BORDER GATEWAY PROTOCOL (BGP)

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Purpose

The purpose of this lab is to explore the routing protocol Border Gateway Protocol (BGP). By implementing BGP, the goal was to build on existing knowledge of routing (EIGRP, OSPF) and add a level of complexity by routing between different protocols with BGP. In addition, in order to fully understand BGP, it was expected that we implement two variations of BGP in addition to the basic configurations.

Background Information

BGP, or Border Gateway Protocol, is used to route information across a network. BGP is similar to an airport. The purpose of an airport is to transport travelers from different countries from destination to destination. Just as an airport uses flight numbers to track routes from different locations, BGP uses autonomous systems (AS), or routing domains, to keep track of routing paths. One flight may be from the United States to Germany. In our BGP example, one router may be running a routing protocol called EIGRP (Enhanced Interior Gateway Routing Protocol) on its interfaces. The router running EIGRP is like the United States. The EIGRP router is connected to another router, which is running OSPF (Open Shortest Path First) on its interfaces. This router running OSPF is like Germany. In order to travel between the United States and Germany, one must travel through customs, which occur in an airport. The customs process is like BGP. The customs officer must have all necessary information from the country the traveler is from. In the same way, BGP must be fully redistributed in the EIGRP routing protocol and vice versa in order for the network to be advertised. Some flights are more expensive than others. If there is a layover from America to France before getting to Germany, that will be more expensive than a direct flight to Germany from America. BGP works similarly. The path that it directs routers to take depends on the weight of the path, the local preference, and other attributes. However, with BGP, the higher the weight or local preference, the more the route is preferred.

Lab Summary

First, I created a topology and assigned appropriate IPv4 and IPv6 addresses. I created a network in which Routers 4,5, and 6 would route BGP and Routers 1, 2, and 3 were connected to the BGP routers respectively. R4 and R1 shared the same network and ran EIGRP, R5 and R2 shared the same network and ran OSPF, and R6 and R3 shared the same network and ran EIGRP as well. In the internal network, R4, R5, and R6 were all connected together, with each pair of directly connected interfaces on their own network. After configuring the correct addresses, I configured EIGRP and OSPF on the external and internal routers for both IPv4 and IPv6. Next, I configured BGP on the internal routers. To configure BGP, I created two address families, one for IPv4 and one for IPv6. In each address family, I configured the correct directly connected network and the addresses of the neighboring routers. Next, I redistributed BGP on all routing protocols on the internal routers. I also redistributed the corresponding routing protocol in BGP configuration mode. To test that the basic BGP configuration was correctly configured, I ran pinged across the network from the external routers and verified that the external routers received external routes from their routing protocol. To manipulate the paths that the routers took, I manipulated the weight of the routes on R4. The default path that R1 took to R2 was through R4 to R5. To manipulate the path, on R4, I configured the address associated with R6 to have a weight of 100, which is significantly larger than the default

weight of 0. In changing the weight of the route connected to R6, all prefixes received from R6 also received a weight of 100 in the routing table. The second attribute that I manipulated was local preference. In determining the route path, BGP first considers weight, then looks at local preference. The default BGP local preference is 100. I manipulated the route from R2 to R1 to use R6 as the next hop router instead of R4.

Lab Commands

```
R1(config)#router bgp [AS number between 1 and 64511]
```

This command initializes BGP on the router. It configures the router to use the assigned Autonomous System number. There can only be one autonomous system configured per router, meaning both IPv4 and IPv6 addresses are configured on the same AS.

```
R1(config-router)#network [ipv4 or ipv6 network address]
```

This command specifies the networks for BGP to advertise. The networks advertised should be the directly connected networks on the router.

```
R1(config-router)#address-family ipv4 {multicast, unicast, none}
```

The command places the router in address family configuration mode, which allows for BGP configurations within standard IPv4 prefixes. The same command can be used to configure IPv6 address families, but with the `address-family ipv6` command.

```
R1(config-router)#neighbor [ipv4 or ipv6 address] route-as [AS number of the neighbor]
```

This command identifies the adjacent interfaces of all other BGP routers. The AS number should be of the neighboring router's BGP configuration.

```
R1(config-router)#neighbor [ipv4 or ipv6 address] weight [number]
```

When BGP selects a route, it prefers the route with the highest weight. Weight is Cisco proprietary and is local to the router it is configured on. When weight is configured on the corresponding neighbor, all routes learned from that neighbor will also have the new configured weight. The BGP weight range is from 0 to 5535, with the default being 0.

```
R1(config-router)#redistribute [routing protocol] [process-id]
```

This command is used to share information across routing protocols from one domain to another. BGP supports redistribution across connected routes, EIGRP, ISIS, mobile, OSPF, static, or RIP routes. For the process-id portion of the command, the number is the autonomous system number, if the protocol is BGP or EIGRP. If the routing protocol is OSPF, the number is the corresponding process id of the router. By default, the process-id portion of the command is not defined.

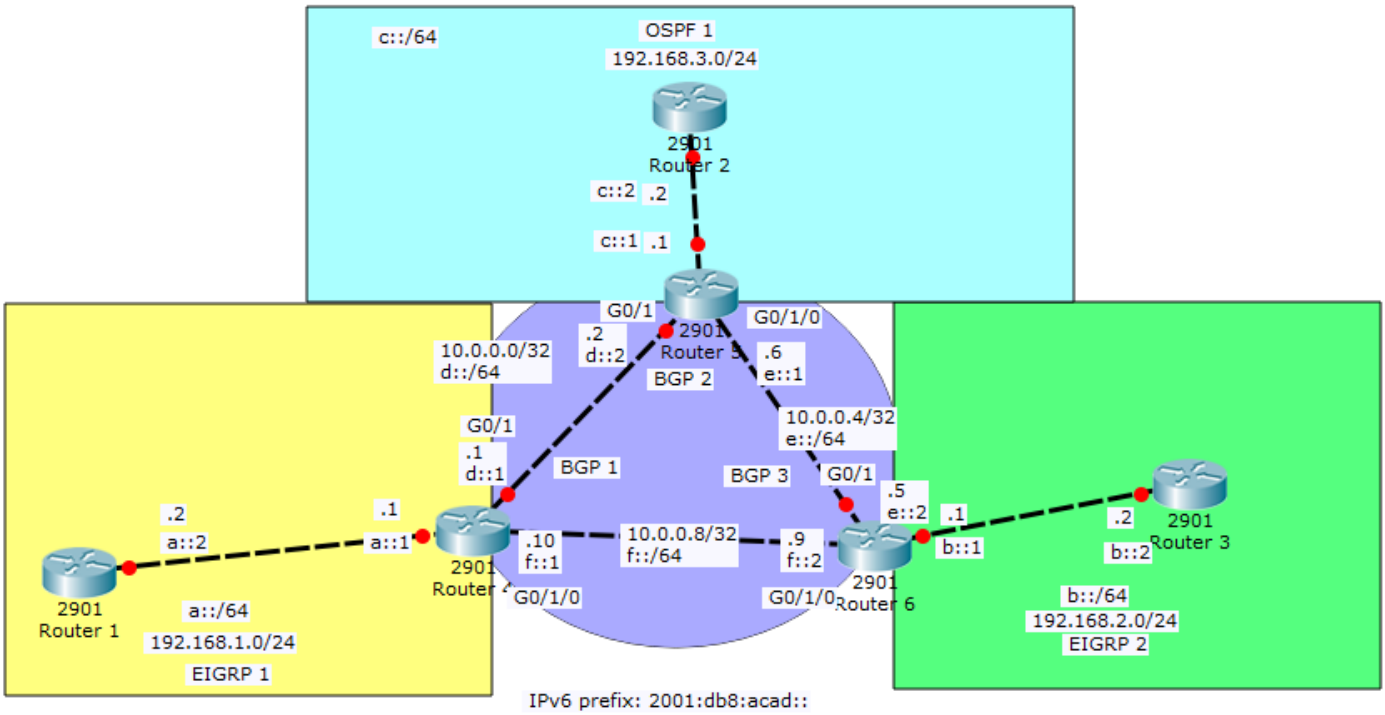
```
R1(config-router)#neighbor [ipv4 or ipv6 address] route-map [route map name]
[in or out]
```

This command applies a route map to incoming or outgoing routes. The ip address is of the neighboring router. The route map name is the name of the route map configured on the router. The in/out refers to whether the route map will be applied to incoming or outgoing routes.

```
R1(config-router)#route-map [route map name]
R1(config-route-map)#set local-preference [number]
```

This group of commands creates a route map under a unique name and sets the local preference within the route map to the number of your choice. Local preference for BGP ranges from 0 to 4294967295, with the default being 100. Local preference is used by BGP as the secondary metric in selecting routes. The higher the local preference, the more likely the route will be selected.

Network Diagram



Configurations

Router 1 show run:

```
Current configuration : 1436 bytes
Last configuration change at
16:34:23 UTC Fri Oct 21 2016
version 15.1
no service password-encryption
hostname R1
no ip domain lookup
ipv6 unicast-routing
ipv6 cef
interface FastEthernet0/0
 ip address 192.168.1.2
255.255.255.0
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:A::2/64
 ipv6 eigrp 1
router eigrp 1
 network 192.168.1.0
ip forward-protocol nd
ipv6 router eigrp 1
banner motd ^C
AUTHORIZED ACCESS ONLY
Configured by Sonya Lao
^C
line con 0
line aux 0
line vty 0 4
 login
 transport input all
scheduler allocate 20000 1000
end
```

Router 2 show run:

```
Current configuration : 1407 bytes
version 12.4
service timestamps debug datetime
msec
service timestamps log datetime
msec
no service password-encryption
hostname R2
ip cef
no ip domain lookup
ipv6 unicast-routing
ipv6 cef
interface FastEthernet0/0
 ip address 192.168.3.2
255.255.255.0
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:C::2/64
 ipv6 ospf 10 area 0
router ospf 1
 log-adjacency-changes
 network 192.168.3.0 0.0.0.255 area
0
ipv6 router ospf 10
 router-id 2.2.2.2
 log-adjacency-changes
banner motd ^C
AUTHORIZED ACCESS ONLY
Configured by Sonya Lao
^C
line con 0
line aux 0
line vty 0 4
 login
scheduler allocate 20000 1000
end
```

Router 3 show run:

```
Current configuration : 1635 bytes

Last configuration change at
15:18:41 UTC Fri Oct 21 2016
version 15.2
hostname R3
no ip domain lookup
ipv6 unicast-routing
ipv6 cef
interface GigabitEthernet0/0
 ip address 192.168.2.2
255.255.255.0
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:B::2/64
 ipv6 eigrp 20
router eigrp 2
 network 192.168.2.0
ip forward-protocol nd
banner motd ^C
AUTHORIZED ACCESS ONLY
Configured by Sonya Lao
^C
line con 0
line aux 0
line 2
line vty 0 4
 login
 transport input all
scheduler allocate 20000 1000
end
```

Router 4 show run:

```
Current configuration : 2673 bytes
Last configuration change at
15:27:23 UTC Fri Oct 21 2016
version 15.2
hostname R4
no ip domain lookup
ipv6 unicast-routing
ipv6 cef
interface GigabitEthernet0/0
 ip address 192.168.1.1
255.255.255.0
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:A::1/64
 ipv6 eigrp 10
interface GigabitEthernet0/1
 ip address 10.0.0.1
255.255.255.252
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:D::1/64
 ipv6 eigrp 10
interface GigabitEthernet0/1/0
 ip address 10.0.0.10
255.255.255.252
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:F::1/64
 ipv6 eigrp 10
router eigrp 1
 network 10.0.0.0 0.0.0.3
 network 10.0.0.8 0.0.0.3
 network 192.168.1.0
 redistribute bgp 1 metric 100 1
255 1 1500
 eigrp router-id 4.4.4.4
router bgp 1
 bgp router-id 4.4.4.4
 bgp log-neighbor-changes
 neighbor 10.0.0.2 remote-as 2
 neighbor 10.0.0.9 remote-as 3
 neighbor 2001:DB8:ACAD:D::2
remote-as 2
 neighbor 2001:DB8:ACAD:F::2
remote-as 3
  address-family ipv4
  network 192.168.1.0
  redistribute eigrp 1
  neighbor 10.0.0.2 activate
  neighbor 10.0.0.9 activate
  neighbor 10.0.0.9 weight 100
```

```
  no neighbor 2001:DB8:ACAD:D::2
activate
  no neighbor 2001:DB8:ACAD:F::2
activate
 exit-address-family
  address-family ipv6
  redistribute eigrp 10
  network 2001:DB8:ACAD:A::/64
  neighbor 2001:DB8:ACAD:D::2
activate
  neighbor 2001:DB8:ACAD:F::2
activate
 exit-address-family
ip forward-protocol nd
ipv6 router eigrp 10
 redistribute bgp 1
control-plane
gatekeeper
 shutdown
banner motd ^C
AUTHORIZED ACCESS ONLY
Configured by Sonya Lao
^C
line con 0
line aux 0
line 2
line vty 0 4
 login
 transport input all
scheduler allocate 20000 1000
end
```

Router 5 show run:

```
Current configuration : 3011 bytes
Last configuration change at
16:03:06 UTC Fri Oct 21 2016
version 15.2
no service password-encryption
hostname R5
ip cef
no ip domain lookup
ipv6 unicast-routing
ipv6 cef
interface GigabitEthernet0/0
 ip address 192.168.3.1
255.255.255.0
 ip broadcast-address 192.168.3.0
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:C::1/64
 ipv6 ospf 10 area 0
interface GigabitEthernet0/1
 ip address 10.0.0.2
255.255.255.252
 ip broadcast-address 10.0.0.0
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:D::2/64
 ipv6 ospf 10 area 0
interface GigabitEthernet0/1/0
 ip address 10.0.0.6
255.255.255.252
 ip broadcast-address 10.0.0.4
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:E::1/64
 ipv6 ospf 10 area 0
router ospf 1
 router-id 4.4.4.4
 redistribute bgp 2
 network 10.0.0.0 0.0.0.3 area 0
 network 10.0.0.4 0.0.0.3 area 0
 network 192.168.3.0 0.0.0.255 area
0
router bgp 2
 bgp router-id 5.5.5.5
 bgp log-neighbor-changes
 neighbor 10.0.0.1 remote-as 1
 neighbor 10.0.0.5 remote-as 3
 neighbor 2001:DB8:ACAD:D::1
remote-as 1
 neighbor 2001:DB8:ACAD:E::2
remote-as 3
  address-family ipv4
  network 192.168.3.0
  redistribute ospf 1
  neighbor 10.0.0.1 activate
```

```
  neighbor 10.0.0.5 activate
  neighbor 10.0.0.5 route-map
LOCAL-PREF-150 in
  no neighbor 2001:DB8:ACAD:D::1
activate
  no neighbor 2001:DB8:ACAD:E::2
activate
 exit-address-family
address-family ipv6
  redistribute ospf 10
  network 2001:DB8:ACAD:C::/64
  neighbor 2001:DB8:ACAD:D::1
activate
  neighbor 2001:DB8:ACAD:E::2
activate
  neighbor 2001:DB8:ACAD:E::2
route-map LOCAL-PREF-150 in

end
```

```
 exit-address-family
ip forward-protocol nd
ipv6 router ospf 10
 router-id 5.5.5.5
 redistribute bgp 2
route-map LOCAL-PREF-150 permit 10
 set local-preference 150
control-plane
mgcp profile default
gatekeeper
 shutdown
banner motd ^C
AUTHORIZED ACCESS ONLY
Configured by Sonya Lao
^C
```

Router 6 show run:

```
Current configuration : 2723 bytes
Last configuration change at
16:39:39 UTC Fri Oct 21 2016
version 15.2
no service password-encryption
hostname R6
ip cef
no ip domain lookup
ipv6 unicast-routing
ipv6 cef
multilink bundle-name authenticated
interface GigabitEthernet0/0
 ip address 192.168.2.1
255.255.255.0
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:B::1/64
 ipv6 eigrp 20
interface GigabitEthernet0/1
 ip address 10.0.0.5
255.255.255.252
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:E::2/64
 ipv6 eigrp 20
interface GigabitEthernet0/1/0
 ip address 10.0.0.9
255.255.255.252
 duplex auto
 speed auto
 ipv6 address 2001:DB8:ACAD:F::2/64
 ipv6 eigrp 20
router eigrp 2
 network 10.0.0.4 0.0.0.3
 network 10.0.0.8 0.0.0.3
 network 192.168.2.0
 redistribute bgp 3 metric 100 1
255 1 1500
 eigrp router-id 6.6.6.6
router bgp 3
 bgp router-id 6.6.6.6
 bgp log-neighbor-changes
 neighbor 10.0.0.6 remote-as 2
 neighbor 10.0.0.10 remote-as 1
 neighbor 2001:DB8:ACAD:E::1
remote-as 2
 neighbor 2001:DB8:ACAD:F::1
remote-as 1
  address-family ipv4
  network 192.168.2.0
```

```
  redistribute eigrp 2
  neighbor 10.0.0.6 activate
  neighbor 10.0.0.10 activate
  no neighbor 2001:DB8:ACAD:E::1
activate
  no neighbor 2001:DB8:ACAD:F::1
activate
 exit-address-family
address-family ipv6
  redistribute eigrp 20
  network 2001:DB8:ACAD:B::/64
  neighbor 2001:DB8:ACAD:E::1
activate
  neighbor 2001:DB8:ACAD:F::1
activate
 exit-address-family
ipv6 router eigrp 20
 redistribute bgp 3 metric 100 1
255 1 1500
banner motd ^C
AUTHORIZED ACCESS ONLY
Configured by Sonya Lao
^C
end
```

R1 show ip route:

```
R1#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override
Gateway of last resort is not set
      10.0.0.0/30 is subnetted, 3 subnets
D        10.0.0.0 [90/28416] via 192.168.1.1, 01:18:07, FastEthernet0/0
D EX     10.0.0.4 [170/25602816] via 192.168.1.1, 01:16:53, FastEthernet0/0
D        10.0.0.8 [90/28416] via 192.168.1.1, 01:17:41, FastEthernet0/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, FastEthernet0/0
L        192.168.1.2/32 is directly connected, FastEthernet0/0
D EX  192.168.2.0/24 [170/25602816] via 192.168.1.1, 01:16:53, FastEthernet0/0
D EX  192.168.3.0/24 [170/25602816] via 192.168.1.1, 00:36:43, FastEthernet0/0
```

R1 show ipv6 route:

```
R1#sh ipv6 route
IPv6 Routing Table - default - 3 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       D - EIGRP, EX - EIGRP external, NM - NEMO, ND - Neighbor Discovery
       l - LISP
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
EX  2001:DB8:ACAD:C::/64 [170/25600512]
     via FE80::4255:39FF:FED2:3690, GigabitEthernet0/0
C   2001:DB8:ACAD:A::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:ACAD:A::2/128 [0/0]
     via FastEthernet0/0, receive
EX  2001:DB8:ACAD:B::/64 [170/25600512]
     via FE80::4255:39FF:FED2:3690, GigabitEthernet0/0
L   FF00::/8 [0/0]
     via Null0, receive
```

R2 show ip route:

```
R2#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/30 is subnetted, 2 subnets
O       10.0.0.0 [110/2] via 192.168.3.1, 01:16:31, FastEthernet0/0
O       10.0.0.4 [110/2] via 192.168.3.1, 01:16:31, FastEthernet0/0
O E2 192.168.1.0/24 [110/1] via 192.168.3.1, 00:35:53, FastEthernet0/0
O E2 192.168.2.0/24 [110/1] via 192.168.3.1, 00:35:53, FastEthernet0/0
C    192.168.3.0/24 is directly connected, FastEthernet0/0
```

R2 show ipv6 route:

```
R2#  sh ipv6 route
IPv6 Routing Table - Default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, M - MIPv6, R - RIP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
OE2 2001:DB8:ACAD:A::/64 [110/1]
     via FE80::32E4:DBFF:FE67:1778, FastEthernet0/0
OE2 2001:DB8:ACAD:B::/64 [110/1]
     via FE80::32E4:DBFF:FE67:1778, FastEthernet0/0
C   2001:DB8:ACAD:C::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:DB8:ACAD:C::2/128 [0/0]
     via FastEthernet0/0, receive
O   2001:DB8:ACAD:D::/64 [110/2]
     via FE80::32E4:DBFF:FE67:1778, FastEthernet0/0
O   2001:DB8:ACAD:E::/64 [110/2]
     via FE80::32E4:DBFF:FE67:1778, FastEthernet0/0
L   FF00::/8 [0/0]
     via Null0, receive
```

R3 show ip route:

```
R3#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override
Gateway of last resort is not set
      10.0.0.0/30 is subnetted, 3 subnets
D EX     10.0.0.0 [170/25600512] via 192.168.2.1, 01:15:24, GigabitEthernet0/0
D        10.0.0.4 [90/3072] via 192.168.2.1, 01:16:07, GigabitEthernet0/0
D        10.0.0.8 [90/3072] via 192.168.2.1, 01:16:12, GigabitEthernet0/0
D EX  192.168.1.0/24
           [170/25600512] via 192.168.2.1, 01:15:24, GigabitEthernet0/0
      192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.2.0/24 is directly connected, GigabitEthernet0/0
L        192.168.2.2/32 is directly connected, GigabitEthernet0/0
D EX  192.168.3.0/24
           [170/25600512] via 192.168.2.1, 00:35:13, GigabitEthernet0/0
```

R3 show ipv6 route:

```
R3#sh ipv6 route
IPv6 Routing Table - default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
       H - NHRP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea
       IS - ISIS summary, D - EIGRP, EX - EIGRP external, NM - NEMO
       ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
EX  2001:DB8:ACAD:A::/64 [170/25600512]
     via FE80::4255:39FF:FED2:3690, GigabitEthernet0/0
C   2001:DB8:ACAD:B::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:B::2/128 [0/0]
     via GigabitEthernet0/0, receive
EX  2001:DB8:ACAD:C::/64 [170/25600512]
     via FE80::4255:39FF:FED2:3690, GigabitEthernet0/0
D   2001:DB8:ACAD:E::/64 [90/3072]
     via FE80::4255:39FF:FED2:3690, GigabitEthernet0/0
D   2001:DB8:ACAD:F::/64 [90/3072]
     via FE80::4255:39FF:FED2:3690, GigabitEthernet0/0
L   FF00::/8 [0/0]
     via Null0, receive
```

R4 show ip route:

```
R4#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override
Gateway of last resort is not set
      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C        10.0.0.0/30 is directly connected, GigabitEthernet0/1
L        10.0.0.1/32 is directly connected, GigabitEthernet0/1
B        10.0.0.4/30 [20/0] via 10.0.0.9, 01:14:34
C        10.0.0.8/30 is directly connected, GigabitEthernet0/1/0
L        10.0.0.10/32 is directly connected, GigabitEthernet0/1/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/0
L        192.168.1.1/32 is directly connected, GigabitEthernet0/0
B     192.168.2.0/24 [20/0] via 10.0.0.9, 01:14:34
B     192.168.3.0/24 [20/0] via 10.0.0.9, 00:34:24
```

R4 show ipv6 route:

```
R4#sh ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
       H - NHRP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea
       IS - ISIS summary, D - EIGRP, EX - EIGRP external, NM - NEMO
       ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
C   2001:DB8:ACAD:A::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:A::1/128 [0/0]
     via GigabitEthernet0/0, receive
B   2001:DB8:ACAD:B::/64 [20/0]
     via FE80::4255:39FF:FED2:36A0, GigabitEthernet0/1/0
B   2001:DB8:ACAD:C::/64 [20/0]
     via FE80::32E4:DBFF:FE67:1779, GigabitEthernet0/1
C   2001:DB8:ACAD:D::/64 [0/0]
     via GigabitEthernet0/1, directly connected
L   2001:DB8:ACAD:D::1/128 [0/0]
     via GigabitEthernet0/1, receive
C   2001:DB8:ACAD:F::/64 [0/0]
     via GigabitEthernet0/1/0, directly connected
L   2001:DB8:ACAD:F::1/128 [0/0]
     via GigabitEthernet0/1/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

R5 show ip route:

```
R5#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override
Gateway of last resort is not set
      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C        10.0.0.0/30 is directly connected, GigabitEthernet0/1
L        10.0.0.2/32 is directly connected, GigabitEthernet0/1
C        10.0.0.4/30 is directly connected, GigabitEthernet0/1/0
L        10.0.0.6/32 is directly connected, GigabitEthernet0/1/0
B        10.0.0.8/30 [20/0] via 10.0.0.5, 00:33:27
B     192.168.1.0/24 [20/0] via 10.0.0.5, 00:33:27
B     192.168.2.0/24 [20/0] via 10.0.0.5, 00:33:27
      192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.3.0/24 is directly connected, GigabitEthernet0/0
L        192.168.3.1/32 is directly connected, GigabitEthernet0/0
```

R5 show ipv6 route:

```
R5#sh ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
       H - NHRP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea
       IS - ISIS summary, D - EIGRP, EX - EIGRP external, NM - NEMO
       ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, l - LISP
B   2001:DB8:ACAD:A::/64 [20/0]
     via FE80::4255:39FF:FED2:3691, GigabitEthernet0/1/0
B   2001:DB8:ACAD:B::/64 [20/0]
     via FE80::4255:39FF:FED2:3691, GigabitEthernet0/1/0
C   2001:DB8:ACAD:C::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:C::1/128 [0/0]
     via GigabitEthernet0/0, receive
C   2001:DB8:ACAD:D::/64 [0/0]
     via GigabitEthernet0/1, directly connected
L   2001:DB8:ACAD:D::2/128 [0/0]
     via GigabitEthernet0/1, receive
C   2001:DB8:ACAD:E::/64 [0/0]
     via GigabitEthernet0/1/0, directly connected
L   2001:DB8:ACAD:E::1/128 [0/0]
     via GigabitEthernet0/1/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

R6 show ip route:

```
R6#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override
Gateway of last resort is not set
      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
B        10.0.0.0/30 [20/0] via 10.0.0.10, 01:12:30
C        10.0.0.4/30 is directly connected, GigabitEthernet0/1
L        10.0.0.5/32 is directly connected, GigabitEthernet0/1
C        10.0.0.8/30 is directly connected, GigabitEthernet0/1/0
L        10.0.0.9/32 is directly connected, GigabitEthernet0/1/0
B     192.168.1.0/24 [20/0] via 10.0.0.10, 01:12:30
      192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.2.0/24 is directly connected, GigabitEthernet0/0
L        192.168.2.1/32 is directly connected, GigabitEthernet0/0
B     192.168.3.0/24 [20/0] via 10.0.0.6, 00:32:20
```

R6 show ipv6 route:

```
R6#sh ipv6 route

IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
       H - NHRP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea
       IS - ISIS summary, D - EIGRP, EX - EIGRP external, NM - NEMO
       B   2001:DB8:ACAD:A::/64 [20/0]
     via FE80::7ADA:6EFF:FE99:AB30, GigabitEthernet0/1/0
C   2001:DB8:ACAD:B::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:B::1/128 [0/0]
     via GigabitEthernet0/0, receive
B   2001:DB8:ACAD:C::/64 [20/0]
     via FE80::32E4:DBFF:FE67:1788, GigabitEthernet0/1
C   2001:DB8:ACAD:E::/64 [0/0]
     via GigabitEthernet0/1, directly connected
L   2001:DB8:ACAD:E::2/128 [0/0]
     via GigabitEthernet0/1, receive
C   2001:DB8:ACAD:F::/64 [0/0]
     via GigabitEthernet0/1/0, directly connected
L   2001:DB8:ACAD:F::2/128 [0/0]
     via GigabitEthernet0/1/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

R4 show ip bgp:

```
R4#sh ip bgp
BGP table version is 21, local router ID is 4.4.4.4
Status codes: s suppressed, d damped, h history, * valid, > best, i -
internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-
Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *   10.0.0.0/30      10.0.0.2                 0             0 2 ?
 *>                   0.0.0.0                  0         32768 ?
 *   10.0.0.4/30      10.0.0.2                 0             0 2 ?
 *>                   10.0.0.9                 0           100 3 ?
 *   10.0.0.8/30      10.0.0.2                               0 2 3 ?
 *                    10.0.0.9                 0           100 3 ?
 *>                   0.0.0.0                  0         32768 ?
 *>  192.168.1.0      0.0.0.0                  0         32768 i
 *   192.168.2.0      10.0.0.2                               0 2 3 i
 *>                   10.0.0.9                 0           100 3 i
 *>  192.168.3.0      10.0.0.9                             100 3 2 i
 *                    10.0.0.2                 0             0 2 i
```

R4 show bgp ipv6 unicast:

```
R4#sh bgp ipv6 unicast
BGP table version is 15, local router ID is 4.4.4.4
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  2001:DB8:ACAD:A::/64
                       ::                       0         32768 i
 *   2001:DB8:ACAD:B::/64
                        2001:DB8:ACAD:D::2
                                                              0 2 3 i
 *>                  2001:DB8:ACAD:F::2
                                                0             0 3 i
 *   2001:DB8:ACAD:C::/64
                        2001:DB8:ACAD:F::2
                                                              0 3 2 i
 *>                  2001:DB8:ACAD:D::2
                                                0             0 2 i
```

R5 show ip bgp:

```
R5#sh ip bgp
BGP table version is 7, local router ID is 5.5.5.5
Status codes: s suppressed, d damped, h history, * valid, > best, i -
internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-
Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *   10.0.0.0/30      10.0.0.5                 150      0 3 1 ?
 *                    10.0.0.1                 0            0 1 ?
 *>                   0.0.0.0                  0         32768 ?
 *   10.0.0.4/30      10.0.0.5                 0    150      0 3 ?
 *                    10.0.0.1                              0 1 3 ?
 *>                   0.0.0.0                  0         32768 ?
 *>  10.0.0.8/30      10.0.0.5                 0    150      0 3 ?
 *                    10.0.0.1                 0            0 1 ?
 *>  192.168.1.0      10.0.0.5                 150      0 3 1 i
 *                    10.0.0.1                 0            0 1 i
 *>  192.168.2.0      10.0.0.5                 0    150      0 3 i
 *                    10.0.0.1                              0 1 3 i
 *>  192.168.3.0      0.0.0.0                  0         32768 i
```

R5 show bgp ipv6 unicast:

```
R5#sh bgp ipv6 unicast
BGP table version is 4, local router ID is 5.5.5.5
RPKI validation codes: V valid, I invalid, N Not found
     Network          Next Hop            Metric LocPrf Weight Path
 *>  2001:DB8:ACAD:A::/64
                      2001:DB8:ACAD:E::2
                                               150      0 3 1 i
 *                    2001:DB8:ACAD:D::1
                                            0            0 1 i
 *> 2001:DB8:ACAD:B::/64
                      2001:DB8:ACAD:E::2
                                            0    150      0 3 i
 *                    2001:DB8:ACAD:D::1
                                                         0 1 3 i
 *>  2001:DB8:ACAD:C::/64
                      ::                    0         32768 i
```

R6 show ip bgp:

```
R6#sh ip bgp
BGP table version is 15, local router ID is 6.6.6.6
Status codes: s suppressed, d damped, h history, * valid, > best, i -
internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-
Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *   10.0.0.0/30      10.0.0.6                 0             0 2 ?
 *>                   10.0.0.10                0             0 1 ?
 *   10.0.0.4/30      10.0.0.6                 0             0 2 ?
 *>                   0.0.0.0                  0         32768 ?
 *   10.0.0.8/30      10.0.0.10                0             0 1 ?
 *>                   0.0.0.0                  0         32768 ?
 *>  192.168.1.0      10.0.0.10                0             0 1 i
 *>  192.168.2.0      0.0.0.0                  0         32768 i
 *>  192.168.3.0      10.0.0.6                 0             0 2 i
```

R6 show bgp ipv6 unicast:

```
R6#sh bgp ipv6 unicast
BGP table version is 16, local router ID is 6.6.6.6
Status codes: s suppressed, d damped, h history, * valid, > best, i -
internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-
Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  2001:DB8:ACAD:A::/64
                      2001:DB8:ACAD:F::1
                                           0             0 1 i
 *>  2001:DB8:ACAD:B::/64
                      ::                   0         32768 i
 *   2001:DB8:ACAD:C::/64
                      2001:DB8:ACAD:F::1
                                                       0 1 2 i
 *>                   2001:DB8:ACAD:E::1
                                           0             0 2 i
```

R1 ping to 192.168.2.2

```
R1#ping 192.168.2.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
```

R1 ping to 2001:db8:acad:b::2

```
R1#ping 2001:db8:acad:b::2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:B::2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 0/2/8 ms
```

R1 traceroute to 192.168.3.2

```
R1#traceroute 192.168.3.2
Type escape sequence to abort.
Tracing the route to 192.168.3.2
VRF info: (vrf in name/id, vrf out name/id)
  1 192.168.1.1 4 msec 0 msec 0 msec
  2 10.0.0.9 4 msec 0 msec 0 msec
  3 10.0.0.6 4 msec 0 msec 0 msec
  4 192.168.3.2 4 msec *  0 msec
```

R2 traceroute to 192.168.1.2

```
R2#traceroute 192.168.1.2

Type escape sequence to abort.
Tracing the route to 192.168.1.2

  1 192.168.3.1 4 msec 0 msec 0 msec
  2 10.0.0.5 4 msec 0 msec 0 msec
  3 10.0.0.10 0 msec 0 msec 0 msec
  4 192.168.1.2 4 msec *  0 msec
```

R2 traceroute to 2001:db8:acad:a::2

```
R2#traceroute 2001:db8:acad:a::2

Type escape sequence to abort.
Tracing the route to 2001:DB8:ACAD:A::2

  1 2001:DB8:ACAD:C::1 4 msec 0 msec 0 msec
  2 2001:DB8:ACAD:E::2 4 msec 0 msec 0 msec
  3 2001:DB8:ACAD:F::1 4 msec 0 msec 0 msec
  4 2001:DB8:ACAD:A::1 4 mesc 0 msec 0 msec
```

Problems

When I first began my configuration of BGP, I was unable to ping across the network. Even though I had placed the correct network and neighbor statements on the correct routers, BGP was not getting advertised. To fix the issue, I asked my peers and looked online for why BGP was not advertising its networks. I discovered that redistribution was also necessary in order for BGP to route between different routing protocols. Thus, to fix the problem, I placed redistribution statements for the corresponding EIGRP and OSPF Autonomous System numbers in both address families. I also placed `redistribute bgp [as-number]` with the correct AS number in the EIGRP and OSPF configurations.

When configuring a variation of BGP, I decided to change the local preference, which determines the internal cost of a destination. In order to do so, I did not realize that I had to configure a route map. At first, I simply assigned a neighbor to a route map with the local preference of 150. After a traceroute showed that R2 was still going directly to R4 to reach R1, I looked into how I wrote the command, and realized that I should have place the statement attaching the neighbor to the route map to be on inbound routes, not outbound.

My second variation of BGP was to change the weight of the route from R4 to R6. I wanted the path from R1 to R2 to go through R6 instead of R5, but I configured the higher weight on the network between R4 and R5. Thus, I ran many traceroutes, but R1 still went directly through R5 to reach R2. After conducting more research and understanding the purpose weight better, I realized I needed to configure the path between R4 and R6 to have a higher weight. After I did so, the traceroute on R1 showed that it went through R6 before reaching R5.

Conclusion

BGP is a robust routing protocol that is extremely important to networking. It is applicable in many situations and the variability with the attributes makes the protocol scalable as well. For example, many service providers use BGP to transfer information on thousands of IP prefixes, but small businesses also use BGP.