Assignment-5

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GNS3:

GNS3 stands for Graphical Network simulator-3 which is a simulation software widely used by network engineers for constructing and testing virtual complex networks. The results of such simulations are directly manifested in what happens in real networks. Hence it is a useful tool for debugging and planning the construction of networks.

In this assignment we try to simulate two specified networks which use the intra-routing protocols : RIP and OSPF.

RIP:

RIP is an intra-AS routing protocol (also: interior gateway protocol). It uses a distance vector protocol at its heart using hop-count as its cost metric. Like any other distance vector implementation, the nodes in RIP communicate periodicaly with messages named \textbf{RIP advertisements}. Each time an RIP advertisement is received from a neighbour, the routing table inside every router is updated, if necessary, as per Bellman-Ford's equation.

OSPF:

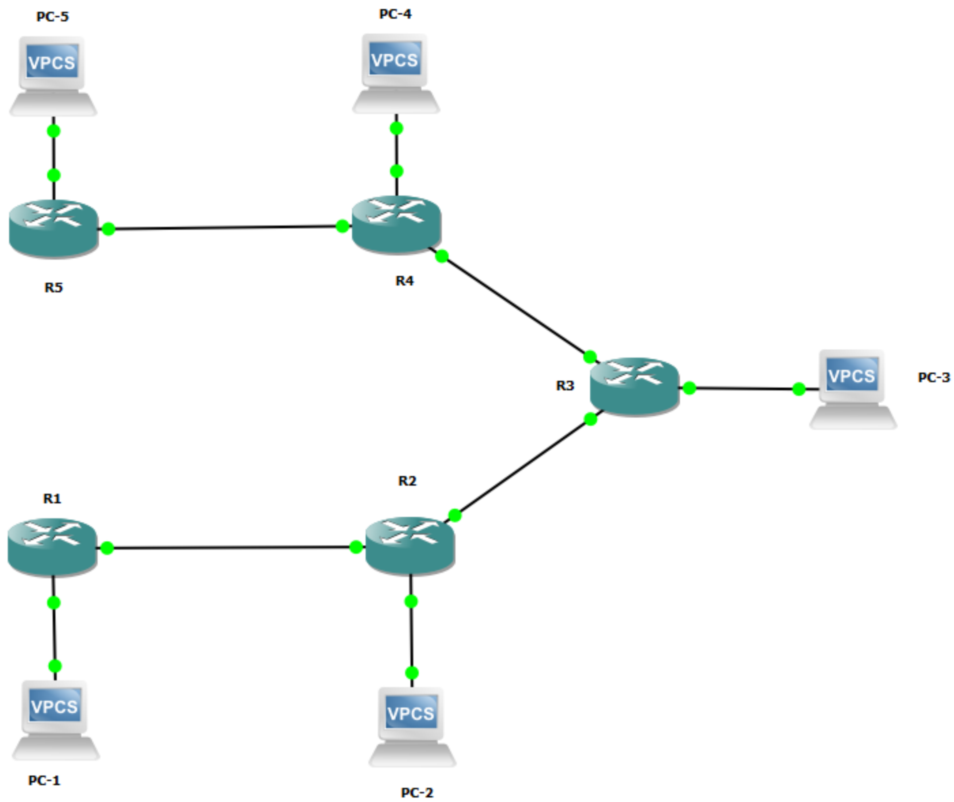
OSPF is another intra-AS routing protocol. They are usually deployed in the upper-tier ISPs. The most recent verison of this is OSPF2 and it is majorly in use in the present times. At its heart, this protocol uses the Dijkstras least-cost path algorithm. Each router in the network, constructs the whole topology and then processes this network to fill its routing tables. In this protocol, **the routers broadcast** their link-state information to all the routers in the topology and not just its neighbours.

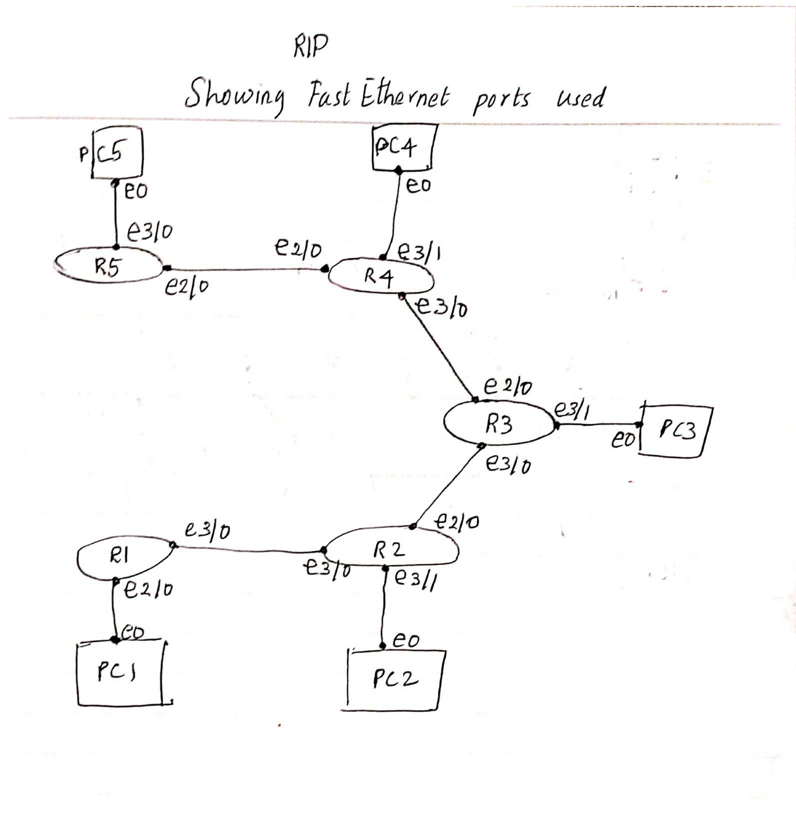
As the construction of whole topology in each router could make the protocol inefficient. For this reason, the implemntation also supports a **heirarchical division**. In such cases, the topology is divided into areas which each area running its own OSPF algorithm. The interconnection between these areas is done through the **area border routers** which lie on the edge of the areas. Also there is an AS that is configured to be **backbone area** that serves the purpose of routing the traffic between these areas.

In this assignment we will look into details of the implementations and working of these protocols. For this we will used the specified topologies and configure them as specified. Later we will understand how the protocols work using ping and inspection of forwarding tables in each of the routers.

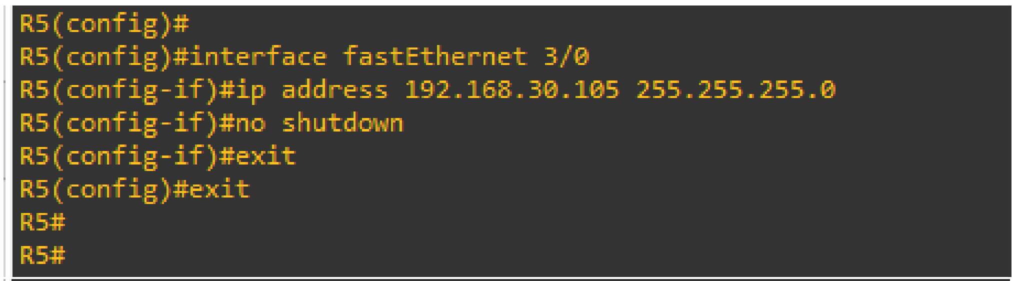
A TOPOLOGY POWERED BY RIP:

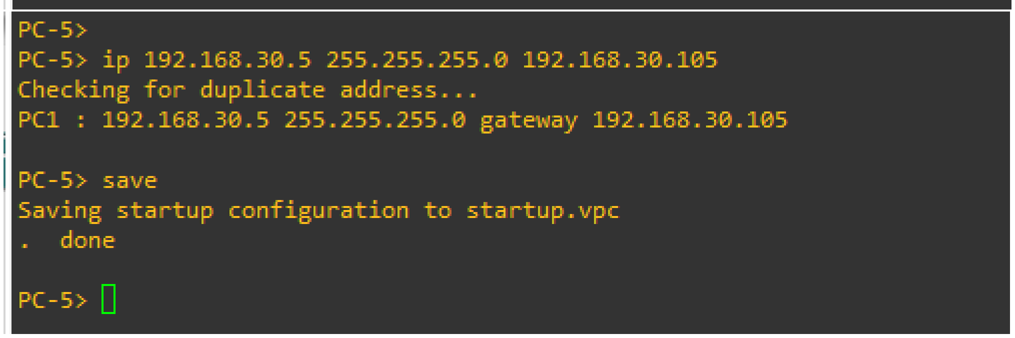
We simulate the following topology on GNS3:



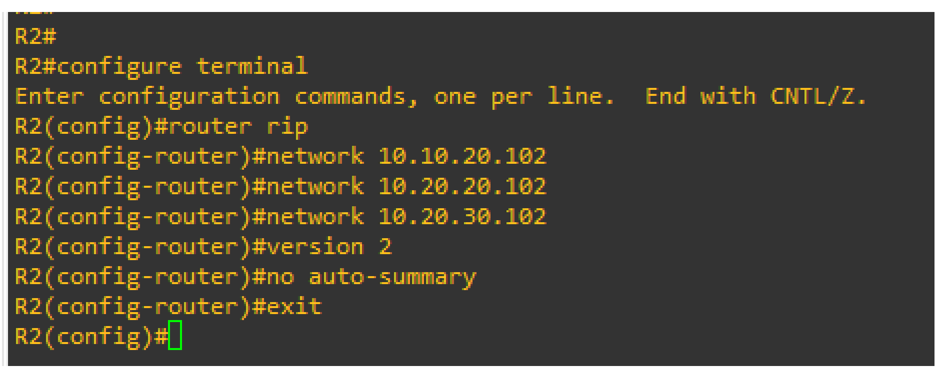


The image above corresponds to the fastEthernet ports used in the network. **Please note that these are not the same as given in the problem statement** because of limited options that were provided during router image installation in GNS3.





The two images above exemplify configuring a router interface and configuring a PC in the network respectively.



Showing an example of configuring RIP protocol in a router.

```
R1#
R1#show 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

R    192.168.30.0/24 [120/4] via 10.10.20.102, 00:00:14, FastEthernet3/0
R    192.168.10.0/24 [120/3] via 10.10.20.102, 00:00:14, FastEthernet3/0
R    192.168.20.0/24 [120/3] via 10.10.20.102, 00:00:14, FastEthernet3/0
     10.0.0.0/24 is subnetted, 6 subnets
R       10.20.30.0 [120/1] via 10.10.20.102, 00:00:14, FastEthernet3/0
R       10.30.30.0 [120/2] via 10.10.20.102, 00:00:14, FastEthernet3/0
R       10.20.20.0 [120/1] via 10.10.20.102, 00:00:14, FastEthernet3/0
C       10.10.10.0 is directly connected, FastEthernet2/0
C       10.10.20.0 is directly connected, FastEthernet3/0
R       10.30.40.0 [120/2] via 10.10.20.102, 00:00:16, FastEthernet3/0
R1#
```

```
R1#
R1#show ip route rip
R    192.168.30.0/24 [120/4] via 10.10.20.102, 00:00:27, FastEthernet3/0
R    192.168.10.0/24 [120/3] via 10.10.20.102, 00:00:27, FastEthernet3/0
R    192.168.20.0/24 [120/3] via 10.10.20.102, 00:00:27, FastEthernet3/0
     10.0.0.0/24 is subnetted, 6 subnets
R       10.20.30.0 [120/1] via 10.10.20.102, 00:00:27, FastEthernet3/0
R       10.30.30.0 [120/2] via 10.10.20.102, 00:00:27, FastEthernet3/0
R       10.20.20.0 [120/1] via 10.10.20.102, 00:00:27, FastEthernet3/0
R       10.30.40.0 [120/2] via 10.10.20.102, 00:00:27, FastEthernet3/0
R1#
```

The above two images show the full IP routing table and RIP routing table of the router R1 respectively. All of the RIP-learnt subnets correspond to the interface FastEthernet 3/0 which can be verified against the image showing port numbers above. Also we can verify that routes to all the subnets are learnt by the router (count = 9) which corresponds to number of subnets in the network. All the routes in the lower image of the two correspond to the routes learnt through RIP, the interior gateway protocol in use.

ROUTER : R1

```
R2#
R2#show 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

R    192.168.30.0/24 [120/3] via 10.20.30.103, 00:00:25, FastEthernet2/0
R    192.168.10.0/24 [120/2] via 10.20.30.103, 00:00:25, FastEthernet2/0
R    192.168.20.0/24 [120/2] via 10.20.30.103, 00:00:25, FastEthernet2/0
     10.0.0.0/24 is subnetted, 6 subnets
C       10.20.30.0 is directly connected, FastEthernet2/0
R       10.30.30.0 [120/1] via 10.20.30.103, 00:00:25, FastEthernet2/0
C       10.20.20.0 is directly connected, FastEthernet3/1
R       10.10.10.0 [120/1] via 10.10.20.101, 00:00:04, FastEthernet3/0
C       10.10.20.0 is directly connected, FastEthernet3/0
R       10.30.40.0 [120/1] via 10.20.30.103, 00:00:27, FastEthernet2/0
R2#
```

```
R2#
R2#show ip route rip
R    192.168.30.0/24 [120/3] via 10.20.30.103, 00:00:03, FastEthernet2/0
R    192.168.10.0/24 [120/2] via 10.20.30.103, 00:00:03, FastEthernet2/0
R    192.168.20.0/24 [120/2] via 10.20.30.103, 00:00:03, FastEthernet2/0
     10.0.0.0/24 is subnetted, 6 subnets
R       10.30.30.0 [120/1] via 10.20.30.103, 00:00:03, FastEthernet2/0
R       10.10.10.0 [120/1] via 10.10.20.101, 00:00:12, FastEthernet3/0
R       10.30.40.0 [120/1] via 10.20.30.103, 00:00:03, FastEthernet2/0
R2#
```

The above two images show the full IP routing table and RIP routing table of the router R2 respectively. Only one subnet is forwarded through the interface FastEthernet 3/1 which corresponds to its direct connection with PC2. Using RIP protocol, only one subnet is routed through FastEthernet 3/0 which also can be verified from the topology. Also we can verify that routes to all the subnets are learnt by the router (count = 9) which corresponds to number of subnets in the network. All the routes in the lower image of the two correspond to the routes learnt through RIP, the interior gateway protocol in use.

ROUTER : R2

```
R3#
R3#show 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

R    192.168.30.0/24 [120/2] via 10.30.40.104, 00:00:28, FastEthernet2/0
R    192.168.10.0/24 [120/1] via 10.30.40.104, 00:00:28, FastEthernet2/0
R    192.168.20.0/24 [120/1] via 10.30.40.104, 00:00:28, FastEthernet2/0
     10.0.0.0/24 is subnetted, 6 subnets
C       10.20.30.0 is directly connected, FastEthernet3/0
C       10.30.30.0 is directly connected, FastEthernet3/1
R       10.20.20.0 [120/1] via 10.20.30.102, 00:00:20, FastEthernet3/0
R       10.10.10.0 [120/2] via 10.20.30.102, 00:00:20, FastEthernet3/0
R       10.10.20.0 [120/1] via 10.20.30.102, 00:00:23, FastEthernet3/0
C       10.30.40.0 is directly connected, FastEthernet2/0
R3#
```

```
R3#
R3#show ip route rip
R    192.168.30.0/24 [120/2] via 10.30.40.104, 00:00:04, FastEthernet2/0
R    192.168.10.0/24 [120/1] via 10.30.40.104, 00:00:04, FastEthernet2/0
R    192.168.20.0/24 [120/1] via 10.30.40.104, 00:00:04, FastEthernet2/0
     10.0.0.0/24 is subnetted, 6 subnets
R       10.20.20.0 [120/1] via 10.20.30.102, 00:00:27, FastEthernet3/0
R       10.10.10.0 [120/2] via 10.20.30.102, 00:00:27, FastEthernet3/0
R       10.10.20.0 [120/1] via 10.20.30.102, 00:00:27, FastEthernet3/0
R3#
R3#
```

The above two images show the full IP routing table and RIP routing table of the router R3 respectively. Only one subnet is routed through the interface FastEthernet 3/1 which corresponds to its direct connection with PC3. Using RIP protocol, exactly half of the subnets routed via FastEthernet3/0 and the other half are routed through FastEthernet2/0 which is justified by its symmetric position in the topology. Also we can verify that routes to all the subnets are learnt by the router (count = 9) which corresponds to number of subnets in the network. All the routes in the lower image of the two correspond to the routes learnt through RIP, the interior gateway protocol in use.

ROUTER : R3

```
R4#
R4#show 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

R    192.168.30.0/24 [120/1] via 192.168.20.105, 00:00:25, FastEthernet2/0
C    192.168.10.0/24 is directly connected, FastEthernet3/1
C    192.168.20.0/24 is directly connected, FastEthernet2/0
     10.0.0.0/24 is subnetted, 6 subnets
R       10.20.30.0 [120/1] via 10.30.40.103, 00:00:18, FastEthernet3/0
R       10.30.30.0 [120/1] via 10.30.40.103, 00:00:18, FastEthernet3/0
R       10.20.20.0 [120/2] via 10.30.40.103, 00:00:18, FastEthernet3/0
R       10.10.10.0 [120/3] via 10.30.40.103, 00:00:18, FastEthernet3/0
R       10.10.20.0 [120/2] via 10.30.40.103, 00:00:20, FastEthernet3/0
C       10.30.40.0 is directly connected, FastEthernet3/0
R4#
```

```
R4#
R4#show ip route rip
R    192.168.30.0/24 [120/1] via 192.168.20.105, 00:00:00, FastEthernet2/0
     10.0.0.0/24 is subnetted, 6 subnets
R       10.20.30.0 [120/1] via 10.30.40.103, 00:00:23, FastEthernet3/0
R       10.30.30.0 [120/1] via 10.30.40.103, 00:00:23, FastEthernet3/0
R       10.20.20.0 [120/2] via 10.30.40.103, 00:00:23, FastEthernet3/0
R       10.10.10.0 [120/3] via 10.30.40.103, 00:00:23, FastEthernet3/0
R       10.10.20.0 [120/2] via 10.30.40.103, 00:00:23, FastEthernet3/0
R4#
```

The above two images show the full IP routing table and RIP routing table of the router R4 respectively. Only one subnet is forwarded through the interface FastEthernet 3/1 which corresponds to its direct connection with PC4. Using RIP protocol, only one subnet is routed through FastEthernet 2/0 which also can be verified from the topology. Also we can verify that routes to all the subnets are learnt by the router (count = 9) which corresponds to number of subnets in the network. All the routes in the lower image of the two correspond to the routes learnt through RIP, the interior gateway protocol in use.

ROUTER : R4

```
R5#
R5#show 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    192.168.30.0/24 is directly connected, FastEthernet3/0
R    192.168.10.0/24 [120/1] via 192.168.20.104, 00:00:13, FastEthernet2/0
C    192.168.20.0/24 is directly connected, FastEthernet2/0
     10.0.0.0/24 is subnetted, 6 subnets
R       10.20.30.0 [120/2] via 192.168.20.104, 00:00:13, FastEthernet2/0
R       10.30.30.0 [120/2] via 192.168.20.104, 00:00:13, FastEthernet2/0
R       10.20.20.0 [120/3] via 192.168.20.104, 00:00:13, FastEthernet2/0
R       10.10.10.0 [120/4] via 192.168.20.104, 00:00:13, FastEthernet2/0
R       10.10.20.0 [120/3] via 192.168.20.104, 00:00:15, FastEthernet2/0
R       10.30.40.0 [120/1] via 192.168.20.104, 00:00:15, FastEthernet2/0
R5#
```

```
R5#show ip route rip
R    192.168.10.0/24 [120/1] via 192.168.20.104, 00:00:22, FastEthernet2/0
     10.0.0.0/24 is subnetted, 6 subnets
R       10.20.30.0 [120/2] via 192.168.20.104, 00:00:22, FastEthernet2/0
R       10.30.30.0 [120/2] via 192.168.20.104, 00:00:22, FastEthernet2/0
R       10.20.20.0 [120/3] via 192.168.20.104, 00:00:22, FastEthernet2/0
R       10.10.10.0 [120/4] via 192.168.20.104, 00:00:22, FastEthernet2/0
R       10.10.20.0 [120/3] via 192.168.20.104, 00:00:22, FastEthernet2/0
R       10.30.40.0 [120/1] via 192.168.20.104, 00:00:22, FastEthernet2/0
R5#
```

The above two images show the full IP routing table and RIP routing table of the router R5 respectively. Only one subnet is forwarded through the interface FastEthernet 3/0 which corresponds to its direct connection with PC5. All of the RIP-learnt subnets correspond to the interface FastEthernet 2/0 which can be verified against the image showing port numbers above. Also we can verify that routes to all the subnets are learnt by the router (count $=$ 9) which corresponds to number of subnets in the network. All the routes in the lower image of the two correspond to the routes learnt through RIP, the interior gateway protocol in use.

ROUTER : R5

```
PC-1>
PC-1> ping 192.168.30.5 -w 5000
84 bytes from 192.168.30.5 icmp_seq=1 ttl=59 time=105.253 ms
84 bytes from 192.168.30.5 icmp_seq=2 ttl=59 time=85.946 ms
84 bytes from 192.168.30.5 icmp_seq=3 ttl=59 time=93.792 ms
84 bytes from 192.168.30.5 icmp_seq=4 ttl=59 time=88.102 ms
84 bytes from 192.168.30.5 icmp_seq=5 ttl=59 time=107.768 ms

PC-1> ping 192.168.10.4 -w 5000
84 bytes from 192.168.10.4 icmp_seq=1 ttl=60 time=3073.402 ms
84 bytes from 192.168.10.4 icmp_seq=2 ttl=60 time=74.078 ms
84 bytes from 192.168.10.4 icmp_seq=3 ttl=60 time=80.882 ms
84 bytes from 192.168.10.4 icmp_seq=4 ttl=60 time=80.741 ms
84 bytes from 192.168.10.4 icmp_seq=5 ttl=60 time=80.746 ms

PC-1> ping 10.30.30.3 -w 5000
84 bytes from 10.30.30.3 icmp_seq=1 ttl=61 time=3053.309 ms
84 bytes from 10.30.30.3 icmp_seq=2 ttl=61 time=54.618 ms
 84 bytes from 10.30.30.3 icmp_seq=3 ttl=61 time=55.551 ms
84 bytes from 10.30.30.3 icmp_seq=4 ttl=61 time=59.715 ms
84 bytes from 10.30.30.3 icmp_seq=5 ttl=61 time=58.689 ms

PC-1> ping 10.20.20.2 -w 5000
84 bytes from 10.20.20.2 icmp_seq=1 ttl=62 time=3032.460 ms
84 bytes from 10.20.20.2 icmp_seq=2 ttl=62 time=36.883 ms
84 bytes from 10.20.20.2 icmp_seq=3 ttl=62 time=40.460 ms
84 bytes from 10.20.20.2 icmp_seq=4 ttl=62 time=39.075 ms
84 bytes from 10.20.20.2 icmp_seq=5 ttl=62 time=41.932 ms

PC-1>
```

Ping-ing the PCs : 5,4,3,2 respectively from PC1 and the response. Hence PC1 is able to communicate with the rest of the hosts as expected.

```
PC-2>
PC-2> ping 192.168.10.4 -w 5000
84 bytes from 192.168.10.4 icmp_seq=1 ttl=61 time=3046.180 ms
84 bytes from 192.168.10.4 icmp_seq=2 ttl=61 time=53.853 ms
84 bytes from 192.168.10.4 icmp_seq=3 ttl=61 time=41.076 ms
84 bytes from 192.168.10.4 icmp_seq=4 ttl=61 time=64.757 ms
84 bytes from 192.168.10.4 icmp_seq=5 ttl=61 time=63.198 ms

PC-2> ping 10.30.30.3 -w 5000
84 bytes from 10.30.30.3 icmp_seq=1 ttl=62 time=31.042 ms
84 bytes from 10.30.30.3 icmp_seq=2 ttl=62 time=38.895 ms
84 bytes from 10.30.30.3 icmp_seq=3 ttl=62 time=34.872 ms
84 bytes from 10.30.30.3 icmp_seq=4 ttl=62 time=38.897 ms
84 bytes from 10.30.30.3 icmp_seq=5 ttl=62 time=31.051 ms

PC-2> ping 10.10.10.1 -w 5000
84 bytes from 10.10.10.1 icmp_seq=1 ttl=62 time=3039.305 ms
84 bytes from 10.10.10.1 icmp_seq=2 ttl=62 time=33.852 ms
84 bytes from 10.10.10.1 icmp_seq=3 ttl=62 time=43.081 ms
84 bytes from 10.10.10.1 icmp_seq=4 ttl=62 time=24.248 ms
84 bytes from 10.10.10.1 icmp_seq=5 ttl=62 time=39.308 ms

PC-2> ping 192.168.30.5 -w 5000
84 bytes from 192.168.30.5 icmp_seq=1 ttl=60 time=3051.380 ms
84 bytes from 192.168.30.5 icmp_seq=2 ttl=60 time=54.425 ms
84 bytes from 192.168.30.5 icmp_seq=3 ttl=60 time=80.499 ms
84 bytes from 192.168.30.5 icmp_seq=4 ttl=60 time=56.109 ms
84 bytes from 192.168.30.5 icmp_seq=5 ttl=60 time=75.470 ms

PC-2>
```

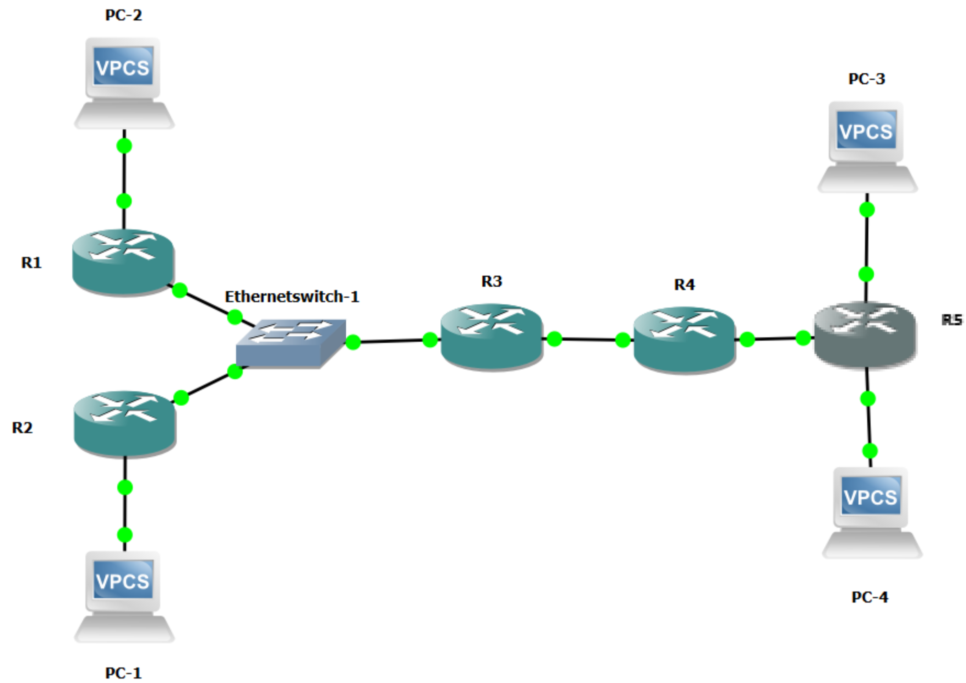
Ping-ing the PCs : 4,3,1,2 respectively from PC2 and the response. Hence PC2 is able to communicate with the rest of the hosts as expected.

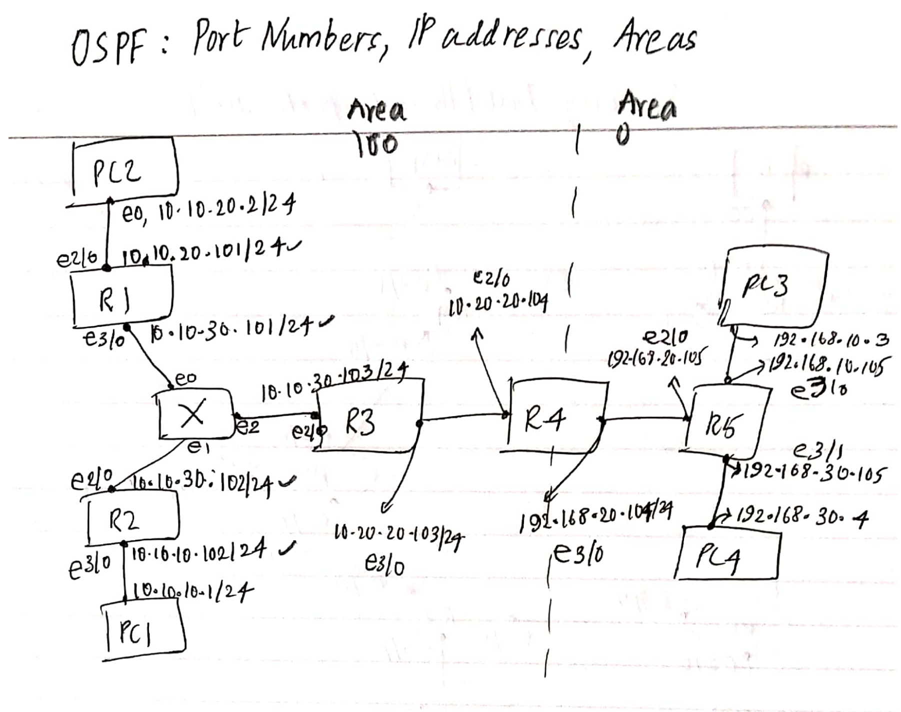
```
PC-3>
PC-3> ping 10.10.10.1 -w 5000
84 bytes from 10.10.10.1 icmp_seq=1 ttl=61 time=62.932 ms
84 bytes from 10.10.10.1 icmp_seq=2 ttl=61 time=58.841 ms
84 bytes from 10.10.10.1 icmp_seq=3 ttl=61 time=60.184 ms
84 bytes from 10.10.10.1 icmp_seq=4 ttl=61 time=3061.211 ms
84 bytes from 10.10.10.1 icmp_seq=5 ttl=61 time=58.846 ms

PC-3> ping 192.168.10.4 -w 5000
84 bytes from 192.168.10.4 icmp_seq=1 ttl=62 time=3027.071 ms
84 bytes from 192.168.10.4 icmp_seq=2 ttl=62 time=34.091 ms
84 bytes from 192.168.10.4 icmp_seq=3 ttl=62 time=39.915 ms
84 bytes from 192.168.10.4 icmp_seq=4 ttl=62 time=33.576 ms
84 bytes from 192.168.10.4 icmp_seq=5 ttl=62 time=37.125 ms

PC-3> ping 10.20.20.2 -w 5000
84 bytes from 10.20.20.2 icmp_seq=1 ttl=62 time=22.923 ms
84 bytes from 10.20.20.2 icmp_seq=2 ttl=62 time=34.483 ms
84 bytes from 10.20.20.2 icmp_seq=3 ttl=62 time=25.917 ms
84 bytes from 10.20.20.2 icmp_seq=4 ttl=62 time=41.087 ms
84 bytes from 10.20.20.2 icmp_seq=5 ttl=62 time=39.651 ms

PC-3> ping 192.168.30.5 -w 5000
84 bytes from 192.168.30.5 icmp_seq=1 ttl=61 time=3068.608 ms
84 bytes from 192.168.30.5 icmp_seq=2 ttl=61 time=36.950 ms
84 bytes from 192.168.30.5 icmp_seq=3 ttl=61 time=61.895 ms
84 bytes from 192.168.30.5 icmp_seq=4 ttl=61 time=58.346 ms
84 bytes from 192.168.30.5 icmp_seq=5 ttl=61 time=63.123 ms

PC-3>
```

Ping-ing the PCs : 1,4,2,5 respectively from PC3 and the response. Hence PC3 is able to communicate with the rest of the hosts as expected.

A TOPOLOGY POWERED BY OSPF:

We simulate the following topology on GNS3 to configure and test OSPF protocol:





The above diagram shows the FastEthernet ports, IP addresses of the interfaces and the division of the areas in the OSPF network. Note that it has two areas with codes 100 and 0. **These port numbers are different from those given in assignment, however the IP addresses, areas and the topology is the same.** Also note the area-0 corresponds to the **backbone** area in the hierarchical implementation of OSPF protocol.

```
R4#
R4#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R4(config)#interface fastEthernet 2/0
R4(config-if)#ip address 10.20.20.104 255.255.255.0
R4(config-if)#no shutdown
R4(config-if)#exit
```

```
PC-1> ip 10.10.10.1 255.255.255.0 10.10.10.102
Checking for duplicate address...
PC1 : 10.10.10.1 255.255.255.0 gateway 10.10.10.102

PC-1> save
Saving startup configuration to startup.vpc
.  done

PC-1>
```

The above two images show the method of configuration of IP address to router interface and PC interface respectively.

```
R4(config)#
R4(config)#router ospf 120
R4(config-router)#network 10.20.20.0 0.0.0.255 area 100
R4(config-router)#network 192.168.20.0 0.0.0.255 area 0
R4(config-router)#exit
R4(config)#
R4(config)#
```

The above picture shows an example configuration of OSPF for the router R4. Note that R4 is connected to two subnets from different areas 100 and 0 and is a border gateway router.

```
R1#
R1#show 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

O IA 192.168.30.0/24 [110/4] via 10.10.30.103, 00:00:17, FastEthernet3/0
O IA 192.168.10.0/24 [110/4] via 10.10.30.103, 00:00:27, FastEthernet3/0
O IA 192.168.20.0/24 [110/3] via 10.10.30.103, 00:00:50, FastEthernet3/0
     10.0.0.0/24 is subnetted, 4 subnets
O       10.20.20.0 [110/2] via 10.10.30.103, 00:00:50, FastEthernet3/0
O       10.10.10.0 [110/2] via 10.10.30.102, 00:00:50, FastEthernet3/0
C       10.10.20.0 is directly connected, FastEthernet2/0
C       10.10.30.0 is directly connected, FastEthernet3/0
R1#
```

```
R1#
R1#show ip route ospf
O IA 192.168.30.0/24 [110/4] via 10.10.30.103, 00:00:23, FastEthernet3/0
O IA 192.168.10.0/24 [110/4] via 10.10.30.103, 00:00:32, FastEthernet3/0
O IA 192.168.20.0/24 [110/3] via 10.10.30.103, 00:00:56, FastEthernet3/0
     10.0.0.0/24 is subnetted, 4 subnets
O       10.20.20.0 [110/2] via 10.10.30.103, 00:00:56, FastEthernet3/0
O       10.10.10.0 [110/2] via 10.10.30.102, 00:00:56, FastEthernet3/0
R1#
R1#
```

The above two images show the full IP routing table and OSPF routing table of the router R1 respectively. Only one subnet is forwarded through the interface FastEthernet 2/0 which corresponds to its direct connection with PC2. All of the OSPF-learnt subnets correspond to the interface FastEthernet 3/0 which can be verified against the image showing port numbers above. Also we can verify that routes to all the subnets are learnt by the router (count=7) which corresponds to number of subnets in the network. This count also shows that the routers are oblivious to presence of switches in a subnet. Since the router R1 is in area 100, from the lower image(above) it can be verified that inter-area OSPF learnt routes are to subnets: 192.168.30.0/24, 192.168.10.0/24, 192.168.20.0/24 which correspond to the subnets in area-0. This is indicated by a special mention "O IA" : OSPF inter-area. OSPF routing table also shows the next hop router as well the interface to be used to forward to a particular subnet . Only for one subnet, the next-hop IP is 10.10.10.102 which corresponds to the subnet between the router R2 and PC : PC1.

```
R2#
R2#show 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

O IA 192.168.30.0/24 [110/4] via 10.10.30.103, 00:03:13, FastEthernet2/0
O IA 192.168.10.0/24 [110/4] via 10.10.30.103, 00:03:23, FastEthernet2/0
O IA 192.168.20.0/24 [110/3] via 10.10.30.103, 00:03:46, FastEthernet2/0
     10.0.0.0/24 is subnetted, 4 subnets
O       10.20.20.0 [110/2] via 10.10.30.103, 00:03:46, FastEthernet2/0
C       10.10.10.0 is directly connected, FastEthernet3/0
O       10.10.20.0 [110/2] via 10.10.30.101, 00:03:46, FastEthernet2/0
C       10.10.30.0 is directly connected, FastEthernet2/0
R2#
```

```
R2#
R2#show ip route ospf
O IA 192.168.30.0/24 [110/4] via 10.10.30.103, 00:03:21, FastEthernet2/0
O IA 192.168.10.0/24 [110/4] via 10.10.30.103, 00:03:31, FastEthernet2/0
O IA 192.168.20.0/24 [110/3] via 10.10.30.103, 00:03:54, FastEthernet2/0
     10.0.0.0/24 is subnetted, 4 subnets
O       10.20.20.0 [110/2] via 10.10.30.103, 00:03:54, FastEthernet2/0
O       10.10.20.0 [110/2] via 10.10.30.101, 00:03:54, FastEthernet2/0
R2#
R2#
```

The above two images show the full IP routing table and OSPF routing table of the router R2 respectively. Only one subnet is forwarded through the interface FastEthernet 3/0 which corresponds to its direct connection with PC1. All of the OSPF-learnt subnets correspond to the interface FastEthernet 2/0 which can be verified against the image showing port numbers above. Also we can verify that routes to all the subnets are learnt by the router (count=7) which corresponds to number of subnets in the network. This count also shows that the routers are oblivious to presence of switches in a subnet. Since the router R2 is in area 100, from the lower image(above) it can be verified that inter-area OSPF learnt routes are to subnets: 192.168.30.0/24, 192.168.10.0/24, 192.168.20.0/24 which correspond to the subnets in area-0. This is indicated by a special mention "O IA" : OSPF inter-area. In the OSPF routing table, we can also see the next hop router as well the interface to be used to forward to a particular subnet. Only for one of the subnets, the next-hop IP is 10.10.10.101 which corresponds to the subnet between the router R1 and PC : PC2.

```
R3#
R3#show 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

O IA 192.168.30.0/24 [110/3] via 10.20.20.104, 00:03:55, FastEthernet3/0
O IA 192.168.10.0/24 [110/3] via 10.20.20.104, 00:04:05, FastEthernet3/0
O IA 192.168.20.0/24 [110/2] via 10.20.20.104, 00:04:28, FastEthernet3/0
     10.0.0.0/24 is subnetted, 4 subnets
C       10.20.20.0 is directly connected, FastEthernet3/0
O       10.10.10.0 [110/2] via 10.10.30.102, 00:04:28, FastEthernet2/0
O       10.10.20.0 [110/2] via 10.10.30.101, 00:04:28, FastEthernet2/0
C       10.10.30.0 is directly connected, FastEthernet2/0
R3#
```

```
R3#
R3#show ip route ospf
O IA 192.168.30.0/24 [110/3] via 10.20.20.104, 00:04:00, FastEthernet3/0
O IA 192.168.10.0/24 [110/3] via 10.20.20.104, 00:04:10, FastEthernet3/0
O IA 192.168.20.0/24 [110/2] via 10.20.20.104, 00:04:34, FastEthernet3/0
     10.0.0.0/24 is subnetted, 4 subnets
O       10.10.10.0 [110/2] via 10.10.30.102, 00:04:34, FastEthernet2/0
O       10.10.20.0 [110/2] via 10.10.30.101, 00:04:34, FastEthernet2/0
R3#
R3#
```

The above two images show the full IP routing table and OSPF routing table of the router R3 respectively. We can see that two subnets are learnt via intra OSPF protocol. Another two subents are directly connected and three are learny via inter-area OSPF. The same can be verified from the topology as well. Also we can verify that routes to all the subnets are learnt by the router (count=7) which corresponds to number of subnets in the network. This count also shows that the routers are oblivious to presence of switches in a subnet. Since the router R3 is in area 100, from the lower image(above) it can be verified that inter-area OSPF learnt routes are to subnets: 192.168.30.0/24, 192.168.10.0/24, 192.168.20.0/24 which correspond to the subnets in area-0. This is indicated by a special mention "O IA" : OSPF inter-area. In the OSPF routing table, we can also see the next hop router as well the interface to be used to forward to a particular subnet.

```
R4#
R4#show 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

O    192.168.30.0/24 [110/2] via 192.168.20.105, 00:04:54, FastEthernet3/0
O    192.168.10.0/24 [110/2] via 192.168.20.105, 00:04:54, FastEthernet3/0
C    192.168.20.0/24 is directly connected, FastEthernet3/0
     10.0.0.0/24 is subnetted, 4 subnets
C       10.20.20.0 is directly connected, FastEthernet2/0
O       10.10.10.0 [110/3] via 10.20.20.103, 00:05:28, FastEthernet2/0
O       10.10.20.0 [110/3] via 10.20.20.103, 00:05:28, FastEthernet2/0
O       10.10.30.0 [110/2] via 10.20.20.103, 00:05:28, FastEthernet2/0
R4#
```

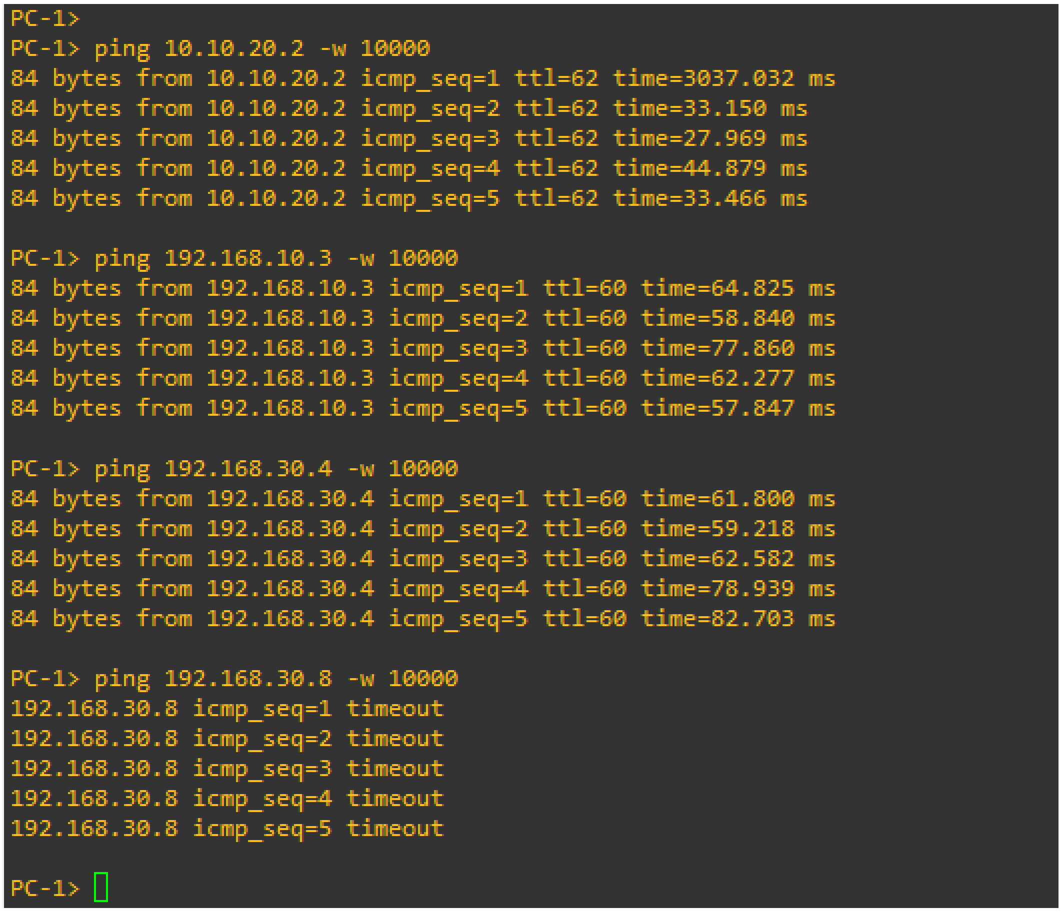
```
R4#
R4#show ip route ospf
O    192.168.30.0/24 [110/2] via 192.168.20.105, 00:05:00, FastEthernet3/0
O    192.168.10.0/24 [110/2] via 192.168.20.105, 00:05:00, FastEthernet3/0
     10.0.0.0/24 is subnetted, 4 subnets
O       10.10.10.0 [110/3] via 10.20.20.103, 00:05:34, FastEthernet2/0
O       10.10.20.0 [110/3] via 10.20.20.103, 00:05:34, FastEthernet2/0
O       10.10.30.0 [110/2] via 10.20.20.103, 00:05:34, FastEthernet2/0
R4#
R4#
```

The above two images show the full IP routing table and OSPF routing table of the router R4 respectively. Two subents are directly connected and the rest of them are learnt via intra-area OSPF. This is beacuse the router R4 is a border gateway router and belongs to both the areas. Hence it learns both the area 100, 0's routing information without a need for inter-aera communication. The same can be verified from the topology as well. Also we can verify that routes to all the subnets are learnt by the router (count=7) which corresponds to number of subnets in the network. This count also shows that the routers are oblivious to presence of switches in a subnet. In the OSPF routing table, we can also see the next hop router as well the interface to be used to forward to a particular subnet.

```
R5#
R5#show 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    192.168.30.0/24 is directly connected, FastEthernet3/1
C    192.168.10.0/24 is directly connected, FastEthernet3/0
C    192.168.20.0/24 is directly connected, FastEthernet2/0
     10.0.0.0/24 is subnetted, 4 subnets
O IA    10.20.20.0 [110/2] via 192.168.20.104, 00:05:45, FastEthernet2/0
O IA    10.10.10.0 [110/4] via 192.168.20.104, 00:05:45, FastEthernet2/0
O IA    10.10.20.0 [110/4] via 192.168.20.104, 00:05:45, FastEthernet2/0
O IA    10.10.30.0 [110/3] via 192.168.20.104, 00:05:45, FastEthernet2/0
R5#
```

```
R5#
R5#show ip route ospf
     10.0.0.0/24 is subnetted, 4 subnets
O IA    10.20.20.0 [110/2] via 192.168.20.104, 00:05:57, FastEthernet2/0
O IA    10.10.10.0 [110/4] via 192.168.20.104, 00:05:57, FastEthernet2/0
O IA    10.10.20.0 [110/4] via 192.168.20.104, 00:05:57, FastEthernet2/0
O IA    10.10.30.0 [110/3] via 192.168.20.104, 00:05:57, FastEthernet2/0
R5#
R5#
```

The above two images show the full IP routing table and OSPF routing table of the router R5 respectively. We can see that three subnets are directly connected via the ports: FastEthernet3/1,3/0,2/0 to PCs4,3,R4 respectively. Since the router R5 is in area 0, from the lower image(above) it can be verified that inter-area OSPF learnt routes are to subnets: 10.10.20.0/24, 10.10.20.0/24, 10.10.10.0/24 and 10.10.30.0/24 which correspond to the subnets in area-100. This is indicated by a special mention "O IA" : OSPF inter-area. The same can be verified from the topology as well. Also we can verify that routes to all the subnets are learnt by the router (count=7) which corresponds to number of subnets in the network. This count also shows that the routers are oblivious to presence of switches in a subnet. In the OSPF routing table, we can also see the next hop router is always 192.168.20.104 corresponding to the interface FastEthernet 2/0. This is as expected from the topology.


```
PC-1>
PC-1> ping 10.10.20.2 -w 10000
84 bytes from 10.10.20.2 icmp_seq=1 ttl=62 time=3037.032 ms
84 bytes from 10.10.20.2 icmp_seq=2 ttl=62 time=33.150 ms
84 bytes from 10.10.20.2 icmp_seq=3 ttl=62 time=27.969 ms
84 bytes from 10.10.20.2 icmp_seq=4 ttl=62 time=44.879 ms
84 bytes from 10.10.20.2 icmp_seq=5 ttl=62 time=33.466 ms

PC-1> ping 192.168.10.3 -w 10000
84 bytes from 192.168.10.3 icmp_seq=1 ttl=60 time=64.825 ms
84 bytes from 192.168.10.3 icmp_seq=2 ttl=60 time=58.840 ms
84 bytes from 192.168.10.3 icmp_seq=3 ttl=60 time=77.860 ms
84 bytes from 192.168.10.3 icmp_seq=4 ttl=60 time=62.277 ms
84 bytes from 192.168.10.3 icmp_seq=5 ttl=60 time=57.847 ms

PC-1> ping 192.168.30.4 -w 10000
84 bytes from 192.168.30.4 icmp_seq=1 ttl=60 time=61.800 ms
84 bytes from 192.168.30.4 icmp_seq=2 ttl=60 time=59.218 ms
84 bytes from 192.168.30.4 icmp_seq=3 ttl=60 time=62.582 ms
84 bytes from 192.168.30.4 icmp_seq=4 ttl=60 time=78.939 ms
84 bytes from 192.168.30.4 icmp_seq=5 ttl=60 time=82.703 ms

PC-1> ping 192.168.30.8 -w 10000
192.168.30.8 icmp_seq=1 timeout
192.168.30.8 icmp_seq=2 timeout
192.168.30.8 icmp_seq=3 timeout
192.168.30.8 icmp_seq=4 timeout
192.168.30.8 icmp_seq=5 timeout

PC-1>
```

Ping-ing the PCs : 2,3,4 respectively from PC1 and the response. Also note that when we give a false IP address in the ping command, as shown above, we see a series of timeouts. Hence we can see that PC1 is able to communicate with the rest of the hosts as expected.

```
PC-4>
PC-4> ping 10.10.10.1 -w 10000
84 bytes from 10.10.10.1 icmp_seq=1 ttl=60 time=3076.017 ms
84 bytes from 10.10.10.1 icmp_seq=2 ttl=60 time=68.292 ms
84 bytes from 10.10.10.1 icmp_seq=3 ttl=60 time=77.745 ms
84 bytes from 10.10.10.1 icmp_seq=4 ttl=60 time=66.734 ms
84 bytes from 10.10.10.1 icmp_seq=5 ttl=60 time=82.420 ms

PC-4> ping 10.10.20.2 -w 10000
84 bytes from 10.10.20.2 icmp_seq=1 ttl=60 time=3078.922 ms
84 bytes from 10.10.20.2 icmp_seq=2 ttl=60 time=81.820 ms
84 bytes from 10.10.20.2 icmp_seq=3 ttl=60 time=82.133 ms
84 bytes from 10.10.20.2 icmp_seq=4 ttl=60 time=73.543 ms
84 bytes from 10.10.20.2 icmp_seq=5 ttl=60 time=74.797 ms

PC-4> ping 192.168.10.3 -w 10000
84 bytes from 192.168.10.3 icmp_seq=1 ttl=63 time=3022.415 ms
84 bytes from 192.168.10.3 icmp_seq=2 ttl=63 time=21.944 ms
84 bytes from 192.168.10.3 icmp_seq=3 ttl=63 time=16.961 ms
84 bytes from 192.168.10.3 icmp_seq=4 ttl=63 time=15.960 ms
84 bytes from 192.168.10.3 icmp_seq=5 ttl=63 time=20.942 ms

PC-4>
```

Ping-ing the PCs : 1,2,4 respectively from PC4 and the response. Hence PC4 is able to communicate with the rest of the hosts as expected.

Showing the OSPF neighbour command run below:

Routers order : R1,R2,R3,R4,R5

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.10.30.102      1   FULL/BDR        00:00:34    10.10.30.102    FastEthernet3/0
10.20.20.103      1   FULL/DR         00:00:31    10.10.30.103    FastEthernet3/0
R1#
R1#
R1#
```

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.10.30.101      1   FULL/DROTHER    00:00:32    10.10.30.101    FastEthernet2/0
10.20.20.103      1   FULL/DR         00:00:33    10.10.30.103    FastEthernet2/0
R2#
R2#
R2#
```

```
R3#
R3#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.20.104    1   FULL/DR         00:00:33    10.20.20.104    FastEthernet3/0
10.10.30.101      1   FULL/DROTHER    00:00:29    10.10.30.101    FastEthernet2/0
10.10.30.102      1   FULL/BDR        00:00:35    10.10.30.102    FastEthernet2/0
R3#
```

```
R4#
R4#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.20.105    1   FULL/DR         00:00:31    192.168.20.105  FastEthernet3/0
10.20.20.103      1   FULL/BDR        00:00:34    10.20.20.103    FastEthernet2/0
R4#
R4#
```

```
R5#
R5#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.20.104    1   FULL/BDR        00:00:33    192.168.20.104  FastEthernet2/0
R5#
R5#
```