

Configuration and Management of Networks

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Configuration and Management of Networks

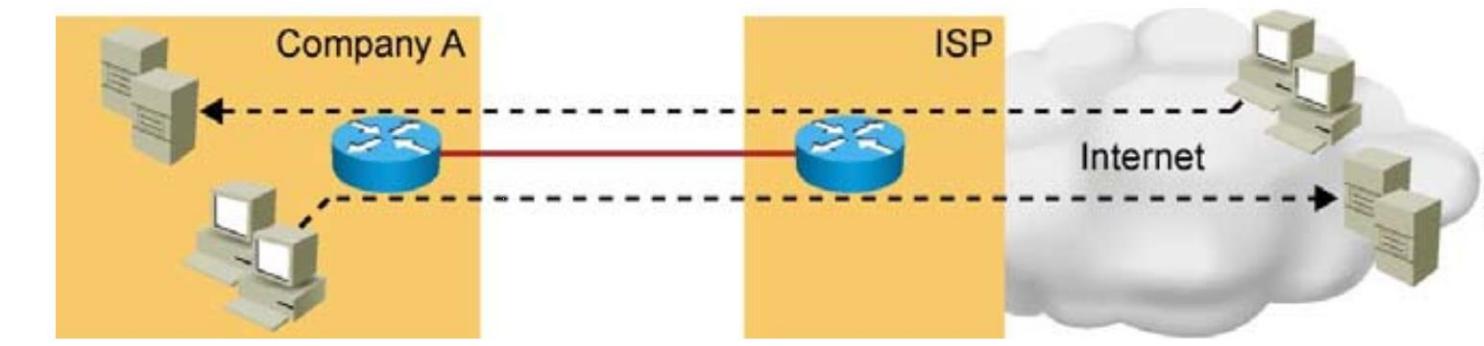
BGP – Connecting to an ISP

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:

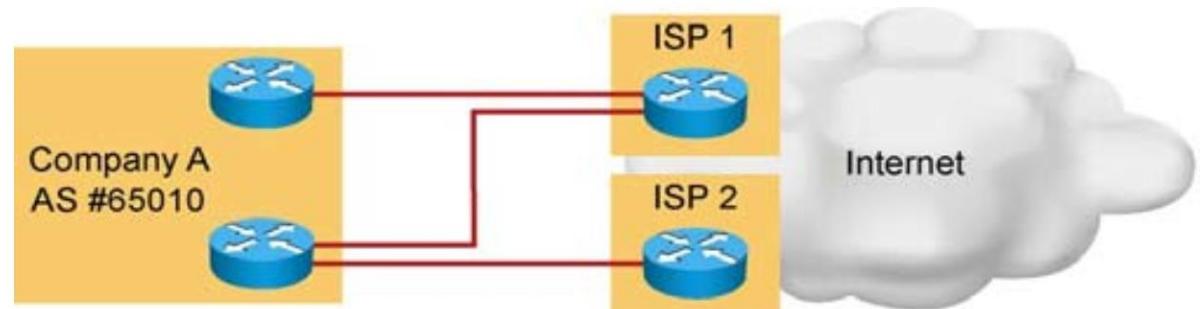
- **One-way**: private IP address space with address translation
- **Two-way**: public IP address space (in combination with private) and proper routing



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BGP – Connecting to an ISP

- 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

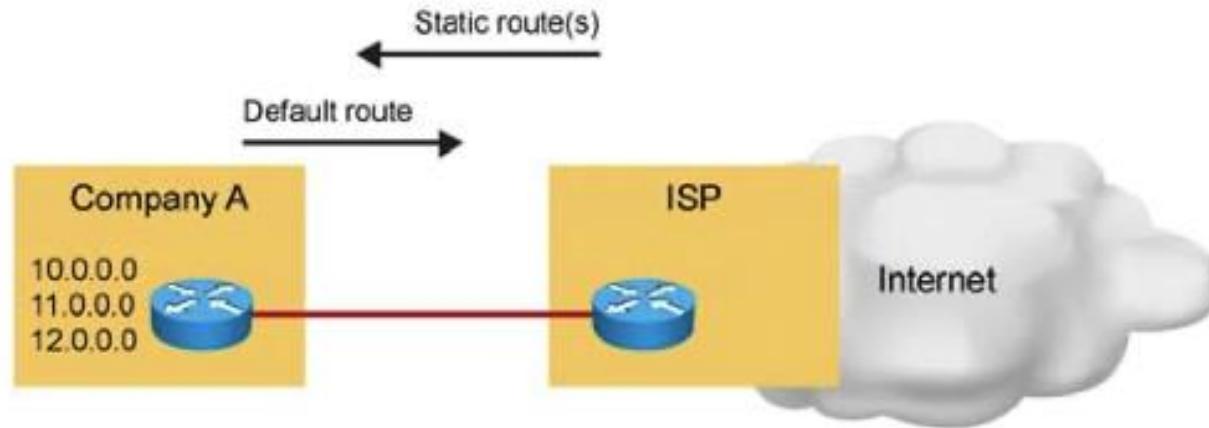


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BGP – Connecting to an ISP

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



```
nv set vrf default router static 0.0.0.0/0 via 203.0.113.1
```

```
nv set vrf default router ospf default-originate on
```

```
nv set vrf default router static 10.0.0.0/8 via 203.0.113.2
```

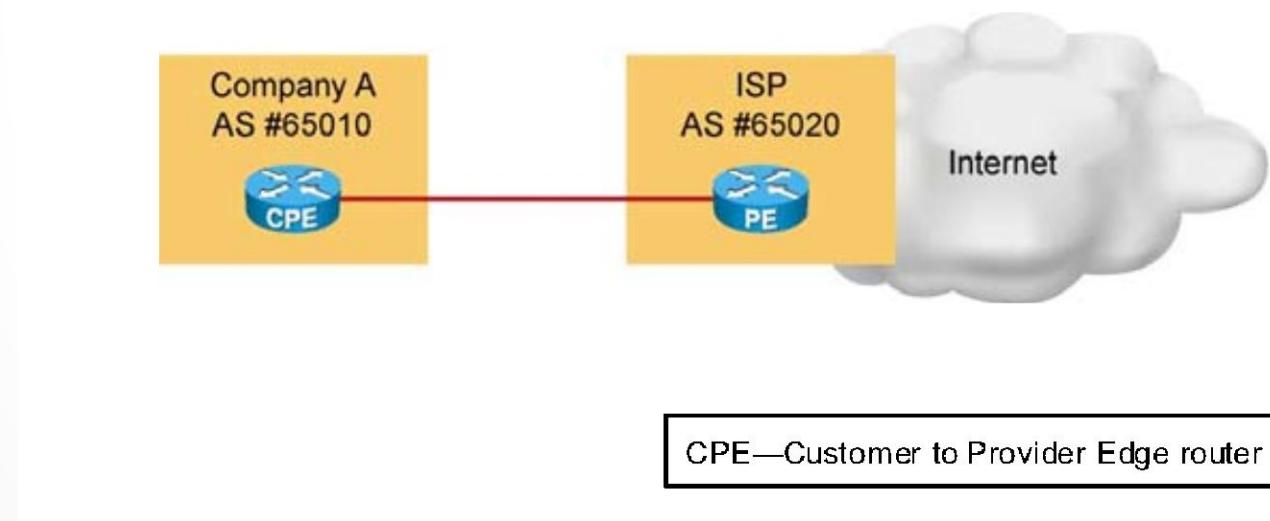
```
nv set vrf default router static 11.0.0.0/8 via 203.0.113.2
```

```
nv set vrf default router static 12.0.0.0/8 via 203.0.113.2
```

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BGP – Connecting to an ISP

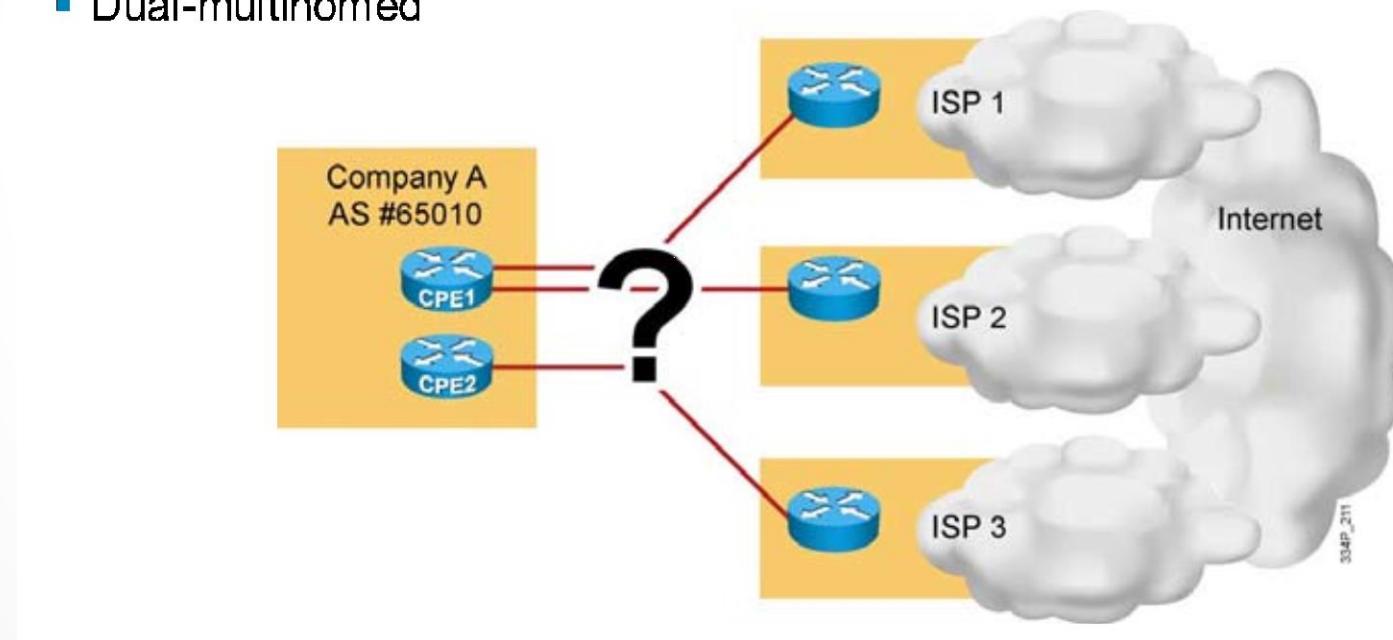
- The customer deploys BGP to announce its public networks
- The ISP announces a default route, a subset of Internet routes, or a complete Internet routing table
- Typically used for inter-AS routing



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BGP – Connecting to an ISP

- Single-homed
- Dual-homed
- Multihomed
- Dual-multihomed

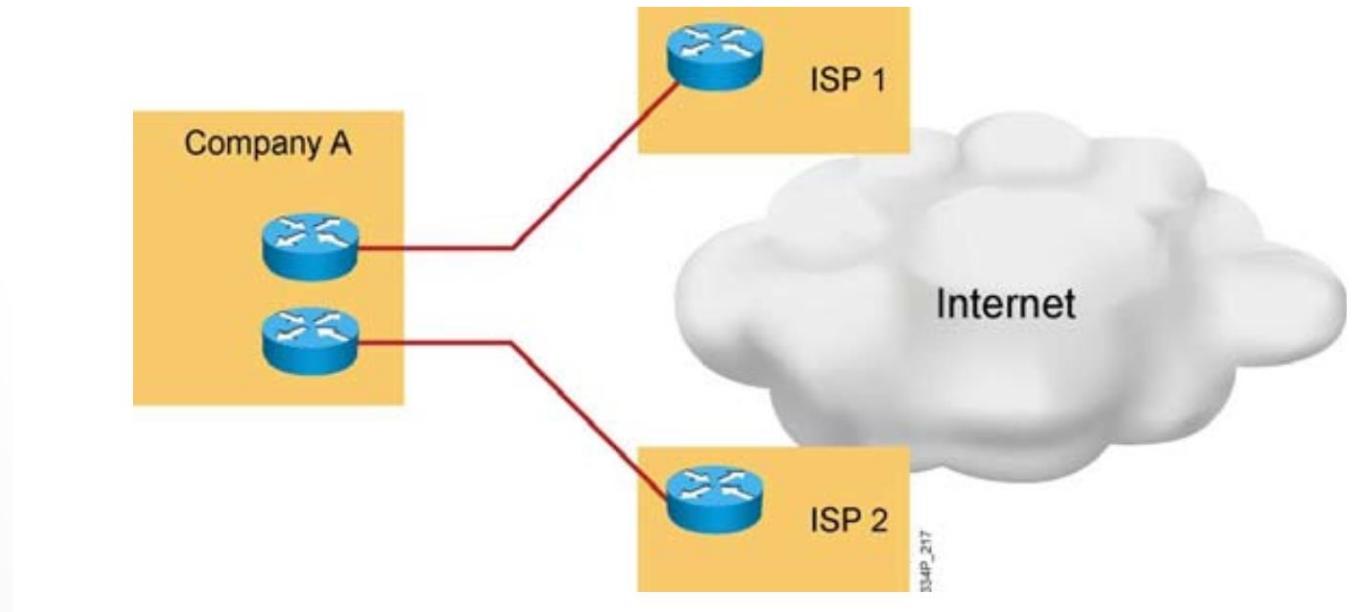


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BGP – Multihoming from 2 providers

Characteristics:

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



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BGP – Terminology

- Autonomous system (AS): a collection of networks under a single administrative domain
- Interdomain routing: routing between the customer and the ISP
- Internal routing: uses IGP protocol (RIP, OSPF, EIGRP, and so on) to exchange routing information inside the AS
- External routing: uses EGP protocol (BGP) to exchange routes between autonomous systems
- Two BGP implementations:
 - Internal BGP (IBGP): when BGP is used inside an AS
 - External BGP (EBGP): when BGP is used between autonomous systems

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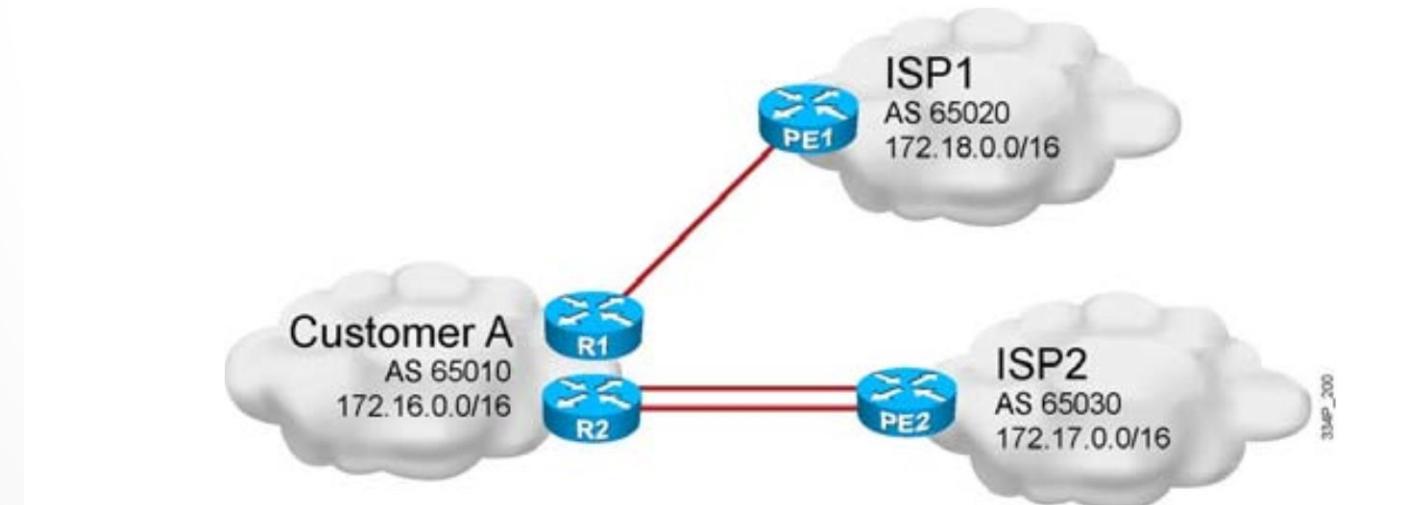
BGP – Connecting to an ISP

Multihoming options with respect to connections

- Using a single connection to an individual ISP
- Using multiple connections to an individual ISP

Multihoming options with respect to routing

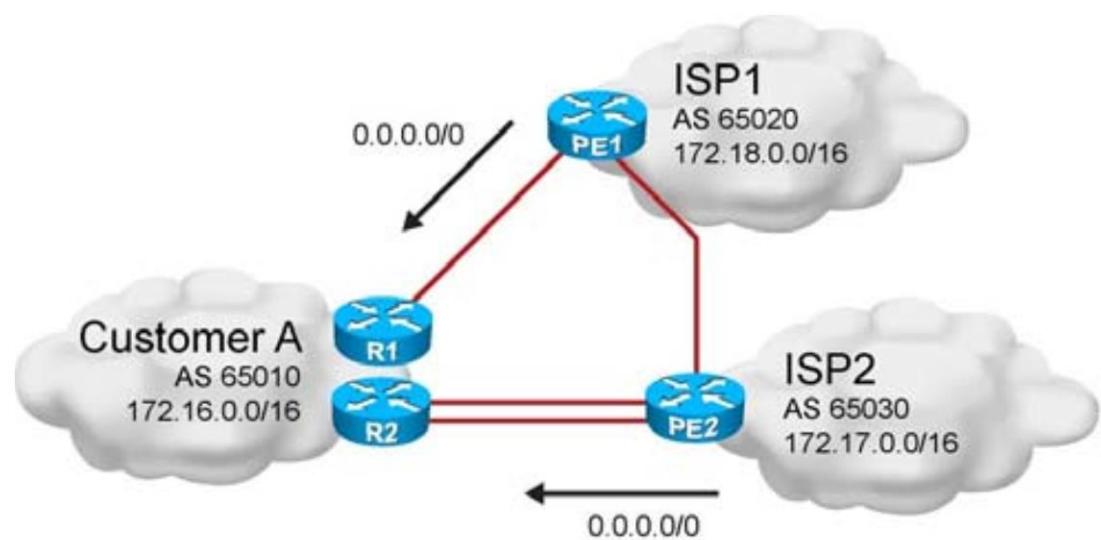
- Default routes from all providers
- Default routes and partial Internet routing from the providers
- Full Internet routing from the providers



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BGP – Default routes

- Customer A receives the default route from each ISP.

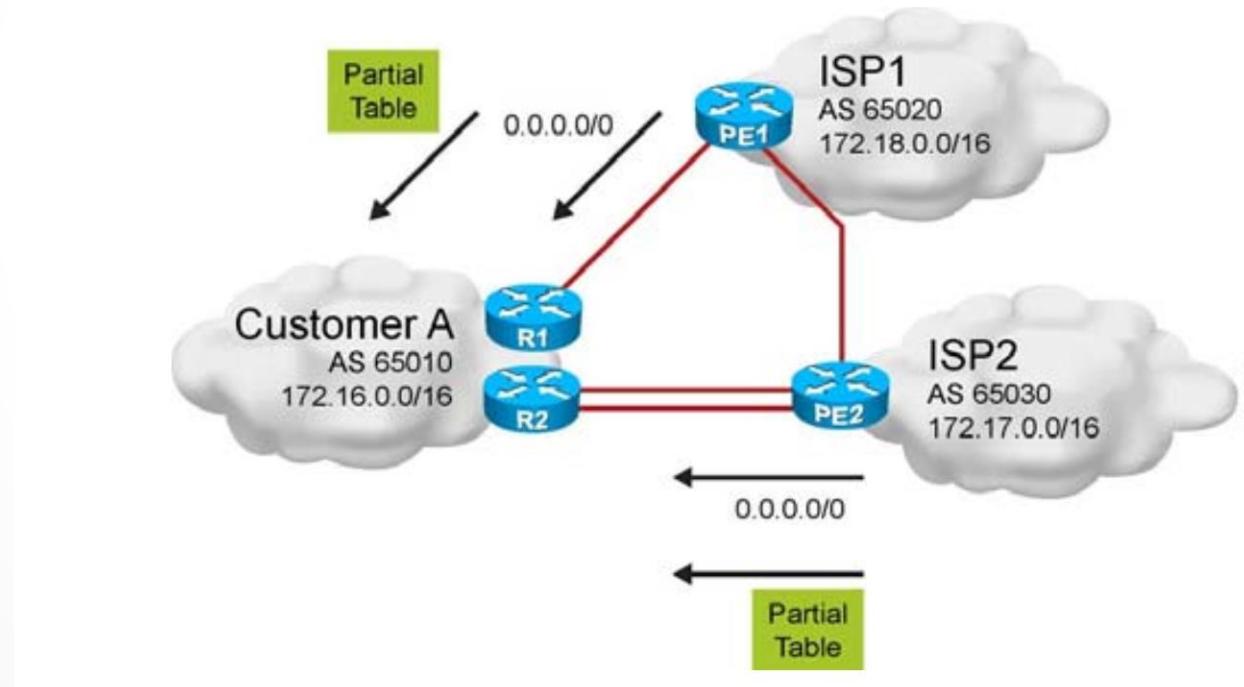


Only one default route will be used (the one with smallest IGP cost)

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BGP – Default routes and partial tables

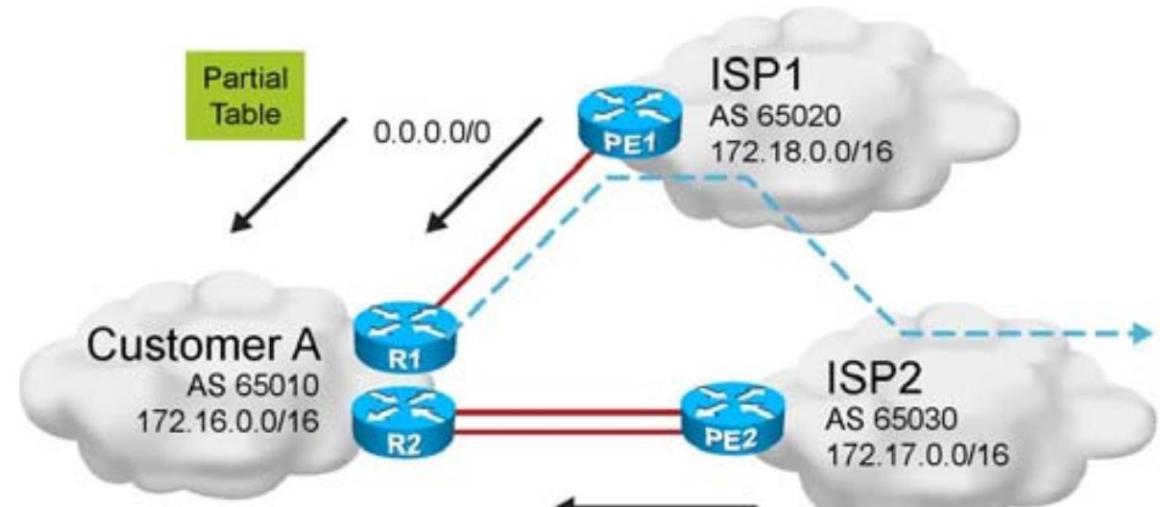
- Customer A receives the default route from each ISP.
- Customer A receives a partial routing table from each ISP.



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BGP – Default routes and partial tables

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

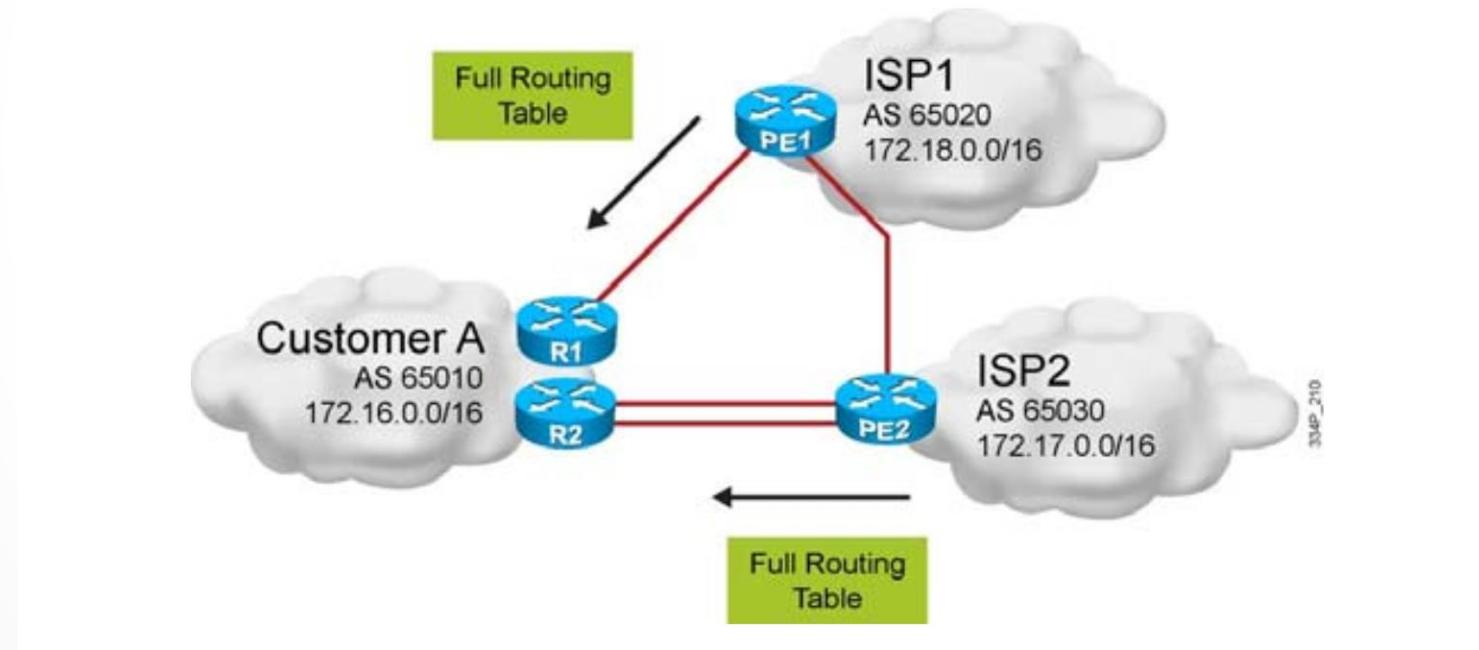


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BGP – Full Table

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



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BGP – Routing between ASes

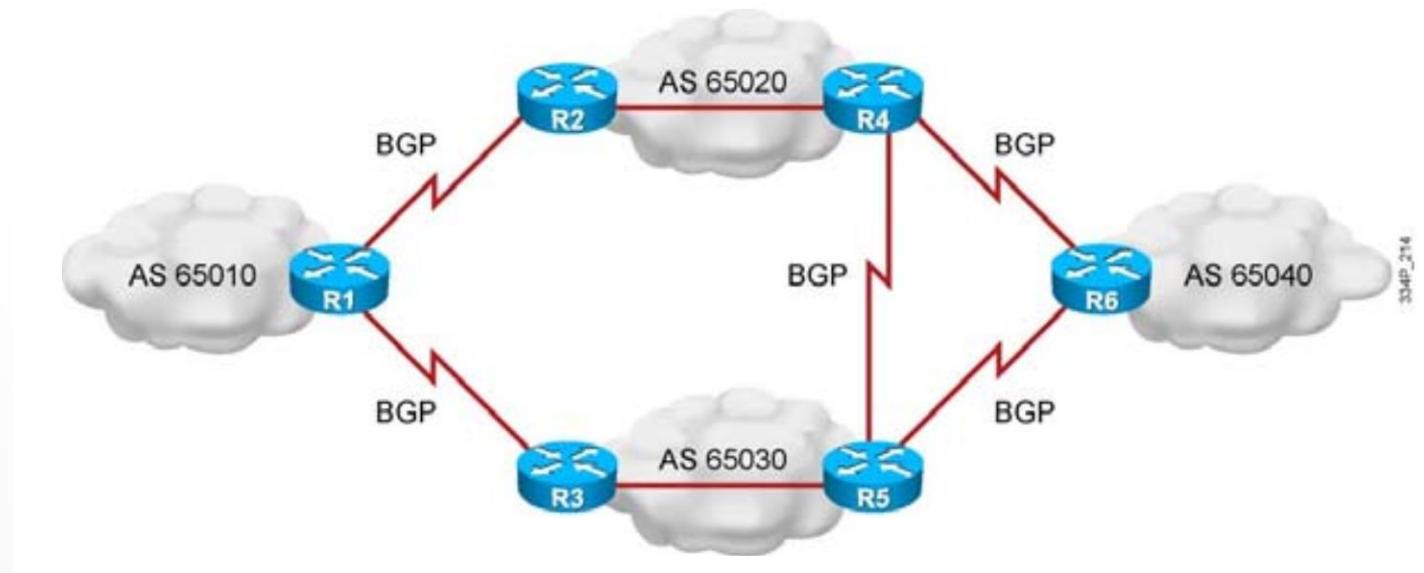
- Autonomous system (AS) – a collection of networks under a single technical administration.
 - 16-bit numbers (as of January 2009 32-bit numbers are available)
 - Ranging from 1 to 65535
 - Private AS: 64512–65535
- Internet Assigned Numbers Authority (IANA) allocates AS numbers.
- IGPs operate within an AS.
- BGP is used between autonomous systems.



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BGP

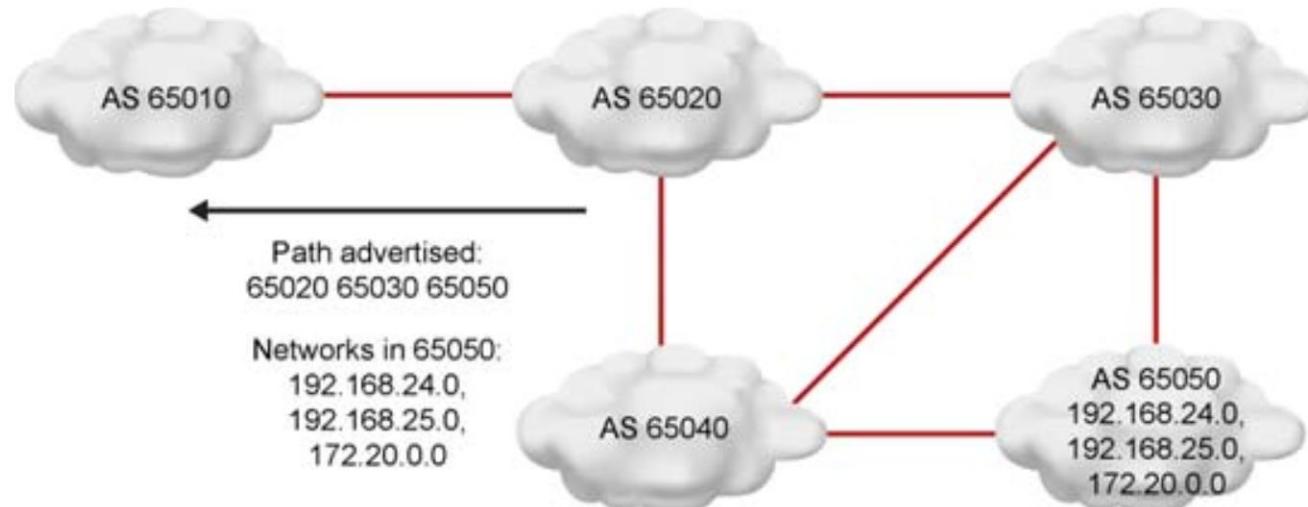
- BGP is used to provide an interdomain routing system.
- BGP guarantees the exchange of loop-free routing information.
- BGP works differently than IGPs.
 - BGP is a policy-based routing protocol.
 - Control traffic flow using multiple BGP path attributes.



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BGP

- BGP announces:
 - Paths
 - Networks that are reachable at the end of the path
- The path is described by using attributes.
- The administrator can define data flow through autonomous systems.



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BGP

BGP is a path vector protocol with the following properties:

- Reliable updates: BGP runs on top of TCP (port 179)
- Incremental, triggered updates only
- Periodic keepalive messages to verify TCP connectivity
- Rich metrics (called path vectors or attributes)
- Designed to scale to huge internetworks (for example, the Internet)

It has enhancements over distance vector protocols.

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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 is associated with BGP attributes
- IP routing table (forwarding database)
 - List of best paths to destination networks used to forward traffic

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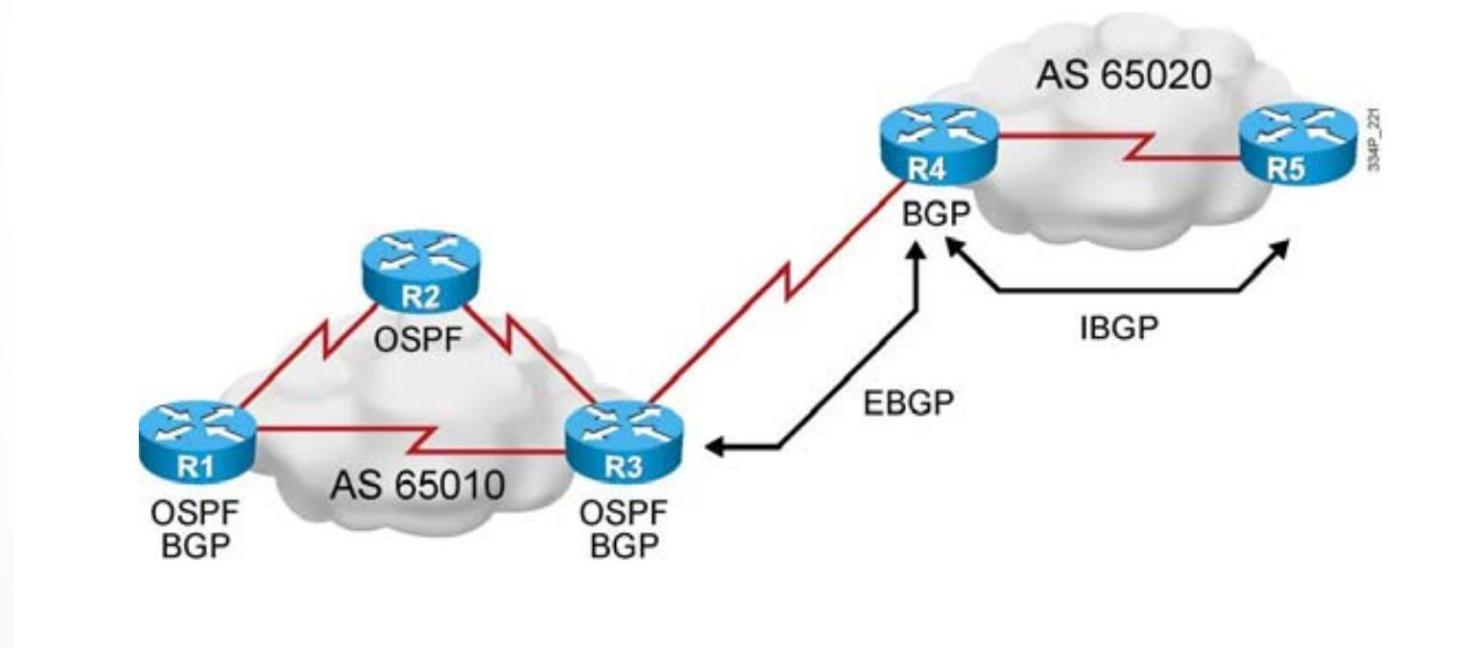
BGP Summary

- BGP is typically used for interdomain routing.
- Three common ways to perform multihoming with BGP are as follows:
 - Each ISP passes only a default route.
 - Each ISP passes only a default route and specific provider-owned routes.
 - Each ISP passes all routes.
- BGP is the external routing protocol used between autonomous systems. Forwarding is based on policies and not on best path.
- BGP routers exchange network reachability information called path vectors, made up of path attributes.
- A router 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, and an IP routing table.

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BGP

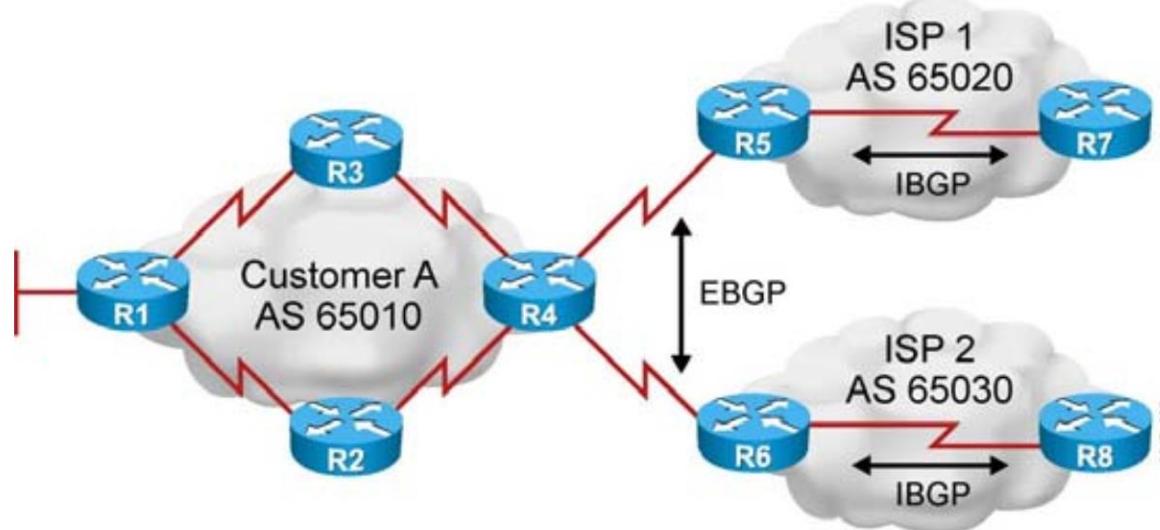
- A “BGP neighbor” is also known as a “BGP peer”
- TCP connection



Configuration and Management of Networks

BGP

- A BGP neighbor in same AS
- Requirements:
 - Same AS number
 - Defined neighbors
 - Reachability

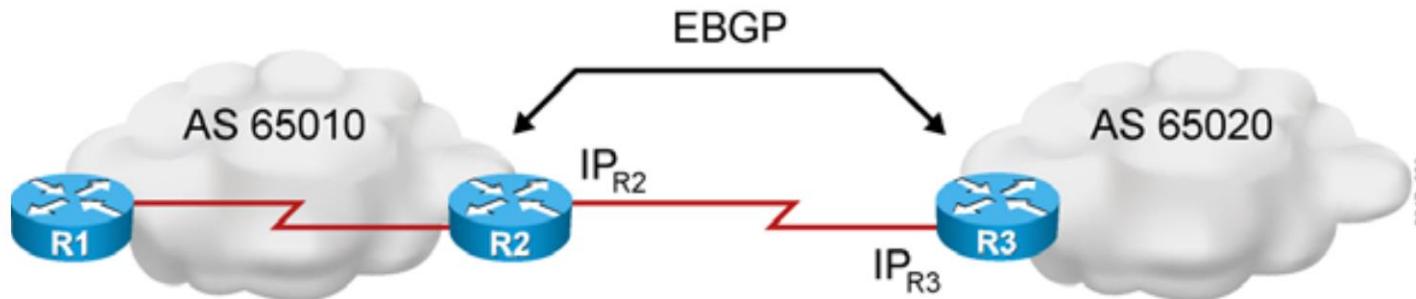


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BGP - Basic Configuration

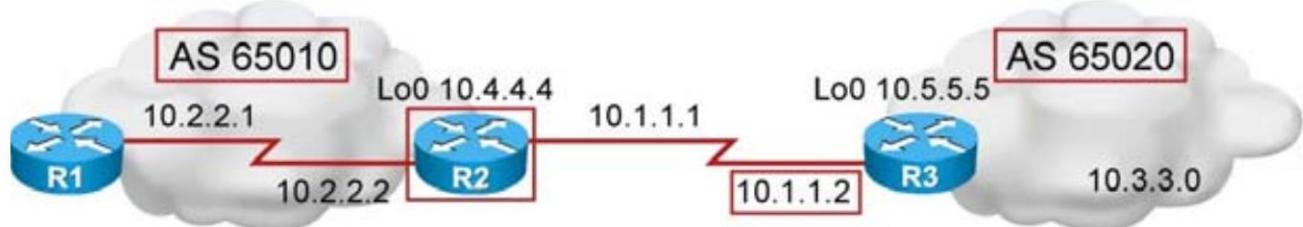
- Define the BGP process
- Establish a EBGP neighbor relationship
- Advertise the networks



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Configuration and Management of Networks

BGP



```
R2(config) #
```

```
router bgp 65010
```

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

```
nv set router bgp autonomous-system 65010  
nv set router bgp router-id 1.1.1.1
```

```
R2(config-router) #
```

```
neighbor 10.1.1.2 remote-as 65020
```

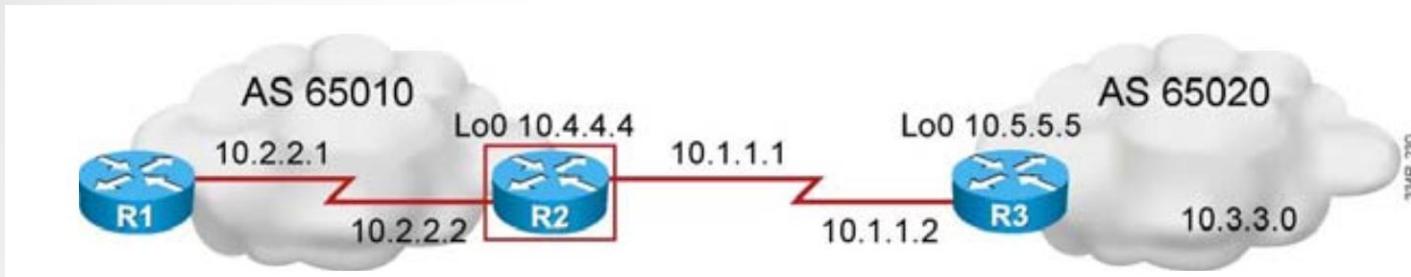
Activate EBGP session to the neighbor

- Remote router IP Address and AS number

```
nv set vrf default router bgp neighbor 10.1.1.2 remote-as 65020  
nv set vrf default router bgp neighbor 10.1.1.2 type external
```

Configuration and Management of Networks

BGP



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

```
nv set vrf default router bgp address-family ipv4-unicast static-network 10.2.2.0/24
nv set vrf default router bgp address-family ipv4-unicast static-network 10.4.4.0/24
```

Configuration and Management of Networks

BGP

BGP will only advertise a network if there's an exact match in the routing table . The prefix and prefix length must match exactly .

Example 1: Network Not Found (No Advertisement)

```
nv set vrf default router bgp address-family ipv4-unicast static-network 192.168.1.1/24
```

Result:  No advertisement - Router looks for 192.168.1.1/24 in routing table but cannot find it .
Why: 192.168.1.1/24 is a host address (ends in .1), not a network address. The routing table likely has 192.168.1.0/24.

```
# Create static route to Null0 (blackhole route)
nv set vrf default router static 192.168.0.0/16 blackhole

# Advertise the route via BGP
nv set vrf default router bgp address-family ipv4-unicast static-network 192.168.0.0/16
```

Result:  Advertised - The exact route (192.168.0.0/16) now exists in the routing table .
Use case: Summary/aggregate route for multiple more-specific subnets .

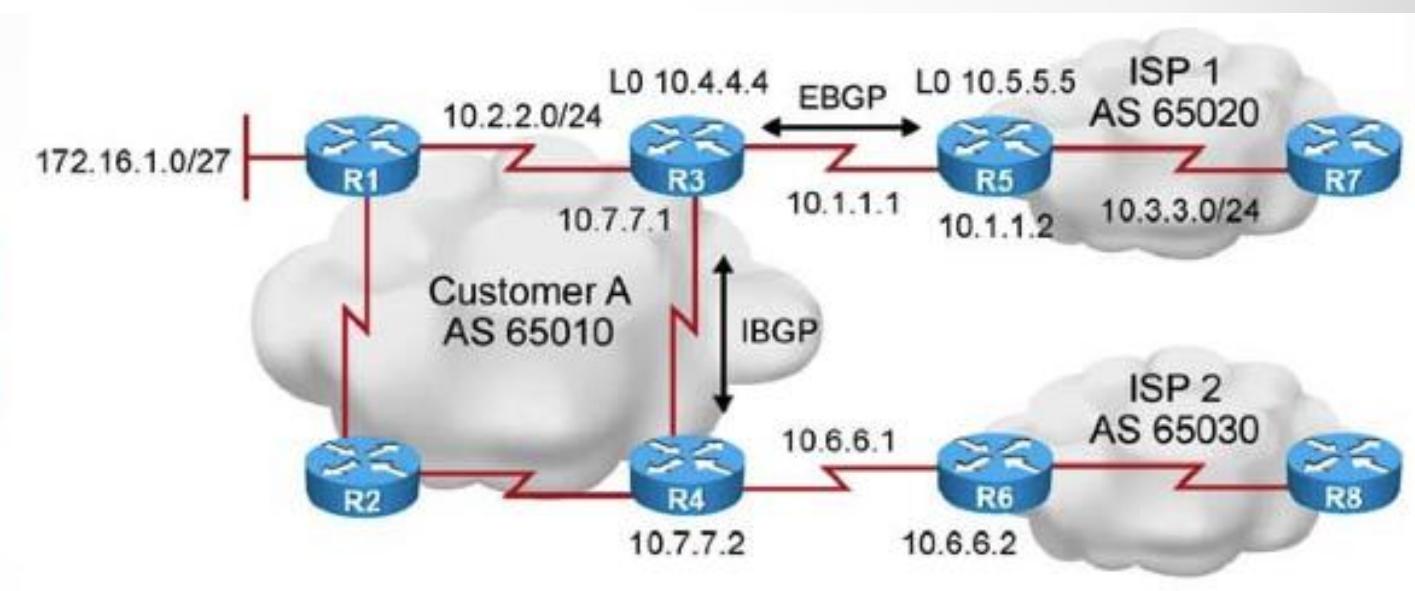
Configuration and Management of Networks

BGP EBGP and IBGP

```
R3#  
router bgp 65010  
neighbor 10.7.7.2 remote-as 65010  
neighbor 10.1.1.2 remote-as 65020  
network 10.2.2.0 mask 255.255.255.0  
network 172.16.0.0 mask 255.255.0.0  
  
ip route 172.16.0.0 255.255.0.0 Null0
```



IBGP
EBGP

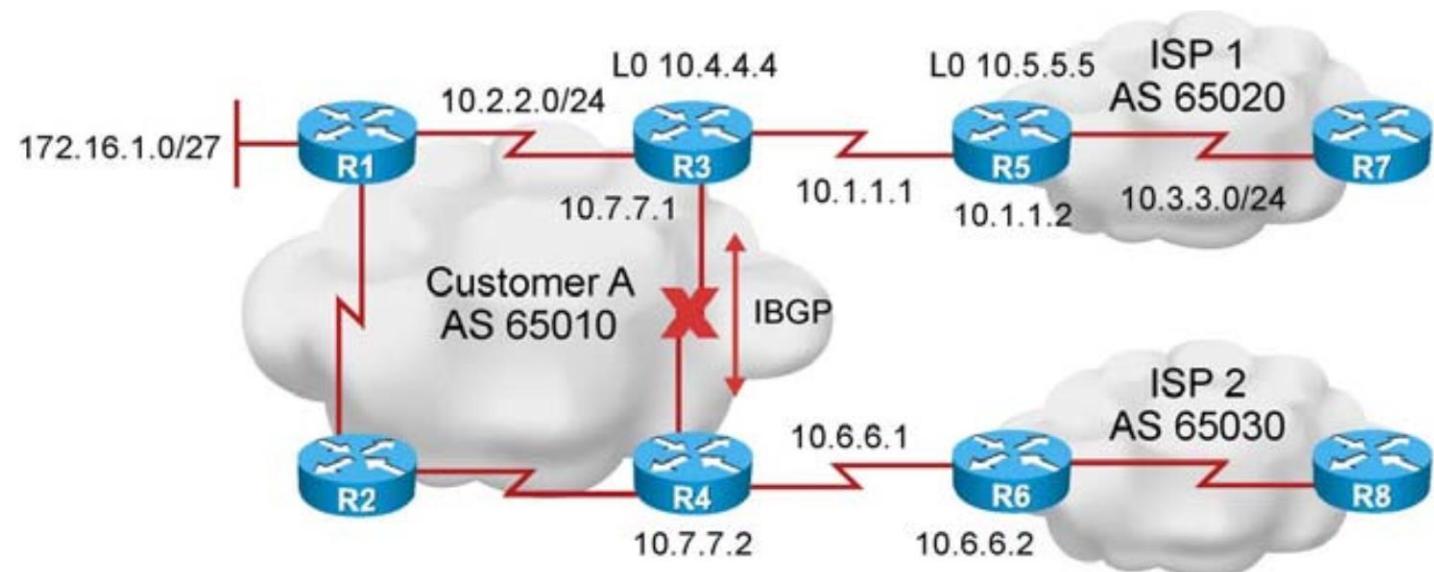


```
nv set router bgp autonomous-system 65010  
nv set router bgp router-id 3.3.3.3  
nv set vrf default router bgp neighbor 10.7.7.2 remote-as 65010  
nv set vrf default router bgp neighbor 10.7.7.2 type internal  
nv set vrf default router bgp neighbor 10.1.1.2 remote-as 65020  
nv set vrf default router bgp neighbor 10.1.1.2 type external  
# === Enable IPv4 Unicast Address Family ===  
nv set vrf default router bgp address-family ipv4-unicast enable on  
# === Create Static Blackhole Route for Summary ===  
nv set vrf default router static 172.16.0.0/16 blackhole  
# === Advertise Networks via BGP ===  
nv set vrf default router bgp address-family ipv4-unicast static-network 10.2.2.0/24  
nv set vrf default router bgp address-family ipv4-unicast static-network 172.16.0.0/16
```

Configuration and Management of Networks

BGP

- 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?



Configuration and Management of Networks

BGP

Create a BGP packet:

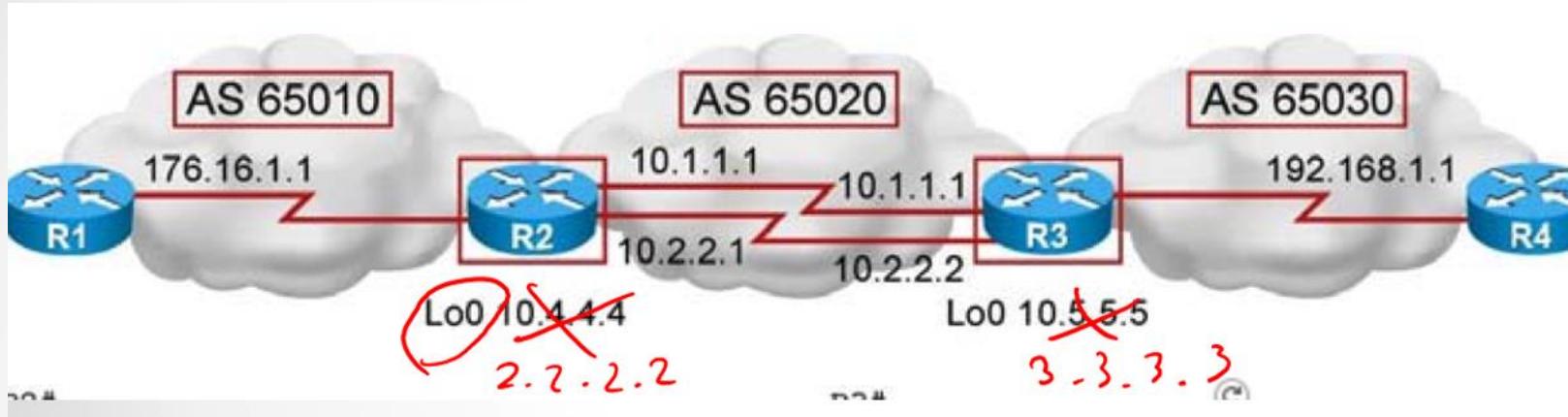
- The destination IP address defined by the neighbor statement
- The source IP address defined by the outbound interface

The source address of the received BGP packet is compared to list of neighbor statements:

- If a match is found in the list of neighbors, a relationship is established.
- If no match is found in the list of neighbors, the packet is ignored.

Configuration and Management of Networks

BGP IGP with loopback interfaces



```
nv set vrf default router ospf enable on  
nv set vrf default router ospf router-id 2.2.2.2  
nv set interface lo router ospf area 0  
nv set interface swp2 router ospf area 0  
nv set router bgp autonomous-system 65020  
nv set router bgp router-id 2.2.2.2  
  
nv set vrf default router bgp neighbor 172.16.1.1 remote-as 65010  
nv set vrf default router bgp neighbor 172.16.1.1 type external  
  
nv set vrf default router bgp neighbor 3.3.3.3 remote-as 65020  
nv set vrf default router bgp neighbor 3.3.3.3 type internal  
nv set vrf default router bgp neighbor 3.3.3.3 update-source lo  
nv set vrf default router bgp address-family ipv4-unicast enable on
```

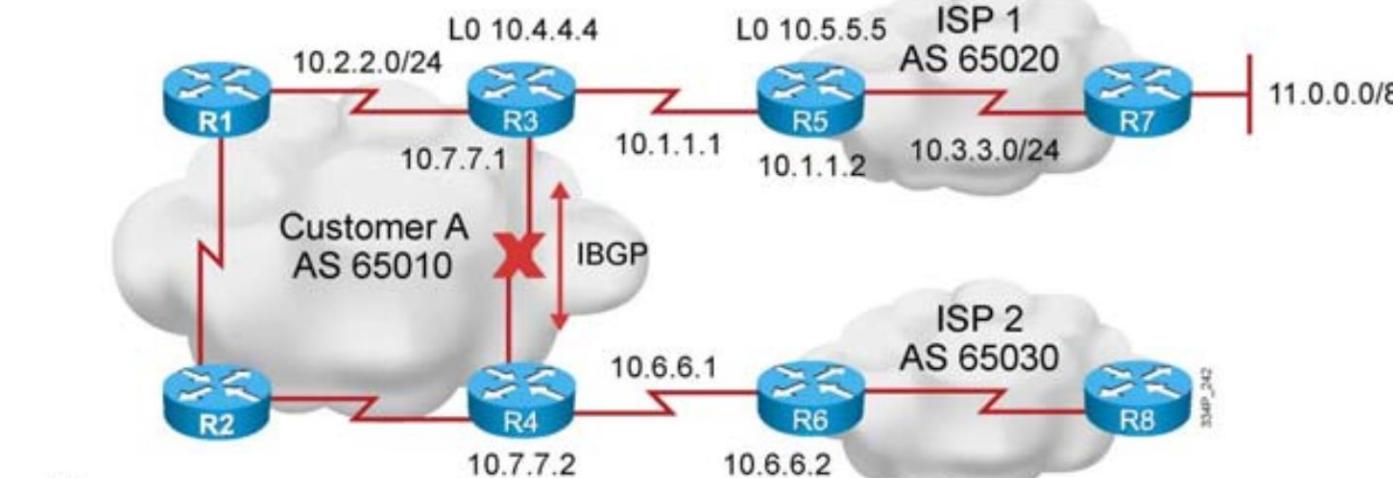
```
nv set vrf default router ospf enable on  
nv set vrf default router ospf router-id 3.3.3.3  
nv set interface lo router ospf area 0  
nv set interface swp1 router ospf area 0  
nv set router bgp autonomous-system 65020  
nv set router bgp router-id 3.3.3.3  
  
nv set vrf default router bgp neighbor 192.168.1.1 remote-as 65030  
nv set vrf default router bgp neighbor 192.168.1.1 type external  
  
nv set vrf default router bgp neighbor 2.2.2.2 remote-as 65020  
nv set vrf default router bgp neighbor 2.2.2.2 type internal  
nv set vrf default router bgp neighbor 2.2.2.2 update-source lo  
nv set vrf default router bgp address-family ipv4-unicast enable on
```

Configuration and Management of Networks

BGP

- IBGP does not modify next hop.

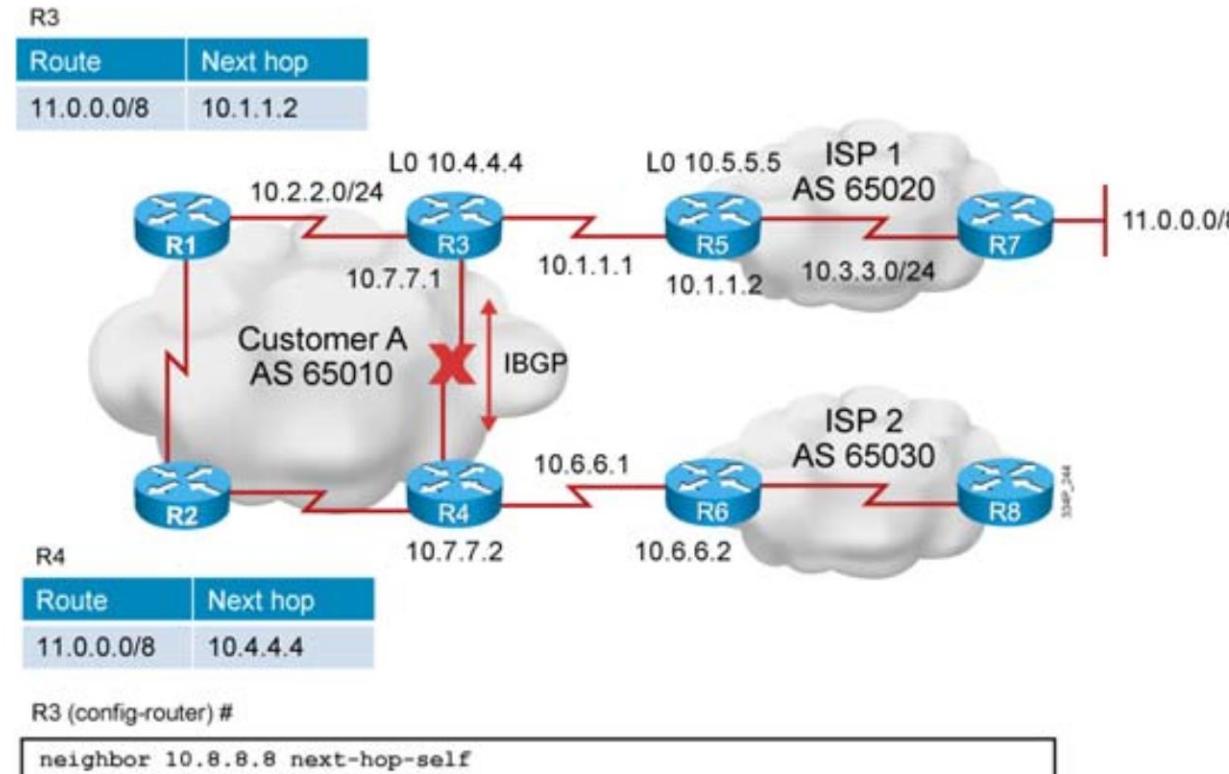
R3	
Route	Next hop
11.0.0.0/8	10.1.1.2



R4	
Route	Next hop
11.0.0.0/8	10.1.1.2

Configuration and Management of Networks

BGP



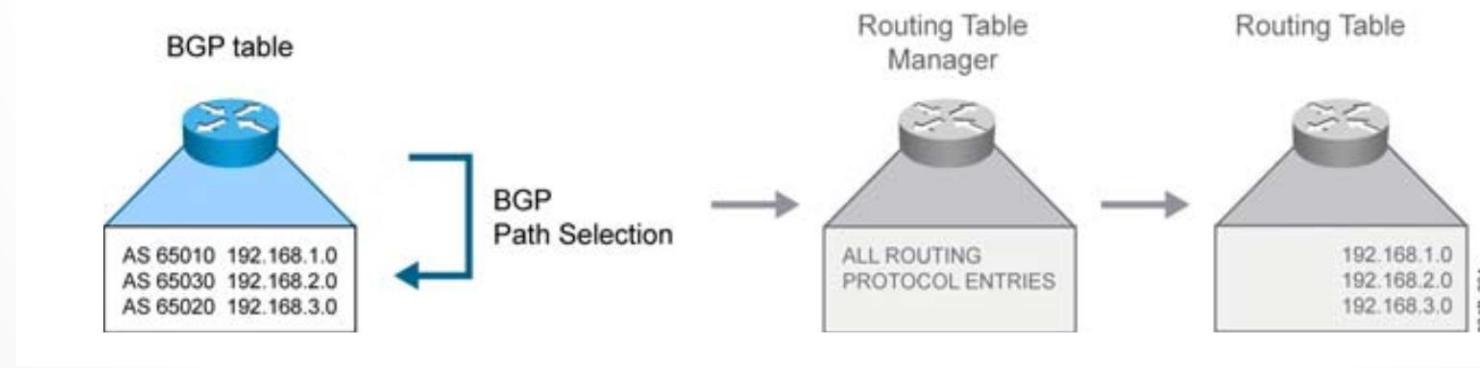
- Forces all updates for neighbor R4 to be advertised with this router as the next hop—the same IP address as for the source of the BGP packet.

```
nv set vrf default router bgp neighbor 10.8.8.8 address-family ipv4-unicast nexthop-setting next-hop-self on
```

Configuration and Management of Networks

BGP – Path selection process

- The BGP table can have several paths for each network to choose from
- BGP is not designed to perform load balancing:
 - Paths are chosen because of policy.
 - Paths are not chosen based upon bandwidth.
- The BGP selection process eliminates any multiple paths until a single best path remains.

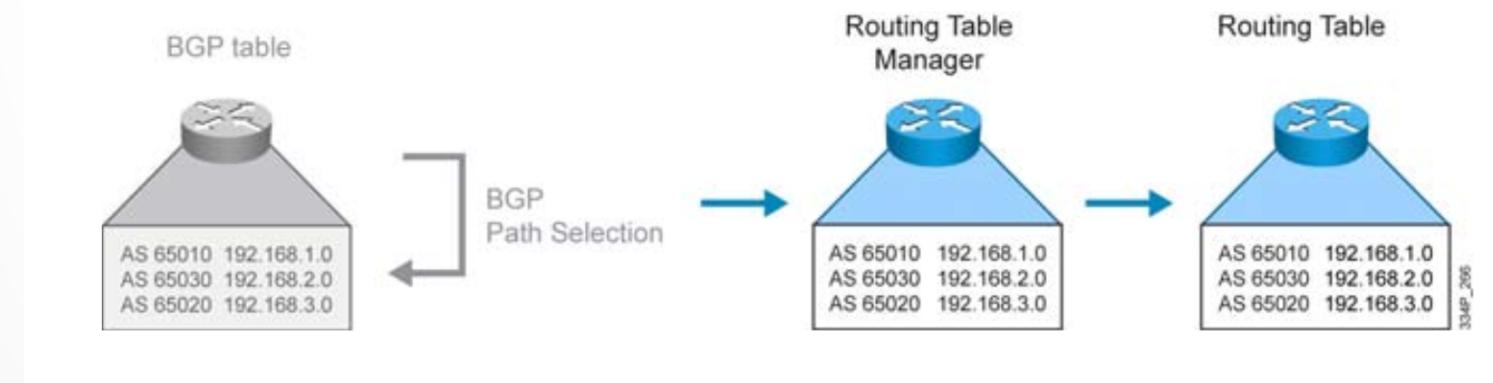


Configuration and Management of Networks

BGP

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.



Configuration and Management of Networks

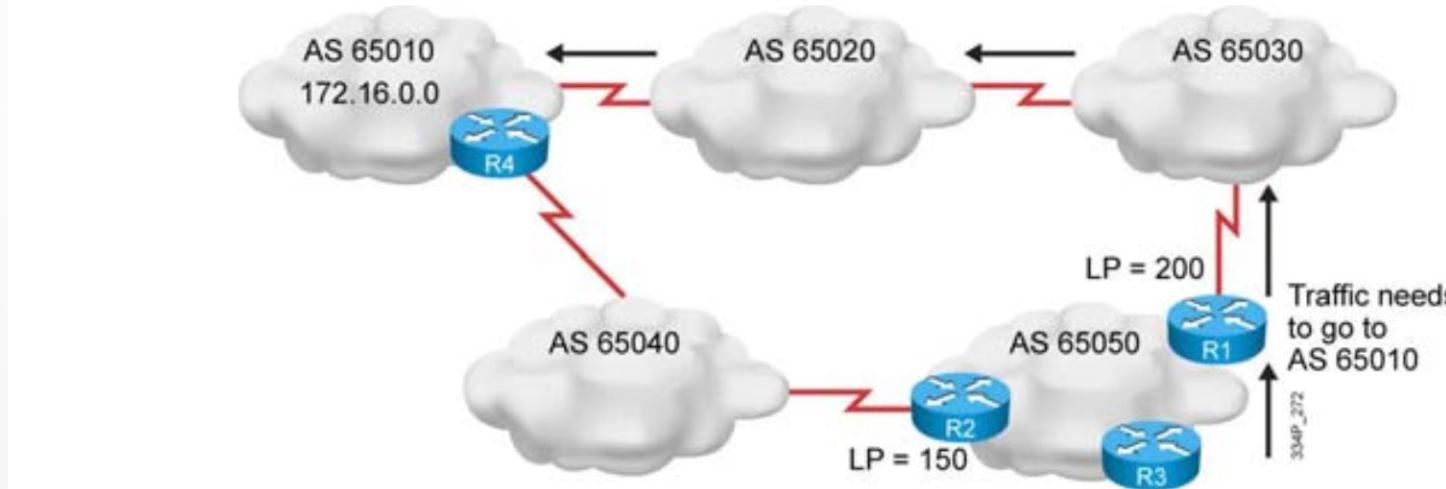
BGP Decision Process

1	Prefer highest local preference (global within AS).
2	Prefer route originated by the local router (next-hop= 0.0.0.0).
3	Prefer Shortest AS path
4	Prefer lowest origin code (IGP<EGP<incomplete).
5	Prefer lowest MED (exchanged between autonomous systems)
6	Prefer the EBGP path over the IBGP path.
7	Prefer the path through the closest IGP neighbor
8	Prefer the oldest route for EBGP paths
	Prefer the path with the lowest neighbor BGP router ID

Configuration and Management of Networks

BGP – Local Preference

- 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



Configuration and Management of Networks

BGP Set with routing map

Second BGP path selection criteria

Prefer highest local preference (global within AS)

Local preference can be set when

- processing incoming route updates
- doing redistribution
- sending outgoing route updates

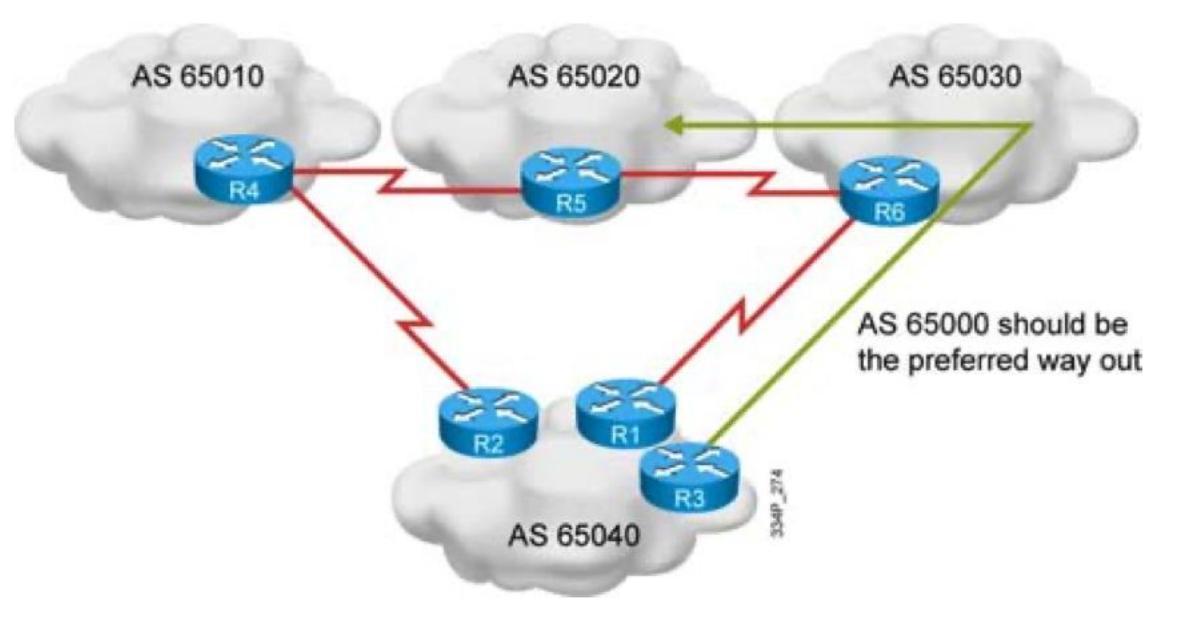
BGP local preference can be specified per neighbor by complex criteria with route maps

Configuration and Management of Networks

BGP

R1#

```
<output omitted>
!
router bgp 64520
  neighbor 10.0.0.1 route-map RM-SET-LP in
!
route-map RM-SET-LP permit 10
  set local-preference 150
```



```
nv set router bgp autonomous-system 64520  
nv set router bgp router-id 192.168.1.1  
nv set vrf default router bgp address-family ipv4-unicast enable on
```

```
nv set router policy route-map RM-SET-LP rule 10 action permit  
nv set router policy route-map RM-SET-LP rule 10 set local-preference 150
```

```
nv set vrf default router bgp neighbor 10.0.0.1 remote-as 65000  
nv set vrf default router bgp neighbor 10.0.0.1 type external  
nv set vrf default router bgp neighbor 10.0.0.1 address-family ipv4-unicast policy inbound route-map RM-SET-LP
```

Configuration and Management of Networks

BGP – Set AS paths with route map

Third BGP path selection criteria

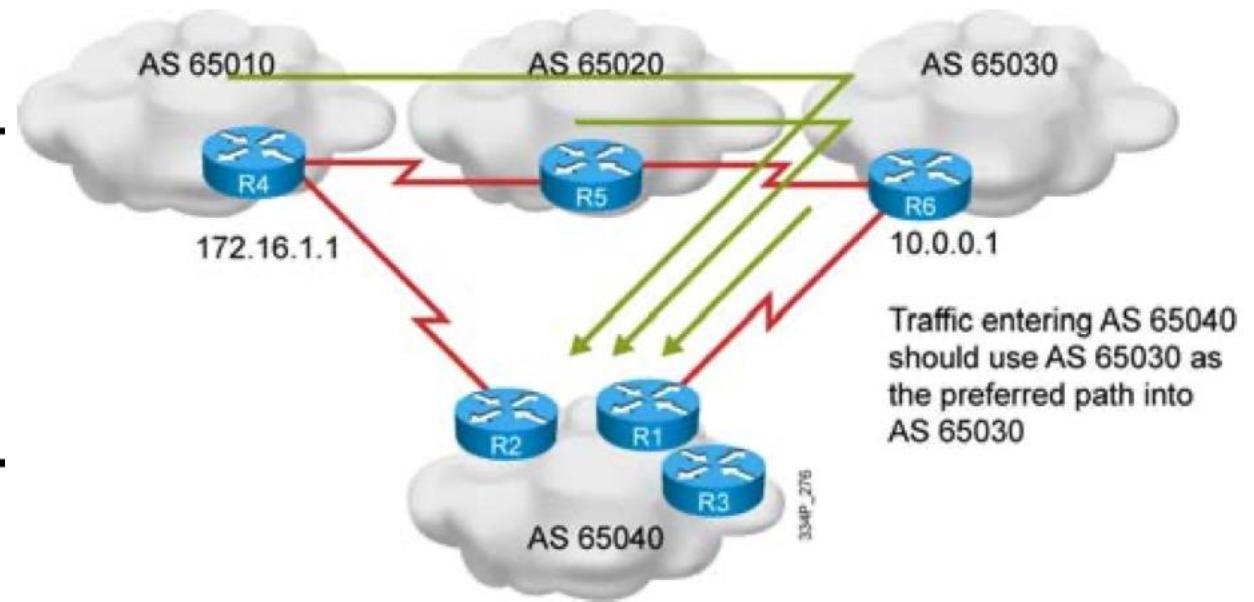
- Prefer shorter AS paths (only length is compared)
- Influences the outbound path selection in a multihomed AS
- Manual manipulation of AS path length—AS path prepending
- AS path prepending can be specified per neighbor by complex criteria with route maps (AS path filters, prefix lists, or other BGP attributes that match the routes in any combination)

Configuration and Management of Networks

BGP – AS path prepending

R2

```
<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
```



```
nv set router policy route-map RM-SET-ASPath rule 10 action permit
nv set router policy route-map RM-SET-ASPath rule 10 set as-path-prepend last-as 3
```

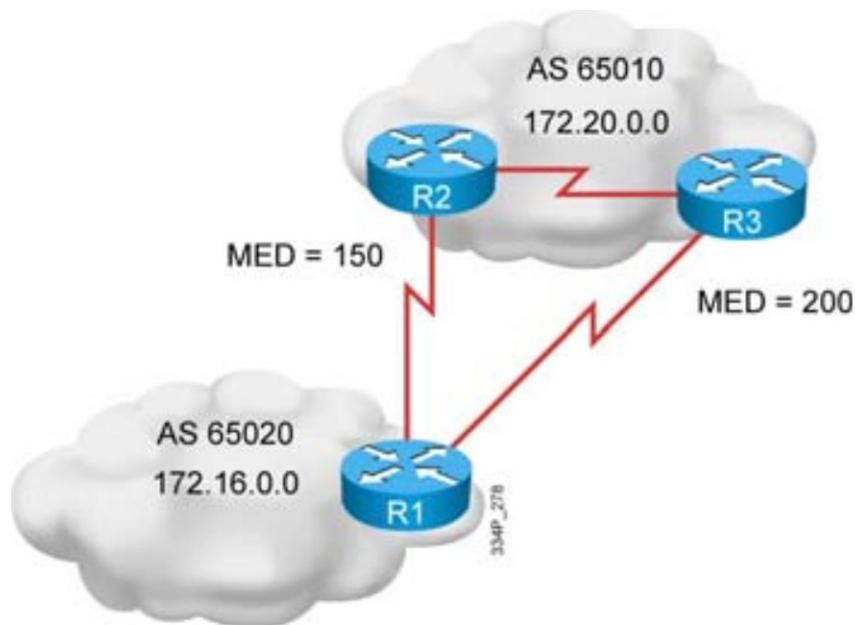
```
# Apply to neighbor
nv set vrf default router bgp neighbor 172.16.1.1 address-family ipv4-unicast policy outbound route-map RM-SET-ASPath
```

last-as 3 adds 3 times the last AS (65040)

Configuration and Management of Networks

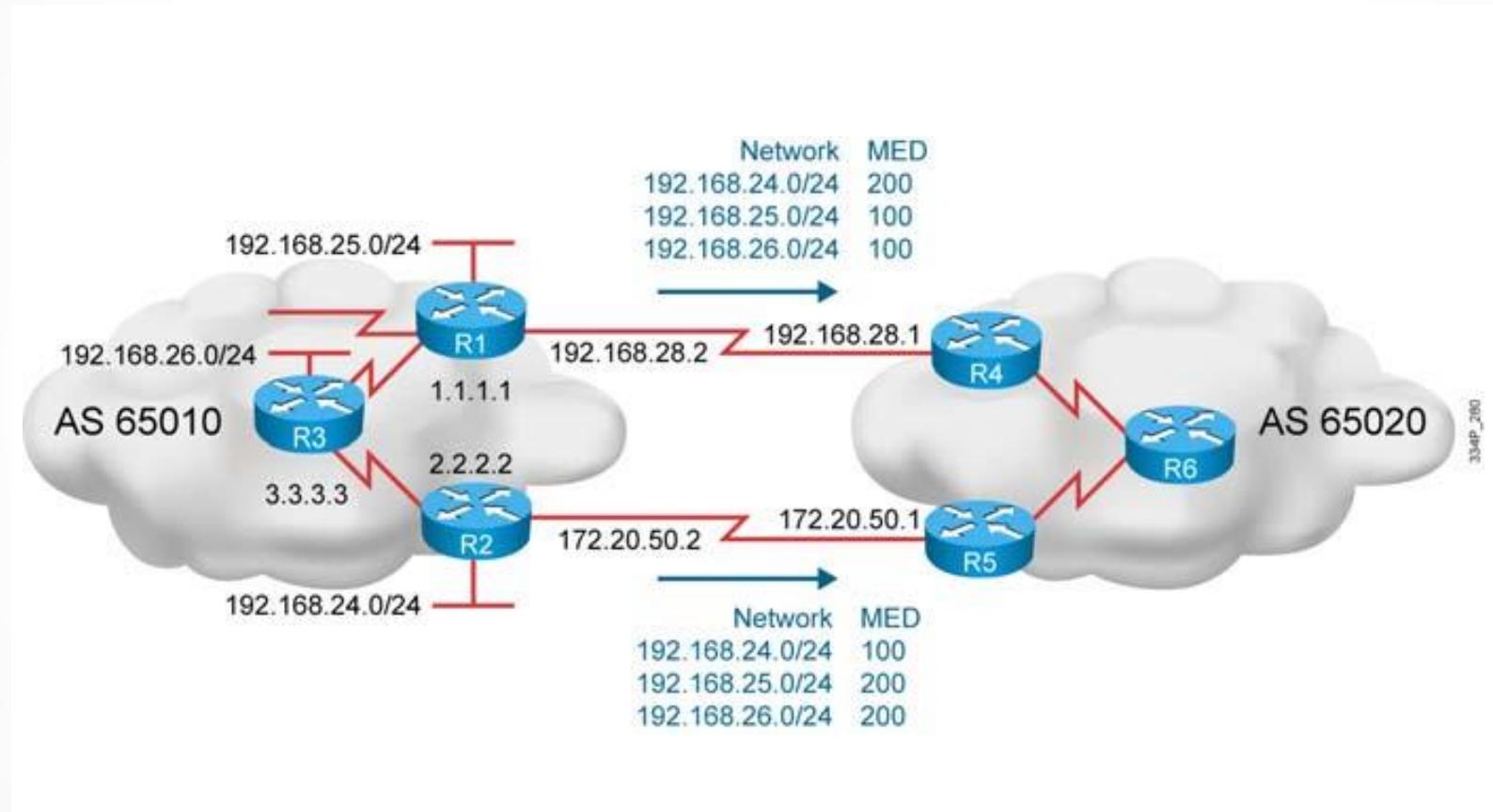
BGP – MED Attribute

- 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 owned by this AS.
- The MED attribute is **optional** and **nontransitive**.



Configuration and Management of Networks

BGP



Configuration and Management of Networks

BGP - MED

R1

```
nv set router bgp autonomous-system 65010  
nv set router bgp router-id 2.2.2.2
```

```
nv set vrf default router bgp neighbor 1.1.1.1 remote-as 65010  
nv set vrf default router bgp neighbor 1.1.1.1 type internal  
nv set vrf default router bgp neighbor 1.1.1.1 update-source lo
```

```
nv set vrf default router bgp neighbor 3.3.3.3 remote-as 65010  
nv set vrf default router bgp neighbor 3.3.3.3 type internal  
nv set vrf default router bgp neighbor 3.3.3.3 update-source lo
```

```
nv set vrf default router bgp neighbor 192.168.28.1 remote-as 65020  
nv set vrf default router bgp neighbor 192.168.28.1 type external
```

```
nv set router policy prefix-list PRIORITY-NETS rule 10 match 192.168.25.0/24  
nv set router policy prefix-list PRIORITY-NETS rule 10 action permit  
nv set router policy prefix-list PRIORITY-NETS rule 20 match 192.168.26.0/24  
nv set router policy prefix-list PRIORITY-NETS rule 20 action permit
```

```
nv set router policy route-map MED-65020 rule 10 action permit  
nv set router policy route-map MED-65020 rule 10 match ip-prefix-list PRIORITY-NETS  
nv set router policy route-map MED-65020 rule 10 set metric 100
```

```
nv set router policy route-map MED-65020 rule 100 action permit  
nv set router policy route-map MED-65020 rule 100 set metric 200
```

```
nv set vrf default router bgp neighbor 192.168.28.1 address-family ipv4-unicast policy outbound route-map MED-65020
```

Configuration and Management of Networks

BGP - MED

R2

```
nv set router bgp autonomous-system 65010  
nv set router bgp router-id 1.1.1.1
```

```
nv set vrf default router bgp neighbor 2.2.2.2 remote-as 65010  
nv set vrf default router bgp neighbor 2.2.2.2 type internal  
nv set vrf default router bgp neighbor 2.2.2.2 update-source lo
```

```
nv set vrf default router bgp neighbor 3.3.3.3 remote-as 65010  
nv set vrf default router bgp neighbor 3.3.3.3 type internal  
nv set vrf default router bgp neighbor 3.3.3.3 update-source lo
```

```
nv set vrf default router bgp neighbor 172.20.50.1 remote-as 65020  
nv set vrf default router bgp neighbor 172.20.50.1 type external
```

```
nv set router policy prefix-list PRIORITY-NET rule 10 match 192.168.24.0/24  
nv set router policy prefix-list PRIORITY-NET rule 10 action permit
```

```
nv set router policy route-map MED-65020 rule 10 action permit  
nv set router policy route-map MED-65020 rule 10 match ip-prefix-list PRIORITY-NET  
nv set router policy route-map MED-65020 rule 10 set metric 100
```

```
nv set router policy route-map MED-65020 rule 100 action permit  
nv set router policy route-map MED-65020 rule 100 set metric 200
```

```
nv set vrf default router bgp neighbor 172.20.50.1 address-family ipv4-unicast policy outbound route-map MED-65020
```