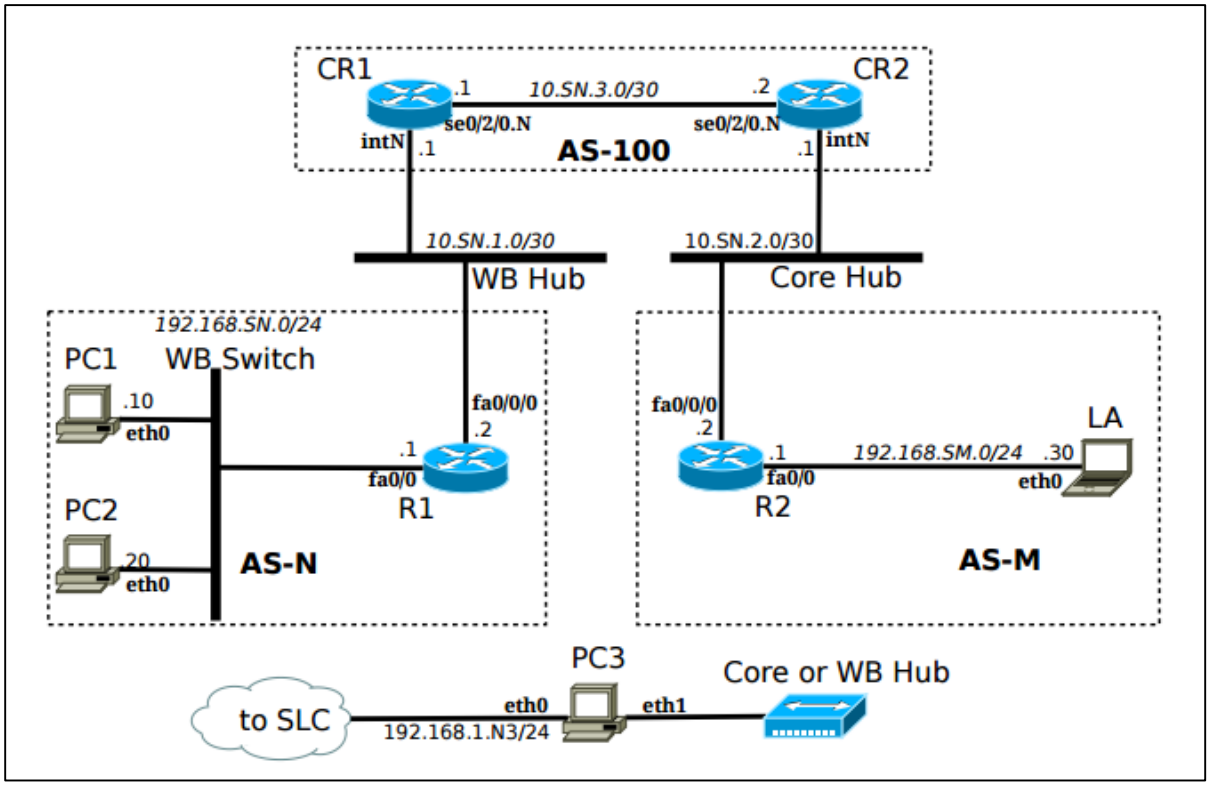
Inter Domain Routing:

Experiment 4.1 Topology Setup



The above topology was setup.

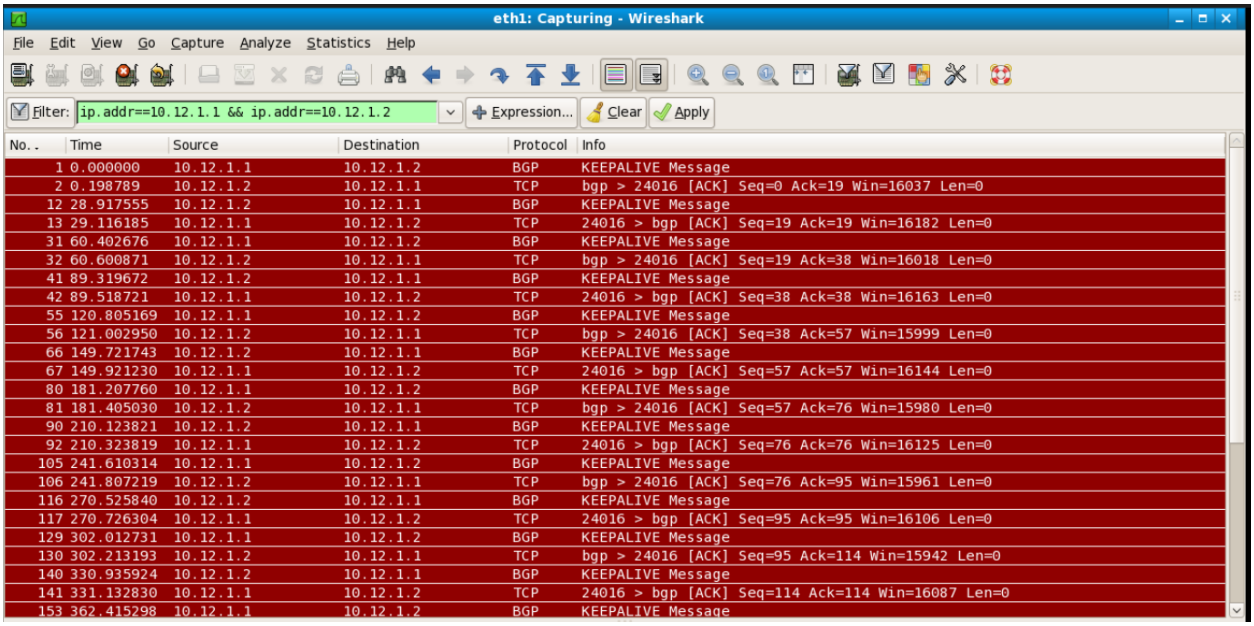
- **PC1** – 192.168.12.10/24 **PC2** – 192.168.12.20/24 **LA** – 192.168.16.30/24
  R1 fa0/0 – 192.168.12.1/24 **R1 fa0/0/0** – 10.12.1.2/30
  CR1 fa0/1 – 10.12.1.1/30 **CR1 se0/2/0.2** – 10.12.3.1/30
  CR2 fa0/1 – 10.31.2.1/30 **CR2 se0/2/0.2** – 10.31.3.2/30
  R2 fa0/0 – 192.168.16.0/24 **R2 fa0/0/0** – 10.12.2.2/30

- PC3 is connected to the workbench hub/core hub.

Experiment 4.2: Basic BGP

- Started wireshark on PC3
- BGP is configured on all the router.

- AS-N is AS-1 and AS-M is AS-6.
- Captured BGP packet exchanged between R1 and C1 and observed BGP OPEN message, BGP KEEPALIVE message and BGP UPDATE message. We saw the BGP session being established and once the session was established the keepalives were being exchanged periodically.



No.	Time	Source	Destination	Protocol	Info
1	0.000000	10.12.1.1	10.12.1.2	BGP	KEEPALIVE Message
2	0.198789	10.12.1.2	10.12.1.1	TCP	bgp > 24016 [ACK] Seq=0 Ack=19 Win=16037 Len=0
12	28.917555	10.12.1.2	10.12.1.1	BGP	KEEPALIVE Message
13	29.116185	10.12.1.1	10.12.1.2	TCP	24016 > bgp [ACK] Seq=19 Ack=19 Win=16182 Len=0
31	60.402676	10.12.1.1	10.12.1.2	BGP	KEEPALIVE Message
32	60.600871	10.12.1.2	10.12.1.1	TCP	bgp > 24016 [ACK] Seq=19 Ack=38 Win=16018 Len=0
41	89.319672	10.12.1.2	10.12.1.1	BGP	KEEPALIVE Message
42	89.518721	10.12.1.1	10.12.1.2	TCP	24016 > bgp [ACK] Seq=38 Ack=38 Win=16163 Len=0
55	120.805169	10.12.1.1	10.12.1.2	BGP	KEEPALIVE Message
56	121.002950	10.12.1.2	10.12.1.1	TCP	bgp > 24016 [ACK] Seq=38 Ack=57 Win=15999 Len=0
66	149.721743	10.12.1.2	10.12.1.1	BGP	KEEPALIVE Message
67	149.921230	10.12.1.1	10.12.1.2	TCP	24016 > bgp [ACK] Seq=57 Ack=57 Win=16144 Len=0
80	181.207760	10.12.1.1	10.12.1.2	BGP	KEEPALIVE Message
81	181.405030	10.12.1.2	10.12.1.1	TCP	bgp > 24016 [ACK] Seq=57 Ack=76 Win=15980 Len=0
90	210.123821	10.12.1.2	10.12.1.1	BGP	KEEPALIVE Message
92	210.323819	10.12.1.1	10.12.1.2	TCP	24016 > bgp [ACK] Seq=76 Ack=76 Win=16125 Len=0
105	241.610314	10.12.1.1	10.12.1.2	BGP	KEEPALIVE Message
106	241.807219	10.12.1.2	10.12.1.1	TCP	bgp > 24016 [ACK] Seq=76 Ack=95 Win=15961 Len=0
116	270.525840	10.12.1.2	10.12.1.1	BGP	KEEPALIVE Message
117	270.726304	10.12.1.1	10.12.1.2	TCP	24016 > bgp [ACK] Seq=95 Ack=95 Win=16106 Len=0
129	302.012731	10.12.1.1	10.12.1.2	BGP	KEEPALIVE Message
130	302.213193	10.12.1.2	10.12.1.1	TCP	bgp > 24016 [ACK] Seq=95 Ack=114 Win=15942 Len=0
140	330.935924	10.12.1.2	10.12.1.1	BGP	KEEPALIVE Message
141	331.132830	10.12.1.1	10.12.1.2	TCP	24016 > bgp [ACK] Seq=114 Ack=114 Win=16087 Len=0
153	362.415298	10.12.1.1	10.12.1.2	BGP	KEEPALIVE Message

- Route on CR1 and CR2 are verified using **show ip route.** There were no routes present for the AS-1 and AS-6.
- BGP summary on CR1 and CR2 are verified using **show ip bgp.** Here we see the AS-1 and AS-6 subnets as these were obtained through the advertisements of R1 and R2 respectively.

```
R1C#sh ip bgp
BGP table version is 12, local router ID is 10.99.99.1
Status codes: s suppressed, d damped, h history, * valid, > best,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
*> 10.11.3.0/30     0.0.0.0                  0         32768 i
* i10.12.3.0/30     10.12.3.2                0    100      0 i
* i                 10.14.3.2                0    100      0 i
* i                 10.13.3.2                0    100      0 i
*>                  0.0.0.0                  0         32768 i
* i10.13.3.0/30     10.12.3.2                0    100      0 i
* i                 10.13.3.2                0    100      0 i
* i                 10.14.3.2                0    100      0 i
*>                  0.0.0.0                  0         32768 i
* i10.14.3.0/30     10.12.3.2                0    100      0 i
* i                 10.13.3.2                0    100      0 i
* i                 10.14.3.2                0    100      0 i
*>                  0.0.0.0                  0         32768 i
*> 192.168.12.0     10.12.1.2                0             0 2 i
*> 192.168.13.0     10.13.1.2                0             0 3 i
*> 192.168.14.0     10.14.1.2                0             0 4 i
* i192.168.16.0     10.12.2.2                0    100      0 6 i
* i                 10.12.2.2                0    100      0 6 i
* i                 10.12.2.2                0    100      0 6 i
* i192.168.17.0     10.13.2.2                0    100      0 7 i
* i                 10.13.2.2                0    100      0 7 i
* i                 10.13.2.2                0    100      0 7 i
* i192.168.18.0     10.14.2.2                0    100      0 8 i
* i                 10.14.2.2                0    100      0 8 i
* i                 10.14.2.2                0    100      0 8 i
```

```
R2C#sh ip bgp
BGP table version is 20, local router ID is 10.255.255.254
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
r>i10.11.3.0/30     10.12.3.1                0    100      0 i
r i                 10.13.3.1                0    100      0 i
r i                 10.14.3.1                0    100      0 i
* i10.12.3.0/30     10.12.3.1                0    100      0 i
*>                  0.0.0.0                  0         32768 i
* i                 10.13.3.1                0    100      0 i
* i                 10.14.3.1                0    100      0 i
* i10.13.3.0/30     10.12.3.1                0    100      0 i
* i                 10.13.3.1                0    100      0 i
*>                  0.0.0.0                  0         32768 i
* i                 10.14.3.1                0    100      0 i
* i10.14.3.0/30     10.12.3.1                0    100      0 i
* i                 10.13.3.1                0    100      0 i
* i                 10.14.3.1                0    100      0 i
*>                  0.0.0.0                  0         32768 i
* i192.168.12.0     10.12.1.2                0    100      0 2 i
* i                 10.12.1.2                0    100      0 2 i
* i                 10.12.1.2                0    100      0 2 i
* i192.168.13.0     10.13.1.2                0    100      0 3 i
* i                 10.13.1.2                0    100      0 3 i
* i                 10.13.1.2                0    100      0 3 i
* i192.168.14.0     10.14.1.2                0    100      0 4 i
* i                 10.14.1.2                0    100      0 4 i
* i                 10.14.1.2                0    100      0 4 i
*> 192.168.16.0     10.12.2.2                0             0 6 i
*> 192.168.17.0     10.13.2.2                0             0 7 i
*> 192.168.18.0     10.14.2.2                0             0 8 i
```

- Tried pinging laptop from **PC2**, but can't reach because CR1 doesn't know how to reach R2 and CR2 does not know how to reach R1. As a result R1 doesn't know the next hop to reach the AS-6 subnets. As a result, the trace stops at R1.

```
File  Edit  View  Terminal  Tabs  Help
From 192.168.12.1 icmp_seq=49 Destination Host Unreachable
From 192.168.12.1 icmp_seq=50 Destination Host Unreachable
From 192.168.12.1 icmp_seq=51 Destination Host Unreachable
From 192.168.12.1 icmp_seq=52 Destination Host Unreachable

--- 192.168.16.30 ping statistics ---
52 packets transmitted, 0 received, +52 errors, 100% packet loss, time 51000ms

[team12@netlab-wb2pc2 ~]$ ping 192.168.16.30
PING 192.168.16.30 (192.168.16.30) 56(84) bytes of data.
From 192.168.12.1 icmp_seq=1 Destination Host Unreachable
From 192.168.12.1 icmp_seq=2 Destination Host Unreachable
From 192.168.12.1 icmp_seq=3 Destination Host Unreachable
From 192.168.12.1 icmp_seq=4 Destination Host Unreachable
From 192.168.12.1 icmp_seq=5 Destination Host Unreachable
From 192.168.12.1 icmp_seq=6 Destination Host Unreachable
From 192.168.12.1 icmp_seq=7 Destination Host Unreachable
From 192.168.12.1 icmp_seq=8 Destination Host Unreachable
From 192.168.12.1 icmp_seq=9 Destination Host Unreachable

--- 192.168.16.30 ping statistics ---
9 packets transmitted, 0 received, +9 errors, 100% packet loss, time 8000ms

[team12@netlab-wb2pc2 ~]$
```

- Route on R1 is verified using **show ip route**, but there is no route for 192.168.16.0/24 network.

```
R1C#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

B    192.168.12.0/24 [20/0] via 10.12.1.2, 00:17:06
B    192.168.13.0/24 [20/0] via 10.13.1.2, 00:24:38
B    192.168.14.0/24 [20/0] via 10.14.1.2, 00:31:24
     10.0.0.0/8 is variably subnetted, 10 subnets, 2 masks
C       10.11.1.0/30 is directly connected, FastEthernet0/0
C       10.11.3.0/30 is directly connected, Serial0/2/0.1
C       10.13.3.0/30 is directly connected, Serial0/2/0.3
C       10.14.1.0/30 is directly connected, FastEthernet0/1/0
C       10.12.3.0/30 is directly connected, Serial0/2/0.2
C       10.13.1.0/30 is directly connected, FastEthernet0/0/0
C       10.14.3.0/30 is directly connected, Serial0/2/0.4
C       10.12.1.0/30 is directly connected, FastEthernet0/1
C       10.99.99.1/32 is directly connected, Loopback0
C       10.255.255.252/30 is directly connected, Serial0/2/0.255
R1C#
```

- The above problem is fixed by adding static routes on CR1 and CR2

  ip route 10.12.2.0 255.255.255.252 10.12.3.2 for CR1

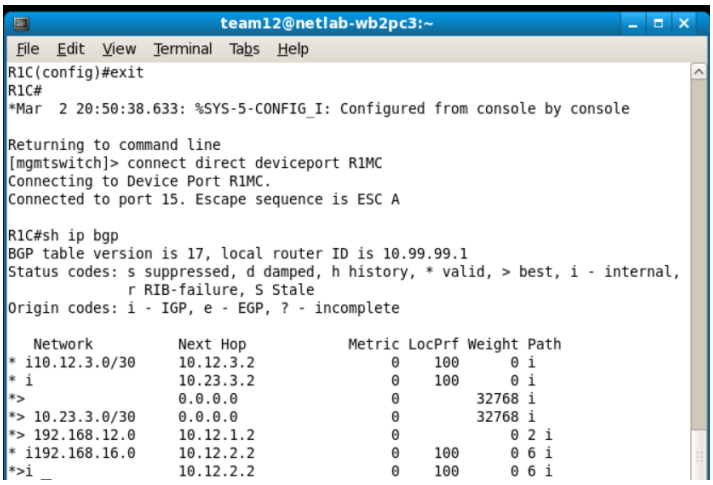
  ip route 10.12.1.0 255.255.255.252 10.12.3.1 for CR2

- Route and bgp summary on CR1 and CR2 are again checked. We can see in the show ip route outputs that CR1 is learning now about the 192.168.16.0/24 network through BGP and CR2 is learning about the 192.168.12.0/24 network through BGP.

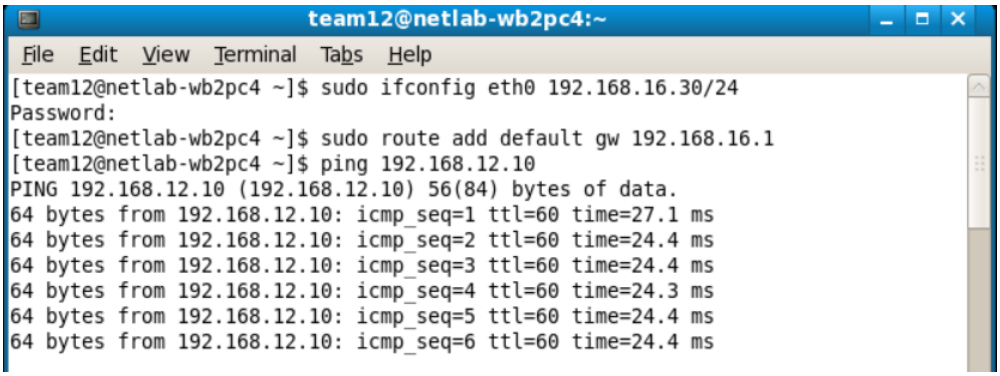
CR2

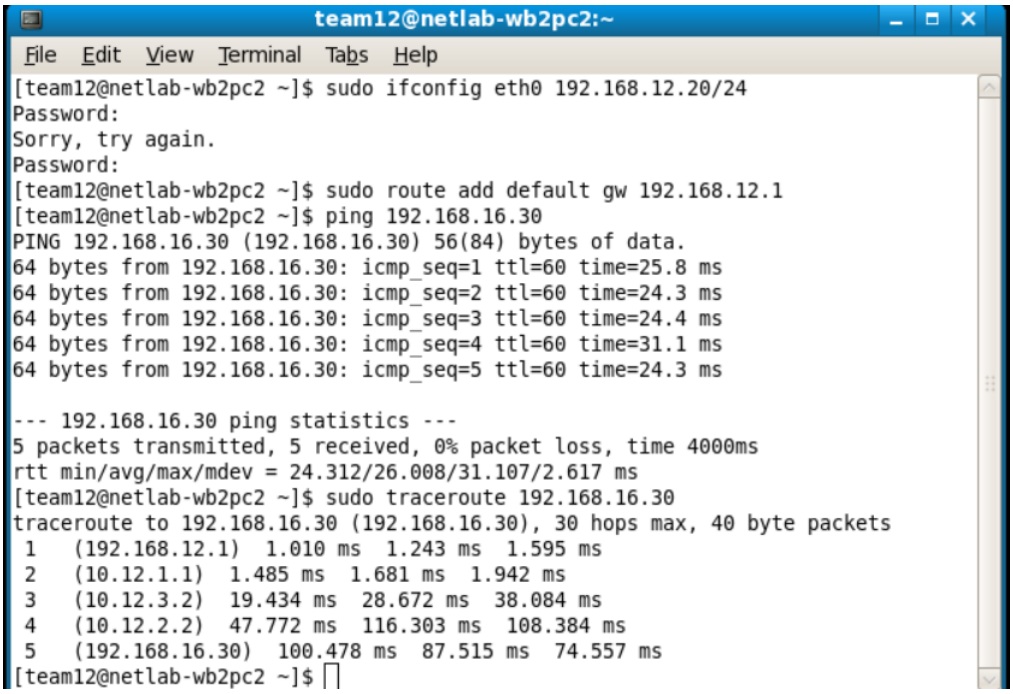
```
R2C#sh ip bgp
BGP table version is 20, local router ID is 10.255.255.254
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
r>i10.11.3.0/30     10.12.3.1                0    100      0 i
r i                 10.13.3.1                0    100      0 i
r i                 10.14.3.1                0    100      0 i
* i10.12.3.0/30     10.12.3.1                0    100      0 i
*>                  0.0.0.0                  0         32768 i
* i                 10.13.3.1                0    100      0 i
* i                 10.14.3.1                0    100      0 i
* i10.13.3.0/30     10.12.3.1                0    100      0 i
* i                 10.13.3.1                0    100      0 i
*>                  0.0.0.0                  0         32768 i
* i                 10.14.3.1                0    100      0 i
* i10.14.3.0/30     10.12.3.1                0    100      0 i
* i                 10.13.3.1                0    100      0 i
* i                 10.14.3.1                0    100      0 i
*>                  0.0.0.0                  0         32768 i
* i192.168.12.0     10.12.1.2                0    100      0 2 i
* i                 10.12.1.2                0    100      0 2 i
* i                 10.12.1.2                0    100      0 2 i
* i192.168.13.0     10.13.1.2                0    100      0 3 i
* i                 10.13.1.2                0    100      0 3 i
* i                 10.13.1.2                0    100      0 3 i
* i192.168.14.0     10.14.1.2                0    100      0 4 i
* i                 10.14.1.2                0    100      0 4 i
* i                 10.14.1.2                0    100      0 4 i
*> 192.168.16.0     10.12.2.2                0             0 6 i
*> 192.168.17.0     10.13.2.2                0             0 7 i
*> 192.168.18.0     10.14.2.2                0             0 8 i
```

CR1



- Tried pinging laptop from PC2. We were able to ping now because after the static route was added on the core routers, they started learning about the AS-1 and AS-6 subnets through BGP and in turn advertising them to their BGP neighbors. As a result, R1 now learns about the AS-6 subnet and R2 now learns about the AS-1 subnet. Their routing tables are also updated with the new learnt BGP route.





- The traceroute between AS-1 and AS-6 i.e. from PC2 to Laptop is given above.

Experiment 4.3: BGP and OSPF route redistribution

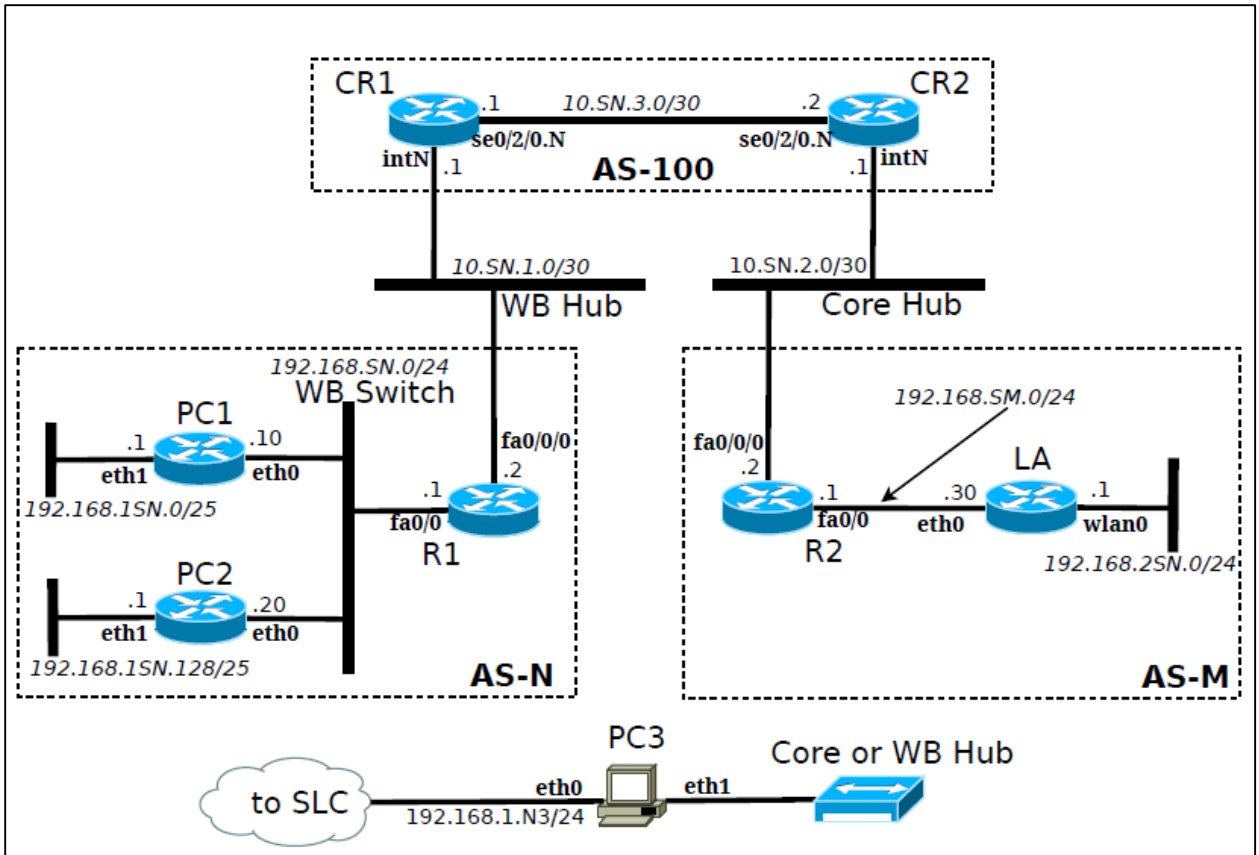


Figure 2: *Modified network topology*

- The topology was modified as shown above.
  PC1 eth1 – 192.168.112.1/25
  PC2 eth1 – 192.168.113.128/25
  Laptop wlan0 - 192.168.212.1/24
- Each computer was converted into an OSPF router with **area 0** using the Quagga Software by running Zebra and OSPF daemon. OSPF was enabled on the internal network directly connected into the internal routers (i.e. only on fa0/0)

```
sudo /etc/init.d/zebra start|stop|restart|status
sudo /etc/init.d/ospfd start|stop|restart|status
```

- After running the OSPF daemon, the OSPF router access on PC1, PC2 and Laptop was gained by telnet using following command.
  `telnet 127.0.0.1 ospfd`

- OSPF was enabled on networks attached on eth1 and eth0 of PC1 and PC2. Also the OSPF was enabled on Laptop interface eth0 and wlan0. Eth1 was used as the router-id for PC1 and PC2, while wlan0 was used as the router-id for Laptop.
- OSPF was configured on R1 and R2 on the interface fa0/0 of each workbench routers.
- After configuring the OSPF, following routes were seen on R1 and R2 (workbench routers).

R1

```
R1WB2#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inte
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 -
       ia - IS-IS inter area, * - candidate default, U - per-us
       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
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
B       10.12.3.0/30 [20/0] via 10.12.1.1, 00:01:39
C       10.12.1.0/30 is directly connected, FastEthernet0/0/0
B       10.31.3.0/30 [20/0] via 10.12.1.1, 00:01:39
C       10.12.99.1/32 is directly connected, Loopback0
     192.168.112.0/25 is subnetted, 1 subnets
O       192.168.112.0 [110/11] via 192.168.12.10, 00:12:40, Fa
B    192.168.16.0/24 [20/0] via 10.12.1.1, 00:01:40
```

R2

```
R2WB2#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF int
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 -
       ia - IS-IS inter area, * - candidate default, U - per-u
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

B    192.168.12.0/24 [20/0] via 10.12.2.1, 00:03:23
O    192.168.212.0/24 [110/11] via 192.168.16.30, 00:11:57, Fa
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C       10.12.2.0/30 is directly connected, FastEthernet0/0/0
B       10.12.3.0/30 [20/0] via 10.12.2.1, 01:56:07
B       10.31.3.0/30 [20/0] via 10.12.2.1, 01:40:52
C       10.12.99.2/32 is directly connected, Loopback0
C    192.168.16.0/24 is directly connected, FastEthernet0/0
```

The routes with the codes O are the OSPF routes . These routes are seen because we are running OSPF as well on the routers along with BGP. On R1, two OSPF routes were seen as we had advertised two networks 192.168.112.128/25 and 192.168.112.0/25 using OSPF on PC1 and PC2. One ospf router was seen on R2 as we had advertised only one network 192.168.212.0/24 on Laptop.

- The prefixes advertised by AS-1, were contiguous, so we used following command in the BGP configuration mode on R1 to summarize them while redistributing them in BGP.
  `aggregate-address 192.168.112.0 255.255.255.0 summary-only`

- The BGP routes were redistributed on R1 and R2 (workbench Routers) using following command in BGP configuration mode:
  R1

```
redistribute ospf 12
```

R2

```
redistribute ospf 16
```

- BGP routes were redistributed in OSPF configuration mode on R1 and R2 (workbench routers) using following command:

R1

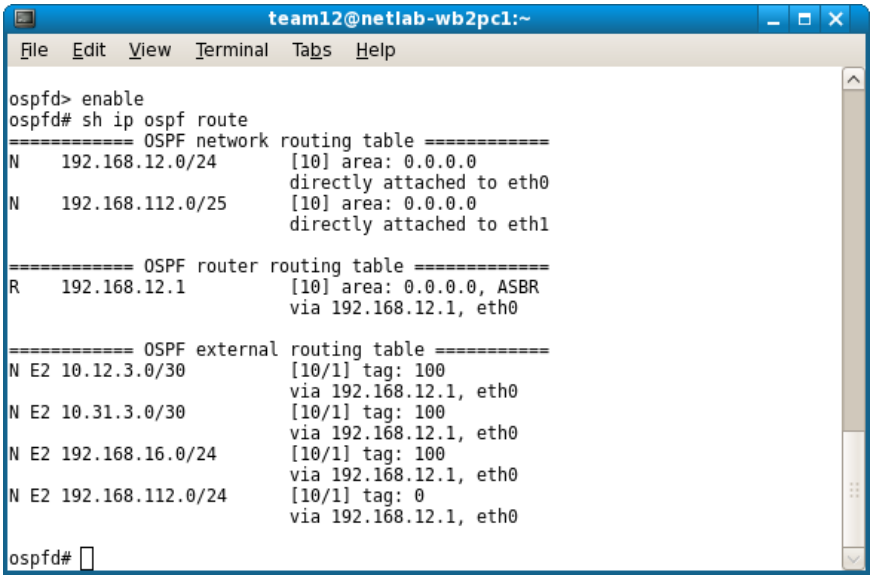
```
Redistribute bgp 2 subnets
```

R2

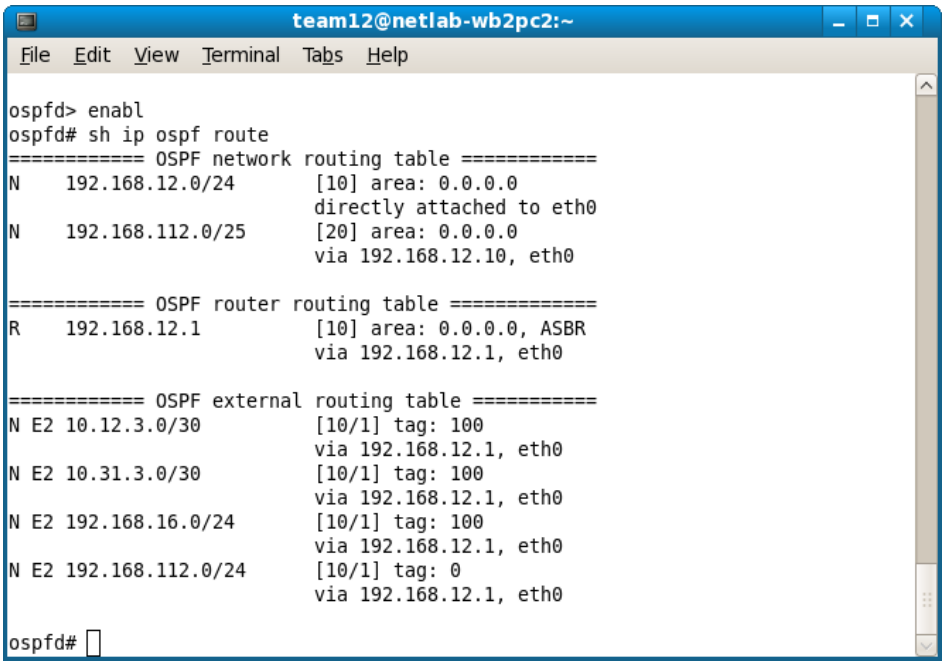
```
Redistribute bgp 6 subnets
```

- Routing tables were again checked on PC-based routers, Workbench Routers and the Core Routers) and found that the routes were successfully redistributed.

OSPF Routes PC1



OSPF routes on PC2



OSPF Routes on Laptop