Routing Protocols

Additional documentation for GNS3 project available at
https://github.com/adriano-pinaffo/routing-protocols

June, 2018

Versioning

Version	Change	Date
v.01	Original	May, 2018
v.02	Added static EIGRP neighbor	June, 2018

Definitions

Routing protocols: protocols for routers to exchange information.
Routed protocols: protocols that can be routed, like IP.

Types

IGP: Interior Gateway Protocols
RIP, RIPv2, EIGRP, OSPF, ISIS

EGP: Exterior Gateway Protocols
BGP

Distance Vector: routers communicate with ***neighbor*** routers advertising networks as measures of distance and vector.
RIP, RIPv2, EIGRP
- Simple, flat design, minimum knowledge, convergence time is not crucial
- Sends full routing table periodically

Link State: Routers communicate with ***all other*** routers exchanging link-state information to build a topology. Improvement from Distance Vector
OSPF, ISIS
- Large, hierarchical, knowledge is important, convergence is crucial
- Sends triggered updates when change occurs with changes part only

Distance Vector issues (with RIPv1)

NW1 ——- R1 ——- R2 ——- R3 ——- NW3
All routing table is sent to neighbor router as routing update. When there is convergence all routers will have routes to all networks. Now R2 will have route to NW1 through R1 with 1 hop. Thus, if connection from R1 to NW1 is lost R1 will mark it as unreachable and should update R2 so it updates R3. Problem is that route updates, by default, take 30 seconds and if R2 update is sent to R1 before it gets informed NW1 is out, R1 will update its routing table, which will indicate that to reach NW1 it's 2 hops through R2. When R1 finally sends the update, R2 will update its routing table saying that to reach NW1 it's 3 hops through R1, and that will go on and on to infinity. Packets would get into loop until TTL is reached. To avoid it, max hop of 15 was created, and if hop gets to 16, route is removed.

Split Horizon rule

It solves the issue above. A route is never advertised back to original router, that is where the route came from, so R2 should never advertise NW1 to R1 and the above problem would never happen.

Split Horizon problem

```
NW1 ——- R1 ——- R2 ——- R3 ——- NW3
                \       /
                   R4
```

In more complex topologies, there is more than 1 path to reach a network. Here R2 has two routes to reach NW1, 1 hop through R1 and 2 hops through R4. The route through R1 wins and goes to the routing table. When R1 loses connectivity to NW1 it will advertise to R2, which should remove that entry from its routing table but as it has a second route it starts using that one, and if it updates R1 before R4 updates R2, R1 will have that route back to its routing table with 3 hops through R2. It will also update R4 with 4 hops to reach NW1 and loop will happen between R1, R2 and R3.

Route Poisoning and Poison Reverse

It solves the issue above. When network is down, router sends to its neighbor routers a Poison message informing the network is down. Receiving router does 3 things: sends back ACK (Poison reverse), updates routing table to 16 hops to reach the network, and sends Poison messages to its neighbor routers of their own. In time, all the network converges and all routers will know the network is out. But still, in some cases in even more complex networks, that route may slip in. So, if R1 loses connectivity to NW1, it sends a Poison message to R2 and R4. But if there´s a delay in the network it´s possible that R4 sends an update to R2 before R4 receives the Poison message from R1 and after R2 received the Poison message from R1, thus making the bad route back to the topology

Holddown Timers

It solves the issue above. After a Poison message is received, router places the route in a Holddown Timer of 180 seconds. No route to the same network with higher number of hops (as before the Poison message) is added to the routing table during this 180 seconds. If a route with a higher number of hops is received from another router, it will be kept in a buffer during this 180 seconds. The router will commit it to the routing table after that Holddown Timer expires because if the network is really down, another Poison message will arrive and the route to this bad network will be removed from buffer for good. So, if R1 loses connectivity to NW1, it sends a Poison message to R2 and R4. R2 will receive the Poison message and place NW1 route in a Holddown Timer of 180 seconds. Now, even if R4 sends an update to R2 with a route to NW1, R2 will keep that route in the buffer. Shortly the Poison message from R1 is received by R4, which will send its Poison message to R2, which will clean the NW1 route from the buffer.

Link State protocols

```
          5
    R2 ----- NW2
 5 /    \ 15   30        5
R1       R4 ----- R5 ----- NW5
 5 \    / 15
```

R3

They work with 3 tables (EIGRP):

- Neighbor table: has information of the neighbor routers. Important to know where the updates come from.
- Topology table: has path to all possible networks participating in the topology
- Routing table: created from Topology table

For R1:

Neighbor table

Neighbor	Interface
R2	S0/0/0
R3	S0/0/1

Topology table

Destination	Cost	Interface
NW2	10	S0/0/0
NW5	55	S0/0/0
NW2	40	S0/0/1
NW5	55	S0/0/1

Routing table

Destination	Cost	Interface
NW2	10	S0/0/0
NW5	55	S0/0/0
NW5	55	S0/0/1

:: NW5 has the same cost through 2 different paths, so both routes are kept for load-balancing.

After Routing table is crafted, it is sent to neighbors and they will decide what is the best path.

Shortest Path First (SPF) Tree

This is the algorithm that chooses the best path for the Routing table

```
            R1
           /  \
        R2     R3
       /         \
    NW2           R4
                    \
                     R2
                       \
                        NW2
```

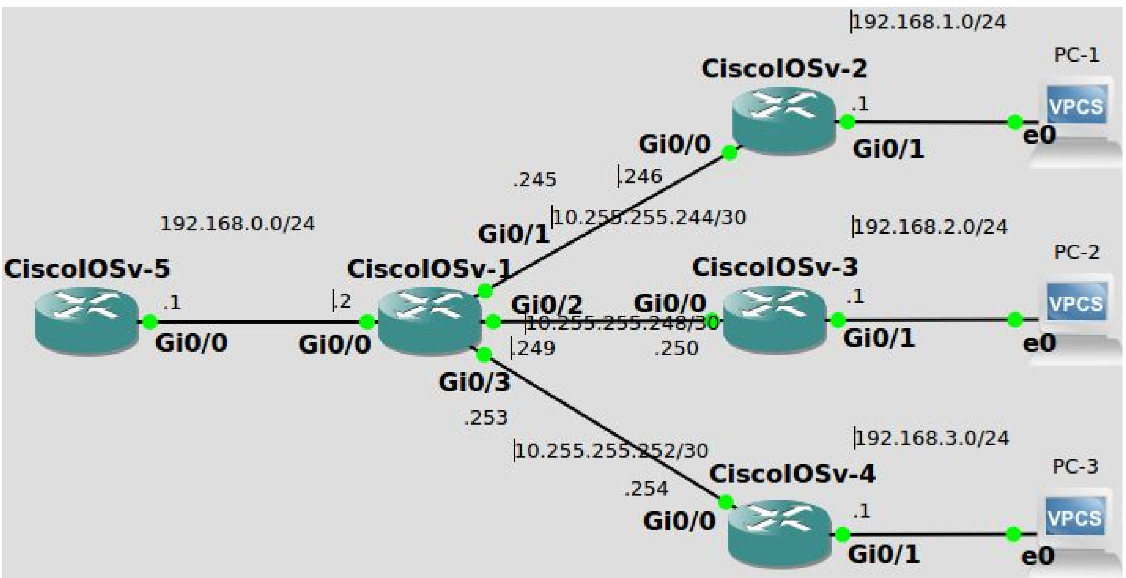
:: For NW2 it will choose the path from the left because it's the shortest of the 2.

RIP (Routing Information Protocol)

Details:

- Distance Vector Protocol
- Periodic Updates
- Loops in complex topologies
- Hop count is metric
- Maximum Hop Count is 15
- Administrative Distance is 120 (used when comparing more than one routing protocol serving the same destination)

RIPv1	RIPv2
Classful	Classless
No VLSM	VLSM
No subnet with updates	Subnet with updates
Updates through broadcast	Updates through Multicast (224.0.0.9)
No authentication	Supports authentication
No manual summarization	Manual summarization



Configuration

router rip

! enables rip

version 2

! enables RIPv2

no auto-summary

! makes it classless

passive-interface gigabitethernet 0/1

! doesn't advertise in the gigabitethernet 0/1, in case it's Intranet.

network 192.168.0.0

! enales rip to advertise 192.168.0.0 to neighbors (with the mask configured in all the interfaces)

In order to not advertise interconnections:

conf t

access-list 10 deny 10.255.255.252 /30

access-list 10 deny 10.255.255.248 /30

access-list 10 deny 10.255.255.244 /30

access-list 10 permit any

router rip

distribute-list 10 out GigabitEthernet0/0

! this will not advertise the 10.X.X.X networks out GigabitEthernet0/0 interface, but those 10.X.X.X networks must be participating in the rip scheme.
! Be aware that packets out these 10.X.X.X interfaces will not have a return path, so use the other interface as source

show ip protocols

```
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
        GigabitEthernet0/0 filtered by 10 (per-user), default is not set
        GigabitEthernet0/1 filtered by 10 (per-user), default is not set
        GigabitEthernet0/2 filtered by 10 (per-user), default is not set
        GigabitEthernet0/3 filtered by 10 (per-user), default is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 26 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
        Interface           Send  Recv  Triggered RIP  Key-chain
        GigabitEthernet0/0  2     2
        GigabitEthernet0/1  2     2
        GigabitEthernet0/2  2     2
        GigabitEthernet0/3  2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
        10.0.0.0
        192.168.0.0
  Routing Information Sources:
        Gateway          Distance  Last Update
        10.255.255.250   120       00:00:08
        10.255.255.254   120       00:00:25
        10.255.255.246   120       00:00:09
  Distance: (default is 120)
```

! It shows filter is applied by 10 (distribute-list 10)
! Routing for Networks: local networks participating in the rip scheme

show 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
        a - application route
        + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

        192.168.0.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.0.0/24 is directly connected, GigabitEthernet0/0
L       192.168.0.1/32 is directly connected, GigabitEthernet0/0
R       192.168.1.0/24 [120/2] via 192.168.0.2, 00:00:21, GigabitEthernet0/0
R       192.168.2.0/24 [120/2] via 192.168.0.2, 00:00:21, GigabitEthernet0/0
R       192.168.3.0/24 [120/2] via 192.168.0.2, 00:00:11, GigabitEthernet0/0
```

! R 192.168.1.0/24 [120/2] means that network 192.168.1.0/24 was learned through RIP protocol, which has an administrative distance of 120 and 2 ho counts.

EIGRP (Enhanced Interior Gateway Routing Protocol)

- Hybrid Routing Protocol, it's distance vector but can only have a full overview of the network, like link state protocols. That's why it's loop free.
- It has fast convergence
- Fully classless
- EIGRP updates contain five metrics: minimum bandwidth, delay, load, reliability, and maximum transmission unit (MTU).
- To compute best path, by default, only bandwidth and delay are used, instead of hop count like RIP
- Load balancing across equal paths
- Backup Route of the main route
- Administrative distance is 90
- Hello packets are sent by neighbors
- Autonomous System Numbers have to match between neighbors
- Keeps 3 tables: neighbor table, topology table, and routing table, as explained in Link State protocols session.

```
             R1 ----- 200.200.200.0/24
            /    \
  S0/0/0   /       \
    ----- R2 ------- R3 -----
  Fa0/0
```

For R2:

Neighbor table

Neighbor	Interface
R1	S0/0/0
R3	S0/0/1

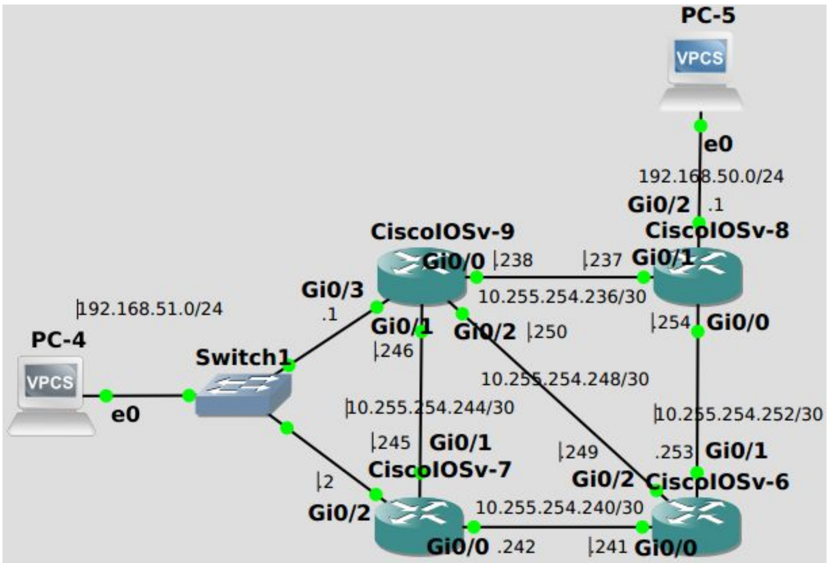
Topology table

Network	Neighbor	FD	AD
200.200.200.0/24	R1	3000	2000 S
200.200.200.0/24	R3	3500	2500 FS

:: AD is Advertised Distance, the cost for R1 to get to the network.
:: FD is Feasible Distance, the cost for me (R2) to get to the network (the real full cost).
:: S is the Successor, the best path, which is the one with the lowest FD.
:: FS is the Feasible Successor, the backup route to the network. This only happens if the AD of the second route is less than the FD of the successor, as 2500 is less than 3000 it makes as FS.

Routing table

Network	Neighbor	FD	Interface
200.200.200.0/24	R1	3000	S0/0/0



Configuation

For CiscoIOSv-9:

router eigrp 100

! Sets up EIGR with autonomous system 100 (all devices must be in the same autonomous system)

no auto-summary

! Even though EIGRP is classless, auto-summary must be disabled

network 10.0.0.0 0.255.255.255

network 192.168.0.0 0.0.255.255

! Sets up networks to advertise and interfaces to participate in the EIGRP scheme

To set a default route

ip route 0.0.0.0 0.0.0.0 10.255.254.233

redistribute static metric 100000 1000 255 1 1500

For CiscoIOSv-8:

passive-interface gigabitethernet 0/2

sh ip protocols

```
Routing Protocol is "eigrp 100"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  EIGRP-IPv4 Protocol for AS(100)
        Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
        Soft SIA disabled
        NSF-aware route hold timer is 240
        Router-ID: 192.168.51.1
        Topology : 0 (base)
        Active Timer: 3 min
        Distance: internal 90 external 170
        Maximum path: 4
        Maximum hopcount 100
        Maximum metric variance 1
```

Automatic Summarization: disabled
Maximum path: 4
Routing for Networks:
10.0.0.0
192.168.0.0/16
Routing Information Sources:

Gateway	Distance	Last Update
192.168.51.2	90	00:08:35
10.255.254.237	90	00:08:35
10.255.254.249	90	00:08:35
10.255.254.245	90	00:08:38

Distance: internal 90 external 170
! 10.X.X.X networks are intercos between the routers and are being advertised because distribute command was not used
! Last Update is from 8 minutes ago because EIGRP only triggers update when there is a change in the topology

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
a - application route
+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks
C 10.255.254.236/30 is directly connected, GigabitEthernet0/0
L 10.255.254.238/32 is directly connected, GigabitEthernet0/0
D 10.255.254.240/30
[90/3072] via 192.168.51.2, 00:11:14, GigabitEthernet0/3
[90/3072] via 10.255.254.249, 00:11:14, GigabitEthernet0/2
[90/3072] via 10.255.254.245, 00:11:14, GigabitEthernet0/1
C 10.255.254.244/30 is directly connected, GigabitEthernet0/1
L 10.255.254.246/32 is directly connected, GigabitEthernet0/1
C 10.255.254.248/30 is directly connected, GigabitEthernet0/2
L 10.255.254.250/32 is directly connected, GigabitEthernet0/2
D 10.255.254.252/30
[90/3072] via 10.255.254.249, 00:11:14, GigabitEthernet0/2
[90/3072] via 10.255.254.237, 00:11:14, GigabitEthernet0/0
D 192.168.50.0/24
[90/3072] via 10.255.254.237, 00:11:11, GigabitEthernet0/0
192.168.51.0/24 is variably subnetted, 2 subnets, 2 masks
C 192.168.51.0/24 is directly connected, GigabitEthernet0/3
L 192.168.51.1/32 is directly connected, GigabitEthernet0/3
! D is EIGRP learned network
! Path to network 10.255.254.240/30 has 3 successors, equally good in terms of FD (Feasible Distance). sh ip eigrp topology shows details about this.

#sh ip eigrp neighbors

EIGRP-IPv4 Neighbors for AS(100)
H Address Interface Hold Uptime SRTT RTO Q Seq
(sec) (ms) Cnt Num
3 192.168.51.2 Gi0/3 14 00:12:42 5 100 0 13
2 10.255.254.245 Gi0/1 13 00:13:33 3 100 0 12
1 10.255.254.249 Gi0/2 13 00:15:06 1 100 0 16
0 10.255.254.237 Gi0/0 11 00:15:06 1 100 0 8

sh ip eigrp topology

```
EIGRP-IPv4 Topology Table for AS(100)/ID(192.168.51.1)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
        r - reply Status, s - sia Status

P 10.255.254.236/30, 1 successors, FD is 2816
        via Connected, GigabitEthernet0/0
P 10.255.254.248/30, 1 successors, FD is 2816
        via Connected, GigabitEthernet0/2
P 10.255.254.244/30, 1 successors, FD is 2816
        via Connected, GigabitEthernet0/1
P 192.168.51.0/24, 1 successors, FD is 2816
        via Connected, GigabitEthernet0/3
P 10.255.254.252/30, 2 successors, FD is 3072
        via 10.255.254.237 (3072/2816), GigabitEthernet0/0
        via 10.255.254.249 (3072/2816), GigabitEthernet0/2
P 192.168.50.0/24, 1 successors, FD is 3072
        via 10.255.254.237 (3072/2816), GigabitEthernet0/0
P 10.255.254.240/30, 3 successors, FD is 3072
        via 10.255.254.245 (3072/2816), GigabitEthernet0/1
        via 10.255.254.249 (3072/2816), GigabitEthernet0/2
        via 192.168.51.2 (3072/2816), GigabitEthernet0/3
! as shown in sh ip route 10.255.254.240/30 network has 3 successors
! (3072/2816) is (FD/AD)
```

#sh ip eigrp topology detail-links

```
EIGRP-IPv4 Topology Table for AS(100)/ID(192.168.51.1)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
        r - reply Status, s - sia Status

P 10.255.254.236/30, 1 successors, FD is 2816, serno 1
        via Connected, GigabitEthernet0/0
P 10.255.254.248/30, 1 successors, FD is 2816, serno 3
        via Connected, GigabitEthernet0/2
P 10.255.254.244/30, 1 successors, FD is 2816, serno 2
        via Connected, GigabitEthernet0/1
        via 192.168.51.2 (3072/2816), GigabitEthernet0/3
P 192.168.51.0/24, 1 successors, FD is 2816, serno 9
        via Connected, GigabitEthernet0/3
        via 10.255.254.245 (3072/2816), GigabitEthernet0/1
P 10.255.254.252/30, 2 successors, FD is 3072, serno 8
        via 10.255.254.237 (3072/2816), GigabitEthernet0/0
        via 10.255.254.249 (3072/2816), GigabitEthernet0/2
        via 192.168.51.2 (3328/3072), GigabitEthernet0/3
        via 10.255.254.245 (3328/3072), GigabitEthernet0/1
P 192.168.50.0/24, 1 successors, FD is 3072, serno 4
        via 10.255.254.237 (3072/2816), GigabitEthernet0/0
        via 10.255.254.249 (3328/3072), GigabitEthernet0/2
P 10.255.254.240/30, 3 successors, FD is 3072, serno 11
        via 10.255.254.245 (3072/2816), GigabitEthernet0/1
        via 10.255.254.249 (3072/2816), GigabitEthernet0/2
        via 192.168.51.2 (3072/2816), GigabitEthernet0/3
        via 10.255.254.237 (3328/3072), GigabitEthernet0/0
! the detail-links option shows also the candidates that didn't become the successor, that is, the backup routes
```

#do sh ip eigrp topology 192.168.50.0

```
EIGRP-IPv4 Topology Entry for AS(100)/ID(192.168.51.1) for 192.168.50.0/24
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 3072
  Descriptor Blocks:
  10.255.254.237 (GigabitEthernet0/0), from 10.255.254.237, Send flag is 0x0
        Composite metric is (3072/2816), route is Internal
        Vector metric:
        Minimum bandwidth is 1000000 Kbit
```

Total delay is 20 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 1
Originating router is 192.168.50.1
10.255.254.249 (GigabitEthernet0/2), from 10.255.254.249, Send flag is 0x0
Composite metric is (3328/3072), route is Internal
Vector metric:
Minimum bandwidth is 1000000 Kbit
Total delay is 30 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 2
Originating router is 192.168.50.1
! by singling out one network, more information is shown regarding the five metrics for EIGRP.

sh ip eigrp timers

EIGRP-IPv4 Timers for AS(100)
Hello Process
ExpirationType
| 1.179 (parent)
| 1.179 Hello (Gi0/2)
| 1.923 Hello (Gi0/3)
| 2.456 Hello (Gi0/1)
| 4.235 Hello (Gi0/0)

Update Process
ExpirationType
| 11.589 (parent)
| 11.589 (parent)
| 11.589 Peer holding
| 12.955 (parent)
| 12.955 Peer holding
| 13.419 (parent)
| 13.419 Peer holding
| 13.627 (parent)
| 13.627 Peer holding

SIA Process
ExpirationType
| 0.000 (parent)

#debug ip eigrp

EIGRP-IPv4 Route Event debugging is on
*Apr 16 01:07:17.014: %DUAL-5-NBRCHANGE: EIGRP-IPv4 100: Neighbor 10.255.254.250 (GigabitEthernet0/2) is resync: peer graceful-restart
*Apr 16 01:07:17.014: EIGRP-IPv4(100): Int 10.255.254.236/30 M 3840 - 1000000 50000000 SM 3584 - 1509949440 610
*Apr 16 01:07:17.014: EIGRP-IPv4(100): Int 10.255.254.244/30 M 3072 - 1000000 20000000 SM 2816 - 2524971008 152
*Apr 16 01:07:17.014: EIGRP-IPv4(100): Int 192.168.51.0/24 M 3072 - 1000000 20000000 SM 2816 - 2524971008 152
*Apr 16 01:07:17.024: EIGRP-IPv4(100): table(default): 10.255.254.240/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.024: EIGRP-IPv4(100): table(default): 10.255.254.252/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.024: EIGRP-IPv4(100): table(default): 10.255.254.248/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.025: EIGRP-IPv4(100): table(default): 10.255.254.236/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.025: EIGRP-IPv4(100): table(default): 192.168.50.0/24 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.025: EIGRP-IPv4(100): table(default): 10.255.254.244/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.025: EIGRP-IPv4(100): table(default): 192.168.51.0/24 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.028: EIGRP-IPv4(100): table(default): 10.255.254.240/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.028: EIGRP-IPv4(100): table(default): 10.255.254.252/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.028: EIGRP-IPv4(100): table(default): 10.255.254.248/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.029: EIGRP-IPv4(100): table(default): 10.255.254.236/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.029: EIGRP-IPv4(100): table(default): 192.168.50.0/24 - do advertise out GigabitEthernet0/2

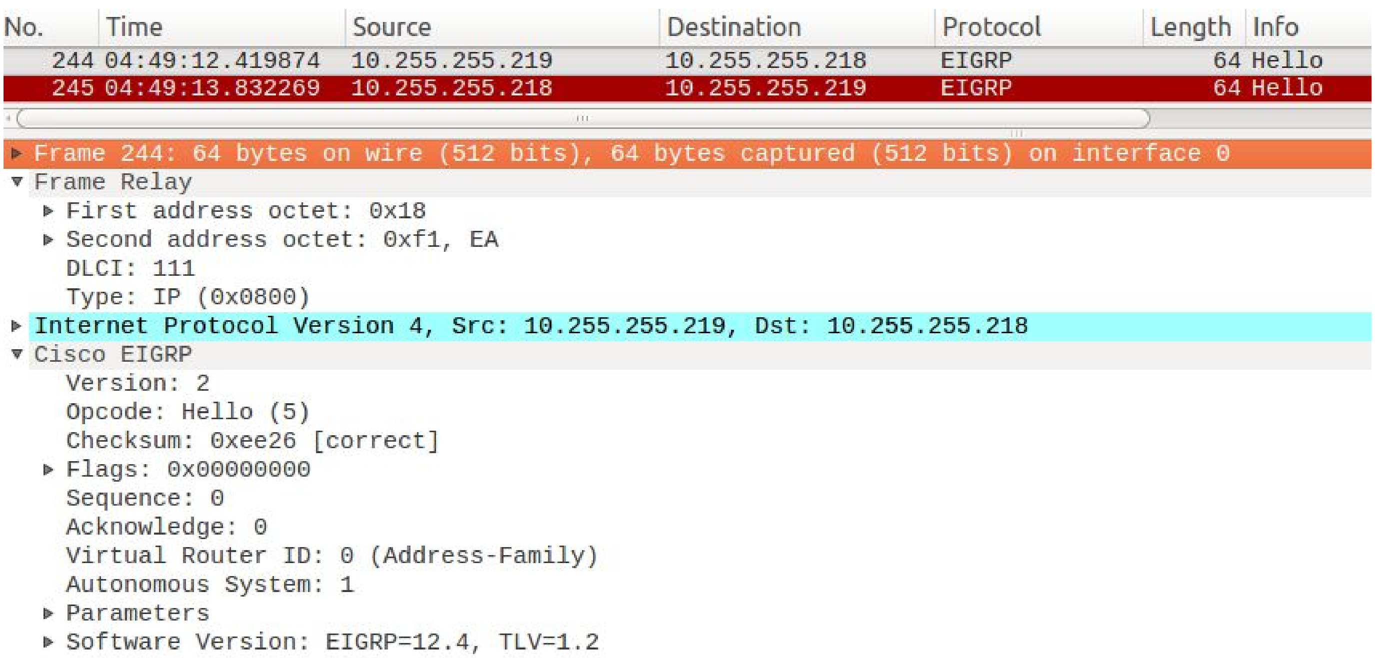
*Apr 16 01:07:17.029: EIGRP-IPv4(100): table(default): 10.255.254.244/30 - do advertise out GigabitEthernet0/2
*Apr 16 01:07:17.029: EIGRP-IPv4(100): table(default): 192.168.51.0/24 - do advertise out GigabitEthernet0/2

Static Neighbors

Static neighbors can be configured in each router, which would force the router to send hello packets to the neighbor in Unicast format, as opposed to Multicast. This makes a lot more sense in EIGRP over Frame Relay multipoint topologies where one spoke cannot form neighbor relationship with another spoke and the hub won't forward Hello packets in Multicast. In that type of topology a static neighbor can be configured so the relationship with the other spoke can be formed. The drawback of this scheme is that dynamic peering is off and static neighbors must be configured in all routers in the topology.

neighbor 10.255.255.219 serial 0/0
:: static router is configured

*Mar 1 00:28:40.807: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighbor 10.255.255.217 (Serial0/0) is down: Static peer configured
R11(config-router)#
*Mar 1 00:29:34.003: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighbor 10.255.255.219 (Serial0/0) is up: new adjacency
:: when static router is configured previous dynamic peering stops working and now they must be configured manually.



EIGRP Hello packet sent to Unicast address over Frame Relay

Influencing path

Path from PC-4 to PC-5 is through CiscoIOSv-9, then CiscoIOSv-8.
PC-4> trace 192.168.50.11
trace to 192.168.50.11, 8 hops max, press Ctrl+C to stop
 1   192.168.51.1   1.394 ms 1.095 ms 1.257 ms
 2   10.255.254.237   1.951 ms 2.000 ms 2.315 ms
 3   *192.168.50.11   2.519 ms (ICMP type:3, code:3, Destination port unreachable)

Extract from CiscoIOSv-9 (sh ip eigrp topology 192.168.50.0) shows interface in CiscoIOSv-8 as next hop.

P 192.168.50.0/24, 1 successors, FD is 3072
    via 10.255.254.237 (3072/2816), GigabitEthernet0/0

Extract from Cisco IOSv-9 (sh ip eigrp topology 192.168.50.0) shows all metrics sent in the updates, including delay and minimum bandwidth.

```
EIGRP-IPv4 Topology Entry for AS(100)/ID(192.168.51.1) for 192.168.50.0/24
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 3072
  Descriptor Blocks:
  10.255.254.237 (GigabitEthernet0/0), from 10.255.254.237, Send flag is 0x0
        Composite metric is (3072/2816), route is Internal
        Vector metric:
        Minimum bandwidth is 1000000 Kbit
        Total delay is 20 microseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 1
        Originating router is 192.168.50.1
  10.255.254.249 (GigabitEthernet0/2), from 10.255.254.249, Send flag is 0x0
        Composite metric is (3328/3072), route is Internal
        Vector metric:
        Minimum bandwidth is 1000000 Kbit
        Total delay is 30 microseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 2
        Originating router is 192.168.50.1
```

Delay in Interface G0/0 is 20 microseconds computing AD of 2816 and for G0/2 is 30 microseconds computing AD of 3072.

Delay set up in the interface:

do sh interface | inc line|DLY

```
GigabitEthernet0/0 is up, line protocol is up
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 10 usec,
GigabitEthernet0/1 is up, line protocol is up
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 10 usec,
! DLY is one of the items used for EIGRP to calculate Total delay metric.
```

Increasing the delay in G0/0 to make it have a higher AD than G0/2.

delay 3

do sh interface | inc line|DLY

```
GigabitEthernet0/0 is up, line protocol is up
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 30 usec,
GigabitEthernet0/1 is up, line protocol is up
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 10 usec,
```

Now topology changed:

do sh ip eigrp topology de

```
EIGRP-IPv4 Topology Table for AS(100)/ID(192.168.51.1)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
        r - reply Status, s - sia Status

P 10.255.254.236/30, 1 successors, FD is 3328, serno 21
```

via Connected, GigabitEthernet0/0
via 10.255.254.245 (3584/3328), GigabitEthernet0/1
via 192.168.51.2 (3584/3328), GigabitEthernet0/3
via 10.255.254.249 (3328/3072), GigabitEthernet0/2
P 10.255.254.248/30, 1 successors, FD is 2816, serno 3
via Connected, GigabitEthernet0/2
P 10.255.254.244/30, 1 successors, FD is 2816, serno 2
via Connected, GigabitEthernet0/1
via 192.168.51.2 (3072/2816), GigabitEthernet0/3
P 192.168.51.0/24, 1 successors, FD is 2816, serno 9
via Connected, GigabitEthernet0/3
via 10.255.254.245 (3072/2816), GigabitEthernet0/1
P 10.255.254.252/30, 1 successors, FD is 3072, serno 12
via 10.255.254.249 (3072/2816), GigabitEthernet0/2
via 10.255.254.237 (3584/2816), GigabitEthernet0/0
via 192.168.51.2 (3328/3072), GigabitEthernet0/3
via 10.255.254.245 (3328/3072), GigabitEthernet0/1
P 192.168.50.0/24, 1 successors, FD is 3328, serno 20, Stats m(18)M(18)A(18)c(1)
via 10.255.254.249 (3328/3072), GigabitEthernet0/2
via 10.255.254.237 (3584/2816), GigabitEthernet0/0
via 10.255.254.245 (3584/3328), GigabitEthernet0/1
via 192.168.51.2 (3584/3328), GigabitEthernet0/3
P 10.255.254.240/30, 3 successors, FD is 3072, serno 11
via 10.255.254.245 (3072/2816), GigabitEthernet0/1
via 10.255.254.249 (3072/2816), GigabitEthernet0/2
via 192.168.51.2 (3072/2816), GigabitEthernet0/3
via 10.255.254.237 (3840/3072), GigabitEthernet0/0
! Network 192.168.50.0 has one successor and it's through CiscoIOSv-6 as FD from CiscoIOSv-9 increased from 3072 to 3584. As it increased that much, the other 2 routes that were not in the list before, now became Feasible successors.

do sh ip eigrp topology 192.168.50.0
EIGRP-IPv4 Topology Entry for AS(100)/ID(192.168.51.1) for 192.168.50.0/24
State is Passive, Query origin flag is 1, 1 Successor(s), FD is 3328
Descriptor Blocks:
10.255.254.249 (GigabitEthernet0/2), from 10.255.254.249, Send flag is 0x0
Composite metric is (3328/3072), route is Internal
Vector metric:
Minimum bandwidth is 1000000 Kbit
Total delay is 30 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 2
Originating router is 192.168.50.1
10.255.254.237 (GigabitEthernet0/0), from 10.255.254.237, Send flag is 0x0
Composite metric is (3584/2816), route is Internal
Vector metric:
Minimum bandwidth is 1000000 Kbit
Total delay is 40 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 1
Originating router is 192.168.50.1
10.255.254.245 (GigabitEthernet0/1), from 10.255.254.245, Send flag is 0x0
Composite metric is (3584/3328), route is Internal
Vector metric:
Minimum bandwidth is 1000000 Kbit
Total delay is 40 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 3

Originating router is 192.168.50.1
192.168.51.2 (GigabitEthernet0/3), from 192.168.51.2, Send flag is 0x0
Composite metric is (3584/3328), route is Internal
Vector metric:
Minimum bandwidth is 1000000 Kbit
Total delay is 40 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 3
Originating router is 192.168.50.1
! this output shows the delay in G0/0 went up to 40 microseconds.

Route from PC-4 to PC-5

PC-4> trace 192.168.50.11

trace to 192.168.50.11, 8 hops max, press Ctrl+C to stop
1 192.168.51.1 1.276 ms 1.240 ms 1.184 ms
2 10.255.254.249 2.446 ms 2.025 ms 2.059 ms
3 10.255.254.254 2.262 ms 2.153 ms 2.545 ms
4 *192.168.50.11 3.733 ms (ICMP type:3, code:3, Destination port unreachable)
even though it has 4 hops now, it's the preferred route because of EIGRP calculation.

It's also possible to influence by offset-list, which arbitrarily increases the FD.

access-list 10 permit 192.168.50.0 0.0.0.255

! First create an access-list with the destination network

offset-list 10 in 1000 GigabitEthernet0/2

! 10 is the access list
! in means to apply offset in incoming packets
! 1000 is the amount to increase in FD (from 3328 to 4328)
! then comes the interface to apply the change

do sh ip eigrp topology 192.168.50.0

EIGRP-IPv4 Topology Entry for AS(100)/ID(10.255.254.238) for 192.168.50.0/24
State is Passive, Query origin flag is 1, 2 Successor(s), FD is 3584
Descriptor Blocks:
10.255.254.245 (GigabitEthernet0/1), from 10.255.254.245, Send flag is 0x0
Composite metric is (3584/3328), route is Internal
Vector metric:
Minimum bandwidth is 1000000 Kbit
Total delay is 40 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 3
Originating router is 10.255.254.254
192.168.51.2 (GigabitEthernet0/3), from 192.168.51.2, Send flag is 0x0
Composite metric is (3584/3328), route is Internal
Vector metric:
Minimum bandwidth is 1000000 Kbit
Total delay is 40 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 3
Originating router is 10.255.254.254
10.255.254.249 (GigabitEthernet0/2), from 10.255.254.249, Send flag is 0x0
Composite metric is (4328/4072), route is Internal
Vector metric:
Minimum bandwidth is 1000000 Kbit

Total delay is 69 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 2
Originating router is 10.255.254.254
10.255.254.237 (GigabitEthernet0/0), from 10.255.254.237, Send flag is 0x0
Composite metric is (3840/2816), route is Internal
Vector metric:
Minimum bandwidth is 1000000 Kbit
Total delay is 50 microseconds
Reliability is 255/255
Load is 1/255
Minimum MTU is 1500
Hop count is 1
Originating router is 10.255.254.254

Now, trace shows even one more hop because of the topology change

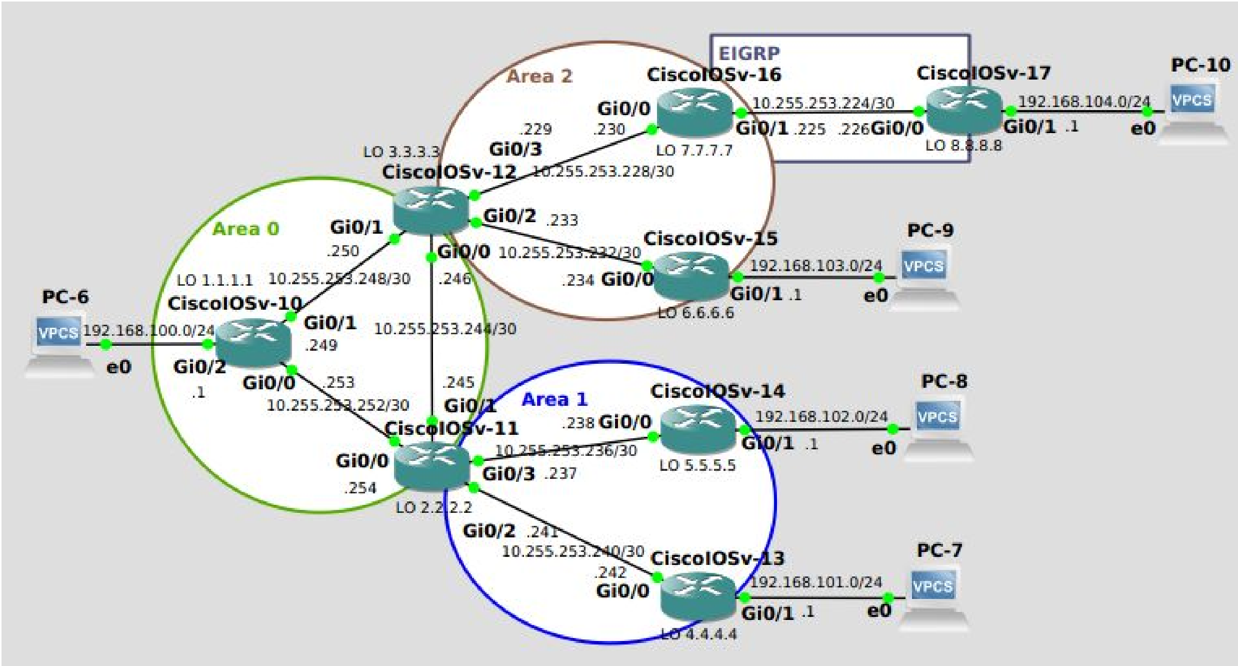
PC-4> trace 192.168.50.11

trace to 192.168.50.11, 8 hops max, press Ctrl+C to stop
1 192.168.51.1 1.452 ms 1.328 ms 1.356 ms
2 10.255.254.245 1.703 ms 1.656 ms 1.957 ms
3 10.255.254.241 2.678 ms 2.709 ms 2.829 ms
4 10.255.254.254 3.227 ms 2.667 ms 3.024 ms
5 *192.168.50.11 4.187 ms (ICMP type:3, code:3, Destination port unreachable)

!!! It is also possible to change the default administrative distance to influence but it's more dangerous as it can create loops.

OSPF (Open Shortest Path First)

- Link State protocol
- 100% loop free
- Fast convergence
- Classless
- Uses cost (bandwidth) as metric
- Sends partial updates only (like EIGRP)
- Administrative distance is 110



Areas

An area is a logical collection of OSPF networks, routers and links with the same area ID. A router must maintain a topological database for the area to which it belongs. Thus, the router doesn't have detailed information about network topology outside of its area, reducing the database size.

Areas limit the scope of route information distribution. It is not possible to do route update filtering within an area. The link-state database (LSDB) of routers within the same area must be synchronized and be exactly the same; however, route summarization and filtering is possible between different areas. The main benefit of creating areas is a reduction in the number of routes to propagate - by the filtering and the summarization of routes.

A router with interfaces in 2 or more areas is an area border router (ABR), that is, it's in the OSPF boundary between two areas.
An autonomous system boundary router (ASBR) advertises external destinations. External routes are routes redistributed into OSPF from another protocol, like EIGRP.

Normal areas

Are standard or backbone areas. Standard areas are areas that accept intra-area, inter-area and external routes (all routes). Backbone (area 0) connects independent areas into a single domain and must not be partitioned. If backbone is not contiguous, that is, area 0 does not reach all other areas in the OSPF domain, a virtual link can be created to bridge the further area to area 0.

Stub areas

Are areas in which advertisements of external routes (outside OSPF domain) are not allowed, instead default summary route 0.0.0.0 is inserted to reach external routes. They are shielded

from external routes, but receive information about networks of other areas of the same OSPF domain.
Command: # area 5 stub ! on all routers of the area

PS: stub areas will not receive routes from External AS
CiscoIOSv-24(config-router)#redistribute rip
*Apr 30 04:36:37.909: %OSPF-4-ASBR_WITHOUT_VALID_AREA: Router is currently an ASBR while having only one area which is a stub area

Totally stubby areas

Keep their LSDB-only information about routing within their area, plus the default route. They don't receive information about other areas in the same OSPF domain, unlike stub areas.
Summary Net is defined as 0.0.0.0 as the Link ID and the ADV Router is the ABR.
Command: # area 5 stub ! on all area routers
Command: # area 5 stub no-summary ! on the ABR so it sends default route as LSA type 3

Not-so-stubby areas (NSSAs)

Are an extension of OSPF stub areas. They also prevent flooding of autonomous system external (AS-external) link-state advertisements (LSAs) into NSSAs, relying on default routing. They are placed at the edge of the OSPF routing domain. The difference from stubby areas is that NSSA can import external routes into the OSPF routing domain, thus providing transit service to small routing domains outside the OSPF routing domain. It allows the attachment of non-OSPF routers, which uses type-7 LSA.
Command: # area 5 nssa ! on all area routers
Command: # area 5 nssa default-information-originate ! on ABR so it advertises the default route

PS.: unlike Stub areas, NSSA will receive and forward routes from External AS.

Not-so-stubby area (NSSA) totally stub areas

Are like pure NSSA but will keep type 3 and 5 (AS-external) from leaking into NSSA totally stub area
Command: # area 5 nssa no-summary

Area	Restriction
Normal	None
Stub	No Type 5 AS-external LSA allowed
Totally Stub	No Type 3, 4 or 5 LSAs allowed except the default summary route
NSSA	No Type 5 AS-external LSAs allowed, but Type 7 LSAs that convert to Type 5 at the NSSA ABR can traverse
NSSA Totally Stub	No Type 3, 4 or 5 LSAs except the default summary route, but Type 7 LSAs that convert to Type 5 at the NSSA ABR are allowed

Virtual Link

Is a way to connect an area that is not connected to area 0 by using a third area, known as transit area. The transit area cannot be a stub area or nssa, otherwise…
CiscoIOSv-33(config-router)#area 6 virtual-link 9.9.9.9
% OSPF: Virtual links are not allowed in NSSA and stub areas
Command: # area 4 virtual-link <router-id> ! router-id is the ID of the router associated with virtual link neighbor.

In router 2.2.2.2: # area 1 virtual-link 20.20.20.20
In router 20.20.20.20: # area 1 virtual-link 2.2.2.2

DR - Designated Router
Rather than broadcasting LSAs to all OSPF neighbors, routing devices send their LSAs to the DR, which then 1) originates network link advertisements, and 2) establishes adjacencies with all routing devices on the network, thus participating in the synchronizing of the link-state databases.
DR election happens when the OSPF network is initially established, The router with the highest router-id (IP address or the loopback) is elected the DR. The second highest is the BDR (backup designated router).

ABR - Area Border Router
Router that bridges 2 (or more) areas. Ex. CiscoIOSv-11 and CiscoIOSv-12

ASBR - Autonomous System Boundary Router
Router that bridges OSPF domain and another autonomous system (AS) ruled by another routing protocol, like RIP or EIGRP.

LSA - Link-State Advertisement

LSA Types	LSA Name	Link State ID
1	Router	Router ID
2	Network	Interface IP of DR
3	Network Summary	Network Address
4	ASBR Summary	Router ID of ASBR
5	AS-External	Network Address

LSA Type 1 (Router) - Links directly connected to the router. All routers (through their interfaces) participating in the area, will have the exact same copy of the Router Database. The DR makes sure to sync it up.
:: Command: *sh ip ospf database router* shows all the routes learned with LSA type 1. You can limit the search for a specific router like, *sh ip ospf database router 1.1.1.1*.

LSA Type 2 (Network) - DR advertising on behalf of a network. That is the route learned where that router is the DR.
:: Command: sh ip ospf database network shows all the routes learned with LSA type 2. You can limit the search for a specific network like, sh ip ospf database network network 10.255.253.250.

LSA Type 3 (Network Summary) - BR advertising all the routes they know about (except for LSA type 4 and 5).

:: Command: *sh ip ospf database summary* shows all the routes learned with LSA type 3. You can limit the search for a specific network like, *sh ip ospf database summary 192.168.101.0*.

LSA Type 4 (ASBR Summary) - ASBR advertising its own route to backbone (area 0) so they know show to reach LSA Type 5-learned networks.

:: Command: *sh ip ospf database asbr-summary* shows how to reach ASBR routers.

LSA Type 5 (AS-External) - Route learned from another routing protocol. Usually it's the route distributed through ASBR.

:: Command: *sh ip ospf database external* shows all the routes learned with LSA Type 5.

Configuration

router ospf 1

:: start OSPF with process ID one (this is not like autonomous system). Each OSPF router may run in a different process ID

network 10.0.0.0 0.255.255.255 area 0

:: sets up the network to participate in that area (all the interfaces within that network will start participating in area 0)

Route Redistribution

redistribute eigrp 100

:: in EIGRP networks this redistribute those routes into OSPF domain

redistribute ospf 7 metric 10000 100 255 1 1500

:: in EIGRP ASBR, this redistribute OSPF routes into EIGRP AS.

redistribute ospf 11 metric 4

:: in RIP ASBR, this redistributes OSPF routes into RIP networks.

redistribute rip subnets

:: in RIP ASBR, this redistributes RIP routes into OSPF

redistribute bgp 30 metric 100 metric-type 1 subnets

:: in OSPF, this redistributes BGP subnets

redistribute static subnets

:: In OSPF, this redistributes static routes

default-information originate

:: redistribute default route into OSPF backbone

Checking

Showing what interfaces are participating in which area

R1# sh ip ospf interface brief

Interface	PID	Area	IP Address/Mask	Cost	State	Nbrs F/C
Gi0/2	1	0	192.168.100.1/24	1	DR	0/0
Gi0/1	1	0	10.255.253.249/30	1	BDR	1/1
Gi0/0	1	0	10.255.253.253/30	1	BDR	1/1

R2# sh ip ospf interface brief

Interface	PID	Area	IP Address/Mask	Cost	State	Nbrs F/C
Gi0/0	2	0	10.255.253.254/30	1	DR	1/1
Gi0/1	2	0	10.255.253.245/30	1	BDR	1/1
Gi0/2	2	1	10.255.253.241/30	1	BDR	1/1
Gi0/3	2	1	10.255.253.237/30	1	BDR	1/1

R7# sh ip ospf interface brief

Interface	PID	Area	IP Address/Mask	Cost	State	Nbrs F/C
Gi0/0	7	2	10.255.253.230/30	1	DR	1/1

Showing OSPF routes

R1# sh ip route ospf

```
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
        a - application route
        + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

        10.0.0.0/8 is variably subnetted, 10 subnets, 2 masks
O E2    10.255.253.224/30
        [110/20] via 10.255.253.250, 00:19:43, GigabitEthernet0/1
O IA    10.255.253.228/30
        [110/2] via 10.255.253.250, 00:19:43, GigabitEthernet0/1
O IA    10.255.253.232/30
        [110/2] via 10.255.253.250, 00:19:43, GigabitEthernet0/1
O IA    10.255.253.236/30
        [110/2] via 10.255.253.254, 00:19:43, GigabitEthernet0/0
O IA    10.255.253.240/30
        [110/2] via 10.255.253.254, 00:19:43, GigabitEthernet0/0
O       10.255.253.244/30
        [110/2] via 10.255.253.254, 00:19:43, GigabitEthernet0/0
        [110/2] via 10.255.253.250, 00:19:43, GigabitEthernet0/1
O IA  192.168.101.0/24
        [110/3] via 10.255.253.254, 00:19:43, GigabitEthernet0/0
O IA  192.168.102.0/24
        [110/3] via 10.255.253.254, 00:19:43, GigabitEthernet0/0
O IA  192.168.103.0/24
        [110/3] via 10.255.253.250, 00:19:34, GigabitEthernet0/1
O E2  192.168.104.0/24
        [110/20] via 10.255.253.250, 00:19:43, GigabitEthernet0/1
```

Showing details for OSPF running in the router

R1# sh ip protocols

```
*** IP Routing is NSF aware ***

Routing Protocol is "application"
  Sending updates every 0 seconds
  Invalid after 0 seconds, hold down 0, flushed after 0
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
```

```
  Maximum path: 32
  Routing for Networks:
  Routing Information Sources:
    Gateway         Distance      Last Update
  Distance: (default is 4)

Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 1.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.0.0.0 0.255.255.255 area 0
    192.0.0.0 0.255.255.255 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    7.7.7.7              110      00:22:04
    2.2.2.2              110      00:22:04
    3.3.3.3              110      00:21:55
  Distance: (default is 110)
```

R1# sh ip ospf neighbor

```
Neighbor ID     Pri   State           Dead Time   Address         Interface
3.3.3.3           1   FULL/DR         00:00:39    10.255.253.250  GigabitEthernet0/1
2.2.2.2           1   FULL/DR         00:00:31    10.255.253.254  GigabitEthernet0/0
```

Showing OSPF database

R1# sh ip ospf database

```
            OSPF Router with ID (1.1.1.1) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1500        0x80000002 0x00A187 3
2.2.2.2         2.2.2.2         1502        0x80000002 0x00B451 2
3.3.3.3         3.3.3.3         1502        0x80000002 0x0022E2 2

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.255.253.246  3.3.3.3         1502        0x80000001 0x00EB32
10.255.253.250  3.3.3.3         1501        0x80000001 0x00918C
10.255.253.254  2.2.2.2         1501        0x80000001 0x0065BC

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.255.253.228  3.3.3.3         1541        0x80000001 0x00C97C
10.255.253.232  3.3.3.3         1541        0x80000001 0x00A1A0
10.255.253.236  2.2.2.2         1542        0x80000001 0x0097AA
10.255.253.240  2.2.2.2         1542        0x80000001 0x006FCE
192.168.101.0   2.2.2.2         1498        0x80000001 0x005410
192.168.102.0   2.2.2.2         1498        0x80000001 0x00491A
192.168.103.0   3.3.3.3         1488        0x80000001 0x00203E

                Summary ASB Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
```

```
7.7.7.7     3.3.3.3     1498        0x80000001 0x00E72B

            Type-5 AS External Link States

Link ID     ADV Router          Age         Seq#        Checksum Tag
10.255.253.224  7.7.7.7         1547        0x80000001 0x00CDD0 0
192.168.104.0   7.7.7.7         1545        0x80000001 0x00E6CB 0
```

Showing routes learned through LSA type 1

#sh ip ospf database router

```
            OSPF Router with ID (1.1.1.1) (Process ID 1)

             Router Link States (Area 0)

  LS age: 1874
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 1.1.1.1
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000002
  Checksum: 0xA187
  Length: 60
  Number of Links: 3

            Link connected to: a Stub Network
            (Link ID) Network/subnet number: 192.168.100.0
            (Link Data) Network Mask: 255.255.255.0
            Number of MTID metrics: 0
            TOS 0 Metrics: 1

            Link connected to: a Transit Network
            (Link ID) Designated Router address: 10.255.253.250
            (Link Data) Router Interface address: 10.255.253.249
            Number of MTID metrics: 0
            TOS 0 Metrics: 1

            Link connected to: a Transit Network
            (Link ID) Designated Router address: 10.255.253.254
            (Link Data) Router Interface address: 10.255.253.253
            Number of MTID metrics: 0
            TOS 0 Metrics: 1


  LS age: 1875
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 2.2.2.2
  Advertising Router: 2.2.2.2
  LS Seq Number: 80000002
  Checksum: 0xB451
  Length: 48
  Area Border Router
  Number of Links: 2

            Link connected to: a Transit Network
            (Link ID) Designated Router address: 10.255.253.254
            (Link Data) Router Interface address: 10.255.253.254
            Number of MTID metrics: 0
            TOS 0 Metrics: 1

            Link connected to: a Transit Network
```

```
        (Link ID) Designated Router address: 10.255.253.246
        (Link Data) Router Interface address: 10.255.253.245
        Number of MTID metrics: 0
        TOS 0 Metrics: 1


  LS age: 1875
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 3.3.3.3
  Advertising Router: 3.3.3.3
  LS Seq Number: 80000002
  Checksum: 0x22E2
  Length: 48
  Area Border Router
  Number of Links: 2

        Link connected to: a Transit Network
        (Link ID) Designated Router address: 10.255.253.250
        (Link Data) Router Interface address: 10.255.253.250
        Number of MTID metrics: 0
        TOS 0 Metrics: 1

        Link connected to: a Transit Network
        (Link ID) Designated Router address: 10.255.253.246
        (Link Data) Router Interface address: 10.255.253.246
        Number of MTID metrics: 0
        TOS 0 Metrics: 1
```

Showing routes learned through LSA Type 2

#sh ip ospf database network

```
        OSPF Router with ID (1.1.1.1) (Process ID 1)

         Net Link States (Area 0)

  LS age: 624
  Options: (No TOS-capability, DC)
  LS Type: Network Links
  Link State ID: 10.255.253.246 (address of Designated Router)
  Advertising Router: 3.3.3.3
  LS Seq Number: 80000002
  Checksum: 0xE933
  Length: 32
  Network Mask: /30
    Attached Router: 3.3.3.3
    Attached Router: 2.2.2.2

  LS age: 624
  Options: (No TOS-capability, DC)
  LS Type: Network Links
  Link State ID: 10.255.253.250 (address of Designated Router)
  Advertising Router: 3.3.3.3
  LS Seq Number: 80000002
  Checksum: 0x8F8D
  Length: 32
  Network Mask: /30
    Attached Router: 3.3.3.3
    Attached Router: 1.1.1.1

  LS age: 600
  Options: (No TOS-capability, DC)
```

LS Type: Network Links
Link State ID: 10.255.253.254 (address of Designated Router)
Advertising Router: 2.2.2.2
LS Seq Number: 80000002
Checksum: 0x63BD
Length: 32
Network Mask: /30
  Attached Router: 2.2.2.2
  Attached Router: 1.1.1.1

Showing routes learned through LSA Type 3

sh ip ospf database summary

```
            OSPF Router with ID (1.1.1.1) (Process ID 1)

             Summary Net Link States (Area 0)

  LS age: 1901
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.255.253.228 (summary Network Number)
  Advertising Router: 3.3.3.3
  LS Seq Number: 80000002
  Checksum: 0xC77D
  Length: 28
  Network Mask: /30
    MTID: 0     Metric: 1

  LS age: 1901
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.255.253.232 (summary Network Number)
  Advertising Router: 3.3.3.3
  LS Seq Number: 80000002
  Checksum: 0x9FA1
  Length: 28
  Network Mask: /30
    MTID: 0     Metric: 1

  LS age: 1876
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.255.253.236 (summary Network Number)
  Advertising Router: 2.2.2.2
  LS Seq Number: 80000002
  Checksum: 0x95AB
  Length: 28
  Network Mask: /30
    MTID: 0     Metric: 1

  LS age: 1876
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.255.253.240 (summary Network Number)
  Advertising Router: 2.2.2.2
  LS Seq Number: 80000002
  Checksum: 0x6DCF
  Length: 28
  Network Mask: /30
    MTID: 0     Metric: 1

  LS age: 1876
```

```
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 192.168.101.0 (summary Network Number)
  Advertising Router: 2.2.2.2
  LS Seq Number: 80000002
  Checksum: 0x5211
  Length: 28
  Network Mask: /24
    MTID: 0     Metric: 2

  LS age: 1876
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 192.168.102.0 (summary Network Number)
  Advertising Router: 2.2.2.2
  LS Seq Number: 80000002
  Checksum: 0x471B
  Length: 28
  Network Mask: /24
        MTID: 0     Metric: 2

  LS age: 1901
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 192.168.103.0 (summary Network Number)
  Advertising Router: 3.3.3.3
  LS Seq Number: 80000002
  Checksum: 0x1E3F
  Length: 28
  Network Mask: /24
    MTID: 0     Metric: 2
```

Showing routes learned through LSA Type 4

sh ip ospf database asbr-summary

```
        OSPF Router with ID (1.1.1.1) (Process ID 1)

         Summary ASB Link States (Area 0)

  LS age: 1162
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(AS Boundary Router)
  Link State ID: 7.7.7.7 (AS Boundary Router address)
  Advertising Router: 3.3.3.3
  LS Seq Number: 80000003
  Checksum: 0xE32D
  Length: 28
  Network Mask: /0
    MTID: 0     Metric: 1
```

Showing routes learned through LSA Type 5

sh ip ospf database external

```
        OSPF Router with ID (1.1.1.1) (Process ID 1)

         Type-5 AS External Link States

  LS age: 440
  Options: (No TOS-capability, DC, Upward)
  LS Type: AS External Link
```

Link State ID: 10.255.253.224 (External Network Number)
Advertising Router: 7.7.7.7
LS Seq Number: 80000003
Checksum: 0xC9D2
Length: 36
Network Mask: /30
  Metric Type: 2 (Larger than any link state path)
  MTID: 0
  Metric: 20
  Forward Address: 0.0.0.0
  External Route Tag: 0

LS age: 440
Options: (No TOS-capability, DC, Upward)
LS Type: AS External Link
Link State ID: 192.168.104.0 (External Network Number)
Advertising Router: 7.7.7.7
LS Seq Number: 80000003
Checksum: 0xE2CD
Length: 36
Network Mask: /24
  Metric Type: 2 (Larger than any link state path)
  MTID: 0
  Metric: 20
  Forward Address: 0.0.0.0
  External Route Tag: 0

BGP (Border Gateway Protocol)

Path vector protocol, standardized for routing among autonomous systems (AS) on the Internet. Unlike the others above, which are considered as internal gateway protocols (IGP), BGP is considered an exterior gateway Protocol (EGP) as packets can travel from one AS to another.

Autonomous System is the infrastructure under your control. The devices in it can be exposed to the Internet or not. That's why BGP comes in two flavors:

iBGP - Internal BGP, will route traffic within the AS
eBGP - External BGP, will route traffic between different AS's.
The distinction between iBGP and eBGP is the ASN (Autonomous System Number), i.e. if it's different it means eBGP is taking care of traffic, otherwise iBGP kicks in. Overall, the protocol will behave alike regardless the flavor.

Technically, ASNs are assigned in blocks by Internet Assigned Numbers Authority (IANA) to Regional Internet Registries (RIRs). RIRs then assigns ASN to entities in their areas. There are basically 5 RIRs around the globe:

- APNIC for Asia Pacific
- RIPE NCC for Europe and Middle East
- AFRINIC for Africa
- ARIN for US, Canada, and some Caribbean countries
- LACNIC for Latin America

Delegation from IANA to RIRs can be found here: http://www.iana.org/assignments/as-numbers
Each RIR keeps its own list of assigned ASNs, ARIN's for instance is here:
ftp://ftp.arin.net/info/asn.txt

Unlike IGPs, BGP only exchange information with neighbors which it established relationships. So, before advertising networks, it's necessary to establish a relationship (to peer) with some other AS, or other device in the same AS.

Configuration

router bgp 2

:: will configure bgp ASN 2

neighbor 101.101.101.101 remote-as 2

:: will establish a neighbor relationship (peer) with 101.101.101.101
:: this is a loopback interface and the ASN is the same, which means it will be iBGP
:: in order for the relationship to work, connectivity must be working between local loopback and remote loopback (relationship can also be done using the regular interface address)

neighbor 101.101.101.101 update-source loopback 0

:: this command will make the router use the local loopback to establish the relationship with router 101.101.101.101, otherwise it will use the egress interface address and it will fail (because in the remote router you will reference the local loopback as the neighbor).

neighbor 101.101.101.101 next-hop-self

:: when there is a border router advertising networks to internal routers using iBGP, it will place as the next hop the address of the remote AS, which is not reachable by the internal routers. This command advertises itself as the next hop.

neighbor 101.101.101.101 ebgp-multihop

:: for peering with router that sits more than 1 hop away (eBGP time to live is 1 by default)
:: also it won't use default routes. Have specific routes for that

#network 220.0.0.0 mask 255.255.255.0

:: advertises network 220.0.0.0

Checking

#do sh ip bgp summary

BGP router identifier 101.101.101.101, local AS number 10
BGP table version is 15, main routing table version 15
6 network entries using 720 bytes of memory
10 path entries using 520 bytes of memory
11/6 BGP path/bestpath attribute entries using 1364 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 3 (at peak 3) using 96 bytes of memory
BGP using 2772 total bytes of memory
BGP activity 7/1 prefixes, 11/1 paths, scan interval 60 secs

```
Neighbor          V       AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
100.100.100.100 4  10     48      48       15       0         0 00:41:01         4
200.0.0.2         4       20      11       11       15        0         0 00:03:54
```

:: shows peering information. Empty state and Up/Down with some time means it's working. PfxRcd shows how many networks were advertised.

#do sh ip bgp

```
BGP table version is 15, local router ID is 101.101.101.101
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
        r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
* i70.0.0.0/22      100.100.100.100     281856    100      0 i
*>                  10.255.252.242      281856         32768 i
*> 110.0.0.0/22     200.0.0.2           1         0 20 i
r  150.0.0.0/22     200.0.0.2                     0 20 30 i
r>i                 100.100.100.100     20        100      0 30 i
*  200.0.0.0        200.0.0.2           0         0 20 i
*>                  0.0.0.0             0         32768 i
*> 210.0.0.0        200.0.0.2                     0 20 i
* i         100.100.100.100             0         100      0 30 i
r>i220.0.0.0        100.100.100.100               0        100      0 i
```

:: among other information, it shows all known valid networks (*) with best paths (>), their next hops and their path, which is the ASN sequence to reach that network.