OSPF – Open Shortest Path First:

- OSPF stand for Open Shortest Path First.
- It is Standard protocol.
- It is a link state protocol and sends update based in state of link.
- Like when a link comes up and goes down it sends the updates.
- OSPF protocols number 89.
- It use SPF (Shortest path first) algorithm.
- OSPF Support Unlimited hop count.
- Metric is cost (cost = 10^8/BW).
- OSPF External and Internal Administrative distance is 110.
- It supports VLSM and CIDR.
- It support only equal cost load balancing.
- In OSPF introduces the concept of Area's to ease management and control traffic (To stop LSA Flooding).
- Must have one are called as area 0.
- All the areas must connect to area 0.
- It Support Authentication.
- OSPF use multicast address 224.0.0.5 to send the hello packet.
- OSPF use multicast address 224.0.0.6 for all designated routers.
- Faster convergence.
- Sends Hello packet every 10 seconds.
- OSPF Hello timer is 10 seconds and Dead timer is 40 seconds.
- Router's send only changes in updates and not the entire routing tables in periodic updates.
- OSPF have Neighbor table, Database (Topology) table and Routing table.
- OSPF protocols supports both IPV4 and IPV6 routed protocols.
- OSPF sends all updates in the form of LSA (Link state advertisement).
- OSPF sends update with a sequence number of 0x80000001.
- The sequence number ends with 0x7FFFFFFF and start again.

OSPF Configuration:

```
#router ospf 1

#network Network Id   wildcard mask  area 0

# network Network Id   wildcard mask  area 0
```

OSPF Tables:

Neighbor Table:

- Directly connected network

How to check?

Sh ip ospf neighbor

```
R2#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
1.1.1.1           1   FULL/BDR        00:00:39    192.168.12.1    FastEthernet0/0
```

Database Table (Topology Table):

- List of the all links and all router will same this table i.e... Identical database.

How to check?

Sh ip ospf database

```
R2#sh ip ospf database

            OSPF Router with ID (2.2.2.2) (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         150         0x80000004 0x004ADA 2
2.2.2.2         2.2.2.2         151         0x80000004 0x003ADD 2

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.12.2    2.2.2.2         151         0x80000002 0x008D20
```

Routing Table:

- It contains Best Path towards the destination.

How to check?

Sh ip route

```
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
       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, + - replicated route

Gateway of last resort is not set

      1.0.0.0/32 is subnetted, 1 subnets
O        1.1.1.1 [110/2] via 192.168.12.1, 00:37:31, FastEthernet0/0
      2.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        2.0.0.0/8 is directly connected, Loopback0
L        2.2.2.2/32 is directly connected, Loopback0
      192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.12.0/24 is directly connected, FastEthernet0/0
L        192.168.12.2/32 is directly connected, FastEthernet0/0
```


OSPF Terminologies:

Area:

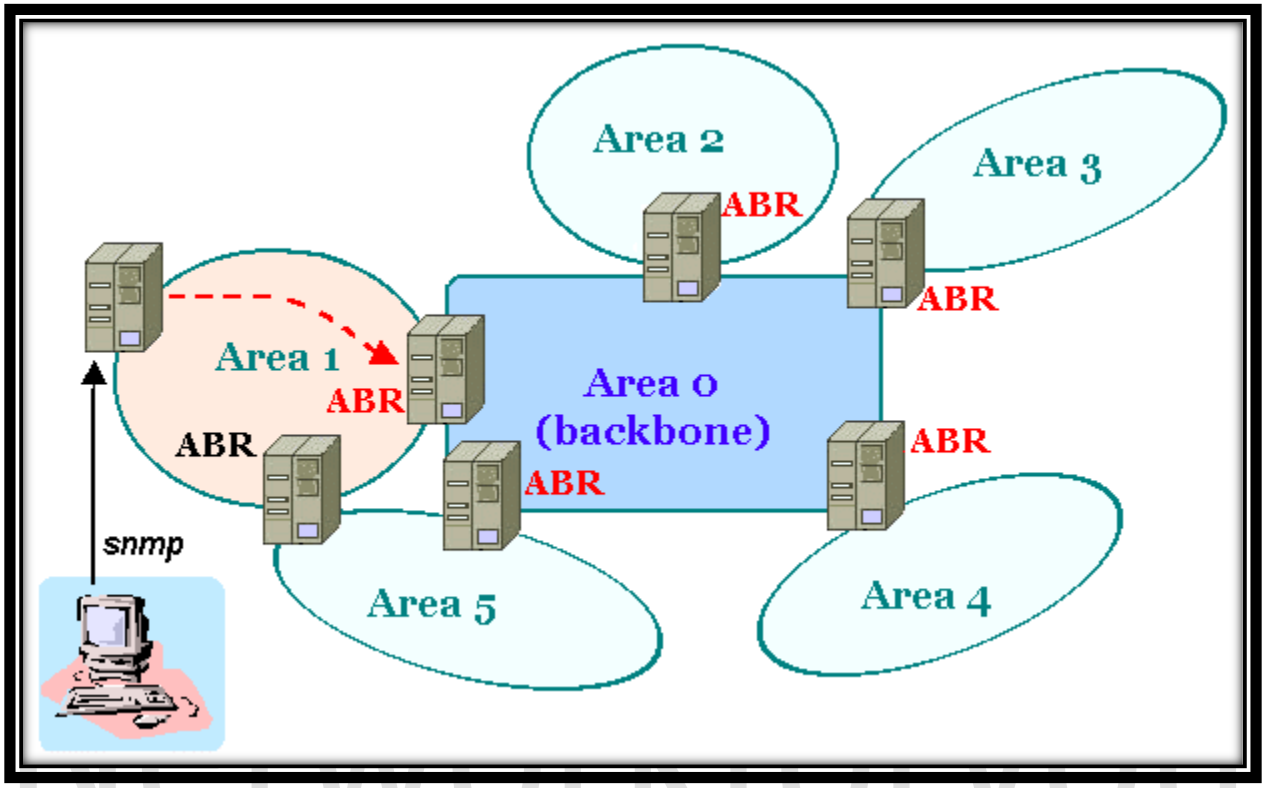
- In OSPF protocol Area concept is use to stop LSA flooding (Area is like Sub netting).
- It allows separating the large internetwork into smaller networks called areas.

Backbone:

- In OSPF Protocol Backbone is central point of this implementation (It is Area 0).
- Routers running in this area required to maintain complete database of entire network.
- All areas in OSPF are needed to connect with this area (Area 0).

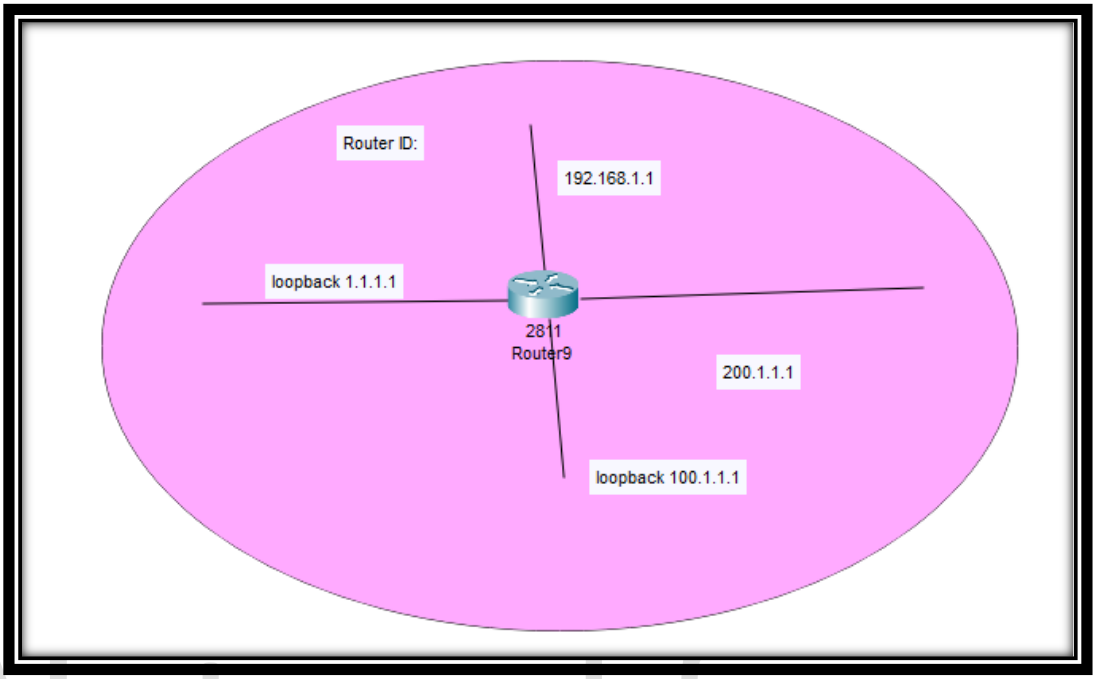
Area off Backbone:

- In OSPF area off backbone is the extension of the backbone.
- Routers running in this area required to maintain specific database instead of complete.



Router Id:

- Every router in OSPF network needs the unique OSPF Router ID.
- The OSPF Router ID is used to provide and give a unique identity to the OSPF router.
- There are different ways in OSPF protocol which is can be identified.
- The Highest IP address of the active Physical Interface of the router becomes the router ID.
- If a logical interface is configured then Highest IP address of logical interface become Router ID.
- If specify the Router ID manually then it takes priority over all and become the Router ID.
- In other words we can say OSPF Router identify themselves using an OSPF router ID which is in the form of an IP address.
- (Loopback) is configured; the highest IP address of the logical interface is taken as Router Id. Or in other words This will default to being the highest ip address of any loopback interfaces configured on the router, or the highest other ip address if a loop back does not exist.
- Loop back interface never go down so the router ID will not change. So it will be good to create loop back.
- You can also manually specify the router ID.
- Best practices are to use a Loopback or manually set the router ID.



How to check what is router Id? --- Type sh ip protocol.

How to configure Router Id?

Router Id Configuration:

Router ospf 1
Router-id 1.1.1.1

Then try to reload or use clear ip ospf process command for this to take effect.

R1#clear ip ospf process

Link:

- Link is an interface running OSPF routing protocol.
- When we add an interface in OSPF process, it will be considered as a link.

State:

- In OSPF state is the information associated with an interface.
- A link or interface contains several information such as IP address, UP or Down status, subnet.
- A Link also have subnet mask, type of interface, type of network, bandwidth and delay etc.
- OSPF dynamic protocols consider this information as the state.

LSA:

- Link State Advertisement (LSA) is data packet; it contains Link-State and routing information.
- OSPF uses it to share and learn network information.

LSDB:

- Every OSPF router maintains a Link State Database (LSDB).
- Link State Database (LSDB) is collection of all Link State Advertisement received by router.
- Every LSA has unique sequence numbers, OSPF stores LSA in LSDB with sequence number.

Internal Router:

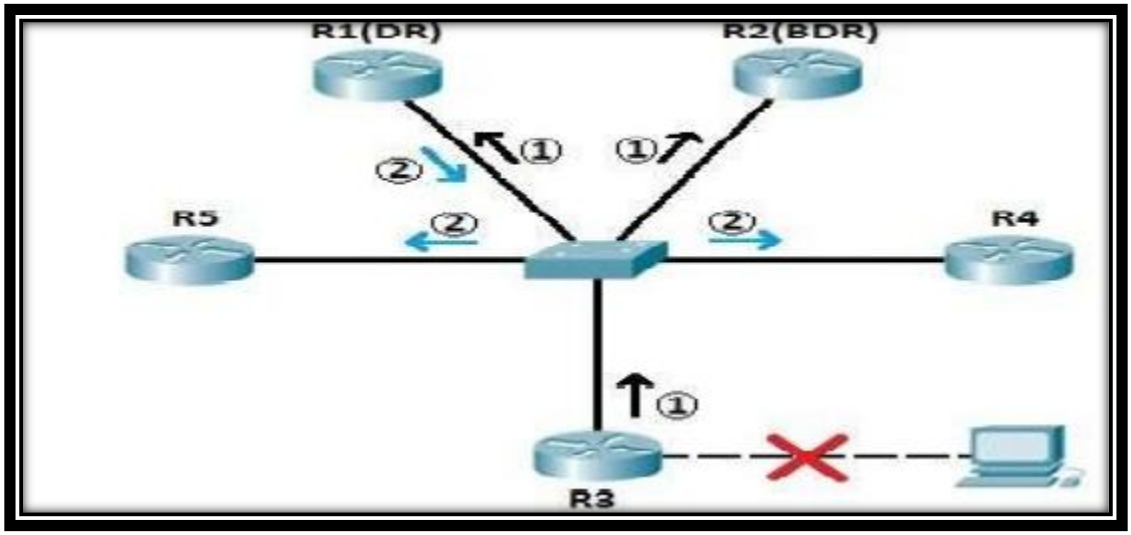
- It is a router that has only OSPF neighbor relationships with routers in the same area.
- In OSPF internal Router has all of its interfaces in single areas.

Backbone Router:

- The Area 0 is known as backbone area and the routers in area 0 are known as backbone Router. If the routers exist partially in the area 0 then also it is a Backbone Router.

Designated Router (DR) and Backup Designated Router (BDR):

- Designated Router is router interface elected among all routers on network segment.
- And Backup designated (BDR) is a backup for the Designated Router (DR) in OSPF.
- DRs are used for reducing network traffic by providing a source for routing updates.
- The Designated Rotuer (DR) maintains a complete topology table of the network.
- The DR sends the updates to the others routers via multicast.
- All routers in an area will form slave- master relationship with Designated Router (DR).



Router Priority:

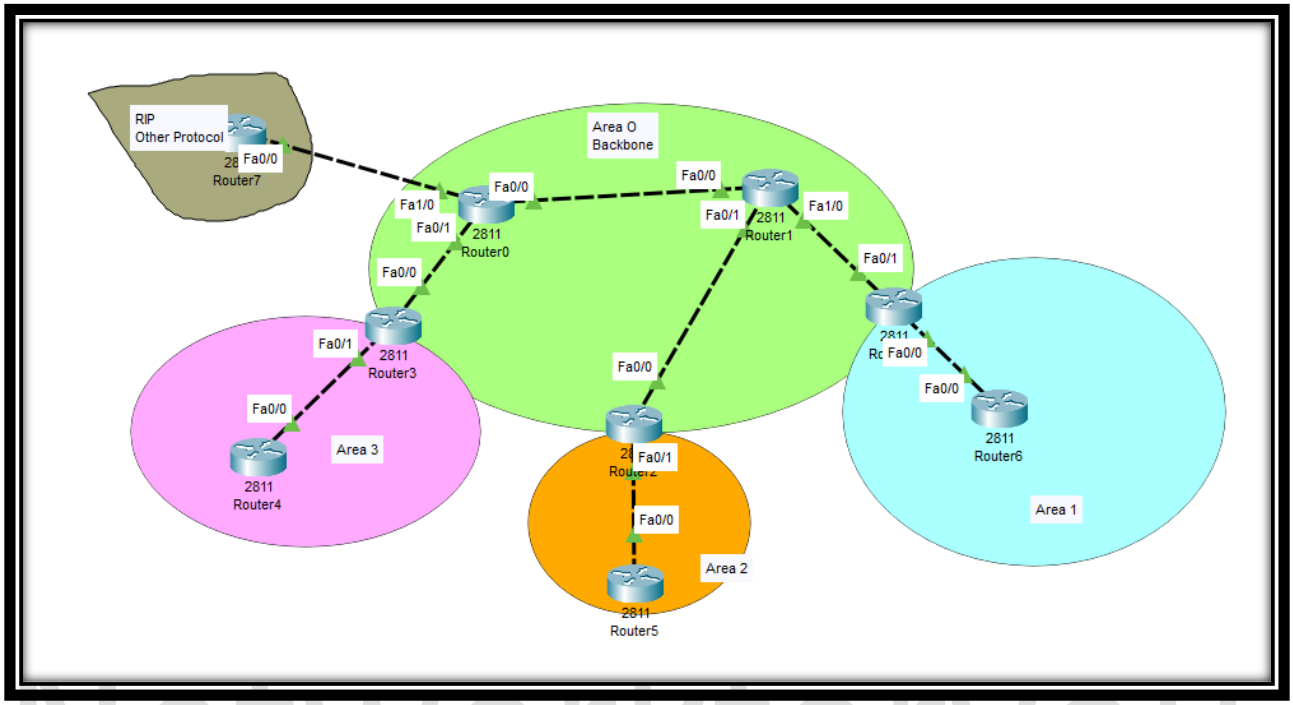
- It is used to determine who will become Designated or Backup Designated Router.
- In OSPF the default priority is one (1).
- In OSPF router Priority value range is between 0 to 255.
- The range of priority values that allow a router to be a candidate are 1 to through 255.
- A priority setting of zero (0) means router can never become the DR or BDR.

Area Border Router (ABR):

- ABR is router that connects one or more OSPF Areas to the main backbone network (Area 0).

Autonomous System Boundary Router (ASBR):

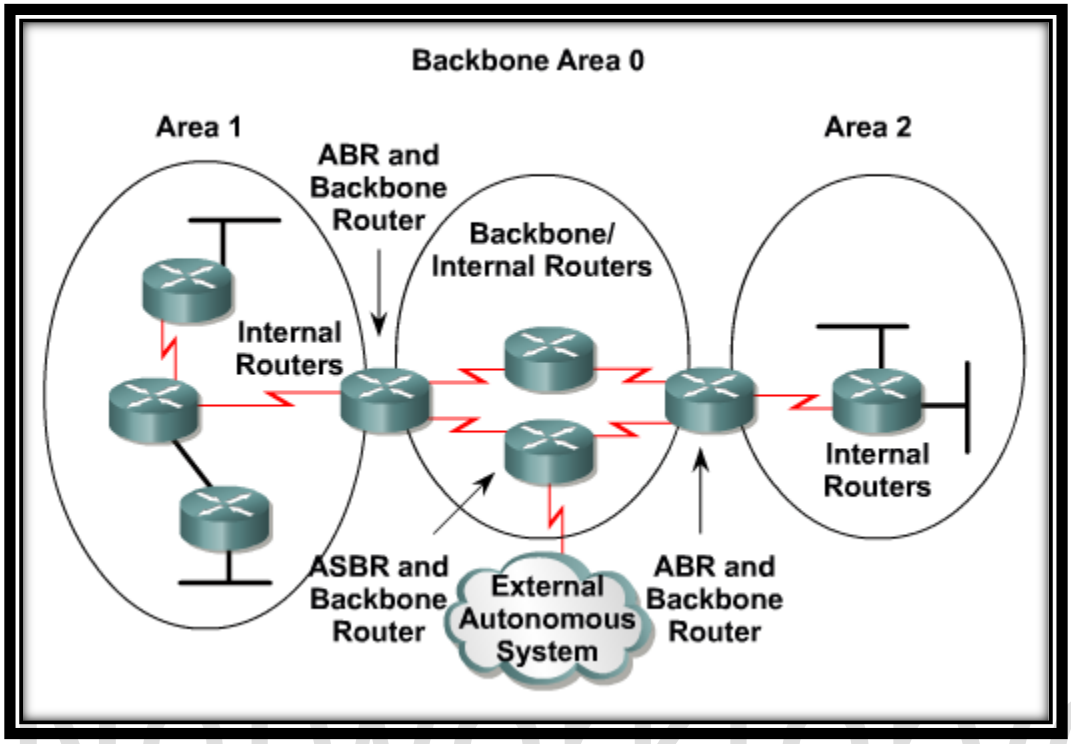
- If it is one interface is in OSPF domain and other Interface is in any other routing protocol.
- It requires redistribution in order to make router as Autonomous system boundary router.
- To check the Autonomous System Boundary Router run the command: sh ip protocols.



OSPF Version 2 for IPV 4 and if you are using IP Version 6 then OSPF Version 3

Area Concept in OSPF:

- Internal Router = within same area (Routers received from other routers in the same area appear as Internal OSPF Area)
- Backbone Router = Area 0 (The Area 0 is known as backbone area and the routers in area 0 are known as backbone Router. If the routers exist partially in the area 0 then also it is a Backbone Router.)
- ASBR = Autonomous system boundary router ---------- Connect different protocol.
- ABR = Area Border Router ---------- It connect from different Area to Area 0. (Example one Interface in other Area and other interface is in Area 0)



OSPF Basic configuration:

- OSPF Protocols use wild card mask which is 32 bits long.
- It is inverted of subnet masks with the zero bits indicating that the corresponding bit position must match the same bit position in the IP address.
- The one bit indicates that the corresponding bit position does not have to match the bit positon in the IP address.

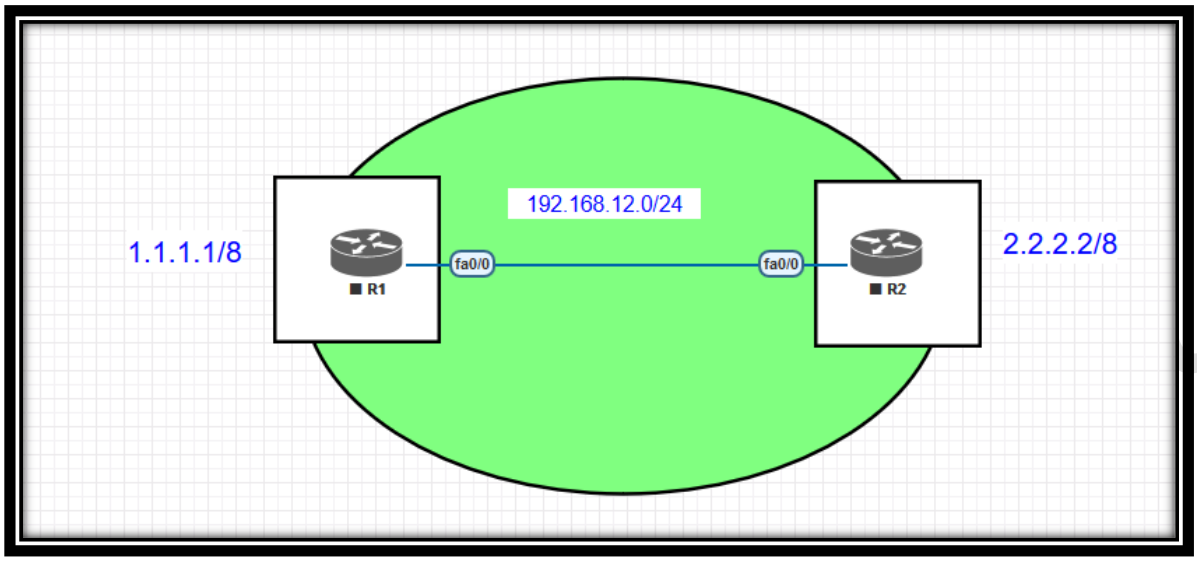
Neighbor Configuration:

- To make two OSPF routers neighbors, simple enable OSPF on the connected interfaces.
- There are two ways to enable OSPF like by using the network command or by enabling the OSPF proves on the interface directly.

OSPF Neighbor Requirements are given below:

- Hello and dead timers must match
- The devices must be on the same subnet.
- The devices must not be passive on connected Interface.
- The devices must be in the same area.
- The devices must have unique Router ID.
- The devices must have the same authentication configuration if they have then.
- If MTU mismatch then OSPF Neighbors stuck in exstart (MTU must be same on both neighbors else it will stuck in exstart).

Lab Time:



Router R1 Configuration:	Router R2 Configuration:
en config t hostname R1 int f0/0 ip add 192.168.12.1 255.255.255.0 no sh int loopback 0 ip add 1.1.1.1 255.0.0.0 no sh	en config t hostname R2 int f0/0 ip add 192.168.12.2 255.255.255.0 no sh int loopback 0 ip add 2.2.2.2 255.0.0.0 no sh

router ospf 1 network 192.168.12.0 0.0.0.255 area 0 network 1.0.0.0 0.255.255.255 area 0	router ospf 1 network 192.168.12.0 0.0.0.255 area 0 network 2.0.0.0 0.255.255.255 area 0
Sh ip ospf neighbor	To Verify OSPF neighbor relationship
Sh ip ospf interface f0/0	To Verfy OSPF neighbor relationship
Sh ip ospf	To Verify OSPF Process
Sh ip ospf database	To Verify OSPF database
Sh ip protocols	To Verify running protocols on Router
debug ip ospf packet	ON debug for OSPF packets
debug ip ospf hello	ON debug for OSPF Hello Packet

```
R2#Sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
1.1.1.1           1   FULL/BDR        00:00:38    192.168.12.1    FastEthernet0/0
R2#
R2#
R2#
R2#
R2#
R2#
R2#
R2#Sh ip ospf interface f0/0
FastEthernet0/0 is up, line protocol is up
  Internet Address 192.168.12.2/24, Area 0
  Process ID 1, Router ID 2.2.2.2, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 2.2.2.2, Interface address 192.168.12.2
  Backup Designated router (ID) 1.1.1.1, Interface address 192.168.12.1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:01
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, 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 1.1.1.1  (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
R2#
```

```
R2#Sh ip ospf
 Routing Process "ospf 1" with ID 2.2.2.2
 Start time: 00:09:06.844, Time elapsed: 00:48:49.320
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 Supports Link-local Signaling (LLS)
 Supports area transit capability
 Event-log enabled, Maximum number of events: 1000, Mode: cyclic
 Router is not originating router-LSAs with maximum metric
 Initial SPF schedule delay 5000 msecs
 Minimum hold time between two consecutive SPFs 10000 msecs
 Maximum wait time between two consecutive SPFs 10000 msecs
 Incremental-SPF disabled
 Minimum LSA interval 5 secs
 Minimum LSA arrival 1000 msecs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 1. 1 normal 0 stub 0 nssa
 Number of areas transit capable is 0
 External flood list length 0
 IETF NSF helper support enabled
 Cisco NSF helper support enabled
 Reference bandwidth unit is 100 mbps
    Area BACKBONE(0)
        Number of interfaces in this area is 2 (1 loopback)
        Area has no authentication
        SPF algorithm last executed 00:48:08.032 ago
        SPF algorithm executed 3 times
        Area ranges are
        Number of LSA 3. Checksum Sum 0x0112D7
        Number of opaque link LSA 0. Checksum Sum 0x000000
        Number of DCbitless LSA 0
```

```
R2#Sh ip ospf database

            OSPF Router with ID (2.2.2.2) (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         1019        0x80000004 0x004ADA 2
2.2.2.2         2.2.2.2         1020        0x80000004 0x003ADD 2

                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.12.2    2.2.2.2         1020        0x80000002 0x008D20
```

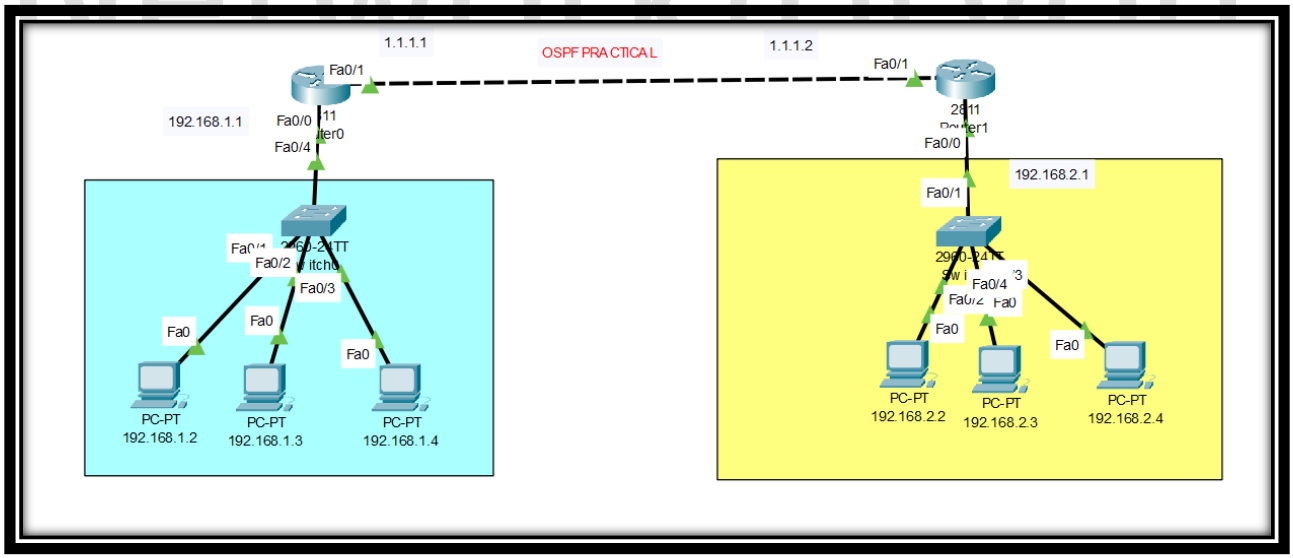
```
R2#Sh ip protocols
*** IP Routing is NSF aware ***

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 2.2.2.2
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    2.0.0.0 0.255.255.255 area 0
    192.168.12.0 0.0.0.255 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    1.1.1.1              110      00:52:42
  Distance: (default is 110)
```

```
R2#debug ip ospf packet
OSPF packet debugging is on
R2#
*Oct  6 22:13:01.899: OSPF: rcv. v:2 t:1 l:48 rid:1.1.1.1
      aid:0.0.0.0 chk:4D40 aut:0 auk: from FastEthernet0/0
*Oct  6 22:13:11.867: OSPF: rcv. v:2 t:1 l:48 rid:1.1.1.1
      aid:0.0.0.0 chk:4D40 aut:0 auk: from FastEthernet0/0
*Oct  6 22:13:20.879: OSPF: rcv. v:2 t:1 l:48 rid:1.1.1.1
      aid:0.0.0.0 chk:4D40 aut:0 auk: from FastEthernet0/0
*Oct  6 22:13:30.051: OSPF: rcv. v:2 t:1 l:48 rid:1.1.1.1
      aid:0.0.0.0 chk:4D40 aut:0 auk: from FastEthernet0/0
*Oct  6 22:13:39.503: OSPF: rcv. v:2 t:1 l:48 rid:1.1.1.1
      aid:0.0.0.0 chk:4D40 aut:0 auk: from FastEthernet0/0
R2#u all
All possible debugging has been turned off
R2#
*Oct  6 22:13:49.475: OSPF: rcv. v:2 t:1 l:48 rid:1.1.1.1
      aid:0.0.0.0 chk:4D40 aut:0 auk: from FastEthernet0/0
```

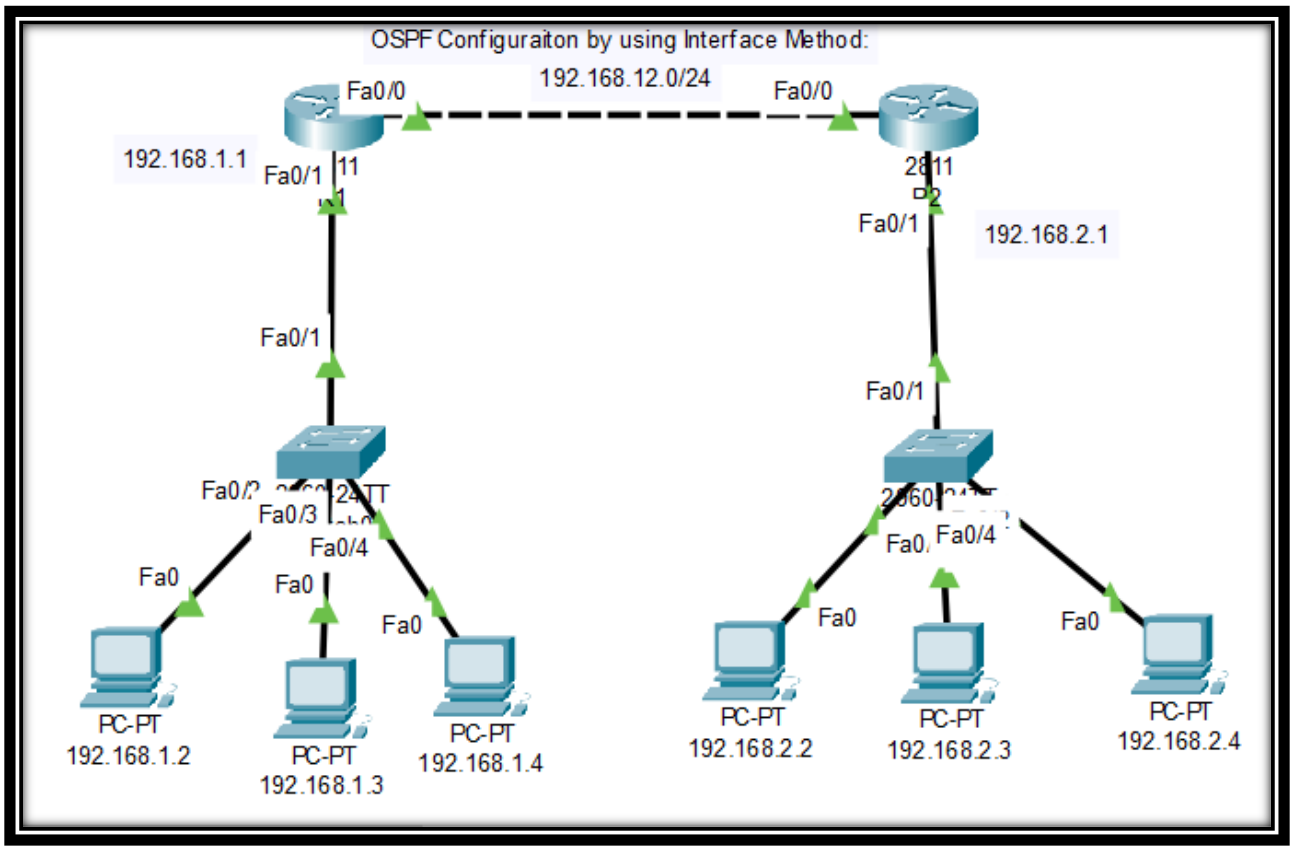
```
R2#debug ip ospf hello
OSPF hello events debugging is on
R2#
*Oct  6 22:14:46.703: OSPF: Rcv hello from 1.1.1.1 area 0 from FastEthernet0/0 192.168.12.1
*Oct  6 22:14:46.707: OSPF: End of hello processing
*Oct  6 22:14:53.511: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/0 from 192.168.12.2
*Oct  6 22:14:55.771: OSPF: Rcv hello from 1.1.1.1 area 0 from FastEthernet0/0 192.168.12.1
*Oct  6 22:14:55.771: OSPF: End of hello processing
*Oct  6 22:15:02.615: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/0 from 192.168.12.2
*Oct  6 22:15:04.919: OSPF: Rcv hello from 1.1.1.1 area 0 from FastEthernet0/0 192.168.12.1
*Oct  6 22:15:04.919: OSPF: End of hello processing
*Oct  6 22:15:12.063: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/0 from 192.168.12.2
*Oct  6 22:15:14.247: OSPF: Rcv hello from 1.1.1.1 area 0 from FastEthernet0/0 192.168.12.1
*Oct  6 22:15:14.247: OSPF: End of hello processing
R2#
*Oct  6 22:15:22.055: OSPF: Send hello to 224.0.0.5 area 0 on FastEthernet0/0 from 192.168.12.2u
all
All possible debugging has been turned off
R2#
*Oct  6 22:15:23.351: OSPF: Rcv hello from 1.1.1.1 area 0 from FastEthernet0/0 192.168.12.1
*Oct  6 22:15:23.351: OSPF: End of hello processing
```

Lab 2:



R1 Configuration	R2 Configuration
en config t hostname R1 int f0/0 ip add 192.168.1.1 255.255.255.0 no sh int f0/1 ip add 1.1.1.1 255.0.0.0 no sh router ospf 1 network 192.168.1.0 0.0.0.255 area 0 network 1.0.0.0 0.255.255.255 area 0	en config t hostname R2 int f0/0 ip add 192.168.2.1 255.255.255.0 no sh int f0/1 ip add 1.1.1.2 255.0.0.0 no sh router ospf 1 network 192.168.2.0 0.0.0.255 area 0 network 1.0.0.0 0.255.255.255 area 0

Lab 3 Configuration of OSPF by using Interface Method:



R1 Configuration:	R2 Configuration
en config t hostname R1 int f0/0 ip add 192.168.12.1 255.255.255.0 no sh int f0/1 ip add 192.168.1.1 255.255.255.0 no sh	en config t hostname R2 int f0/0 ip add 192.168.12.2 255.255.255.0 no sh int f0/1 ip add 192.168.2.1 255.255.255.0 no sh

router ospf 1 router-id 1.1.1.1 int f0/0 ip ospf 1 area 0 int f0/1 ip ospf 1 area 0	router ospf 1 router-id 2.2.2.2 int f0/0 ip ospf 1 area 0 int f0/1 ip ospf 1 area 0

OSPF Metric:

- OSPF uses a metric called cost, which is based on the bandwidth of an interface.
- We can use this formula to calculate Cost. **Cost = Reference Bandwidth / Interface Bandwidth**
- The reference bandwidth is a default values on CISCO routers is 100Mbps (10^8) interface.
- So we can divide the reference bandwidth by the bandwidth of the interface and we will get the cost.
- The lower the cost the better the path is.
- In router that has lowest cumulative cost value between source and destination will be selected for routing tables.
- If two paths is equal cost, then OSPF will use both paths and do load balance amount them 50-50.

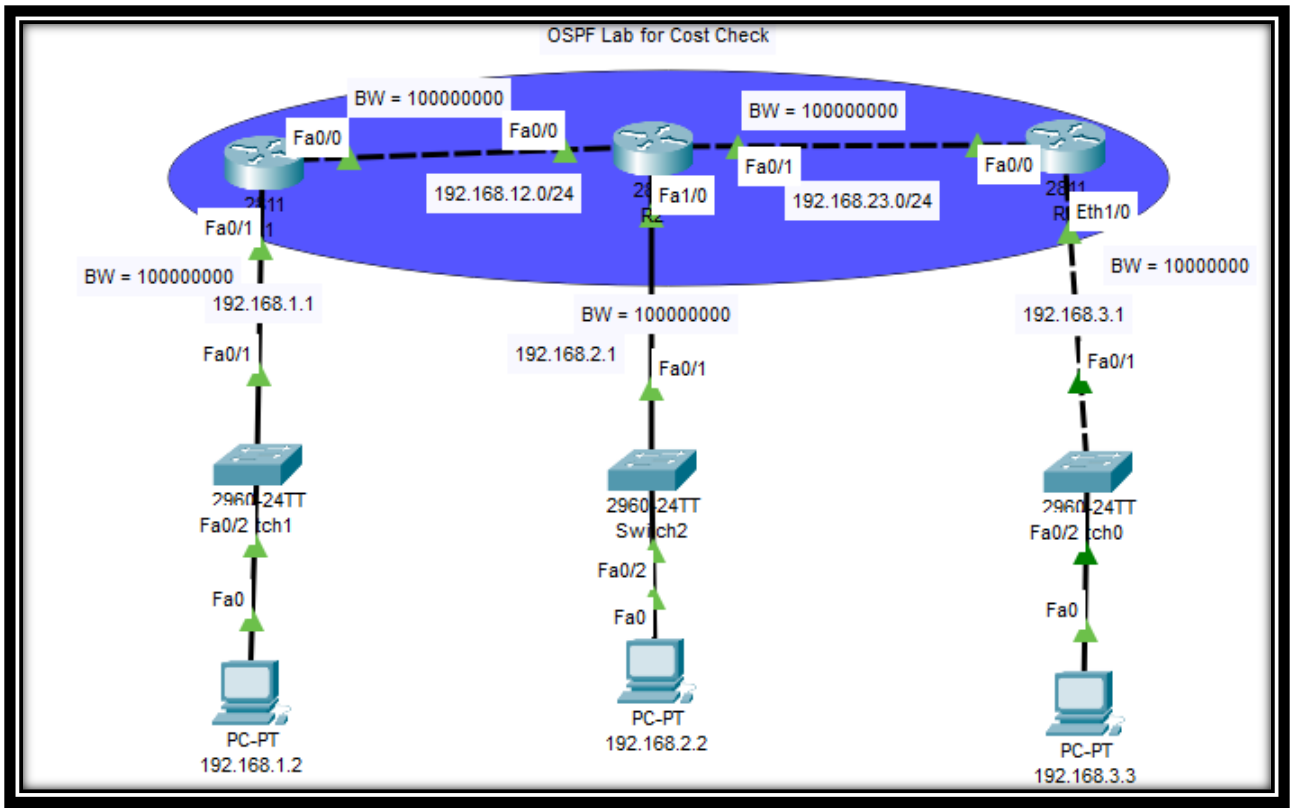
Default Cost of an Interfaces			
Interface Type	**Bandwidth**	**Metric Calculation**	**Cost**
Ethernet Link	10Mbps	100000000/10000000=10	10
FastEthernet Link	100Mbps	100000000/100000000 = 1	1
Serial Link	1544Kbps	100000000/1544000 = 64.76	64
Gigabyte Link	1 Gbps		1
10 Gigabit Link	10 Gbps		1
40 Gigabit Link	40 Gbps		1
100 Gigabit Link	100 Gbps		1

Note: Megabyte is the unit of digital information with prefix mega (10^6). 1 Megabyte is equal to 10^6 bytes = 1,000,000 bytes in decimal (SI)

OSPF Lab for Cost Verification:

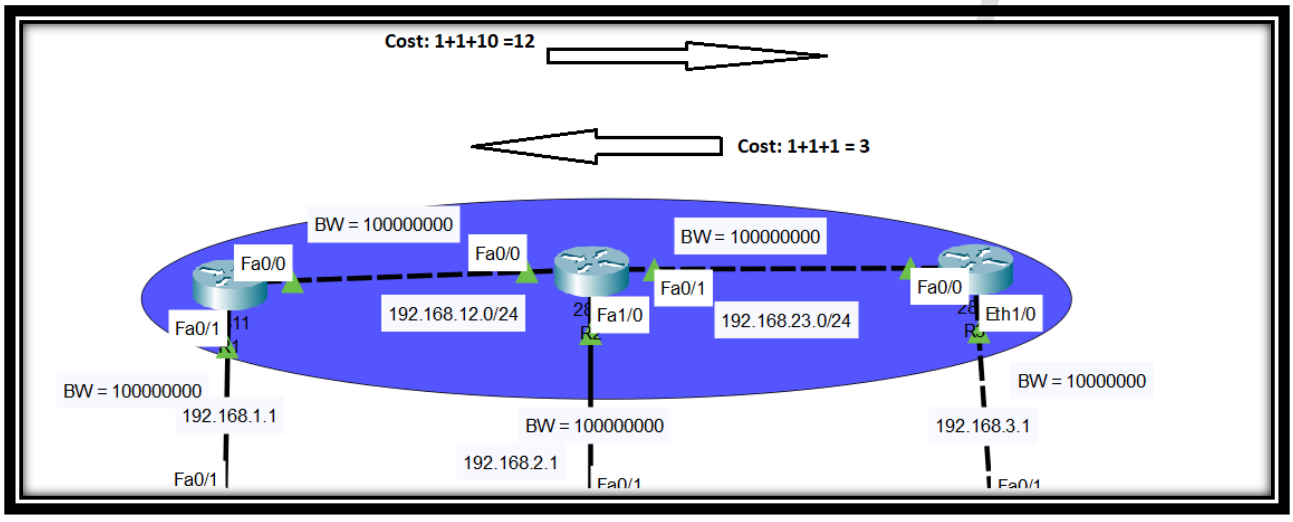
- In this lab we are using 3x Router and one router interface we will keep as Ethernet and all other router interface as Fast Ethernet.

- So in this Lab we will see cost for different between Fast Ethernet and Ethernet.
- That is Ethernet interface will have 10 as cost where as Fast Ethernet will have 1 as cost.
- Let see below is given the topology diagram and configuration for this lab.



R1 Configuration	R2 Configuration	R3 Configuration
en config t hostname R1 int f0/1 ip add 192.168.1.1 255.255.255.0 no sh	en config t hostname R2 int f0/1 ip add 192.168.23.1 255.255.255.0 no sh	en config t hostname R3 int eth1/0 ip add 192.168.3.1 255.255.255.0 no sh

int f0/0 ip add 192.168.12.1 255.255.255.0 no sh router ospf 1 int f0/0 ip ospf 1 area 0 int f0/1 ip ospf 1 area 0	int f0/0 ip add 192.168.12.2 255.255.255.0 no sh int f1/0 ip add 192.168.2.1 255.255.255.0 no sh router ospf 1 int f0/0 ip ospf 1 area 0 int f0/1 ip ospf 1 area 0 int f1/0 ip ospf 1 area 0	int f0/0 ip add 192.168.23.2 255.255.255.0 no sh router ospf 1 int f0/0 ip ospf 1 area 0 int eth1/0 ip ospf 1 area 0



From PC 192.168.1.2 to PC 192.168.3.2 total OSPF Cost is 12 because in the way one Ethernet Link which is connected between R3 to PC 192.168.3.2. Cost is counting from outgoing interfaces to reach destination.

```
R1#sh ip route
Codes: C - connected, S - static, I - IGRP, 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

C    192.168.1.0/24 is directly connected, FastEthernet0/1
O    192.168.2.0/24 [110/2] via 192.168.12.2, 00:07:12, FastEthernet0/0
O    192.168.3.0/24 [110/12] via 192.168.12.2, 00:06:14, FastEthernet0/0
C    192.168.12.0/24 is directly connected, FastEthernet0/0
O    192.168.23.0/24 [110/2] via 192.168.12.2, 00:06:24, FastEthernet0/0
```

Here Cost is 12 Because we use Ethernet Interface

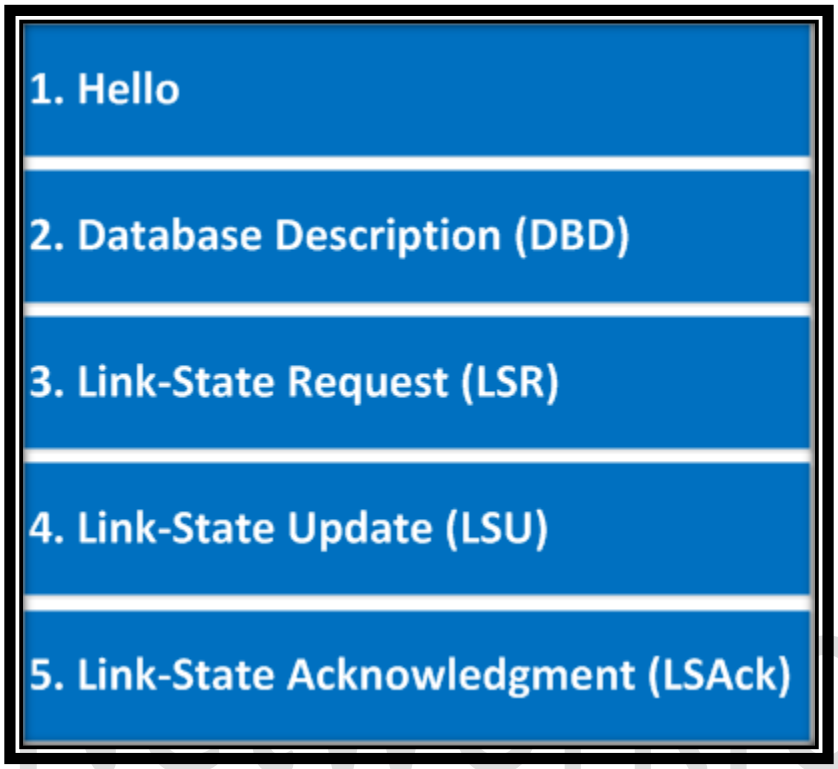
```
R3#sh ip ospf int f0/0

FastEthernet0/0 is up, line protocol is up
  Internet address is 192.168.23.2/24, Area 0
  Process ID 1, Router ID 192.168.23.2, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.23.2, Interface address 192.168.23.2
  Backup Designated Router (ID) 192.168.23.1, Interface address 192.168.23.1
  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 192.168.23.1  (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
```

```
R3#sh ip ospf int e1/0

Ethernet1/0 is up, line protocol is up
  Internet address is 192.168.3.1/24, Area 0
  Process ID 1, Router ID 192.168.23.2, Network Type BROADCAST, Cost: 10
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.23.2, Interface address 192.168.3.1
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
  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 0, Adjacent neighbor count is 0
  Suppress hello for 0 neighbor(s)
```

OSPF Packet Types:



- OSPF uses its own protocol like EIGRP and doesn't use TCP or UDP.
- OSPF has protocols # 89 for all its Packets.
- OSPF have 5 packets as given above.
- **Hello:** neighbor discovery, building neighbor adjacencies and maintain them.
- **DBD:** This packet is used to check if the LSDB between 2 routers is the same (The DBD is a summary of the LSDB).
- **LSR:** Requests specific link-state records from an OSPF neighbor.
- **LSU:** Sends Specific Link-state records that were requested (This packet is like an envelope with multiple LSAs in its)
- **LSAck:** OSPF is a reliable protocol so we have a packet to acknowledge the others.

No.	Time	Source	Destination	Protocol	Length	Info
34	53.938570	192.168.12.1	192.168.12.2	OSPF	78	DB Description
37	55.463009	192.168.12.2	224.0.0.5	OSPF	94	Hello Packet
38	55.670231	192.168.12.1	224.0.0.5	OSPF	94	Hello Packet
39	58.198497	192.168.12.2	192.168.12.1	OSPF	78	DB Description
40	58.209628	192.168.12.1	192.168.12.2	OSPF	98	DB Description
41	58.220756	192.168.12.2	192.168.12.1	OSPF	98	DB Description
42	58.231888	192.168.12.1	192.168.12.2	OSPF	70	LS Request
43	58.231899	192.168.12.1	192.168.12.2	OSPF	78	DB Description
44	58.242204	192.168.12.2	192.168.12.1	OSPF	98	LS Update
45	58.242214	192.168.12.2	192.168.12.1	OSPF	70	LS Request
46	58.252455	192.168.12.1	192.168.12.2	OSPF	110	LS Update
47	58.263590	192.168.12.2	224.0.0.5	OSPF	110	LS Update
48	58.274717	192.168.12.1	192.168.12.2	OSPF	78	LS Acknowledge
49	58.699993	192.168.12.2	224.0.0.5	OSPF	94	LS Update
50	58.730304	192.168.12.2	224.0.0.5	OSPF	98	LS Update
51	58.750474	192.168.12.1	224.0.0.6	OSPF	110	LS Update
52	58.772042	192.168.12.2	224.0.0.5	OSPF	110	LS Update
53	60.741040	192.168.12.1	224.0.0.6	OSPF	118	LS Acknowledge
54	60.761217	192.168.12.2	224.0.0.5	OSPF	98	LS Acknowledge

R1# debug ip ospf packet

***Oct 9 19:46:49.383: OSPF: rcv. v:2 t:1 l:48 rid:2.2.2.2**
aid:0.0.0.0 chk:4D40 aut:0 auk: from FastEthernet0/0

If we use debug ip OSPF packet we can look at the OSPF packet on our routers.
Let see different field we have as show above.

- **V:2** stand for OSPF Version 2. If we run IPV6 then we will have Version 3.
- **T:1** stands for OSPF packet number 1 which is a hello packet.
- **L:48** is the packet length in Bytes.
- **RID: 2.2.2.2** is the Router ID.
- **AID** is the area ID in dotted decimal (we can write decimal area 0 or dotted decimal (area 0.0.0.0).
- **CHK 4D40** is the checksum of this OSPF packet so we can check if the packet is corrupt or not.
- **AUT:0** is the authentication type. We have 3 options: 0 mean no authentication, 1= Clear test and 2 = MD5.
- **AUK:** If we enable authentication, we will see some information here.

OSPF States:

OSPF has to get through 7 states in order to become neighbors.

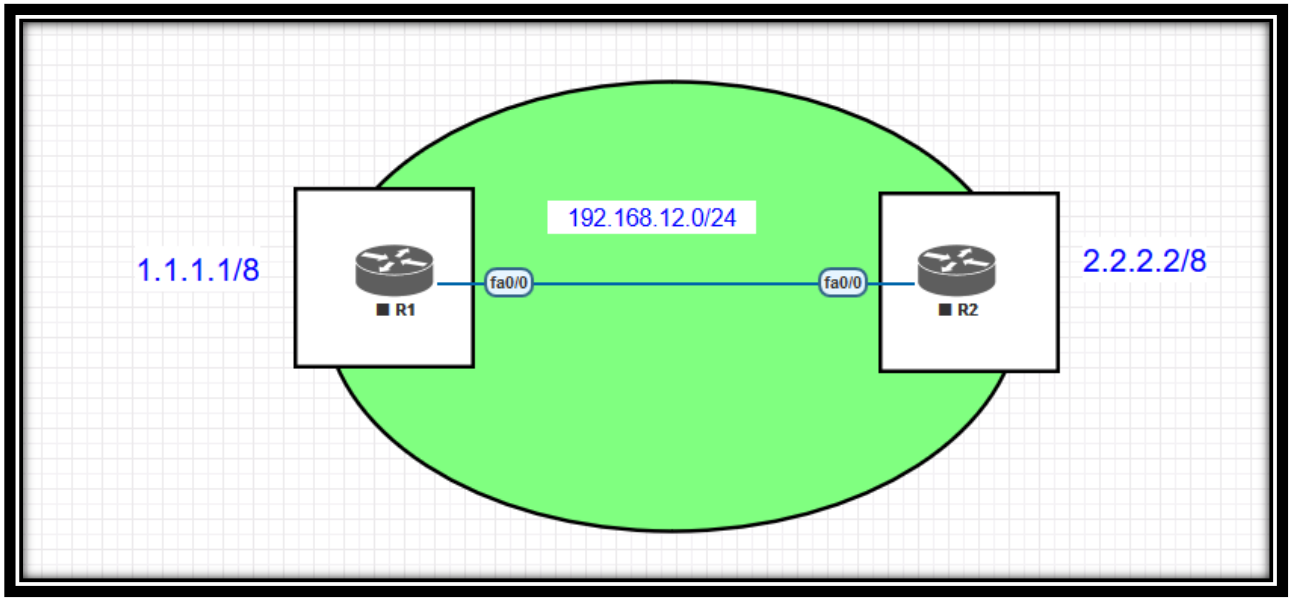
1. **Down:** no OSPF neighbors detected at this moment. (When OSPF is not working)
2. **Init:** The interface has detected a Hello packet coming from a neighbor, but bi-directional communication has not yet been established. (1 Side Hello)
3. **Two-way:** When hello is exchanged between two OSPF routers that is called 2 way. Designated Router (DR) and BDR is elected in this stage. (2 Side Hello)
4. **Exstart State**: Beginning of the LSDB exchange between both routers. Routers will start to exchange link state information. Master & slave is elected in this stage. (DBD exchange going on)
5. **Exchange State**: Routers will describe their entire link-state database by sending database description packets. At this state, packets could be flooded to other interfaces on the router. (DBD Done)
6. **Loading State**: In this state actual database is exchanged means that LS-Request, LS-Update, LS Acknowledgement are also exchanged. (LSR, LSU, Ask)
7. **Full State**: At this state, the adjacency is complete. The neighboring routers are fully adjacent. Adjacent routers will have a similar link-state database. (Done)

Let see that this states in Router R1 First we need to debug in router as given below.

R1# debug ip ospf adj

R1# clear ip ospf process

Reset all OSPF process [no]: yes




```
*Oct  9 23:36:55.767: OSPF: Nbr state is 2WAY
*Oct  9 23:37:00.767: OSPF: Rcv DBD from 2.2.2.2 on FastEthernet0/0 seq 0x208C opt 0x52 flag 0x7 len 32  mtu 1500 state 2W
AY
*Oct  9 23:37:00.767: OSPF: Nbr state is 2WAY
R1#
R1#
*Oct  9 23:37:05.543: OSPF: Rcv DBD from 2.2.2.2 on FastEthernet0/0 seq 0x208C opt 0x52 flag 0x7 len 32  mtu 1500 state 2W
AY
*Oct  9 23:37:05.543: OSPF: Nbr state is 2WAY
*Oct  9 23:37:10.535: OSPF: Rcv DBD from 2.2.2.2 on FastEthernet0/0 seq 0x208C opt 0x52 flag 0x7 len 32  mtu 1500 state 2W
AY
*Oct  9 23:37:10.535: OSPF: Nbr state is 2WAY
*Oct  9 23:37:15.379: OSPF: Rcv DBD from 2.2.2.2 on FastEthernet0/0 seq 0x208C opt 0x52 flag 0x7 len 32  mtu 1500 state 2W
AY
*Oct  9 23:37:15.379: OSPF: Nbr state is 2WAY
*Oct  9 23:37:20.075: OSPF: Rcv DBD from 2.2.2.2 on FastEthernet0/0 seq 0x208C opt 0x52 flag 0x7 len 32  mtu 1500 state 2W
AY
*Oct  9 23:37:20.075: OSPF: Nbr state is 2WAY
*Oct  9 23:37:24.987: OSPF: Rcv DBD from 2.2.2.2 on FastEthernet0/0 seq 0x208C opt 0x52 flag 0x7 len 32  mtu 1500 state 2W
AY
*Oct  9 23:37:24.987: OSPF: Nbr state is 2WAY
*Oct  9 23:37:27.323: OSPF: end of Wait on interface FastEthernet0/0
*Oct  9 23:37:27.323: OSPF: DR/BDR election on FastEthernet0/0
*Oct  9 23:37:27.323: OSPF: Elect BDR 1.1.1.1
*Oct  9 23:37:27.323: OSPF: Elect DR 2.2.2.2
*Oct  9 23:37:27.323: OSPF: Elect BDR 1.1.1.1
*Oct  9 23:37:27.323: OSPF: Elect DR 2.2.2.2
*Oct  9 23:37:27.323:       DR: 2.2.2.2 (Id)   BDR: 1.1.1.1 (Id)
*Oct  9 23:37:27.323: OSPF: FastEthernet0/0 Nbr 2.2.2.2: Prepare dbase exchange
*Oct  9 23:37:27.323: OSPF: Send DBD to 2.2.2.2 on FastEthernet0/0 seq 0x1 opt 0x52 flag 0x7 len 32
*Oct  9 23:37:29.803: OSPF: Rcv DBD from 2.2.2.2 on FastEthernet0/0 seq 0x208C opt 0x52 flag 0x7 len 32  mtu 1500 state EX
START
*Oct  9 23:37:29.803: OSPF: NBR Negotiation Done. We are the SLAVE
*Oct  9 23:37:29.803: OSPF: FastEthernet0/0 Nbr 2.2.2.2: Summary list built, size 1
*Oct  9 23:37:29.803: OSPF: Send DBD to 2.2.2.2 on FastEthernet0/0 seq 0x208C opt 0x52 flag 0x2 len 52
*Oct  9 23:37:29.815: OSPF: Rcv DBD from 2.2.2.2 on FastEthernet0/0 seq 0x208D opt 0x52 flag 0x1 len 52  mtu 1500 state EX
CHANGE
*Oct  9 23:37:29.815: OSPF: Exchange Done with 2.2.2.2 on FastEthernet0/0
*Oct  9 23:37:29.815: OSPF: Send LS REQ to 2.2.2.2 length 12 LSA count 1
*Oct  9 23:37:29.815: OSPF: Send DBD to 2.2.2.2 on FastEthernet0/0 seq 0x208D opt 0x52 flag 0x0 len 32
*Oct  9 23:37:29.827: OSPF: Rcv LS UPD from 2.2.2.2 on FastEthernet0/0 length 76 LSA count 1
*Oct  9 23:37:29.827: OSPF: Synchronized with 2.2.2.2 on FastEthernet0/0, state FULL
*Oct  9 23:37:29.827: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthernet0/0 from LOADING to FULL, Loading Done
*Oct  9 23:37:29.827: OSPF: Rcv LS REQ from 2.2.2.2 on FastEthernet0/0 length 36 LSA count 1
*Oct  9 23:37:30.327: OSPF: Build router LSA for area 0, router ID 1.1.1.1, seq 0x80000002, process 1
R1#
```

DR (Designated Router) and BDR (Backup Designated Router):

- Open Shortest Path First (OSPF) uses DR and BDR on each multi-access network.
- DR & BDR election occurs in multi-access Broadcast & Non-Broadcast network types.
- DR is the Router in charge to maintain the Open Shortest Path First topology table.
- DR is the Router in charge to distribute updates to other routers within same segment.
- When a router is not the Designated Router (DR) or BDR it is called a DROTHER.
- All other routers will form adjacencies only with the elected DR and BDR routers.
- DR reduces the network traffic between neighbors by providing single source of updates.
- It is possible to change the priority if we like by using the ip ospf priority, command.
- Default Open Shortest Path First (OSPF) priority is set to one (1) which can be changed.
- A priority of 0 means the router can never be elected as Designated Router DR or BDR.
- In Open Shortest Path First (OSPF) use clear ip ospf process before change takes effect.

DR and BDR Election:

The default Designated Router (DR) election criteria are as follows:

- The Router configured with the highest priority wins the election.
- The default priority is 1 and the possible values range between 0 – 255.
- If the priority is set to 0, the router will not participate in the DR/BDR election.
- If the routers configured priority, tie then it uses highest Router ID (RID) as tiebreaker.
- Router with the second highest priority value becomes the Backup Designated Router.
- If a router with the higher priority comes online after the election has taken place;
- It will not become Designated Router (DR) or BDR until DR and BDR router fail.
- If the DR fails, BDR will take over; another election will take place to elect a new BDR.
- In Designated Router and Backup Designated Router, Preemption is not supported.
- First router to come up will be DR and the second will be Backup Designated Router.
- Each other router will exchange routing information only with the DR and the BDR.
- DR will then distribute topology information to every other router inside the same area.
- To send routing information to a DR or BDR, the multicast address of 224.0.0.6 is used.
- A Designated Router DR sends routing updates to the multicast address of 224.0.0.5.
- If the DR fails, the BDR will take its role of redistributing routing information to other.

Configuration for Setting OSPF priority:

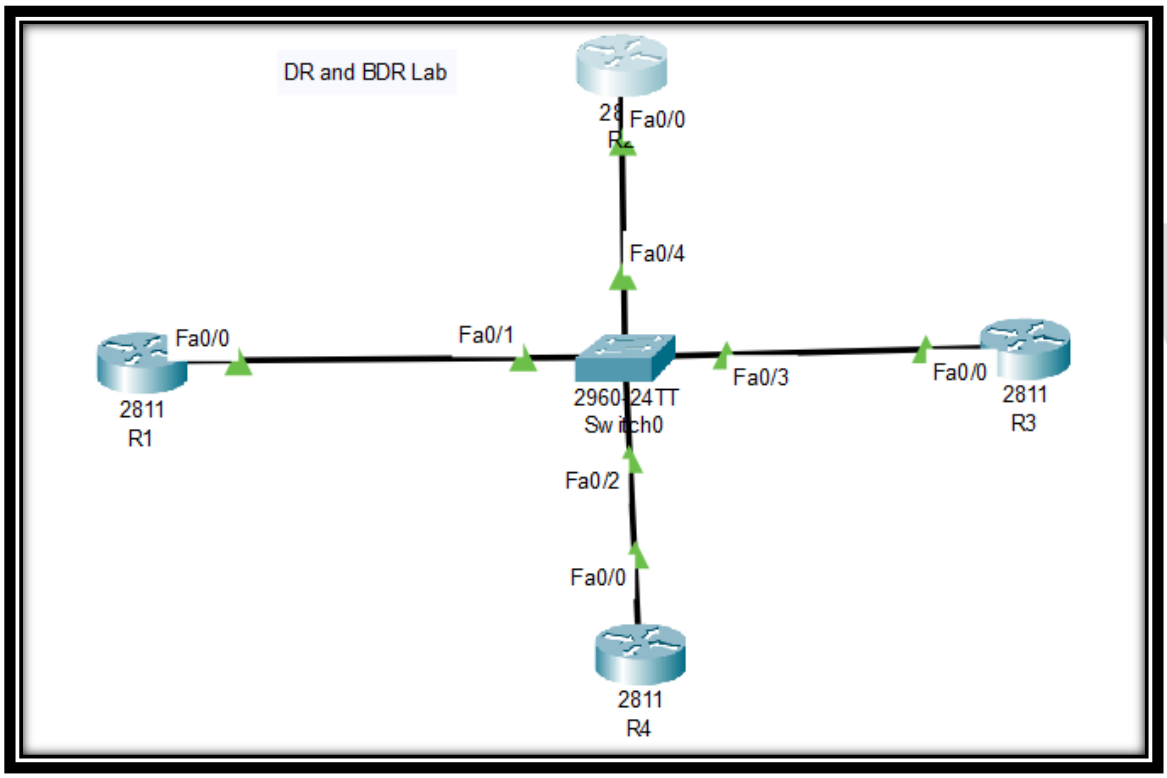
Example:
Router1 (config) # int f0/0
Router1 (config-if) ip ospf priority 200

Router2 (config)# int f0/0
Router2(config-if)#ip ospf priority 0

Then reset OSPF on interface to take effect.

- When a Link state changes on a router connected to multi-access segment, it sends a multicast LSU packet to 224.0.0.6 ('all designated routers & Backup designated routers').
- The DR multicasts the update to 224.0.0.5 ('all OSPF router's)

Lab time: DR and BDR Lab:



We can do configuration and check who is DR and BDR by using command sh ip ospf neig.

Please find the below configuration for this Lab.

R1 Configuration	R2Configuration
en config t hostname R1 int f0/0 ip add 192.168.1.1 255.255.255.0 no sh router ospf 1 int f0/0 ip ospf 1 area 0	en config t hostname R2 int f0/0 ip add 192.168.1.2 255.255.255.0 no sh router ospf 1 int f0/0 ip ospf 1 area 0
R3 Configuration	**R4 Configuration**
en config t hostname R3 int f0/0 ip add 192.168.1.3 255.255.255.0 no sh router ospf 1 int f0/0 ip ospf 1 area 0	en config t hostname R4 int f0/0 ip add 192.168.1.4 255.255.255.0 no sh router ospf 1 int f0/0 ip ospf 1 area 0


```
R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.2       1   FULL/BDR        00:00:39    192.168.1.2     FastEthernet0/0
192.168.1.3       1   FULL/DROTHER    00:00:37    192.168.1.3     FastEthernet0/0
192.168.1.4       1   FULL/DROTHER    00:00:37    192.168.1.4     FastEthernet0/0
```

```
R2#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.1       1   FULL/DR         00:00:38    192.168.1.1     FastEthernet0/0
192.168.1.3       1   FULL/DROTHER    00:00:39    192.168.1.3     FastEthernet0/0
192.168.1.4       1   FULL/DROTHER    00:00:38    192.168.1.4     FastEthernet0/0
```

If you observe here R1 router ie. With ip add 192.168.1.1 become DR and R2 router (192.168.1.2) become BDR. Why ?? Because what router first we configuration that time he taken himself as DR. when we reset OSPF it will change. Let try we need to go all router and write command clear ip ospf process.

```
R2#clear ip ospf process
Reset ALL OSPF processes? [no]: yes

R2#
00:26:05: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on FastEthernet0/0 from 2WAY to DOWN, Neighbor Down: Adjacency forced to
reset

00:26:05: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.4 on FastEthernet0/0 from FULL to DOWN, Neighbor Down: Adjacency forced to
reset

00:26:05: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.3 on FastEthernet0/0 from FULL to DOWN, Neighbor Down: Adjacency forced to
reset

00:26:05: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.1 on FastEthernet0/0 from 2WAY to DOWN, Neighbor Down: Interface down or
detached

00:26:05: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.4 on FastEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or
detached

00:26:05: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.3 on FastEthernet0/0 from FULL to DOWN, Neighbor Down: Interface down or
detached

R2#
00:26:13: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.4 on FastEthernet0/0 from LOADING to FULL, Loading Done

00:26:14: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.3 on FastEthernet0/0 from LOADING to FULL, Loading Done
```

After reset ospf in all routers then R4 (192.168.1.4) become DR and R3 (192.168.1.3) become BDR and remaining become DROTHER.


```
R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.3       1   FULL/BDR        00:00:37    192.168.1.3     FastEthernet0/0
192.168.1.2       1   2WAY/DROTHER    00:00:38    192.168.1.2     FastEthernet0/0
192.168.1.4       1   FULL/DR         00:00:35    192.168.1.4     FastEthernet0/0
R1#
```

Let increase priority of R1 from 1 to 200 an, reset OSPF and check.

```
R1(config)#int f0/0
R1(config-if)#ip ospf pri
R1(config-if)#ip ospf priority 200
R1(config-if)#^Z
R1#
%SYS-5-CONFIG_I: Configured from console by console

R1#cle
R1#clear ip os
R1#clear ip ospf pro
R1#clear ip ospf process
Reset ALL OSPF processes? [no]: yes

R1#
00:33:50: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.3 on FastEthernet0/0 from FULL to DOWN, Neighbor Down: Adjacency forced to
reset

00:33:50: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.2 on FastEthernet0/0 from 2WAY to DOWN, Neighbor Down: Adjacency forced to
reset

00:33:50: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.1.4 on FastEthernet0/0 from FULL to DOWN, Neighbor Down: Adjacency forced to
reset
```

If we see in router 2 now we have DR as R1 and R4 as BDR.

```
R2#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.1.4       1   FULL/BDR        00:00:30    192.168.1.4     FastEthernet0/0
192.168.1.1     200   FULL/DR         00:00:30    192.168.1.1     FastEthernet0/0
192.168.1.3       1   2WAY/DROTHER    00:00:31    192.168.1.3     FastEthernet0/0
```

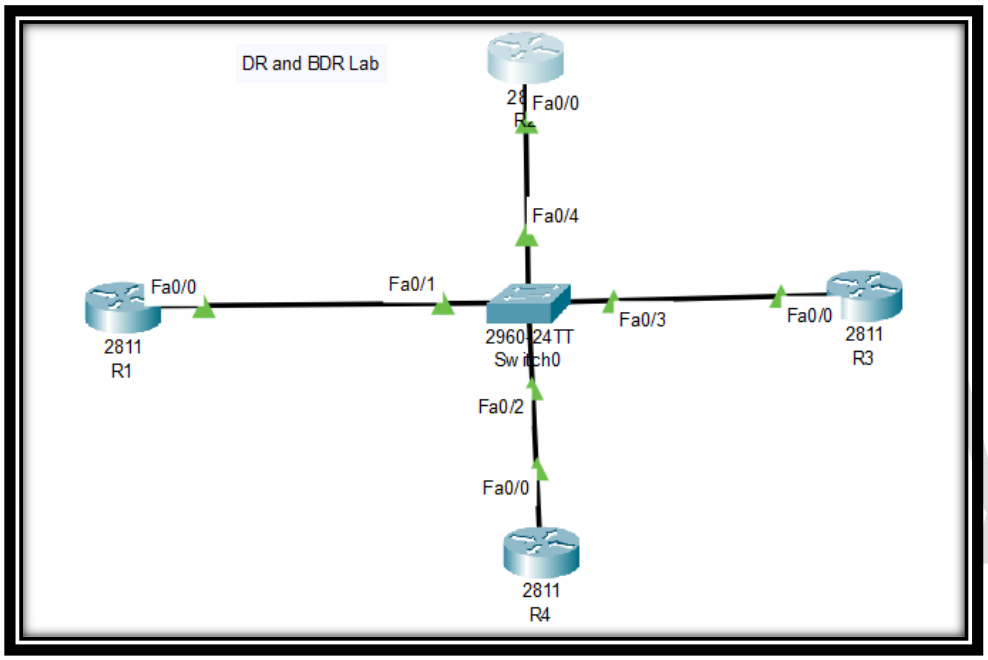
OSPF Network Types:

- The network type defines how the neighbor relationship will be formed.
- In different network type we will see behavior of OSPF like hello timer; Dead timer and DR/BDR are elected or not etc.
- There are five different OSPF network types on a CISCO router point –to-point, broadcast, non-broadcast, point-to-multipoint non-broadcast and point-to-multipoint.

Network Type	Hello Timer	Dead Timer	Adjacency
Broadcast	10	40	Automatic + DR/BDR
Non-Broadcast	30	120	Manual + DR/BDR
Point-to-Multipoint	30	120	Automatic No DR/BDR
Point-to-Multipoint non-Broadcast	30	120	Manual No DR/BDR
Point-to Point	10	40	Automatic No DR/BDR

Broadcast Networks:

- A network type that connects two or more OSPF routers over a broadcast media such as Ethernet.
- The Broadcast network type requires that a link support Layer 2 Broadcast Capabilities.
- On Broadcast networks neighbors are dynamically discovered by the hellos that send to the Multicast address of 244.0.0.5.On Broadcast network DR and BDR are elected
- The Broadcast network type has a 10 second Hello and 40 second Dead timer.



R1 Configuration	R2Configuration
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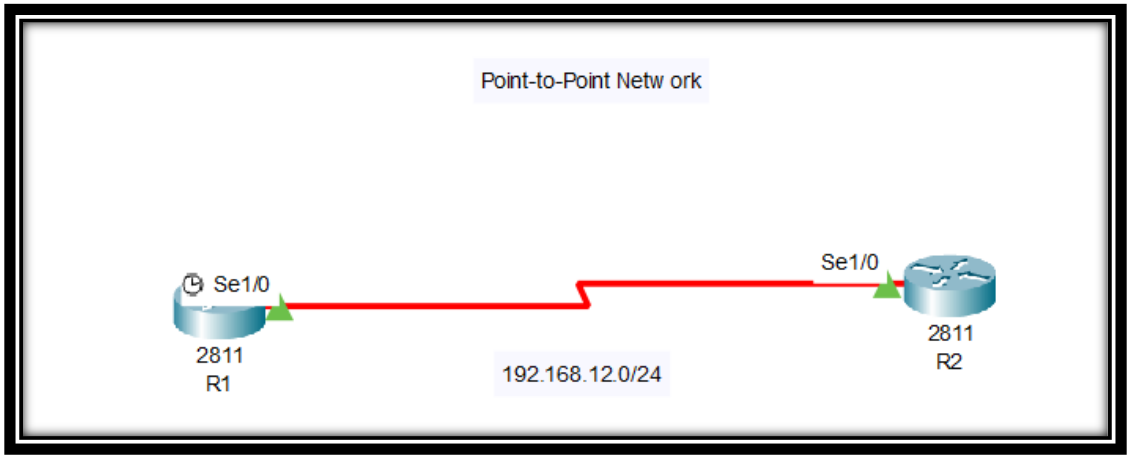
R3 Configuration	**R4 Configuration**
en	en

config t hostname R3 int f0/0 ip add 192.168.1.3 255.255.255.0 no sh router ospf 1 int f0/0 ip ospf 1 area 0	config t hostname R4 int f0/0 ip add 192.168.1.4 255.255.255.0 no sh router ospf 1 int f0/0 ip ospf 1 area 0

```
R1#sh ip ospf int f0/0

FastEthernet0/0 is up, line protocol is up
  Internet address is 192.168.1.1/24, Area 0
  Process ID 1, Router ID 192.168.1.1, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 200
  Designated Router (ID) 192.168.1.1, Interface address 192.168.1.1
  Backup Designated Router (ID) 192.168.1.4, Interface address 192.168.1.4
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
  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 3, Adjacent neighbor count is 3
    Adjacent with neighbor 192.168.1.3
    Adjacent with neighbor 200.1.1.1
    Adjacent with neighbor 192.168.1.4  (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
```

Point-to-Point Networks:

- Point-to-Point network types are intended to be use between two directly connected routers.
- An Example of a Point-to-Point link is a serial link connecting just two routers using PPP (Point-to-Point Protocol).
- In Point-to-point link, OSPF does not select a DR or BDR.
- Hello Packets are sending to the Multicast address 224.0.0.5.
- In Point-to-Point Network Hello timer is 10 second and dead timer is 40 second and Neighbor discovers dynamically.



Configuration:

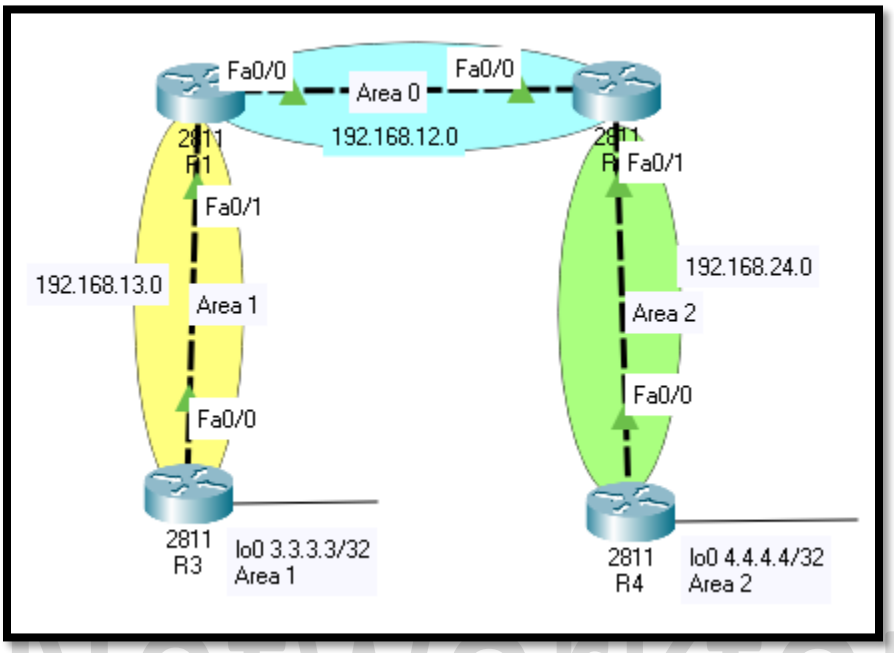
R1 Configuration	R2 Configuration
en config t hostname R1 int s1/0 ip add 192.168.12.1 255.255.255.0 no sh router ospf 1 network 192.168.12.0 0.0.0.255 area 0	en config t hostname R2 int s1/0 ip add 192.168.12.2 255.255.255.0 no sh router ospf 1 network 192.168.12.0 0.0.0.255 area 0
sh ip ospf int s1/0 sh ip ospf neighbor	This command is use to check output

```
R1#sh ip ospf int s1/0

Serial1/0 is up, line protocol is up
  Internet address is 192.168.12.1/24, Area 0
  Process ID 1, Router ID 192.168.12.1, 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 00:00:03
  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 192.168.12.2
  Suppress hello for 0 neighbor(s)
```

In Point-to-Point
NO DR and BDR

```
R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.12.2      0   FULL/  -        00:00:31    192.168.12.2    Serial1/0
```

OSPF Multi-Area Lab:

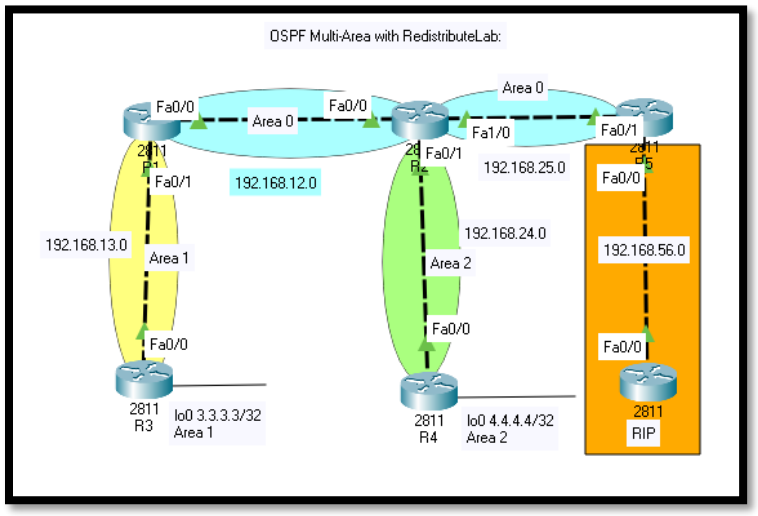


R1 Configuration:	R2 Configuration:
en config t hostname R1 interface f0/0 ip address 192.168.12.1 255.255.255.0 no sh interface f0/1 ip address 192.168.13.1 255.255.255.0 no sh router ospf 1 network 192.168.12.0 0.0.0.255 area 0 network 192.168.13.0 0.0.0.255 area 1	en config t hostname R2 interface f0/0 ip address 192.168.12.2 255.255.255.0 no sh interface f0/1 ip address 192.168.24.1 255.255.255.0 no sh router ospf 1 network 192.168.12.0 0.0.0.255 area 0 network 192.168.24.0 0.0.0.255 area 2
R3 Configuration:	**R4 Configuration:**
en config t	en config t

hostname R3 interface Loopback0 ip address 3.3.3.3 255.255.255.255 interface f0/0 ip address 192.168.13.2 255.255.255.0 no sh router ospf 1 network 3.3.3.3 0.0.0.0 area 1 network 192.168.13.0 0.0.0.255 area 1	hostname R4 interface Loopback0 ip address 4.4.4.4 255.255.255.255 interface f0/0 ip address 192.168.24.2 255.255.255.0 no sh router ospf 1 network 4.4.4.4 0.0.0.0 area 2 network 192.168.24.0 0.0.0.255 area 2

```
R2#sh ip ospf
 Routing Process "ospf 1" with ID 192.168.25.1
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 It is an area border router
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 Number of external LSA 1. Checksum Sum 0x00126a
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 2. 2 normal 0 stub 0 nssa
 External flood list length 0
    Area BACKBONE(0)
        Number of interfaces in this area is 2
        Area has no authentication
        SPF algorithm executed 5 times
        Area ranges are
        Number of LSA 9. Checksum Sum 0x035b4b
        Number of opaque link LSA 0. Checksum Sum 0x000000
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
 --More--
```

OSPF Multi-Area with Redistribute Lab:



R1 Configuration:	R2 Configuration:
en config t hostname R1 interface f0/0 ip address 192.168.12.1 255.255.255.0 no sh interface f0/1 ip address 192.168.13.1 255.255.255.0 no sh router ospf 1 network 192.168.12.0 0.0.0.255 area 0 network 192.168.13.0 0.0.0.255 area 1	en config t hostname R2 interface f0/0 ip address 192.168.12.2 255.255.255.0 no sh interface f0/1 ip address 192.168.24.1 255.255.255.0 no sh interface f1/0 ip address 192.168.25.1 255.255.255.0 no sh router ospf 1 network 192.168.12.0 0.0.0.255 area 0 network 192.168.24.0 0.0.0.255 area 2 network 192.168.25.0 0.0.0.255 area 0
R3 Configuration:	**R4 Configuration:**
en	en

config t hostname R3 interface Loopback0 ip address 3.3.3.3 255.255.255.255 interface f0/0 ip address 192.168.13.2 255.255.255.0 no sh router ospf 1 network 3.3.3.3 0.0.0.0 area 1 network 192.168.13.0 0.0.0.255 area 1	config t hostname R4 interface Loopback0 ip address 4.4.4.4 255.255.255.255 interface f0/0 ip address 192.168.24.2 255.255.255.0 no sh router ospf 1 network 4.4.4.4 0.0.0.0 area 2 network 192.168.24.0 0.0.0.255 area 2
R5 Configuration:	**R6 Configuration:**
en config t hostname R5 interface f0/1 ip address 192.168.25.2 255.255.255.0 no sh interface f0/0 ip address 192.168.56.1 255.255.255.0 no sh router rip version 2 no auto-summary network 192.168.56.0 redistribute ospf 1 metric 1 router ospf 1 network 192.168.25.0 0.0.0.255 area 0 redistribute rip subnets	en config t hostname R6 interface f0/0 ip address 192.168.56.2 255.255.255.0 no sh router rip version 2 no auto-summary network 192.168.56.0

Sh ip route:

```
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
3.0.0.0/32 is subnetted, 1 subnets
O IA 3.3.3.3/32 [110/3] via 192.168.12.1, 00:07:04, FastEthernet0/0
4.0.0.0/32 is subnetted, 1 subnets
O 4.4.4.4/32 [110/2] via 192.168.24.2, 00:07:09, FastEthernet0/1
192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C 192.168.12.0/24 is directly connected, FastEthernet0/0
L 192.168.12.2/32 is directly connected, FastEthernet0/0
O IA 192.168.13.0/24 [110/2] via 192.168.12.1, 00:07:04, FastEthernet0/0
192.168.24.0/24 is variably subnetted, 2 subnets, 2 masks
C 192.168.24.0/24 is directly connected, FastEthernet0/1
L 192.168.24.1/32 is directly connected, FastEthernet0/1
192.168.25.0/24 is variably subnetted, 2 subnets, 2 masks
C 192.168.25.0/24 is directly connected, FastEthernet1/0
L 192.168.25.1/32 is directly connected, FastEthernet1/0
O E2 192.168.56.0/24 [110/20] via 192.168.25.2, 00:07:04, FastEthernet1/0
```

```
R2#sh ip ospf
 Routing Process "ospf 1" with ID 192.168.25.1
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 It is an area border router
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 Number of external LSA 1. Checksum Sum 0x00126a
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 2. 2 normal 0 stub 0 nssa
 External flood list length 0
    Area BACKBONE(0)
        Number of interfaces in this area is 2
        Area has no authentication
        SPF algorithm executed 2 times
        Area ranges are
        Number of LSA 9. Checksum Sum 0x03e5ea
        Number of opaque link LSA 0. Checksum Sum 0x000000
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
 --More--
```

```
R5#sh ip ospf
 Routing Process "ospf 1" with ID 192.168.56.1
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 It is an autonomous system boundary router
 SPF schedule delay 5 secs, Hold time between two SPFs 10 secs
 Minimum LSA interval 5 secs. Minimum LSA arrival 1 secs
 Number of external LSA 1. Checksum Sum 0x00126a
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 1. 1 normal 0 stub 0 nssa
 External flood list length 0
    Area BACKBONE(0)
        Number of interfaces in this area is 1
        Area has no authentication
        SPF algorithm executed 2 times
        Area ranges are
        Number of LSA 9. Checksum Sum 0x03e5ea
        Number of opaque link LSA 0. Checksum Sum 0x000000
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
 --More--
```

```
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

     3.0.0.0/32 is subnetted, 1 subnets
R       3.3.3.3/32 [120/1] via 192.168.56.1, 00:00:07, FastEthernet0/0
     4.0.0.0/32 is subnetted, 1 subnets
R       4.4.4.4/32 [120/1] via 192.168.56.1, 00:00:07, FastEthernet0/0
R    192.168.12.0/24 [120/1] via 192.168.56.1, 00:00:07, FastEthernet0/0
R    192.168.13.0/24 [120/1] via 192.168.56.1, 00:00:07, FastEthernet0/0
R    192.168.24.0/24 [120/1] via 192.168.56.1, 00:00:07, FastEthernet0/0
R    192.168.25.0/24 [120/1] via 192.168.56.1, 00:00:07, FastEthernet0/0
     192.168.56.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.56.0/24 is directly connected, FastEthernet0/0
L       192.168.56.2/32 is directly connected, FastEthernet0/0
```

```
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

     3.0.0.0/32 is subnetted, 1 subnets
O IA    3.3.3.3/32 [110/4] via 192.168.25.1, 00:10:33, FastEthernet0/1
     4.0.0.0/32 is subnetted, 1 subnets
O IA    4.4.4.4/32 [110/3] via 192.168.25.1, 00:10:33, FastEthernet0/1
O    192.168.12.0/24 [110/2] via 192.168.25.1, 00:10:33, FastEthernet0/1
O IA 192.168.13.0/24 [110/3] via 192.168.25.1, 00:10:33, FastEthernet0/1
O IA 192.168.24.0/24 [110/2] via 192.168.25.1, 00:10:33, FastEthernet0/1
     192.168.25.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.25.0/24 is directly connected, FastEthernet0/1
L       192.168.25.2/32 is directly connected, FastEthernet0/1
     192.168.56.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.56.0/24 is directly connected, FastEthernet0/0
L       192.168.56.1/32 is directly connected, FastEthernet0/0
```

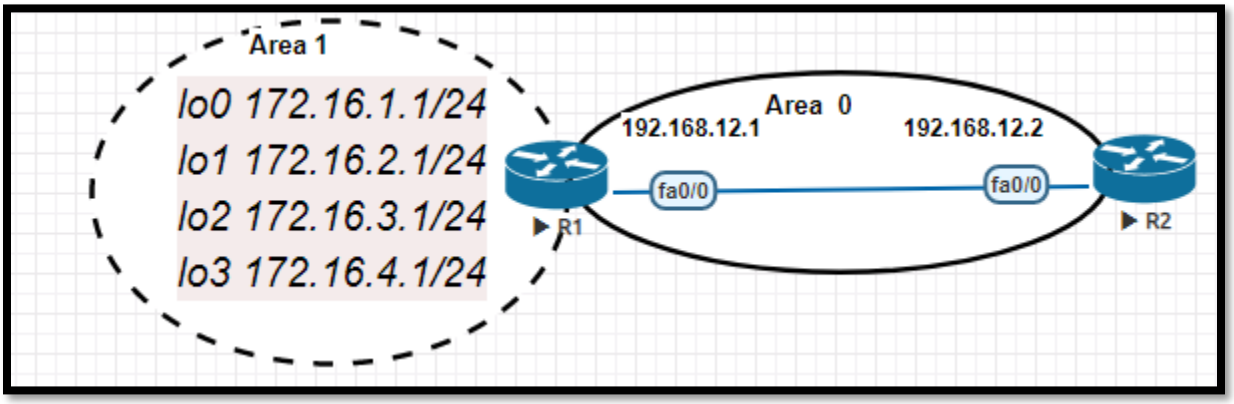
OSPF Summarization:

- Route summarization, also called route aggregation.
- It is a method of minimizing the number of routing tables in an IP (Internet Protocol) network.
- It works by consolidating selected multiple routes into a single route advertisement.
- The route summarization helps to reduce OSPF traffic and the route computation.
- OSPF support Route summarization only at ABR (Area Boarder Router) or ASBR (Autonomous system boundary router).

Advantages of Summarization:

- **Saves Memory** -Routing tables will be smaller which reduces memory requirements.
- **Saves Bandwidth** -There are less routes to advertise so we save some bandwidth.
- **Saves CPU Cycles** - Less packets to process and smaller routing tables to work on.
- **Stability** -Prevents routing table instability due to flapping networks.

OSPF Summarization at ABR Lab:



R1 Configuration	R2 Configuration
en config t hostname R1 int f0/0 ip add 192.168.12.1 255.255.255.0 no sh int lo0 ip add 172.16.1.1 255.255.255.0 int lo1 ip add 172.16.2.1 255.255.255.0 int lo2 ip add 172.16.3.1 255.255.255.0 int lo3 ip add 172.16.4.1 255.255.255.0 router ospf 1 int f0/0 ip ospf 1 area 0	en config t hostname R2 int f0/0 ip add 192.168.12.2 255.255.255.0 no sh int lo0 ip add 2.2.2.2 255.0.0.0 router ospf 1 int f0/0 ip ospf 1 area 0 int lo0 ip ospf 1 area 0

int lo0 ip ospf 1 area 1 int lo1 ip ospf 1 area 1 int lo2 ip ospf 1 area 1 int lo3 ip ospf 1 area 1 **area 1 range 172.16.0.0 255.255.248.0**	

Calculating the Summarize route:

172.16.1.0

172.16.4.0

172.16.00000 001.0 = 8 + 8 + 5 = 21 => 255.255.248.0

172.16.00000 100.0

So IP will be 172.16.0.0 and subnet mask is 255.255.248.0

128	64	32	16	8	4	2	1
1	1	0	0	0	0	0	0

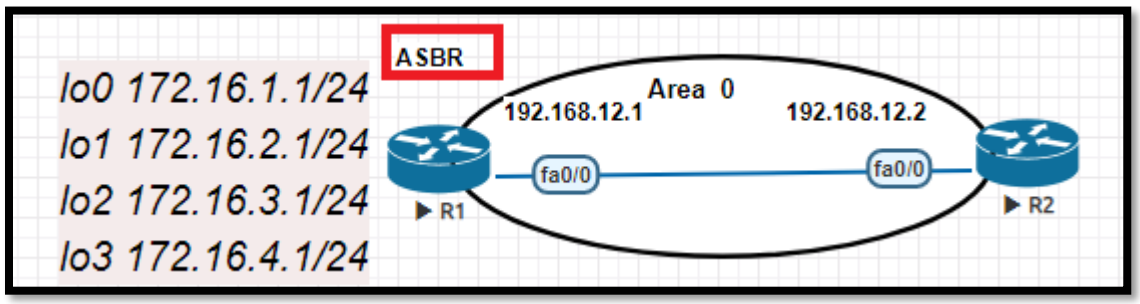
```
R1#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.12.0/24 is directly connected, FastEthernet0/0
     2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/11] via 192.168.12.2, 00:04:46, FastEthernet0/0
     172.16.0.0/16 is variably subnetted, 5 subnets, 2 masks
C       172.16.4.0/24 is directly connected, Loopback3
O       172.16.0.0/21 is a summary, 00:04:46, Null0
C       172.16.1.0/24 is directly connected, Loopback0
C       172.16.2.0/24 is directly connected, Loopback1
C       172.16.3.0/24 is directly connected, Loopback2
```



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

Gateway of last resort is not set

C    192.168.12.0/24 is directly connected, FastEthernet0/0
C    2.0.0.0/8 is directly connected, Loopback0
     172.16.0.0/21 is subnetted, 1 subnets
O IA    172.16.0.0 [110/11] via 192.168.12.1, 00:00:25, FastEthernet0/0
```

```
R2#ping 172.16.1.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/17/28 ms
R2#ping 172.16.2.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 8/12/20 ms
R2#ping 172.16.3.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 8/18/24 ms
R2#ping 172.16.4.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.4.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 8/12/20 ms
```

OSPF Summarization at ASBR Lab:



R1 Configuration	R2 Configuration
en config t hostname R1	en config t hostname R2

int f0/0 ip add 192.168.12.1 255.255.255.0 no sh int lo0 ip add 172.16.1.1 255.255.255.0 int lo1 ip add 172.16.2.1 255.255.255.0 int lo2 ip add 172.16.3.1 255.255.255.0 int lo3 ip add 172.16.4.1 255.255.255.0 router ospf 1 int f0/0 ip ospf 1 area 1 **router ospf 1** **redistribute connected subnets** **summary-address 172.16.0.0 255.255.248.0**	int f0/0 ip add 192.168.12.2 255.255.255.0 no sh int lo0 ip add 2.2.2.2 255.0.0.0 router ospf 1 int f0/0 ip ospf 1 area 1 int lo0 ip ospf 1 area 1

Calculating the Summarize route:

172.16.1.0

172.16.4.0

172.16.00000 001.0 = 8 + 8 + 5 = 21 => 255.255.248.0

172.16.00000 100.0

So IP will be 172.16.0.0 and subnet mask is 255.255.248.0

128	64	32	16	8	4	2	1
1	1	0	0	0	0	0	0

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

Gateway of last resort is not set

C    192.168.12.0/24 is directly connected, FastEthernet0/0
C    2.0.0.0/8 is directly connected, Loopback0
     172.16.0.0/21 is subnetted, 1 subnets
O E2    172.16.0.0 [110/20] via 192.168.12.1, 00:00:13, FastEthernet0/0
```