BIRZEIT UNIVERSITY

Faculty of Engineering & Technology

Electrical & Computer Engineering Department

ENCS4130

Experiment No. 4

Dynamic Routing 2 - OSPF

Prepared by : Tareq Shannak

ID Number :   1181404

Instructor : Dr. Ahmad Alsadeh

Teaching Assistant : Katy Sadi

Section : 2

Date : 25/7/2021

Abstract

The aim of this experiment is to simulate networks in Cisco packet tracer using routers, switches and PCs, configure IP routing with good sub-netting in Cisco routers and routing dynamically with Open Shortest Path First (OSPF) protocol. Also, we will know how OSPF selects the router IDs for each router.

Table of Contents

Table of Figures

Table of Tables

1. Theory

1.1. Introduction

There are two primary ways of configuring routing: statically and dynamically. Static routing is typically used on very small networks, where the number of routes to be configured is just as small. However, static routing is sometimes used in larger networks as a small piece of an overall dynamically controlled routing infrastructure. In such cases, static routes typically configure default routes, or direct traffic out of the network to another network controlled by another party.

Dynamic routing is built to deal with network changes automatically as the topology changes within the network, and are typically used on all other network types not previously mentioned.

1.2. Types of Dynamic Routing

After selecting the dynamic routing method, the engineer must make some additional decisions involving the types of dynamic routing protocols. At the highest level are two main categories of dynamic routing protocol: exterior gateway protocols (EGPs) and interior gateway protocols (IGPs). EGPs connect multiple network domains; they're called exterior because the protocol is exterior to the network domains. (A domain in this case is a specific organization or service provider network.) IGPs handle the routing inside these network domains; these protocols are the most common, as each company with a network handles its own network domain.

Modern networks use only a single EGP: the Border Gateway Protocol (BGP). As you might expect, a number of different IGPs are available, depending on the requirements of each network. Four IGPs are the most popular:

- Open Shortest Path First (OSPF)
- Enhanced Interior Gateway Routing Protocol (EIGRP)
- Intermediate System to Intermediate System (IS-IS)
- Routing Information Protocol (RIP)

1.3. OSPF Definition

Open Shortest Path First (OSPF) is a link-state routing protocol that was developed for IP networks and is based on the Shortest Path First (SPF) algorithm. OSPF is an Interior Gateway Protocol (IGP).

In an OSPF network, routers or systems within the same area maintain an identical link-state database that describes the topology of the area. Each router or system in the area generates its link-state database from the link-state advertisements (LSAs) that it receives from all the other routers or systems in the same area and the LSAs that itself generates. An LSA is a packet that contains information about neighbors and path costs. Based on the link-state database, each router or system calculates a shortest-path spanning tree, with itself as the root, using the SPF algorithm.

1.4. OSPF Configuration

Figure 1 shows the commands that we used to configure OSPF routing for a simple router.

```
Router(config)#router ospf 1
Router(config-router)#network 192.168.0.8 0.0.0.3 area 0
Router(config-router)#network 192.168.0.12 0.0.0.3 area 0
Router(config-router)#network 192.168.2.0 0.0.0.127 area 2
```

Figure 1 - Commands to configure OSPF

1.5. OSPF Advantages

OSPF has the following key advantages:

Compared with distance-vector routing protocols such as the Routing Information Protocol (RIP), OSPF is more suitable for serving large, heterogeneous internetworks. OSPF can recalculate the routes in a short amount of time when the network topology changes.

With OSPF, you can divide an Autonomous System (AS) into areas and keep area topologies separate to decrease the OSPF routing traffic and the size of the link-state database of each area.

OSPF provides equal-cost multipath routing. You can add duplicate routes to the TCP stack using different next hops.

2. Procedure & Discussion

2.1. Topology

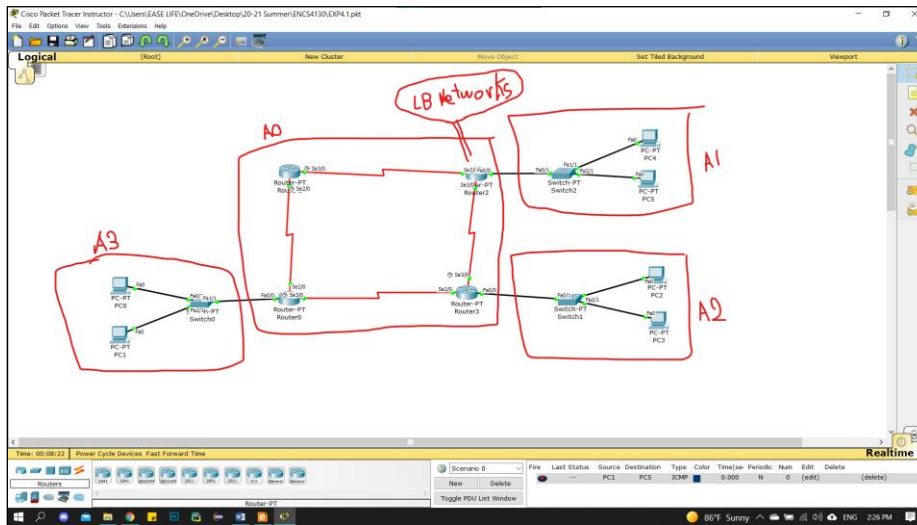The topology in the figure below has been built in Cisco packet tracer.

Figure 2 - Topology 1

2.2. Networks IPs

Table 1 shows sub-netting the IPs of networks and PCs and identify the areas.

#Area	#Net	Network	Device	Interface	IP	Subnet Mask	Wildcard Mask
A0	0	192.168.0.0/30	Router 2	Se2/0	192.168.0.1	255.255.255.252	0.0.0.3
			Router 1	Se3/0	192.168.0.2	255.255.255.252	0.0.0.3
	1	192.168.4.0/30	Router 0	Se2/0	192.168.0.5	255.255.255.252	0.0.0.3
			Router 1	Se2/0	192.168.0.6	255.255.255.252	0.0.0.3
	2	192.168.8.0/30	Router 0	Se3/0	192.168.0.9	255.255.255.252	0.0.0.3
			Router 3	Se2/0	192.168.0.10	255.255.255.252	0.0.0.3
	3	192.168.12.0/30	Router 2	Se3/0	192.168.0.13	255.255.255.252	0.0.0.3
			Router 3	Se3/0	192.168.0.14	255.255.255.252	0.0.0.3
A1	4	192.168.1.0/24	Router 2	Fa0/0	192.168.1.1	255.255.255.0	0.0.0.255
			PC4	Fa0	192.168.1.2	255.255.255.0	0.0.0.255
			PC5	Fa0	192.168.1.3	255.255.255.0	0.0.0.255
A2	5	192.168.2.0/25	Router 3	Fa0/0	192.168.2.1	255.255.255.128	0.0.0.127
			PC2	Fa0	192.168.2.2	255.255.255.128	0.0.0.127
			PC3	Fa0	192.168.2.3	255.255.255.128	0.0.0.127
A3	6	192.168.2.128/25	Router 0	Fa0/0	192.168.2.129	255.255.255.128	0.0.0.127
			PC0	Fa0	192.168.2.130	255.255.255.128	0.0.0.127
			PC1	Fa0	192.168.2.131	255.255.255.128	0.0.0.127
Sum. 172.16.0.0 /22	-	172.16.0.0/24	Router 2	LB0	172.16.0.1	255.255.255.0	0.0.0.255
	-	172.16.1.0/24	Router 2	LB1	172.16.1.1	255.255.255.0	0.0.0.255
	-	172.16.2.0/24	Router 2	LB2	172.16.2.1	255.255.255.0	0.0.0.255
	-	172.16.3.0/24	Router 2	LB3	172.16.3.1	255.255.255.0	0.0.0.255
Sum. 172.16.4.0 /23	-	172.16.4.0/24	Router 2	LB4	172.16.4.1	255.255.255.0	0.0.0.255
	-	172.16.5.0/24	Router 2	LB5	172.16.5.1	255.255.255.0	0.0.0.255

Table 1 - Networks IPs

2.3.Configuring OSPF Routing

From Table 1, each PC has been configured its IP address, subnet mask and gateway. Also, the routers have been turned on for each interface that we used in the network and each interface has been given a certain IP address.

After that, OSPF has been configured by writing commands in the routers that specify process ID of the routing, and select which networks contain this specified router by writing the network ID, wildcard mask and the area number.

2.4.Changing the cost

Finally, the cost of serial interface 2/0 in router 0 has changed from 1 to 5 by changing the bandwidth to 20000KB according to the equation below.

$$Bandwidth = \frac{100MB}{Cost} = \frac{100MB}{5} = 20000KB$$

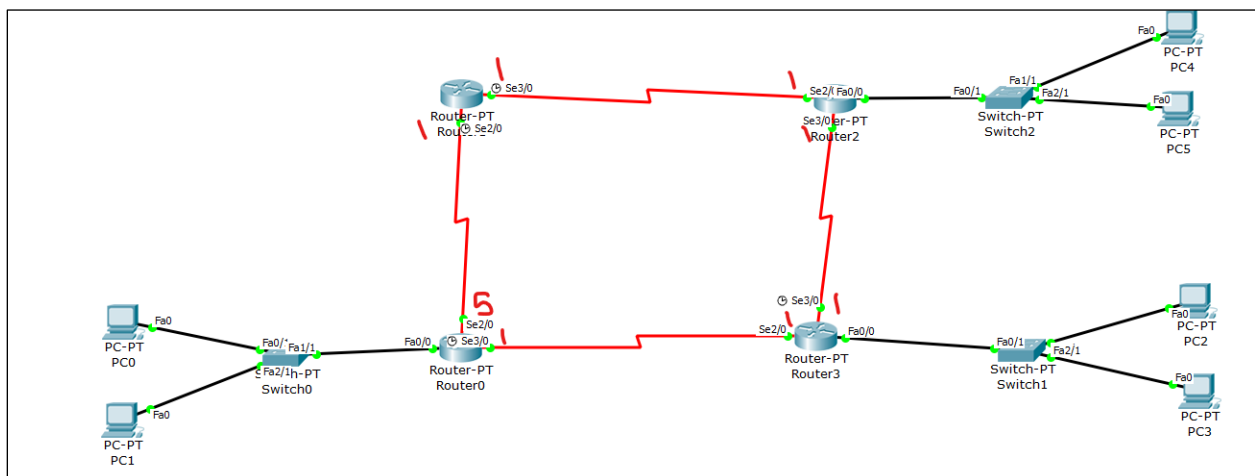Figure 2 shows the costs between the routers.

Figure 3 - Costs between Cisco Routers

2.5.Important Questions

- **Why do we need for loopback interfaces?**

The loopback interface is useful because it is an interface with an IP address which never goes down. OSPF, without a specifically defined Router ID, will pick a Router ID on its own. It chooses the Router ID from the IP addresses of the configured and enabled interfaces. A loopback is a good choice since the loopback interface is always up unless someone specifically shuts it down. Other interfaces may go down if there is a problem on the link.

- **What is the router-id for OSPF? And why do we need it? Hardcore the router-id for R1, R2 and R3 as 1.1.1.1, 2.2.2.2 and 3.3.3.3 respectively. And Verify that.**

Each Router in an OSPF network needs a unique OSPF Router ID. The OSPF Router ID is used to provide a unique identity to the OSPF Router. OSPF Router ID should not be changed after the OSPF process has been started and the ospf neighbor-ships are established. If you change the OSPF router ID, we need to either reload the IOS or use "clear ip ospf process" command, for OSPF Router ID change to take effect. Reloading the IOS or using "clear ip ospf process" commad can cause temporary network outage.

Figure 4 shows how to configure the router-id for a router manually, and Figure 5 ensures that the router-id has changed in the router.

```
Router(config)#router ospf 1
Router(config-router)#ro
Router(config-router)#router-id 1.1.1.1
Router(config-router)#Reload or use "clear ip ospf process" command, for this to take effect

Router(config-router)#ex
Router(config)#clea
Router(config)#ex
Router#
%SYS-5-CONFIG_I: Configured from console by console
clea
Router#clear ip os
Router#clear ip ospf pro
Router#clear ip ospf process
Reset ALL OSPF processes? [no]: yes

Router#
```

Figure 4 - Configure Router-ID Manually

```
Router#show ip protocols

Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 1.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```

Figure 5 - Show Router-ID

3. Results

Figure 6 shows that the messages have been received successfully to the PCs that we chose randomly. Therefore, our network's devices communicate with each other perfectly using dynamic routing which its type is OSPF.
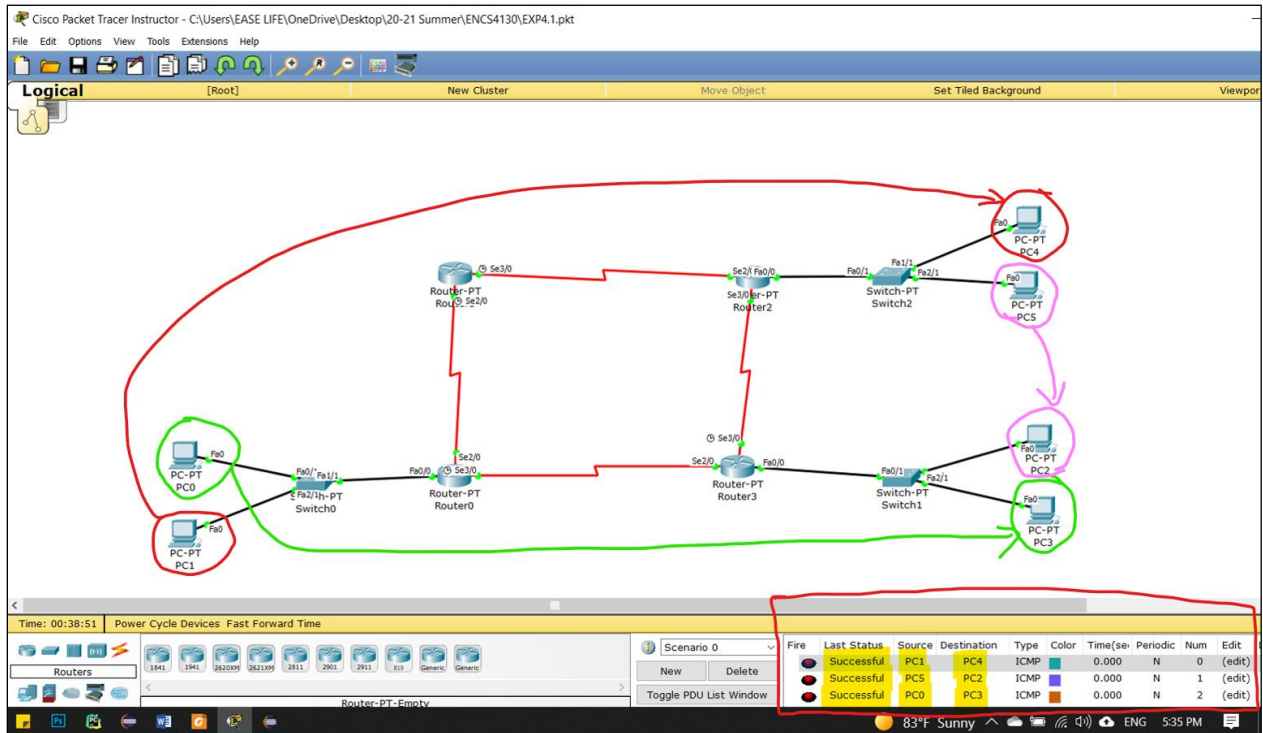

Figure 6 - Ping Requests

To see the path of our message that has been passed from PC0 to PC4, tracert command has been executed as shown in Figure 7.
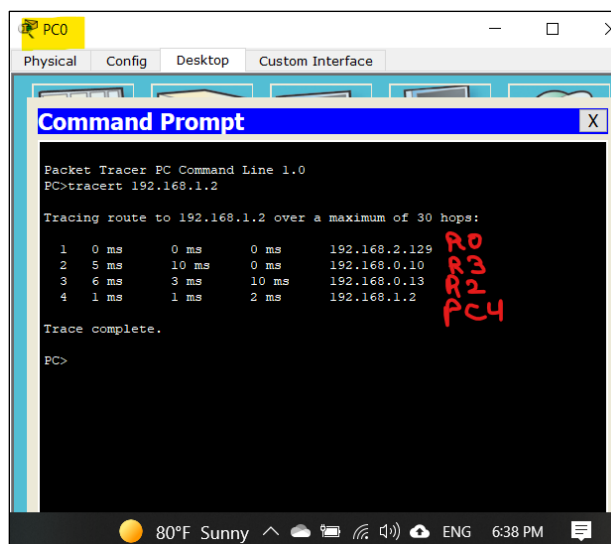

Figure 7 - Tracert from PC0 to PC5

We can see that the message passed from router 3 instead of router 1 because the cost of the serial interface 2/0 (cost = 5) is more than the cost of the serial interface 3/0 (cost = 1) as shown in Figure 8.
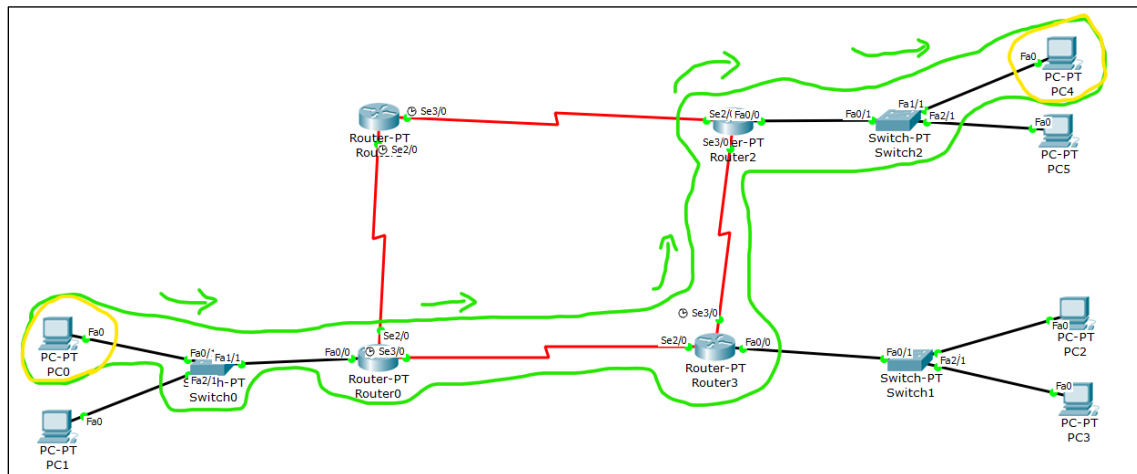

Figure 8 - Path of the message's packets from PC0 to PC4

4. Problem

4.1. Topology

Figure 9 shows the topology of the problem. Every serial connection has a certain cost.
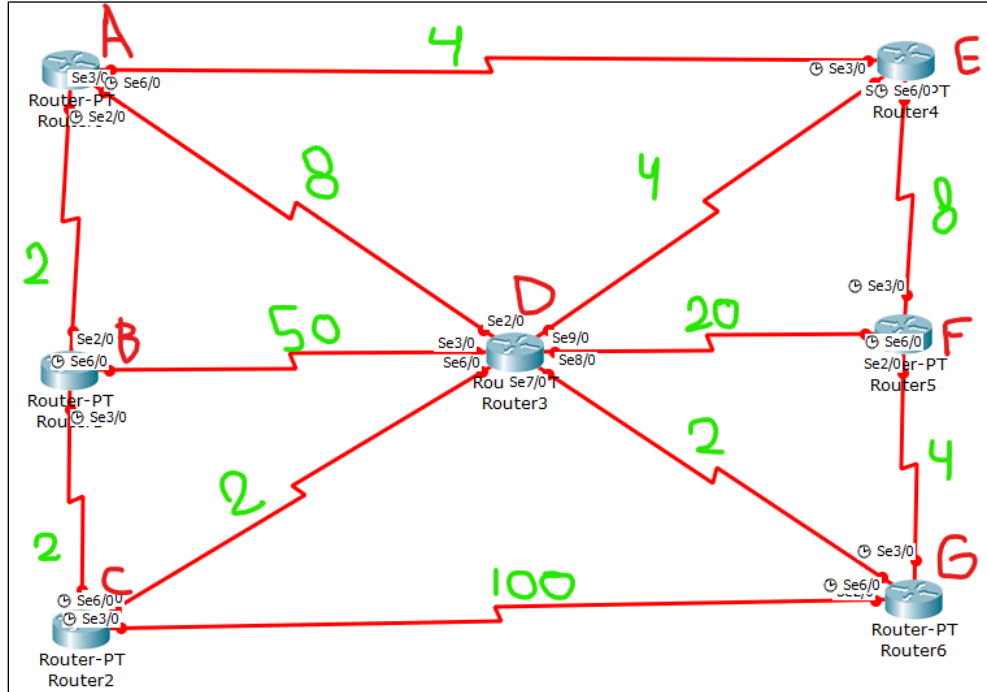

Figure 9 - Problem's Topology

4.2. Dijkstra's Algorithm

The shortest paths between routers has calculated using Dijkstra's algorithm as shown in Table 2 to know the shortest path between Router0 and Router6.

N	D(B)	D(C)	D(D)	D(E)	D(F)	D(G)
A	2, A	∞	8, A	4, A	∞	∞
AB		4, B	8, A	4, A	∞	∞
ABC			6, C	4, A	∞	104, C
ABCE			6, C		12, E	104, C
ABCED					12, E	8, D
ABCEDG					12, E/G	
ABCEDGF						

Table 2 - Dijkstra's algorithm

The shortest path from Router0 (A) to Router6 (G) using Dijkstra's algorithm:

$$G\ (8, D) \leftarrow D\ (6, C) \leftarrow C\ (4, B) \leftarrow B\ (2, A) \leftarrow A$$
$$R0 \rightarrow R1 \rightarrow R2 \rightarrow R3 \rightarrow R6$$

The cost of the shortest path = 8

4.3. Addressing the network using class C 192.14.4.0

Table 3 shows sub-netting the IPs of networks and routers.

#Area	#Net	Network	Device	Interface	IP	Subnet Mask	Wildcard Mask
A0	0	192.14.4.0/30	R0	Se2/0	192.14.4.1	255.255.255.252	0.0.0.3
			R1	Se3/0	192.14.4.2	255.255.255.252	0.0.0.3
	1	192.14.4.4/30	R1	Se2/0	192.14.4.5	255.255.255.252	0.0.0.3
			R2	Se3/0	192.14.4.6	255.255.255.252	0.0.0.3
	2	192.14.4.8/30	R2	Se2/0	192.14.4.9	255.255.255.252	0.0.0.3
			R6	Se3/0	192.14.4.10	255.255.255.252	0.0.0.3
	3	192.14.4.12/30	R6	Se2/0	192.14.4.13	255.255.255.252	0.0.0.3
			R5	Se3/0	192.14.4.14	255.255.255.252	0.0.0.3
	4	192.14.4.16/30	R5	Se2/0	192.14.4.17	255.255.255.252	0.0.0.3
			R4	Se3/0	192.14.4.18	255.255.255.252	0.0.0.3
	5	192.14.4.20/30	R4	Se2/0	192.14.4.21	255.255.255.252	0.0.0.3
			R0	Se3/0	192.14.4.22	255.255.255.252	0.0.0.3
	6	192.14.4.24/30	R0	Se6/0	192.14.4.25	255.255.255.252	0.0.0.3
			R3	Se2/0	192.14.4.26	255.255.255.252	0.0.0.3
	7	192.14.4.28/30	R1	Se6/0	192.14.4.29	255.255.255.252	0.0.0.3
			R3	Se3/0	192.14.4.30	255.255.255.252	0.0.0.3
	8	192.14.4.32/30	R2	Se6/0	192.14.4.33	255.255.255.252	0.0.0.3
			R3	Se6/0	192.14.4.34	255.255.255.252	0.0.0.3
	9	192.14.4.36/30	R6	Se6/0	192.14.4.37	255.255.255.252	0.0.0.3
			R3	Se7/0	192.14.4.38	255.255.255.252	0.0.0.3
	10	192.14.4.40/30	R5	Se6/0	192.14.4.41	255.255.255.252	0.0.0.3
			R3	Se8/0	192.14.4.42	255.255.255.252	0.0.0.3
	11	192.14.4.44/30	R4	Se6/0	192.14.4.45	255.255.255.252	0.0.0.3
			R3	Se9/0	192.14.4.46	255.255.255.252	0.0.0.3

Table 3 - Networks IPs

Assuming all routers are in area 0, OSPF routing has configured. We configured a loopback with IP address 7.7.7.7/24 to router 6 and advertised it into OSPF process.

4.4. Configure bandwidth values between links

Table 4 shows how to calculate the bandwidths for each certain cost.

Cost	$Bandwidth = \dfrac{100MB}{Cost}$
2	$\dfrac{100MB}{2} = 50000KB$
4	$\dfrac{100MB}{4} = 25000KB$
8	$\dfrac{100MB}{8} = 12500KB$
20	$\dfrac{100MB}{20} = 5000KB$
50	$\dfrac{100MB}{50} = 2000KB$
100	$\dfrac{100MB}{100} = 1000KB$

Table 4 - Calculating Bandwidths

Table 5 gives every interface in every router a certain bandwidth according to the value of the cost which is in Figure 9.

Device	Interface	Bandwidth
R0	Se2/0	50000KB
	Se3/0	25000KB
	Se6/0	12500KB
R1	Se3/0	50000KB
	Se2/0	50000KB
	Se6/0	2000KB
R2	Se3/0	1000KB
	Se2/0	50000KB
	Se6/0	50000KB
R3	Se2/0	12500KB
	Se3/0	2000KB
	Se6/0	50000KB
	Se7/0	50000KB
	Se8/0	5000KB
	Se9/0	25000KB
R4	Se3/0	25000KB
	Se2/0	12500KB
	Se6/0	25000KB
R5	Se3/0	12500KB
	Se2/0	25000KB
	Se6/0	5000KB
R6	Se3/0	25000KB
	Se2/0	1000KB
	Se6/0	50000KB

Table 5 - Bandwidths of the interfaces

4.5. Tracert from Router0 to Router7 (LB0)

When tracert command executed, the packets passed throw $R0 \rightarrow R1 \rightarrow R2 \rightarrow R3 \rightarrow R6$ to reach the loopback interface which is path with the lowest cost as shown on Figure 10 and it is the same result when we calculated it using Dijkstra's algorithm.
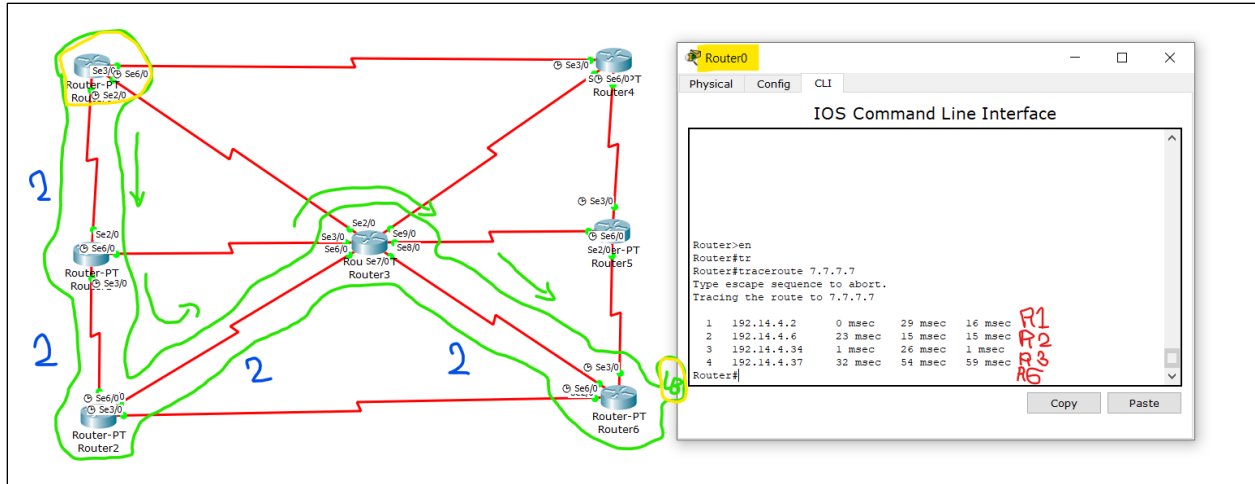
Figure 10 - Tracert from Router0 to Router7

From Figure 11, we can see that the cost from Router0 to Router6 is 8 which is correct according to our Dijkstra's solution.
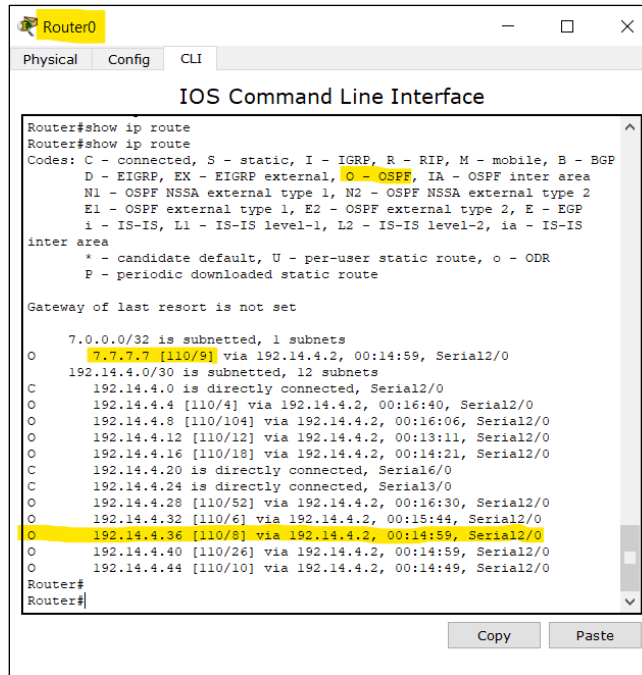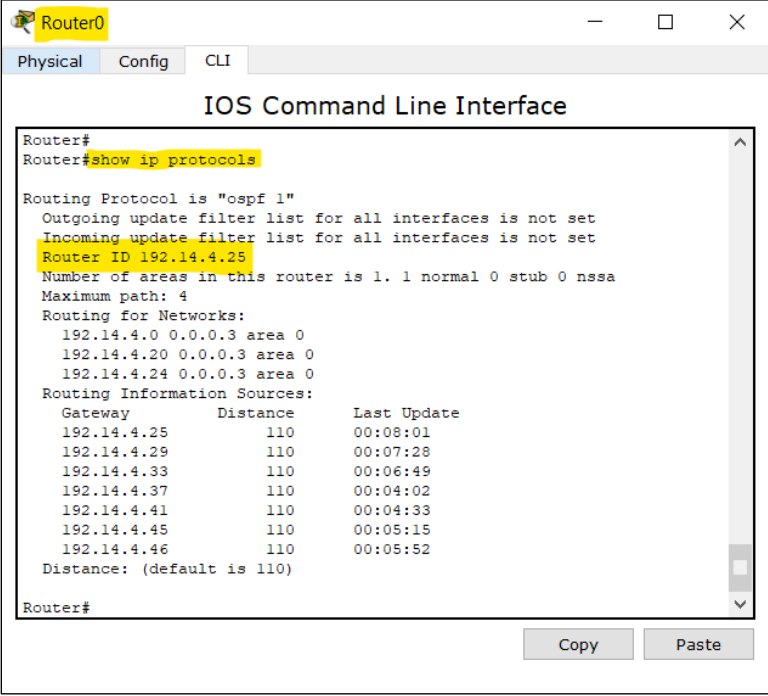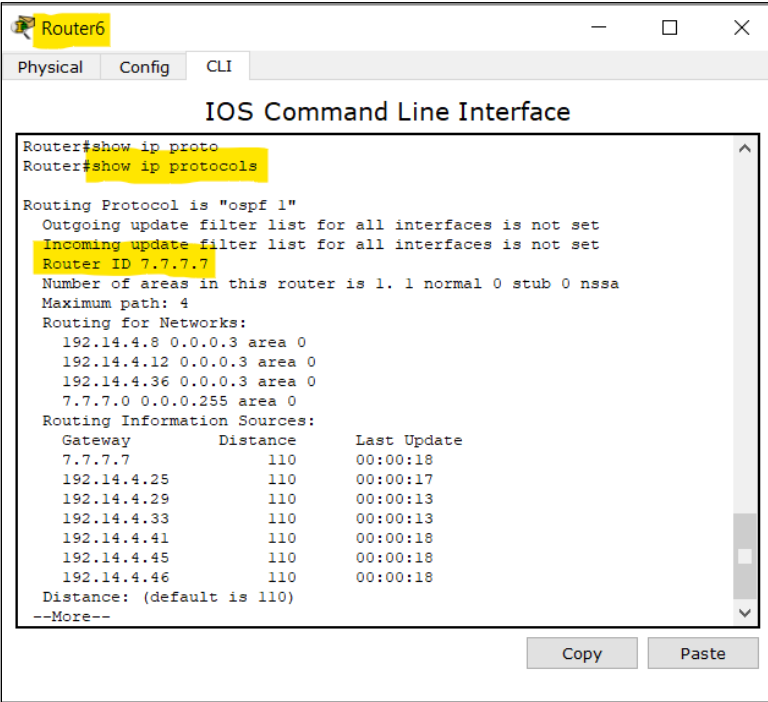
Figure 11 - show IP route command in R0

The router-id for Router0 is 192.14.4.25 as shown on Figure 12 which is the highest IP address on a non-loopback interface, and the router-id for Router6 is 7.7.7.7 as shown on Figure 13 which is the highest IP address on a loopback interface in Router6.

Figure 12 - Router-id for Router0

Figure 13 - Router-id for Router6

5. Conclusion

The results that were obtained from the previous procedures are successful and agree with the theoretical results. Moreover, we conclude that we can use Cisco Packet Tracer to build our topologies and advertise them, so we became more familiar with this program. We learned what every number in the IP address means and does.

We learnt another dynamic routing protocol that finds the shortest path depending on the costs to reach the destination successfully. OSPF is a great protocol to routing the topology.

We knew that every router in the OSPF process has a special Router ID which be selected by three methods: Manual configuration of the router ID, Highest IP address on a loopback interface, Highest IP address on a non-loopback interface.

6. References

[1] Jim Kurose and Keith Ross. *Computer Networking: A Top Down Approach*, 8th Edition, Addison-Wesley, 2021.

[2] https://www.ibm.com/docs/en/i/7.4?topic=routing-open-shortest-path-first
Accessed on 28 July 11:22pm.

[3] https://www.pearsonitcertification.com/articles/article.aspx?p=2435847
Accessed on 30 July 2:06pm.

[4] https://networkengineering.stackexchange.com/questions/22894/whatss-the-function-of-a-loopback-interface-in-routing-protocols
Accessed on 30 July 5:17pm.

[5] ENCS4130 Course Slides and Lab Manual.

[6] ENCS3320 Course Slides.

[7] Cisco Packet Tracer.