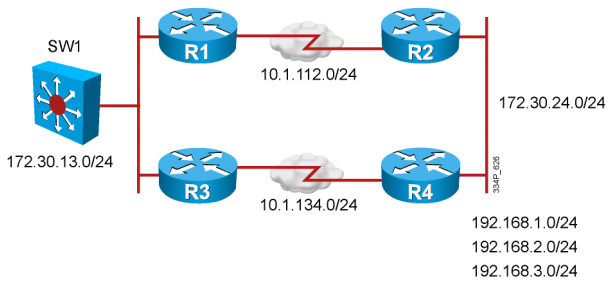
- Configure EIGRP.
- Examine and verify that EIGRP is operating.
- Verify the IP routing table for EIGRP routes.
- Examine the path of IP packets when destination-based forwarding is used (without PBR configuration applied).
- Configure PBR.
- Examine the path of the IP packets after PBR configuration.

# Sample Solution and Alternatives

This topic describes a sample solution and possible alternatives.

## Sample Solution

- EIGRP is configured on all the routers.
- EIGRP automatic summarization takes effect.
- PBR is configured on R1 and R3 to manipulate the path selection.







A sample solution includes the implementation details and the details for each task of the implementation plan. Different solutions are possible; the figure shows a few details of a successful configuration.

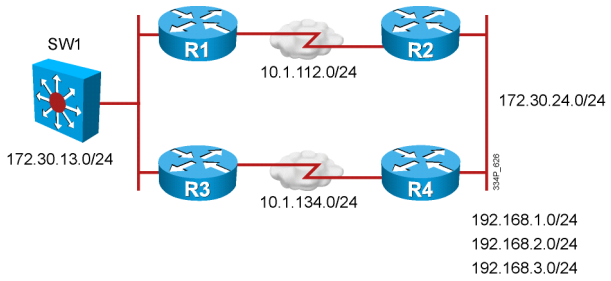
The proper implementation of the routing protocol might include the following details:

- EIGRP AS 1 is implemented.
- IP addressing is used with mask /24.
- Automatic summarization is not desired, because the hiding of subnets might prevent a successful PBR implementation.
- After successful EIGRP configuration and verification of the path that is taken for the packets, PBR needs to be configured. Path manipulation is configured in the router where path manipulation is desired. Often, this router is close to the source.

## Alternative Solutions

- Another routing protocol can be used to provide a different path.
- Static routes can be used.
- The metric and administrative distance can be changed.
- Another path control manipulation tool can be used.







To manipulate the path or to influence destination-based forwarding, another routing protocol can be selected and configured.

Instead of a routing protocol, static routes can be configured. This solution is not scalable, but it provides control over packet forwarding. Static routes can also be used as a path manipulation mechanism, because a static route has a lower administrative distance value than any routing protocol.

You can manipulate the path by changing the metric of the link, the administrative distance of the static routes, or the routing protocol.

Instead of using PBR as a path-control tool, you can use one of several other tools, including filtering (prefix lists, distribute lists, administrative distance, route tagging, offset lists, and Cisco IOS IP SLAs).

## Q and A

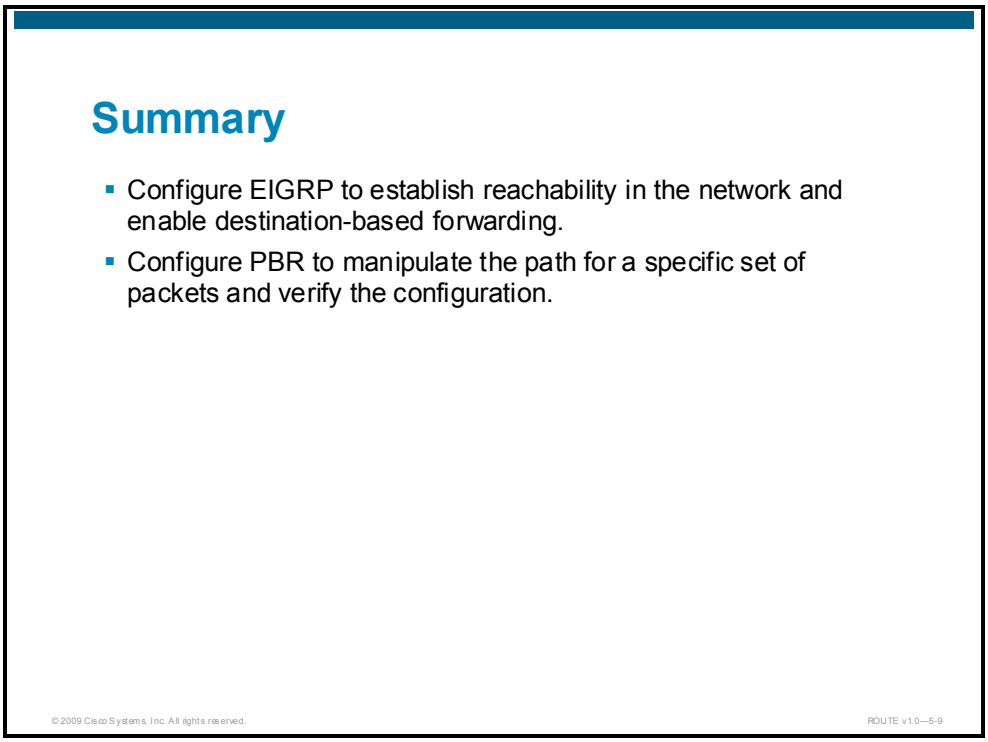
1. Why is routing protocol selection important?
2. Why is changing the default destination-based forwarding important?
3. Which tool is used for PBR implementation?
4. How is classification in the route map performed?
5. How is the path between the packet source and destination verified?




1. A routing protocol exchanges routing updates and populates the IP routing table, which is used for destination-based forwarding.
2. Sometimes, simple destination-based routing is not sufficient. In these cases, network designers may route packets by source address, protocol type, or application type, so that they can optimally shape traffic patterns.
3. PBR uses route maps to match packets and set where to forward packets that pass a route map match clause.
4. The **match** commands in route maps are used to match the traffic.
5. Basic connectivity between the source and destination is verified using the **ping** command. The path is verified hop by hop using the **traceroute** command.

# Summary

This topic summarizes the key points that were discussed in this lesson.



Lesson 3

# References to Additional Path Control in E-Learning

## Overview

The *Implementing Cisco IP Routing* (ROUTE) v1.0 instructor-led training (ILT) course is a comprehensive learning experience. Among the learning tools that it makes available to you are e-learning modules, which complement the classroom instructor-led content, as well as self-paced materials and demonstrations. Upon accessing the e-learning content, you will be able to reinforce the knowledge that is acquired in class and witness real-life scenarios that are demonstrated in real routers and switches. The content structure is flexible; you can navigate it at your own pace, at the time of your choosing, and at the depth you desire, according to your level of experience.

This lesson provides an overview of the "Implementing Path Control" e-learning module. The content includes demonstrations that cover several topics in path control, such as additional design considerations, route tagging, policy routing, and Cisco IOS IP Service Level Agreements (SLAs).

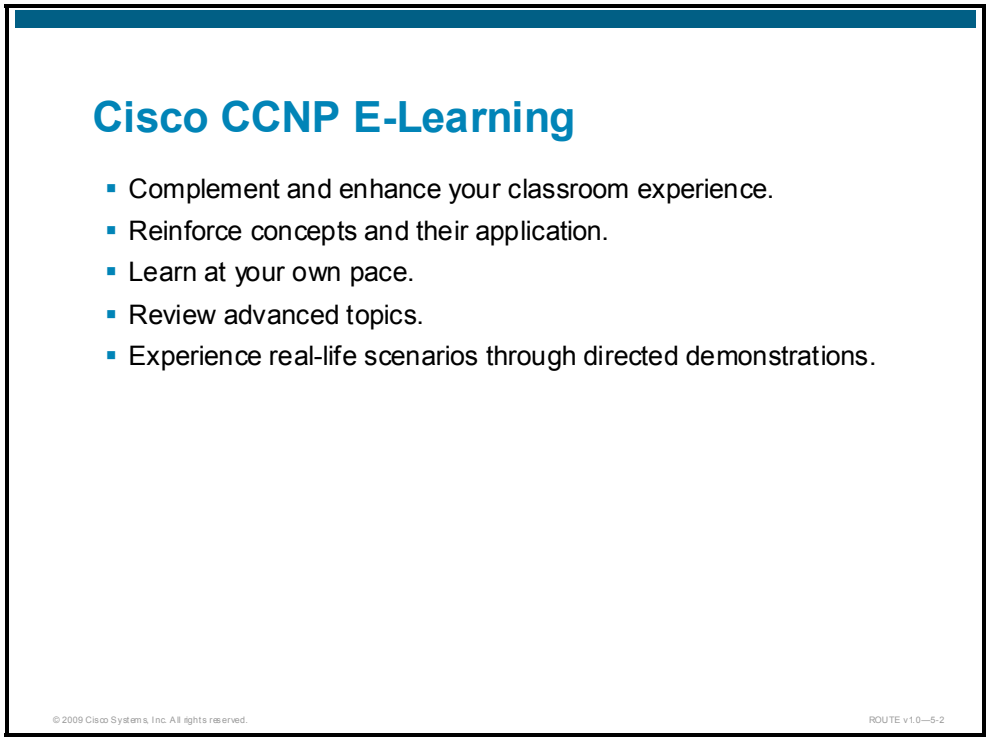
## Objectives

Upon completing this lesson, you will be able to review the e-learning modules that pertain to path control. This ability includes being able to meet these objectives:

- Describe the contents of the "Implementing Path Control" e-learning module
- Understand the process of accessing and using e-learning content

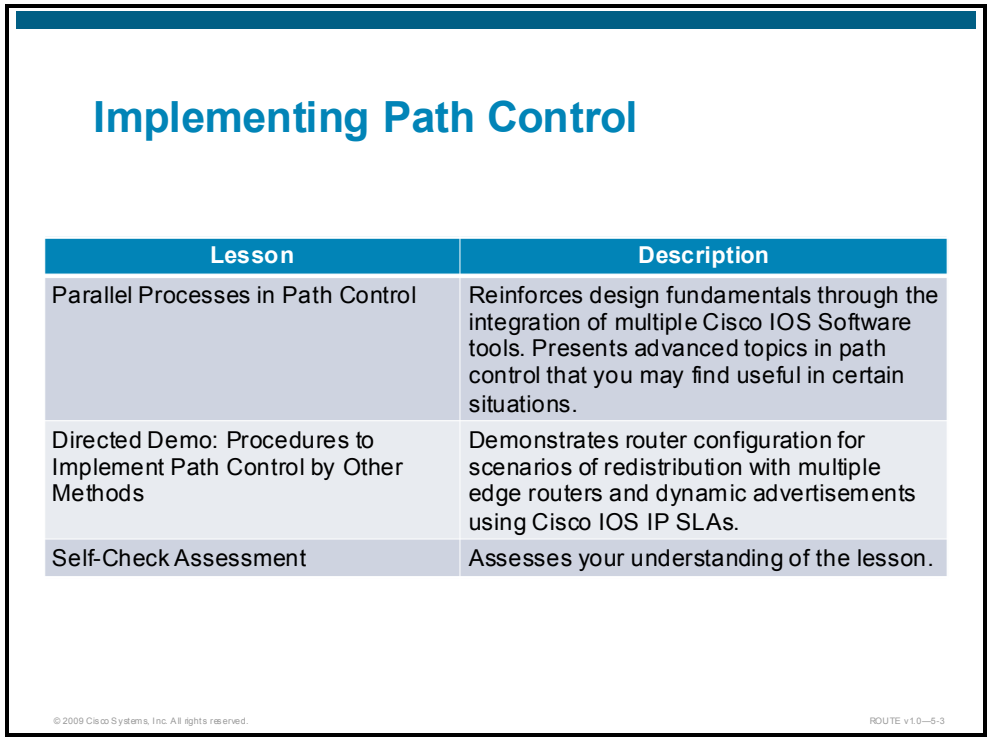
# Preview of E-Learning on Implementing Path Control

This topic describes e-learning products that teach the configuration and implementation of path control.




One of the key ideas behind the design of the Cisco CCNP® curriculum is the understanding that there is no one "best" method of learning for every student. Some students prefer individual labs, while others prefer one-on-one tutoring, hands-on sessions, self-paced computer-assisted instruction, direct-discovery learning, or cooperative learning, among others.

E-learning solutions offer new approaches that complement and enhance classroom-based learning. Designed with flexibility and learning effectiveness in mind, the “Implementing Path Control” e-learning module is based on knowledge that you acquired during your *Implementing Cisco IP Routing* (ROUTE) v1.0 ILT course.




The “Implementing Path Control” e-learning module covers topics that complement the classroom module that you are reviewing. After you take a brief introductory lesson that discusses design issues and the integrated approach to path control, you will be able to follow a directed demonstration of real-life scenarios that combine multiple Cisco IOS Software features to accomplish specific objectives. These demonstrations include the use of tools such as administrative distance, route tagging, and IP SLA tracking.

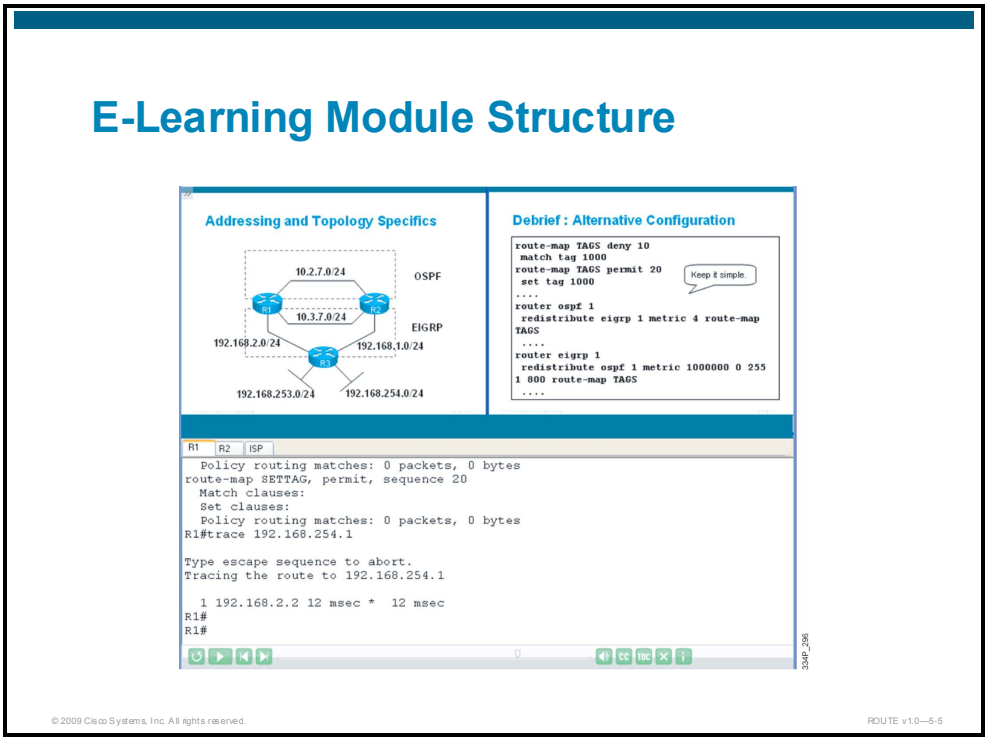
## Where to Find E-Learning Modules





The “Implementing Path Control” e-learning module is available on CD as part of your classroom materials. Please contact your instructor with any questions you have about finding and accessing the CD.

The objectives of the “Implementing Path Control” e-learning module are part of your CCNP certification exam. As such, candidates for CCNP certification should review these objectives.

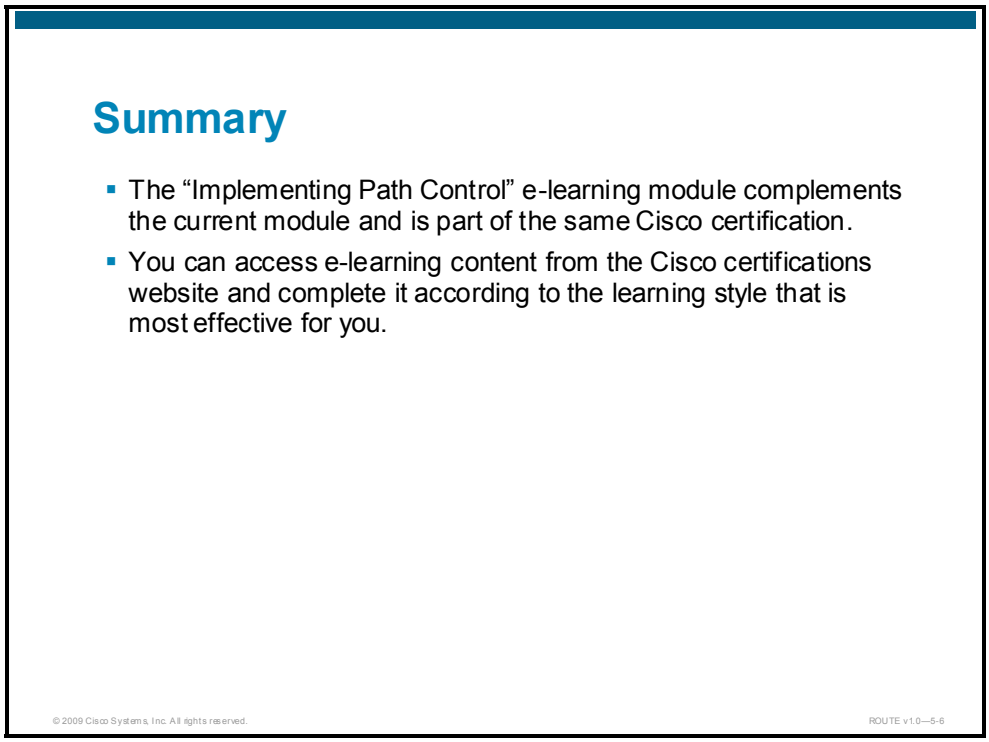



Utilizing a combination of lecture sessions, animated content, lab demonstrations, and assessments, each e-learning module presents a hierarchical structure of lessons and topics. You can navigate through the structure by using an intuitive GUI that includes playback controls, slide selection, and lesson and topic selection. By using these tools, you will be able to navigate the content at your own pace.

The three-panel screen that is used for directed demonstrations allows you to focus on the device console demonstrations, while still allowing you to look at the command syntax and topology diagram for verification and additional information.

# Summary

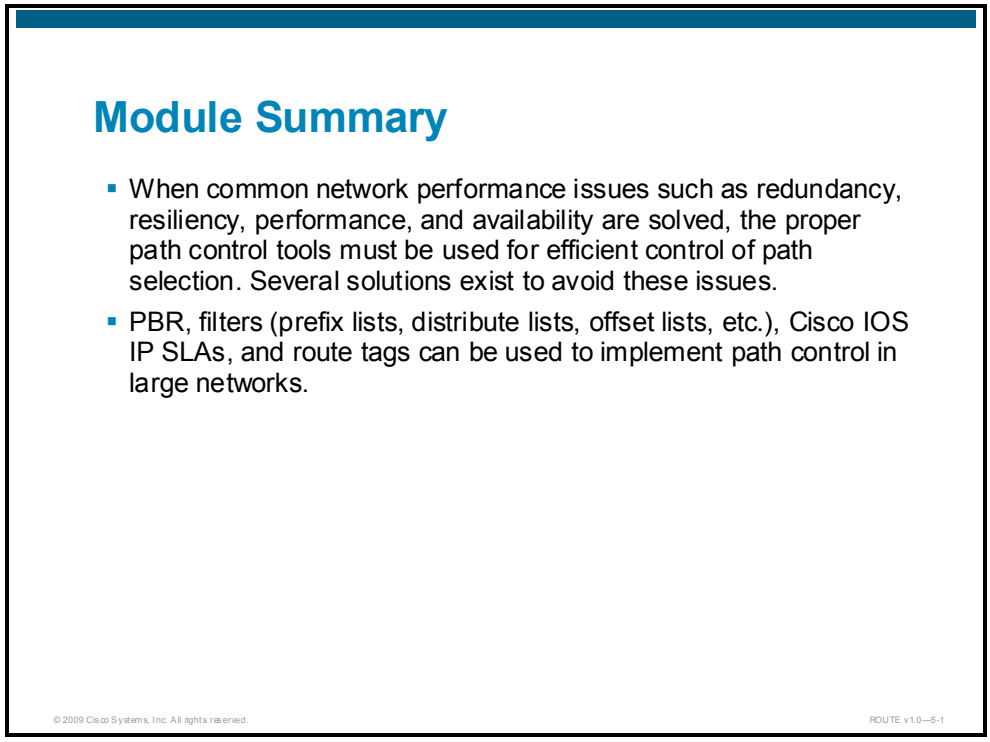
This topic summarizes the key points that were discussed in this lesson.



# Module Summary

This topic summarizes the key points that were discussed in this module.




This module covered common network performance issues such as redundancy, resiliency, performance, and availability. A solution to these issues frequently results in an inefficient path being selected, and the default destination-based routing is not the best solution. You must change the routing table by manipulating routing updates that are entered in the routing table or by bypassing the routing table.

Several tools can be used for efficient path control:

- Route maps
- Prefix lists
- Distribute lists
- Administrative distance
- Route tagging
- Offset lists
- Cisco IOS IP SLAs
- PBR

All these tools must first match traffic, then set actions for the matched traffic.

# Module Self-Check

Use the questions here to review what you learned in this module. The correct answers and solutions are found in the Module Self-Check Answer Key.

Q1) Which four issues result from multiple paths? (Choose four.) (Source: Assessing Path Control Network Performance Issues)

A) suboptimal routing
B) unavailable redundant paths
C) traffic that is optimized for only one application
D) uneven load sharing
E) incomplete route summarization

Q2) Which three tools can be used for path manipulation? (Choose three.) (Source: Assessing Path Control Network Performance Issues)

A) filters
B) PBR
C) redistribution
D) route maps
E) summarization

Q3) Path control tools can be used to bypass the IP routing table. (Source: Assessing Path Control Network Performance Issues)

A) true
B) false

Q4) Which two commands are used inside route maps? (Choose two.) (Source: Assessing Path Control Network Performance Issues)

A) **classify**
B) **set**
C) **redistribute**
D) **match**
E) **policy**

Q5) Which command is used to match traffic inside route maps based on access list 10? (Source: Assessing Path Control Network Performance Issues)

A) **match ip address 10**
B) **match access-list 10**
C) **match ip acl 10**
D) **match ip access-list 10**

Q6) Which path control tool uses mask filtering, for which either a defined prefix is matched or part of an address space with a subnet mask that is longer or shorter than a set number is matched? (Source: Assessing Path Control Network Performance Issues)

A) distribute lists
B) administrative distance
C) route tagging
D) offset lists
E) Cisco IOS IP SLAs
F) prefix lists

Q7) Which tool can be used for end-to-end network performance tests that are based on clear measurement metrics, as well as for path control? (Source: Assessing Path Control Network Performance Issues)

A) distribute lists
B) administrative distance
C) route tagging
D) offset lists
E) Cisco IOS IP SLAs
F) prefix lists

Q8) Policy-based routing avoids destination-based routing. (Source: Assessing Path Control Network Performance Issues)

A) true
B) false

Q9) To which two of these are path control tools applied? (Choose two.) (Source: Assessing Path Control Network Performance Issues)

A) incoming traffic
B) outgoing traffic
C) traffic that is locally generated in the router
D) MTU-sized packets

Q10) Which two commands provide a basic connectivity test? (Choose two.) (Source: Assessing Path Control Network Performance Issues)

A) **show route-map**
B) **show ip policy**
C) **ping**
D) **traceroute**

Q11) Which command defines the interface on which to output packets that pass a route map match clause for policy routing and for which the Cisco IOS Software has no explicit route to a destination? (Source: Assessing Path Control Network Performance Issues)

A) **set ip next-hop 10.1.1.1**
B) **set interface ethernet 0**
C) **set ip default next-hop 10.1.1.1**
D) **set default interface ethernet 0**

Q12) Which command displays route maps that are configured on interfaces? (Source: Assessing Path Control Network Performance Issues)

A) **show ip policy**
B) **show route-map** *map-name*
C) **show ip routing table**
D) **show ip interface brief**

Q13) Policy-based routing uses a route map for its configuration and can be fast-switched or switched by Cisco Express Forwarding. (Source: Assessing Path Control Network Performance Issues)

A) true
B) false

Q14) The **show ip policy** command output shows policy routing matches. (Source: Assessing Path Control Network Performance Issues)

A) true
B) false

# Module Self-Check Answer Key

Q1) A, B, C, D

Q2) A, B, D

Q3) A

Q4) B, D

Q5) A

Q6) F

Q7) E

Q8) A

Q9) A, C

Q10) C, D

Q11) D

Q12) A

Q13) A

Q14) B

# Module 6

# Connecting an Enterprise Network to an ISP Network

## Overview

The Internet has become a vital resource in many organizations, which requires a single connection and frequently redundant connections to multiple ISPs. With multiple connections, Border Gateway Protocol (BGP) is an alternative to using default routes to control path selections. BGP provides several alternatives to using default routes.

Use of BGP as a routing protocol requires that an administrator understand how to properly configure BGP for scalable internetworking. This module discusses BGP configuration and verification when connecting an enterprise network to ISP networks.

## Module Objectives

Upon completing this module, you will be able to implement and verify a Layer 3 solution using BGP to connect an enterprise network to an ISP. This ability includes being able to meet these objectives:

- Discuss the components and methods that are used to connect an enterprise network to an ISP
- Explain the advantages of using BGP to connect an enterprise network to an ISP, while comparing the functions and uses of EBGP and IBGP
- Compare and contrast the requirements for establishing EBGP-to-IBGP neighbor relationships
- Implement BGP operations for ISP connections in an enterprise network
- Discuss the lab results for configuring BGP operations
- Configure and verify BGP operations in a multihomed environment using the BGP attributes and route maps to control all BGP routes to and from the router
- Discuss the lab results for manipulating the EBGP path selections
- Discuss the e-learning modules that pertain to additional topics in IPv6 and remote access connectivity

Lesson 1

# Planning the Enterprise-to-ISP Connection

## Overview

Planning needs to be completed before the connection of an enterprise network to an ISP can be implemented. To plan the connectivity to an ISP properly, the designer must understand many aspects, including the session origination point—either from the enterprise network toward the Internet or from the Internet toward the enterprise network; the prerequisites for successfully implementing such connectivity; and the available routing options and which routing option should be used in certain cases. The connectivity redundancy considerations must also be taken into account.

## Objectives

Upon completing this lesson, you will be able to justify the components and methods that are used to connect an enterprise network to an ISP. This ability includes being able to meet these objectives:

- Connect enterprise networks to an ISP
- Exchange routing updates with an ISP
- Define the types of connections to an ISP

# Connecting Enterprise Networks to an ISP

This topic describes the connectivity requirements between an enterprise network and an ISP.

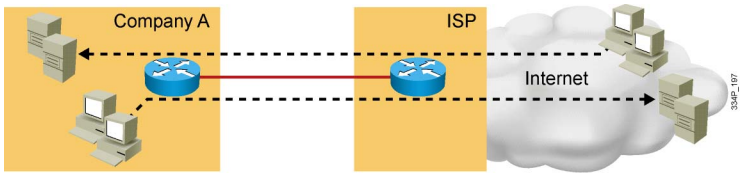
## Session Origin Initiation

Enterprise session initiation requirement:

- **One-way:** Connectivity from an enterprise network toward the Internet is the only connectivity required.
- **Two-way:** Connectivity from the Internet to an enterprise network is also required.

Solutions:

- **One-way:** Private IP address space with address translation
- **Two-way:** Public IP address space (in combination with private) and proper routing







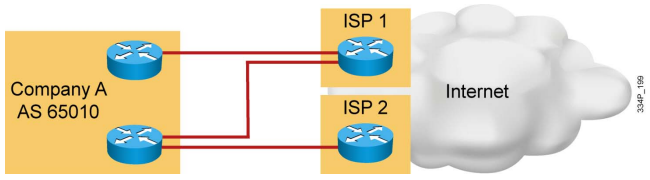
Modern corporate IP networks are connected to the global Internet and make use of the Internet for some of their data transport needs. Corporations provide many services via the Internet to customers and business partners; systems from web servers to mainframes to workstations can be accessible from anywhere in the world.

In the rare cases in which only connectivity from the clients to the Internet is required, public addresses with network translation are used to allow clients on a private network to communicate with servers on the public Internet.

Typically, not only do clients from an enterprise network need to access external resources that are located on the public Internet, but clients that are external to the enterprise network also need to access resources in the enterprise network.

## Enterprise Network-to-ISP Connectivity Requirements

- Public IP address space (subpool or whole /24 subnet)
- Link type and bandwidth availability
- Routing options
- Connection redundancy
- Independency in regard to an ISP:
  - Public IP address space
  - AS number







The first parameter that needs to be determined is the number of public IP addresses, which are used to translate client private addresses for those clients that need to access resources on the Internet. These public IP addresses are also used for those enterprise servers that need to be accessible from the Internet. These servers are either equipped with public addresses or addresses that are statically translated from private to public addresses.

In the second parameter, the enterprise network-to-ISP connection link type and speed, which depends on the ISP, needs to be determined. The link types that are available include leased line, Ethernet over fiber optics or copper, and xDSL. The bandwidth assignment must be done properly to address the enterprise Internet connectivity requirements.

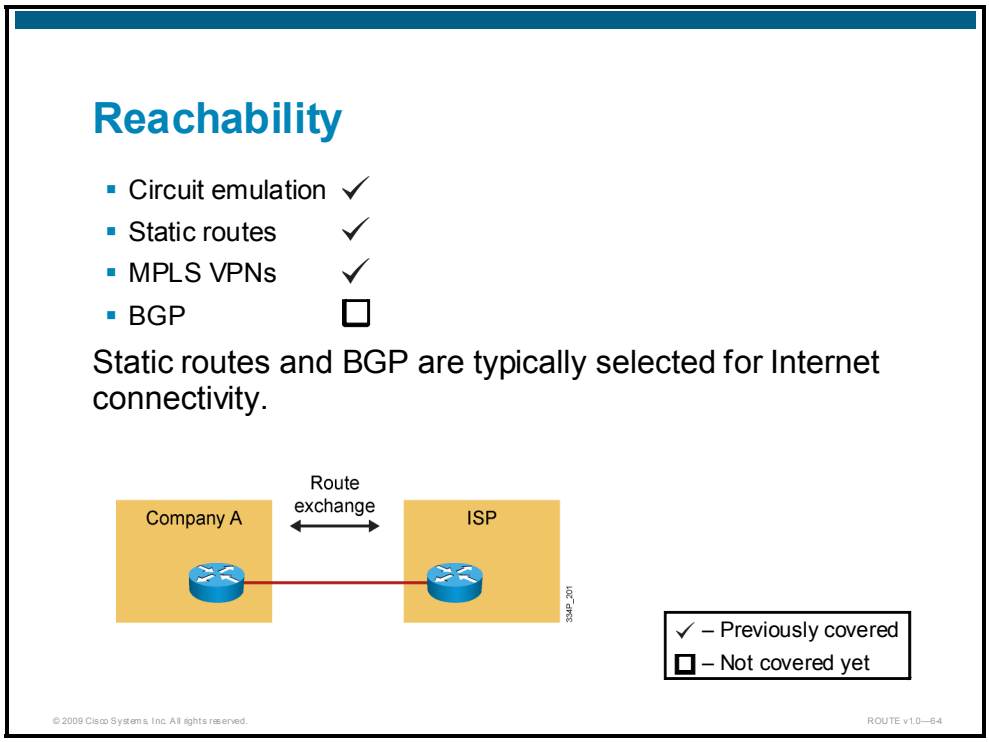
In the third parameter, a proper routing protocol must be selected. The selection is typically made between static and dynamic routing.

The fourth parameter relates to the issue of connectivity redundancy. An evaluation is needed to determine which kind of redundancy is required for the enterprise network-to-ISP connectivity. Redundancy includes edge router redundancy, link redundancy, and ISP redundancy, where the ISP redundancy connects to multiple ISPs.

When assessing these parameters, it must be taken into account whether an enterprise network needs to be independent of the selected ISP or ISPs. If independency is required, the public IP address space should not be used from the ISP public address space, but should instead be acquired from the regional Internet authority. Similarly, independency is required for the enterprise network autonomous system (AS). The AS number must be a public assigned number and not from the private AS number pool that can be assigned by the ISP.

# Exchanging Routing Updates with an ISP

This topic describes the methods for exchanging routing information across an ISP.




Connecting an enterprise network to an ISP requires routing information to be exchanged between the network and the ISP.

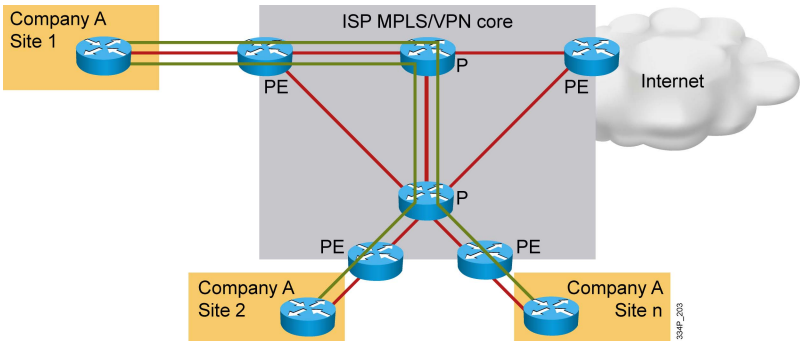
The selection of the routing means depends on the answers to these questions:

- Should this routing respond to the changes in a network topology?
- Does routing need to support one link or multiple links to an ISP?
- Is traffic load balancing over multiple links required?
- Will the enterprise network be connected to multiple ISPs?
- Should the ISP offer merely a transport capability that requires connecting different customer locations, perhaps via certain Layer 2 technologies?
- What is the amount of routing information that needs to be exchanged with an ISP?
- Which routing options does the ISP offer?

## Using Circuit Emulation

- Used to provide different Layer 2 connectivity to customers via the common Layer 3 infrastructure of a service point:
  - Ethernet, Frame Relay, PPP, HDLC, ATM, Layer 2 connectivity
  - No routing with the service point from the customer perspective







Sometimes a customer needs Layer 2 connectivity between two or more locations. The following examples illustrate the need for Layer 2 connectivity:

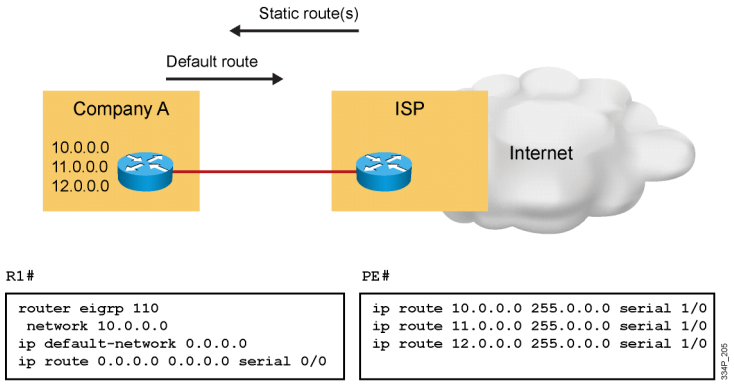
- The locations might include data centers with geographically distributed clusters that require Layer 2 connectivity to properly function.
- The customer is in a migration process but still requires Layer 2 connectivity.
- The customer is connecting to another partner, and there is a requirement for Layer 2 connectivity.

A Layer 2 connection requirement might range from Ethernet, Frame Relay, PPP, High-Level Data Link Control (HDLC), or even ATM. In such cases, modern service providers employ their IP-based core network that is enhanced with Multiprotocol Label Switching (MPLS) technologies to provide such connectivity.

With this connectivity, there is no need for a routing exchange between the ISP and the customer. From the customer, it looks like the ISP is providing a Layer 2 port. From the perspective of the ISP, two ports from distant locations must be connected together.

## Using Static Routes

- The customer uses the default route toward the ISP.
- The service provider uses static routes for customer public networks.
- No automatic adjustment to any changes in the network.




R1#

```
router eigrp 110
 network 10.0.0.0
ip default-network 0.0.0.0
ip route 0.0.0.0 0.0.0.0 serial 0/0
```

PE#

```
ip route 10.0.0.0 255.0.0.0 serial 1/0
ip route 11.0.0.0 255.0.0.0 serial 1/0
ip route 12.0.0.0 255.0.0.0 serial 1/0
```



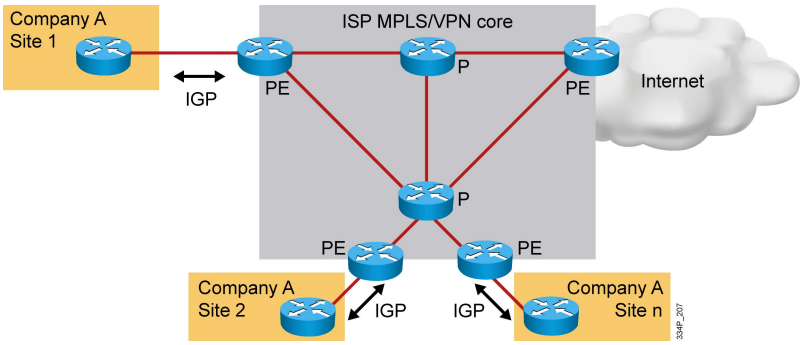

Static routes are the simplest way of exchanging routing information with an ISP. These static routes must agree with the ISP upon routing configuration, and they do not change afterward; or, if they do change, these changes should not occur very often.

Static routes are typically used for Internet connectivity when a customer is connected through a single connection to an ISP. The customer can use the default route toward the ISP, and the ISP must deploy a static route or routes that encompass the public networks of the customer. The ISP typically would also redistribute this information into its Border Gateway Protocol (BGP).

Although static routes are a simple solution, they also have some drawbacks, especially in terms of flexibility and adaptability. For example, if there were a change in a network topology beyond a directly connected link failure, the static routes would not adapt. If adaptation needs to be achieved, either the static routes need to be combined with an IP service level agreement (SLA) functionality that in turn would indicate that a static route is down if a certain condition is met, or dynamic routing is used. Note that using an IP SLA cannot completely substitute dynamic routing, because it cannot react to all changes in the topology in the Internet.

## Using MPLS VPN

- Used to connect multiple customer locations via the common Layer 3 infrastructure of a service provider:
  - A special VPN can be used to provide Internet connectivity.
  - Routing used can be static or dynamic, depending on the service provider.
  - The customer routers are connected to the service provider PE routers.







Multiprotocol Label Switching Virtual Private Networks (MPLS VPNs) are used when a customer has multiple locations that need to be interconnected through an ISP and does not want to use expensive Layer 2 technologies such as leased lines.

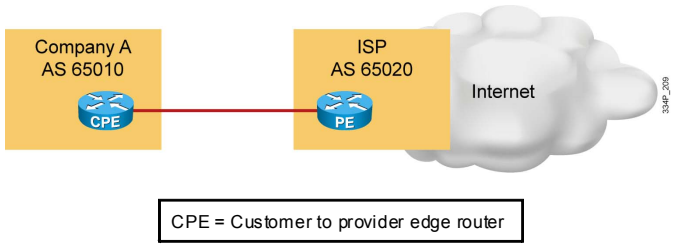
With MPLS VPNs, the ISP uses a common IP-based core network that is enhanced with MPLS technology to provide secure and manageable connectivity for different customers to their geographically diverse sites. In this way, the traffic from different customers can share the same physical wire, but at the same time, traffic is tagged with the labels in such way that the traffic cannot intermix.

When a customer uses MPLS VPN functionality, the routing between the customer and the ISP is required to provide connectivity between the customer locations. Routing options range from static to dynamic and include Routing Information Protocol (RIP), Enhanced Interior Gateway Routing Protocol (EIGRP), Open Shortest Path First (OSPF), Intermediate System-to-Intermediate System (IS-IS), or even BGP, depending on what the ISP offers. Different locations could use different routing protocols, though this situation typically would not occur.

With an MPLS VPN deployment, the service provider can also offer Internet connectivity through the same MPLS core network, either through a special Internet VPN or through a global routing table. To exchange the Internet routing information, either BGP or a default routing is used.

## Using BGP

- The customer deploys BGP to announce its public networks.
- The ISP announces a default route, a subset of Internet routes, or a complete Internet routing table.
- Typically used for inter-AS routing.




CPE = Customer to provider edge router



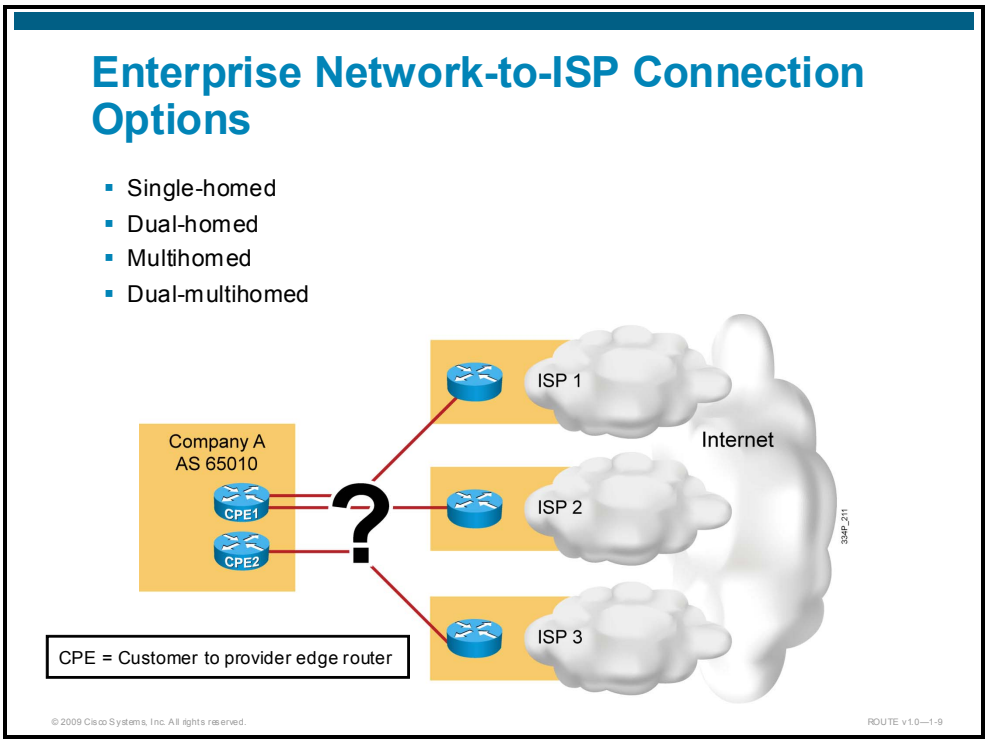

A typical option that is used to provide dynamic routing exchange when Internet connectivity is deployed is BGP. BGP dynamically exchanges routing information and thus reacts to topology changes, including those changes beyond a customer-to-ISP link failure.

From the routing perspective, three options can be used:

- An ISP (or multiple ISPs) announces a default route only. If two ISPs are used, one ISP will be the primary and the second ISP will serve as the backup.
- An ISP (or multiple ISPs) announces a default route and a subset of Internet routes, typically its own public address space. This results in the shortest path being used to the directly connected public networks. For public networks that are not directly connected, one of the ISPs is the primary and the second ISP is the backup.
- An ISP (or multiple ISPs) announces a complete Internet routing table. The shortest path to any destination will be chosen according to the routing table.

# Defining the Types of Connections to an ISP

This topic describes the types of enterprise-to-ISP connections and their effect on the selection of an exchange method.




When connecting an enterprise network to an ISP, redundancy is a serious concern. The following different aspects can be addressed to achieve connectivity redundancy:

- Deployment of redundant links
- Deployment of redundant equipment
- Use of redundancy within a single router

From the connection perspective, a customer can be connected to a single ISP or to multiple ISPs.

With a single ISP connection, redundancy can still be achieved if two links toward the same ISP are used effectively, making a customer dual-homed. When no link redundancy is used, the customer is simply single-homed, and in a failure within an ISP network, the connectivity to the Internet is interrupted.

With multiple ISP connections, the redundancy is built into the design, because the customer is multihomed and thus resistant to a single ISP failure. To enhance the resiliency further, a customer can have two links toward a single ISP, making the solution dual-multihomed.

## Single-Homed ISP Connectivity

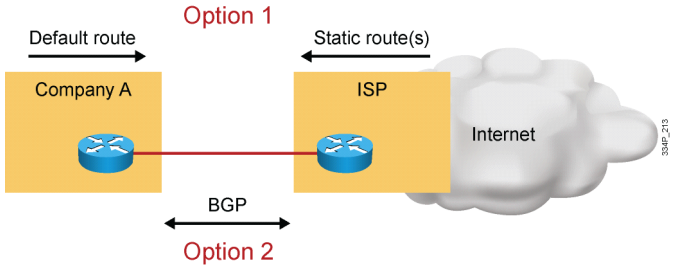
Link failure results in broken connectivity.

Option 1: Routing with static routes

- A default route from an enterprise network
- A static route or routes from an ISP for customer networks

Option 2: Routing with BGP

- The customer announces its public network.
- The ISP announces the default route to the customer.







Single-homed ISP connectivity is used in cases when a loss in Internet connectivity is not as vital or problematic to a customer (though these days, the Internet typically is a vital resource).

In this case, a customer uses a single connection to a single ISP. The type of connection depends on the ISP offering and can include a leased line, xDSL, or an Ethernet connection. Failure of a link results in no Internet connectivity.

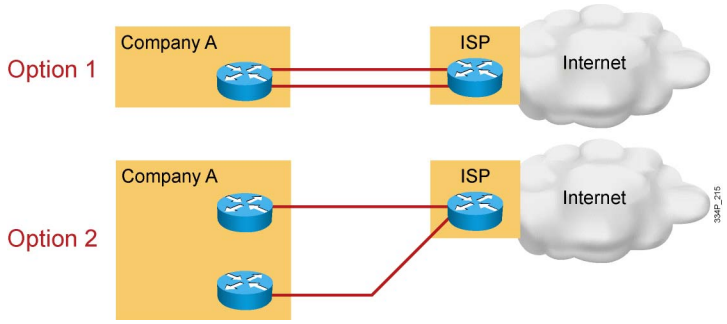
Such Internet access to a single ISP does not require BGP. Static routes are typically used to manage the routing. If BGP is used, the customer uses it to dynamically announce its public networks to an ISP; the ISP announces only a default route to the customer, because that is sufficient to provide the connectivity through a single link to the Internet.

## Dual-Homed ISP Connectivity

Characteristics:

- Connected with two links to the same ISP
- Can use a single router or two edge routers
- Can use static routes or BGP







When a customer is connected to a single ISP only, resiliency can still be achieved by deploying a second link to the same ISP. With a second link being used, the routing must be properly configured to allow usage of such a link.

Depending on the SLA that is signed with the ISP, the routing that is deployed could achieve these benefits:

- Primary and backup link functionality, where a single primary link is used to forward and receive traffic to and from the ISP, and the secondary link is used only when the first link fails
- Load sharing between the links, achieved with Cisco Express Forwarding switching

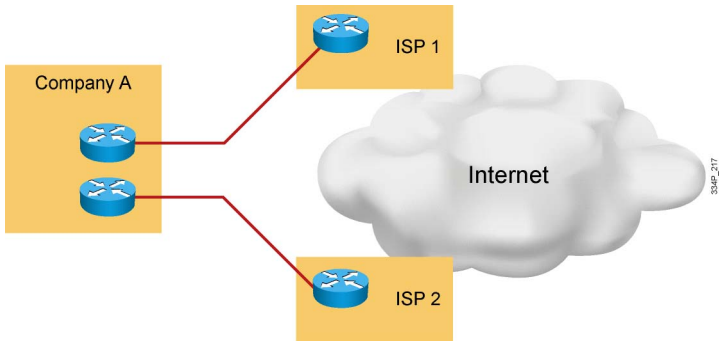
In both cases, the routing that is used can be based on either static or dynamic routes, which would typically include BGP.

To enhance the resiliency further, the two links can terminate at separate customer routers.

## Multihomed ISP Connectivity

Characteristics:

- Connected to two or more different ISPs
- Can use a single router or multiple edge routers
- Dynamic routing with BGP







A proper resiliency is achieved by connecting to two or more different ISPs. The benefits of connecting to two or more different ISPs are the following:

- Resistance to a failure beyond a directly connected link to a single ISP.
- Sharing the load for different destination networks between ISPs based on the network proximity.
- Scaling the solution beyond two ISPs.
- Achieving a solution independent of an ISP. An ISP change requires an update of routing configuration and change of a link. The public IP address space that is used remains the same.

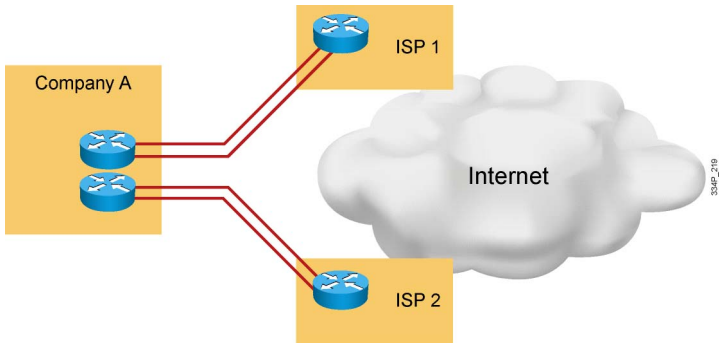
Connections from different ISPs can terminate on the same router or different routers to further enhance the resiliency. The routing must be capable of reacting to dynamic changes, and BGP is typically used to achieve this flexibility.

## Dual-Multihomed ISP Connectivity

Characteristics:

- Connected to two or more different ISPs with two links per ISP
- Typically uses multiple edge routers (one per ISP)
- Dynamic routing with BGP







Multihoming exists when an AS has more than one connection to the Internet. Two typical reasons for multihoming are as follows:

- To increase the reliability of the connection to the Internet:
  - If one connection fails, the other connection remains available.
- To increase the performance of the connection:
  - Better paths can be used to certain destinations.

The benefits of BGP are apparent when an AS has multiple External Border Gateway Protocol (EBGP) connections to either a single AS or multiple autonomous systems. Having multiple connections allows an organization to have redundant connections to the Internet so that if a single path becomes unavailable, connectivity can still be maintained.

# Summary

This topic summarizes the key points that were discussed in this lesson.

## Summary

- Connecting an enterprise network to an ISP requires, at a minimum, a public IP address pool, a proper link to the ISP, consideration of redundancy requirements, and the proper routing protocol.
- To exchange routing updates with an ISP, the customer can use different options. Static routes and BGP are the options that are most commonly used.
- The way in which the customer connects to an ISP depends on the redundancy requirements, where a single-homed connectivity has no redundancy, and the dual-multihomed connectivity has the most redundancy built in.

Lesson 2

# Considering the Advantages of Using BGP

## Overview

Border Gateway Protocol (BGP) is an exterior gateway protocol (EGP), and this lesson describes how BGP may be used by enterprises to connect to ISPs. BGP routes between autonomous systems by using path vector attributes upon which routing policy decisions at the autonomous system (AS) level are enforced.

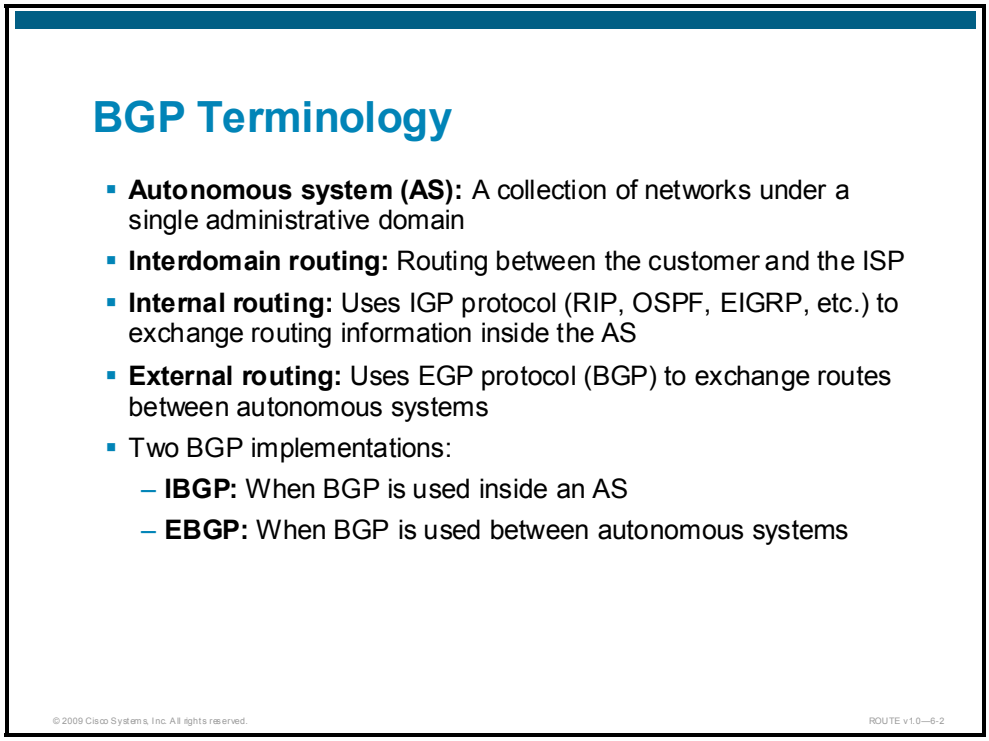
## Objectives

Upon completing this lesson, you will be able to explain the advantages of using BGP to connect an enterprise network to an ISP, while comparing the functions and uses of External Border Gateway Protocol (EBGP) and Internal Border Gateway Protocol (IBGP). This ability includes being able to meet these objectives:

- Use BGP to connect to an ISP
- Describe BGP multihoming options
- Configure BGP routing between autonomous systems
- Explain path vector functionality
- Identify features of BGP

# Using BGP to Connect to an ISP

This topic describes connectivity between an enterprise network and an ISP that requires the use of BGP, including a description of the issues that arise when an enterprise decides to connect to the Internet through multiple ISPs.




The Internet is a collection of autonomous systems that are interconnected to allow communication among these autonomous systems. BGP provides the routing between these autonomous systems.

Enterprises that want to connect to the Internet do so through one or more ISPs. If your organization has only one connection to one ISP, then you probably do not need to use BGP; instead, you would use a default route. However, if you have multiple connections to one or multiple ISPs, then BGP might be appropriate, because it allows manipulation of path attributes so that the optimal path can be selected.

To understand BGP, it is necessary to first understand how it is different from the other protocols that are discussed so far in this course. One way to categorize routing protocols is by whether the protocols are interior or exterior, as follows:

- **Interior gateway protocol (IGP)** is a routing protocol that exchanges routing information within an AS. Routing Information Protocol (RIP), Open Shortest Path First (OSPF), and Enhanced Interior Gateway Routing Protocol (EIGRP) are examples of IGPs.
- **EGP** is a routing protocol that exchanges routing information between different autonomous systems. BGP is an example of an EGP.

BGP is an Interdomain Routing Protocol (IDRP), also known as an EGP. BGP version 4 (BGP4) is the latest version of BGP and is defined in RFC 4271. As noted in this RFC, the classic definition of an AS is “a set of routers under a single technical administration, using an IGP and common metrics to route packets within the autonomous system, and using an interautonomous system routing protocol (also called an EGP) to determine how to route packets to other autonomous systems.”

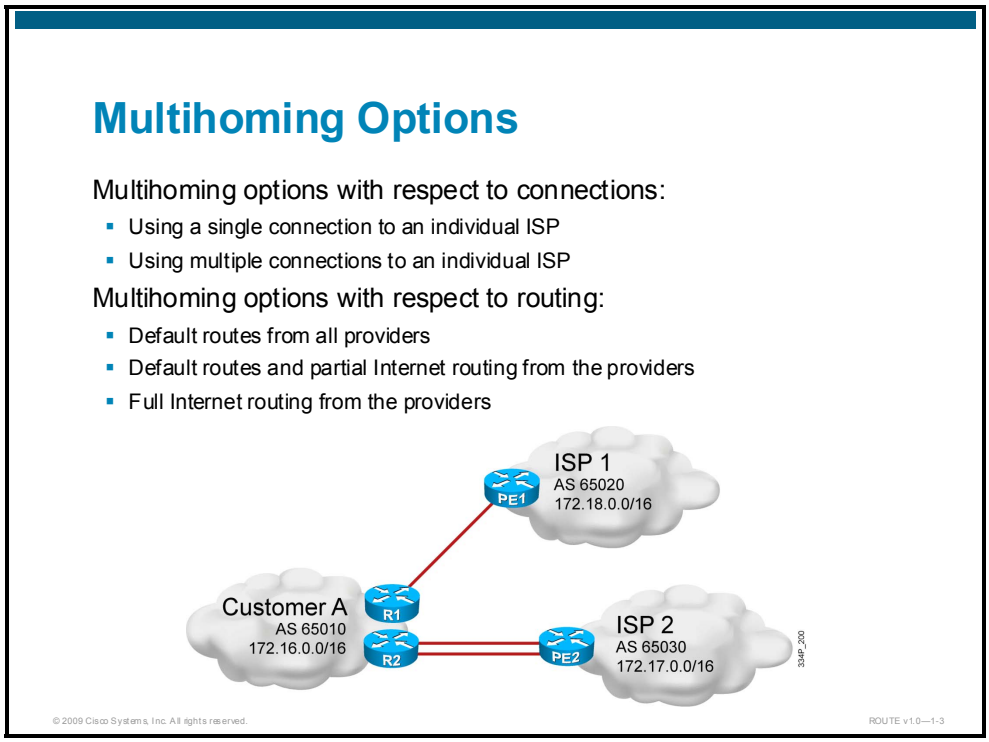
 

Autonomous systems can use more than one IGP, potentially with several sets of metrics. From the point of view of BGP, the most important characteristic of an AS is that it appears to other autonomous systems to have a single coherent interior routing plan and presents a consistent picture of reachable destinations. All parts of an AS must connect to each other.

When BGP is running between routers in different autonomous systems, it is called EBGP. When BGP is running between routers in the same AS, it is called IBGP. BGP allows the path that packets take to be manipulated by the AS, as described in this module. It is important to understand how BGP works to avoid creating problems for the AS that result from running BGP.

# BGP Multihoming Options

This topic describes BGP multihoming options.




An organization can be multihomed to either a single ISP or to multiple ISPs. A drawback to having all connections homed to a single ISP is that connectivity issues in that single ISP can cause your AS to lose connectivity to the Internet. By having connections to multiple ISPs, an organization gains the following benefits:

- A redundancy with the multiple connections
- Not tied into the routing policy of a single ISP
- More paths to the same networks for better policy manipulation

A multihomed AS will run EBGP with its external neighbors and might also run IBGP internally.

If an organization has determined that it will perform multihoming with BGP, there are three common ways to do this:

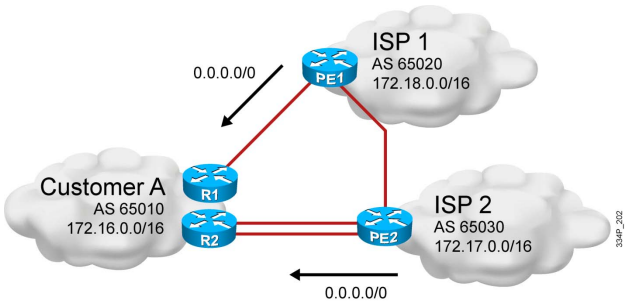
- Each ISP passes only a default route to the AS:
  - The default route is passed to the internal routers.
- Each ISP passes only a default route and provider-owned specific routes to the AS:
  - These routes may be passed to internal routers, or all internal routers in the transit path can run BGP and pass these routes between them.
- Each ISP passes all routes to the AS:
  - All internal routers in the transit path run BGP and pass these routes between them.

These options are described in the following pages.

## Default Routes from Providers

- Customer A receives the default route from each ISP.







The first multihoming option is to receive only a default route from each ISP. This configuration requires the fewest resources within the AS, because a default route is used to reach any external destinations. The AS sends all its routes to the ISPs, which process and pass the routes on to other autonomous systems.

If a router in the AS learns about multiple default routes, the local interior routing protocol installs the best default route in the routing table. From the perspective of this router, it chooses the default route with the least-cost IGP metric. This IGP default route will route packets that are destined to the external networks to an edge router of this AS, which is running EBGP with the ISPs. The edge router will use the BGP default route to reach all external networks.

The route that inbound packets take to reach the AS is chosen outside the AS (within the ISPs and other autonomous systems).

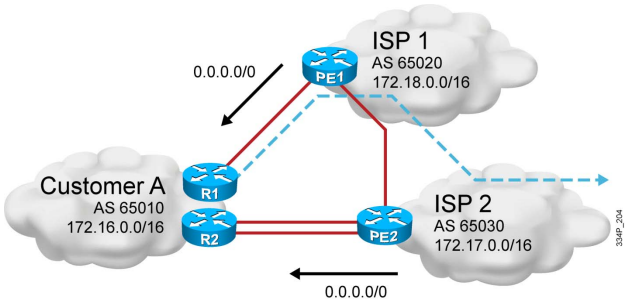
Regional ISPs that have multiple connections to national or international ISPs commonly implement this option. The regional ISPs do not use BGP for path manipulation; however, ISPs require the capability of adding new customers as well as the networks of the customers. If the regional ISP does not use BGP, then each time that the regional ISP adds a new set of networks, the customers must wait until the national ISPs add these networks to their BGP process and place static routes pointing at the regional ISP. By running EBGP with the national or international ISPs, the regional ISP needs to add only the new networks of the customers to its BGP process. These new networks automatically propagate across the Internet with minimal delay.

A customer that chooses to receive default routes from all providers must understand the following limitations of this option:

- Path manipulation cannot be performed, because only a single route is being received from each ISP.
- Bandwidth manipulation is extremely difficult and can be accomplished only by manipulating the IGP metric of the default route.
- Diverting some of the traffic from one exit point to another is challenging, because all destinations are using the same default route for path selection.

## Default Routes from Providers (Cont.)

- One of the ISPs is used for sending traffic out of the customer network.
- Can result in the suboptimal routing of packets.







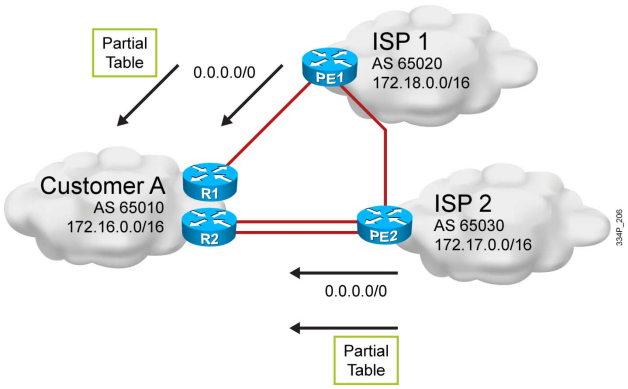
In the figure, AS 65020 and AS 65030 send default routes into AS 65010—the Customer A network. Because of the IGP metric in the Customer A network and because of the configuration of routers R1 and R2, the provider edge 1 (PE1) router from ISP 1 is selected as the default gateway to reach any external network outside of the Customer A autonomous system.

This procedure can lead to suboptimal routing. For example, if the goal is to reach network 172.17.0.0, the packets will be sent toward ISP 1 to PE1, because the PE1 router is the preferred way out of the Customer A autonomous system. ISP 1 then forwards the traffic to the final destination to ISP 2.

## Default Routes and Partial Table from Providers

- Customer A receives the default route from each ISP.
- Customer A receives a partial routing table from each ISP.







In the second design option for multihoming, all ISPs pass default routes plus the selected specific routes to the AS.

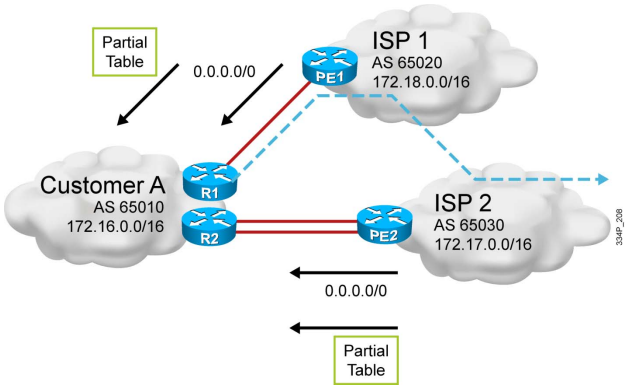
An enterprise that is running EBGP with an ISP that wants a partial routing table generally receives the networks that the ISP and its other customers own. The enterprise can also receive the routes from any other AS.

Major ISPs are assigned between 2000 and 10,000 classless interdomain routing (CIDR) blocks of IP addresses from the Internet Assigned Numbers Authority (IANA), which the ISPs reassign to their customers. If the ISP passes this information to a customer that wants only a partial BGP routing table, the customer can redistribute these routes into its IGP. The internal routers of the customer (these routers are not running BGP) can then receive these routes via redistribution. The routers can take the nearest exit point that is based on the best metric of specific networks instead of taking the nearest exit point that is based on the default route.

Acquiring a partial BGP table from each provider is beneficial, because path selection will be more predictable than when using a default route.

## Default Routes and Partial Table from Providers (Cont.)

- The partial table is used to forward traffic to the correct ISP.
- If the destination is unknown, a default route to one of the ISPs is used.





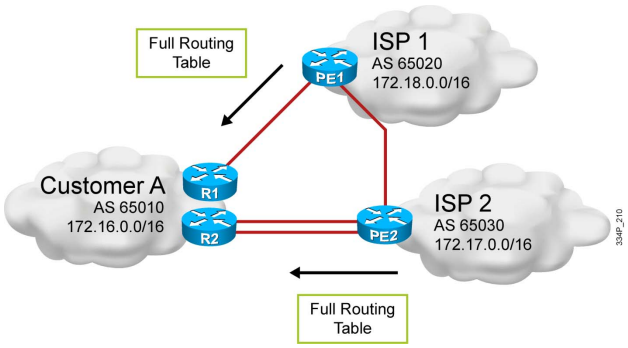


In the figure, ISPs in AS 65020 and AS 65030 send default routes and the routes that each ISP owns (partial table) to Customer A (AS 65010).

By running IBGP between the internal routers R1 and R2 within AS 65010, AS 65010 can choose the optimal path to reach the destination networks within ISP 1 and ISP 2. If Customer A is sending the traffic to an unknown destination, one of the default routes (from ISP 1 or ISP 2) is used. Again, this process can lead to suboptimal routing, as shown in the figure. The unknown routes to another AS are not shown in the figure, because these routes are not specifically advertised to AS 65010 by ISP 1 and ISP 2. The IGP metric that is used to reach the default route within the AS selects the default gateway out of the Customer A network.

## Full Internet Routing from Providers

- Customer A receives a full routing table from each ISP.
- Requires that enough memory and CPU resources are available.







In the third multihoming option, all ISPs pass all routes to the AS, and IBGP is run on at least the routers in the transit path in this AS. This option allows the internal routers of the AS to take the path through the best ISP for each route.

This configuration requires many resources within the AS, because it must process all the external routes.

The AS sends all its routes to the ISPs, which process the routes and pass the routes to other autonomous systems.

In the figure, AS 65020 and AS 65030 send all routes into AS 65010. The ISP that a specific router within AS 65010 uses to reach the external networks is determined by the BGP protocol.

The routers in AS 65010 can be configured to influence the path to certain networks. For example, R1 and R2 can influence the outbound traffic from AS 65010.

# BGP Routing Between Autonomous Systems

This topic describes how BGP routes between autonomous systems.

## Autonomous System

- A collection of networks under a single technical administration:
  - 16-bit numbers (“new” BGP AS numbering system extends to 32-bit numbers)
  - Ranging from 1 to 65535
  - Private AS: 64512 to 65535
- IANA allocates AS numbers.
- IGPs operate within an AS.
- BGP is used between autonomous systems.





Recall that an AS is a collection of networks under a single technical administration. IGPs operate within an AS, and BGP (specifically BGP4) is used between autonomous systems on the Internet.

The IANA is the organization that is responsible for allocating AS numbers. Specifically, the American Registry for Internet Numbers (ARIN) has the jurisdiction to assign numbers for the Americas, the Caribbean, and Africa. Réseaux IP Européens Network Coordination Centre (RIPE NIC) administers AS numbers for Europe, and the Asia Pacific Network Information Center (APNIC) administers the numbers for the Asia Pacific region.

AS numbers traditionally were 16-bit numbers ranging from 1 to 65535. RFC 1930 provides guidelines for the use of AS numbers. A range of AS numbers, 64512 through 65535, is reserved for private use, much like private IP addresses. The AS numbers that are used in this course are all in the private range to avoid publishing AS numbers belonging to organizations.

| | |
|---|---|
| **Note** | Using an IANA-assigned AS number rather than a private AS number is necessary only if your organization plans to use an EGP such as BGP and connect to a public network such as the Internet. |

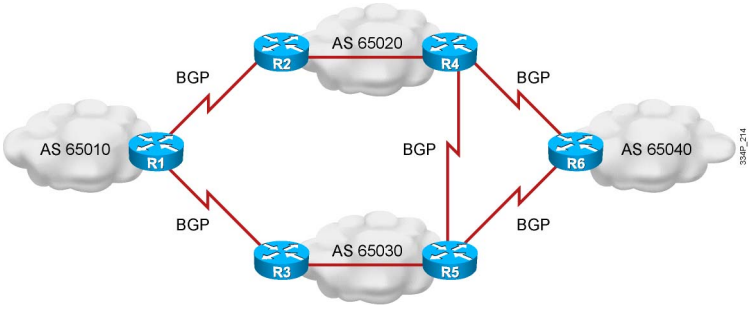
As the 16-bit AS range was coming to exhaustion, the IANA extended in 2007 the AS number registry to a 32-bit range (0 to 4,294,967,295). Most networks can still use the “old” AS 16-bit range. Routers that are using the new range need their code to be updated to extend the AS number field size to 32 bits. Routers that are using the old system still use the 16-bit AS number field. When a router that is using the new AS range communicates with a router that is using the old AS range, it uses the reserved AS transition number 23456 in 16-bit form.

For readability purposes, the 32-bit AS range is written in two parts. The old AS system ranges from 0.1 to 0.65535; the new AS system ranges from 1.0 to 65535.65535.

AS numbers from 65512 to 65535 are still reserved for private usage in the new system.

## BGP Routing Between Autonomous Systems

- BGP is used to provide an interdomain routing system.
- BGP guarantees the exchange of loop-free routing information.
- BGP works differently than IGPs:
  - BGP is a PBR protocol.
  - Control traffic flow using multiple BGP path attributes.







The main goal of BGP is to provide an interdomain routing system that guarantees loop-free exchange of routing information between autonomous systems. Routers exchange information about paths to destination networks.

BGP is a successor of EGP, which was developed to isolate networks from each other as the Internet grew.

There are many RFCs relating to BGP4, which is the current version of BGP. These RFCs include 1772, 1773, 1774, 1930, 1966, 1997, 1998, 2042, 2385, 2439, 2545, 2547, 2796, 2858, 2918, 3065, 3107, 3392, 4223, and 4271.

BGP4 has many enhancements over earlier protocols. The Internet uses BGP4 extensively to connect ISPs and to connect enterprises to ISPs.

BGP4 and its extensions are the only acceptable versions of BGP that are available for use on the public-based Internet. BGP4 carries a network mask for each advertised network and supports both variable-length subnet masking (VLSM) and CIDR. BGP4 predecessors did not support these capabilities, which are currently mandatory on the Internet.

When using CIDR on a core router for a major ISP, the IP routing table—which is composed mostly of BGP routes—has more than 175,000 CIDR blocks. Not using CIDR at the Internet level would cause the IP routing table to have more than 2,000,000 entries. Using BGP4 and CIDR prevents the Internet routing table from becoming too large to interconnect millions of users.

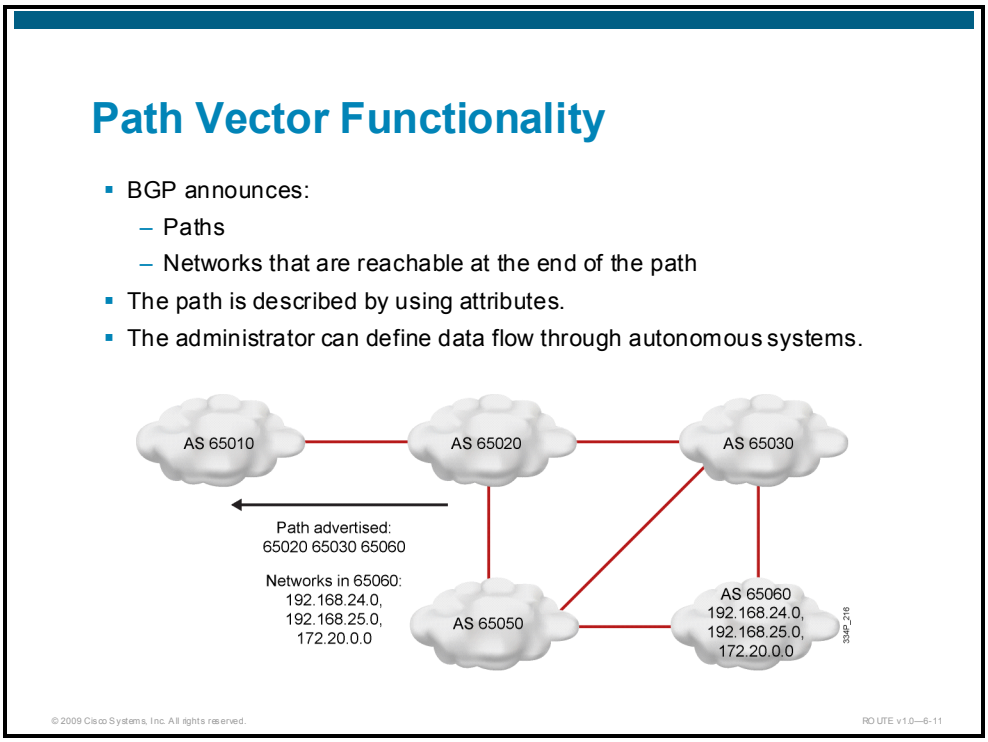
# Comparison with IGPs

BGP works differently than IGPs. An internal routing protocol looks for the quickest path from one point in a corporate network to another based on certain metrics. RIP uses hop counts that attempt to cross the least number of Layer 3 devices to reach the destination network. OSPF and EIGRP look for the best speed that is available according to the bandwidth statement on the interface. All internal routing protocols consider the path cost to get somewhere.

In contrast, BGP—an external routing protocol—does not consider speed to determine the best path. Instead, BGP is a policy-based routing (PBR) protocol that allows an AS to control traffic flow using multiple BGP path attributes. BGP allows a provider to use all its bandwidth by manipulating these path attributes.

# Path Vector Functionality

This topic describes how BGP uses path vector functionality.

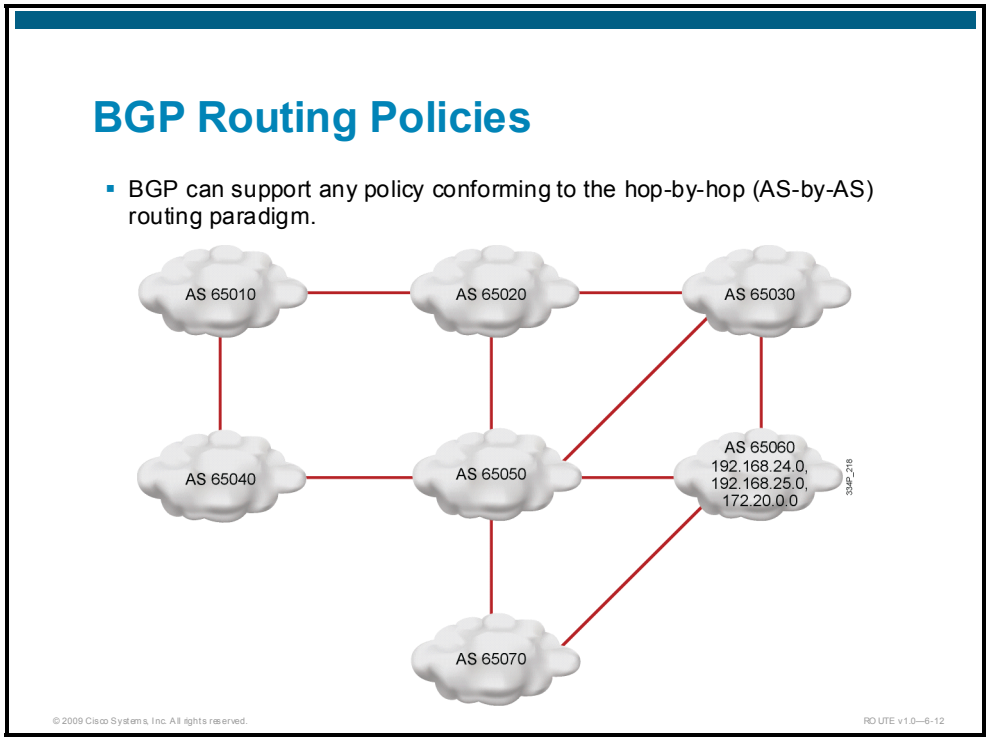



Internal routing protocols announce a list of networks and the metrics to get to each network. In contrast, BGP routers exchange network reachability information, called path vectors, which are made up of path attributes (like metrics). The path vector information includes a list of the complete path of BGP AS numbers (hop by hop) that are necessary to reach a destination network and the networks that are reachable at the end of the path. Other attributes include the IP address to get to the next AS (the next-hop attribute) and an indication of how the networks at the end of the path were introduced into BGP (the origin code attribute).

This AS path information is useful to construct a graph of loop-free autonomous systems and is used to identify routing policies so that restrictions on routing behavior can be enforced based on the AS path.

The AS path is always loop-free. A router that is running BGP does not accept a routing update that already includes the router AS number in the path list, because the update has already passed through its AS, and accepting it again would result in a routing loop.

An administrator can define policies or rules about how data will flow through the autonomous systems.




BGP allows routing policy decisions at the AS level to be enforced. These policies can be implemented for all networks that are owned by an AS, for a certain CIDR block of network numbers (prefixes), or for individual networks or subnetworks.

BGP specifies that a BGP router can advertise to neighboring autonomous systems only those routes that it uses itself. This rule reflects the hop-by-hop routing paradigm that the Internet generally uses.

The hop-by-hop routing paradigm does not support all possible policies. For example, BGP does not enable one AS to send traffic to a neighboring AS, intending that the traffic takes a different route from that taken by traffic that originates in that neighboring AS. In other words, how a neighboring AS routes traffic cannot be influenced, but how traffic gets to a neighboring AS can be influenced. However, BGP supports any policy that conforms to the hop-by-hop routing paradigm.

Because the Internet currently uses the hop-by-hop routing paradigm only, and because BGP can support any policy that conforms to that paradigm, BGP is highly applicable as an interautonomous system (inter-AS) routing protocol.

## Example: BGP Routing Policies

For example, in the figure, the following paths are possible for AS 65010 to reach networks in AS 65060 through AS 65020:

- 65020 65030 65060
- 65020 65050 65060
- 65020 65030 65050 65070 65060
- 65020 65050 65030 65060
- 65020 65050 65070 65060

AS 65010 does not see all these possibilities.

AS 65020 advertises to AS 65010 only its best path of 65020 65030 65060, the same way that IGPs announce only their best least-cost routes. This path is the only path through AS 65020 that AS 65010 sees. All packets that are destined for 65060 through 65020 will take this path.

Even though other paths exist, AS 65010 can only use what AS 65020 advertises for the networks in AS 65060. The AS path that is advertised, 65020 65030 65060, is the AS-by-AS (hop-by-hop) path that AS 65020 will use to reach the networks in AS 65060. AS 65020 will not announce another path, such as 65020 65050 65030 65060, because it did not choose that as the best path based on the BGP routing policy in AS 65020.

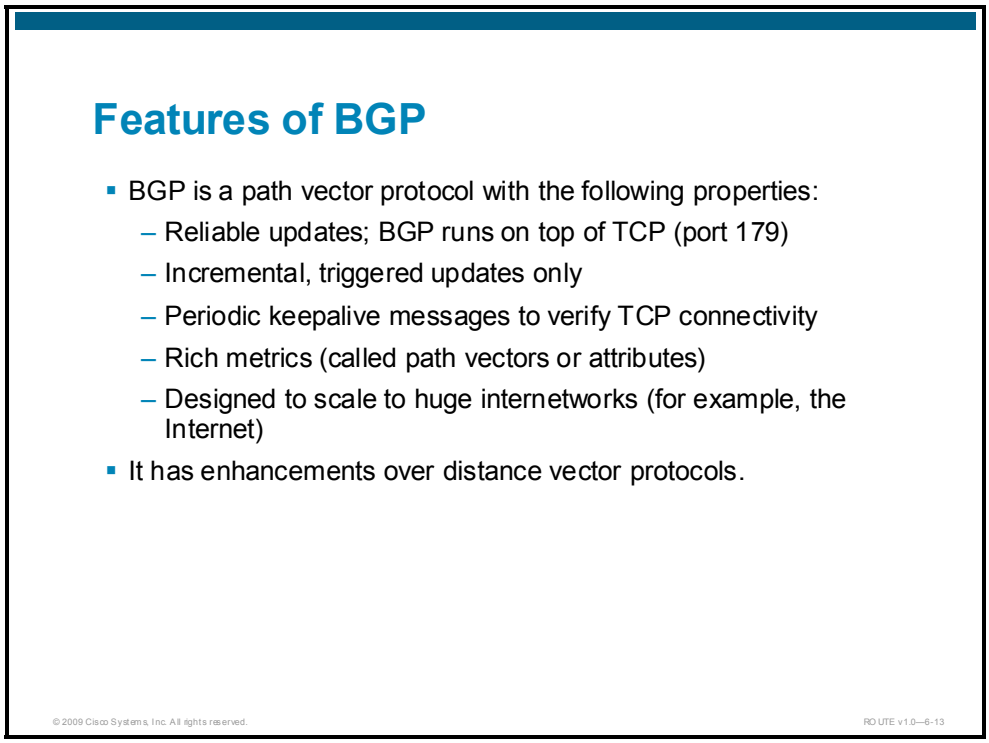
AS 65010 will not learn about the second-best path or any other paths from AS 65020 unless the best path of AS 65020 becomes unavailable.

Even if AS 65010 were aware of another path through AS 65020 and wanted to use it, AS 65020 would not route packets along that other path, because AS 65020 selected 65030 65060 as its best path and all AS 65020 routers will use that path as a matter of BGP policy. BGP does not let one AS send traffic to a neighboring AS, intending that the traffic takes a different route from that taken by traffic that is originating in the neighboring AS.

To reach the networks in AS 65060, AS 65010 can choose to use AS 65020, or it can choose to go through the path that AS 65040 is advertising. AS 65010 selects the best path to take based on its own BGP routing policies.

# Features of BGP

This topic describes the features of BGP in terms of deployment, enhancements over other distance vector routing protocols, and database types.




BGP is categorized as an advanced distance vector protocol, but it is actually a path vector protocol. BGP is very different from standard distance vector protocols like RIP.

BGP uses TCP as its transport protocol, which provides reliable connection-oriented delivery. BGP assumes that its communication is reliable; therefore, it does not have to implement retransmission or error recovery mechanisms. BGP uses TCP port 179. Two routers that are using BGP form a TCP connection with one another and exchange messages to open and confirm the connection parameters. These two BGP routers are called “peer routers,” or “neighbors.”

After the connection is made, BGP peers exchange complete routing tables. However, because the connection is reliable, BGP peers send only changes (incremental, or triggered, updates) after that. Reliable links do not require periodic routing updates; therefore, routers use triggered updates instead. BGP sends keepalive messages, like the hello messages that are sent by OSPF, Intermediate System-to-Intermediate System (IS-IS), and EIGRP.

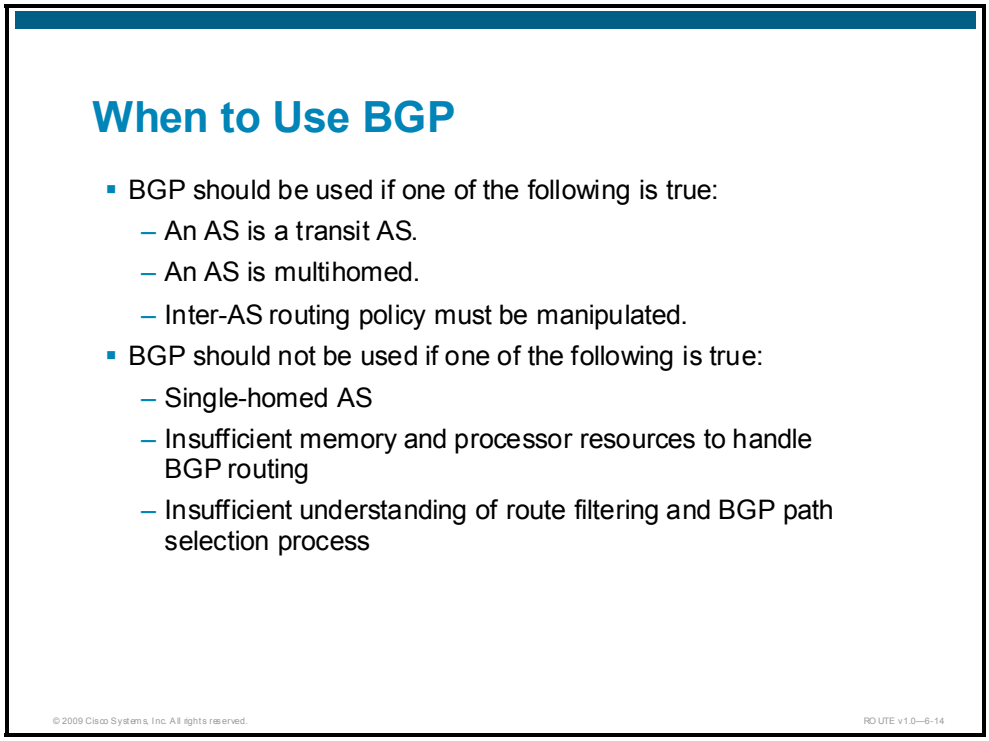
BGP is the only IP routing protocol to use TCP as its transport layer. OSPF, IGRP, and EIGRP reside directly above the IP layer, and RIP version 1 (RIPv1) and RIP version 2 (RIPv2) use User Datagram Protocol (UDP) for their transport layer.

OSPF and EIGRP have their own internal function to ensure that update packets are explicitly acknowledged. These protocols use a one-for-one window so that if either OSPF or EIGRP has multiple packets to send, the next packet cannot be sent until OSPF or EIGRP receive an acknowledgment from the first update packet. This process can be very inefficient and cause latency issues if thousands of update packets must be exchanged over relatively slow serial links. OSPF and EIGRP rarely have thousands of update packets to send. EIGRP can hold more than 100 networks in one EIGRP update packet, so 100 EIGRP update packets can hold up to 10,000 networks, and most organizations do not have 10,000 subnets in their corporations.

BGP, however, has more than 175,000 networks (and growing) on the Internet to advertise, and it uses TCP to manage the acknowledgment function. TCP uses a dynamic window, which allows 65,576 bytes to be outstanding before it stops and waits for an acknowledgment. For example, if 1000-byte packets are being sent, there would need to be 65 packets that have not been acknowledged for BGP to stop and wait for an acknowledgment when using the maximum window size.

TCP is designed to use a sliding window, where the receiver will acknowledge at the halfway point of the sending window. This method allows any TCP application, such as BGP, to continue to stream packets without having to stop and wait, as would be required with OSPF or EIGRP.




BGP allows ISPs to communicate and exchange packets. These ISPs have multiple connections to each other and agreements to exchange updates. BGP is used to implement the agreements between two or more autonomous systems.

Improper controlling and filtering of BGP updates can potentially allow an outside AS to affect the traffic flow to your AS. It is important to know how BGP operates and how to configure it properly to prevent this situation.

For example, if a customer is connected to ISP A and ISP B (for redundancy), the goal is to implement a routing policy to ensure that ISP A does not send traffic to ISP B via the AS of the customer. The customer does not want to waste valuable resources and bandwidth within its AS to route traffic for its ISPs, but will want to be able to receive traffic that is destined to its AS through each ISP.

BGP should be used in the following cases:

- If an AS is a transit AS, where packets transit the AS to reach other autonomous systems
- If an AS is multihomed with multiple connections to other autonomous systems
- If an inter-AS routing policy must be manipulated, where path selection for traffic that is entering and leaving the AS must be influenced

BGP is not always an appropriate solution to interconnect autonomous systems. There are several cases where BGP should not be used:

- When the network is a single-homed AS with a single connection to the Internet or other AS. An AS with one exit path uses the default route as the most appropriate solution. BGP would unnecessarily use router CPU resources and memory.
- When there are insufficient memory and processor resources in the network edge router to process BGP routing.

- When there is insufficient understanding of route filtering and the BGP path selection process.
- If the routing policy that is implemented in an AS is consistent with the policy in the ISP AS, it is not necessary or desirable to configure BGP in that AS.

## BGP Databases

- BGP neighbor table:
  - List of BGP neighbors
- BGP table:
  - List of all networks learned from each BGP neighbor
  - Multiple paths to same destination network can be present
  - Each path associated with BGP attributes
- IP routing table (forwarding database):
  - List of best paths to destination networks used to forward traffic




A router that is running BGP keeps its own tables to store BGP information that it receives from and sends to other routers, including a neighbor table, a BGP table (also called a forwarding database or topology database), and an IP routing table.

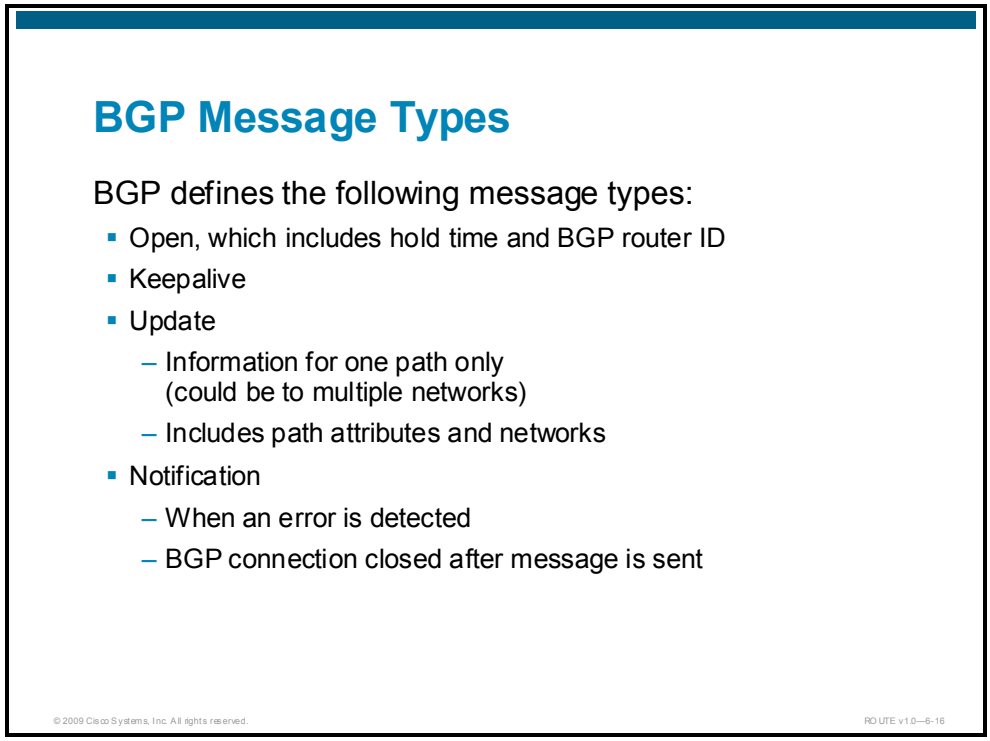
For BGP to establish an adjacency, it must be explicitly configured for each neighbor. BGP forms a TCP relationship with each of the configured neighbors and keeps track of the state of these relationships by periodically sending a BGP/TCP keepalive message.

**Note** The BGP sends BGP/TCP keepalives by default every 60 seconds.

After establishing an adjacency, the neighbors exchange the BGP routes that are in their IP routing table. Each router collects these routes from each neighbor that successfully establishes an adjacency and then places the routes in its BGP forwarding database. All routes that have been learned from each neighbor are placed into the BGP forwarding database. The best routes for each network are selected from the BGP forwarding database using the BGP route selection process and are then offered to the IP routing table.

Each router compares the offered BGP routes to any other possible paths to those networks, and the best route—based on administrative distance—is installed in the IP routing table.

EBGP routes (BGP routes that are learned from an external AS) have an administrative distance of 20. IBGP routes (BGP routes that are learned from within the AS) have an administrative distance of 200.




The four BGP message types are open, keepalive, update, and notification.

After a TCP connection is established, the first message that is sent by each side is an open message. If the open message is acceptable, the side that receives the message sends a keepalive message confirming the open message. After the receiving side confirms the open message and establishes the BGP connection, the BGP peers can exchange any update, keepalive, and notification messages.

BGP peers initially exchange their full BGP routing tables. Incremental updates are sent only after topology changes in the network occur. BGP peers send keepalive messages to ensure that the connection between the BGP peers still exists, and send notification packets in response to errors or special conditions.

Here are more details about the different types of BGP messages:

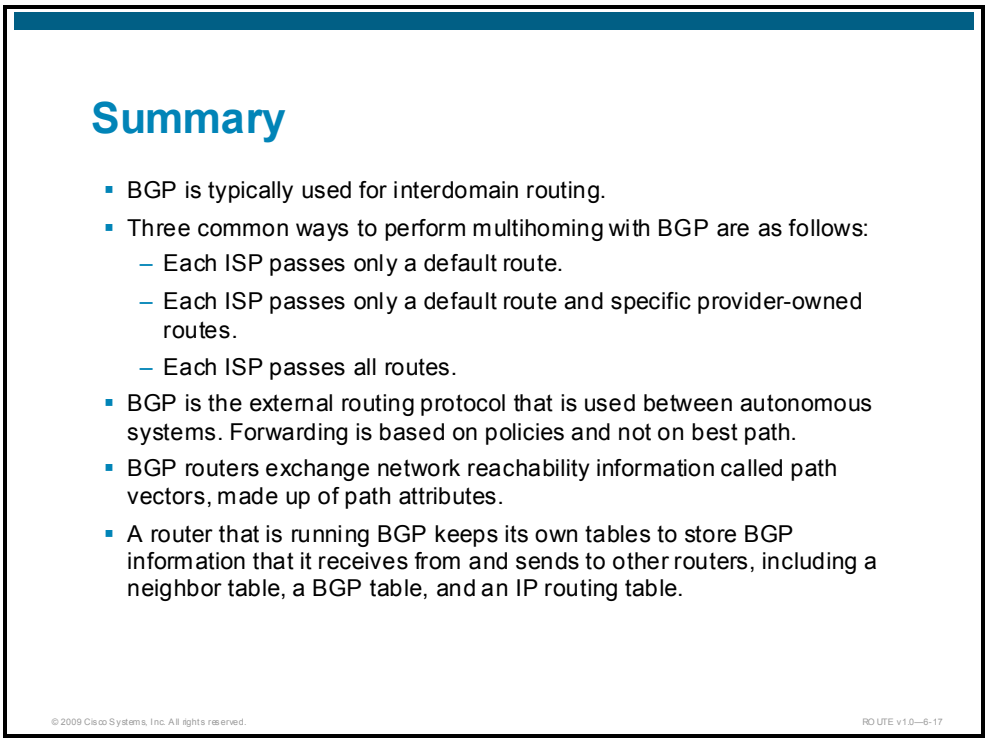
- **Open message**: An open message includes the following information:
  - **Version number**: The suggested version number. The highest common version that both routers support is used. Most BGP implementations today use BGP4.
  - **AS number**: The AS number of the local router. The peer router verifies this information. If it is not the AS number that is expected, the BGP session is ended.
  - **Hold time**: Maximum number of seconds that can elapse between the successive keepalive and update messages from the sender. On receipt of an open message, the router calculates the value of the hold timer by using whichever is smaller: its configured hold time or the hold time that was received in the open message.
  - **BGP router ID**: This 32-bit field indicates the BGP ID of the sender. The BGP ID is an IP address that is assigned to that router, and it is determined at startup. The BGP router ID is chosen in the same way that the OSPF router ID is chosen—it is the highest active IP address on the router unless a loopback interface with an IP address exists. In this case, the router ID is the highest loopback IP address. The router ID can also be statically configured.

- **Optional parameters**: These parameters are type, length, value (TLV) encoded. An example of an optional parameter is session authentication.

- **Keepalive message**: BGP keepalive messages are exchanged between BGP peers frequently enough to keep the hold timer from expiring. If the negotiated holdtime interval is 0, then periodic keepalive messages are not sent. A keepalive message consists of only a message header.
- **Update message**: A BGP update message has information on one path only; multiple paths require multiple update messages. All the attributes in the update message refer to that path, and the networks are those that can be reached through that path. An update message can include the following fields:
  - **Withdrawn routes**: This list displays IP address prefixes for routes that are withdrawn from service, if any.
  - **Path attributes**: These attributes include the AS path, origin, local preference, and so on (as described later in this module). Each path attribute includes the attribute TLV. The attribute type consists of the attribute flags, followed by the attribute type code.
  - **Network-layer reachability information**: This field contains a list of IP address prefixes that are reachable by this path.
- **Notification message**: A BGP notification message is sent when an error condition is detected; the BGP connection is closed immediately after this is sent. Notification messages include an error code, an error subcode, and data that is related to the error.

# Summary

This topic summarizes the key points that were discussed in this lesson.



Lesson 3

# Comparing the Functions and Uses of EBGP and IBGP

## Overview

This lesson explains important terminology that is used in establishing Border Gateway Protocol (BGP) peering relationships.

This lesson describes and defines External Border Gateway Protocol (EBGP) and Internal Border Gateway Protocol (IBGP) neighbors as well as the requirements for establishing peering relationships. In addition, this lesson examines the difference between an interior gateway protocol (IGP) and BGP and explains the reason for having all routers in the transit path within an autonomous system (AS) that is running IBGP.

Understanding the relationship between various types of BGP routers and the common terminology that is used when you are discussing these routers is necessary for troubleshooting connectivity issues between BGP neighbors. The following terms are explained: BGP speaker, BGP router, BGP neighbor, and BGP peer.

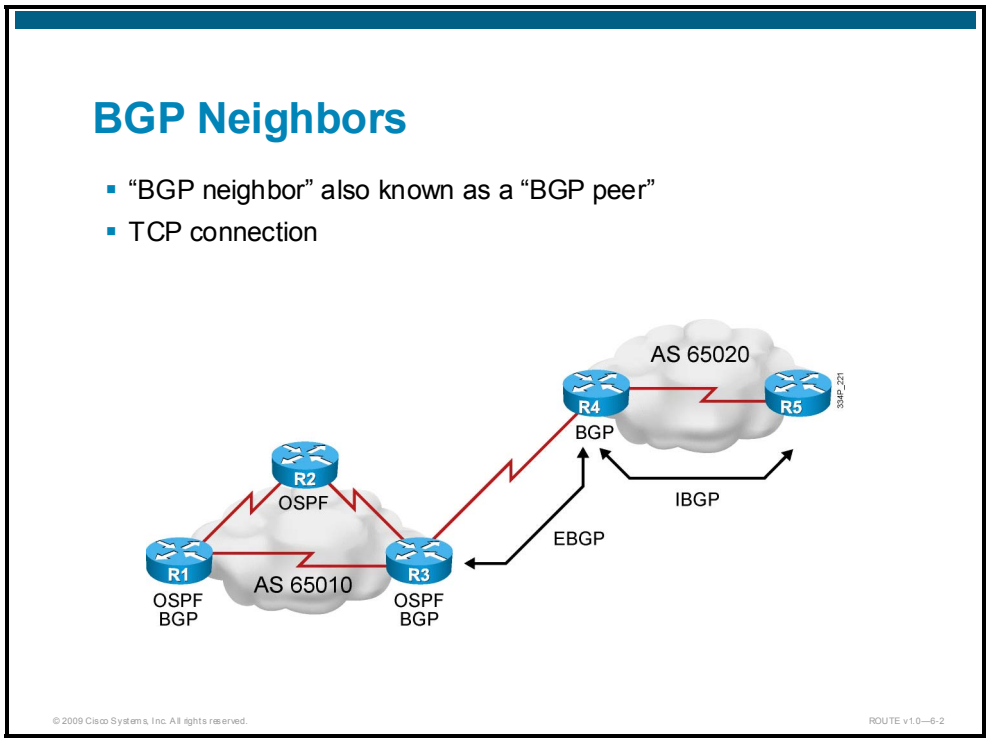
## Objectives

Upon completing this lesson, you will be able to compare and contrast the requirements for establishing EBGP-to-IBGP neighbor relationships. This ability includes being able to meet these objectives:

- Define BGP neighbor relationships
- Establish EBGP neighbor relationships
- Establish IBGP neighbor relationships

# BGP Neighbor Relationships

This topic describes terms that are used for BGP routers and their relationships.



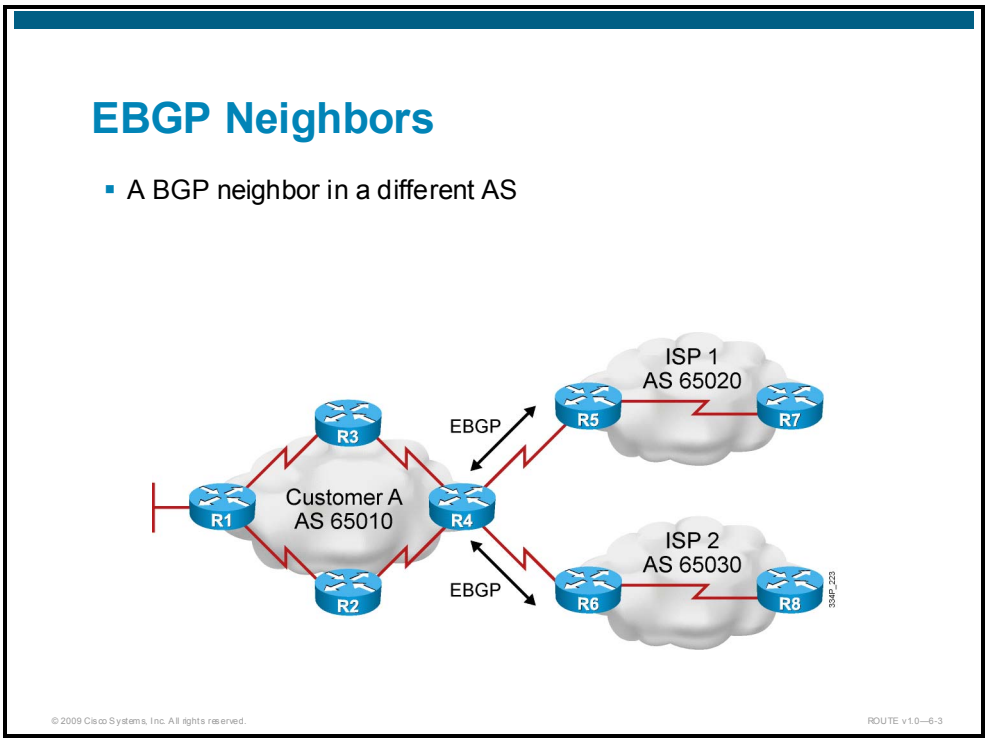

No single router can manage communications with all the routers that run BGP. There are tens of thousands of routers that run BGP, and these routers are connected to the Internet, representing more than 21,000 autonomous systems.

A BGP router forms a direct neighbor relationship with a limited number of other BGP routers. Through these BGP neighbors, a BGP router learns of the paths that are available through the Internet to reach any advertised network. Any router that runs BGP is known as a "BGP speaker." The term "BGP peer" has a specific meaning—it is a BGP speaker that is configured to form a neighbor relationship with another BGP speaker for directly exchanging BGP routing information with each other. A BGP speaker has a limited number of BGP neighbors with which it peers and forms a TCP-based relationship.

BGP peers are also known as "BGP neighbors" and can be either internal or external to the AS. The IBGP peer typically forms the neighbor relationship inside the ISP network. The EBGP peer forms the neighbor relationship between the enterprise network and the ISP. External neighbors, as well as internal neighbors, require a TCP connection to be established. The processing of the BGP routes and its attributes is typically different, as is the connection type. External neighbors are directly connected. A network that is assigned to the link between neighbors, as well as the next-hop IP address, must be reachable for routing purposes.

# Establishing EBGP Neighbor Relationships

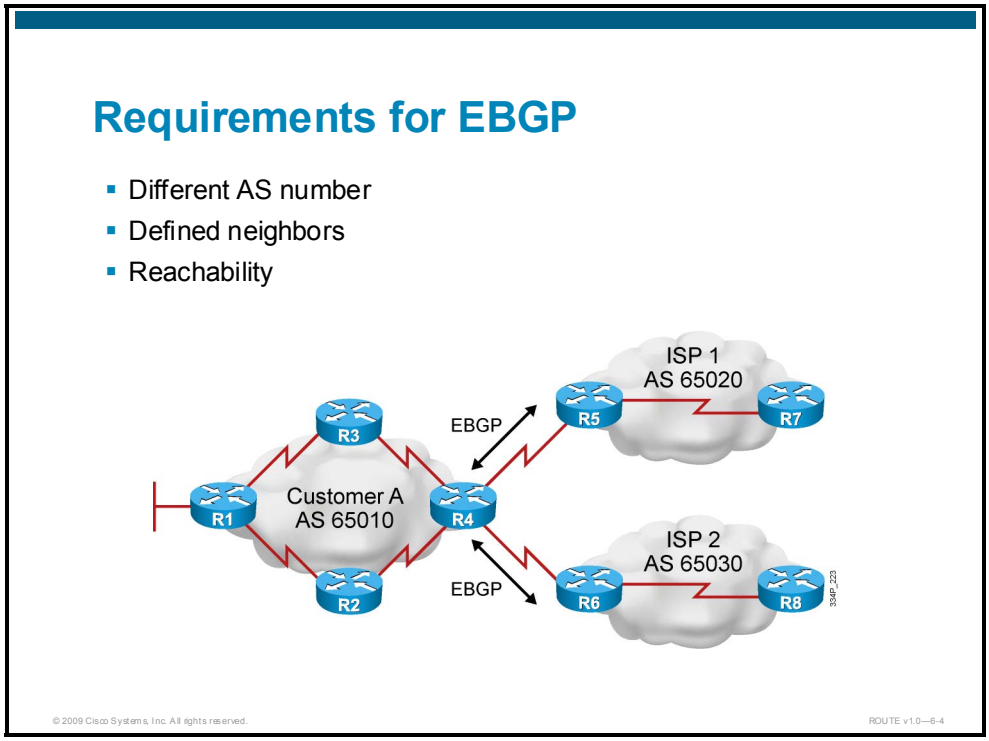
This topic describes the requirements for establishing an EBGP neighbor relationship.




Recall that when BGP is running between routers in different autonomous systems, it is called EBGP. By default, routers that are running EBGP are directly connected to each other.

An EBGP neighbor is a router outside a home AS. An enterprise network can have a connection to one or several ISPs, and the ISPs themselves might be connected to several other ISPs as well. For each such connection between different autonomous systems, there is an EBGP session that is required between EBGP neighboring routers. EBGP neighbors are directly connected, and they establish a TCP session before exchanging BGP updates.

When multiple different autonomous systems are connected to each other and an enterprise network is connected to multiple ISPs, BGP runs between the ISPs and the enterprise network. In the figure, the Customer A network is connected to two ISPs, and an EBGP session is established between routers R3 and R5 as well as between R4 and R6. Routers establish neighbor relationships and exchange BGP routing updates with one another. In the figure, Customer A routers learn the paths to the external autonomous systems from their respective EBGP neighbors.




There are several different requirements for establishing an EBGP neighbor relationship:

- **Different AS number**: EBGP neighbors must reside in different autonomous systems to be able to form an EBGP relationship.
- **Defined neighbors**: A TCP session must be established before starting BGP routing update exchanges.
- **Reachability**: EBGP neighbors must be directly connected and IP addresses on that link must be reachable inside each AS.

IGP is the routing protocol that runs inside an AS. An IGP is not run between the EBGP neighbors that are residing in different autonomous systems. For two routers to exchange BGP routing updates, the TCP-reliable transport layer on each side must successfully pass the TCP three-way handshake before a BGP session can be established. Therefore, the IP address that is used in the BGP neighbor command must be reachable without using an IGP, which can be accomplished by pointing at an address that is reachable through a directly connected network or by using static routes to that IP address. Generally, the neighbor address that is used is the address on a network that is directly connected.

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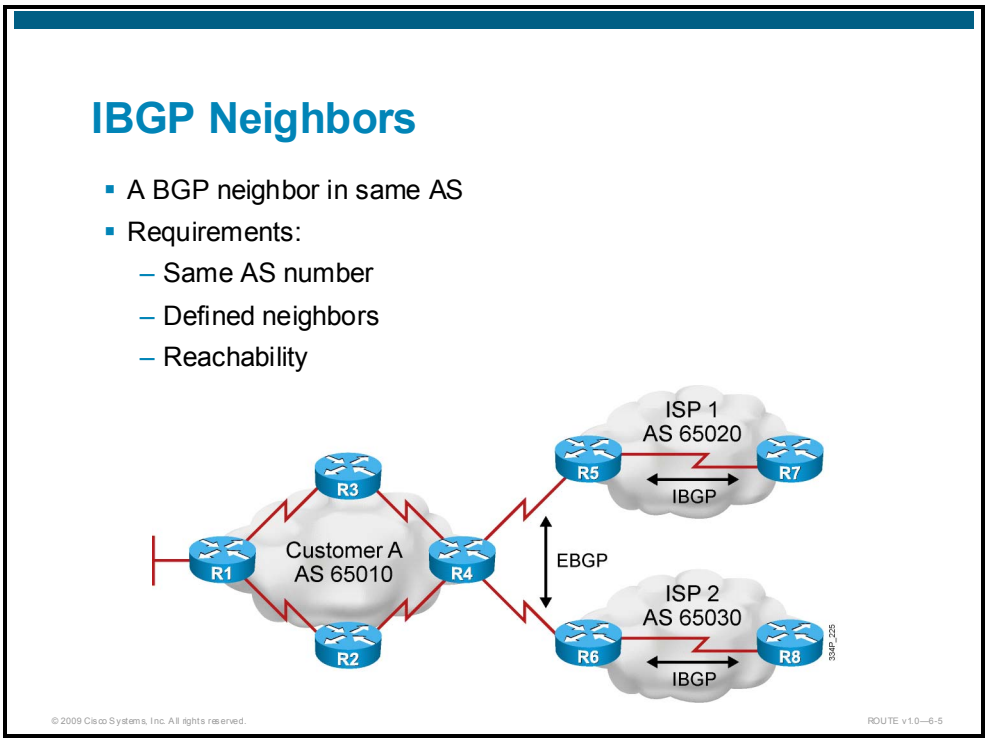



Recall that BGP that runs between routers within the same AS is called IBGP. IBGP runs within an AS to exchange BGP information so that all BGP speakers have the same BGP routing information about outside autonomous systems.

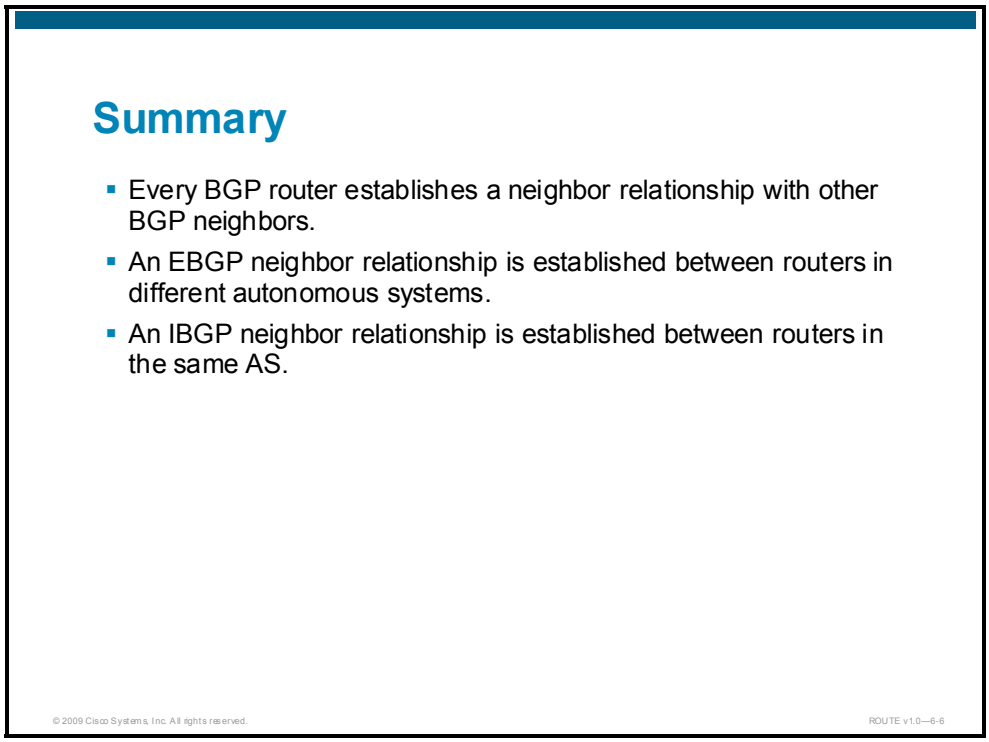
When multiple routers in an AS are running BGP, they exchange BGP routing updates with one another. In the figure, R4 learns the paths to the external autonomous systems from its EBGP neighbors (R5 and R6). If the link between R3 and R4 goes down, R3 must learn new routes to the external autonomous systems. Other BGP routers within AS 65010 that were using R3 to get to external networks must also be informed that the path through R3 is not available. Those BGP routers within AS 65010 need to have the alternate paths through R4 in their BGP forwarding database. IBGP is typically established between the customer edge routers (CE routers) inside the enterprise network autonomous system as well as between the routers inside each ISP.

There are several different requirements for establishing an IBGP neighbor relationship:

- **Same AS number:** IBGP neighbors must reside in the same AS to be able to form an IBGP relationship.
- **Defined neighbors:** A TCP session must be established between neighbors before exchanging BGP routing updates.
- **Reachability:** IBGP neighbors must be reachable; therefore, IGP typically runs inside an AS.

# Summary

This topic summarizes the key points that were discussed in this lesson.



Lesson 4

# Configuring and Verifying Basic BGP Operations

## Overview

This lesson presents the commands and configuration examples to configure Border Gateway Protocol (BGP) properly.

After a successful configuration, BGP will be able to establish a neighbor relationship, set the next-hop address, set the source IP address of a BGP update, and announce networks to other BGP routers.

A router that is running BGP goes through several neighbor states through which BGP progresses to establish a BGP session, and offers hints for troubleshooting BGP, because the session can be stuck in the stuck-in-active (SIA) or idle state. External BGP (EBGP) and Internal BGP (IBGP) configuration is explained, as well as authentication between neighbors.

This lesson also shows how to use the **show** and **debug** commands for troubleshooting BGP, providing a baseline for troubleshooting. A thorough understanding of this material is necessary to use BGP.

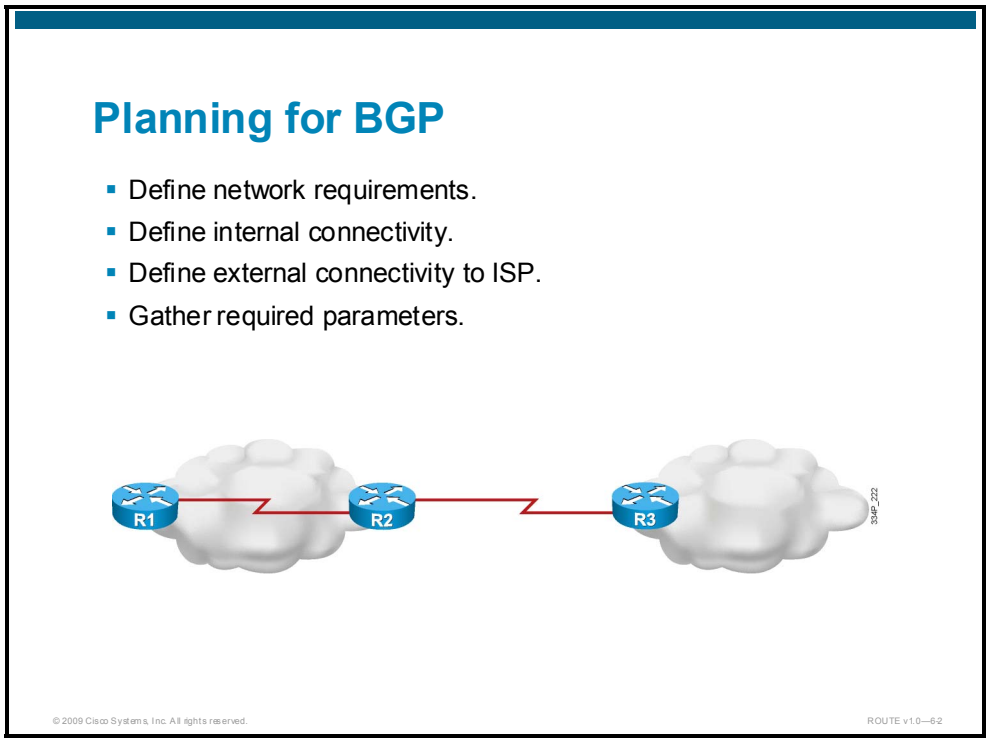
## Objectives

Upon completing this lesson, you will be able to implement BGP operations for ISP connections in an enterprise network. This ability includes being able to meet these objectives:

- Identify specifications for implementing BGP
- Establish internal and external BGP neighbor relationships
- Determine how to shut down a BGP neighbor
- Understand BGP configuration considerations
- Identify BGP neighbor states
- Implement authentication in BGP
- Create an example of activating basic BGP
- Configure BGP verification

# Specifications for Implementing BGP

This topic describes the types of information that are contained in a typical implementation plan.



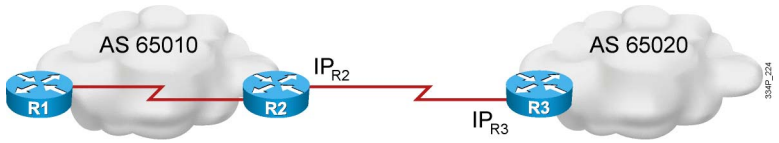

Before BGP configuration, a network administrator must define the network requirements, including the internal connectivity for IBGP design and configuration as well as the external connectivity to the ISP for EBGP design and configuration.

The next step is to gather all the parameters that are needed to provide enough details for a network operator to start the BGP configuration.

## Requirements for Basic BGP Configuration

- AS numbers
- Neighbors (IP addresses)
- Networks to be advertised







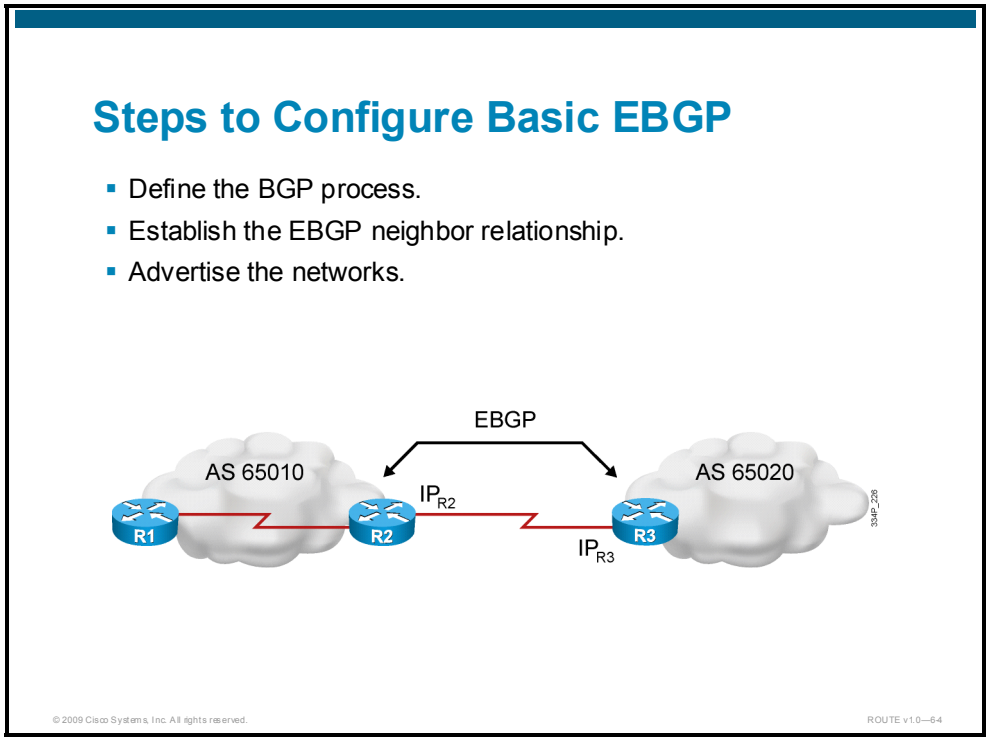
The requirements to configure basic BGP include the following details:

- Autonomous system (AS) numbers (your own and all remote AS numbers)
- All the neighbors (peers) that are involved in BGP, and IP addressing that is used among the BGP neighbors
- Networks that need to be advertised into BGP

A typical BGP configuration involves configuring BGP between a customer network and an ISP. This process is called EBGP. Many times, IBGP is required, as well as all the collected details for a complete configuration.

# Establishing Internal and External BGP Neighbors

This topic describes the process of activating a BGP session for external and internal neighboring routers.



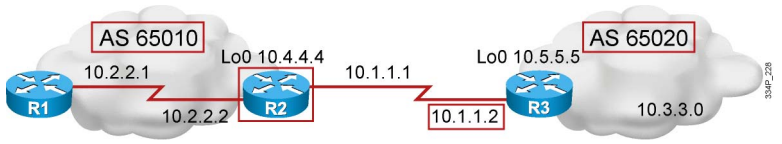

Basic EBGP configuration requires three main steps:

1. Define the BGP process.
2. Establish the neighbor relationship.
3. Advertise the networks into BGP.

To perform these steps, information is needed about the neighbors, which AS numbers are used, which IP address is used as the IP address on a remote router (neighbor), and which network will be advertised.

## Define BGP Process and Activate EBGP Session




```
R2(config)#
router bgp 65010
```

- Define the BGP process locally with a local AS number.

```
R2(config-router)#
neighbor 10.1.1.2 remote-as 65020
```

- Activate EBGP session to the neighbor:
  - Remote router IP address and AS number




The syntax of the basic BGP configuration commands is like the syntax for configuring internal routing protocols. However, there are significant differences in how BGP functions.

Use the **router bgp 65010** command to notify the router that any subsequent subcommands belong to this routing process. This command also identifies the local AS in which this router belongs. AS 65010 is used as an example. The router needs to be informed of the AS number so that it can determine whether the BGP neighbors that are to be configured next are IBGP or EBGP neighbors.

The command enters router configuration mode. The **route bgp** command alone cannot activate BGP on a router. At least one subcommand must be entered under the **router bgp** command to activate the BGP process on the router. A router can only be in one AS at any given time.

If the router is placed in AS 65010 and an attempt is then made to configure with a new **router bgp 65020** command, the router indicates that it is currently configured for AS 65010.

To establish a connection to another AS, insert the AS number with a **neighbor** command in addition to the **router bgp** command so that the router can properly identify the relationship between the neighboring router and itself.

| **Note** | Only one instance of BGP can be configured on the router at a single time. |
|---|---|

Use the **neighbor 10.1.1.2 remote-as 65020** command to activate an EBGP session for a neighboring router.

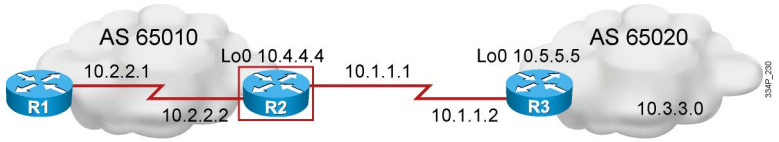
This command identifies a peer router with which the local router will establish a session and is mandatory for the establishment of each neighboring router relationship.

The address that is used in this command is the destination address for all BGP packets that are going to the neighboring router. For BGP to pass BGP routing information, this address must be reachable, because BGP attempts to establish a TCP session and exchange BGP updates with the device at this IP address. An EBGP session is typically established between directly connected neighbors.

The AS number that is a part of this command is used to identify whether this neighbor is an EBGP neighbor or an IBGP neighbor. If the AS number is the same as the AS number for this router, that neighbor is an IBGP neighbor, and the IP address that is listed in this **neighbor** command does not have to be directly connected. If the AS number is different from the AS number for this router, this neighbor is an EBGP neighbor, and the address in this **neighbor** command must be directly connected by default. In the figure, the AS is different, and an EBGP neighbor relationship is established.

For more details about the **neighbor remote-as** and **router bgp** commands, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

## Advertise Networks




Option 1:

```
R2(config-router)#
network 10.2.2.0 mask 255.255.255.0
network 10.4.4.0 mask 255.255.255.0
```

- Configure the local networks to be advertised and include them in BGP

Option 2:

- Redistribution from IGP to BGP




Two options exist when advertising networks into the BGP. The first option is using the **network** command to define the networks that are required. The second option is the redistribution of interior gateway protocol (IGP) routes into the BGP routing process. Redistribution was described in a separate module. The command is explained in the following pages.

Use the **network 10.2.2.0 mask 255.255.255.0** command to permit BGP to advertise 10.2.2.0 if it is present in the IP routing table.

The **network** command determines networks that the router originates. This concept is different from using the **network** command when configuring IGP. Unlike with IGP, the **network** command does not start BGP on specific interfaces; rather, it indicates to BGP which networks it should originate from this router.

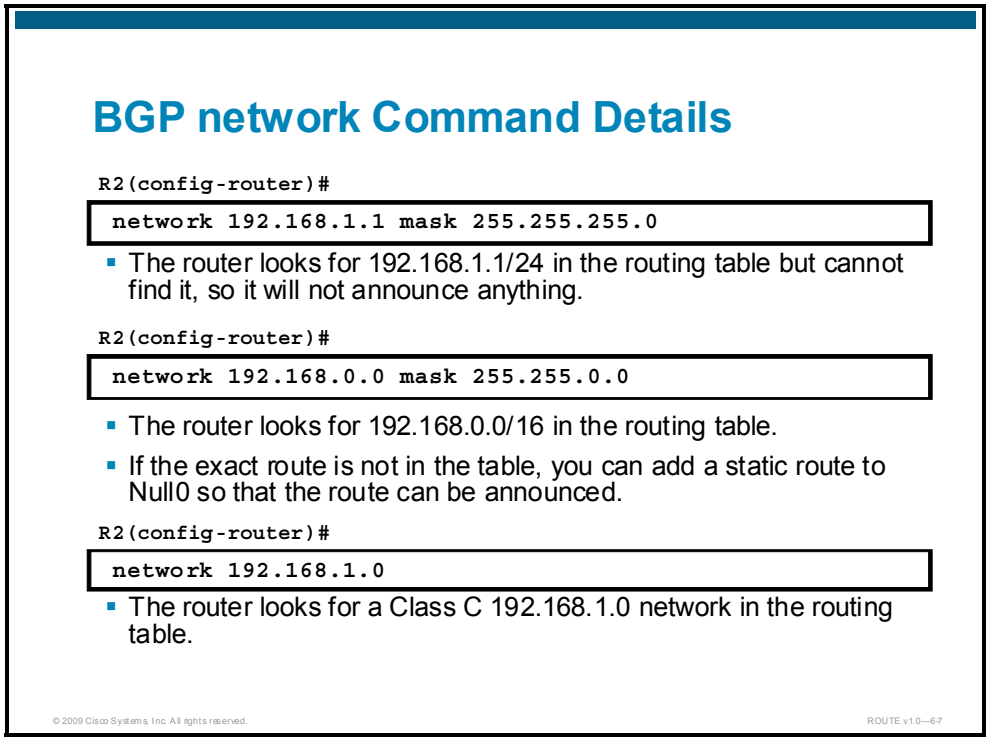
The **mask** parameter indicates that BGP version 4 (BGP4) can manage subnetting and supernetting. The list of **network** commands must include all networks in the AS that are to be advertised, not just those that are locally connected to the router.

Before Cisco IOS Release 12.0, there was a limit of 200 **network** commands per BGP router. This limit has been removed. The resources of the router, such as the configured NVRAM or RAM, determine the maximum number of **network** commands that can be used.

The sole purpose of the **network** command is to notify BGP of the networks that are to be advertised. Without the **mask** option, this command announces only the classful network number. At least one subnet of the specified major network must be present in the IP routing table to allow BGP to start announcing the classful network as a BGP route.

However, if a network mask option is specified, an exact match to the network (both address and mask) must exist in the routing table. Before BGP announces a route, it checks to see whether it can reach it.

For more details about the **network** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html




For example, if the command **network 192.168.1.1 mask 255.255.255.0** is misconfigured, BGP looks for exactly 192.168.1.1/24 in the routing table. It may find 192.168.1.0/24 or 192.168.1.1/32; however, it never finds 192.168.1.1/24. Because the routing table does not contain a specific match to the network, BGP does not announce the 198.168.1.1/24 network to any neighbors.

As another example, if **network 192.168.0.0 mask 255.255.0.0** is specified to advertise a classless interdomain routing (CIDR) block, BGP looks for 192.168.0.0/16 in the routing table. It may find 192.168.1.0/24 or 192.168.1.1/32; however, if it never finds 192.168.0.0/16, BGP does not announce the 192.168.0.0/16 network to any neighbors. In this case, the following static route can be configured toward the null interface so that BGP can find an exact match in the routing table:

**ip route 198.1.0.0 255.255.0.0 null0**

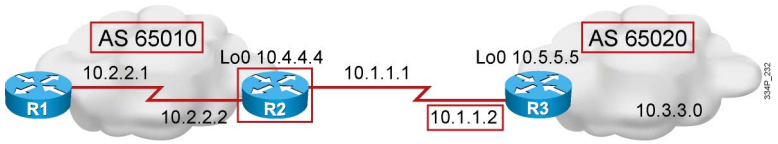
After finding an exact match in the routing table, BGP announces the 192.168.0.0/16 network to any neighbors.

If the **network 192.168.1.0** command is specified without the mask keyword, BGP looks for Class C 192.168.1.0/24 in the routing table.

| | |
|---|---|
| **Note** | The BGP **auto-summary** router configuration command determines how BGP processes redistributed routes. With BGP summarization enabled (with **auto-summary**), all redistributed subnets are summarized to their classful boundaries in the BGP table. When disabled (with **no auto-summary**), all redistributed subnets are present in their original form in the BGP table, so only those subnets would be advertised. In Cisco IOS Release 12.2(8)T, the default behavior of the **auto-summary** command was changed to disabled (**no auto-summary**); in earlier releases, the default was enabled (**auto-summary**). |

## Basic EBGP Configuration




Option 1

```
R2#
!
<output omitted>
!
router bgp 65010
 neighbor 10.1.1.2 remote-as 65020
 network 10.2.2.0 mask 255.255.255.0
 network 10.4.4.0 mask 255.255.255.0
!
```

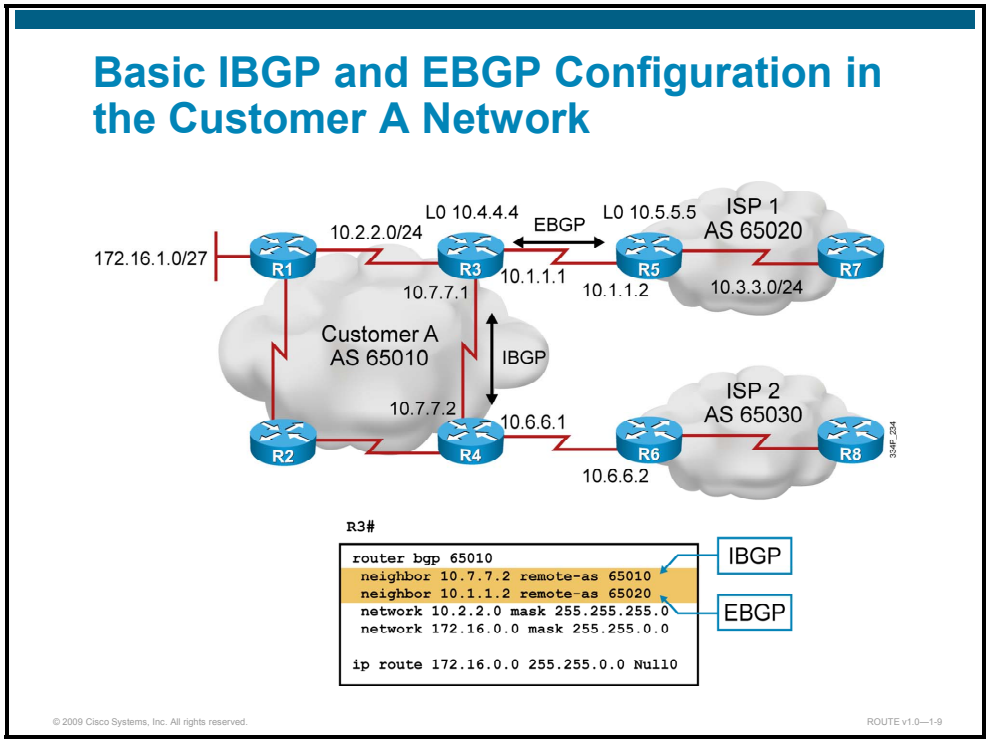
Option 2

```
R2#
!
<output omitted>
router ospf 10
 network 10.2.2.0 0.0.0.255 area 0
 network 10.4.4.0 0.0.0.255 area 0
!
router bgp 65010
 neighbor 10.1.1.2 remote-as 65020
 redistribute ospf
!
```




In option 1, router R2 is configured for EBGP configuration. The local AS number 65010 is used to enter BGP configuration mode. When defining the EBGP, the **neighbor remote-as** statement defines the relationship to the local AS number. The remote AS is different from the local AS, because the neighbor is declared as an EBGP neighbor. R2 will establish a TCP session and start exchanging BGP updates. R2 is configured to advertise two local networks to its neighbor. The exact network entries (10.2.2.0/24 and 10.4.4.0/24) must exist inside the routing table to accept and advertise networks inside the BGP process.

In option 2, R2 is configured for EBGP configuration, but its configuration to advertise the networks is different. The Open Shortest Path First (OSPF) protocol is used as an IGP on R2, and networks 10.2.2.0 and 10.4.4.0 are advertised in OSPF. To advertise the networks into BGP, redistribution from OSPF to BGP is configured.

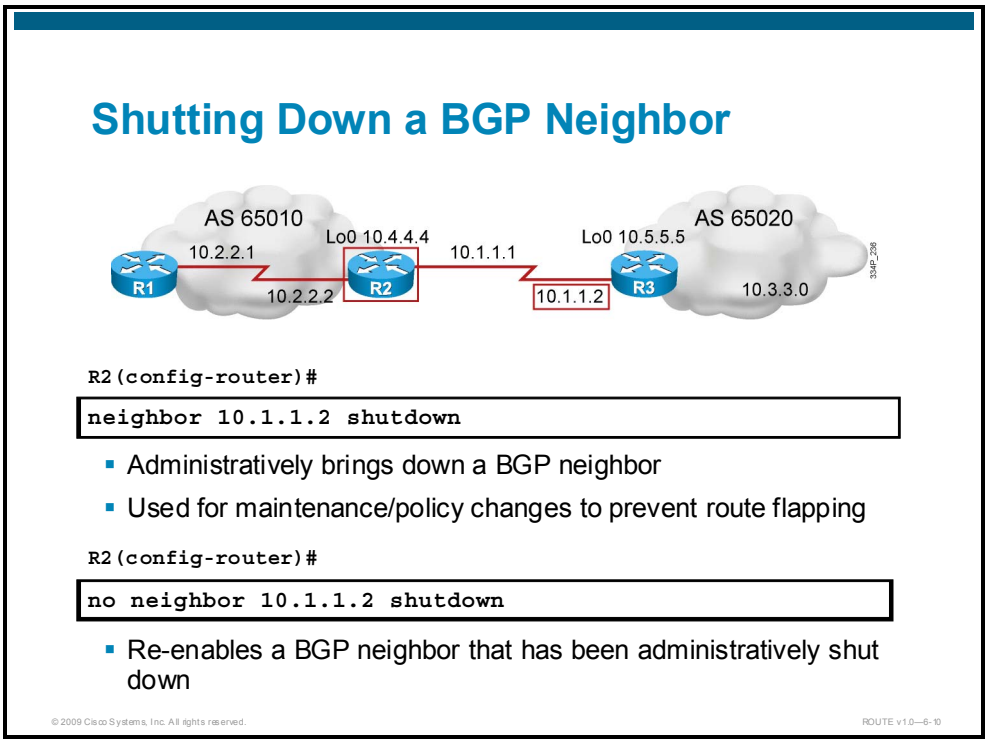



Customer edge routers (CE routers) are connected to provider edge routers (PE routers). EBGP is configured between CE and PE routers, because enterprise networks and ISPs have different AS numbers. If enterprise networks are dual-homed or multihomed, then typically two CE routers are configured for EBGP. To provide reliable connectivity to one or more ISPs, CE routers must exchange BGP routes as well. An IBGP session must be configured between two CE routers.

The figure shows typical BGP configuration of CE router R3. The EBGP neighbor relationship to R5 and IBGP neighbor relationship to R4 is configured. An IBGP session is established to the neighbor with the same AS number as its local AS number (AS 65010). An EBGP neighbor relationship is established with the neighbor with a different AS number (AS 65020) from the local AS number (AS 65010). Network commands are used to advertise two networks. Because network 172.16.0.0 is not directly connected, a static route to the Null0 interface is configured to advertise network 172.16.0.0 into BGP.

# Shutting Down a BGP Neighbor

This topic describes the process of administratively shutting down and re-enabling a BGP neighbor.




Use the **neighbor 10.1.1.2 shutdown** and **no neighbor 10.1.1.2 shutdown** commands to administratively shut down and re-enable a BGP neighbor.

If major policy changes are implemented for a neighboring router and multiple parameters are changed, the neighboring router must be administratively shut down, the changes must be implemented, and then the neighboring router must be brought back up with the **no neighbor 10.1.1.2 shutdown** command.

Using the **neighbor 10.1.1.2 shutdown** command not only terminates the session but removes all associated routing information as well.

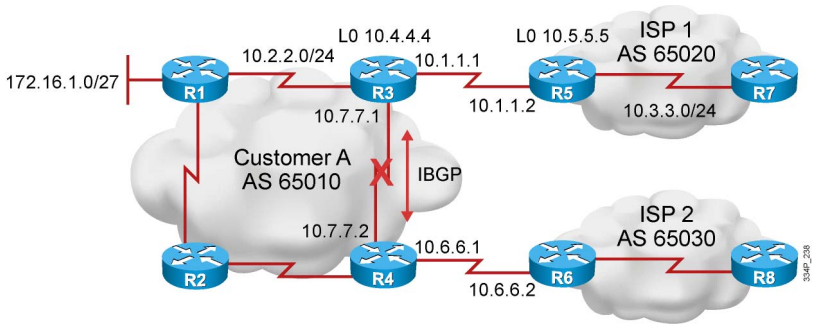
For more details about the **neighbor shutdown** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

# BGP Configuration Considerations

This topic describes what needs to be considered to correctly configure BGP.

## IBGP Peering Issue

- An IBGP neighbor relationship is established.
- What happens if the link between R3 and R4 goes down?
- Which IP address should be used to establish an IBGP session?





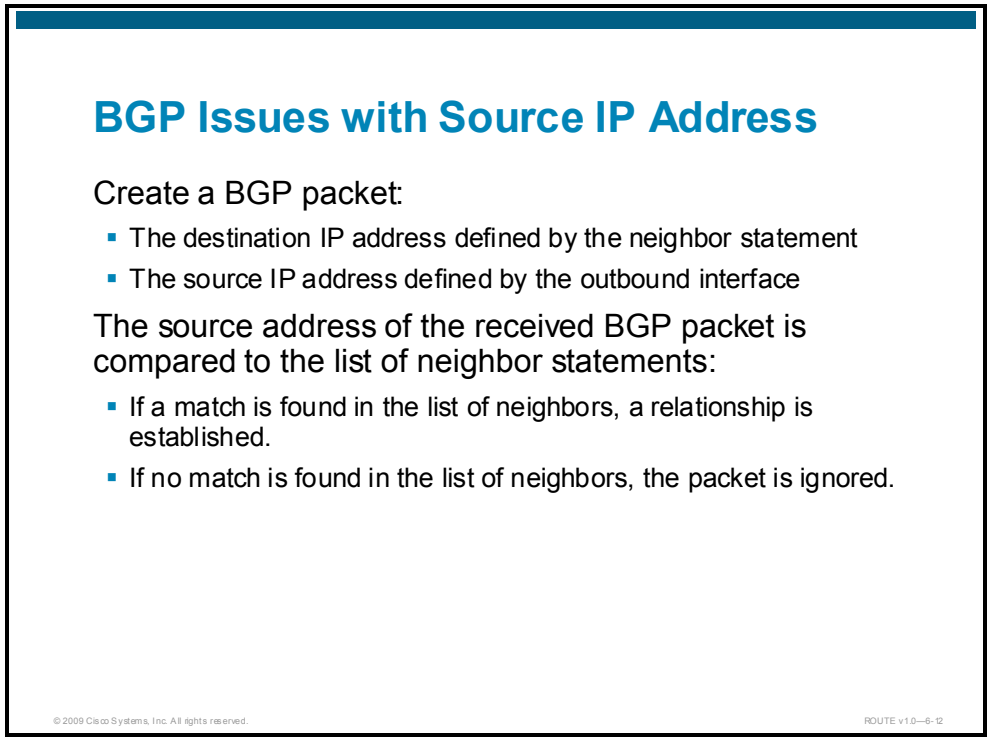


To establish an IBGP session between R3 and R4, as shown in the figure, which neighbor IP address should be used?

The problem is as follows: If R3 uses the **neighbor 10.7.7.2 remote-as 65010** command, but R4 is sending the BGP packets to R3 via R2 and R1, the source IP address will be different.

When R4 receives this BGP packet via R2 and R1, it will not recognize this BGP packet, because the packet will show a different source IP address that was not configured as a neighbor of R4; therefore, the IBGP session between R3 and R4 cannot be established.

A solution to this problem is to establish the IBGP session using a loopback interface when there are multiple paths between the IBGP neighbors.



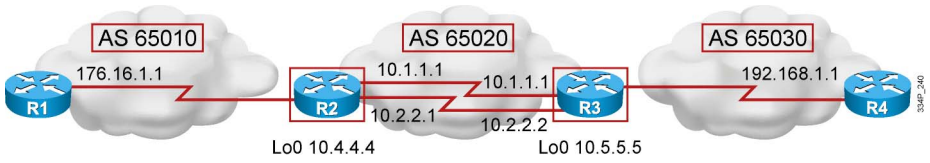

The BGP neighbor statement informs the router of the destination IP address for each update packet. The router must decide which IP address to use as the source IP address in the BGP routing update.

When a router creates a BGP packet for a neighbor, it checks the routing table for the destination network to reach that neighbor. The IP address of the outbound interface, as the routing table indicates, is used as the source IP address of the BGP packet.

When a BGP packet is received for a new BGP session, the source address of the packet is compared to the list of neighbor statements. This source IP address must match the address in the corresponding neighbor statement on the other router. Otherwise, the routers will not be BGP peers because they are not able to establish the BGP session.

## IBGP Using Loopback Addresses

- A loopback interface can be used as the source and destination IP address of all BGP updates between neighbors.
- The **neighbor update-source** command is normally used only with IBGP neighbors.




R2#

```
router bgp 65020
neighbor 172.16.1.1 remote-as 65010
neighbor 10.5.5.5 remote-as 65020
neighbor 10.5.5.5 update-source Loopback 0
!
router eigrp 1
network 10.0.0.0
```

R3#

```
router bgp 65020
neighbor 192.168.1.1 remote-as 65030
neighbor 10.4.4.4 remote-as 65020
neighbor 10.4.4.4 update-source Loopback 0
!
router eigrp 1
network 10.0.0.0
```




Multiple paths can exist to reach each neighbor when peering with IBGP neighboring routers. If the BGP router is using a neighbor address that is assigned to a specific interface on another router, and that interface goes down, the router that is pointing to this address loses its BGP session with that neighbor.

If the router peers instead with the loopback interface of the other router, the loopback interface will always be available as long as the router itself does not fail. This peering arrangement adds resiliency to the IBGP sessions because the routers are not tied into a physical interface, which may go down for any number of reasons.

To peer with the loopback of another internal neighbor, the first router would point the neighbor statement to the loopback address of the other internal neighbor. Ensure that both routers have a route to the loopback address of the other neighbor in their routing table. Also ensure that both routers are announcing their loopback addresses into their local routing protocol.

The **update-source** option in the **neighbor** command overrides the default source IP address that is used for BGP packets. It is necessary to tell the router which IP address to use as the source address for all BGP packets if a loopback interface is to be used instead of the physical interface.

If the **update-source** option is not used in the **neighbor** command, an announcement packet that is going to a neighbor uses the IP address of the exiting interface as the source address for a packet.

When a router creates a packet—whether it is a routing update, a ping, or any other type of IP packet—the router does a lookup in the routing table for the destination address. The routing table lists the appropriate interface to get to the destination address. The address of this outbound interface is used as the source address of that packet by default.

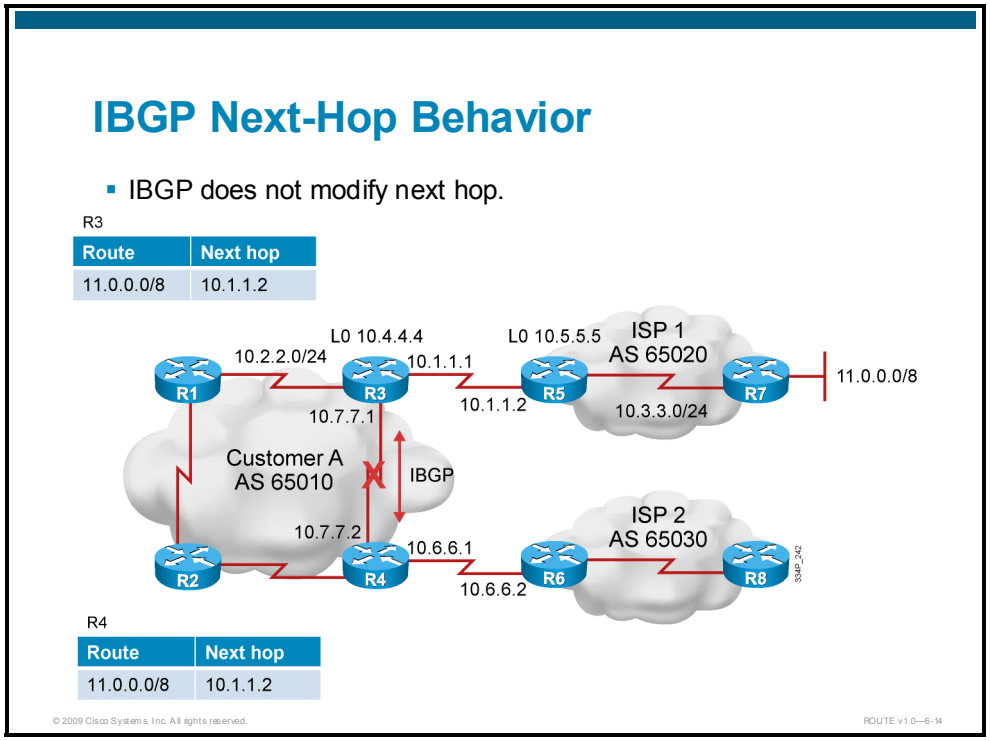
Consider what would happen if a neighboring router uses the loopback interface address in its **neighbor** command for this router, but the **neighbor update-source** command is not used on this router. When the neighboring router receives an update packet and looks at the source address of the packet, it sees that it has no neighbor relationship with that source address, so it discards the packet.

BGP does not accept unsolicited updates; it must be aware of every neighboring router and have a neighbor statement for it.

In the figure, R2 has R1 as an EBGP neighbor and R3 as an IBGP neighbor. R1 and R2 are directly connected. R3 is not directly connected to R2; in the figure, Enhanced Interior Gateway Routing Protocol (EIGRP) is used to provide reachability between R2 and R3. Because the neighbor relationship between R2 and R3 is not tied to a physical interface, R2 peers with the loopback interface on R3 and uses its loopback address as the source IP address, and vice versa. If R2 instead peered with 10.1.1.2 on R3 and that interface went down, the BGP neighbor relationship would also go down.

The **neighbor update-source** command should be used on both routers. If R2 loopback address 10.4.4.4 points to loopback address 10.5.5.5 of R3, and R3 points to loopback address 10.4.4.4 of R2, and neither use the **neighbor update-source** command, the BGP session between these routers will not start.

For more details about **neighbor update-source** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

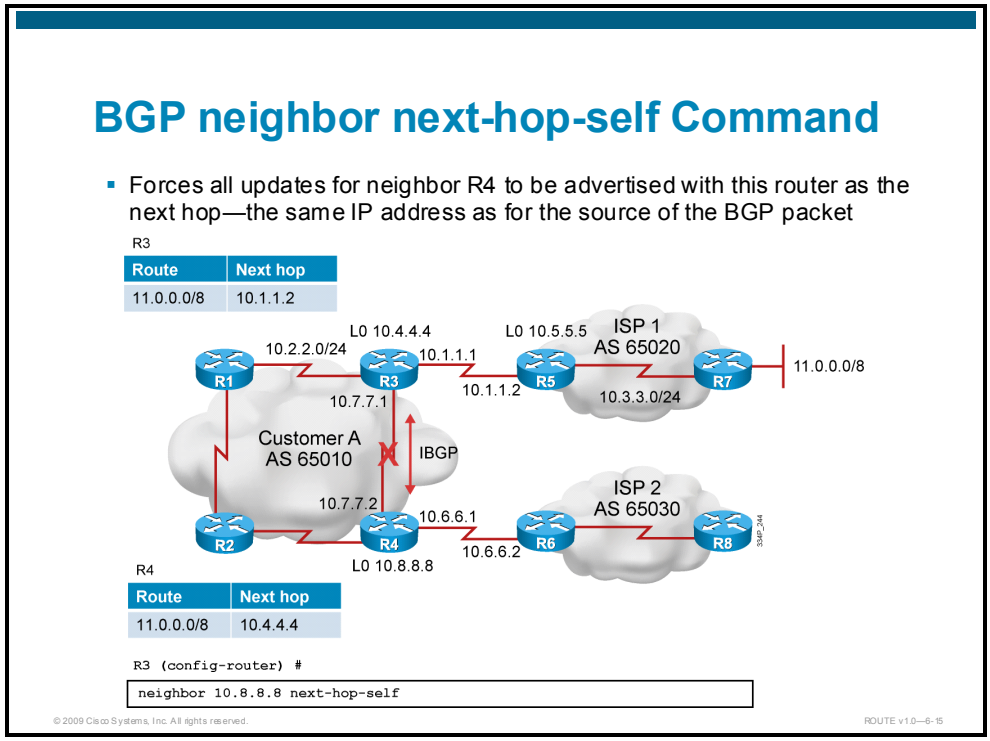



The way in which BGP establishes an IBGP relationship is very different from the way that IGPs behave. BGP is an AS-by-AS routing protocol and not a router-by-router routing protocol. Next hop is the IP address that is used to reach the next AS. The method that BGP uses to denote its next-hop address is also very different from the way that an IGP performs the same function. The default next hop is as follows:

- **EBGP:** IP address of the neighbor router that is sending the update
- **IBGP:** IP address that is advertised by EBGP should be carried in IBGP

In the figure, the next hop for route 11.0.0.0/8 is always the IP address 10.1.1.2 that is advertised by the EBGP neighbor. In case a failure occurs on the link between R3 and R4, and R4 has no information regarding how to reach the address 10.1.1.2, it will not be able to forward packets toward destination network 11.0.0.0/8. This situation occurs even if the physical path exists (through R1 and R2 in the figure).




It is sometimes necessary to override the default next-hop behavior of a router and force it to advertise itself as the next-hop address for routes that are sent to a neighboring router.

The **neighbor next-hop-self** command forces BGP to use its own IP address as the next-hop address for each network that it advertises to its IBGP neighbor, rather than letting the protocol choose the next-hop address to use.

An internal protocol—such as Routing Information Protocol (RIP), EIGRP, or OSPF—always uses the source IP address of a routing update as the next-hop address for each network that is placed in the routing table. The **neighbor next-hop-self** command forces BGP to use the source IP address of the update as the next-hop address for each advertised network.

R3 and R4 are IBGP neighbors, and R3 will advertise all the updates toward R4, with the next hop being the source IP address of the BGP packet that is going from R3 to R4. The figure shows that the next-hop address for the destination network 11.0.0.0 is now loopback interface 0 of R3. It is reachable via R1 and R2, because all the routers in AS 65010 are running the IGP routing protocol that is providing reachability in the local AS. Static routes can be used as well, but IGP is a more scalable solution.

For more details about **neighbor next-hop-self** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

# Identifying BGP Neighbor States

This topic describes BGP neighbor states.

## BGP States

When establishing a BGP session, BGP goes through the following states:

1. **Idle:** Router is searching the routing table to see whether a route exists to reach the neighbor.
2. **Connect:** Router found a route to the neighbor and has completed the three-way TCP handshake.
3. **Open sent:** Open message sent, with the parameters for the BGP session.
4. **Open confirm:** Router received an agreement on the parameters for establishing a session.
   - Alternatively, the router goes into active state if there is no response to the open message.
5. **Established:** Peering is established; routing begins.




After the TCP handshake is complete, the BGP application tries to set up a session with the neighbor. Several steps must occur for the session to be established.

After the **neighbor** command is entered in BGP, BGP takes the IP address that is listed and checks the local routing table for a route to this address. At this point, BGP is in the "idle" state. If BGP does not find a route to the IP address, it stays in the idle state. If it finds a route, it goes to the "connect" state when the TCP handshaking synchronization-acknowledgment (SYN-ACK) packet returns.

After the TCP connection is complete, BGP creates a BGP open packet and sends it to the neighbor. Once BGP sends this open packet, the BGP peering session changes to the "open sent" state. If there is no response for 5 seconds, the state changes to the "active" state.

If a response does come back in a timely manner, BGP goes to the "open confirm" state and starts scanning (evaluating) the routing table for the paths to send to the neighbor. When those paths have been found, BGP then goes to the "established" state and begins routing between the neighbors.

**Note** The states that two BGP routers are going through to establish a session can be observed using **debug** commands. In Cisco IOS Release 12.4, the **debug ip bgp ipv4 unicast** command can be used to see this process. In earlier Cisco IOS Software releases, the **debug ip bgp events** command gave similar output. Debugging uses up router resources and should be turned on only when necessary.

## BGP Established and Idle States

- **Idle:** The router cannot find the address of the neighbor in the routing table.
  - Solution: Check for an IGP problem. Is the neighbor announcing the route?
- **Established:** Proper state for BGP operations.
  - Output of the **show ip bgp summary** command has a number in the state column indicating the number of routes that are learned from this neighbor.




The idle state is an indication that the router does not know how to reach the IP address that is listed in the neighbor statement. The router is idle because of one of the following scenarios:

- It is waiting for a static route to that IP address or network to be configured.
- It is waiting for the local routing protocol (IGP) to learn about this network through an advertisement from another router.

The most common reason for a router to enter the idle state is that the neighbor is not announcing the IP address or the network toward which the neighbor statement of the router is pointing. Check these two conditions first to correct this problem:

1. Ensure that the neighbor announces the route in its local routing protocol (IGP).
2. Verify that an incorrect IP address has not been entered in the neighbor statement.

The established state is the desired state for the neighbor relationship. This state means that both routers have agreed to exchange BGP updates with one another and routing has begun.

## Example: show ip bgp neighbors Command

```
R2#show ip bgp neighbors
BGP neighbor is 172.31.1.3,  remote AS 65010, external link
  BGP version 4, remote router ID 172.31.2.3
  BGP state = Established, up for 00:19:10
  Last read 00:00:10, last write 00:00:10, hold time is 180, keepalive
interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received(old & new)
    Address family IPv4 Unicast: advertised and received
  Message statistics:
    InQ depth is 0
    OutQ depth is 0
                         Sent       Rcvd
    Opens:                  7          7
    Notifications:          0          0
    Updates:               13         38
<output omitted>
```



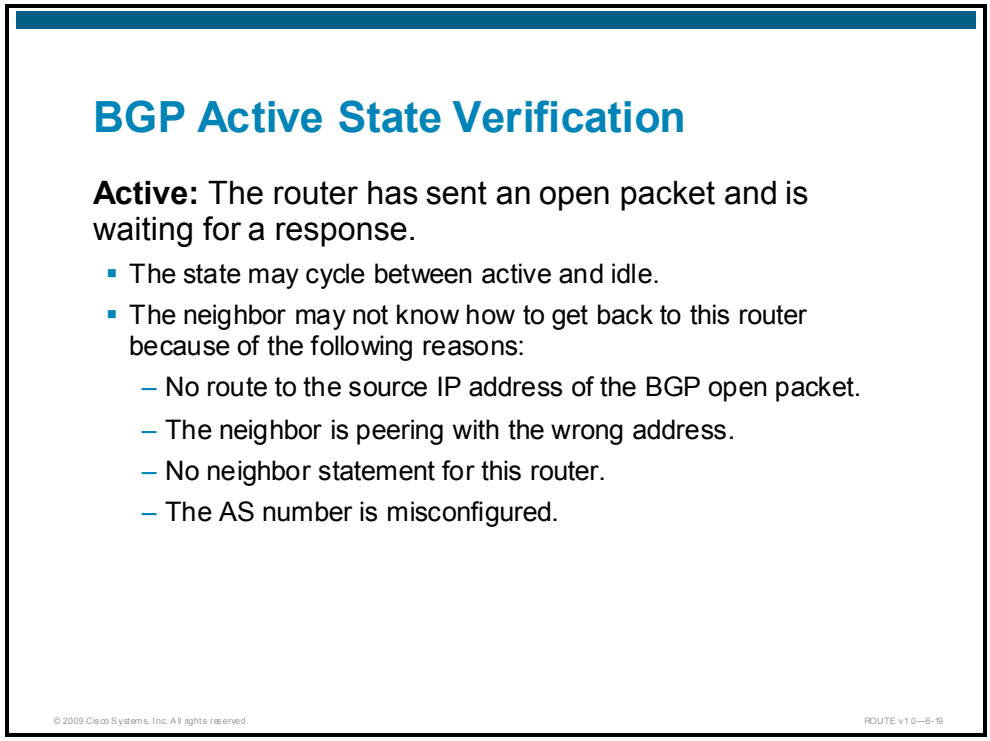




Use the **show ip bgp neighbors** command to display information about the BGP connections to neighbors. In the figure, the BGP state is established, which means that the neighbors have established a TCP connection and the two peers have agreed to use BGP to communicate.

For more details about **show ip bgp neighbors** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

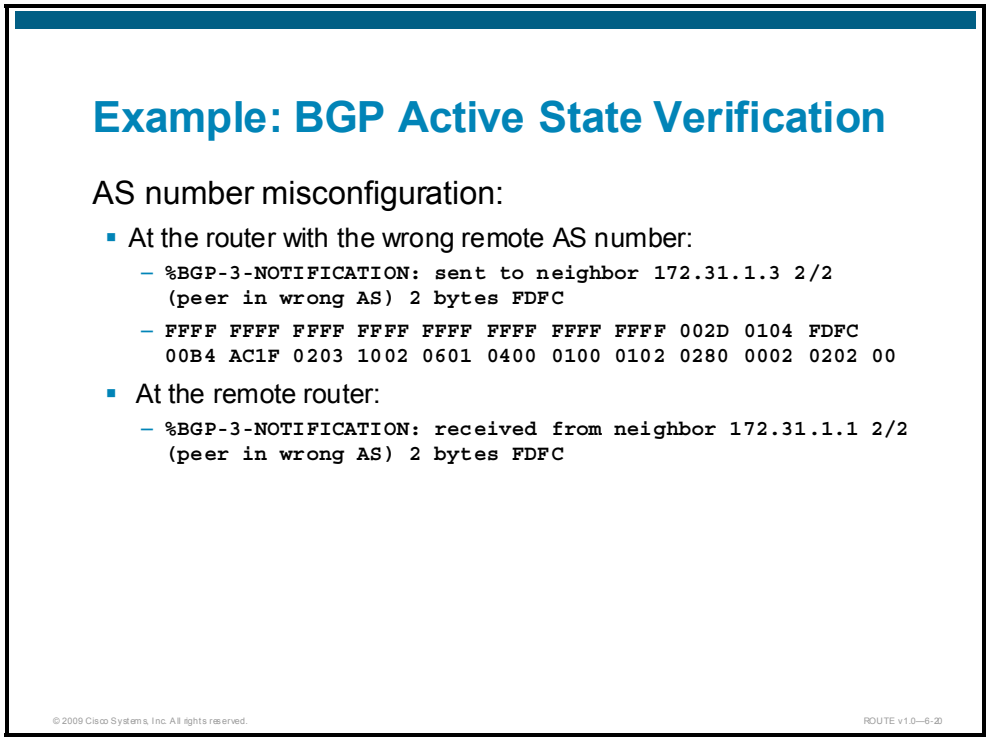



If the router is in the active state, it has found the IP address in the neighbor statement and has created and sent out a BGP open packet. However, the router has not received a response (open confirm packet).

One common problem in this case is that the neighbor may not have a return route to the source IP address. Ensure that the source IP address or network of the packets has been announced to the local routing protocol (IGP).

Another common problem that is associated with the active state occurs when a BGP router attempts to peer with another BGP router that does not have a neighbor statement peering back to the first router, or when the other router is peering with the wrong IP address on the first router. Check to ensure that the other router has a neighbor statement that is peering to the correct address of the router that is in the active state.

If the state toggles between the idle state and the active state, one of the most common problems is AS number misconfiguration.



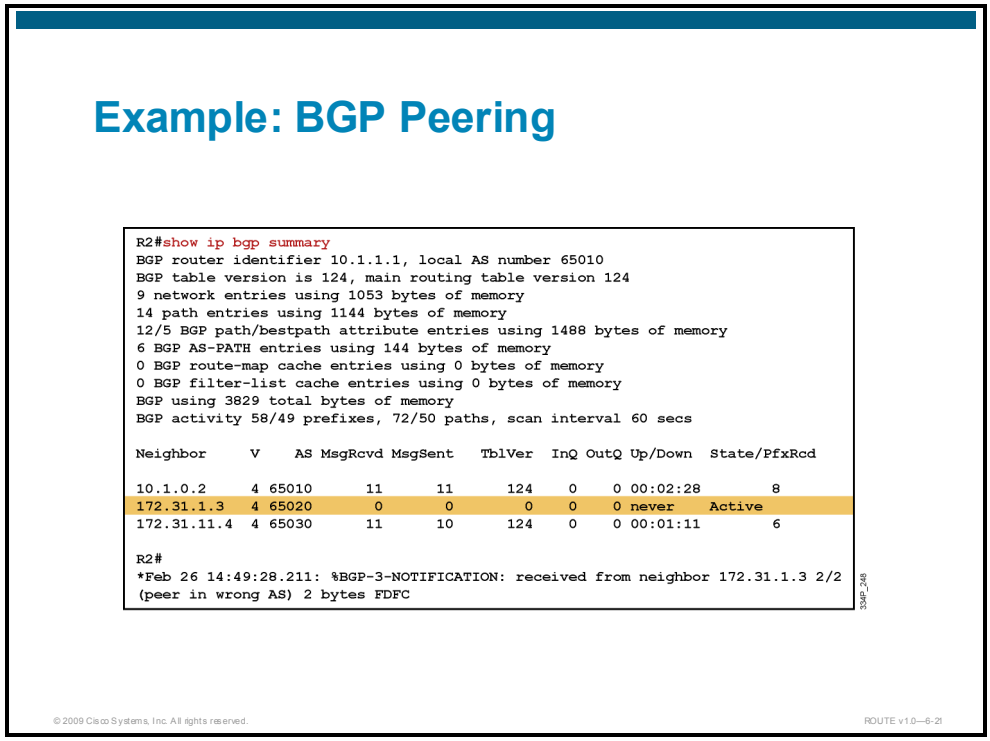

## Example: BGP Active State Verification

If the AS number has been misconfigured, the following console message will be seen at the router with the wrong remote AS number that is configured in the neighbor statement:

```
%BGP-3-NOTIFICATION: sent to neighbor 172.31.1.3 2/2 (peer in
wrong AS) 2 bytes FDE6
FFFF FFFF FFFF FFFF FFFF FFFF FFFF FFFF 002D 0104 FDE6 00B4
AC1F 0203 1002 0601 0400 0100 0102 0280 0002 0202 00
```

At the remote router, the following message will be displayed:

```
%BGP-3-NOTIFICATION: received from neighbor 172.31.1.1 2/2
(peer in wrong AS) 2 bytes FDE6
```




## Example: BGP Peering

The **show ip bgp summary** command is one way to verify the neighbor relationship. The figure presents the output from this command. Some of the details of this command output are as follows:

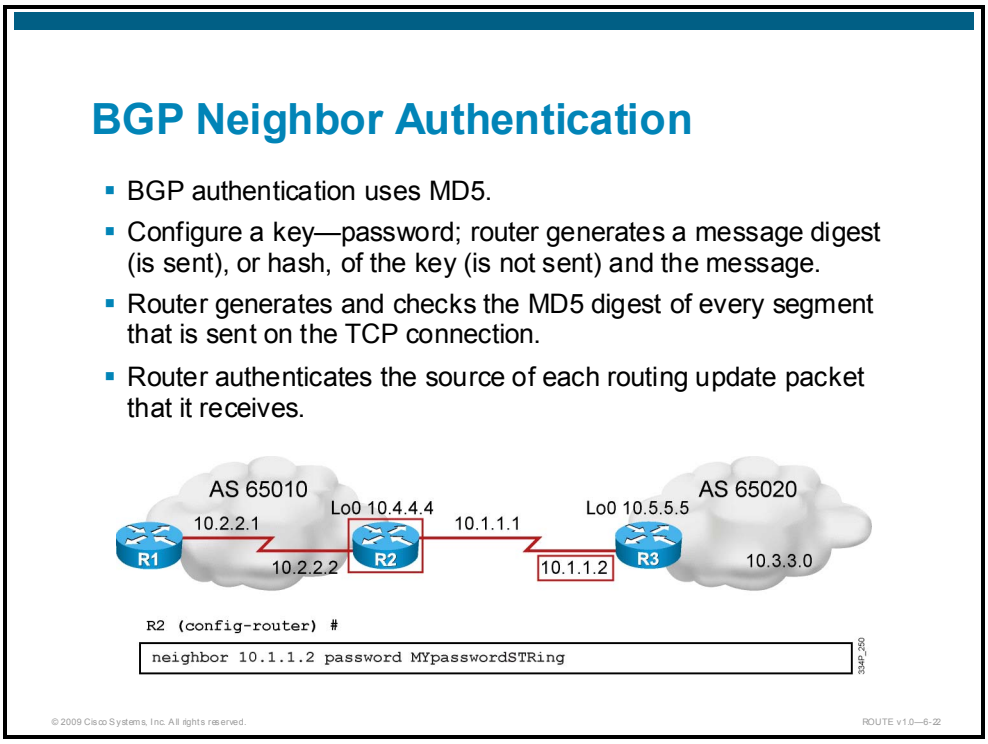
- **BGP router ID:** The IP address that all other BGP speakers recognize as representing this router.
- **BGP table version:** The version increases in increments when the BGP table changes.
- **Main routing table version:** The last version of the BGP database that was injected into the main routing table.
- **Neighbor:** The IP address that is used in the neighbor statement with which this router has a relationship.
- **Version (V):** The version of BGP that this router is running with the listed neighbor.
- **AS:** The AS number of the listed neighbor.
- **Messages received (MsgRcvd):** The number of BGP messages that have been received from this neighbor.
- **Messages sent (MsgSent):** The number of BGP messages that are sent to this neighbor.
- **Table version (TblVer):** The BGP table version.
- **In queue (InQ):** The number of messages waiting to be processed from this neighbor.
- **Out queue (OutQ):** The number of messages that are queued and waiting to be sent to this neighbor. TCP flow control prevents this router from overwhelming a neighbor with a large update.

- **Up/Down:** The length of time that this neighbor has been in the current BGP state (established, active, or idle).
- **State (established, active, idle, open sent, open confirm, or idle [admin])**: The BGP state. A neighbor can be set to administratively shut down (admin state) by using the **neighbor shutdown** router configuration command.
- **Prefix received (PfxRcd):** When the session is in the established state, this value represents the number of BGP network entries that are received from the listed neighbor.

For more details about **show ip bgp summary** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

# BGP Authentication

This topic describes the configuration of Message Digest 5 (MD5) authentication on the BGP TCP connection between two routers.




BGP neighbor authentication can be configured on a router so that the router authenticates the source of each routing update packet that it receives. This authentication is accomplished by the exchange of an authentication key (sometimes referred to as a password) that is known to both the sending and the receiving router.

BGP supports MD5 neighbor authentication. MD5 sends a message digest (also called a "hash") that is created using the key and a message. The message digest is then sent instead of the key. The key itself is not sent to prevent it from being read by an eavesdropper on the line while it is being transmitted.

To enable MD5 authentication on a TCP connection between two BGP peers, use the **neighbor** {*ip-address* | *peer-group-name*} *password string* router configuration command.

MD5 authentication can be configured between two BGP peers, which means that each segment that is sent on the TCP connection between the peers is verified. MD5 authentication must be configured with the same password on both BGP peers; otherwise, the connection between the peers will not be made. Configuring MD5 authentication causes Cisco IOS Software to generate and check the MD5 digest of every segment that is sent on the TCP connection.

| | |
|---|---|
| **Note** | If the authentication string is configured incorrectly, the BGP peering session will not be established. It is recommended that you enter the authentication string carefully and verify that the peering session is established after authentication is configured. |

If a BGP peer group is specified by using the *peer-group-name* argument, all the members of the peer group will inherit the characteristic that is configured with this command.

If a router has a password that is configured for a neighbor, but the neighbor router does not, a message such as the following will appear on the console when the routers attempt to send BGP messages between themselves:

```
%TCP-6-BADAUTH: No MD5 digest from 10.1.0.2(179) to
10.1.0.1(20236)
```

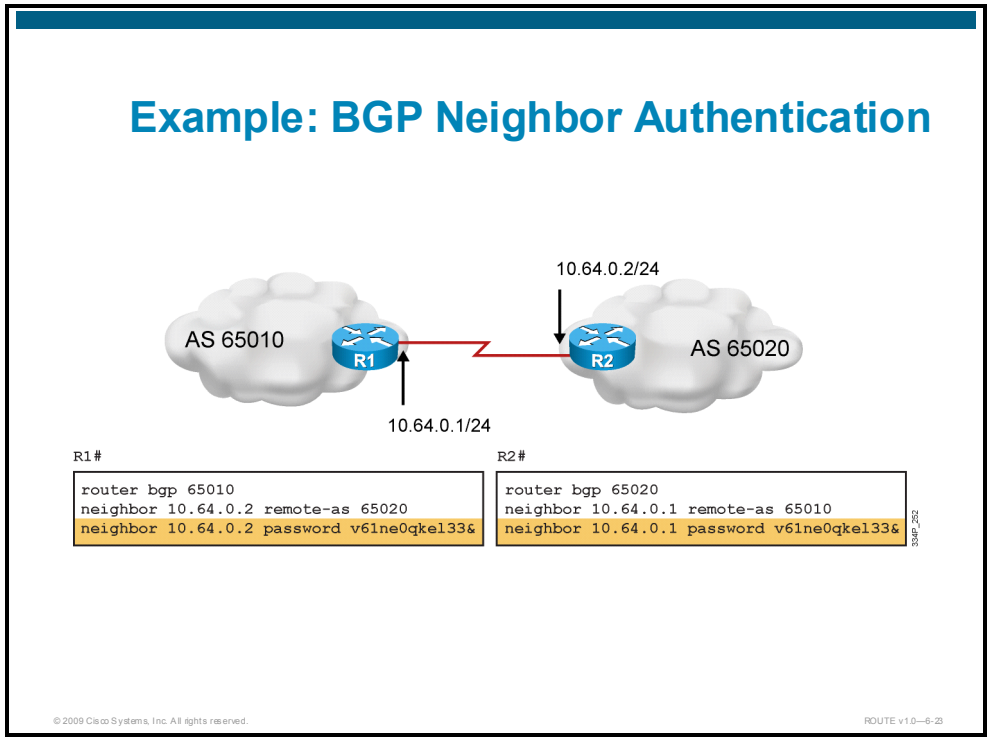
Similarly, if the two routers have different passwords that are configured, a message such as the following will appear on the screen:

```
%TCP-6-BADAUTH: Invalid MD5 digest from 10.1.0.1(12293) to
10.1.0.2(179)
```

If the password or key that is used for MD5 authentication between two BGP peers is configured or changed, the local router will not tear down the existing session after the password is configured. The local router will attempt to maintain the peering session using the new password until the BGP hold-down timer expires. The default time period is 180 seconds. If the password is not entered or changed on the remote router before the hold-down timer expires, the session times out.

| | |
|---|---|
| **Note** | Configuring a new timer value for the hold-down timer will only take effect after the session has been reset. It is not possible to change the configuration of the hold-down timer to avoid resetting the BGP session. |

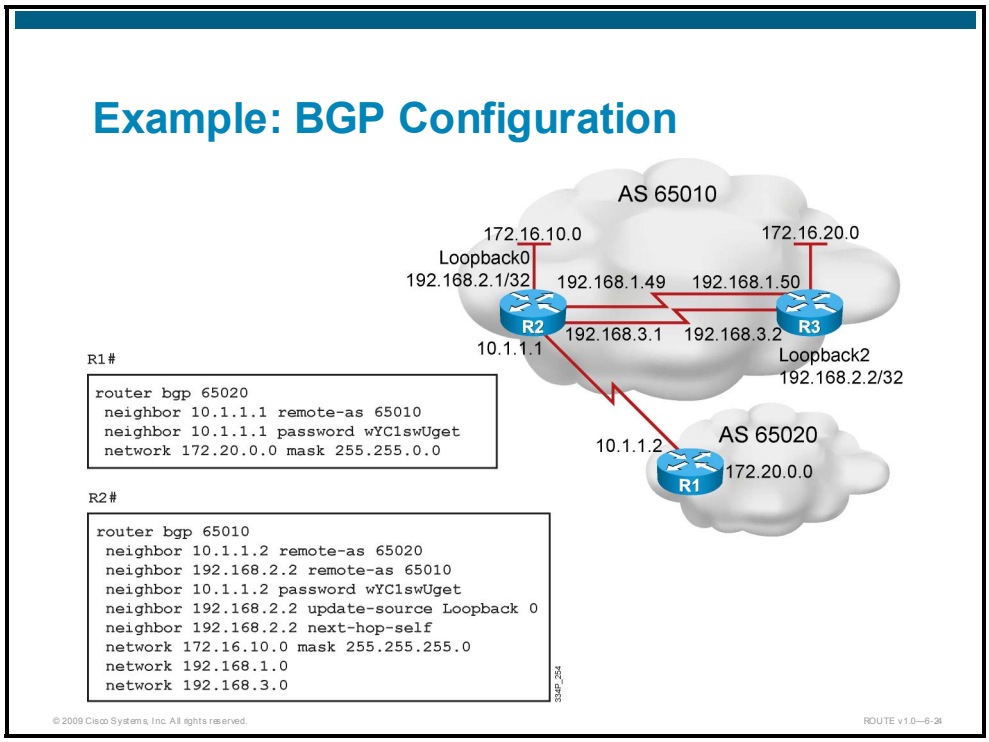
For more details about **neighbor** {*ip-address* | *peer-group-name*} *password string* command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link: http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html




The example in the figure configures MD5 authentication for the BGP peering session between R1 and R2. The same password must be configured on the remote peer before the hold-down timer expires.

# Example of Activating Basic BGP

This topic describes the configuration of BGP operations in a single-homed environment.




The figure shows another BGP example, which will take into account several BGP features and conclude the topic of configuring basic BGP configuration steps. R1 has one EBGP neighbor, R2 has one EBGP and one IBGP neighbor, and R3 has one IBGP neighbor. Showing the configuration of R1 and R2 will explain the basic configuration that is needed to create an EBGP and IBGP neighbor relationship.

The configuration for R1 is as follows:

The first command under the **router bgp 65020** command establishes that R1 has the following BGP neighbor:

- R2 in AS 65010

From the perspective of R1, R2 is an EBGP neighbor. The neighbor statement on R1 for R2 is pointing to the directly connected IP address to reach the EBGP neighbor, R2. Authentication is enabled toward R2 to authenticate the source of routing updates for the EBGP neighbor using password **wYC1swUget**. The **network** command notifies BGP about which network to advertise. It contains a subnet of a Class B address using the **mask** option.

The configuration for R2 is as follows:

The first two commands under the **router bgp 65010** command establish that R2 has the following two BGP neighbors:

- R1 in AS 65020
- R3 in AS 65010

From the perspective of R2, R1 is an EBGP neighbor and R3 is an IBGP neighbor. The neighbor statement on R2 for R1 is pointing to the directly connected IP address to reach the EBGP neighbor, R1. However, the neighbor statement on R2 points to the loopback interface of R3, because R2 has multiple paths to reach R3. If R2 pointed to the 192.168.3.2 IP address of

R3 and that interface went down, R2 would be unable to re-establish the BGP session until the link came back up. By pointing to the loopback interface of R3 instead, the link stays established as long as any path to R3 is available. R3 should also point to the loopback address of R2 in its configuration.

Authentication is enabled toward R1 to authenticate the source of routing updates for the EBGP neighbor using the correct password.

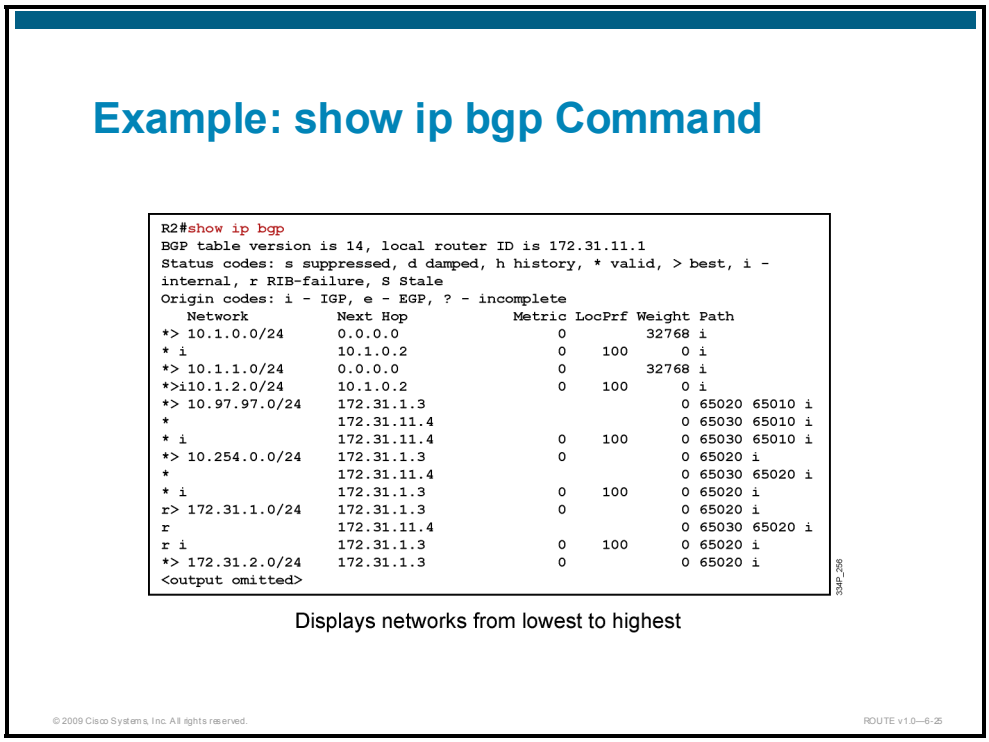
The **neighbor 192.168.2.2 update-source Loopback 0** command notifies R2 to always use its loopback 0 address, 192.168.2.1, as the source IP address when sending an update to R3 (192.168.2.2).

R2 also changes the next-hop address for networks that are reachable through it. The default next-hop setting for networks from AS 65020 is IP address 10.1.1.2. With the **next-hop-self** command, R2 sets the next-hop address to the source IP address of the routing update, which is the R2 loopback 0 interface, as set by the **update-source** command.

Three **network** commands notify BGP about which networks to advertise. The first is a subnet of a Class B address using the **mask** option. The next two network statements are used for the two Class C networks that connect R2 and R3. The default mask is 255.255.255.0, so it does not need to be included in the command.

# BGP Verification

This topic describes the verification of BGP configuration.




Use the **show ip bgp** command to display the BGP topology database (BGP table).

The figure shows partial sample output of the **show ip bgp** command. The status codes are shown at the beginning of each line of output, and the origin codes are shown at the end of each line. In this output, there is an asterisk (*) in most of the entries in the first column. This asterisk means that the next-hop address (in the fifth column) is valid. The next-hop address is not always the router that is directly connected to this router. Other options for the first column are as follows:

- An “s,” for suppressed, indicates that the specified routes are suppressed (usually because routes have been summarized and only the summary route is being sent).
- A “d,” for dampening, indicates that the route is being dampened (penalized) for going up and down too often. Although the route might be up right now, it is not advertised until the penalty has expired.
- An “h,” for history, indicates that the route is unavailable and is probably down; historic information about the route exists, but a best route does not exist.
- An “r,” for Routing Information Base (RIB) failure, indicates that the route was not installed in the RIB. The reason that the route is not installed can be displayed using the **show ip bgp rib-failure** command, as shown in the next figure.
- An “S,” for stale, indicates that the route is stale (this symbol is used in the nonstop forwarding-aware router).

The second column shows “>” when BGP has selected the path as the best path to a network.

The third column is either blank or shows “i.” If it is blank, BGP learned that route from an external peer. An “i” indicates that an IBGP neighbor advertised this path to the router.

The fourth column lists the networks that the router learned.

The Next Hop column lists all the next-hop addresses for each route. This column may contain the entry 0.0.0.0, which signifies that this router is the originator of the route.

The three columns to the left of the Path column list three BGP path attributes that are associated with the path: metric (multi-exit discriminator [MED]), local preference, and weight.

The column with the Path header may contain a sequence of autonomous systems in the path. From left to right, the first AS that is listed is the adjacent AS, from which this network was learned. The last number (the rightmost AS number) is the originating AS of this network. The AS numbers between these two numbers represent the exact path that a packet takes back to the originating AS. If the path column is blank, the route is from the current AS.

The last column signifies how this route was entered into BGP on the original router. If the last column has an “i” in it, the originating router probably used a network statement to introduce this network into BGP.

If the character is an “e,” the originating router learned this network from an exterior gateway protocol (EGP), which is the historical predecessor to BGP. A question mark (?) signifies that BGP cannot absolutely verify the availability of this network because it is redistributed from an IGP into BGP.

## Example: show ip bgp rib-failure Command

- Displays networks that are not installed in the RIB and the reason that they were not installed

```
R2# show ip bgp rib-failure
Network          Next Hop                RIB-failure   RIB-NH Matches
172.31.1.0/24    172.31.1.3        Higher admin distance        n/a
172.31.11.0/24   172.31.11.4       Higher admin distance        n/a
```





Use the **show ip bgp rib-failure** command to display BGP routes that were not installed in the RIB table and the reason that the routes were not installed.

The example in the figure shows that the displayed routes were not installed because a route or routes with a better administrative distance exist in the RIB.

For more details about **show ip bgp rib-failure** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link: http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

## Clearing the BGP Session

- When policies change, the change takes effect immediately.
- The next time that a prefix or path is advertised or received, the new policy is used. This can take a long time for all networks.
- You must trigger an update for immediate action.
- Ways to trigger an update:
  - Hard reset
  - Soft reset
  - Route refresh

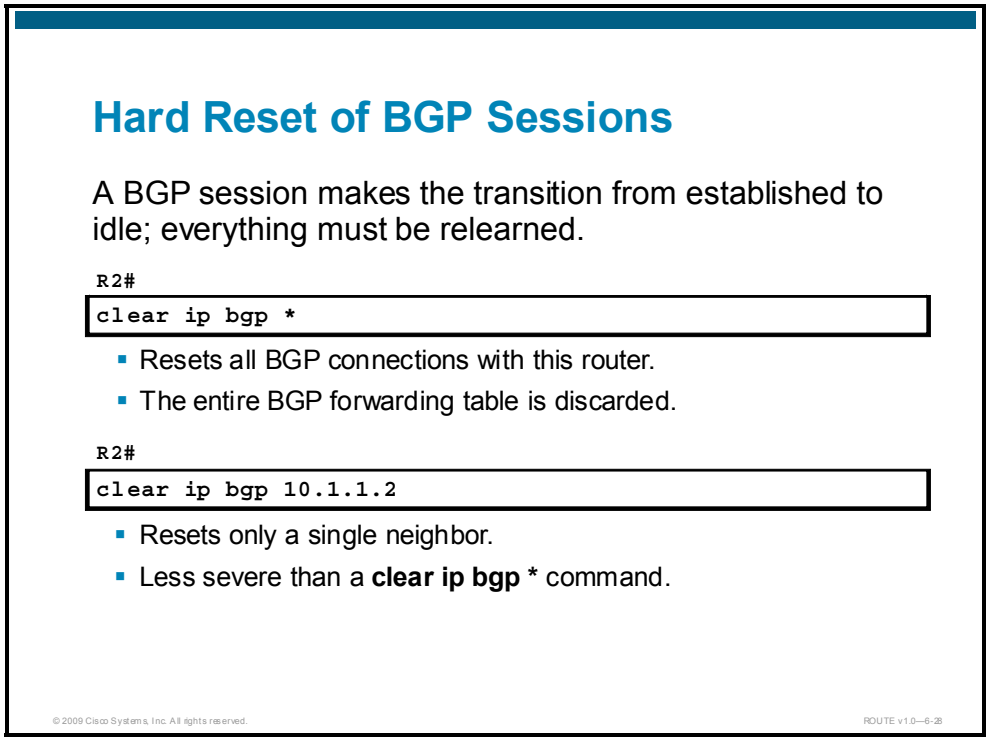



BGP can potentially process huge volumes of routing information. When a policy configuration change occurs, the router cannot go through the huge table of BGP information and recalculate which entry is no longer valid in the local table; also, the router cannot determine which route or routes, already advertised, should be withdrawn from a neighbor.

There is an obvious risk that the first configuration change will be immediately followed by a second, which would cause the whole process to start all over again. To avoid such a problem, Cisco IOS Software applies changes only to those updates that are received or transmitted after the BGP policy configuration change has been performed. The new policy, enforced by the new filters, is applied only on routes that are received or sent after the change.

A network administrator who would like the policy change to be applied on all routes must trigger an update to force the router to let all routes pass through the new filter. If the filter is applied on outgoing information, the router has to resend the BGP table through the new filter. If the filter is applied on incoming information, the router needs its neighbor to resend its BGP table so that it passes through the new filters.

There are three ways to trigger an update: with a hard reset, soft reset, or route refresh.




Resetting a session is a method of informing the neighbor or neighbors of a policy change. If BGP sessions are reset, all information that is received on those sessions is invalidated and removed from the BGP table. Also, the remote neighbor will detect a BGP session down state and will invalidate the routes that were received. After 30 to 60 seconds, the BGP sessions are re-established automatically and the BGP table is exchanged again, but through the new filters. However, resetting the BGP session disrupts packet forwarding.

Both commands that are shown in the figure cause a hard reset of the BGP neighbors that are involved. A hard reset means that the router that is issuing either of these commands will close the appropriate TCP connections, re-establish those TCP sessions as appropriate, and resend all information to each of the neighbors that are affected by the particular command that is used.

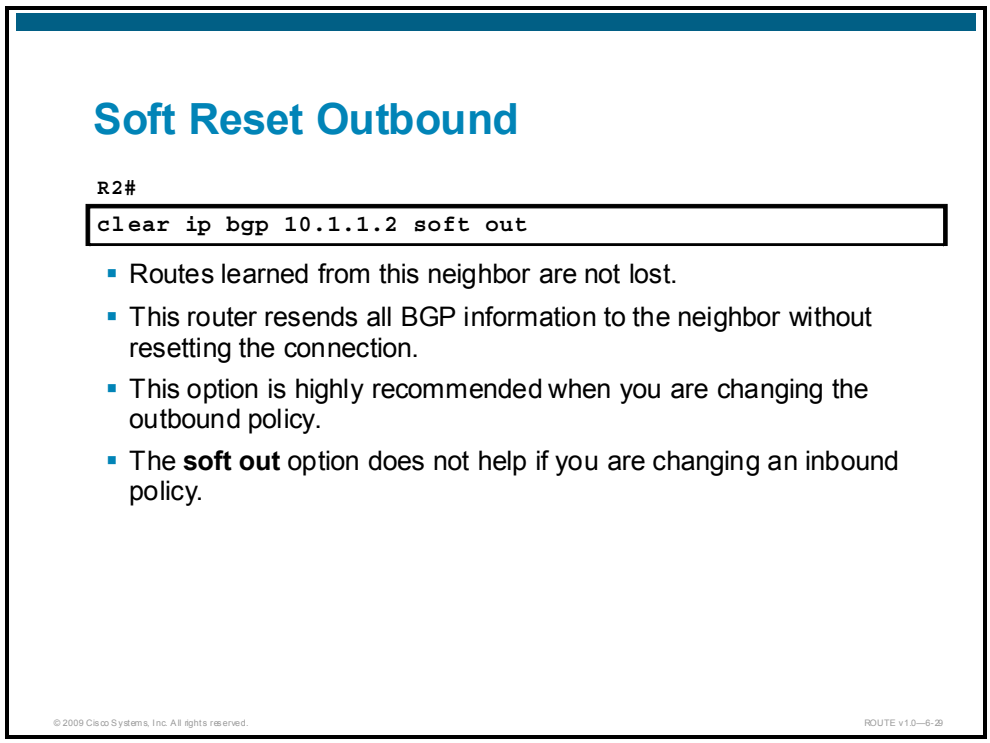
The **clear ip bgp *** command causes the BGP forwarding table on the router that issued this command to be deleted, and all networks must be relearned from every neighbor. If a router has multiple neighbors, this action is a very dramatic event. This command forces all neighbors to resend their entire tables simultaneously.

For example, consider a situation in which R1 has eight neighbors, and each neighbor has a complete Internet table of about 32 MB in size. If R1 issues the **clear ip bgp *** command, all eight routers resend their 32-MB tables at the same time. To hold all these updates, R1 would need 256 MB of RAM. R1 would also need to be able to process all this information. Processing 256 MB of updates would take a considerable number of CPU cycles for R1, further delaying the routing of user data.

If the second command, **clear ip bgp 10.1.1.2**, is used instead, one neighbor is reset at a time. The impact is less severe on the router that is issuing this command; however, it takes longer to change policy for all the neighbors, because each must be done individually rather than all at once as with the **clear ip bgp *** command. The **clear ip bgp** command still performs a hard reset and must re-establish the TCP session with the specified address, but this command affects only a single neighbor at a time.

For more details about **clear ip bgp** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

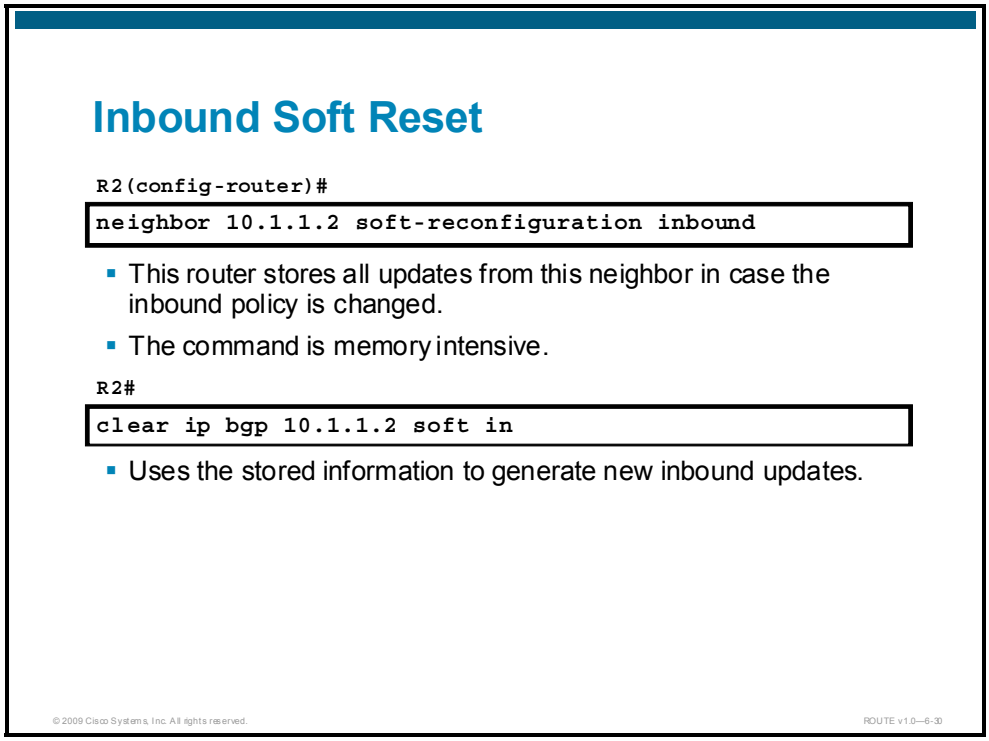
 




The **soft out** option of the **clear ip bgp** command causes BGP to do a soft reset for outbound updates. The router that is issuing the **clear ip bgp 10.1.1.2 soft out** command does not reset the BGP session; instead, the router creates a new update and sends the whole table to the specified neighbor.

This update includes withdrawal commands for the networks that the other neighbor will not see anymore based on the new outbound policy.

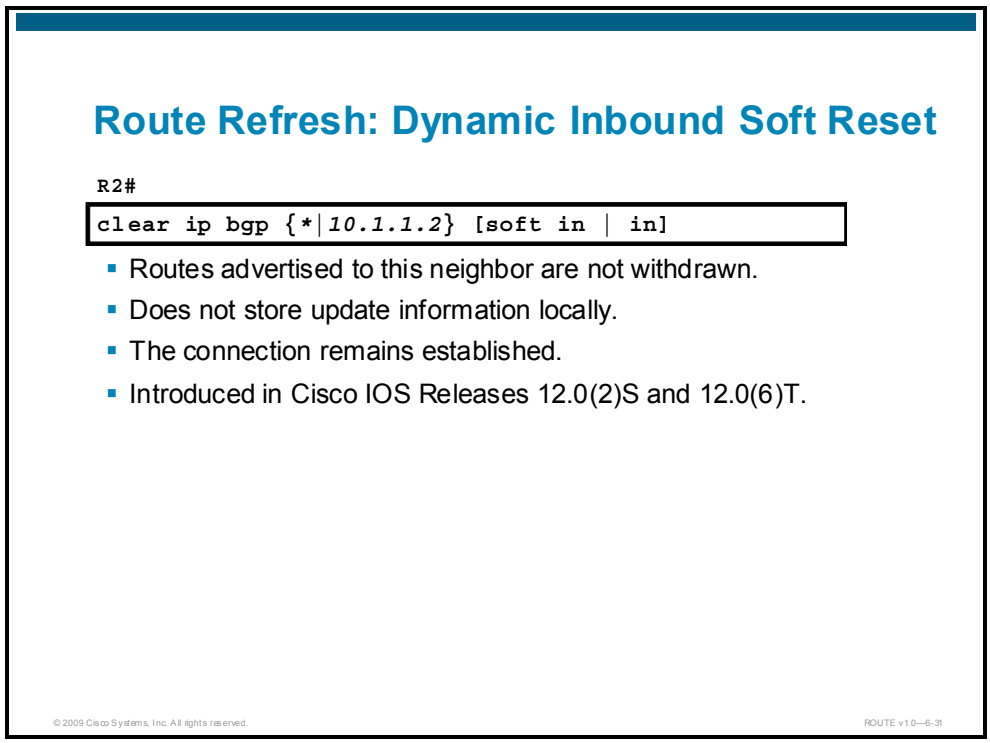
| | |
|---|---|
| **Note** | The **soft** keyword of this command is optional; **clear ip bgp out** does a soft reset for outbound updates. |




There are two ways to perform an inbound soft reconfiguration: using stored routing update information, as shown in the figure, and dynamically, as shown in the next figure.

Enter the **neighbor** command that is shown in the figure to inform BGP to save all updates that were learned from the neighbor that is specified. The BGP router retains an unfiltered table of what that neighbor has sent.

When the inbound policy is changed, use the **clear ip bgp** command that is shown in the figure. The stored unfiltered table is used to generate new inbound updates; the new results are placed in the BGP forwarding database. Therefore, if changes are made, the other side does not have to be forced to resend everything.




Cisco IOS Releases 12.0(2)S and 12.0(6)T introduced a BGP Soft Reset Enhancement feature, also known as "route refresh," which provides automatic support for dynamic soft reset of inbound BGP routing table updates, and is not dependent on stored routing table update information. The **clear ip bgp soft in** command implements this feature. This method requires no preconfiguration and requires significantly less memory than the previous soft method for inbound routing table updates.

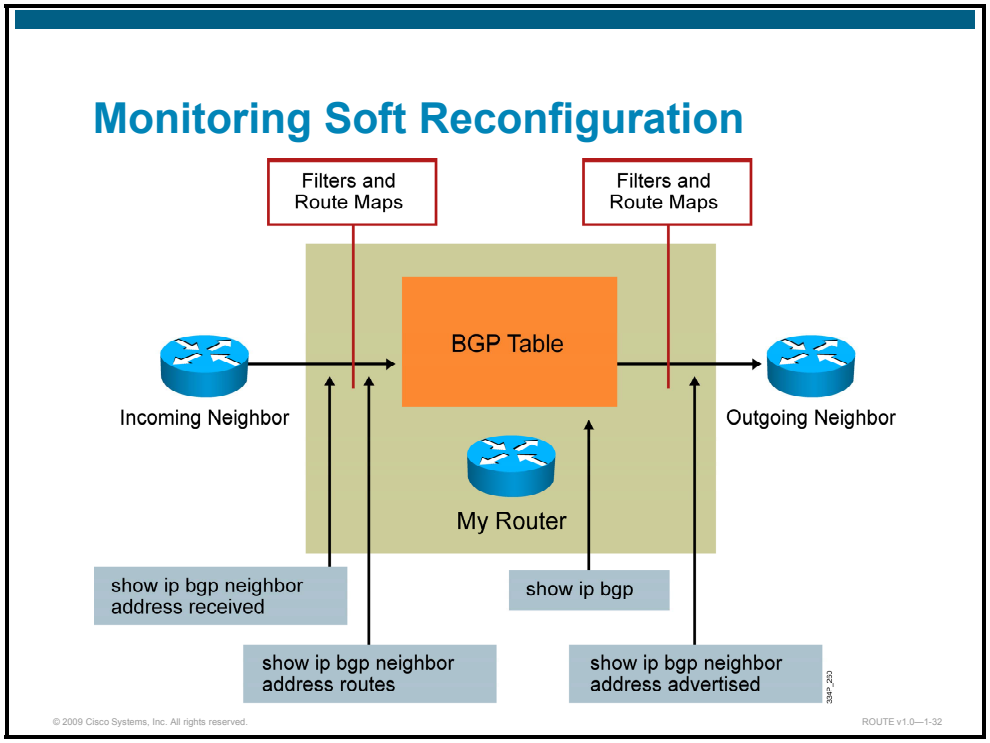
The **soft in** option generates new inbound updates without resetting the BGP session, but it can be memory intensive. BGP does not allow a router to force another BGP speaker to resend its entire table. If the inbound BGP policy is changed and a hard reset is not to be completed, configure the router to perform a soft reconfiguration.

**Note** To determine whether a BGP router supports this route refresh capability, use the **show ip bgp neighbors** command. The following message is displayed in the output when the router supports the route refresh capability:

```
Received route refresh capability from peer
```

If all BGP routers support the route refresh capability, use the **clear ip bgp** {***** | *address* | *peer-group-name*} **in** command. It is not necessary to use the **soft** keyword, because soft reset is automatically assumed when the route refresh capability is supported.

**Note** The **clear ip bgp soft** command performs a soft reconfiguration of both inbound and outbound updates.




When a BGP session is reset and soft reconfiguration is used, several commands exist to monitor the BGP routes that are received, sent, or filtered.

The following commands can be used:

- **show ip bgp neighbor address received**
- **show ip bgp neighbor address routes**
- **show ip bgp**
- **show ip bgp neighbor address advertised**

## debug ip bgp updates Command

```
R1#debug ip bgp updates
Mobile router debugging is on for address family: IPv4 Unicast
R1#clear ip bgp 10.1.0.2
<output omitted>
*Feb 24 11:06:41.309: %BGP-5-ADJCHANGE: neighbor 10.1.0.2 Up
*Feb 24 11:06:41.309: BGP(0): 10.1.0.2 send UPDATE (format)
10.1.1.0/24, next 10.1.0.1, metric 0, path Local
*Feb 24 11:06:41.309: BGP(0): 10.1.0.2 send UPDATE (prepend, chgflags:
0x0) 10.1.0.0/24, next 10.1.0.1, metric 0, path Local
*Feb 24 11:06:41.309: BGP(0): 10.1.0.2 NEXT_HOP part 1 net
10.97.97.0/24, next 172.31.11.4
*Feb 24 11:06:41.309: BGP(0): 10.1.0.2 send UPDATE (format)
10.97.97.0/24, next 172.31.11.4, metric 0, path 65030 65010
*Feb 24 11:06:41.309: BGP(0): 10.1.0.2 NEXT_HOP part 1 net
172.31.22.0/24, next 172.31.11.4
*Feb 24 11:06:41.309: BGP(0): 10.1.0.2 send UPDATE (format)
172.31.22.0/24, next 172.31.11.4, metric 0, path 65030
<output omitted>
*Feb 24 11:06:41.349: BGP(0): 10.1.0.2 rcvd UPDATE w/ attr: nexthop
10.1.0.2, origin i, localpref 100, metric 0
*Feb 24 11:06:41.349: BGP(0): 10.1.0.2 rcvd 10.1.2.0/24
*Feb 24 11:06:41.349: BGP(0): 10.1.0.2 rcvd 10.1.0.0/24
```





The figure shows partial output from the **debug ip bgp updates** command on R1 after the **clear ip bgp** command is issued to clear the BGP sessions with its IBGP neighbor 10.1.0.2.

After the neighbor adjacency is re-established, R1 creates and sends updates to 10.1.0.2. The first update that is highlighted in the figure, “10.1.1.0/24, next 10.1.0.1,” is an update about network 10.1.1.0/24, with a next hop of 10.1.0.1, which is the address of R1.

The second update that is highlighted in the figure, “10.97.97.0/24, next 172.31.11.4,” is an update about network 10.97.97.0/24, with a next hop of 172.31.11.4, which is the address of one of the EBGP neighbors of R1. The EBGP next-hop address is being carried into IBGP.

R1 later receives updates from 10.1.0.2. The update that is highlighted in the figure contains a path to two networks—10.1.2.0/24 and 10.1.0.0/24. The attributes that are shown in this update are described in the next lesson.

| **Note** | Debugging uses up router resources and should be turned on only when necessary. |
|---|---|

For more details about **debug ip bgp updates** command, go to the Cisco IOS Debug Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/debug/command/reference/db_book.html

# Summary

This topic summarizes the key points that were discussed in this lesson.

## Summary

- For a BGP configuration, the following must be defined: BGP requirements, BGP parameters, and connectivity.
- BGP is configured with the following basic BGP commands: **router bgp** *autonomous-system*, **neighbor** *ip-address remote-as autonomous-system*, **network** *network-number* [**mask** *network-mask*].
- The **neighbor shutdown** command administratively shuts down a BGP neighbor.
- When creating a BGP packet, the neighbor statement defines the destination IP address and the outbound interface defines the source IP address.




## Summary (Cont.)

- When establishing a BGP session, BGP goes through the following states: idle, connect, open sent, open confirm, and established.
- You can configure MD5 authentication between two BGP peers, which means that each segment that is sent on the TCP connection between the peers is verified.
- One EBGP neighbor exists in a single-homed environment.
- The **show** and **debug** commands are used to troubleshoot the BGP session.

Lesson 5

# Lab 6-1 Debrief

## Overview

In Lab 6-1, you configured BGP operations. Given a routed network, you had to simulate multihomed ISP connections and configure EBGP on the enterprise router to connect to the two ISPs.

After completing the lab, the instructor will lead the discussion about lab topology, tasks, verification, and checkpoints, as well as a sample solution and alternatives. You will present your implementation plan and solution.

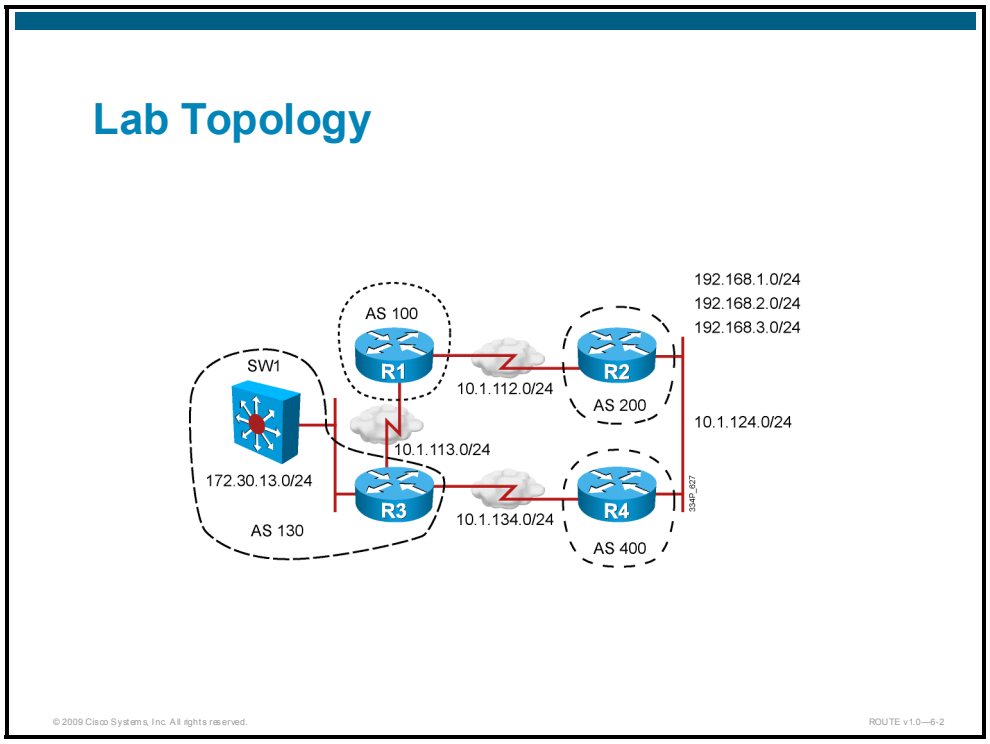
## Objectives

Upon completing this lesson, you will be able to explain the lab topology, configure BGP operations, create checkpoints for configuration and verification, and find alternative solutions. This ability includes being able to meet these objectives:

- Compare your solution, findings, and action log against a set of checkpoints that are provided by the instructor, and identify common and alternative solutions
- Consolidate the lessons that are learned during the review discussions into a set of best-practice methods and commands to aid you in future troubleshooting procedures

# Lab Overview and Verification

This topic describes the lab topology and key checkpoints that are used to create a solution and start verification.




The figure presents a logical lab topology that is used for configuration of a BGP operations lab. The topology uses four pod routers, which are members of an IBGP relationship, and two backbone routers, which are members of an EBGP relationship. The lab is preconfigured with addressing, including loopbacks and an IGP routing protocol.

Based on the topology, you can create a basic BGP operations configuration, including entering BGP processes, creating neighbors, and advertising networks, as well as utilizing additional BGP options, including synchronization, peer groups, and authentication.

## Lab Review: What Did You Accomplish?

- **Task 1:** Perform a lab cleanup.
  - Which steps did you take to remove an unnecessary configuration?
  - How did you create the initial configuration?
- **Task 2:** Configure BGP.
  - What is needed to configure basic BGP?
  - Which steps did you take to configure neighbors, advertise networks, and verify the configuration?
- **Task 3:** Configure BGP authentication.
  - Which authentication type did you select?
  - How can you verify MD5 authentication?

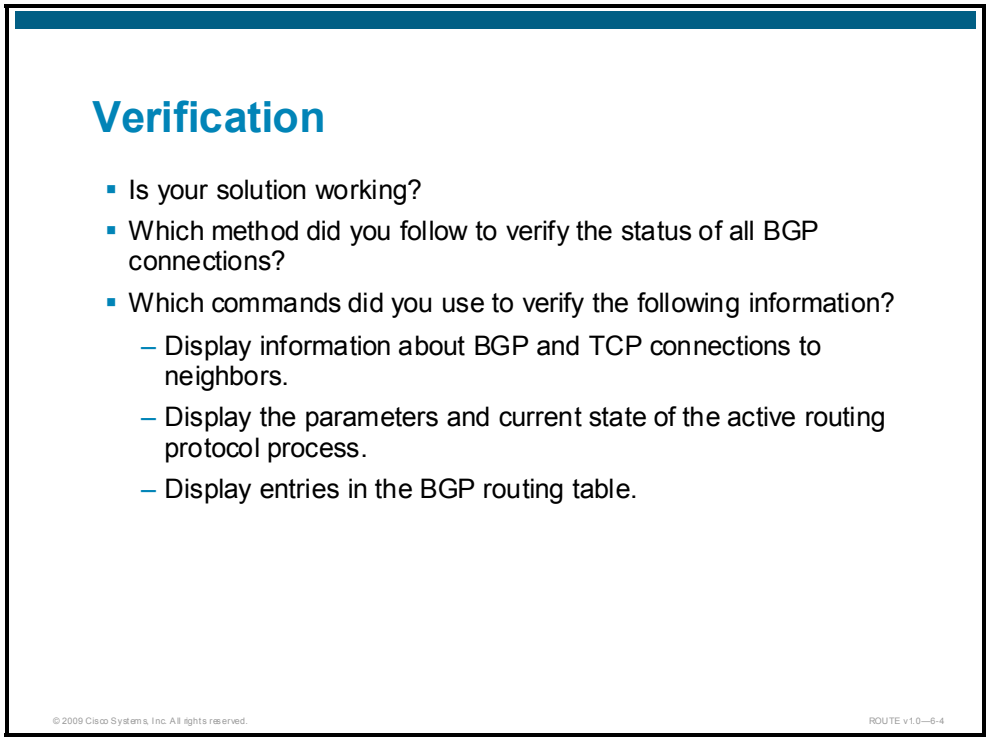



The lab consists of three tasks. You needed an implementation plan to fulfill the lab requirements.

In the first task, you needed to perform a lab cleanup, in which the previous configuration is erased and the lab is prepared with an initial configuration supporting Lab 6-1, “Configure BGP Operations.”

In the second task, you configured basic BGP steps from entering the BGP process to neighbor definition and network advertisements.

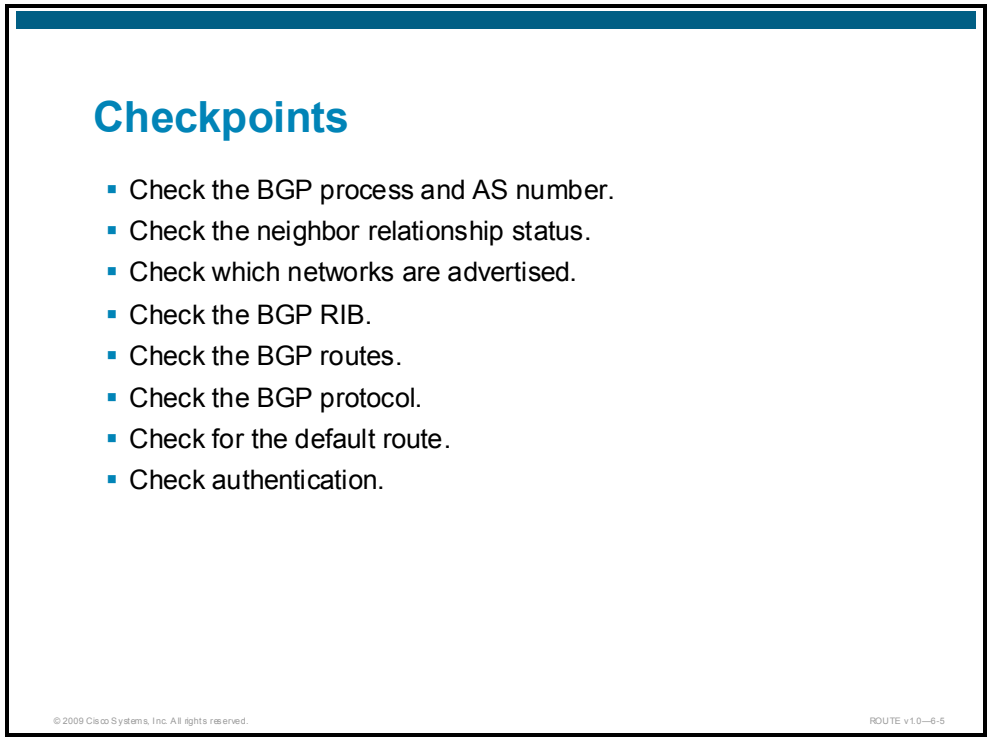
In the third task, you configured additional BGP configuration options including MD5 authentication, and you learned additional commands that are used for better reachability of next hop between IBGP and EBGP neighbors.




After each configuration task, verification takes place where you can check your configurations. Several **show** commands are used during the verification process, showing many parameters of the BGP process and neighbor relationship.

Verification includes use of the following commands:

- **show ip bgp summary:** Displays the status of all BGP connections
- **show ip bgp neighbors:** Displays information about BGP and TCP connections to neighbors
- **show ip protocols:** Displays the parameters and current state of the active routing protocol process
- **show ip bgp:** Displays entries in the BGP routing table




During the configuration and verification phase, you can use several checkpoints. After completing all configuration tasks, BGP configuration can be successfully completed or additional verification and troubleshooting is needed.

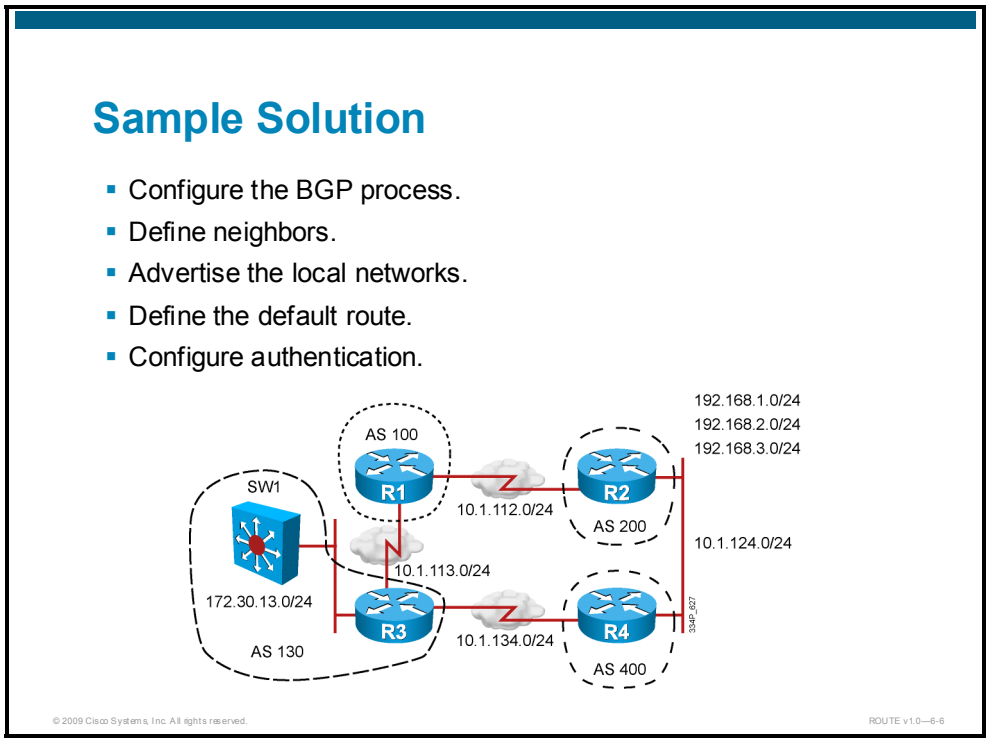
Optionally, you can check the BGP configuration in different stages of the implementation using the checkpoints at each stage.

With different checkpoints, you can check for proper configuration as follows:

- Check the BGP process and AS number.
- Check the neighbor relationship status.
- Check which networks are advertised.
- Check the BGP RIB.
- Check the BGP routes.
- Check the BGP protocol.
- Check for the default route.
- Check authentication.

# Sample Solution and Alternatives

This topic describes a sample solution and possible alternatives.




A sample solution includes configuration steps for each of the tasks. Different solutions are possible; the figure shows the important tasks that are needed for a successful configuration.

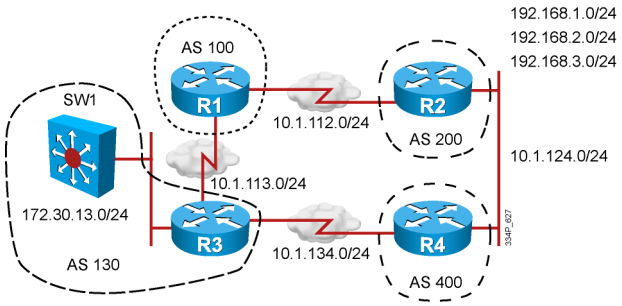
To be able to successfully complete the lab configuration, use the following guidelines:

- Enter the BGP process using the correct AS number.
- Define neighbors using a directly connected interface (EBGP) or loopback interface (IBGP).
- Advertise the local networks into BGP using a network statement with the **mask** keyword.
- Define the default route inside IGP that is used inside the AS.
- Configure authentication on both neighbors.

## Alternative Solutions

- BGP process:
  - Different AS numbers and connectivity options
- EBGP and IBGP neighbors:
  - **update-source** command
- Advertise networks:
  - **next-hop-self**, synchronization







The same or similar results can be achieved by using different configuration steps.

When entering a BGP process, different AS numbers can be used between the neighbors. An EBGP or IBGP neighbor relationship is defined based on which AS number is used among the neighboring routers.

EBGP and IBGP relationships have different connectivity rules. An EBGP neighbor relationship is established between the directly connected neighbors; an IBGP neighbor relationship does not have this requirement. Loopbacks are used for IBGP neighbor relationships.

Networks are advertised with the next-hop attribute, which is processed in a different way that is based on an EBGP or IBGP neighbor relationship. The next-hop attribute can be changed, as well as the network advertisement between the EBGP and IBGP neighbors.

## Q and A

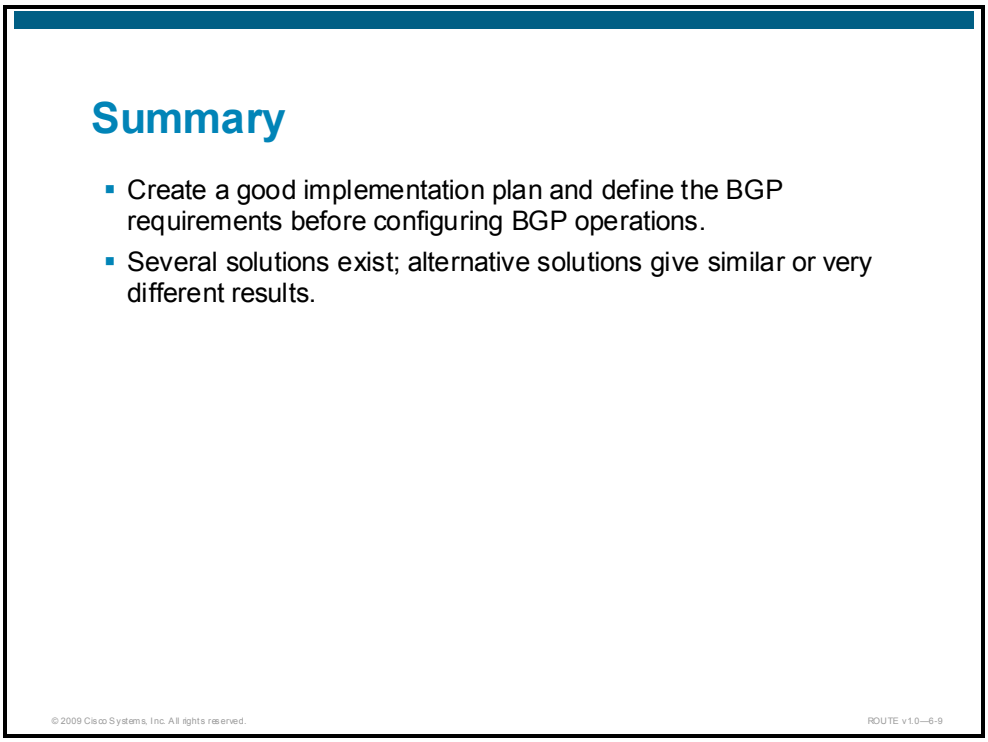
1. Why is the AS number important?
2. Why is the neighbor IP address important?
3. Why is the synchronization rule important?
4. Why is authentication necessary?




1. The AS number is important when creating neighbors because AS numbers define the EBGP or IBGP relationship.
2. An IP address that is used during neighbor configuration is important because EBGP neighbors require directly connected neighbors rather than IBGP neighbors, where there is no need to be directly connected.
3. The synchronization rule says that a router will not advertise routes in BGP until it learns the routes in an IGP. It is safe to have the synchronization rule off only if all routers in the transit path within the AS are running a full-mesh IBGP.
4. Authentication in BGP is used to verify that only trusted neighbors establish the neighbor relationship. If other routers that are configured for BGP are added to the system, they cannot attract traffic and establish the neighbor relationship.

# Summary

This topic summarizes the key points that were discussed in this lesson.



Lesson 6

# Using the BGP Attributes and Path Selection Process

## Overview

Border Gateway Protocol (BGP) is used to perform policy-based routing (PBR). To manipulate the best paths that are chosen by BGP, you need to understand the different attributes that BGP uses and how BGP selects the best path that is based on these attributes.

This lesson explains the BGP path selection process and the BGP attributes and their characteristics, and discusses configuration steps using different attributes for selecting a BGP path. Route filtering using route maps and prefix lists is described as well.

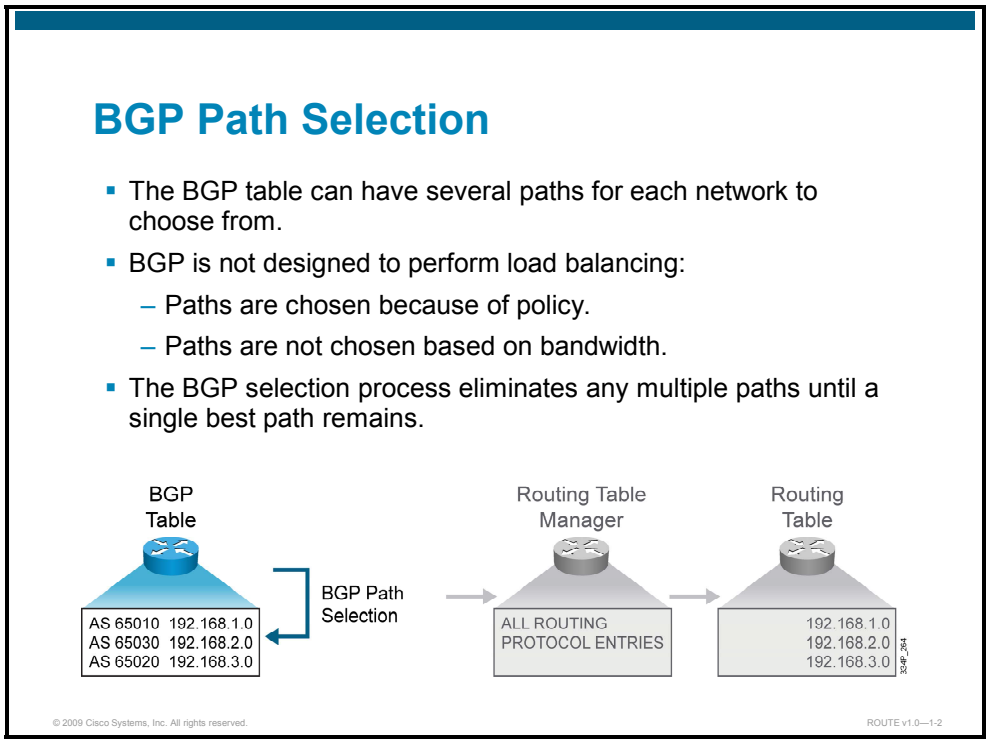
## Objectives

Upon completing this lesson, you will be able to configure and verify BGP operations in a multihomed environment using the BGP attributes and route maps to control all BGP routes to and from the router. This ability includes being able to meet these objectives:

- Understand the BGP path selection process
- Identify the characteristics of BGP attributes for path selection and path manipulation
- Configure filtering of BGP routing updates

# BGP Path Selection

This topic describes the criteria for selecting a BGP path.




Routers often have several neighbors and receive routing updates from each neighbor. All routing updates enter the BGP forwarding table; as a result, multiple paths may exist to reach a given network. The entire BGP forwarding table can be displayed using the **show ip bgp** command.

Next, paths for the network are evaluated to determine which path is best. Paths that are not the best are eliminated from the selection criteria but kept in the BGP forwarding table in case the best path becomes inaccessible. If one of the best paths is not accessible, a new best path must be selected.

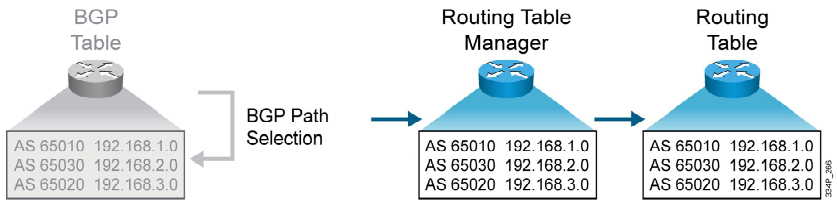
BGP is not designed to perform load balancing; paths are chosen based on policy, not based on bandwidth. The BGP selection process eliminates any multiple paths until a single best path remains.

## Routing Table Manager

The best path is submitted to the routing table manager process.

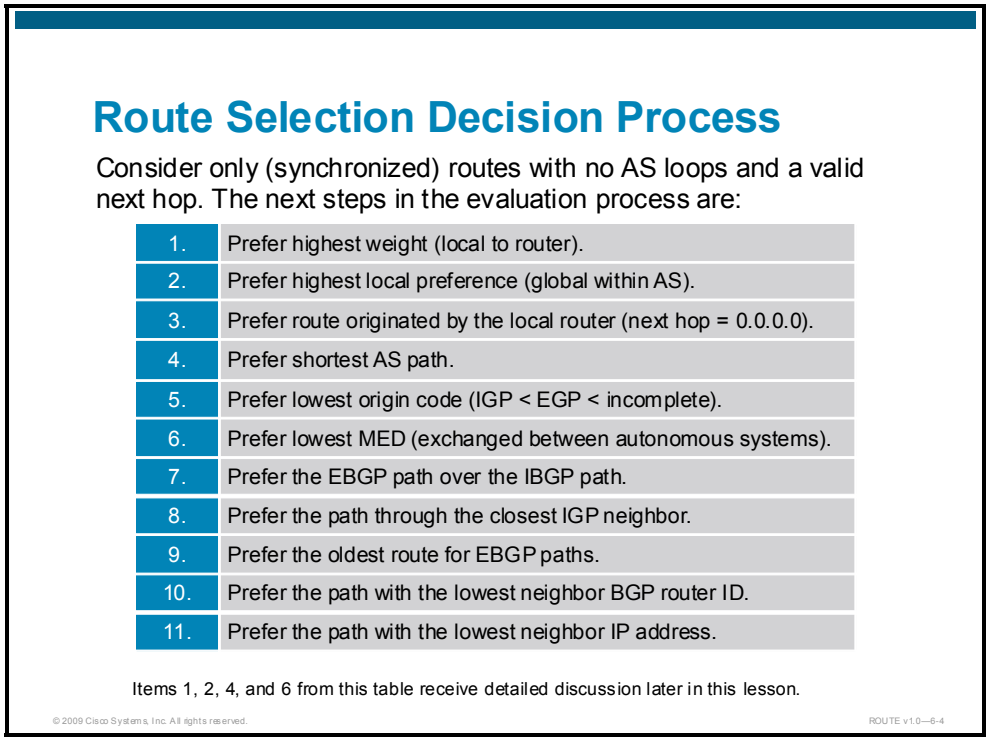
- The best path is evaluated against the routes of other routing protocols for reaching that network.
- The route with the lowest administrative distance from the source will be installed in the routing table.







The best path is submitted to the routing table manager process and is evaluated against any other routing protocols that can also reach that network. The router usually runs BGP and one of the interior gateway protocols (IGP)—Routing Information Protocol (RIP), Enhanced Interior Gateway Routing Protocol (EIGRP), Open Shortest Path First (OSPF), and so on—which are sending candidates for the routing table to the routing table manager. The route from the source with the lowest administrative distance is installed in the routing table. The entire routing table can be displayed using the **show ip route** command.




After BGP receives updates about different destinations from different autonomous systems, it chooses the single best path to reach a specific destination.

The decision process is based on the BGP attributes. When faced with multiple routes to the same destination, BGP chooses the best route for routing traffic toward the destination. BGP considers only synchronized routes with no autonomous system (AS) loops and a valid next hop. The following process summarizes how BGP chooses the best route on a Cisco router:

1. Prefer the route with the highest weight. (Weight is proprietary to Cisco and is local to the router only.)
2. If multiple routes have the same weight, prefer the route with the highest local preference. (The local preference is used within an AS.)
3. If multiple routes have the same local preference, prefer the route that the local router originated. A locally originated route has a next hop of 0.0.0.0 in the BGP table.
4. If none of the routes were locally originated, prefer the route with the shortest AS path.
5. If the AS path length is the same, prefer the lowest origin code (IGP < EGP < incomplete).

6. If all origin codes are the same, prefer the path with the lowest multi-exit discriminator (MED). (The MED is exchanged between autonomous systems.)

   The MED comparison is made only if the neighboring AS is the same for all routes that are considered, unless the **bgp always-compare-med** command is enabled.

> **Note** The most recent Internet Engineering Task Force (IETF) decision regarding BGP MED assigns a value of infinity to the missing MED, making the route that is lacking the MED variable the least preferred. The default behavior of BGP routers that are running Cisco IOS Software is to treat routes without the MED attribute as having a MED of 0, making the route that is lacking the MED variable the most preferred. To configure the router to conform to the IETF standard, use the **bgp bestpath missing-as-worst** command.

7. If the routes have the same MED, prefer external paths (External BGP, or EBGP) to internal paths (Internal BGP, or IBGP).
8. If synchronization is disabled and only internal paths remain, prefer the path through the closest IGP neighbor. This step means that the router will prefer the shortest internal path within the AS to reach the destination (the shortest path to the BGP next hop).
9. For EBGP paths, select the oldest route to minimize the effect of routes that are going up and down (flapping).
10. Prefer the route with the lowest neighbor BGP router ID value.
11. If the BGP router IDs are the same, prefer the router with the lowest neighbor IP address.

Only the best path is entered in the routing table and propagated to the BGP neighbors of the router.

> **Note** The route selection process that is summarized here does not cover all cases but is sufficient for a basic understanding of how BGP selects routes.

For example, suppose there are seven paths to reach network 10.0.0.0. No paths have AS loops, and all paths have valid next-hop addresses, so all seven paths proceed to Step 1, which examines the weight of the paths.

All seven paths have a weight of 0, so all paths proceed to Step 2, which examines the local preference of the paths. Four of the paths have a local preference of 200, and the other three have local preferences of 100, 100, and 150.

The four with a local preference of 200 will continue the evaluation process in the next step. The other three will still be in the BGP forwarding table but are currently disqualified as the best path.

BGP will continue the evaluation process until only a single best path remains. The single best path that remains will be submitted to the IP routing table as the best BGP path.

# Path Selection with Multihomed Connection

An AS rarely implements BGP with only one EBGP connection. This situation generally means that multiple paths exist for each network in the BGP forwarding database.

If only one path exists and it is loop-free and synchronized with the IGP for IBGP, and the next hop is reachable, the path is submitted to the IP routing table. There is no path selection taking place because there is only one path, and manipulating it will derive no benefit.

Only the best path is put in the routing table and propagated to the BGP neighbors of the router.

Without route manipulation, the most common reason for path selection is Step 4—prefer the shortest AS path.

Step 1 looks at weight, which by default is set to 0 for routes that were not originated by this router.

Step 2 compares local preference, which by default is set to 100 for all networks. Both of these steps have an effect only if the network administrator configures the weight or local preference to a nondefault value.

Step 3 looks at networks that are owned by this AS. If one of the routes is injected into the BGP table by the local router, the local router prefers it to any routes that are received from other BGP routers.

Step 4 selects the path that has the fewest autonomous systems to cross. This is the most common reason that a path is selected in BGP. If a network administrator does not like the path with the fewest autonomous systems, the administrator needs to manipulate the weight or local preference to change which outbound path that BGP chooses.

Step 5 looks at how a network was introduced into BGP. This introduction is usually either with network statements (“” for an origin code) or through redistribution (“?” for an origin code).

Step 6 looks at MED to judge where the neighbor AS wants this AS to send packets for a given network. Cisco sets the MED to 0 by default; therefore, MED does not participate in path selection unless the network administrator of the neighbor AS manipulates the paths that are using MED.

If multiple paths have the same number of autonomous systems to traverse, the second most common decision point is Step 7, which states that an externally learned path from an EBGP neighbor is preferred over a path that is learned from an IBGP neighbor. A router in an AS prefers to use the bandwidth of the ISP to reach a network rather than using internal bandwidth to reach an IBGP neighbor on the other side of its own AS.

If the AS path is equal and the router in an AS has no EBGP neighbors for that network (only IBGP neighbors), it makes sense to take the quickest path to the nearest exit point. Step 8 looks for the closest IBGP neighbor; the IGP metric determines what “closest” means (for example, RIP uses hop count, and OSPF uses the least cost that is based on bandwidth).

If the AS path is equal and the costs via all IBGP neighbors are equal, or if all neighbors for this network are EBGP, the oldest path—Step 9—is the next common reason for selecting one path over another. EBGP neighbors rarely establish sessions at the same time. One session is likely older than another, so the paths through that older neighbor are considered more stable because those paths have been up for a longer period.

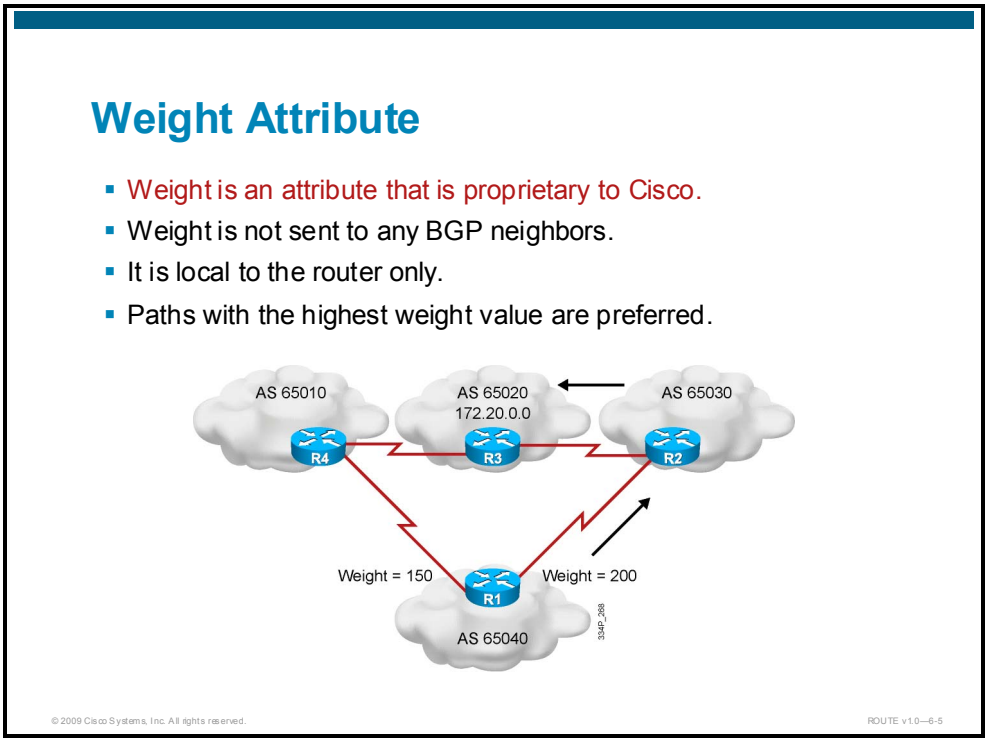
If all the criteria are equal, the next most common decision is to choose the neighbor with the lowest BGP router ID, which is Step 10.

If the BGP router IDs are all the same—for example, if the paths are to the same BGP router—Step 11 states that the route with the lowest neighbor IP address is used.

# Characteristics of BGP Attributes for Path Selection and Path Manipulation

BGP attributes inform the BGP routers that are receiving updates about how to treat the paths to the final network. This topic describes the characteristics of the BGP attributes that affect path selection.




The weight is an attribute that Cisco defines for the path selection process. The weight is configured locally on a router and is not propagated to any other routers. This attribute applies when one router is used with multiple exit points out of an autonomous system, as opposed to the local preference attribute, which is used when two or more routers provide multiple exit points.

The weight can have a value from 0 to 65535. Paths that the router originates have a weight of 32768 by default, and other paths have a weight of 0 by default.

Routes with a higher weight are preferred when multiple routes exist to the same destination.

In the figure, routers R2 and R4 learn about network 172.20.0.0 from AS 65020 and propagate the update to R1. R1 has two ways to reach 172.20.0.0, and it must decide which route to take—the path through R2 or the path through R4.

R1 sets the weight of updates that are coming from R2 to 200 and the weight of those that are coming from R4 to 150. Because the weight for the route that is pointing to R2 is higher than the weight for the route that is pointing to R4, R1 uses R2 as a next hop to reach 172.20.0.0.

## Setting Weight with Route Map

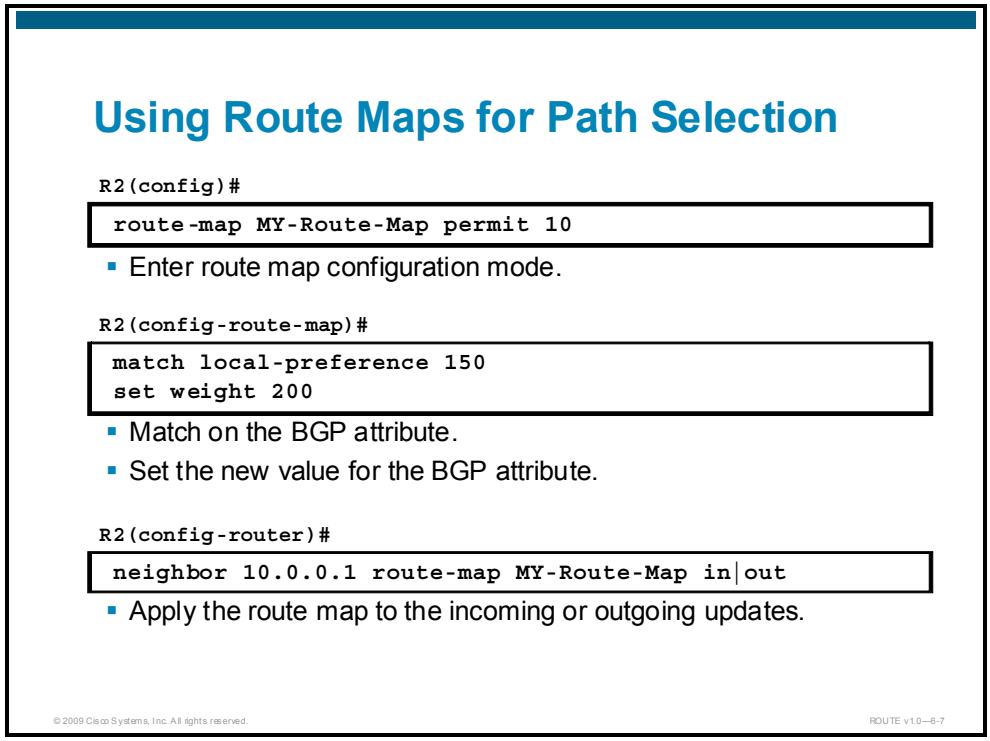
- First BGP path selection criterion.
- Prefer the highest weight (local to router).
- BGP weight can be specified per neighbor by complex criteria using route maps (AS path filters, prefix lists, or other BGP attributes that match the routes in any combination).




One way of changing the path selection is to use weights. Weight is an attribute that is locally significant to a router. Weight is a property or parameter; therefore, it is not seen on any neighboring routers. When designing BGP networks using weights, network administrators should set the weights on every router. If there is more than one path for the same network, a router will choose the path with the highest weight. The default value for weight is 0.

When a route map is applied, it is configured on the router. The route map can be arbitrarily complex and select routes that are based on various selection criteria, such as a network number or AS path. The selected routes can have some altered attributes. The route map can set the weight values of permitted routes. Selection can be done in several route map statements, giving the opportunity to assign a certain weight value to some routes and another weight value to others. A route map can also completely filter out routes. AS path filters, prefix lists, and other BGP attributes are used to match routes, where any combination can be used. Routes that are not matched are discarded.



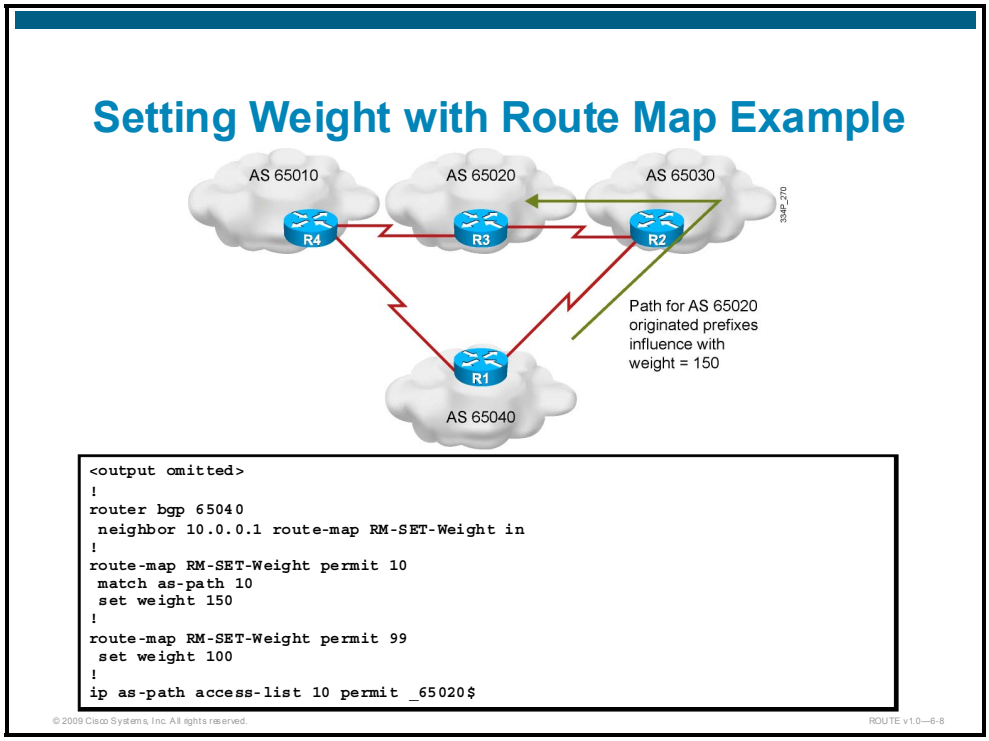

Three steps are needed when using route maps for path selection.

In the first step, a route map must be created. Use the **route-map** command in global configuration mode to create a route map and to enter route map configuration mode.

In the second step, a rule for changing the BGP attributes is created. Use the **match** command in route map configuration mode to define which incoming or outgoing updates will be affected. Use the **set** command in route map configuration mode to change selected BGP attributes.

The last step is required to apply a configured route map to incoming or outgoing routes. Use the **neighbor route-map** command in router configuration mode to apply the route map to BGP updates.

For more details about the **route-map**, **match**, **set**, and **neighbor route-map** commands, go to the Cisco IOS IP Routing: BGP Command Reference on the following link: http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

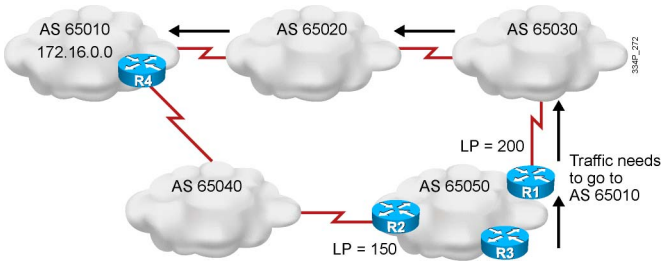



In the figure, the routing policy dictates the selection of AS 65030 as the primary way out of AS 65040 for the traffic that is destined to any network that originated in AS 65020. This limitation is achieved by placing a high weight of 150 on all incoming announcements from AS 65030 (that is, from neighbor 10.0.0.1), which carry the information about the networks that originated in AS 65020.

Targeting traffic coming from AS 65020 is achieved with the **ip as-path access-list** command. The **ip as-path** is a form of access list that uses regular expressions to target a BGP AS. In this example, **_65020$** targets traffic coming from AS 65020. The **ip as-path access-list** command is explained in more detail later in this lesson.

## Local Preference Attribute

- Used to select the outbound EBGP path.
- Sent to IBGP neighbors only (and only within the AS).
- Stripped in the outgoing EBGP updates except in the EBGP updates with confederation peers.
- The local preference attribute is well known and discretionary.
- Default value = 100.
- Paths with the highest local preference value are preferred.







Local preference is a well-known discretionary attribute that provides information to routers in the AS about the path that is preferred for exiting the AS. A path with a higher local preference is preferred.

The local preference is an attribute that is configured on a router and exchanged among routers within the same AS only. The default value for local preference on a Cisco router is 100.

To change the default local preference value of 100, use the **bgp default local-preference** command.

In the figure, AS 65050 receives updates about network 172.16.0.0 from two neighbors. Each of the networks is advertising a different path to the destination. The local preference on R1 for network 172.16.0.0 is set to 200, and the local preference on R2 for network 172.16.0.0 is set to 150.

Because the local preference information is exchanged within AS 65050, all routers are aware of the exit point for network 172.16.0.0 out of AS 65050. In the figure, R1 is configured with a higher local preference than R2, and all the traffic that is destined for network 172.16.0.0 will be sent to R1 as an exit point from AS 65050.

For more details about the **route bgp default local-preference** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

## Setting Local Preference with Route Map

- Second BGP path selection criterion.
- Prefer highest local preference (global within AS).
- Local preference can be set when:
  - Processing incoming route updates
  - Doing redistribution
  - Sending outgoing route updates
- BGP local preference can be specified per neighbor by complex criteria using route maps.




Using BGP in autonomous systems with a single neighbor relationship usually does not require any advanced features. In multihomed situations, however, it is important to ensure that the customer routers choose the correct link.

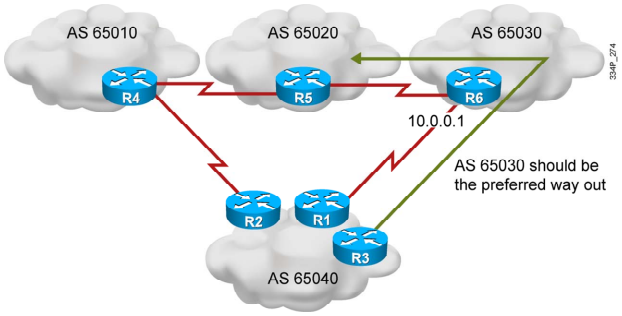
Local preference is the second-strongest criterion in the route selection process. If there are two or more paths that are available for the same network, a router will first compare weight, and if the weights are equal for all paths, the router will then compare the local preference attributes. The path with the highest local preference value will be preferred. The default value for local preference is 100.

Local preference is like weight because it is an attribute. It can be set once and can then be viewed on neighboring routers without having to reset it. This attribute has a default value of 100, which the router will apply to locally originated routes and updates that come in from external neighbors. Updates that come from internal neighbors already have the local preference attribute.

The local preference attribute is automatically stripped from outgoing updates to EBGP sessions. This practice means that this attribute can be used only within a single AS to influence the route selection process.

BGP local preference can be specified per neighbor by complex criteria using route maps. AS path filters, prefix lists, and other BGP attributes are used to match routes, where any combination can be used. Routes that are not matched are discarded.

## Setting Local Preference with Route Map (Cont.)



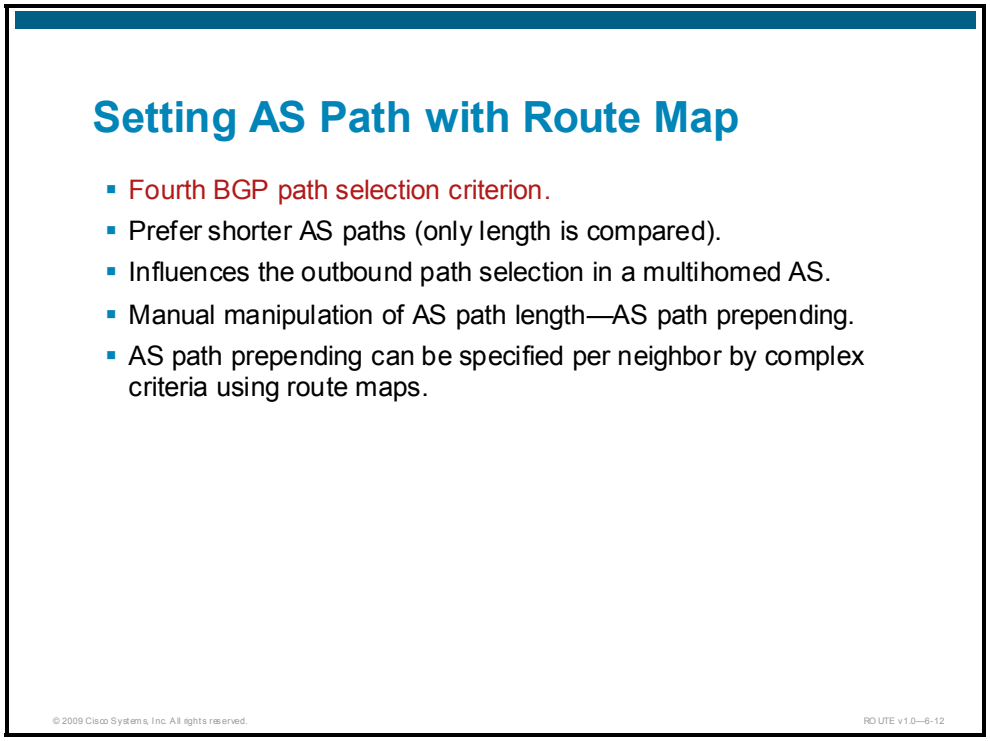

R1#

```
<output omitted>
!
router bgp 65040
 neighbor 10.0.0.1 route-map RM-SET-LP in
!
route-map RM-SET-LP permit 10
 set local-preference 150
```




In the figure, the routing policy dictates the selection of AS 65030 as the primary way out of AS 65040. This limitation is achieved by placing a local preference of 150, which is higher than the default local preference of 100, on all incoming announcements from AS 65030—that is, from neighbor 10.0.0.1.

Updates that are entering AS 65040 from AS 65030 will be processed by all BGP routers inside AS 65040, and these updates will be preferred to other updates that have the default local preference.




When connections to multiple providers are required, it is important that BGP selects the optimum route for traffic to use. The optimum, or best, route may not be what the network designer intended based on design criteria, administrative policies, or corporate mandate.

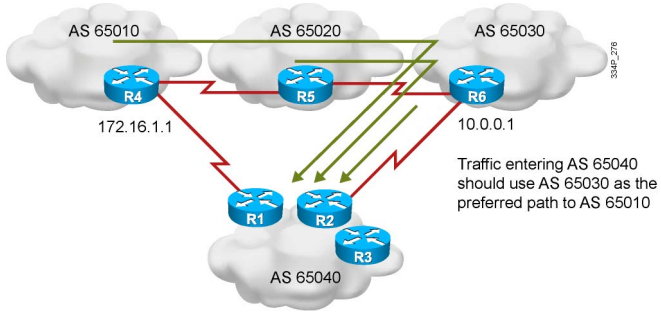
It is fairly easy for an AS to select the appropriate path for outgoing traffic. It is much more complicated to influence other autonomous systems to select the appropriate path for traffic that is returning to a specific AS. It is unlikely that the operator of an AS can request changes in router configurations in another AS. This limitation makes it virtually impossible to influence another AS to select the desired path that is based on the weight and local preference attributes, because both options would require configuration changes in the neighboring AS.

If no BGP path selection tools are configured on the route to influence the traffic flow, BGP will use the shortest AS path—the fourth option in the path selection process. If the AS path is not manually manipulated by some administrative means, the path that is going over the fewest number of autonomous systems is selected by the router regardless of available bandwidth.

However, if the AS that is attempting to influence the incoming traffic flow is sending out EBGP updates with a manipulated AS path attribute over that undesired path, the receiver of this update is less likely to select it as the best, because the AS path now appears to be longer. AS path prepending potentially allows the customer to influence the route selection of its service providers. The AS path is extended with multiple copies of the AS number of the sender. There is no exact mechanism to calculate the required prepended AS path length.

The benefit of manipulating AS paths to influence route selection is that the configuration that is needed is done in the AS that is requesting a desired return path.

## Setting AS Path with Route Map (Cont.)




```
R1#
<output omitted>
!
router bgp 65040
 neighbor 172.16.1.1 route-map RM-SET-ASPath out
!
route-map RM-SET-ASPath permit 10
 set as-path prepend 65040 65040 65040
```




AS paths can be manipulated by prepending AS numbers to existing AS paths. Normally, AS path prepending is performed on outgoing EBGP updates over the undesired return path. Because the AS paths that are sent over the undesired link become longer than the AS path that is sent over the preferred path, the undesired link is now less likely to be used as the return path.

The length of the AS path is extended because additional copies of the AS number of the sender are prepended to the AS path attribute. To avoid clashes with BGP loop prevention mechanisms, no other AS number—except that of the sending AS—should be prepended to the AS path attribute.

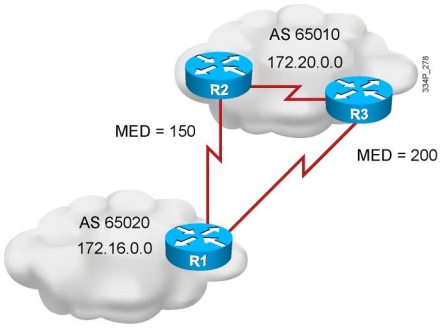
If another AS number is prepended in the AS path, the routers in the AS that has been prepended will reject the update because of BGP loop prevention mechanisms.

Prepending can be configured on a router for all routing updates that are sent to a neighbor or only on a subset of these updates.

In the figure, all updates that are sent to neighbor 172.16.1.1 are prepended three times with AS 65040, the AS number of the sender, thus making that path less preferable for the returning traffic. Keep in mind that if any AS on the path also does AS path prepending, the policy may not work.

## MED Attribute

- The paths with the lowest MED (also called the metric) value are the most desirable.
- MED is used to advertise an exit path to be used by EBGP neighbors to reach networks that are owned by this AS.
- The MED attribute is optional and nontransitive.







The MED attribute, also called the metric, is an optional nontransitive attribute.

The MED is an indication to EBGP neighbors about the preferred path into an AS. The MED attribute is a dynamic way to influence another AS about which path that it should choose to reach a certain route when multiple entry points into an AS exist. A lower metric is preferred.

Unlike local preference, the MED is exchanged between autonomous systems. The MED is sent to EBGP peers. Those routers propagate the MED within their AS, and the routers within the AS use the MED but do not pass it on to the next AS. When the same update is passed on to another AS, the metric is set back to the default of 0. To change this value, use the **default-metric** *number* command under the BGP process. All routes that are advertised to an EBGP neighbor are set to the value that is specified using this command.

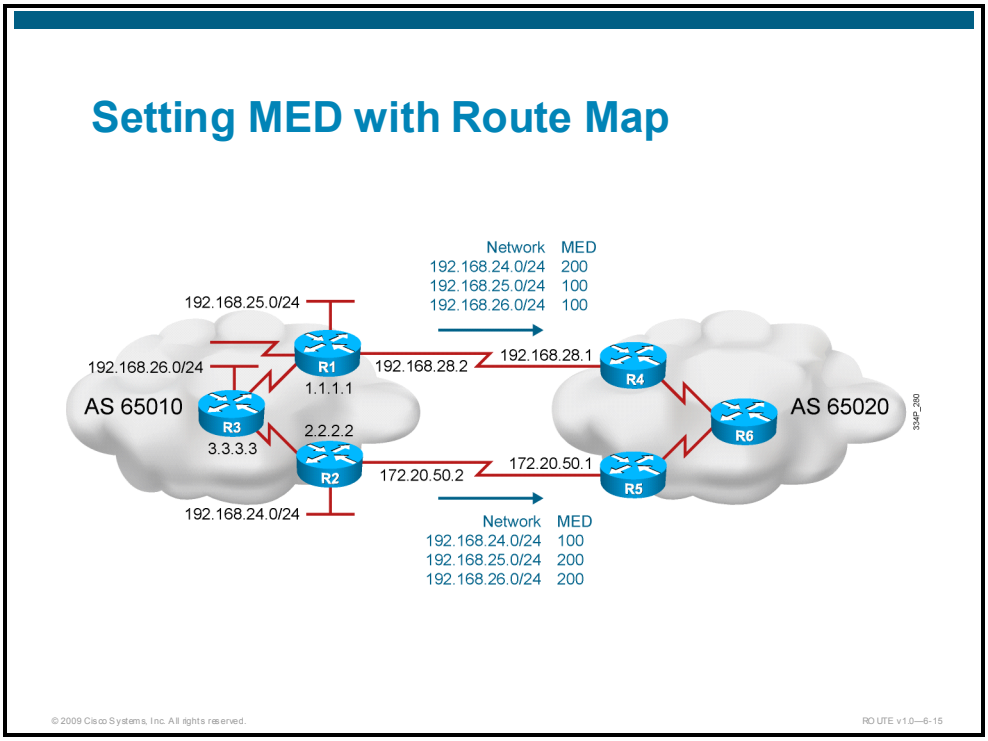
MED influences inbound traffic to an AS, and local preference influences outbound traffic from an AS.

By default, a router compares the MED attribute only for paths from neighbors in the same AS.

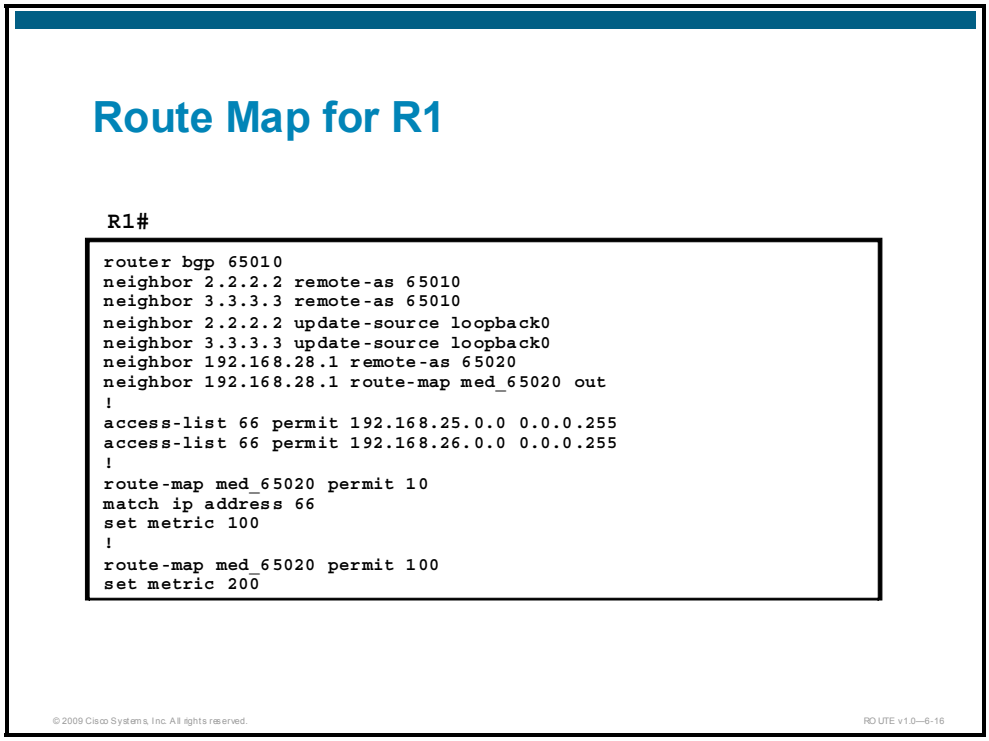
| | |
|---|---|
| **Note** | The MED attribute means that BGP is the only protocol that can affect how routes are sent into an AS. |

In the figure, the R2 MED attribute is set to 150, and the R3 MED attribute is set to 200. When R1 receives updates from R2 and R3, it picks R2 as the best next hop because its MED of 150 is less than the R3 MED of 200.

For more details about the **default-metric** *number* command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html




This figure is used in the following configurations to demonstrate how to manipulate inbound traffic using route maps to change the BGP MED attribute. The intention of these route maps is to designate R1 as the preferred path to reach networks 192.168.25.0/24 and 192.168.26.0/24 and to designate R2 as the preferred path to reach network 192.168.24.0/24. The other networks should still be reachable through each router in a link or router failure.




The MED is set outbound when a router is advertising to an EBGP neighbor. In the configuration example for R1, a route map named “med_65020” is linked to neighbor 192.168.28.1 as an outbound route map.

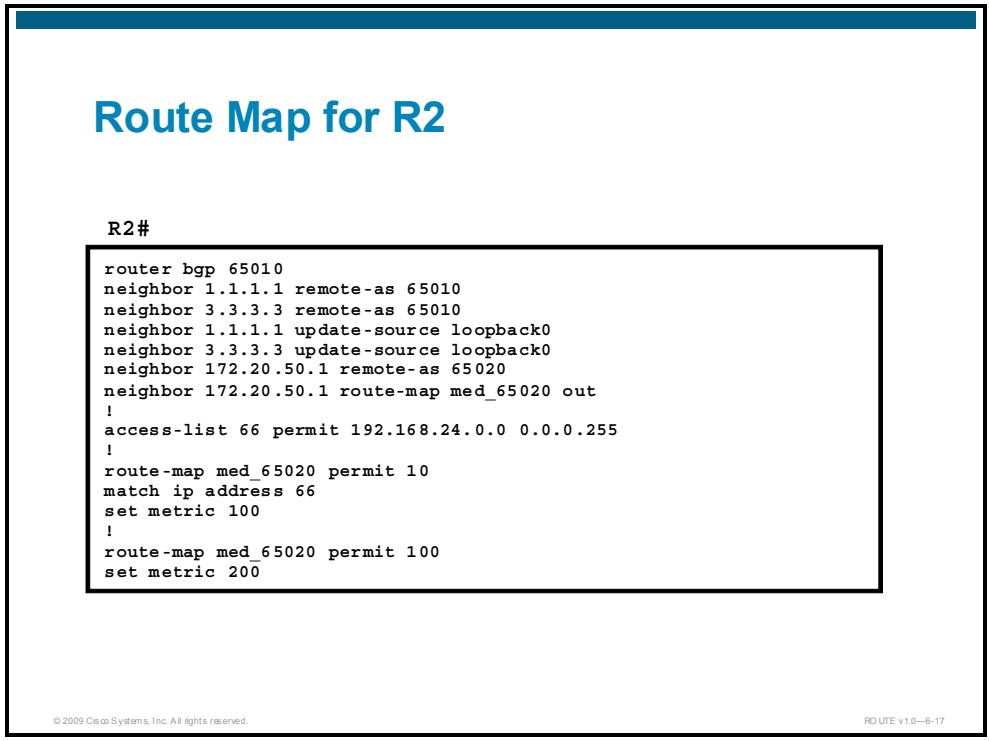
When R1 sends an update to neighbor 192.168.28.1 (R4), it processes the outbound update through route map med_65020 and uses a set statement to change any values that are specified, as long as the preceding match statement is met in that section of the route map.

The first line of the route map is a permit statement with a sequence number of 10 for the route map med_65020; this defines the first route map statement. The match condition for this statement checks all networks that are permitted by access list 66. The first line of access list 66 permits any networks that start with the first three octets of 192.168.25.0, and the second line of access list 66 permits networks that start with the first three octets of 192.168.26.0.

All networks that are permitted by either of these lines are set to a MED of 100. All other networks are denied by this access list (there is an implicit “deny all” at the end of all access lists), so those networks are not set to a MED of 100; their MED is not changed. These other networks must proceed to the next route map statement in the med_65020 route map.

The second statement of the route map is a permit statement with a sequence number of 100 for the route map med_65020. The route map does not have any match statements, just a **set metric 200** command. This is a “permit all” statement for route maps.

Because the network administrator does not specify a match condition for this portion of the route map, all networks that are being processed through this section of the route map (sequence number 100) are permitted and are set to a MED of 200. If the network administrator did not set the MED to 200, by default it would have been a MED of 0. Because 0 is less than 100, the routes with a MED of 0 would have been the preferred paths to the networks in AS 65010.




Similarly, in the configuration example for R2, a route map named “med_65020” is linked to neighbor 172.20.50.1 (R5) as an outbound route map.

Before R2 sends an update to neighbor 172.20.50.1, it will process the outbound update through route map med_65020 and use a set statement to change any values that are specified, as long as the preceding match statement is met in that section of the route map.

The first line of the route map is a permit statement with a sequence number of 10 for the route map med_65020, which defines the first route map statement. The match condition for that line checks all networks that are permitted by access list 66. Access list 66 on R2 permits any networks that start with the first three octets of 192.168.24.0.

Any networks that are permitted by this line are set to a MED of 100. All other networks are denied by this access list and are not set to a MED of 100. These other networks must proceed to the next route map statement in the med_65020 route map.

The second statement of the route map is a permit statement with a sequence number of 100 for the route map med_65020, but it does not have any match statements, just a **set metric 200** command. This is a “permit all” statement for route maps. Because the network administrator does not specify a match condition for this portion of the route map, all networks that are being processed through this second statement of the route map are permitted but are set to a MED of 200.

If the network administrator did not set the MED to 200, by default it would have been set to a MED of 0. Because 0 is less than 100, the routes with a MED of 0 would have been the preferred paths to the networks in AS 65010.

On R6, there are multiple paths to reach each network from AS 65010. These paths all have valid next-hop addresses, have synchronization disabled, and are loop-free. All networks have a weight of 0 and a local preference of 100, so Steps 1 and 2 do not determine the best path.

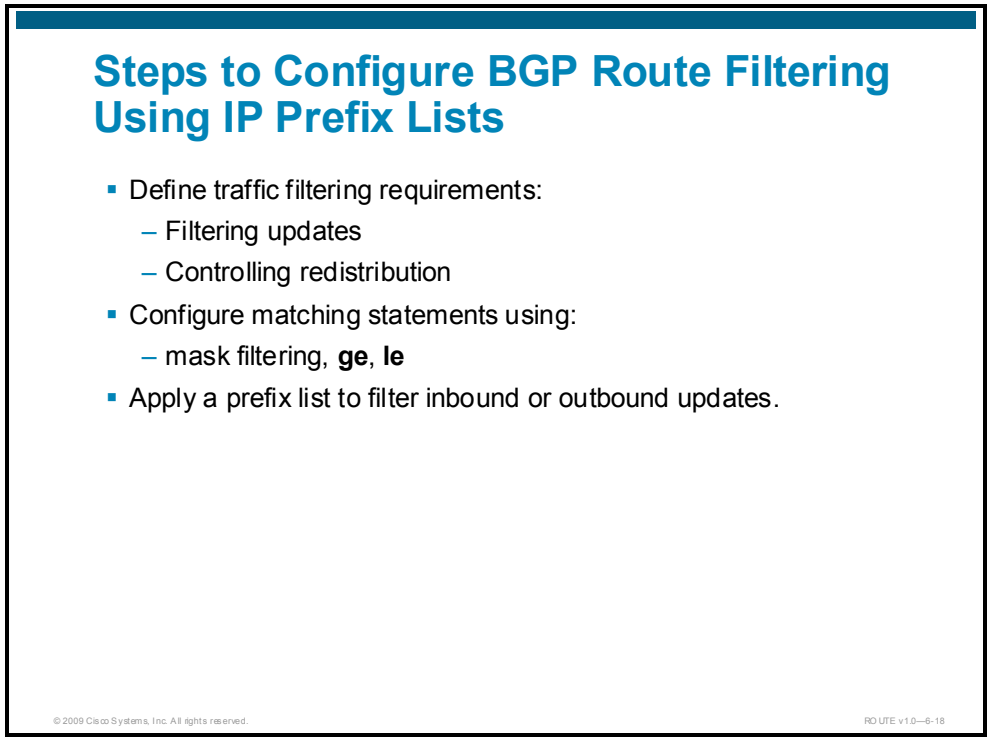
No routes were originated by this router or any router in AS 65020; all networks came from AS 65010, so Step 3 does not apply. All networks have an AS path of one AS (65010) and were introduced into BGP with network statements (“i” is the origin code), so Steps 4 and 5 are equal.

Step 6 states that BGP chooses the lowest MED if all preceding steps are equal or do not apply.

For network 192.168.24.0, the next hop of 172.20.50.2 has a lower MED than the next hop of 192.168.28.2. Therefore, for network 192.168.24.0, the path through 172.20.50.2 is the preferred path. For networks 192.168.25.0 and 192.168.26.0, the next hop of 192.168.28.2 has a lower MED of 100 compared with the MED of 200 through the next hop of 172.20.50.2; therefore, 192.168.28.2 is the preferred path for those networks.

# Filtering of BGP Routing Updates

BGP is receiving a high number of routing updates. To optimize the BGP configuration, route filtering must be applied. This topic describes the steps that are needed to configure filtering of routing updates.




When planning filter configuration using prefix lists, the following steps are required and an implementation plan must be created for these steps:

- Define the traffic filtering requirements:
  - Filtering updates
  - Controlling redistribution
- Configure the matching statements:
  - Use mask filtering, **ge**, **le**
- Apply a prefix list to filter inbound or outbound updates.

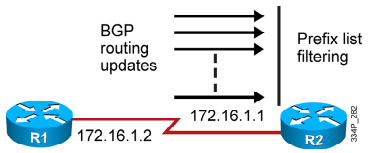
## Configuring Filtering of BGP Routing Updates

```
R2(config)#
ip prefix-list ANY-8to24-NET permit 0.0.0.0/0 ge 8 le 24
```

- Configure a matching statement to match all networks with the mask from /8 to /24.

```
R2(config-router)#
neighbor 172.16.1.2 prefix-list ANY-8to24-NET in
```

- Applies an inbound prefix list filter to prevent distribution of subnets other than /8 to /24. The prefix list is applied to incoming advertisements from the 172.16.1.2 neighbor.







Prefix list entries where the **ge** and **le** options are specified match any prefixes within the address range that are specified using the **ge** and **le** parameters. In the figure, the prefix list named "ANY-8to24-NET" is configured to match routes from any network that has a mask length from 8 to 24 bits. The 0.0.0.0/0 network/length combination does not match a specific network but is used to define any network. The combination of **ge 8 le 24** parameters specifies that any network with a mask length between 8 and 24 is a match.

A prefix list must be applied to inbound or outbound updates. In the figure, the prefix list ANY-8to24-NET is applied to the inbound traffic to prevent distribution of BGP neighbor information. The prefix list is applied to incoming advertisements from the BGP neighbor 172.16.1.2, which prevents distribution of routes from any network that does not have a mask length from 8 to 24 bits.

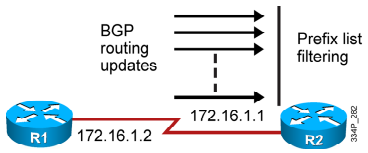
For more details about the **neighbor prefix-list** command, go to the Cisco IOS IP Routing: BGP Command Reference on the following link:
http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html

## Verifying Filtering of BGP Routing Updates

```
R2#show ip prefix-list detail ANY-8to24-NET

ip prefix-list ANY-8to24-NET:
Description: test-list
 count: 1, range entries: 1, sequences: 10 - 10, refcount: 3
 seq 10 permit 0.0.0.0/0 ge 8 le 24 (hit count: 0, refcount: 1)
```

- Display a matching statement for all networks with the mask from /8 to /24.

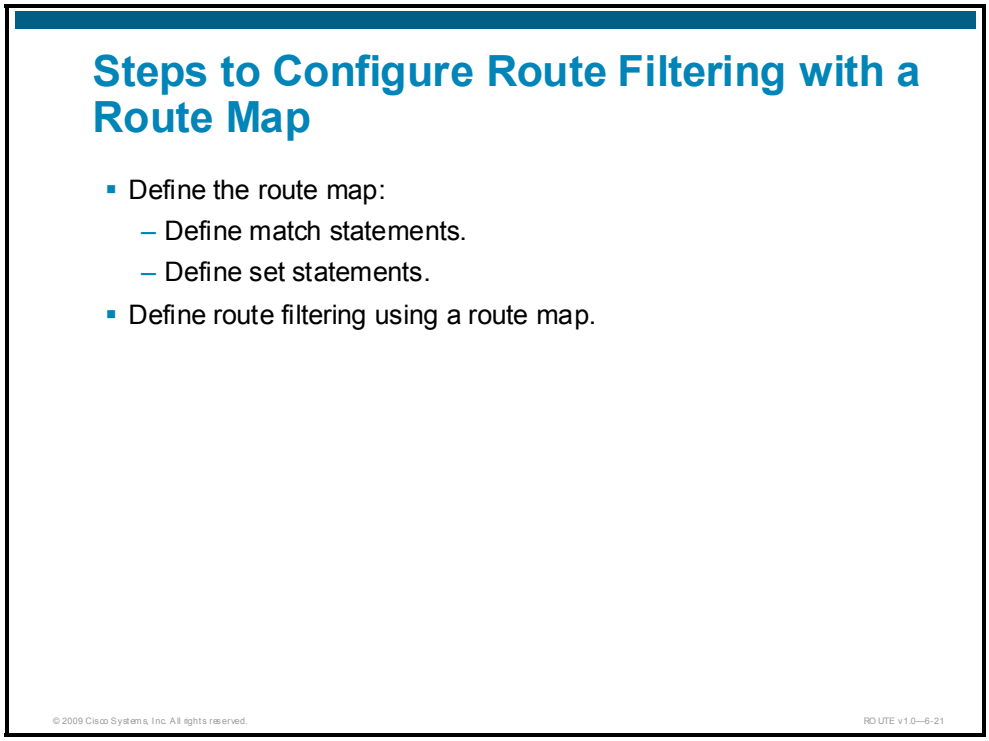






To display information about a prefix list or prefix list entries, use the **show ip prefix-list** command. The **show ip prefix-list** command output shows the count of packets that are being matched. The **clear ip prefix-list** command is used to clear the prefix list hit counters. The hit count is a value indicating the number of matches to a specific prefix list entry.

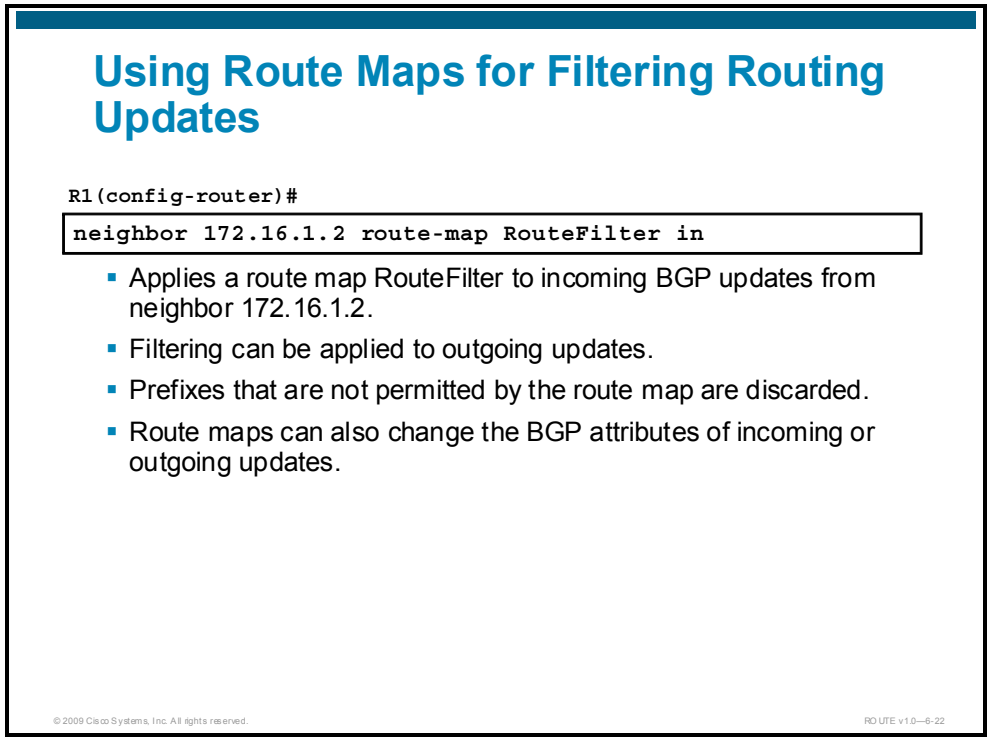
For more details about the **show ip prefix-list** and **clear ip prefix-list** commands, go to the Cisco IOS IP Routing: BGP Command Reference on the following link: http://www.cisco.com/en/US/docs/ios/iproute_bgp/command/reference/irg_book.html




When planning filter configuration using route maps, the following steps are required, and an implementation plan must be created for these steps:

- Define the route map:
  - Define the match statements.
  - Define the set statements.
- Define the route filtering using route maps.

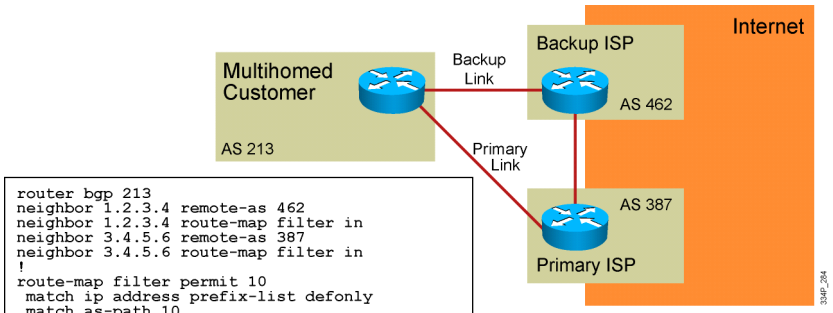



To apply a route map to filter incoming or outgoing BGP routes, use the **neighbor route-map** command in router configuration mode. The routes that are permitted can have their attributes set or changed by the set clauses in the **route-map** command. Setting attributes on routes is useful when attempting to influence route selection. Route map permit statements can be written to change the attributes of the permitted routes or to leave the attributes unchanged. When BGP performs route selection, the attribute values indicate that one route is preferred more than the other.

Similar route filtering could be performed for the OSPF or EIGRP routing process. In this case, the **distribute-list in** or **distribute-list out** commands are used together with the **route-map** command, which defines which updates are dropped and which updates are accepted.

## Using Route Maps as BGP Filters

- **Requirement:** The customer will accept only a default route and use the primary link for outbound traffic.

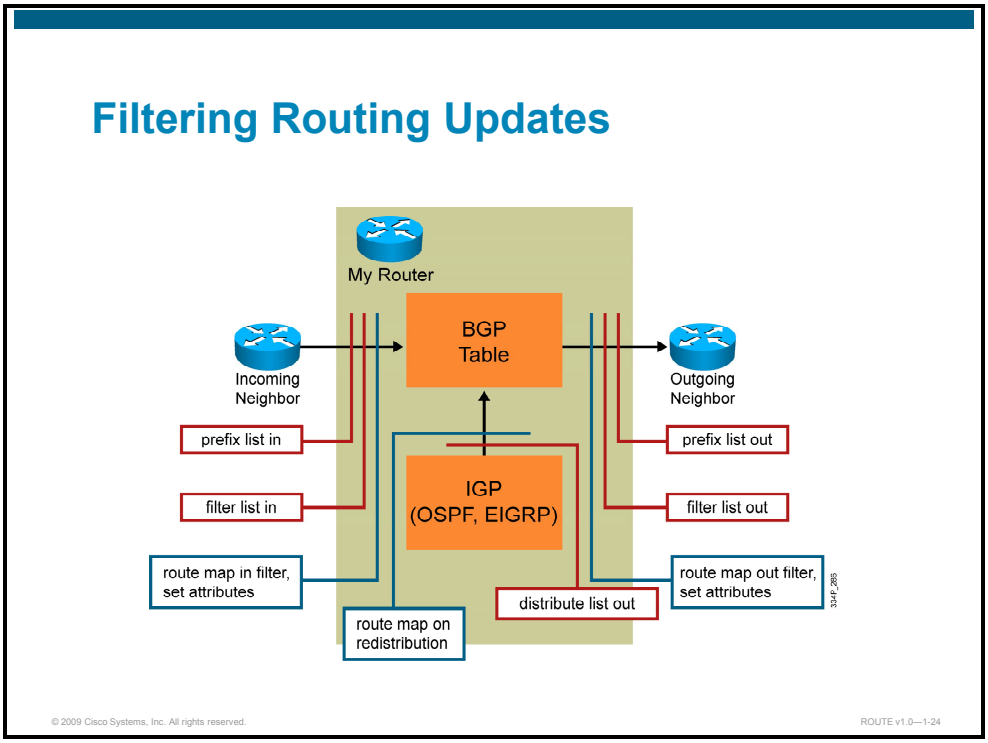



```
router bgp 213
neighbor 1.2.3.4 remote-as 462
neighbor 1.2.3.4 route-map filter in
neighbor 3.4.5.6 remote-as 387
neighbor 3.4.5.6 route-map filter in
!
route-map filter permit 10
 match ip address prefix-list defonly
 match as-path 10
 set weight 150
!
route-map filter permit 20
 match ip address prefix-list defonly
 set weight 100
!
ip as-path access-list 10 permit _387$
ip prefix-list defonly seq 10 permit 0.0.0.0/0
```




In this example, the customer will accept only a default route from the ISPs and will use the link to AS 387 as the primary link for outbound traffic.

The customer router in AS 213 is configured for BGP with two neighbors using the **neighbor remote-as** command. Both neighbors are configured with the **neighbor route-map** command to filter the incoming routing update traffic according to the route map named “filter.” The route map filter allows a default route into the customer network, and with careful setting of the BGP weight attribute, the primary link becomes preferred. A higher value for weight is preferred; the default route that is coming from the ISP in AS 387 gets a weight value of 150, and the secondary default route gets a weight value of 100.




As an option, filter lists, prefix lists, and route maps can be applied on either incoming or outgoing information, or in any combination in BGP. The incoming prefix list, the incoming filter list, and the incoming route map must all permit the routes that are received from a neighbor before they will be accepted into the BGP table. Outgoing routes must pass the outgoing filter list, the outgoing prefix list, and the outgoing route map before they will be transmitted to the neighbor.

When a router is configured to redistribute routing information from IGP into BGP, the routes must successfully pass any prefix list or route map that is applied to the redistribution process before the route is injected into the BGP table.

# Summary

This topic summarizes the key points that were discussed in this lesson.

## Summary

- After BGP receives updates about multiple destinations from different autonomous systems, it follows a multiple-step process for selecting the best route to reach a destination. The best route is a candidate for the routing table.
- BGP metrics are called path attributes and describe the paths to reach each network.
- BGP is receiving a high number of routing updates. To optimize the BGP configuration, route filtering with prefix lists must be applied.
- Route maps are used to set selected attributes for selected routes to control the outbound EBGP path selection.




## Summary (Cont.)

- The local preference attribute is a well-known discretionary attribute that provides an indication to routers in the AS about which path is preferred to exit the AS.
- The weight attribute is an attribute that Cisco defines for the path selection process; routes with a higher weight are preferred when multiple routes exist to the same destination.

Lesson 7

# Lab 6-2 Debrief

## Overview

In Lab 6-2, you manipulated the EBGP path selection with route maps using weight and MED. You used different BGP path selection methods and compared these methods in a routed network.

After completing the lab, the instructor will lead a discussion about the lab topology, tasks, verification, and checkpoints, as well as a sample solution and alternatives. You will present your implementation plan and solution.

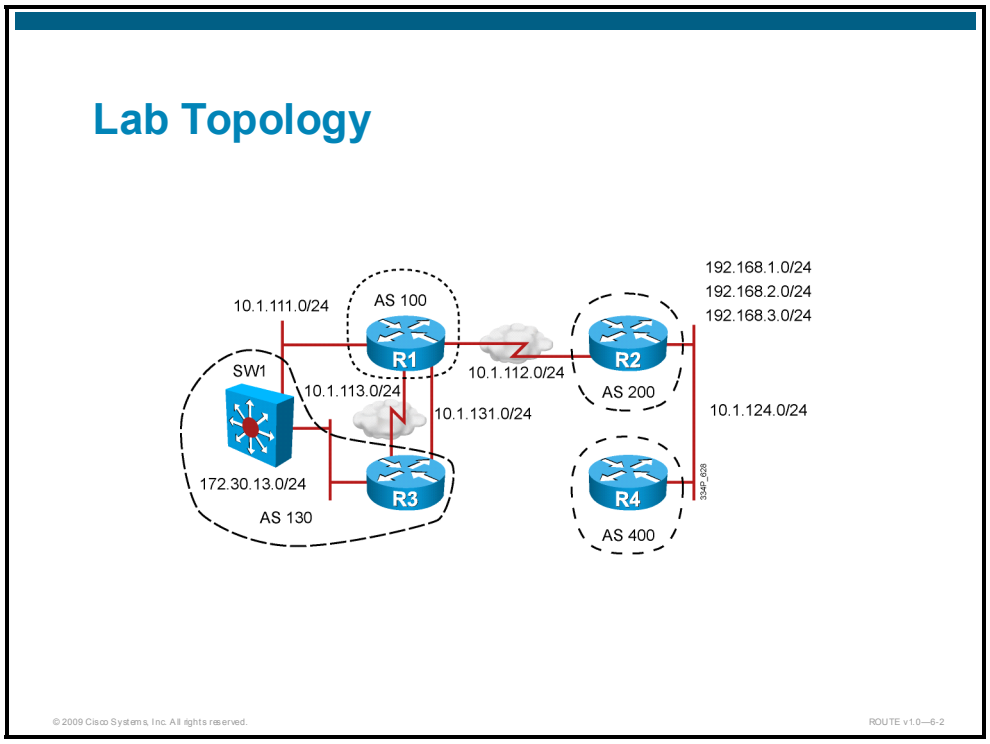
## Objectives

Upon completing this lesson, you will be able to explain the lab topology, configure the BGP path manipulation using local preference, weight, and MED BGP attributes, create checkpoints for configuration and verification, and find alternative solutions. This ability includes being able to meet these objectives:

- Identify the implementation and verification tasks to establish BGP adjacency in the network and manipulate the BGP path using local preference, weight, and MED BGP attributes
- Present a sample solution and identify possible alternative solutions

# Lab Overview and Verification

This topic describes the lab topology and key checkpoints that are used to create a solution and start verification.




This figure presents the lab topology that is used for the configuration of BGP path manipulation. The topology uses four pod routers and two backbone routers, which are members of an EBGP relationship. The lab is preconfigured with addressing, including loopbacks and an IGP routing protocol.

Based on the topology, you can create a BGP path manipulation configuration that includes a complete BGP process, advertising next hop, and synchronization.

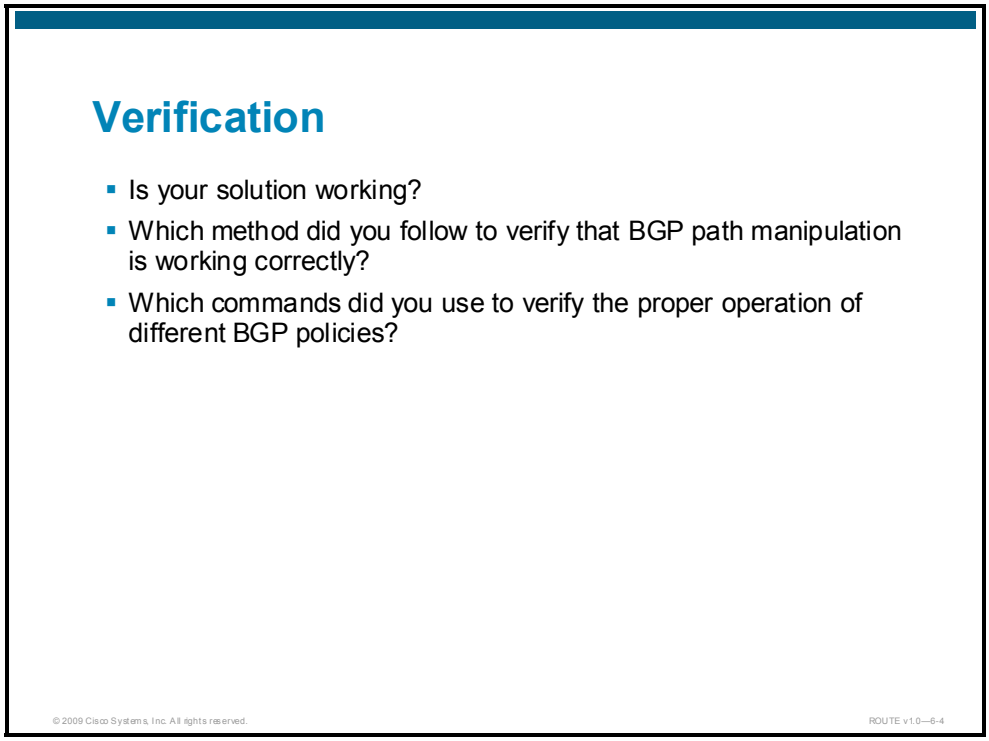
## Lab Review: What Did You Accomplish?

- **Task 1:** Configure and verify BGP adjacencies.
  - Which steps did you take to configure BGP?
  - How did you deal with loopback interfaces?
- **Task 2:** Use MED and weight with route maps for BGP path manipulation.
  - What is the difference between a MED and a weight implementation?
  - In which order did you execute your plan and why?
  - How did you apply a new policy to the BGP neighbor?



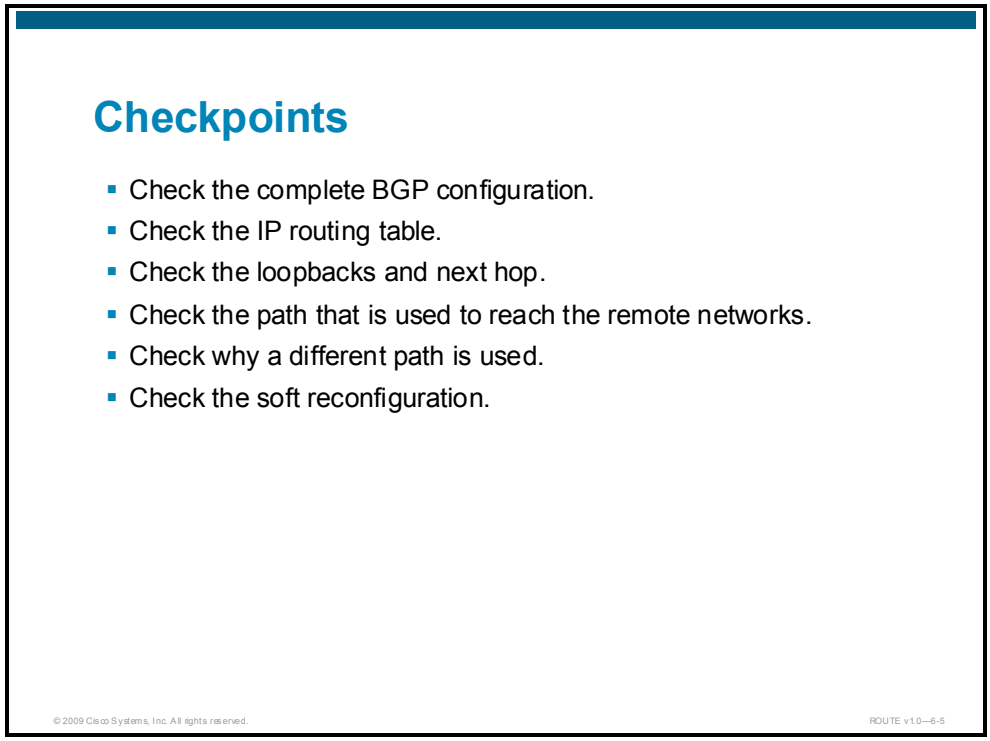

In the first task, you were asked to clean up previous router configurations and establish a new BGP configuration.

In the second task, MED and weight were used to manipulate the path. Each time the policy is changed, there is a need to perform a soft reconfiguration to see the results of the new configuration.




A common approach to verify the proper BGP path manipulation is as follows:

- Verify that all BGP peering sessions are operational. The following commands can be used for this verification:
  - **show ip bgp summary**: Displays the status of all BGP connections
  - **show ip bgp neighbors**: Displays information about the BGP and TCP connections to neighbors
- Verify what the MED and weight values are and which routes are inside the BGP table. The following command can be used for this verification:
  - **show ip bgp:** Displays entries in the BGP routing table
- Verify which BGP routes were entered in the routing table. The following command can be used for this verification:
  - **show ip route**: Displays entries in the IP routing table




During the configuration and verification phase, you can use several checkpoints. After completing all the configuration tasks, BGP configuration can be successfully completed or additional verification and troubleshooting is needed.

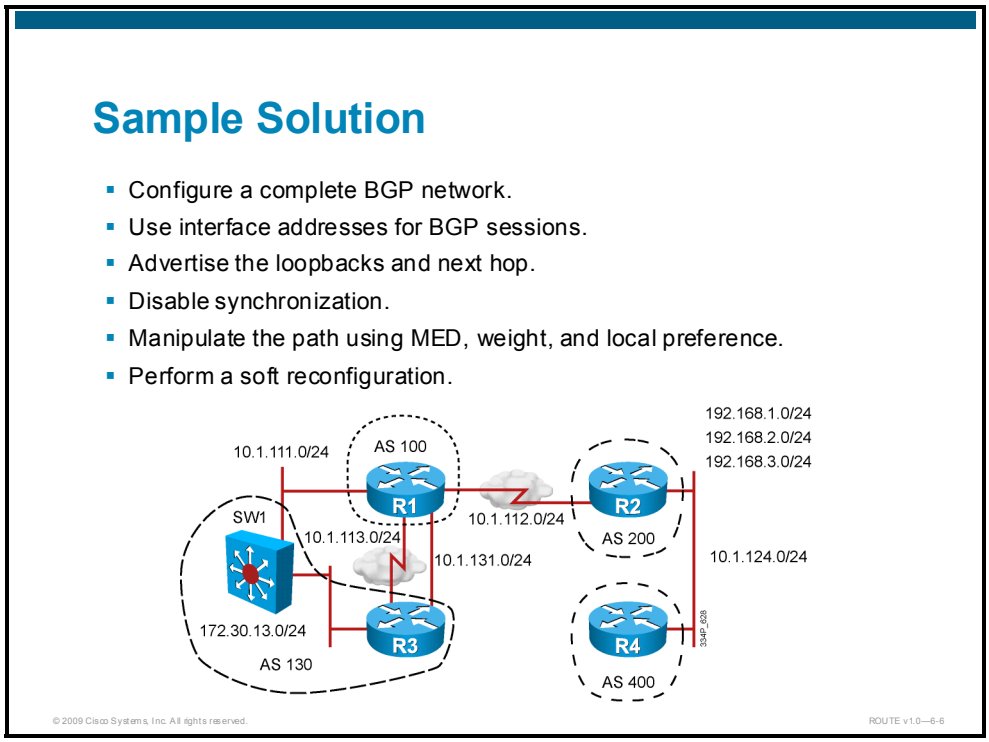
Optionally, you can check the BGP configuration in different stages of the implementation using checkpoints to verify each stage.

With different checkpoints, you can check for proper configuration as follows:

- Check the complete BGP configuration.
- Check the IP routing table.
- Check the loopbacks and next hop.
- Check the path that is used to reach the remote networks.
- Check why a different path is used.
- Check the soft reconfiguration.

# Sample Solution and Alternatives

This topic describes a sample solution and possible alternatives.



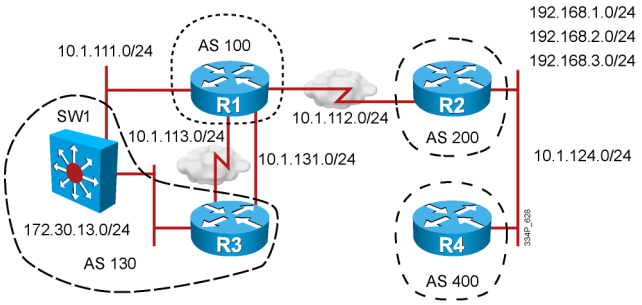

A sample solution includes configuration steps for each of the tasks. Different solutions are possible; the figure shows the important tasks that are required for a successful configuration.

To be able to complete the lab configuration successfully, use the following guidelines:

- Configure a complete BGP network.
- Use loopbacks for the IBGP sessions and the EBGP sessions when several paths are possible.
- Advertise the loopbacks and next hop.
- Disable synchronization.
- Manipulate the path using MED, weight, and local preference.
- Perform a soft reconfiguration.

## Alternative Solutions

- Configure a full-mesh or partial-mesh BGP.
- Use loopbacks or other interfaces for the BGP session.
- Install routes into the IP routing table or advertise the next hop.
- Turn off synchronization when BGP is advertising networks to other peers.
- Use other BGP attributes (besides MED or weight) for path manipulation.
- A soft reset can trigger an update of the BGP table after a policy change.







The same or similar results can be achieved by using different configuration steps.

When configuring a BGP neighbor relationship, it can be either a full-mesh or partial-mesh BGP.

Loopbacks are always on if the router is operational, and it is very convenient to establish BGP sessions between the loopback interfaces. Loopbacks must be advertised inside an IP routing table as well as other next-hop IP addresses.

When a BGP is advertising networks to other peers, the route must be present in the IP routing table or synchronization must be turned *off*.

MED, weight, and local preference can be used to manipulate the path selection. MED is used to influence the inbound EBGP path selection; weight and local preference can be used to influence the outbound EBGP path selection. There are other BGP attributes that can be used to influence the path selection, including AS path.

When the BGP policy changes, there is a need to refresh the BGP and IP routing table. Resetting the BGP session is not an elegant solution. A soft reset is available to trigger an update of the BGP table.

## Q and A

1. Why is the next-hop IP address important?
2. When is synchronization needed?
3. What are different reconfiguration options?
4. What is the difference between MED and weight?




1. Next hop is used when forwarding the packets toward their destination. Every BGP update has information about the remote networks together with the next-hop address that is used for forwarding the packets. The next-hop address must be reachable to forward the packets.

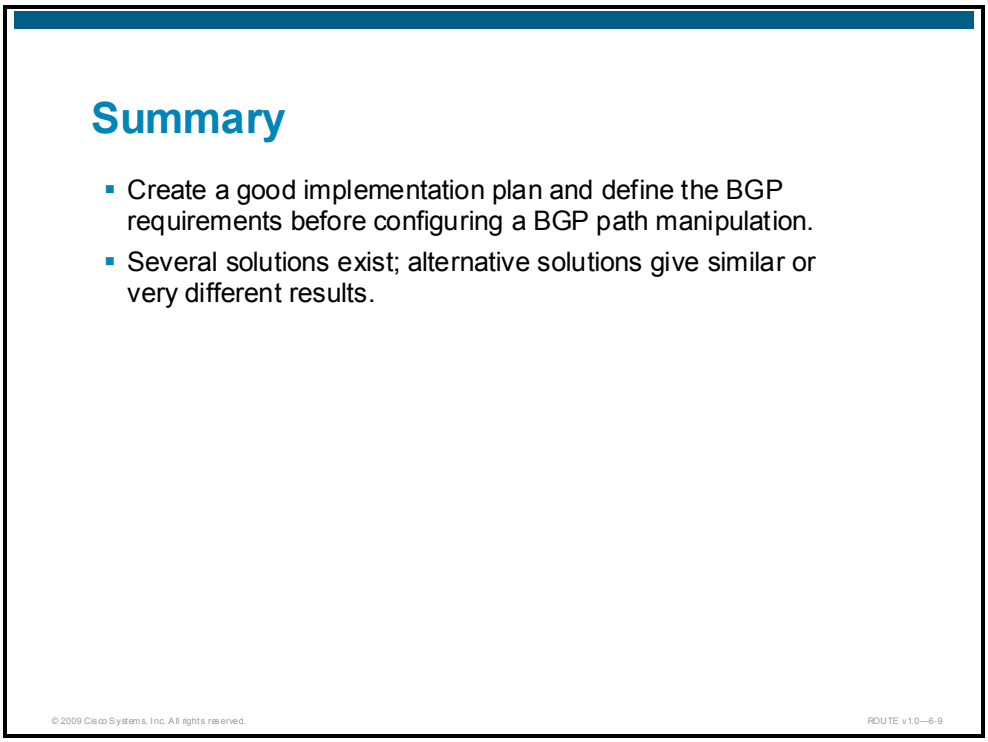
2. The synchronization rule says that a router will not advertise routes in BGP until it learns them from an IGP. It is safe to have the synchronization rule off only if all routers in the transit path within the AS are running a full-mesh IBGP.

3. To update the BGP table, the operator can clear the BGP session or trigger the neighbor to resend the complete BGP table. This last option is called a soft reconfiguration and requires more resources. At the same time, it is not as aggressive as a BGP session staying up all the time.

4. MED is used to manipulate the inbound path to the AS; local preference and weight are used to manipulate the outbound path from the AS.

# Summary

This topic summarizes the key points that were discussed in this lesson.



Lesson 8

# References to IPv6 and Implementing Remote-Access Connectivity in E-Learning

## Overview

The *Implementing Cisco IP Routing* (ROUTE) v1.0 instructor-led training (ILT) course is a comprehensive learning experience. Among the learning tools available are e-learning modules that complement the classroom instructor-led content and help complete your experience with self-paced materials and demonstrations. Upon accessing the e-learning content, you will be able to reinforce the knowledge that was acquired in class and witness real-life scenarios that are demonstrated in real routers and switches. The content structure is flexible, and you can navigate it at your own pace, at the time of your choosing, and at the depth that you desire according to your level of experience.

This lesson presents the topics of IP version 6 (IPv6) and remote access connectivity. Two e-learning modules are reviewed: "Implementing IPv6" and "Implementing Routing Facilities for Branch Offices and Mobile Workers." The content includes demonstrations that cover critical topics in both areas.

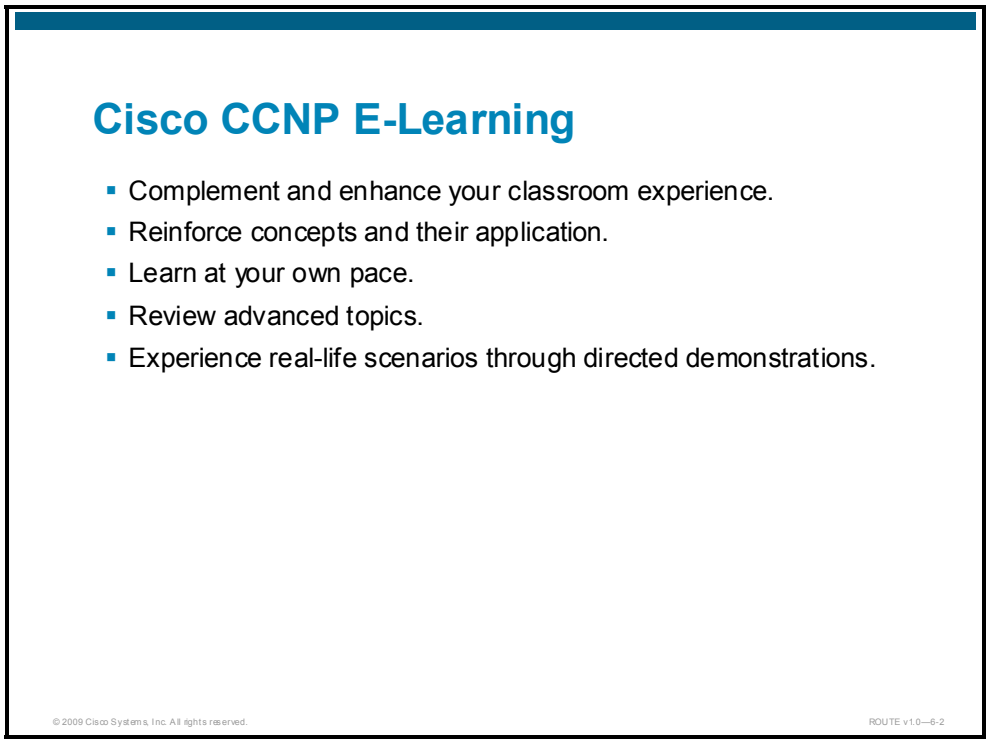
## Objectives

Upon completing this lesson, you will be able to discuss the e-learning modules that pertain to additional topics in IPv6 and remote access connectivity. This ability includes being able to meet these objectives:

- Describe the content of the "Implementing IPv6" e-learning module
- Describe the content of the "Implementing Routing Facilities for Branch Offices and Mobile Workers" e-learning module
- Understand the structure and the process of accessing and using e-learning content

# Preview of E-Learning Modules

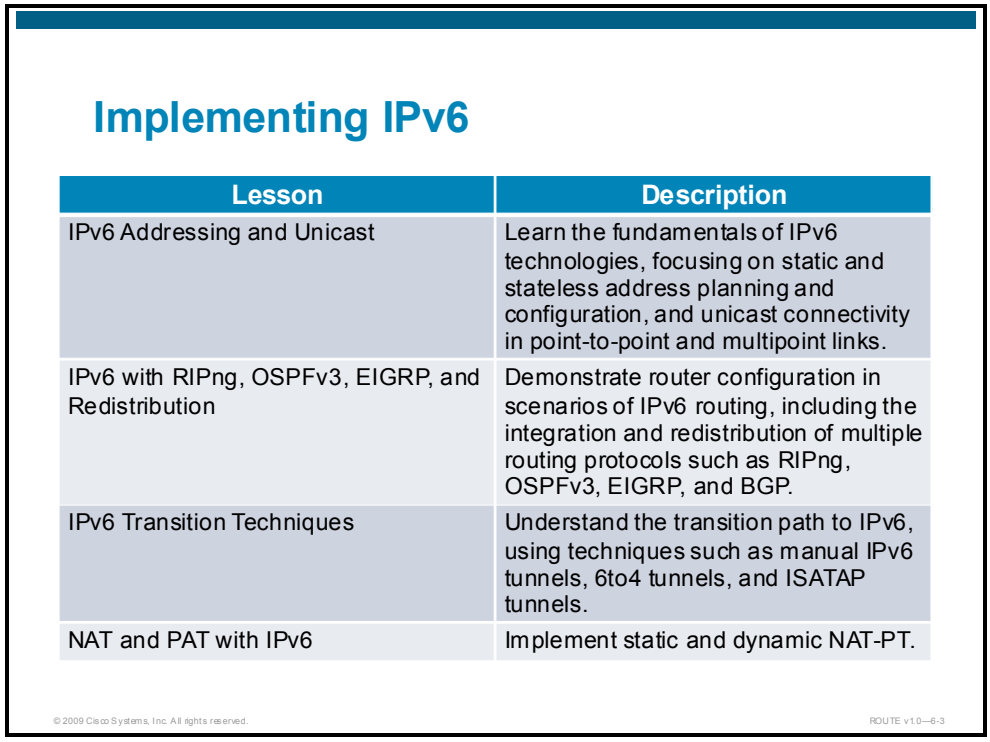
This topic describes two e-learning products that pertain to additional topics in IPv6 and remote access connectivity.




One of the key ideas behind the design of the Cisco CCNP® curriculum is the understanding that there is no one "best" method of learning for every student. Some students prefer individual labs, while others prefer one-on-one tutoring, hands-on sessions, self-paced computer-assisted instruction, direct discovery learning or cooperative learning, and other methods.

E-learning solutions offer new approaches that complement and enhance classroom-based learning. Designed with flexibility and learning effectiveness in mind, the "Implementing IPv6" and "Implementing Routing Facilities for Branch Offices and Mobile Workers" e-learning modules are based on knowledge that you acquired during your *Implementing Cisco IP Routing* (ROUTE) v1.0 instructor-led training course.

Both modules include new concepts and describe these concepts starting with the fundamentals and going into more depth through directed demonstrations.




The “Implementing IPv6” e-learning module covers topics that enhance the “Connecting an Enterprise Network to an ISP Network“ module of the *Implementing Cisco IP Routing* (ROUTE) v1.0 course. It starts with an introductory lesson that discusses the benefits of the protocol and structural and operational fundamentals, such as addressing. Directed demonstrations will guide subsequent lessons on IPv6 routing and routing protocols, IPv4-to-IPv6 transition techniques including IP version 6 (IPv6), 6to4, and Intra-Site Automatic Tunnel Addressing Protocol (ISATAP) tunnels and Network Address Translation (NAT) as well as Port Address Translation (PAT) in IPv6 scenarios. IPv6 is supported by Routing Information Protocol next generation (RIPng), Open Shortest Path First version 3 (OSPFv3), and Enhanced Interior Gateway Routing Protocol (EIGRP).

## Implementing Routing Facilities for Branch Offices and Mobile Workers

| Lesson | Description |
|---|---|
| Analyzing Branch Office Designs and Planning for Branch Office Installations | Watch a discussion on design fundamentals and trends for the branch office. Review the design scenarios that will be demonstrated in the next lesson. |
| Directed Demo: How to Implement Special Facilities for Branch Offices | Demonstrate router configurations in scenarios of branch office connectivity, including verification of existing services, routing around IPsec tunnels using GRE, and other routing facilities. |
| Lab Debrief | Gather conclusions, sample configurations, and alternative methods related to the demonstrations in the previous lesson. |




The "Implementing Routing Facilities for Branch Offices and Mobile Workers" e-learning module also covers topics that enhance the "Connecting an Enterprise Network to an ISP Network" module of the *Implementing Cisco IP Routing* (ROUTE) v1.0 course. It is structured in two major topics: branch office scenarios and mobile worker scenarios.

Branch office designs are analyzed through an introductory lesson that discusses trends and factors to consider in the implementation plan of new installations and upgrades. The directed demonstrations focus on scenarios involving backup connectivity, alternative routing across IPv6 tunnels using Generic Routing Encapsulation (GRE), load sharing, and other situations.

## Implementing Routing Facilities for Branch Offices and Mobile Workers (Cont.)

| Lesson | Description |
|---|---|
| Analyzing Mobile Worker Designs and Planning for Mobile Worker Installations | Review design fundamentals and trends for the mobile worker. Review the design scenarios that will be demonstrated in the next lesson. |
| Directed Demo: Implement Special Facilities for Mobile Workers | Demonstrate router configurations in scenarios of mobile worker connectivity, including verification of existing services, IP addresses, and routing facilities provisioned for mobile workers. |
| Lab Debrief | Gather conclusions, sample configurations, and alternative methods related to the demonstrations in the previous lesson. |




The mobile worker topic is approached in a similar way. An introductory lesson will describe trends and design considerations. This lesson is followed by a directed demonstration of remote access connectivity for mobile users, including addressing and routing considerations around the use of IP Security (IPsec) tunnels as a connectivity option.

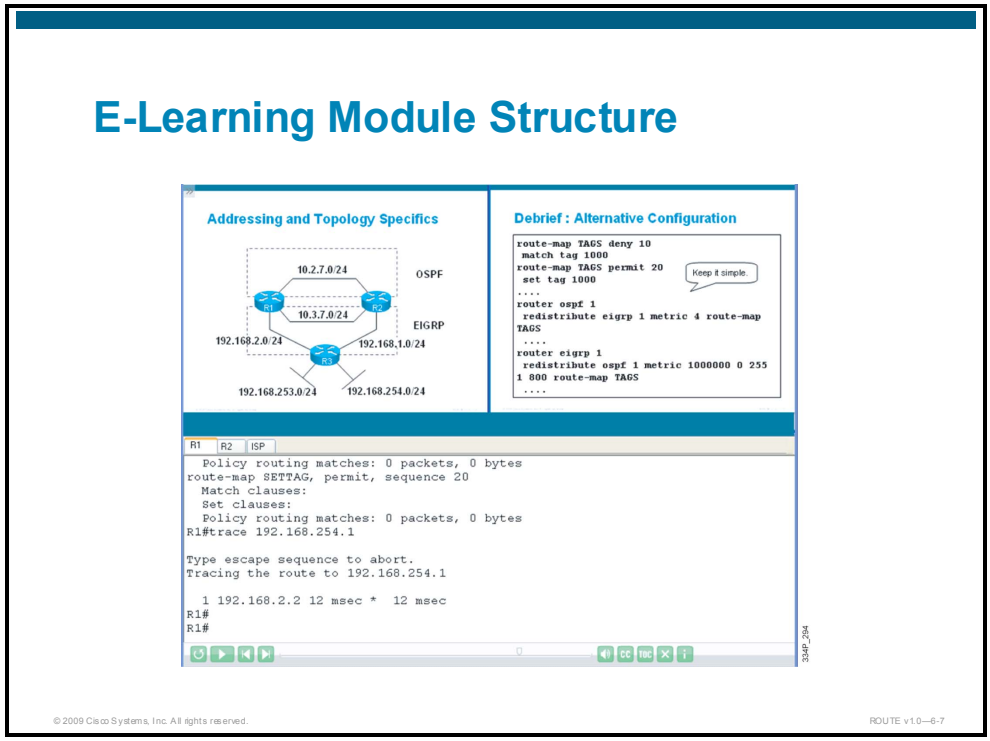
## Where to Find E-Learning Modules





The “Implementing IPv6” and “Implementing Routing Facilities for Branch Offices and Mobile Workers” e-learning modules are available on CD as part of your classroom materials. Please contact your instructor with questions about finding and accessing the CD.

The objectives of the “Implementing IPv6” and “Implementing Routing Facilities for Branch Offices and Mobile Workers” e-learning modules are part of your CCNP certification exam. As such, candidates for the CCNP certification should review these objectives.

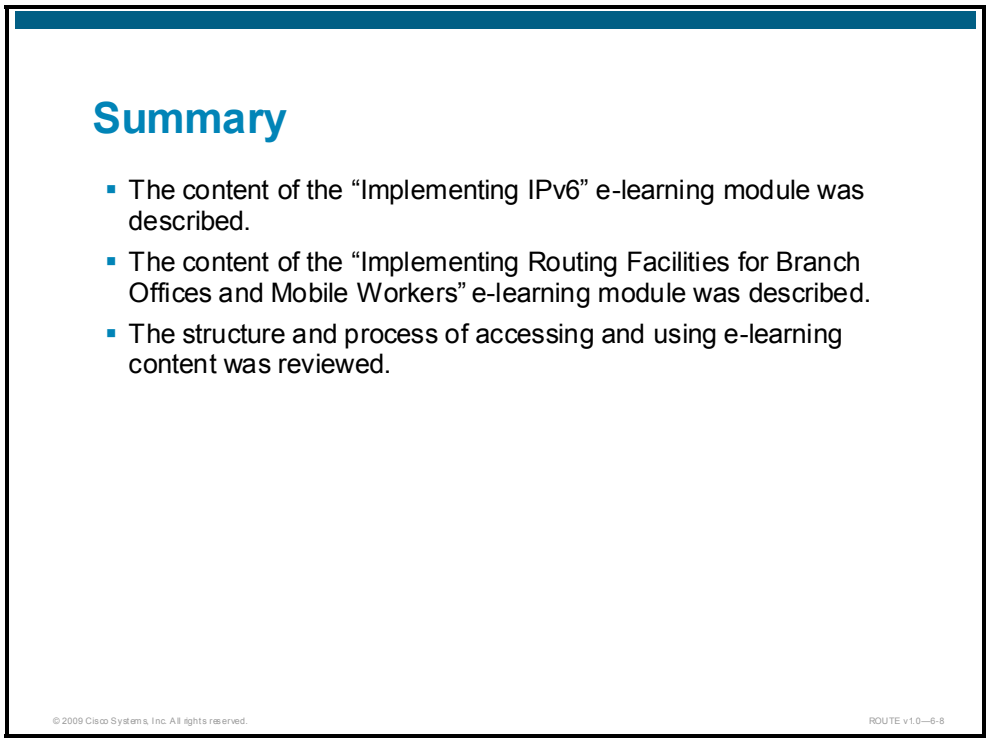



Utilizing a combination of lecture sessions, animated content, lab demonstrations, and assessments, each e-learning module presents a hierarchical structure of lessons and topics. You can navigate through that structure by using an intuitive GUI that includes playback controls, slide selection, and lesson and topic selection. Using these tools, you will be able to navigate the content at your own pace.

The three-panel screen that is presented in the directed demonstrations allows you to focus on the device console demonstrations, while having the command syntax and the topology diagram available for verification and additional information.

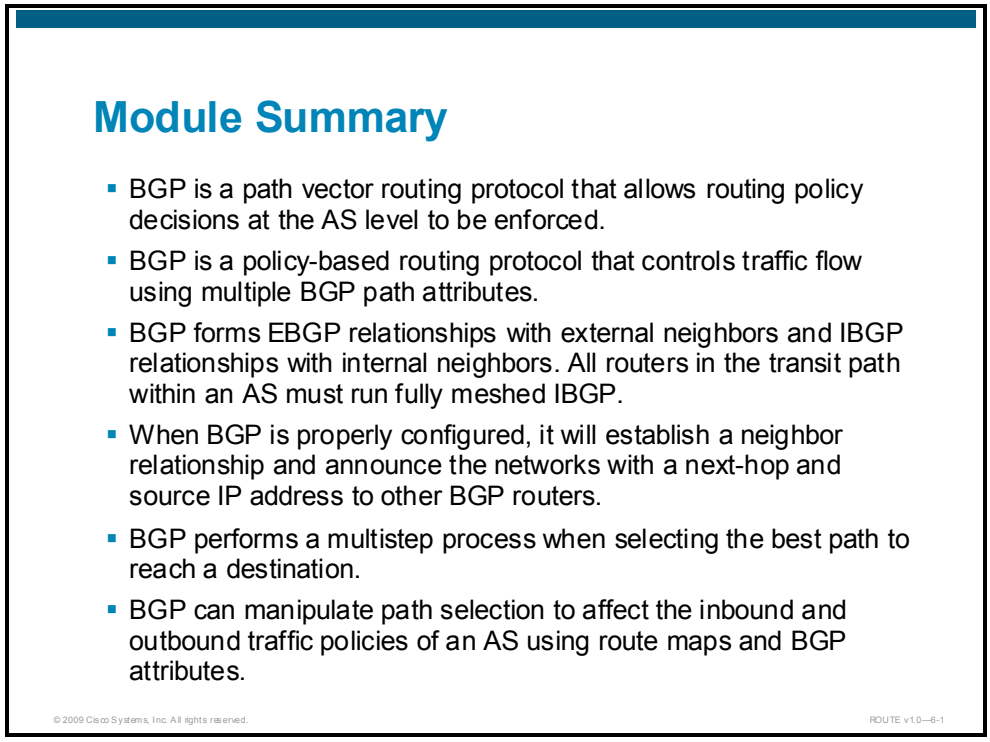
# Summary

This topic summarizes the key points that were discussed in this lesson.



# Module Summary

This topic summarizes the key points that were discussed in this module.




The Internet has proven to be a valuable tool to many companies, resulting in multiple redundant connections to many different ISPs. The function of Border Gateway Protocol (BGP) is to provide alternatives to using default routes to control path selections.

## References

For additional information, refer to these resources:

- RFCs 1772, 1773, 1774, 1930, 1966, 1997, 1998, 2042, 2385, 2439, 2545, 2547, 2796, 2858, 2918, 3065, 3107, 3392, 4223, and 4271
- RFC 1518, *An Architecture for IP Address Allocation with CIDR*
- RFC 1519, *Classless Inter-Domain Routing (CIDR): An Address Assignment and Aggregation Strategy*
- RFC 2050, *Internet Registry IP Allocation Guidelines*

# Module Self-Check

Use the questions here to review what you learned in this module. The correct answers and solutions are found in the Module Self-Check Answer Key.

Q1) Which type of connectivity is typically expected to and from an enterprise network? (Source: Planning the Enterprise-to-ISP Connection)

A) one-way
B) two-way
C) unidirectional
D) connectivity from the clients to the Internet

Q2) What is not a requirement of enterprise network-to-ISP connectivity? (Source: Planning the Enterprise-to-ISP Connection)

A) public IP address space
B) link type and bandwidth availability
C) AS routing policy
D) connection redundancy

Q3) List five routing update exchange options for enterprise network-to-ISP connectivity. (Source: Planning the Enterprise-to-ISP Connection)

_____
_____
_____
_____
_____

Q4) Which one of these statements is not the reason for using BGP as a routing update exchange mechanism? (Source: Planning the Enterprise-to-ISP Connection)

A) A customer deploys BGP to announce its public networks.
B) A BGP is typically used for inter-AS routing.
C) Customer routers are connected to service provider PE routers.
D) Customer network implementation requires a complete Internet routing table.

Q5) What are four enterprise network-to-ISP connection options? (Source: Planning the Enterprise-to-ISP Connection)

_____
_____
_____
_____

Q6) What is a characteristic of dual-multihomed ISP connectivity? (Source: Planning the Enterprise-to-ISP Connection)

A) a connection to two or more different ISPs with two links per ISP
B) a connection to multiple ISPs with one link per ISP
C) the default route points to each ISP from an enterprise network
D) each ISP announces a default route with a different metric to the enterprise network

Q7) What are three common ways to perform multihoming? (Choose three.) (Source: Planning the Enterprise-to-ISP Connection)

A) Each ISP passes only a default route to the AS.
B) Each ISP passes a default route and provider-owned specific routes to the AS.
C) Each ISP passes selected provider-owned routes but no default routes to the AS.
D) Each ISP passes all routes to the AS.

Q8) Which statement about the AS is true? (Source: Considering the Advantages of Using BGP)

A) The AS is a collection of networks under a single administrative domain.
B) The AS is a collection of networks that belong to one enterprise network.
C) The AS requires IGP protocol to exchange routing information between autonomous systems.
D) EBGP neighbors must be configured within the same AS.

Q9) What are the two typical reasons for multihoming? (Choose two.) (Source: Considering the Advantages of Using BGP)

A) to increase the reliability of the connection to the Internet
B) to increase the performance of the connection
C) to increase the bandwidth of the connection
D) to simplify the IGP protocol configuration

Q10) What is a drawback of having all of your connections to a single ISP? (Source: Considering the Advantages of Using BGP)

A) It has redundancy with the multiple connections.
B) Connectivity issues in that single ISP can cause your autonomous system to lose connectivity to the Internet.
C) It is not tied into the routing policy of a single connection.
D) It has more paths to the same networks for better policy manipulation.

Q11) Which two conditions are valid reasons to run BGP in an AS? (Choose two.) (Source: Considering the Advantages of Using BGP)

A) The AS has only a single connection to another AS.
B) Path and packet flow manipulation is required in this AS.
C) You have a limited understanding of BGP routing and route filtering.
D) The AS is an ISP.

Q12) Which routing method best describes BGP? (Source: Considering the Advantages of Using BGP)

A) distance vector
B) link state
C) path vector
D) hybrid of link state and distance vector

Q13) Which protocol does BGP use? (Source: Considering the Advantages of Using BGP)

A) IP protocol number 88
B) IP protocol number 89
C) UDP port 520
D) TCP port 179

Q14) Which four message types are defined by BGP? (Source: Considering the Advantages of Using BGP)

_____
_____
_____
_____

Q15) Which two terms refer to routers that are configured to exchange BGP information with one another? (Choose two.) (Source: Comparing the Functions and Uses of EBGP and IBGP)

A) BGP peer
B) BGP speaker
C) BGP router
D) BGP neighbor

Q16) By default, what are two conditions for routers to be EBGP neighbors? (Choose two.) (Source: Comparing the Functions and Uses of EBGP and IBGP)

A) Routers must be in the same AS.
B) Routers must be in different autonomous systems.
C) Routers are running an IGP between them to establish an adjacency.
D) Routers are directly connected.

Q17) What are three ways to form an adjacency between IBGP neighbors by default? (Choose three.) (Source: Comparing the Functions and Uses of EBGP and IBGP)

A) The neighbors can be directly connected.
B) The neighbors can be reachable from one another by static routes.
C) The neighbors can be reachable from one another by a dynamic internal routing protocol.
D) The neighbors can be in different autonomous systems.

Q18) Which statement about IBGP is true? (Source: Comparing the Functions and Uses of EBGP and IBGP)

A) Routes that are learned via IBGP are never sent to EBGP peers.
B) All the routers between IBGP neighbors must not be running IGP instead of BGP.
C) Routes that are learned via IBGP are never propagated to other IBGP peers.
D) Routes are never learned via IBGP.

Q19) Test your understanding of BGP terminology by matching statements with terms. Write the letter of the statement in front of the term that the statement describes. A statement can describe more than one term. Each term can match multiple statements, but choose only the statement that best describes the term. (Source: Comparing the Functions and Uses of EBGP and IBGP)

**Statement:**

A) These routers never advertise BGP routing information to IBGP neighbors.
B) This is a set of BGP routers that are explicitly configured to exchange BGP information.
C) This is a set of BGP routers that have a neighbor relationship with BGP routers in the same and different autonomous systems.
D) This is a set of BGP routers that, by default, must be directly connected and must be in different autonomous systems.

**Term:**

_____ 1. IBGP neighbors

_____ 2. BGP neighbors

_____ 3. EBGP neighbors

_____ 4. BGP routers

Q20) What does BGP use during the best path selection process? (Source: Comparing the Functions and Uses of EBGP and IBGP)

A) speed
B) AS routing policy
C) bandwidth plus delay
D) number of routers to reach a destination network

Q21) Which four parameters are required for a basic BGP configuration? (Source: Configuring and Verifying Basic BGP Operations)

_____
_____
_____
_____

Q22) Which command indicates to a BGP router whether an IP address belongs to an IBGP or an EBGP neighbor? (Source: Configuring and Verifying Basic BGP Operations)

A) **neighbor** *10.1.1.1* **shutdown**
B) **neighbor** *10.1.1.1* **update-source** *Loopback0*
C) **neighbor** *10.1.1.1* **remote-as** *65010*
D) **neighbor** *10.1.1.1* **next-hop-self**

Q23) Which command sets the source IP address of a BGP update to be the IP address of a specific interface? (Source: Configuring and Verifying Basic BGP Operations)

A) **neighbor** *10.2.2.2* **shutdown**
B) **neighbor** *10.2.2.2* **update-source** *Loopback0*
C) **neighbor** *10.2.2.2* **remote-as** *65020*
D) **neighbor** *10.2.2.2* **next-hop-self**

Q24) What is the result of using this command: **router bgp 65010**? (Source: Configuring and Verifying Basic BGP Operations)

A) The BGP process starts in the router.
B) The BGP process starts on the interface.
C) The neighboring router AS is defined.
D) The router enters into BGP configuration mode with AS number 65010 used locally.

Q25) The **network** command that is used in the router BGP process identifies the interfaces from which to advertise BGP updates. (Source: Configuring and Verifying Basic BGP Operations)

A) true
B) false

Q26) What is the result of using this command: **neighbor 10.3.3.3 shutdown**? (Source: Configuring and Verifying Basic BGP Operations)

A) BGP neighbor 10.3.3.3 is administratively disabled.
B) It prevents BGP neighbor 10.3.3.3 from receiving BGP updates.
C) The BGP process on neighbor 10.3.3.3 is disabled.
D) The command also requires the AS number in order to shut down the neighbor.

Q27) Which command must be used if an EBGP neighbor is not directly connected? (Source: Configuring and Verifying Basic BGP Operations)

A) **neighbor** *10.4.4.4* **ebgp-multihop**
B) **neighbor** *10.4.4.4* **update-source** *Loopback0*
C) **neighbor** *10.4.4.4* **remote-as** *65020*
D) **neighbor** *10.4.4.4* **next-hop-self**

Q28) Which five states does BGP go through during the establishment of a BGP session? (Source: Configuring and Verifying Basic BGP Operations)

_____
_____
_____

Q29) Which state indicates that the router does not have a path to the neighbor IP address? (Source: Configuring and Verifying Basic BGP Operations)

A) active
B) idle
C) established
D) open confirm

Q30) If you configure or change the password or key that is used for MD5 authentication between two BGP peers, the local router will not tear down the existing session after you configure the password. (Source: Configuring and Verifying Basic BGP Operations)

A) true
B) false

Q31) Which **clear ip bgp** command is the least intrusive for resetting a BGP session after changing outbound policy for neighbor 10.5.5.5? (Source: Configuring and Verifying Basic BGP Operations)

A) **clear ip bgp ***
B) **clear ip bgp** *10.5.5.5* **soft out**
C) **clear ip bgp** *10.5.5.5*
D) **clear ip bgp** *10.5.5.5* **soft in**

Q32) Place the BGP selection criteria in order from the first step to the last step that is evaluated to select the BGP path that is submitted to the IP routing table. (Source: Using the BGP Attributes and Path Selection Process)

A) _____ prefer the path with the lowest neighbor BGP router ID
B) _____ prefer the lowest MED
C) _____ prefer the shortest AS path
D) _____ prefer the oldest route for EBGP paths
E) _____ prefer the lowest origin code (IGP < EGP < incomplete)
F) _____ prefer the highest weight
G) _____ prefer the path through the closest IGP neighbor
H) _____ prefer the highest local preference
I) _____ prefer the route that was originated by the local router
J) _____ prefer an EBGP path over an IBGP path
K) _____ prefer the lowest neighbor IP address

Q33) Which description applies to the local preference attribute? (Source: Using the BGP Attributes and Path Selection Process)

A) well-known mandatory
B) well-known discretionary
C) optional transitive
D) optional nontransitive

Q34) Which description applies to the MED attribute? (Source: Using the BGP Attributes and Path Selection Process)

A) well-known mandatory
B) well-known discretionary
C) optional transitive
D) optional nontransitive

Q35) Which description applies to the weight attribute? (Source: Using the BGP Attributes and Path Selection Process)

A) well-known mandatory
B) well-known discretionary
C) optional transitive
D) proprietary to Cisco and not advertised to other BGP routers

Q36) Which two statements regarding local preference are true? (Choose two.) (Source: Using the BGP Attributes and Path Selection Process)

A) The higher value for local preference is preferred.
B) Local preference is used only between EBGP neighbors.
C) The lower value for local preference is preferred.
D) Local preference is used only between IBGP neighbors.

Q37) Which two statements regarding weight are true? (Choose two.) (Source: Using the BGP Attributes and Path Selection Process)

A) The lower value for weight is preferred.
B) The higher value for weight is preferred.
C) Weight is used only between IBGP neighbors.
D) Weight is used only locally inside the router.

Q38) Which two statements regarding the MED are true? (Choose two.) (Source: Using the BGP Attributes and Path Selection Process)

A) The higher value for the MED is preferred.
B) The lower value for the MED is preferred.
C) The MED is exchanged between autonomous systems.
D) The MED is local to an AS.

Q39) Which two statements regarding the AS path are true? (Choose two.) (Source: Using the BGP Attributes and Path Selection Process)

A) The shorter AS path is preferred.
B) The longer AS path is preferred.
C) The AS path is prepended and exchanged between autonomous systems.
D) The AS path is local to an AS.

Q40) Which command changes the MED for all routes? (Source: Using the BGP Attributes and Path Selection Process)

A) **bgp med** *number*
B) **default-metric** *number*
C) **bgp default-metric** *number*
D) **set med** *number*

Q41) The MED is used to decide how to enter an AS from neighboring autonomous systems, when multiple paths exist between two autonomous systems. (Source: Using the BGP Attributes and Path Selection Process)

A) true
B) false

Q42) The MED is set inbound when a router is receiving router updates from an EBGP neighbor. (Source: Using the BGP Attributes and Path Selection Process)

A) true
B) false

Q43) The length of the AS path is extended because additional copies of the AS number of the sender are prepended to the original AS path attribute. To avoid clashes with BGP loop prevention mechanisms, no other AS number, except that of the neighboring AS, should be prepended to the AS path attribute. (Source: Using the BGP Attributes and Path Selection Process)

A) true
B) false

# Module Self-Check Answer Key

Q1) B

Q2) C

Q3) Static routes, Common IGP, MPLS VPNs, Circuit emulation, BGP

Q4) C

Q5) Single-homed, Dual-homed, Multihomed, Dual-multihomed

Q6) A

Q7) A, B, D

Q8) A

Q9) A, B

Q10) B

Q11) B, D

Q12) C

Q13) D

Q14) Open, Keepalive, Update, Notification

Q15) A, D

Q16) B, D

Q17) A, B, C

Q18) C

Q19) 1-A
2-C
3-D
4-B

Q20) B

Q21) Neighbors (peers) that are involved, AS numbers that are used, IP addresses that are used, and networks, which need to be advertised

Q22) C

Q23) B

Q24) D

Q25) B

Q26) A

Q27) A

Q28) Idle, Connect, Open sent, Open confirm, Established

Q29) B

Q30) A

Q31) B

Q32) 1-F
2-H
3-I
4-C
5-E
6-B
7-J
8-G
9-D

10-A
11-K

Q33) B

Q34) D

Q35) D

Q36) A, D

Q37) B, D

Q38) B, C

Q39) A, C

Q40) B

Q41) A

Q42) B

Q43) B