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Configuring IPv4 BGP

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Purpose

The networking infrastructure of the world is supported by BGP. If it were not for BGP, none of us would be able to google “sushi places near me” and get convenient responses out of nowhere in mere milliseconds. In this paper, I go over my process of configuring BGP and provide some background information along the way.

Background Information

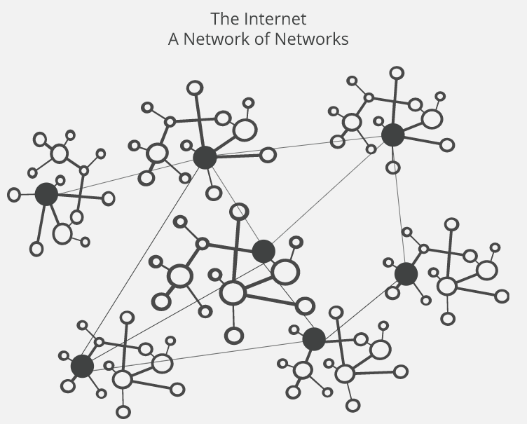
Routing is a significant process in networking, as it allows hosts on different IP networks to connect to each other. **BGP** is a routing protocol simplifying the process of creating routes by using algorithms to figure out the directions automatically. In networking, **routes** are ultimately just **directions** for packets.

There are two options when dealing with traffic on a network; you can configure static routes, or you can set up a routing protocol. I like to think of static routes as absolute directions drawn onto a map, perhaps going through a forest. The directions are set in stone; the directions can’t be altered unless they are manually redrawn. Let’s suppose you are following those directions by carriage through a forest but get stuck because there is a fallen tree or a broken bridge across a river. You are now lost and there is nowhere else to go.

However, this time you’ve got a compass that changes direction based on updates it gets from the current situation, allowing you to navigate more flexibly. It might take a bit longer on this path than as the crow flies, but you avoid rivers and rough terrain. Thus, is the magic of routing protocols— automatic updates and directions, not unlike google maps, but for packets.

Border Gateway Protocol

*BGP* (Border Gateway Protocol) is the most popular routing protocol, commonly used by ISPs (Internet Service Providers) to route customer traffic. Without BGP, the internet would not function nearly as well, if at all. Think of BGP as the postal service that delivers a letter to the recipient in the fastest and most efficient manner possible. When someone submits data across the internet, BGP is responsible for choosing the best path out of all preexisting available paths, which usually means passing through autonomous systems.



*An example of Autonomous systems and their local networks*

So, what are autonomous systems? Autonomous systems (AS) are a collection of routers, each with their own lesser hierarchy of routers that eventually connects to local networks. Each autonomous system is aware of other autonomous system(s) and can broadly determine where to route traffic based on which autonomous system holds the desired destination. ASes typically belong to ISPs (Internet service providers) or other large high-tech organizations, such as tech companies, universities, or scientific institutions. The internet is run under a collection of autonomous systems.

Kingdom Analogy

I suppose one could think of an autonomous system as a form of kingdom. Each kingdom has a ruler that dictates certain policies that the underlying citizens and infrastructure abide to. For example, if a kingdom is landlocked, it likely has a high demand for fish and salt. Therefore, a *policy* is implemented where all traders from the nearest port town have free access to and from the kingdom. Different autonomous systems often have these unique routing *policies*.

There are many paths and roads in the kingdom internally, so much so that if one goes down, alternate routes are readily available. Some kingdoms have routes bridging them, but often a traveler (packet) will have to journey through multiple kingdoms to reach their desired destination. In other words, a packet may have to pass through multiple ASes to reach its destination.

Each AS is assigned a unique, 32-bit number, the *Autonomous System Number* (ASN). These numbers differentiate what “kingdom” a router falls under. Routers with the same AS are part of the same kingdom. To qualify for an ASN, one needs proof of a unique routing policy, knowledge on how to link autonomous systems, and a plentiful quantity of hosts. There is no point in creating a kingdom with only a handful of hosts. If you satisfy these rules, then the closest *regional internet registry* (RIR), may delegate you an ASN.

Internal and External BGP

As I vaguely covered in my analogy, there are two types of BGP: *internal BGP* (within kingdoms) and *external BGP* (between kingdoms).

*External BGP* (eBGP) is the bridge that connects autonomous systems, where neighbors can broadly exchange network prefixes to learn more about each other’s networks.

*Internal BGP* (iBGP) is a TCP based protocol to help advertise and support eBGP routes. The kicker: iBGP alone does not do any routing. To route, one needs an IP based protocol. So why bother with iBGP at all?

Consider an old, flimsy wooden bridge. Driving a cargo truck across would collapse the bridge. But now, with iBGP, that bridge is reinforced with a concrete foundation, metal bearings, and arches to brace the heavy loads. BGP is the only protocol designed to support the hundreds of thousands of routes that make up the internet. As of writing this, the size of the full IPv4 BGP routing table is around 800,000 prefixes without even accounting for IPv6. For reference, the average OSPF router would suffer at around 6000 prefixes. This is often why we see iBGP used in conjunction with an IGP; the IGP does the local routing whilst iBGP contains the major routing table.

Both internal and external BGP sessions establish neighbors based on a peering system. You define a peer with a neighbor statement: for example, *neighbor 10.0.0.1 remote-as 100* states that there is a router connected, *10.0.0.1* running under ASN *100*. The neighbor *10.0.0.1* would need to define this router as a neighbor for a complete peer adjacency to form. Once both routers point to each other, they are peered. Networks are advertised with network statements: for example, *network 10.0.0.0 mask 255.255.255.0* will add the prefix *10.0.0.0/24* to the routing table. Other routers will direct traffic for *10.0.0.0/24* towards the router with the network statement.

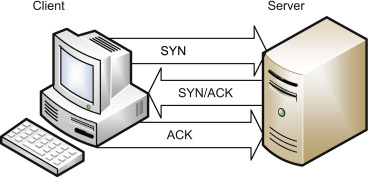
How does BGP function?

The main purpose BGP serves is forwarding traffic to an external network in the most efficient manner possible. Some factors that determine the best path are:

1. The path with the highest *weight*. This is a user defined variable.
2. The path with the highest*LOCAL\_PREF*. Local preference determines which path is preferred when leaving a local AS.
3. The path with the highest*AS\_PATH*. The main purpose of *AS\_PATH* is to prevent infinite routing table updates. It is rather complicated, but essentially if a router goes down in a network, then this might cause the other routers to falsely change their paths, resulting in an infinite loop of changing paths. This can only happen in a distance-vector routing protocol such as BGP or RIP.
4. Favoring *eBGP* paths over iBGP paths.

BGP is a *distance-vector* routing protocol. Distance-vector routing protocols work by advertising their routing tables to their neighbors. If the routes from the neighbor are better than the ones they currently have, the router will update its routing table to the preferable routes. Like all other routing protocols, BGP must first establish a neighbor adjacency with another BGP router to be able to exchange routing information. Unlike other routing protocols, BGP does not broadcast or multicast to discover other BGP neighbors. Neighbor relationships must be established manually and BGP uses TCP port 179 for the connection. There are a couple of different states BGP routers may encounter when becoming neighbors:

1. Idle. In Idle, BGP waits for a “start event”. This could be when a new BGP neighbor is configured or when a reset occurs between peers that already had a connection. After the start event, BGP will initialize a TCP connection with the remote neighbor and initialize some functions. In success, BGP moves to the *Connect* state, while in failure, BGP remains in the *Idle* state.
2. Connect. In *Connect*, BGP waits for the TCP three-way handshake to complete. Both sides need to *synchronize* (SYN) and *acknowledge* (ACK) each other in a TCP three-way handshake. If the results are successful, BGP continues to the *OpenSent* state. If the results are unsuccessful, BGP continues to the *Active* state.



1. Active. BGP will try another TCP three-way handshake to establish a connection with the remote neighbor. On success, BGP will transition to the *OpenSent* state. After a certain amount of time has passed with no success, BGP will transition back to the *Connect* state.
2. OpenSent. BGP will wait for an “Open Message” from the remote neighbor. Open Messages contain information about the BGP router, such as version, ASN, BGP router ID, and hold time. If the versions or hold times mismatch, BGP reverts to the *Idle* state. The ASN determines whether the BGP session will be running iBGP or eBGP. If the TCP session ever fails, BGP will revert to the *Active* state. If all passes, BGP will start sending keepalive messages to maintain the TCP session.
3. OpenConfirm. BGP waits for a keepalive message from the remote BGP neighbor. When the keepalive messages become consistently received, BGP moves to the *Established* state. In any other case, BGP falls back to the *Idle* state.
4. Established. The neighbor adjacency has been formed. As long as keepalive messages are being sent, the neighborship remains up. Otherwise, BGP resets back to Idle state.

Adjacencies are often formed by defining the *directly connected* interface as a neighbor, a common trait in most routing protocols. However, a technique when working with BGP is to use loopback interfaces as neighbors. Using loopbacks is common for iBGP but it also works with eBGP. Loopbacks are preferred because of redundancy: if the physical interface goes down, perhaps due to hardware, loopback interfaces will stay up since they are *virtual*.

Brief History of BGP

In the beginnings of the internet there was no BGP. However, we did have Gateway Gateway Protocol (GGP), a protocol that was not only fabulously named, but a slightly more advanced version of an outdated IGP we have today (RIP). Back then, routers were known as gateways, explaining the redundancy in the name.

GGP was replaced by Exterior Gateway Protocol (EGP) in 1984, created to support the growing network infrastructure around the world. EGP introduced the concept of autonomous systems, which later became a big part of BGP.

Even so, engineers foresaw a fundamental problem with EGP: the inability to detect routing loops. If a topology was configured incorrectly and a router drops, an error could cause packets could circulate endlessly. Among other problems, it needed an update. In 1989 an early version of BGP emerged, BGP-1, closely followed by BGP-2, then BGP-3 in 1991. However, there was a big problem that these three BGPs all shared. They only supported *classful* addressing. This meant that each network could only have one of three prefix sizes: 255, 65535, or 16777215 (the number of hosts). If I wanted one network that could support 500 hosts back in BGP-3, I’d have to opt with a prefix of [**/**16], 65,535 hosts. I’d be wasting over 65,000 of the remaining addresses.

Throughout the 1990s, BGP adopted some innovations, including IPv6, but it wasn’t until 2006 that the current version of BGP (BGP-4) was released with the support of classless inter-domain routing (CIDR). Classless addressing gave engineers much more flexibility with prefixes— the major downside of BGP-3. Even today, the internet is still running the very same BGP-4.

Lab Summary

In this lab, I configured three routing protocols: eBGP, OSPF, and EIGRP. I began by designing a topology composed of seven routers. They were to virtually be placed in a straight line, sectioned off into three networks by the different routing protocols. I created an IP scheme composed of [**/30**] subnets, each subnet implemented on neighbor serial interfaces. These subnets ranged from [**10.10.10.0/30**] to [**10.10.10.20/30**].

A good place to start on these types of configurations is assigning the IPs to the interfaces of the routers. When the stable green port lights indicated linked ethernet, I moved to OSPF configs. As I’d learnt from my previous encounters with OSPF, network statements are the most reliable way to enable an OSPF interface. OSPF-enabled interfaces peer with neighbor OSPF interfaces and share routing information. My topology placed OSPF on the bottom half of the network, met by BGP then EIGRP on top. Since I felt familiar with EIGRP, I moved on to the top section of routers first.

EIGRP is a lot like OSPF in the configuration. Both use network statements with near indistinguishable syntax, which is all I really needed to configure for them to work. While OSPF is entirely a link-state routing protocol, EIGRP is a hybrid of link-state and distance-vector. They are used interchangeably in enterprise networks, though each have their own more specific benefits.

After the IGPs were routing within their small domains, it was time to set up BGP. Initially learning BGP was a little confusing, navigating around the *address-families* and such, but I’ve grown to like it more than OSPF or EIGRP. If I just wanted to configure OSPF on an interface but not broadcast that network to the routing tables, I wouldn’t know where to start or if that’s even possible. However, BGP has separate commands for both adjacencies and network advertisement, giving the admin more control over their network. Eventually, I got eBGP running with full redistribution between OSPF and EIGRP.

Lab commands

|  |  |
| --- | --- |
| **CLI-Command** | A statement necessary for a configuration to work, denoted in bold |
| **[*Argument*]** | An argument necessary for a command to function, denoted in bold italics. |
| *Optional-Statement*  *<Optional Argument>* | An optional argument or statement, not necessary for a command to function, denoted in italics |

Router(config)# **interface [*interface*] [*id*]**

* Enables configuration on a specific interface.

// BGP

Router(config)# **router bgp [*autonomous system number*]**

* Activates a BGP router and enters router configuration mode

The autonomous system number (ASN) is a number that identifies a large collection of routers on the internet. Typically, there are networks run under an ASN by a technical administration. eBGP connects different autonomous systems while iBGP is run within each ASN.

Router(config-router)# **neighbor [*IP address*] remote-as [*neighbor’s ASN*]**

* Used in forming BGP neighbor adjacencies.

Unlike a network statement, this command takes the singular *IP* address of the neighbor’s connected interface. The second argument is to specify the neighbor’s ASN. For a BGP neighborship to be established, each router must have *routes to the neighbor’s IP* and *the correct IP and ASN of their neighbor*. Having proper routes to each neighbor’s IP is critical to forming adjacencies, but this also means these two BGP neighbors could lie anywhere. For example, routers *A* and *C* are connected via router *B*. Theoretically, you could establish a BGP neighbor relationship between routers *A* and *C* if they both have routes to each other’s IPs.

Router(config-router)# **address-family [*protocol*]**

* Enters configuration mode for a BGP address family

As a basic premise, address families are used to separate certain protocols BGP supports. I find that address-families are more workspaces for the desired protocol. For example, one might enter the “ipv4” or “ipv6” address-families to configure IP routing. This is where redistribution, network statements or activation commands occur.

Router(config-router)# **network [*network address*] mask [*subnet mask*]**

* Advertises a directly connected network to the BGP routing table

BGP’s network statements are not to be confused with OSPF or EIGRPs; they aren’t used to form adjacencies between BGP routers. A BGP network statement is typically configured alongside a neighbor statement, where one advertises the network and the other the neighbor establishment.

// OSPF

Router(config)# **router ospf [*process id*]**

* Enables the OSPF routing protocol and enters router configuration mode.

It is good practice for the process ID to be the same, however isn’t necessary for OSPF to form adjacencies; process ID is only locally significant. Each OSPF process retains a different routing table, so depending on the configuration, process ID could determine what routes are redistributed. A router can have multiple OSPF processes but will contain a separate OSPF database per process.

Router(config-router)# **router-id** **[*router* *id*]**

* Uniquely determines an OSPF router within a domain.

Router IDs are automatically determined if not manually set and can play a part in DR/BDR elections after OSPF priority.

Router(config-router)# **network [*network address*] [*wildcard mask*] area [*area number*]**

* Activates OSPFv2 for a specific subnet.

This command is typed after you enter router OSPF configuration mode. Routers in a particular area share a complete topological database and have route summaries of external areas.

// EIGRP

Router(config)# **router eigrp [*instance*]**

* Enables EIGRP of a particular instance on the router and enters router configuration mode.

There can be multiple instances of EIGRP running on a router, however, adjacent routers will only communicate if they are using the same instance.

Router(config-router)# **network [*network address*] [*wildcard mask*]**

* Activates EIGRP on specified network

This command is typed after you enter router EIGRP configuration mode. Other EIGRP routers will gain knowledge of this network and form routes to it.

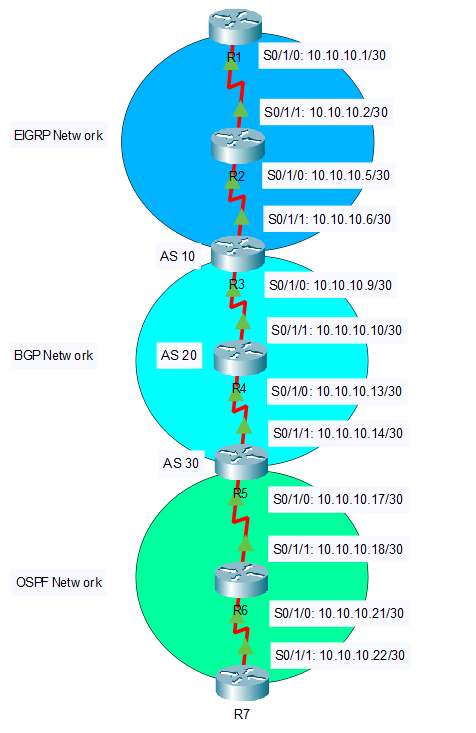
// Redistribution

Router(config-router)# **redistribute [*routing protocol*] [*protocol instance*]** <***metric*** <*value*>> *subnets*

* Redistributes routes from specified routing protocol into the table of a local router

The command is typed in the router where you’d want the routes to redistribute. There are many different additional options when redistributing routes, but I’ve found the *metric* and *subnets* to be the most useful. Each routing protocol has a different *metric*, so when redistributing be sure to use the right one. *Subnets* usually always refers to redistributing classless networks.

Network Diagram



Configurations

Router 1

**R1#sh run**

no service timestamps log datetime msec

no service timestamps debug datetime msec

no service password-encryption

hostname R1

no ip cef

ipv6 unicast-routing

no ipv6 cef

spanning-tree mode pvst

interface GigabitEthernet0/0/0

no ip address

duplex auto

speed auto

shutdown

interface GigabitEthernet0/0/1

no ip address

duplex auto

speed auto

shutdown

interface Serial0/1/0

ip address 10.10.10.1 255.255.255.252

ipv6 address FE80::1 link-local

ipv6 address 1::1/64

ipv6 eigrp 10

interface Serial0/1/1

no ip address

clock rate 2000000

shutdown

interface Vlan1

no ip address

shutdown

router eigrp 10

eigrp router-id 1.1.1.1

network 10.10.10.0 0.0.0.3

ipv6 router eigrp 10

eigrp router-id 1.1.1.0

no shutdown

ip classless

ip flow-export version 9

line con 0

line aux 0

line vty 0 4

login

end

**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, E - EGP

i - IS-IS, 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

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

C 10.10.10.0/30 is directly connected, Serial0/1/0

L 10.10.10.1/32 is directly connected, Serial0/1/0

D 10.10.10.4/30 [90/2681856] via 10.10.10.2, 00:03:35, Serial0/1/0

D EX 10.10.10.8/30 [170/3668480] via 10.10.10.2, 00:03:33, Serial0/1/0

D EX 10.10.10.12/30 [170/3668480] via 10.10.10.2, 00:03:33, Serial0/1/0

D EX 10.10.10.16/30 [170/3668480] via 10.10.10.2, 00:03:33, Serial0/1/0

D EX 10.10.10.20/30 [170/3668480] via 10.10.10.2, 00:03:21, Serial0/1/0

**R1#sh ip eigrp interfaces**

IP-EIGRP interfaces for process 10

Xmit Queue Mean Pacing Time Multicast Pending

Interface Peers Un/Reliable SRTT Un/Reliable Flow Timer Routes

Se0/1/0 1 0/0 1236 0/10 0 0

R1#sh ip eig nei

IP-EIGRP neighbors for process 10

H Address Interface Hold Uptime SRTT RTO Q Seq

(sec) (ms) Cnt Num

0 10.10.10.2 Se0/1/0 12 00:04:10 40 1000 0 9

**R1#sh ip eigrp topology**

IP-EIGRP Topology Table for AS 10/ID(1.1.1.1)

Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,

r - Reply status

P 10.10.10.0/30, 1 successors, FD is 2169856

via Connected, Serial0/1/0

P 10.10.10.4/30, 1 successors, FD is 2681856

via 10.10.10.2 (2681856/2169856), Serial0/1/0

P 10.10.10.8/30, 1 successors, FD is 3668480

via Rstatic (3668480/3156480)

P 10.10.10.12/30, 1 successors, FD is 3668480

via Rstatic (3668480/3156480)

P 10.10.10.16/30, 1 successors, FD is 3668480

via Rstatic (3668480/3156480)

P 10.10.10.20/30, 1 successors, FD is 3668480

via Rstatic (3668480/3156480)

Router 2

**R2#sh run**

no service timestamps log datetime msec

no service timestamps debug datetime msec

no service password-encryption

hostname R2

ip cef

ipv6 unicast-routing

no ipv6 cef

spanning-tree mode pvst

interface GigabitEthernet0/0/0

no ip address

duplex auto

speed auto

shutdown

interface GigabitEthernet0/0/1

no ip address

duplex auto

speed auto

shutdown

interface Serial0/1/0

ip address 10.10.10.5 255.255.255.252

ipv6 address FE80::1 link-local

ipv6 address 2::1/64

ipv6 eigrp 10

interface Serial0/1/1

ip address 10.10.10.2 255.255.255.252

ipv6 address FE80::2 link-local

ipv6 address 1::2/64

ipv6 eigrp 10

clock rate 2000000

interface Vlan1

no ip address

shutdown

router eigrp 10

eigrp router-id 2.2.2.2

network 10.10.10.4 0.0.0.3

network 10.10.10.0 0.0.0.3

ipv6 router eigrp 10

eigrp router-id 2.2.2.0

no shutdown

ip classless

ip flow-export version 9

line con 0

line aux 0

line vty 0 4

login

end

**R2#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, E - EGP

i - IS-IS, 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

10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks

C 10.10.10.0/30 is directly connected, Serial0/1/1

L 10.10.10.2/32 is directly connected, Serial0/1/1

C 10.10.10.4/30 is directly connected, Serial0/1/0

L 10.10.10.5/32 is directly connected, Serial0/1/0

D EX 10.10.10.8/30 [170/3156480] via 10.10.10.6, 00:07:19, Serial0/1/0

D EX 10.10.10.12/30 [170/3156480] via 10.10.10.6, 00:07:19, Serial0/1/0

D EX 10.10.10.16/30 [170/3156480] via 10.10.10.6, 00:07:19, Serial0/1/0

D EX 10.10.10.20/30 [170/3156480] via 10.10.10.6, 00:07:07, Serial0/1/0

**R2#sh ip eigrp interfaces**

IP-EIGRP interfaces for process 10

Xmit Queue Mean Pacing Time Multicast Pending

Interface Peers Un/Reliable SRTT Un/Reliable Flow Timer Routes

Se0/1/0 1 0/0 1236 0/10 0 0

Se0/1/1 1 0/0 1236 0/10 0 0

**R2#sh ip eigrp neighbors**

IP-EIGRP neighbors for process 10

H Address Interface Hold Uptime SRTT RTO Q Seq

(sec) (ms) Cnt Num

0 10.10.10.1 Se0/1/1 11 00:06:51 40 1000 0 11

1 10.10.10.6 Se0/1/0 12 00:06:49 40 1000 0 8

**R2#sh ip eigrp topology**

IP-EIGRP Topology Table for AS 10/ID(2.2.2.2)

Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,

r - Reply status

P 10.10.10.0/30, 1 successors, FD is 2169856

via Connected, Serial0/1/1

P 10.10.10.4/30, 1 successors, FD is 2169856

via Connected, Serial0/1/0

P 10.10.10.8/30, 1 successors, FD is 3156480

via Rstatic (3156480/2644480)

P 10.10.10.12/30, 1 successors, FD is 3156480

via Rstatic (3156480/2644480)

P 10.10.10.16/30, 1 successors, FD is 3156480

via Rstatic (3156480/2644480)

P 10.10.10.20/30, 1 successors, FD is 3156480

via Rstatic (3156480/2644480)

Router 3

**R3#sh run**

no service timestamps log datetime msec

no service timestamps debug datetime msec

no service password-encryption

hostname R3

ip cef

ipv6 unicast-routing

no ipv6 cef

spanning-tree mode pvst

interface GigabitEthernet0/0/0

no ip address

duplex auto

speed auto

shutdown

interface GigabitEthernet0/0/1

no ip address

duplex auto

speed auto

shutdown

interface Serial0/1/0

ip address 10.10.10.9 255.255.255.252

ipv6 address FE80::1 link-local

ipv6 address 3::1/64

interface Serial0/1/1

ip address 10.10.10.6 255.255.255.252

ipv6 address FE80::2 link-local

ipv6 address 2::2/64

ipv6 eigrp 10

clock rate 2000000

interface Vlan1

no ip address

shutdown

router eigrp 10

eigrp router-id 3.3.3.3

redistribute bgp 10 metric 1000 33 255 1 1500

network 10.10.10.4 0.0.0.3

router bgp 10

bgp log-neighbor-changes

no synchronization

neighbor 10.10.10.10 remote-as 20

network 10.10.10.4 mask 255.255.255.252

redistribute eigrp 10

ipv6 router eigrp 10

eigrp router-id 3.3.3.0

no shutdown

ip classless

ip flow-export version 9

line con 0

line aux 0

line vty 0 4

login

end

**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, E - EGP

i - IS-IS, 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

10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks

D 10.10.10.0/30 [90/2681856] via 10.10.10.5, 00:09:01, Serial0/1/1

C 10.10.10.4/30 is directly connected, Serial0/1/1

L 10.10.10.6/32 is directly connected, Serial0/1/1

C 10.10.10.8/30 is directly connected, Serial0/1/0

L 10.10.10.9/32 is directly connected, Serial0/1/0

B 10.10.10.12/30 [20/0] via 10.10.10.10, 00:00:00

B 10.10.10.16/30 [20/0] via 10.10.10.10, 00:00:00

B 10.10.10.20/30 [20/0] via 10.10.10.10, 00:00:00

**R3#sh ip eigrp interfaces**

IP-EIGRP interfaces for process 10

Xmit Queue Mean Pacing Time Multicast Pending

Interface Peers Un/Reliable SRTT Un/Reliable Flow Timer Routes

Se0/1/1 1 0/0 1236 0/10 0 0

**R3#sh ip eigrp neighbors**

IP-EIGRP neighbors for process 10

H Address Interface Hold Uptime SRTT RTO Q Seq

(sec) (ms) Cnt Num

0 10.10.10.5 Se0/1/1 12 00:09:10 40 1000 0 10

**R3#sh ip eigrp topology**

IP-EIGRP Topology Table for AS 10/ID(3.3.3.3)

Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,

r - Reply status

P 10.10.10.0/30, 1 successors, FD is 2681856

via 10.10.10.5 (2681856/2169856), Serial0/1/1

P 10.10.10.4/30, 1 successors, FD is 2169856

via Connected, Serial0/1/1

P 10.10.10.8/30, 1 successors, FD is 2644480

via Redistributed (2644480/0)

P 10.10.10.12/30, 1 successors, FD is 2644480

via Redistributed (2644480/0)

P 10.10.10.16/30, 1 successors, FD is 2644480

via Redistributed (2644480/0)

P 10.10.10.20/30, 1 successors, FD is 2644480

via Redistributed (2644480/0)

**R3#sh ip bgp neighbors**

BGP neighbor is 10.10.10.10, remote AS 20, external link

BGP version 4, remote router ID 10.10.10.13

BGP state = Established, up for 00:10:45

Last read 00:10:45, last write 00:10:45, hold time is 180, keepalive interval is 60 seconds

Neighbor capabilities:

Route refresh: advertised and received(new)

Address family IPv4 Unicast: advertised and received

Message statistics:

InQ depth is 0

OutQ depth is 0

Sent Rcvd

Opens: 1 1

Notifications: 0 0

Updates: 2 4

Keepalives: 11 11

Route Refresh: 0 0

Total: 14 16

Default minimum time between advertisements runs is 30 seconds

For address family: IPv4 Unicast

BGP table version 7, neighbor version 6/0

Output queue size : 0

Index 1, Offset 0, Mask 0x2

1 update-group member

Sent Rcvd

Prefix activity: ---- ----

Prefixes Current: 2 4 (Consumes 138 bytes)

Prefixes total: 2 4

Implicit Withdraw: 0 0

Explicit Withdraw: 0 0

Used as bestpath: n/a 1

Used as multipath: n/a 0

Outbound Inbound

Local Policy Denied Prefixes: -------- -------

Total: 0 0

Number of NLRIs in the update sent: max 3, min 1

Address tracking is enabled, the RIB does have a route to 10.10.10.10

Connections established 1; dropped 1

Last reset never

Transport(tcp) path-mtu-discovery is enabled

Connection state is ESTAB, I/O status: 1, unread input bytes: 0

Connection is ECN Disabled, Minimum incoming TTL 0, Outgoing TTL 1

Local host: 10.10.10.9, Local port: 179

Foreign host: 10.10.10.10, Foreign port: 1025

Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0 mis-ordered: 0 (0 bytes)

Event Timers (current time is 0xC69F4):

Timer Starts Wakeups Next

Retrans 0 0 0x0

TimeWait 0 0 0x0

AckHold 15 0 0x0

SendWnd 0 0 0x0

KeepAlive 11 0 0x0

GiveUp 0 0 0x0

PmtuAger 0 0 0x0

DeadWait 0 0 0x0

Linger 0 0 0x0

ProcessQ 0 0 0x0

iss: 2057115318 snduna: 2057115748 sndnxt: 2057115748 sndwnd: 15955

irs: 3480424370 rcvnxt: 3480424751 rcvwnd: 16004 delrcvwnd: 380

SRTT: 259 ms, RTTO: 579 ms, RTV: 320 ms, KRTT: 0 ms

minRTT: 16 ms, maxRTT: 300 ms, ACK hold: 200 ms

Status Flags: passive open, gen tcbs

Option Flags: nagle, path mtu capable

IP Precedence value : 6

Datagrams (max data segment is 1460 bytes):

Rcvd: 16 (out of order: 0), with data: 0, total data bytes: 0

Sent: 12 (retransmit: 0, fastretransmit: 0, partialack: 0, Second Congestion: 0), with data: 2, total data bytes: 48

Packets received in fast path: 0, fast processed: 0, slow path: 0

fast lock acquisition failures: 0, slow path: 0

**R3#sh ip bgp summary**

BGP router identifier 10.10.10.9, local AS number 10

BGP table version is 7, main routing table version 6

6 network entries using 792 bytes of memory

6 path entries using 312 bytes of memory

4/3 BGP path/bestpath attribute entries using 644 bytes of memory

3 BGP AS-PATH entries using 72 bytes of memory

0 BGP route-map cache entries using 0 bytes of memory

0 BGP filter-list cache entries using 0 bytes of memory

Bitfield cache entries: current 1 (at peak 1) using 32 bytes of memory

BGP using 1852 total bytes of memory

BGP activity 6/0 prefixes, 6/0 paths, scan interval 60 secs

Neighbor V AS MsgRcvd MsgSent TblVer InQ OutQ Up/Down State/PfxRcd

10.10.10.10 4 20 16 12 7 0 0 00:10:52 4

Router 4

**R4#sh run**

no service timestamps log datetime msec

no service timestamps debug datetime msec

no service password-encryption

hostname R4

ip cef

ipv6 unicast-routing

no ipv6 cef

spanning-tree mode pvst

interface GigabitEthernet0/0/0

no ip address

duplex auto

speed auto

shutdown

interface GigabitEthernet0/0/1

no ip address

duplex auto

speed auto

shutdown

interface Serial0/1/0

ip address 10.10.10.13 255.255.255.252

ipv6 address FE80::1 link-local

ipv6 address 4::1/64

interface Serial0/1/1

ip address 10.10.10.10 255.255.255.252

ipv6 address FE80::2 link-local

ipv6 address 3::2/64

clock rate 2000000

interface Vlan1

no ip address

shutdown

router bgp 20

bgp log-neighbor-changes

no synchronization

neighbor 10.10.10.9 remote-as 10

neighbor 10.10.10.14 remote-as 30

network 10.10.10.8 mask 255.255.255.252

network 10.10.10.12 mask 255.255.255.252

ip classless

ip flow-export version 9

line con 0

line aux 0

line vty 0 4

login

end

**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, E - EGP

i - IS-IS, 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

10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks

B 10.10.10.0/30 [20/2681856] via 10.10.10.9, 00:00:00

B 10.10.10.4/30 [20/0] via 10.10.10.9, 00:00:00

C 10.10.10.8/30 is directly connected, Serial0/1/1

L 10.10.10.10/32 is directly connected, Serial0/1/1

C 10.10.10.12/30 is directly connected, Serial0/1/0

L 10.10.10.13/32 is directly connected, Serial0/1/0

B 10.10.10.16/30 [20/0] via 10.10.10.14, 00:00:00

B 10.10.10.20/30 [20/128] via 10.10.10.14, 00:00:00

**R4#sh ip bgp neighbors**

BGP neighbor is 10.10.10.9, remote AS 10, external link

BGP version 4, remote router ID 10.10.10.9

BGP state = Established, up for 00:12:41

Last read 00:12:41, last write 00:12:41, hold time is 180, keepalive interval is 60 seconds

Neighbor capabilities:

Route refresh: advertised and received(new)

Address family IPv4 Unicast: advertised and received

Message statistics:

InQ depth is 0

OutQ depth is 0

Sent Rcvd

Opens: 1 1

Notifications: 0 0

Updates: 4 2

Keepalives: 13 13

Route Refresh: 0 0

Total: 18 16

Default minimum time between advertisements runs is 30 seconds

For address family: IPv4 Unicast

BGP table version 7, neighbor version 6/0

Output queue size : 0

Index 1, Offset 0, Mask 0x2

1 update-group member

Sent Rcvd

Prefix activity: ---- ----

Prefixes Current: 4 2 (Consumes 138 bytes)

Prefixes total: 4 2

Implicit Withdraw: 0 0

Explicit Withdraw: 0 0

Used as bestpath: n/a 1

Used as multipath: n/a 0

Outbound Inbound

Local Policy Denied Prefixes: -------- -------

Total: 0 0

Number of NLRIs in the update sent: max 3, min 1

Address tracking is enabled, the RIB does have a route to 10.10.10.9

Connections established 1; dropped 0

Last reset never

Transport(tcp) path-mtu-discovery is enabled

Connection state is ESTAB, I/O status: 1, unread input bytes: 0

Connection is ECN Disabled, Minimum incoming TTL 0, Outgoing TTL 1

Local host: 10.10.10.10, Local port: 1025

Foreign host: 10.10.10.9, Foreign port: 179

Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0 mis-ordered: 0 (0 bytes)

Event Timers (current time is 0xC69F4):

Timer Starts Wakeups Next

Retrans 0 0 0x0

TimeWait 0 0 0x0

AckHold 15 0 0x0

SendWnd 0 0 0x0

KeepAlive 13 0 0x0

GiveUp 0 0 0x0

PmtuAger 0 0 0x0

DeadWait 0 0 0x0

Linger 0 0 0x0

ProcessQ 0 0 0x0

iss: 2057115318 snduna: 2057115748 sndnxt: 2057115748 sndwnd: 15955

irs: 3480424370 rcvnxt: 3480424751 rcvwnd: 16004 delrcvwnd: 380

SRTT: 259 ms, RTTO: 579 ms, RTV: 320 ms, KRTT: 0 ms

minRTT: 16 ms, maxRTT: 300 ms, ACK hold: 200 ms

Status Flags: passive open, gen tcbs

Option Flags: nagle, path mtu capable

IP Precedence value : 6

Datagrams (max data segment is 1460 bytes):

Rcvd: 16 (out of order: 0), with data: 0, total data bytes: 0

Sent: 14 (retransmit: 0, fastretransmit: 0, partialack: 0, Second Congestion: 0), with data: 4, total data bytes: 96

Packets received in fast path: 0, fast processed: 0, slow path: 0

fast lock acquisition failures: 0, slow path: 0

BGP neighbor is 10.10.10.14, remote AS 30, external link

BGP version 4, remote router ID 10.10.10.17

BGP state = Established, up for 00:12:41

Last read 00:12:41, last write 00:12:41, hold time is 180, keepalive interval is 60 seconds

Neighbor capabilities:

Route refresh: advertised and received(new)

Address family IPv4 Unicast: advertised and received

Message statistics:

InQ depth is 0

OutQ depth is 0

Sent Rcvd

Opens: 1 1

Notifications: 0 0

Updates: 4 2

Keepalives: 13 13

Route Refresh: 0 0

Total: 18 16

Default minimum time between advertisements runs is 30 seconds

For address family: IPv4 Unicast

BGP table version 7, neighbor version 6/0

Output queue size : 0

Index 1, Offset 0, Mask 0x2

1 update-group member

Sent Rcvd

Prefix activity: ---- ----

Prefixes Current: 4 2 (Consumes 138 bytes)

Prefixes total: 4 2

Implicit Withdraw: 0 0

Explicit Withdraw: 0 0

Used as bestpath: n/a 1

Used as multipath: n/a 0

Outbound Inbound

Local Policy Denied Prefixes: -------- -------

Total: 0 0

Number of NLRIs in the update sent: max 3, min 1

Address tracking is enabled, the RIB does have a route to 10.10.10.14

Connections established 1; dropped 0

Last reset never

Transport(tcp) path-mtu-discovery is enabled

Connection state is ESTAB, I/O status: 1, unread input bytes: 0

Connection is ECN Disabled, Minimum incoming TTL 0, Outgoing TTL 1

Local host: 10.10.10.13, Local port: 179

Foreign host: 10.10.10.14, Foreign port: 1025

Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0 mis-ordered: 0 (0 bytes)

Event Timers (current time is 0xC69F4):

Timer Starts Wakeups Next

Retrans 0 0 0x0

TimeWait 0 0 0x0

AckHold 15 0 0x0

SendWnd 0 0 0x0

KeepAlive 13 0 0x0

GiveUp 0 0 0x0

PmtuAger 0 0 0x0

DeadWait 0 0 0x0

Linger 0 0 0x0

ProcessQ 0 0 0x0

iss: 2057115318 snduna: 2057115748 sndnxt: 2057115748 sndwnd: 15955

irs: 3480424370 rcvnxt: 3480424751 rcvwnd: 16004 delrcvwnd: 380

SRTT: 259 ms, RTTO: 579 ms, RTV: 320 ms, KRTT: 0 ms

minRTT: 16 ms, maxRTT: 300 ms, ACK hold: 200 ms

Status Flags: passive open, gen tcbs

Option Flags: nagle, path mtu capable

IP Precedence value : 6

Datagrams (max data segment is 1460 bytes):

Rcvd: 16 (out of order: 0), with data: 0, total data bytes: 0

Sent: 14 (retransmit: 0, fastretransmit: 0, partialack: 0, Second Congestion: 0), with data: 4, total data bytes: 96

Packets received in fast path: 0, fast processed: 0, slow path: 0

fast lock acquisition failures: 0, slow path: 0

**R4#sh ip bgp summary**

BGP router identifier 10.10.10.13, local AS number 20

BGP table version is 7, main routing table version 6

6 network entries using 792 bytes of memory

6 path entries using 312 bytes of memory

4/4 BGP path/bestpath attribute entries using 736 bytes of memory

3 BGP AS-PATH entries using 72 bytes of memory

0 BGP route-map cache entries using 0 bytes of memory

0 BGP filter-list cache entries using 0 bytes of memory

Bitfield cache entries: current 1 (at peak 1) using 32 bytes of memory

BGP using 1944 total bytes of memory

BGP activity 6/0 prefixes, 6/0 paths, scan interval 60 secs

Neighbor V AS MsgRcvd MsgSent TblVer InQ OutQ Up/Down State/PfxRcd

10.10.10.9 4 10 16 14 7 0 0 00:12:48 4

10.10.10.14 4 30 16 14 7 0 0 00:12:49 4

Router 5

**R5#sh run**

no service timestamps log datetime msec

no service timestamps debug datetime msec

no service password-encryption

hostname R5

ip cef

ipv6 unicast-routing

no ipv6 cef

spanning-tree mode pvst

interface GigabitEthernet0/0/0

no ip address

duplex auto

speed auto

shutdown

interface GigabitEthernet0/0/1

no ip address

duplex auto

speed auto

shutdown

interface Serial0/1/0

ip address 10.10.10.17 255.255.255.252

ipv6 address FE80::1 link-local

ipv6 address 5::1/64

ipv6 ospf 10 area 0

interface Serial0/1/1

ip address 10.10.10.14 255.255.255.252

ipv6 address FE80::2 link-local

ipv6 address 4::2/64

clock rate 2000000

interface Vlan1

no ip address

shutdown

router ospf 10

router-id 5.5.5.5

log-adjacency-changes

redistribute bgp 30 subnets

network 10.10.10.16 0.0.0.3 area 0

router bgp 30

bgp log-neighbor-changes

no synchronization

neighbor 10.10.10.13 remote-as 20

network 10.10.10.16 mask 255.255.255.252

redistribute ospf 10

ipv6 router ospf 10

log-adjacency-changes

ip classless

ip flow-export version 9

line con 0

line aux 0

line vty 0 4

login

end

**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, E - EGP

i - IS-IS, 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

10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks

B 10.10.10.0/30 [20/0] via 10.10.10.13, 00:00:00

B 10.10.10.4/30 [20/0] via 10.10.10.13, 00:00:00

B 10.10.10.8/30 [20/0] via 10.10.10.13, 00:00:00

C 10.10.10.12/30 is directly connected, Serial0/1/1

L 10.10.10.14/32 is directly connected, Serial0/1/1

C 10.10.10.16/30 is directly connected, Serial0/1/0

L 10.10.10.17/32 is directly connected, Serial0/1/0

O 10.10.10.20/30 [110/128] via 10.10.10.18, 00:14:33, Serial0/1/0

**R5#sh ip ospf database**

OSPF Router with ID (5.5.5.5) (Process ID 10)

Router Link States (Area 0)

Link ID ADV Router Age Seq# Checksum Link count

5.5.5.5 5.5.5.5 997 0x80000002 0x005fc9 2

6.6.6.6 6.6.6.6 997 0x80000005 0x00bf46 4

7.7.7.7 7.7.7.7 997 0x80000002 0x005fb2 2

Type-5 AS External Link States

Link ID ADV Router Age Seq# Checksum Tag

10.10.10.12 5.5.5.5 1001 0x80000001 0x003f46 0

10.10.10.8 5.5.5.5 1000 0x80000001 0x006722 0

10.10.10.0 5.5.5.5 998 0x80000001 0x00b7d9 0

10.10.10.4 5.5.5.5 998 0x80000001 0x008ffd 0

**R5#sh ip ospf interface**

Serial0/1/0 is up, line protocol is up

Internet address is 10.10.10.17/30, Area 0

Process ID 10, Router ID 5.5.5.5, Network Type POINT-TO-POINT, Cost: 64

Transmit Delay is 1 sec, State POINT-TO-POINT,

Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5

Hello due in 00:00:01

Index 1/1, flood queue length 0

Next 0x0(0)/0x0(0)

Last flood scan length is 1, maximum is 1

Last flood scan time is 0 msec, maximum is 0 msec

Neighbor Count is 1 , Adjacent neighbor count is 1

Adjacent with neighbor 6.6.6.6

Suppress hello for 0 neighbor(s)

**R5#sh ip ospf neighbor**

Neighbor ID Pri State Dead Time Address Interface

6.6.6.6 0 FULL/ - 00:00:35 10.10.10.18 Serial0/1/0

**R5#sh ip bgp neighbors**

BGP neighbor is 10.10.10.13, remote AS 20, external link

BGP version 4, remote router ID 10.10.10.13

BGP state = Established, up for 00:18:42

Last read 00:18:42, last write 00:18:42, hold time is 180, keepalive interval is 60 seconds

Neighbor capabilities:

Route refresh: advertised and received(new)

Address family IPv4 Unicast: advertised and received

Message statistics:

InQ depth is 0

OutQ depth is 0

Sent Rcvd

Opens: 1 1

Notifications: 0 0

Updates: 2 4

Keepalives: 19 19

Route Refresh: 0 0

Total: 22 24

Default minimum time between advertisements runs is 30 seconds

For address family: IPv4 Unicast

BGP table version 9, neighbor version 6/0

Output queue size : 0

Index 1, Offset 0, Mask 0x2

1 update-group member

Sent Rcvd

Prefix activity: ---- ----

Prefixes Current: 2 4 (Consumes 138 bytes)

Prefixes total: 2 4

Implicit Withdraw: 0 0

Explicit Withdraw: 0 0

Used as bestpath: n/a 1

Used as multipath: n/a 0

Outbound Inbound

Local Policy Denied Prefixes: -------- -------

Total: 0 0

Number of NLRIs in the update sent: max 3, min 1

Address tracking is enabled, the RIB does have a route to 10.10.10.13

Connections established 1; dropped 0

Last reset never

Transport(tcp) path-mtu-discovery is enabled

Connection state is ESTAB, I/O status: 1, unread input bytes: 0

Connection is ECN Disabled, Minimum incoming TTL 0, Outgoing TTL 1

Local host: 10.10.10.14, Local port: 1025

Foreign host: 10.10.10.13, Foreign port: 179

Connection tableid (VRF): 0

Enqueued packets for retransmit: 0, input: 0 mis-ordered: 0 (0 bytes)

Event Timers (current time is 0xC69F4):

Timer Starts Wakeups Next

Retrans 0 0 0x0

TimeWait 0 0 0x0

AckHold 23 0 0x0

SendWnd 0 0 0x0

KeepAlive 19 0 0x0

GiveUp 0 0 0x0

PmtuAger 0 0 0x0

DeadWait 0 0 0x0

Linger 0 0 0x0

ProcessQ 0 0 0x0

iss: 2057115318 snduna: 2057115748 sndnxt: 2057115748 sndwnd: 15955

irs: 3480424370 rcvnxt: 3480424751 rcvwnd: 16004 delrcvwnd: 380

SRTT: 259 ms, RTTO: 579 ms, RTV: 320 ms, KRTT: 0 ms

minRTT: 16 ms, maxRTT: 300 ms, ACK hold: 200 ms

Status Flags: passive open, gen tcbs

Option Flags: nagle, path mtu capable

IP Precedence value : 6

Datagrams (max data segment is 1460 bytes):

Rcvd: 24 (out of order: 0), with data: 0, total data bytes: 0

Sent: 20 (retransmit: 0, fastretransmit: 0, partialack: 0, Second Congestion: 0), with data: 2, total data bytes: 48

Packets received in fast path: 0, fast processed: 0, slow path: 0

fast lock acquisition failures: 0, slow path: 0

**R5#sh ip bgp summary**

BGP router identifier 10.10.10.17, local AS number 30

BGP table version is 9, main routing table version 6

6 network entries using 792 bytes of memory

6 path entries using 312 bytes of memory

4/3 BGP path/bestpath attribute entries using 644 bytes of memory

3 BGP AS-PATH entries using 72 bytes of memory

0 BGP route-map cache entries using 0 bytes of memory

0 BGP filter-list cache entries using 0 bytes of memory

Bitfield cache entries: current 1 (at peak 1) using 32 bytes of memory

BGP using 1852 total bytes of memory

BGP activity 6/0 prefixes, 6/0 paths, scan interval 60 secs

Neighbor V AS MsgRcvd MsgSent TblVer InQ OutQ Up/Down State/PfxRcd

10.10.10.13 4 20 24 20 9 0 0 00:18:47 4

Router 6

**R6#sh run**

no service timestamps log datetime msec

no service timestamps debug datetime msec

no service password-encryption

hostname R6

ip cef

ipv6 unicast-routing

no ipv6 cef

spanning-tree mode pvst

interface GigabitEthernet0/0/0

no ip address

duplex auto

speed auto

shutdown

interface GigabitEthernet0/0/1

no ip address

duplex auto

speed auto

shutdown

interface Serial0/1/0

ip address 10.10.10.21 255.255.255.252

ipv6 address FE80::1 link-local

ipv6 address 6::1/64

ipv6 ospf 10 area 0

interface Serial0/1/1

ip address 10.10.10.18 255.255.255.252

ipv6 address FE80::2 link-local

ipv6 address 5::2/64

ipv6 ospf 10 area 0

clock rate 2000000

interface Vlan1

no ip address

shutdown

router ospf 10

router-id 6.6.6.6

log-adjacency-changes

network 10.10.10.16 0.0.0.3 area 0

network 10.10.10.20 0.0.0.3 area 0

ipv6 router ospf 10

log-adjacency-changes

ip classless

ip flow-export version 9

line con 0

line aux 0

line vty 0 4

login

end

**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, E - EGP

i - IS-IS, 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

10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks

O E2 10.10.10.0/30 [110/20] via 10.10.10.17, 00:19:45, Serial0/1/1

O E2 10.10.10.4/30 [110/20] via 10.10.10.17, 00:19:45, Serial0/1/1

O E2 10.10.10.8/30 [110/20] via 10.10.10.17, 00:19:45, Serial0/1/1

O E2 10.10.10.12/30 [110/20] via 10.10.10.17, 00:19:45, Serial0/1/1

C 10.10.10.16/30 is directly connected, Serial0/1/1

L 10.10.10.18/32 is directly connected, Serial0/1/1

C 10.10.10.20/30 is directly connected, Serial0/1/0

L 10.10.10.21/32 is directly connected, Serial0/1/0

**R6#sh ip ospf database**

OSPF Router with ID (6.6.6.6) (Process ID 10)

Router Link States (Area 0)

Link ID ADV Router Age Seq# Checksum Link count

6.6.6.6 6.6.6.6 1209 0x80000005 0x00bf46 4

7.7.7.7 7.7.7.7 1209 0x80000002 0x005fb2 2

5.5.5.5 5.5.5.5 1209 0x80000002 0x005fc9 2

Type-5 AS External Link States

Link ID ADV Router Age Seq# Checksum Tag

10.10.10.12 5.5.5.5 1213 0x80000001 0x003f46 0

10.10.10.8 5.5.5.5 1212 0x80000001 0x006722 0

10.10.10.0 5.5.5.5 1210 0x80000001 0x00b7d9 0

10.10.10.4 5.5.5.5 1210 0x80000001 0x008ffd 0

**R6#sh ip ospf interface**

Serial0/1/0 is up, line protocol is up

Internet address is 10.10.10.21/30, Area 0

Process ID 10, Router ID 6.6.6.6, Network Type POINT-TO-POINT, Cost: 64

Transmit Delay is 1 sec, State POINT-TO-POINT,

Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5

Hello due in 00:00:02

Index 1/1, flood queue length 0

Next 0x0(0)/0x0(0)

Last flood scan length is 1, maximum is 1

Last flood scan time is 0 msec, maximum is 0 msec

Neighbor Count is 1 , Adjacent neighbor count is 1

Adjacent with neighbor 7.7.7.7

Suppress hello for 0 neighbor(s)

Serial0/1/1 is up, line protocol is up

Internet address is 10.10.10.18/30, Area 0

Process ID 10, Router ID 6.6.6.6, Network Type POINT-TO-POINT, Cost: 64

Transmit Delay is 1 sec, State POINT-TO-POINT,

Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5

Hello due in 00:00:00

Index 2/2, flood queue length 0

Next 0x0(0)/0x0(0)

Last flood scan length is 1, maximum is 1

Last flood scan time is 0 msec, maximum is 0 msec

Neighbor Count is 1 , Adjacent neighbor count is 1

Adjacent with neighbor 5.5.5.5

Suppress hello for 0 neighbor(s)

**R6#sh ip ospf neighbor**

Neighbor ID Pri State Dead Time Address Interface

5.5.5.5 0 FULL/ - 00:00:36 10.10.10.17 Serial0/1/1

7.7.7.7 0 FULL/ - 00:00:33 10.10.10.22 Serial0/1/0

Router 7

**R7#sh run**

no service timestamps log datetime msec

no service timestamps debug datetime msec

no service password-encryption

hostname R7

ip cef

ipv6 unicast-routing

no ipv6 cef

spanning-tree mode pvst

interface GigabitEthernet0/0/0

no ip address

duplex auto

speed auto

shutdown

interface GigabitEthernet0/0/1

no ip address

duplex auto

speed auto

shutdown

interface Serial0/1/0

no ip address

clock rate 2000000

shutdown

interface Serial0/1/1

ip address 10.10.10.22 255.255.255.252

ipv6 address FE80::2 link-local

ipv6 address 6::2/64

ipv6 ospf 10 area 0

clock rate 2000000

interface Vlan1

no ip address

shutdown

router ospf 10

router-id 7.7.7.7

log-adjacency-changes

network 10.10.10.20 0.0.0.3 area 0

ipv6 router ospf 10

log-adjacency-changes

ip classless

ip flow-export version 9

line con 0

line aux 0

line vty 0 4

login

end

**R7#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, E - EGP

i - IS-IS, 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

10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks

O E2 10.10.10.0/30 [110/20] via 10.10.10.21, 00:21:27, Serial0/1/1

O E2 10.10.10.4/30 [110/20] via 10.10.10.21, 00:21:27, Serial0/1/1

O E2 10.10.10.8/30 [110/20] via 10.10.10.21, 00:21:27, Serial0/1/1

O E2 10.10.10.12/30 [110/20] via 10.10.10.21, 00:21:27, Serial0/1/1

O 10.10.10.16/30 [110/128] via 10.10.10.21, 00:21:27, Serial0/1/1

C 10.10.10.20/30 is directly connected, Serial0/1/1

L 10.10.10.22/32 is directly connected, Serial0/1/1

**R7#sh ip ospf database**

OSPF Router with ID (7.7.7.7) (Process ID 10)

Router Link States (Area 0)

Link ID ADV Router Age Seq# Checksum Link count

7.7.7.7 7.7.7.7 1318 0x80000002 0x005fb2 2

6.6.6.6 6.6.6.6 1318 0x80000005 0x00bf46 4

5.5.5.5 5.5.5.5 1318 0x80000002 0x005fc9 2

Type-5 AS External Link States

Link ID ADV Router Age Seq# Checksum Tag

10.10.10.12 5.5.5.5 1322 0x80000001 0x003f46 0

10.10.10.8 5.5.5.5 1321 0x80000001 0x006722 0

10.10.10.0 5.5.5.5 1319 0x80000001 0x00b7d9 0

10.10.10.4 5.5.5.5 1319 0x80000001 0x008ffd 0

**R7#sh ip ospf interface**

Serial0/1/1 is up, line protocol is up

Internet address is 10.10.10.22/30, Area 0

Process ID 10, Router ID 7.7.7.7, Network Type POINT-TO-POINT, Cost: 64

Transmit Delay is 1 sec, State POINT-TO-POINT,

Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5

Hello due in 00:00:01

Index 1/1, flood queue length 0

Next 0x0(0)/0x0(0)

Last flood scan length is 1, maximum is 1

Last flood scan time is 0 msec, maximum is 0 msec

Neighbor Count is 1 , Adjacent neighbor count is 1

Adjacent with neighbor 6.6.6.6

Suppress hello for 0 neighbor(s)

**R7#sh ip ospf neighbor**

Neighbor ID Pri State Dead Time Address Interface

6.6.6.6 0 FULL/ - 00:00:31 10.10.10.21 Serial0/1/1

Problems

As BGP was the primary focus, there was the classic problem of deciphering its functionality and how to implement it. I left BGP to configure last since my experience with both OSPF and EIGRP was decent enough to where I wouldn’t have a hard time dealing with them. After I ran through the IGPs and established connectivity within both networks without any noteworthy problems, my last step was to bridge them with a BGP network. So how do you configure BGP?

The first useful article I found, *Configure eBGP in Cisco IOS Router by Arranda Saputra*, gave valuable insight on the main commands needed to set up BGP along with some example configurations of eBGP. From this article, I recognized my network required three different autonomous systems running on each of my BGP routers. Each autonomous system needed a unique ASN because the network was connected through eBGP.

As I may have mentioned before, the difference between BGP and IGPs is that BGP requires **neighbor** statements to form adjacencies. These neighbor statements are often accompanied by **network** statements that tell the BGP network to add a specific subnet to the routing table. Afterwards, BGP exchanges these new routes through the adjacent links to build a complete routing table.

For a BGP adjacency to be established, each router must have *routes to the IP of the desired neighbor* and the *ASN of that neighbor*. Having proper routes to each neighbor’s IP is critical to forming adjacencies and is already guaranteed for directly connected routers, but this also means two BGP neighbors could lie anywhere. For example, routers *A* and *C* are connected via router *B*. Theoretically, you could establish a BGP neighbor relationship between routers *A* and *C* if they both have routes to each other’s IPs.

Thankfully, after assigning the correct network and neighbor statements, my BGP network was fully functional. Once I redistributed all the routes, every router gained a full table.

Conclusion

It always confused me how the vast internet could possibly run. If you asked me before this lab, I would have said something along the lines of “the internet is a mesh of different routing protocols like EIGRP, OSPF, RIP and BGP”. I didn’t have the greatest concept of interior vs exterior routing protocols, so I sort of lumped them all together.

While it isn’t necessarily wrong, a more accurate answer would be that BGP is the main contributor to the internet. Like a metropolitan city, BGP is the infrastructure that supports each district, building and street of the internet. Then, within these smaller areas, you might find OSPF or EIGRP.