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Computer Networks Laboratory – ENCS4130

EXP. No. 5. Dynamic Routing 3 (Path Vector) BGP

Report#1

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Section: 5

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Abstract

The aim of this experiment is to learn how to configure and verify IP routing with Cisco routers, and to learn exterior gateway protocol and interior gateway protocols, and to learn Autonomous systems and Dynamic routing BGP. In this experiment we will use four Cisco routers, Six PCs, One Cisco switch, Several CAT5 straight-wired cables, and Two Serial cable.

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1.Introduction

1.1. Border Gateway Protocol (BGP)

Border Gateway Protocol (BGP) is a standardized exterior gateway protocol designed to exchange routing and reachability information among autonomous systems (AS) on the Internet. BGP is classified as a path-vector routing protocol, and it makes routing decisions based on paths, network policies, or rule-sets configured by a network administrator.

BGP used for routing within an autonomous system is called Interior Border Gateway Protocol, Internal BGP (iBGP). In contrast, the Internet application of the protocol is called Exterior Border Gateway Protocol, External BGP (eBGP) [1].

1.2. Using BGP

BGP helps provide redundancy by enabling routers to quickly adapt and send packets through another connection if one internet path goes down. It is often used in large networks, such as internet service provider networks, wide area networks and infrastructure-as-a-service environments.

BGP is an exterior gateway protocol, which means it is designed to share routing information between different ASes. Alternatively, an interior gateway protocol sends information within a single AS. However, Internal BGP (iBGP) is available to send reachability information within an organization's network.

Each BGP router maintains a standard routing table used to direct packets in transit. BGP uses client-server topology to communicate routing information, with the client initiating a BGP session by sending a request to the server [2].

1.3. BGP Peers/Neighbors

For BGP to function, BGP routers (called speakers) must form neighbor relationships (called peers). There are two types of BGP neighbor relationships:

-iBGP Peers : BGP neighbors within the same autonomous system.

-eBGP Peers : BGP neighbors connecting separate autonomous systems [3].

1.4. BGP Peers Messages

Four message types are used by BGP to negotiate parameters, exchange routing information and indicate errors. They are:

- Open message

After a transport protocol connection is established, the first message sent by each side is an Open message. If the Open message is acceptable, a Keepalive message confirming the Open is sent back. When the Open is confirmed, Update, Keepalive, and Notification messages can be exchanged.

Open messages consist of the BGP header and the following fields:

-version

The current BGP version number is 4.

- local ASN

The autonomous system number is configured in the **config>router** context.

- hold time

Configure the maximum time BGP will wait between successive messages (either keep alive or update) from its peer, before closing the connection. Configure the local hold time with in the **config>router>bgp** context.

*** BGP identifier**

IP address of the BGP system or the router ID. The router ID must be a valid host address.

*** Update message**

Update messages are used to transfer routing information between BGP peers. The information contained in the packet can be used to construct a graph describing the relationships of the various autonomous systems. By applying rules, routing information loops and some other anomalies can be detected and removed from the inter-AS routing, The Update messages consist of a BGP header and the following optional fields:

*** unfeasible routes length**

The field length which lists the routes being withdrawn from service because they are considered unreachable.

*** withdrawn routes**

The associated IP address prefixes for the routes withdrawn from service.

*** total path attribute length**

The total length of the path field that provides the attributes for a possible route to a destination.

*** path attributes**

The path attributes presented in variable length TLV format [4].

1.5. BGP Finite-State Machine (FSM)

As a BGP peer session is forming, it will pass through several states.

1) **Idle:** The initial BGP state.

2) **Connect:** BGP waits for a TCP connection with the remote peer. If successful, an OPEN message is sent. If unsuccessful, the session is placed in an Active state.

3) **Active:** BGP attempts to initiate a TCP connection with the remote peer. If successful, an OPEN message is sent. If unsuccessful, BGP will wait for a ConnectRetry timer to expire, and place the session back in a Connect State.

4) **OpenSent:** BGP has both established the TCP connection and sent an OPEN Message and is awaiting a reply OPEN Message. Once it receives a reply OPEN Message, the BGP peer will send a KEEPALIVE message.

5) **OpenConfirm:** BGP listens for a reply KEEPALIVE message.

6) **Established:** The BGP peer session is fully established. UPDATE messages containing routing information will now be sent [5].

2.Procedure and Discussion

2.1 Building the topology

I built the topology as shown in Figure 1. I used Router-PT for the routers and Switch-PT for the switches and PC-PT for PCs. I used automatically use connection type for the connections between the PCs, switches and routers.

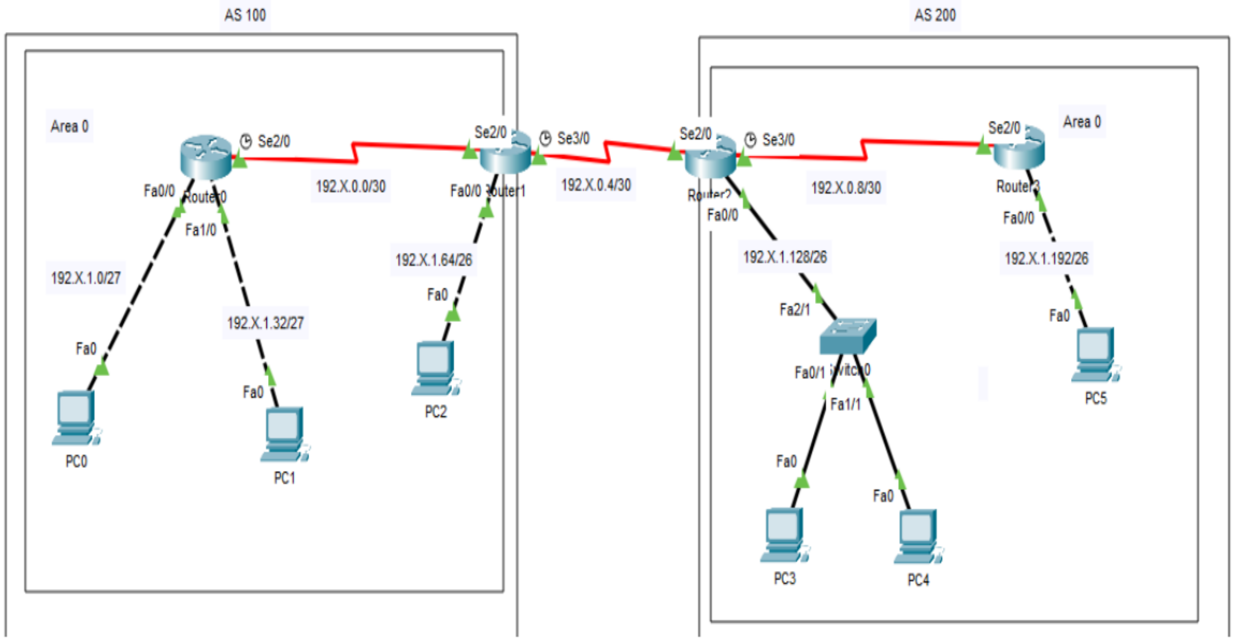


Figure 1: Lab Manual Topology

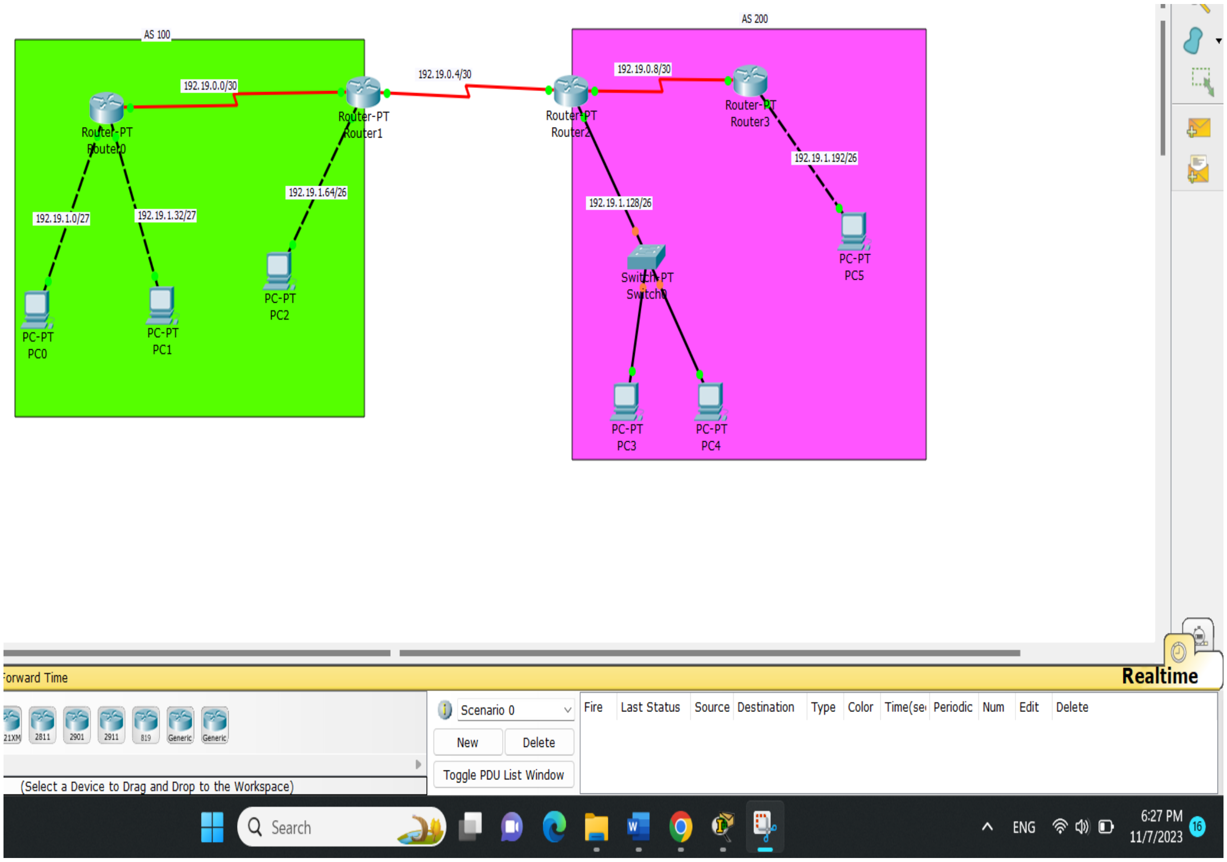
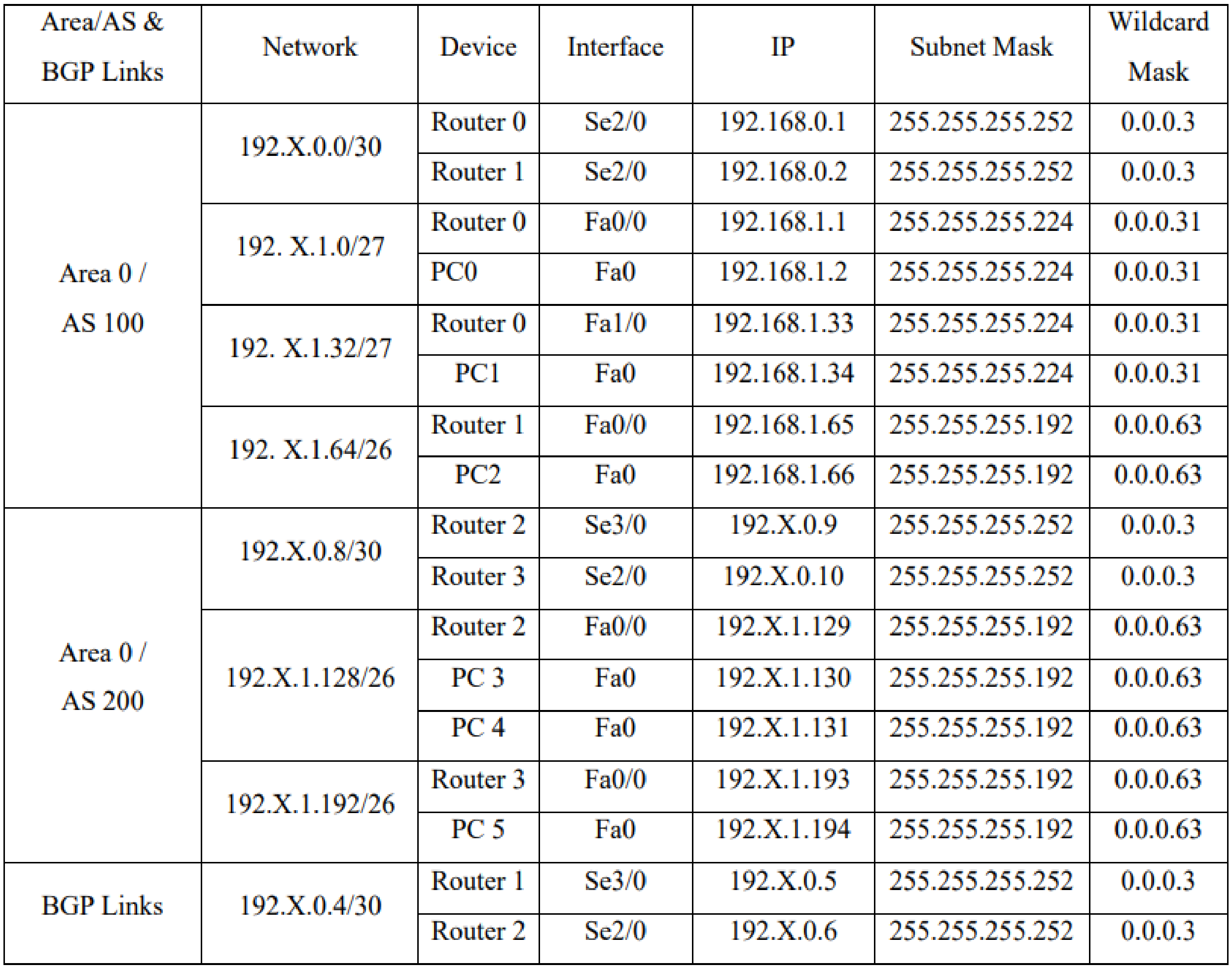


Figure 2: My Topology

In this experiment, we were connected four routers and several PCs on different networks. This was required configuring routing protocols between the routers, and configuring dynamic routing (OSPF) which was used as a routing protocol inside the same Antonymous System and BGP between the different Antonymous Systems.

Table 1: Networks IPS



Area/AS & BGP Links	Network	Device	Interface	IP	Subnet Mask	Wildcard Mask
Area 0 / AS 100	192.X.0.0/30	Router 0	Se2/0	192.168.0.1	255.255.255.252	0.0.0.3
		Router 1	Se2/0	192.168.0.2	255.255.255.252	0.0.0.3
	192. X.1.0/27	Router 0	Fa0/0	192.168.1.1	255.255.255.224	0.0.0.31
		PC0	Fa0	192.168.1.2	255.255.255.224	0.0.0.31
	192. X.1.32/27	Router 0	Fa1/0	192.168.1.33	255.255.255.224	0.0.0.31
		PC1	Fa0	192.168.1.34	255.255.255.224	0.0.0.31
	192. X.1.64/26	Router 1	Fa0/0	192.168.1.65	255.255.255.192	0.0.0.63
		PC2	Fa0	192.168.1.66	255.255.255.192	0.0.0.63
Area 0 / AS 200	192.X.0.8/30	Router 2	Se3/0	192.X.0.9	255.255.255.252	0.0.0.3
		Router 3	Se2/0	192.X.0.10	255.255.255.252	0.0.0.3
	192.X.1.128/26	Router 2	Fa0/0	192.X.1.129	255.255.255.192	0.0.0.63
		PC 3	Fa0	192.X.1.130	255.255.255.192	0.0.0.63
		PC 4	Fa0	192.X.1.131	255.255.255.192	0.0.0.63
	192.X.1.192/26	Router 3	Fa0/0	192.X.1.193	255.255.255.192	0.0.0.63
		PC 5	Fa0	192.X.1.194	255.255.255.192	0.0.0.63
BGP Links	192.X.0.4/30	Router 1	Se3/0	192.X.0.5	255.255.255.252	0.0.0.3
		Router 2	Se2/0	192.X.0.6	255.255.255.252	0.0.0.3

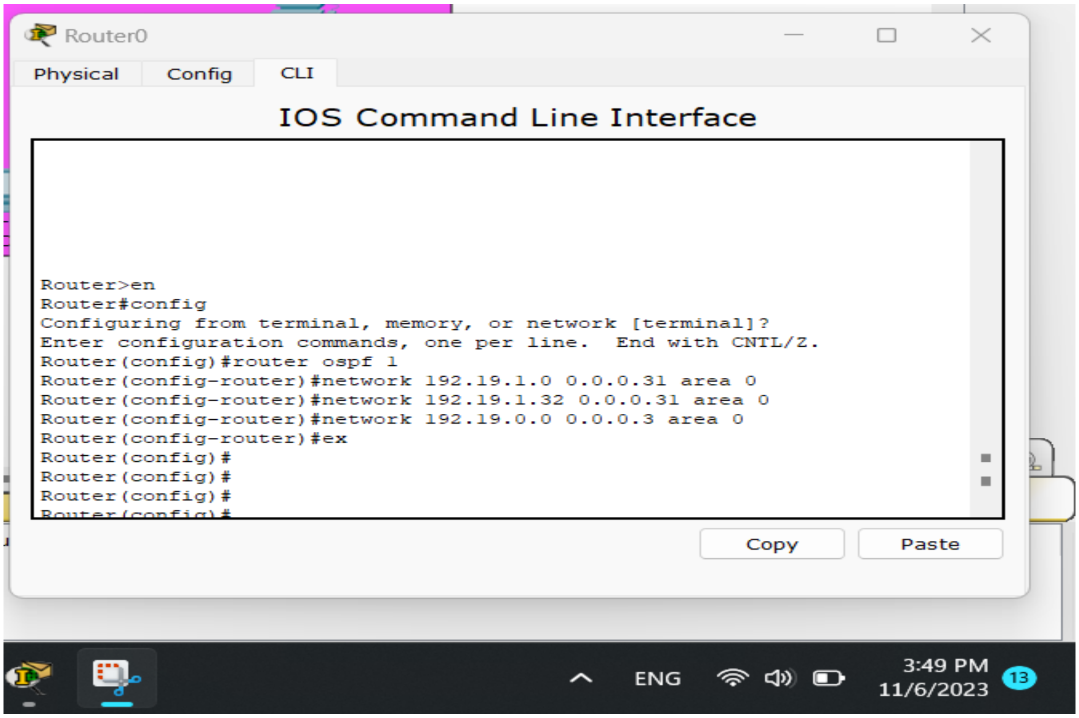
I was used the following IPs shown in Table1 for the configuration, to configure the IPs for the PCs and Routers.

My ID is 1201319 so X=19

2.2 Configuring OSPF Routing

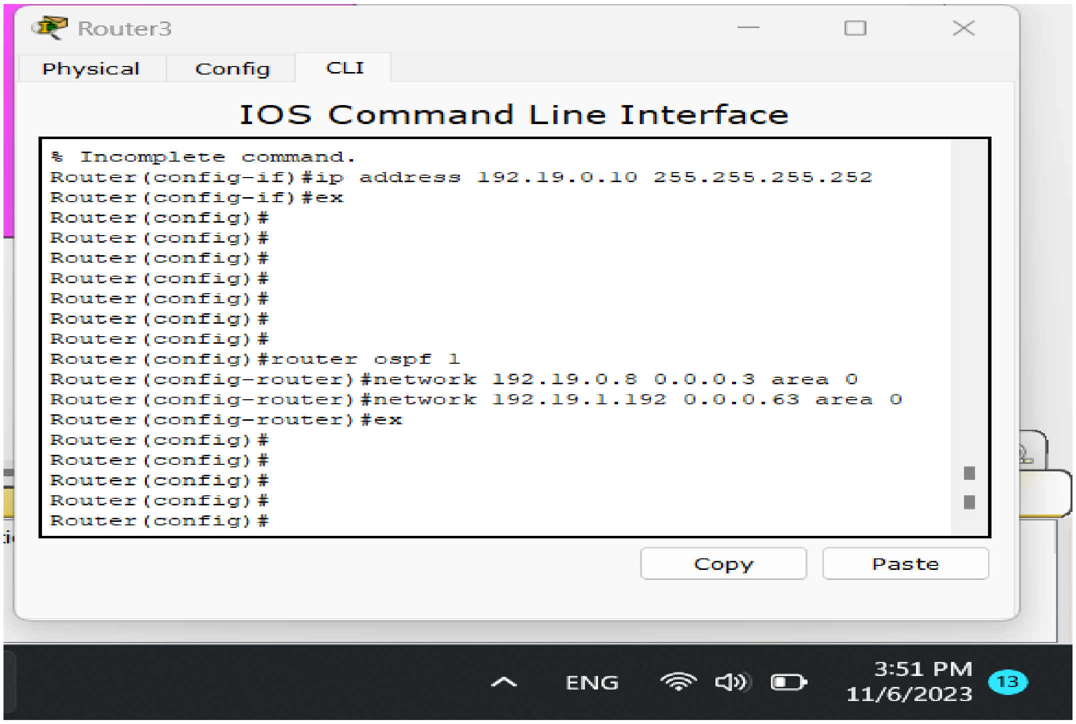
The OSPF routing protocol isn’t set up between Routers 1 and 2 due to their location in separate Autonomous Systems (AS). Therefore, an exterior gateway protocol is required to establish a connection between these two routers.

I assigned IP address for all routers and configure OSPF for router 0 and 3:



```
Router>en
Router#config
Configuring from terminal, memory, or network [terminal]?
Enter configuration commands, one per line.  End with CNTL/Z.
Router(config)#router ospf 1
Router(config-router)#network 192.19.1.0 0.0.0.31 area 0
Router(config-router)#network 192.19.1.32 0.0.0.31 area 0
Router(config-router)#network 192.19.0.0 0.0.0.3 area 0
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
```

Figure 3: configure ospf protocol for router 0



```
% Incomplete command.
Router(config-if)#ip address 192.19.0.10 255.255.255.252
Router(config-if)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#router ospf 1
Router(config-router)#network 192.19.0.8 0.0.0.3 area 0
Router(config-router)#network 192.19.1.192 0.0.0.63 area 0
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
```

Figure 4: configure ospf protocol for router 3

2.3 Configuring BGP Routing

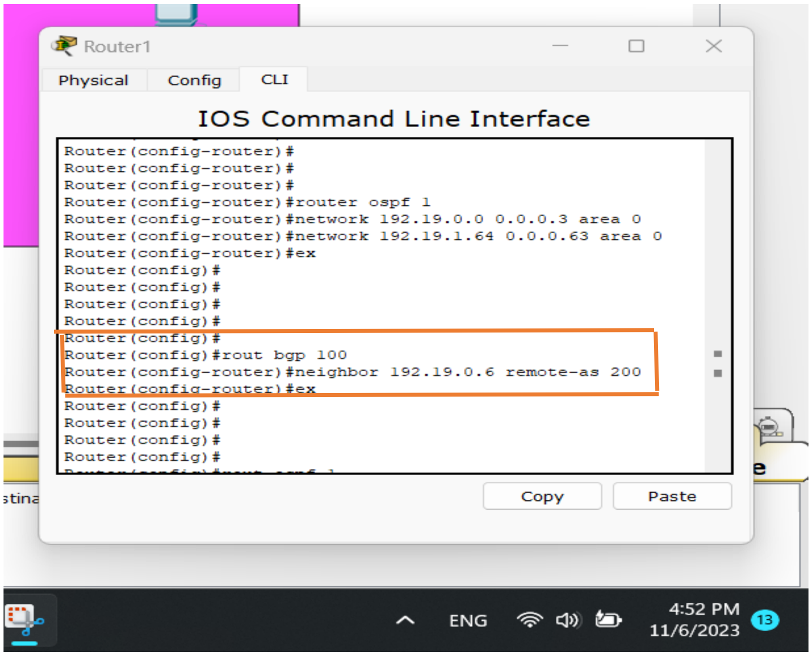
BGP configuration have to be done just on Router 1 and Router 2. The first step in configuring BGP is to enable the BGP process, and specify the router's Autonomous System (AS):

```
Router (config)# router bgp <AS-NUMBER>
```

As shown in Figure 5 and Figure 6 below the AS-NUMBER is the autonomous system number where the router is.

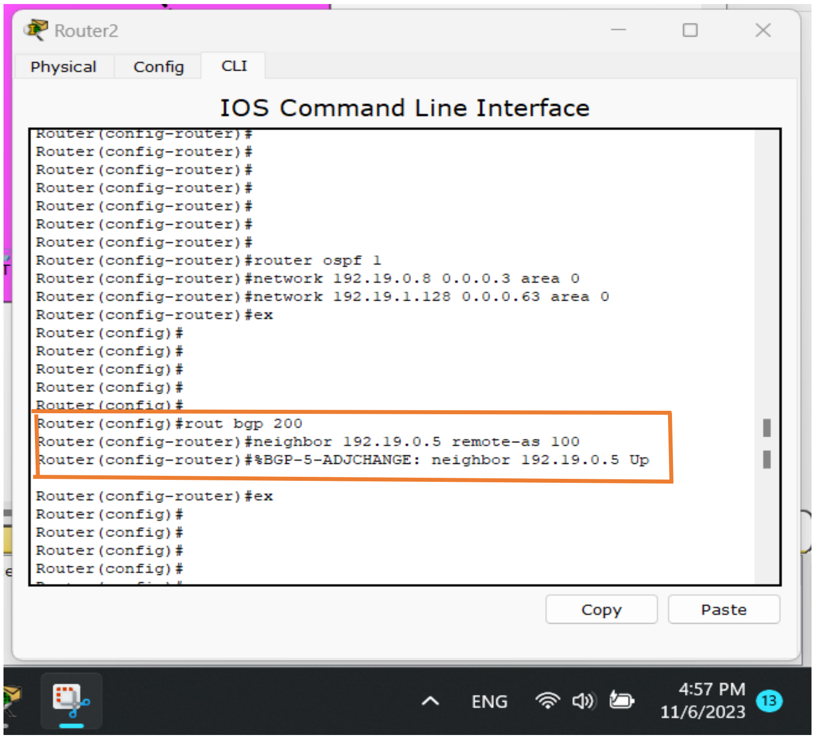
To establish a neighbor relationship with a router in a different AS, the command below is utilized. In this command, IP-ADDRESS-NEXT-INTERFACE refers to the address of the interface on the neighboring peer, while AS_OF_REMOTE_NEIGHBOR represents the autonomous system number of the adjacent AS.

```
Router(config-router)# neighbor <IP-ADDRESS-NEXT-INTERFACE>  remote-
as <AS-OF-REMOTE-NEIGHBOR>
```



```
Router(config-router)#
Router(config-router)#
Router(config-router)#
Router(config-router)#router ospf 1
Router(config-router)#network 192.19.0.0 0.0.0.3 area 0
Router(config-router)#network 192.19.1.64 0.0.0.63 area 0
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#rout bgp 100
Router(config-router)#neighbor 192.19.0.6 remote-as 200
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#rout ospf 1
```

Figure 5: BGP in router1



```
Router(config-router)#
Router(config-router)#
Router(config-router)#
Router(config-router)#
Router(config-router)#
Router(config-router)#
Router(config-router)#
Router(config-router)#router ospf 1
Router(config-router)#network 192.19.0.8 0.0.0.3 area 0
Router(config-router)#network 192.19.1.128 0.0.0.63 area 0
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#rout bgp 200
Router(config-router)#neighbor 192.19.0.5 remote-as 100
Router(config-router)#%BGP-5-ADJCHANGE: neighbor 192.19.0.5 Up

Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
```

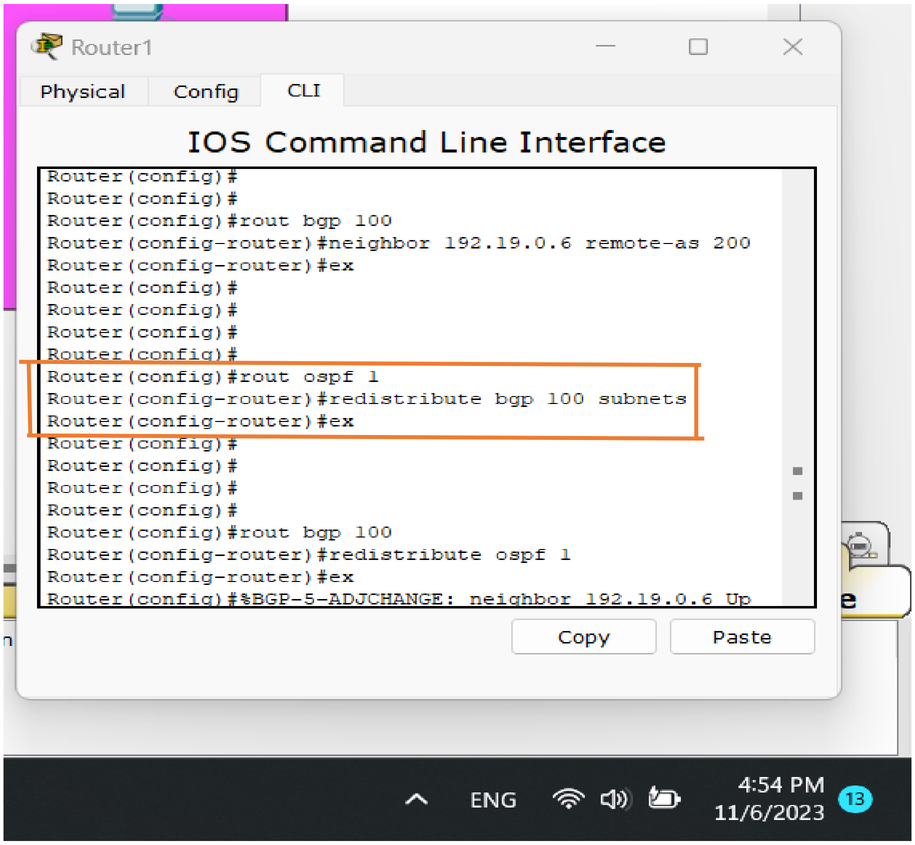
Figure 6 : BGP in router2

The network 192.19.0.4/30, which establishes a connection between Router1 and Router2, spans different Autonomous Systems (ASs). As a result, the BGP routing protocol needs to be configured. To enable data routing, the neighboring AS must also be identified on the router.

2.4 Define the BGP over the OSPF

To allow the OSPF to communicate with the BGP a redistribute command is used to define the BGP protocol over the OSPF protocol as shown in Figure 7 where the 1 is the OSPF ID and the 100 is the autonomous number for the BGP of configured on router1.

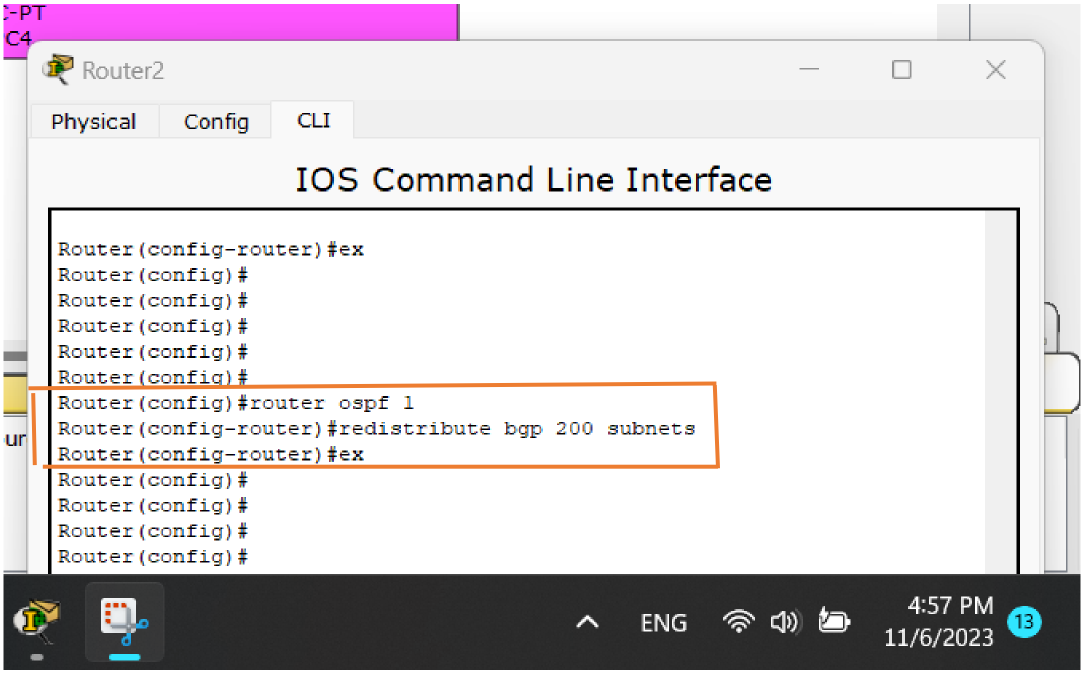
Define the BGP over the OSPF on router 1:



```
Router(config)#
Router(config)#
Router(config)#rout bgp 100
Router(config-router)#neighbor 192.19.0.6 remote-as 200
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#rout ospf 1
Router(config-router)#redistribute bgp 100 subnets
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#rout bgp 100
Router(config-router)#redistribute ospf 1
Router(config-router)#ex
Router(config)#%BGP-5-ADJCHANGE: neighbor 192.19.0.6 Up
```

Figure 7: BGP over OSPF in router 1

Define the BGP over the OSPF on router 2:



```
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#router ospf 1
Router(config-router)#redistribute bgp 200 subnets
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
```

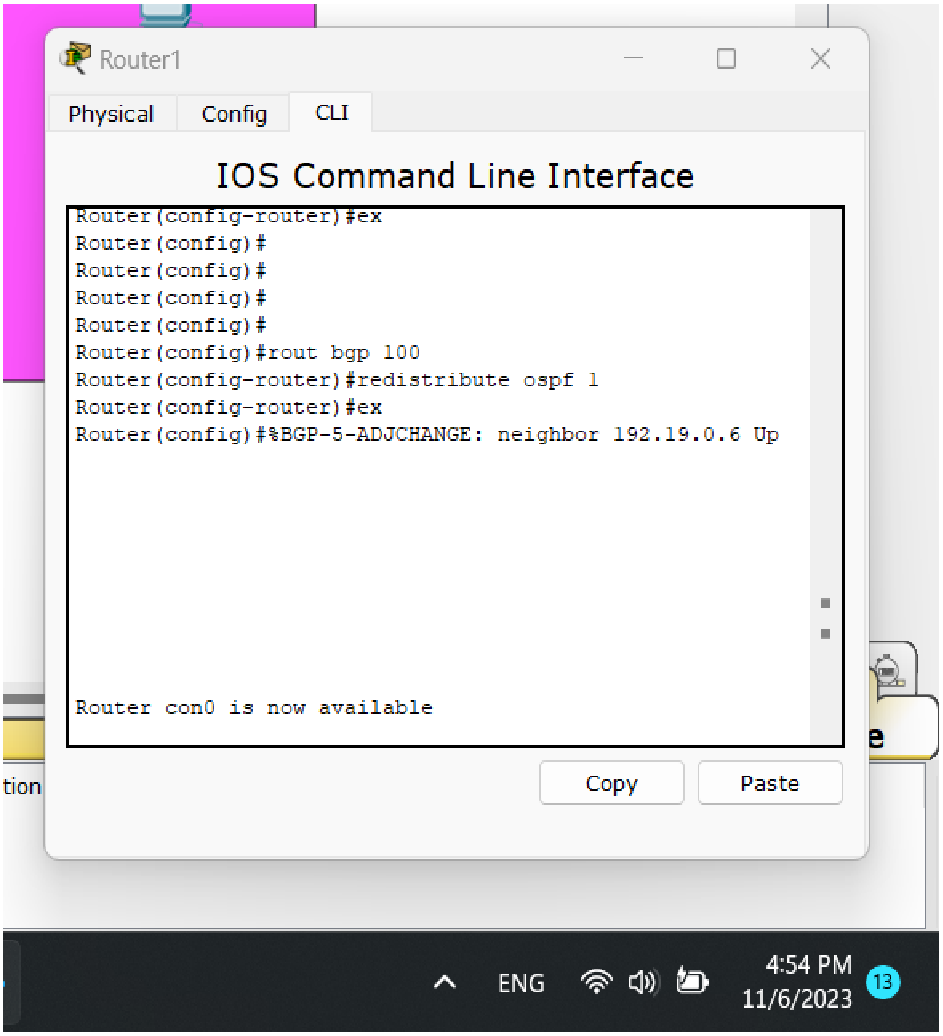
Figure 8: BGP over OSPF in router 2

As shown in figure 8, the 1 is the OSPF ID and the 200 is the autonomous number for the BGP of configured on router2.

2.5 Define the OSPF over the BGP

To allow the BGP to communicate with the OSPF a redistribute command is used to define the OSPF protocol over the BGP protocol as shown in Figure 9 and Figure 10 below.

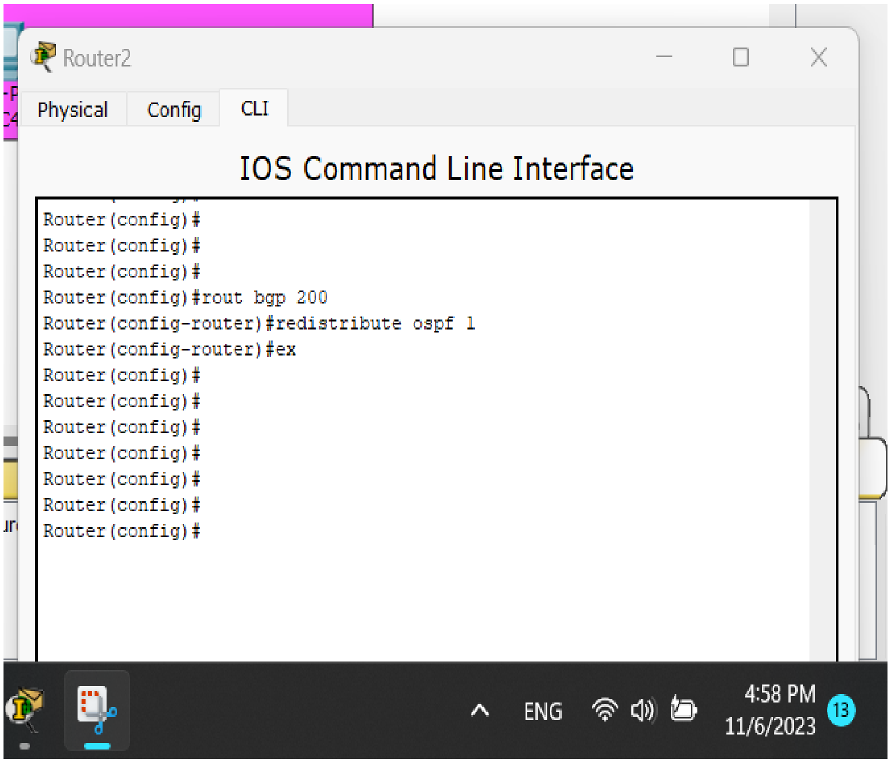
Define the OSPF over the BGP on router 1:



```
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#rout bgp 100
Router(config-router)#redistribute ospf 1
Router(config-router)#ex
Router(config)#%BGP-5-ADJCHANGE: neighbor 192.19.0.6 Up




Router con0 is now available
```

Figure 9: OSPF over BGP in router 1

Define the OSPF over the BGP on router 2:



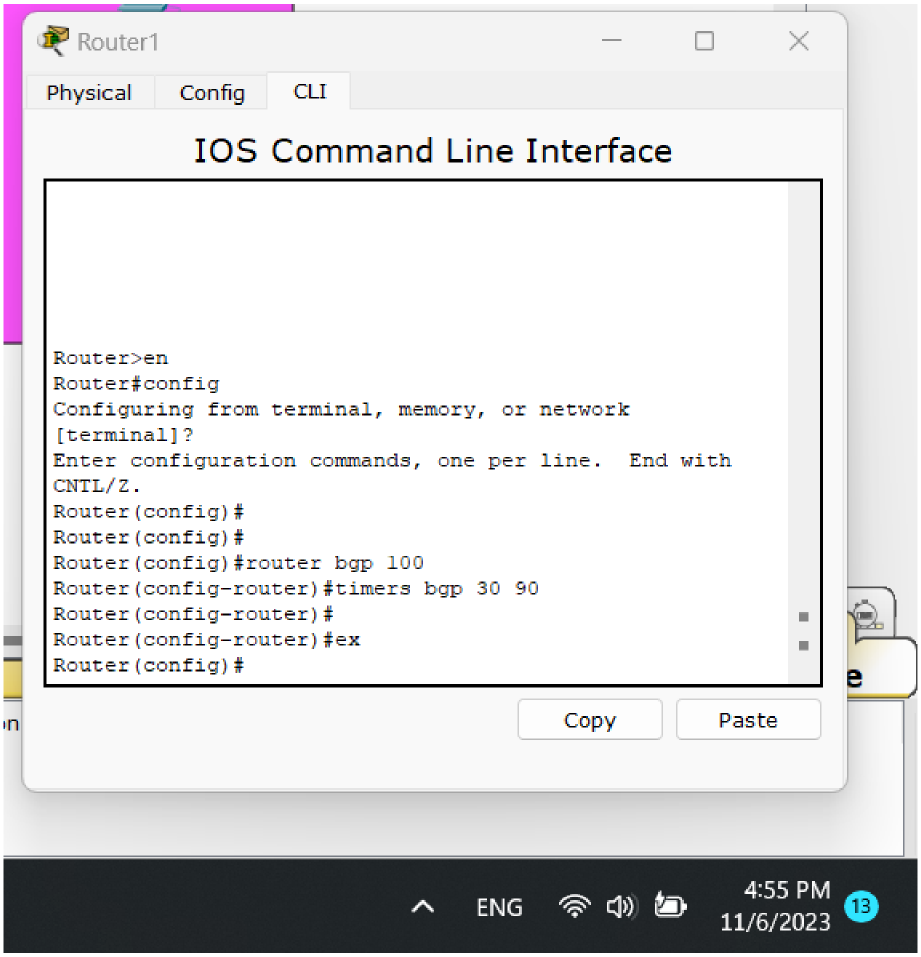
```
Router(config)#
Router(config)#
Router(config)#
Router(config)#rout bgp 200
Router(config-router)#redistribute ospf 1
Router(config-router)#ex
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
Router(config)#
```

Figure 10: OSPF over BGP in router 2

As shown in Figure 10 above 1 is the OSPF ID and 200 is the autonomous number for the BGP of configured on the same router.

2.6 Configuring BGP Timers

In this part, the keep alive time for Router1 is configured to 30 seconds, and the hold time is set to 90 seconds.



```
Router>en
Router#config
Configuring from terminal, memory, or network
[terminal]?
Enter configuration commands, one per line.  End with
CNTL/Z.
Router(config)#
Router(config)#
Router(config)#router bgp 100
Router(config-router)#timers bgp 30 90
Router(config-router)#
Router(config-router)#ex
Router(config)#
```

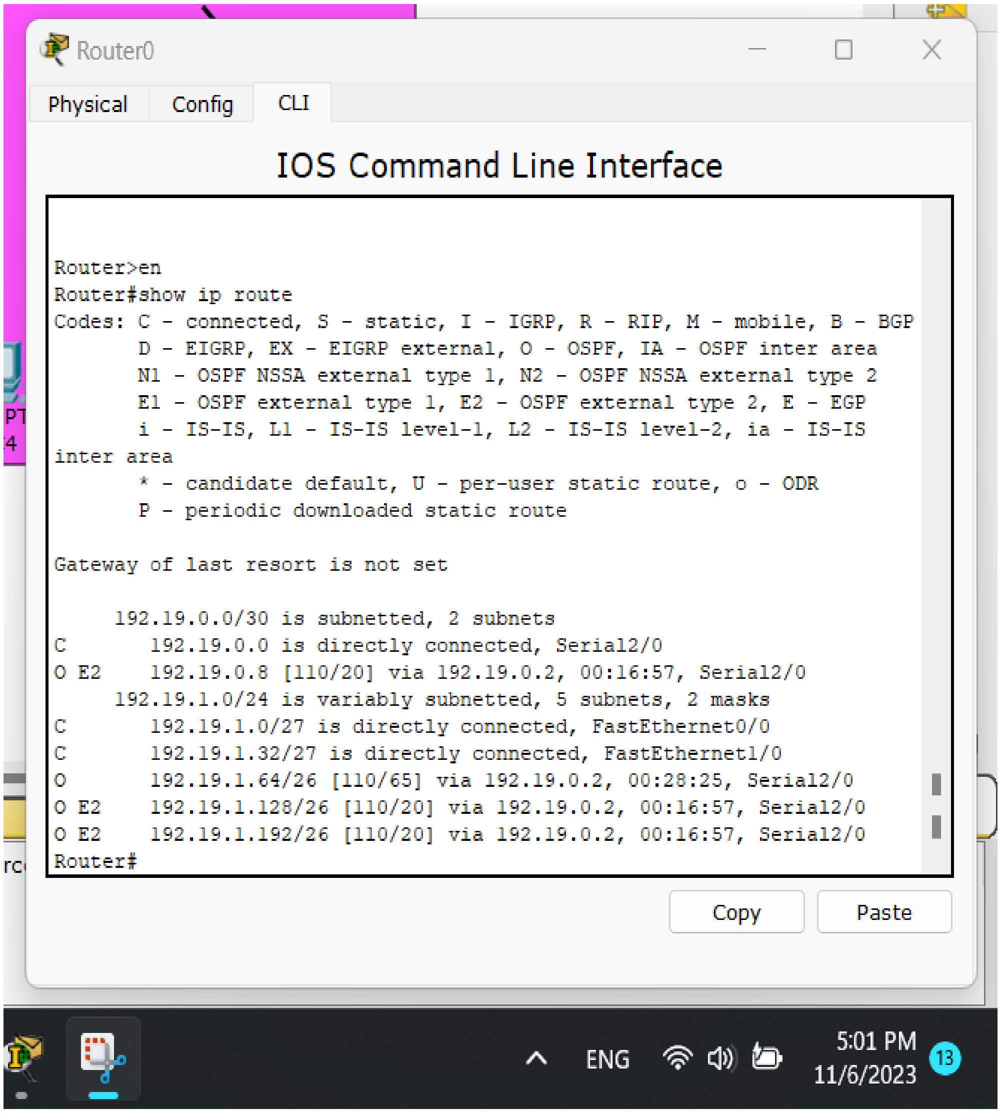
Figure 11 : BGP timer in router 1

These by default will change the timers on router, if the configured Hold-time timers between two peers are different, the peer session will still be established, and the smallest timer value will be used.

3.Results

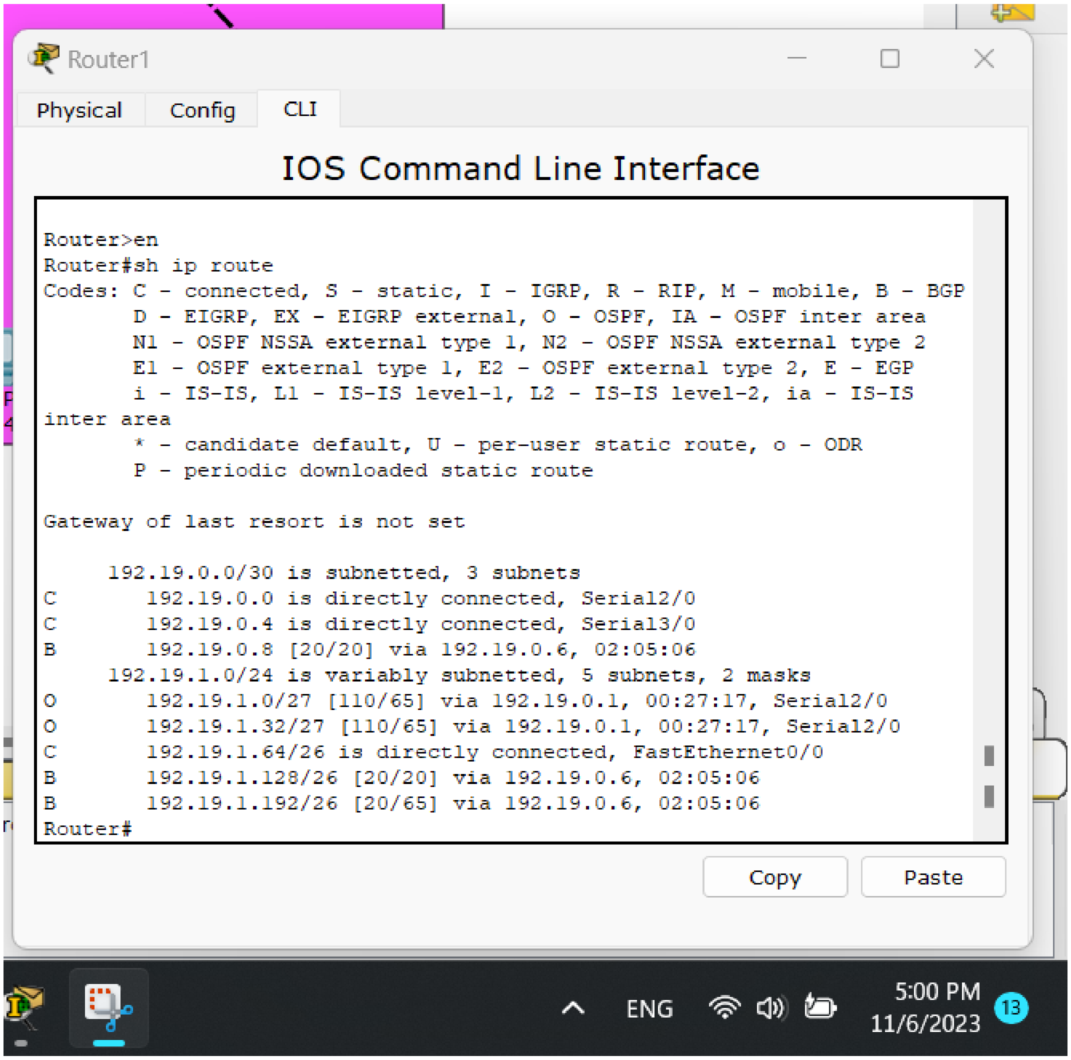
3.1 Routing Tables

This table contains a list of routes that can be advertised to BGP peers.



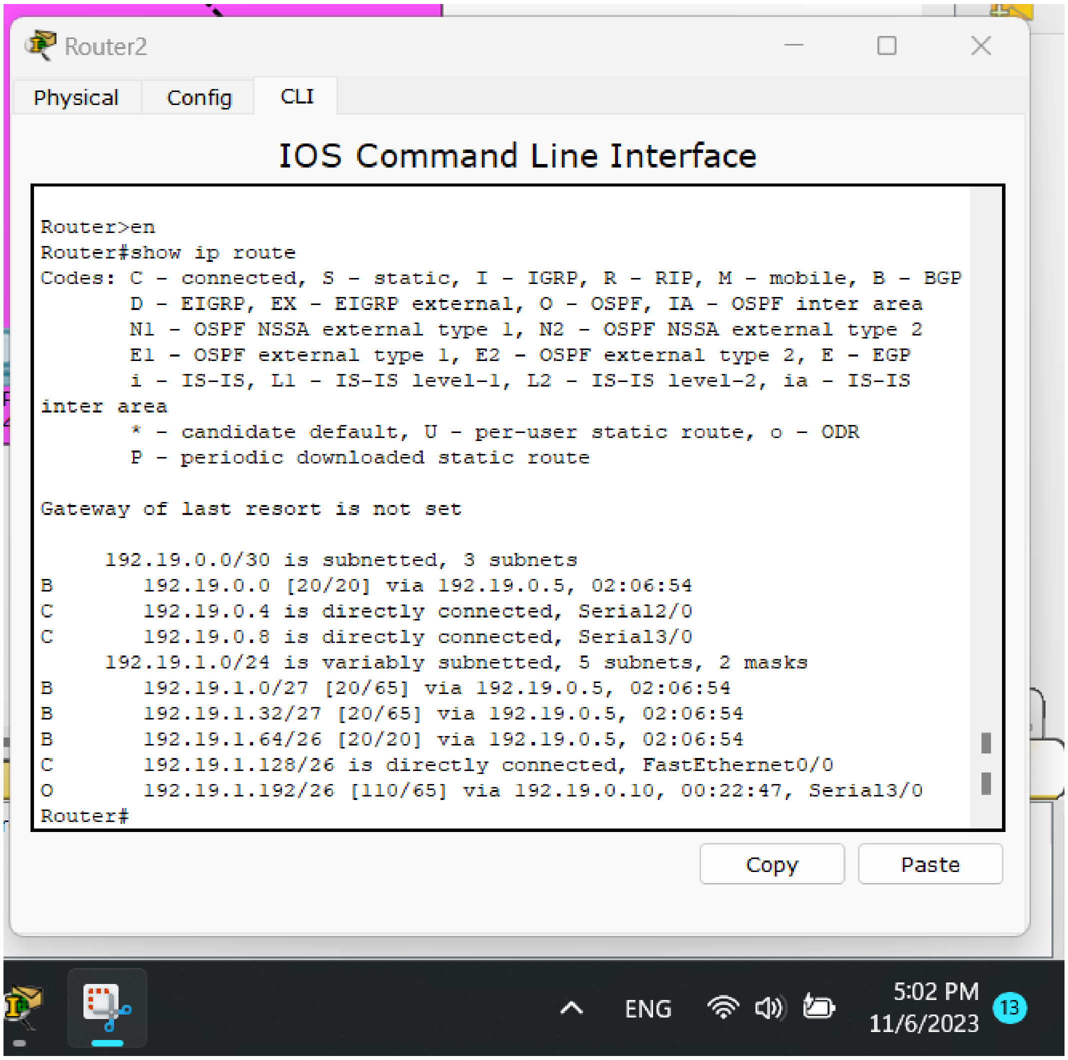
```
Router>en
Router#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external 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

     192.19.0.0/30 is subnetted, 2 subnets
C       192.19.0.0 is directly connected, Serial2/0
O E2    192.19.0.8 [110/20] via 192.19.0.2, 00:16:57, Serial2/0
     192.19.1.0/24 is variably subnetted, 5 subnets, 2 masks
C       192.19.1.0/27 is directly connected, FastEthernet0/0
C       192.19.1.32/27 is directly connected, FastEthernet1/0
O       192.19.1.64/26 [110/65] via 192.19.0.2, 00:28:25, Serial2/0
O E2    192.19.1.128/26 [110/20] via 192.19.0.2, 00:16:57, Serial2/0
O E2    192.19.1.192/26 [110/20] via 192.19.0.2, 00:16:57, Serial2/0
Router#
```

Figure 12: Routing Table for router 0



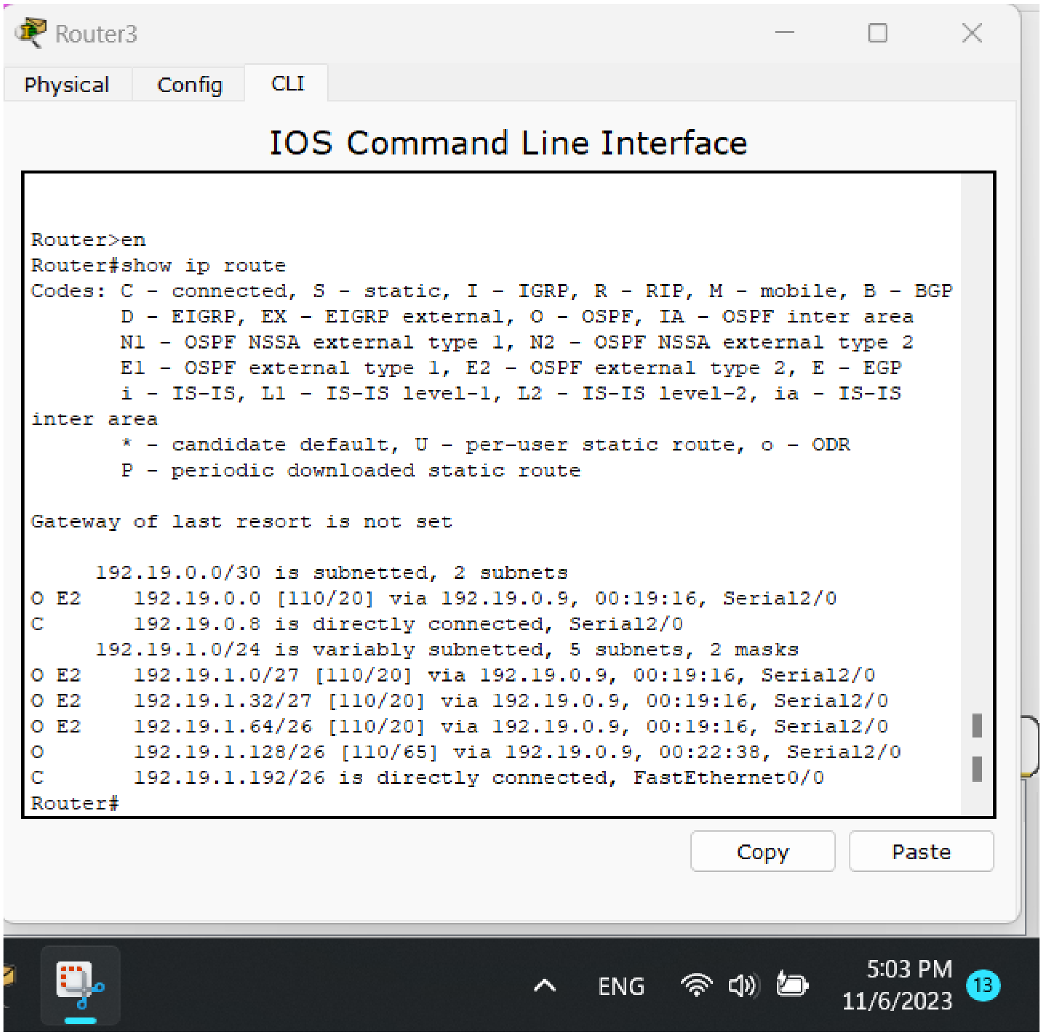
```
Router>en
Router#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 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

     192.19.0.0/30 is subnetted, 3 subnets
C       192.19.0.0 is directly connected, Serial2/0
C       192.19.0.4 is directly connected, Serial3/0
B       192.19.0.8 [20/20] via 192.19.0.6, 02:05:06
     192.19.1.0/24 is variably subnetted, 5 subnets, 2 masks
O       192.19.1.0/27 [110/65] via 192.19.0.1, 00:27:17, Serial2/0
O       192.19.1.32/27 [110/65] via 192.19.0.1, 00:27:17, Serial2/0
C       192.19.1.64/26 is directly connected, FastEthernet0/0
B       192.19.1.128/26 [20/20] via 192.19.0.6, 02:05:06
B       192.19.1.192/26 [20/65] via 192.19.0.6, 02:05:06
Router#
```

Figure 13: Routing Table for router 1



```
Router>en
Router#show 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

     192.19.0.0/30 is subnetted, 3 subnets
B       192.19.0.0 [20/20] via 192.19.0.5, 02:06:54
C       192.19.0.4 is directly connected, Serial2/0
C       192.19.0.8 is directly connected, Serial3/0
     192.19.1.0/24 is variably subnetted, 5 subnets, 2 masks
B       192.19.1.0/27 [20/65] via 192.19.0.5, 02:06:54
B       192.19.1.32/27 [20/65] via 192.19.0.5, 02:06:54
B       192.19.1.64/26 [20/20] via 192.19.0.5, 02:06:54
C       192.19.1.128/26 is directly connected, FastEthernet0/0
O       192.19.1.192/26 [110/65] via 192.19.0.10, 00:22:47, Serial3/0
Router#
```

Figure 14: Routing Table for router 2



```
Router>en
Router#show 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

     192.19.0.0/30 is subnetted, 2 subnets
O E2    192.19.0.0 [110/20] via 192.19.0.9, 00:19:16, Serial2/0
C       192.19.0.8 is directly connected, Serial2/0
     192.19.1.0/24 is variably subnetted, 5 subnets, 2 masks
O E2    192.19.1.0/27 [110/20] via 192.19.0.9, 00:19:16, Serial2/0
O E2    192.19.1.32/27 [110/20] via 192.19.0.9, 00:19:16, Serial2/0
O E2    192.19.1.64/26 [110/20] via 192.19.0.9, 00:19:16, Serial2/0
O       192.19.1.128/26 [110/65] via 192.19.0.9, 00:22:38, Serial2/0
C       192.19.1.192/26 is directly connected, FastEthernet0/0
Router#
```

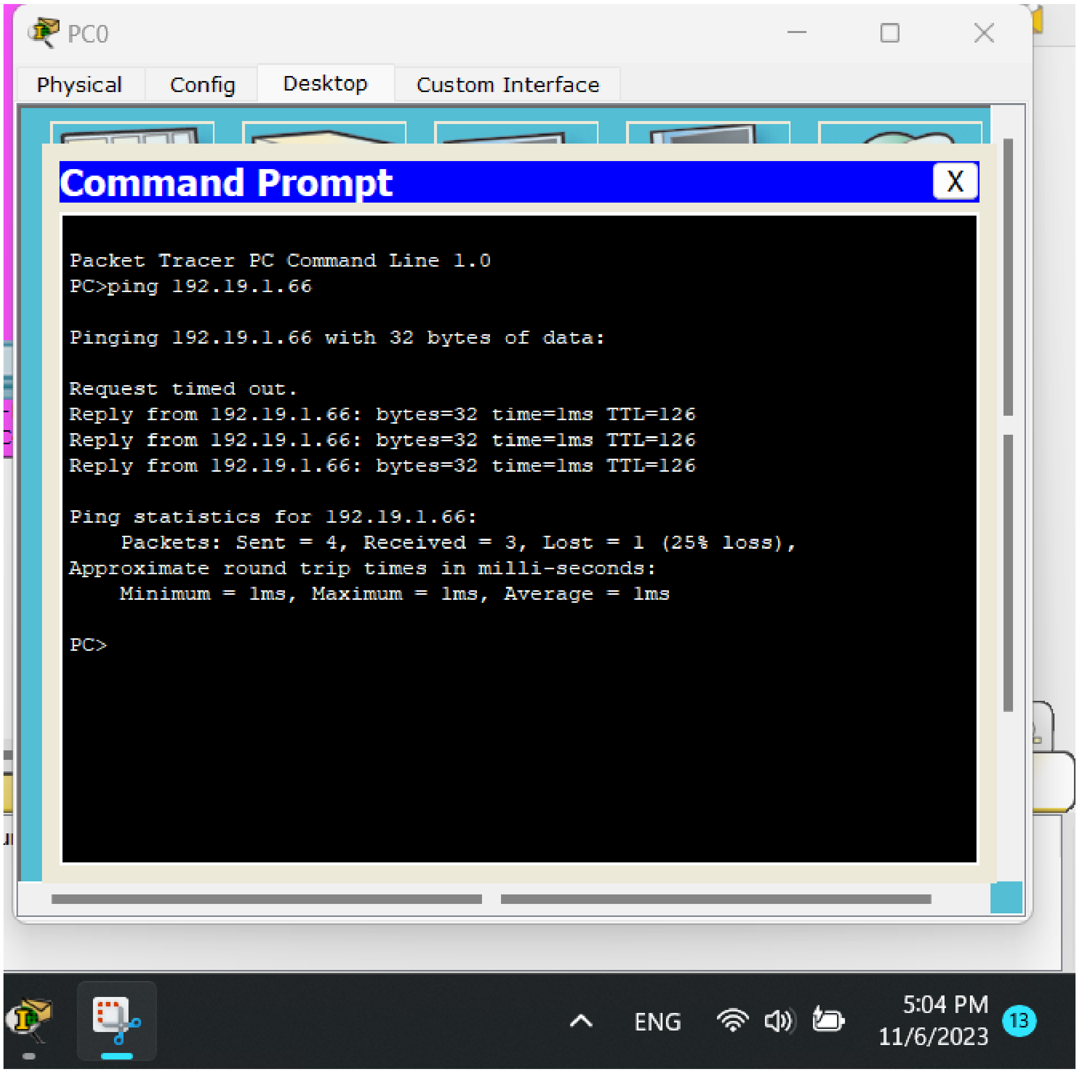
Figure 15: Routing Table for router 3

‘C’ means that the router is directly connected to a network, ‘B’ means that BGP is the protocol used for routing to other Autonomous Systems (ASs), and ’O’ means the use of the OSPF protocol for routing within the same AS, such as the networks connecting Router1 to Router3 and PC3.

3.2 Pings

Several methods were tested to confirm that all devices within the topology are interconnected and capable of communication and the routers can successfully establish connections and seamlessly transmit and receive packets, in this experiment I was used ping command.

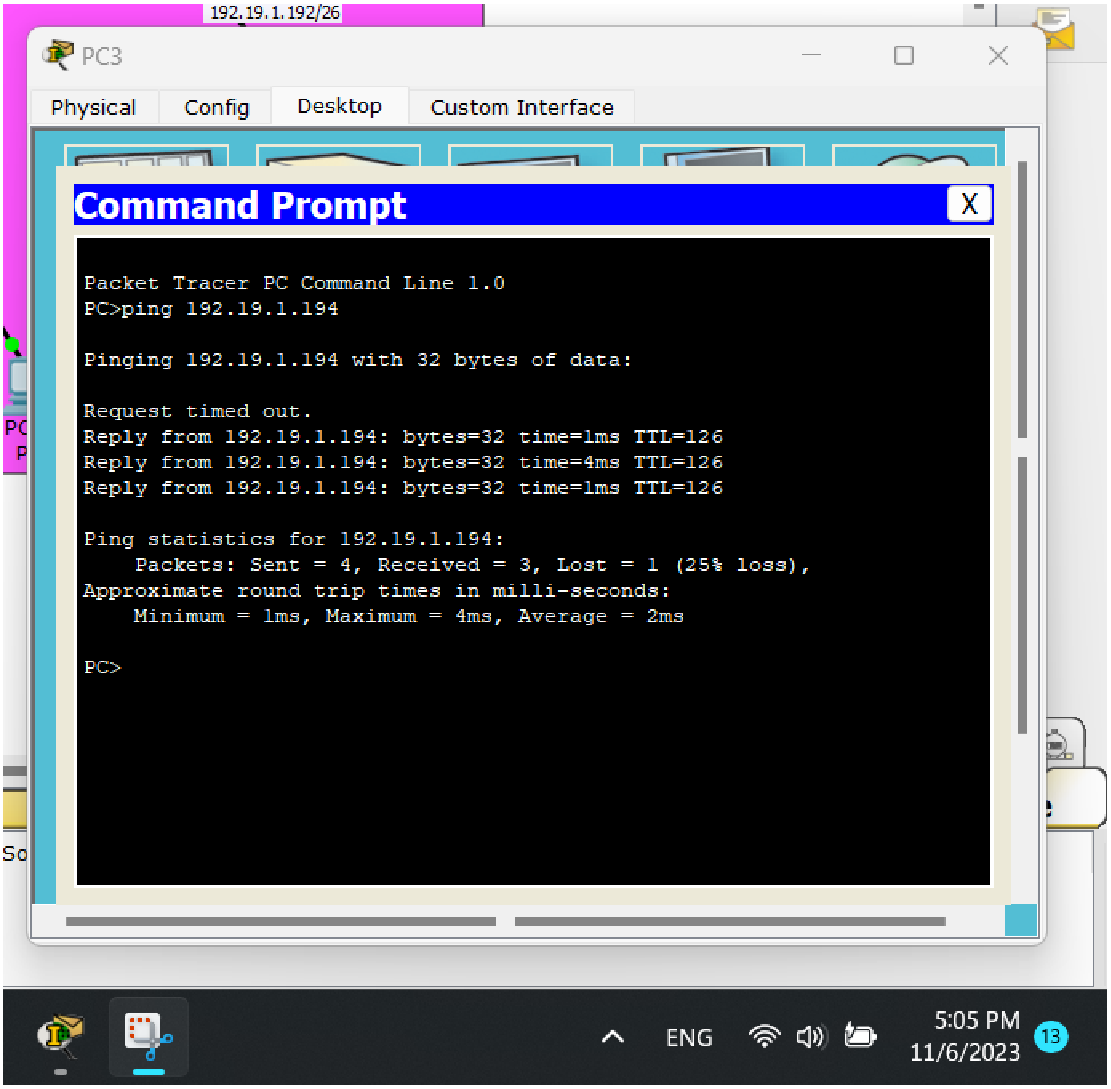
In As1, between PC0 and PC2:



```
Packet Tracer PC Command Line 1.0
PC>ping 192.19.1.66

Pinging 192.19.1.66 with 32 bytes of data:

Request timed out.
Reply from 192.19.1.66: bytes=32 time=1ms TTL=126
Reply from 192.19.1.66: bytes=32 time=1ms TTL=126
Reply from 192.19.1.66: bytes=32 time=1ms TTL=126

Ping statistics for 192.19.1.66:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
Approximate round trip times in milli-seconds:
    Minimum = 1ms, Maximum = 1ms, Average = 1ms

PC>
```

Figure 16: Ping from PC0 to PC2

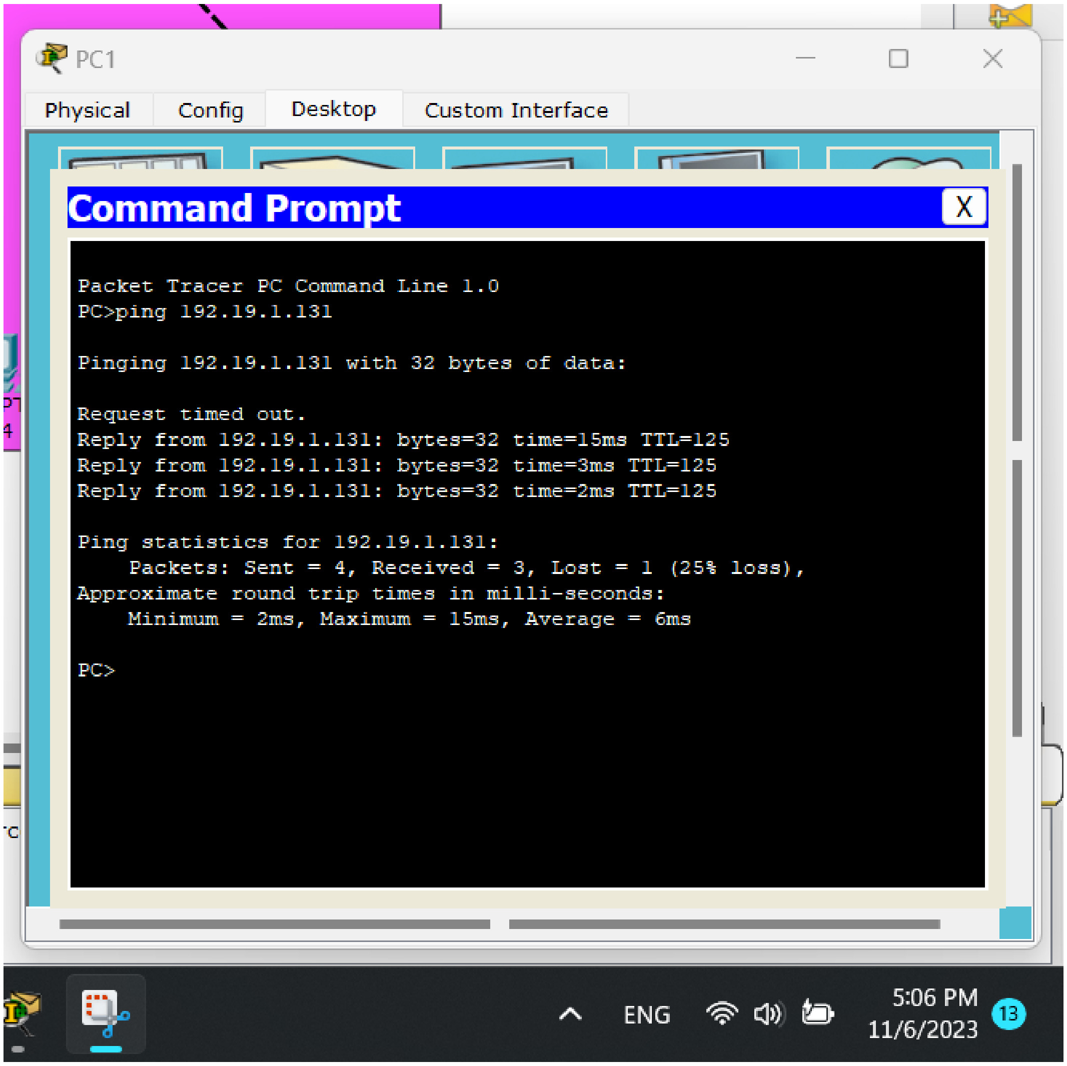
In As2, between PC3 and PC5:



```
Packet Tracer PC Command Line 1.0
PC>ping 192.19.1.194

Pinging 192.19.1.194 with 32 bytes of data:

Request timed out.
Reply from 192.19.1.194: bytes=32 time=1ms TTL=126
Reply from 192.19.1.194: bytes=32 time=4ms TTL=126
Reply from 192.19.1.194: bytes=32 time=1ms TTL=126

Ping statistics for 192.19.1.194:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
Approximate round trip times in milli-seconds:
    Minimum = 1ms, Maximum = 4ms, Average = 2ms

PC>
```

Figure 17: Ping from PC3 to PC5

Between AS1 and AS2, between PC1 and PC4:



```
Packet Tracer PC Command Line 1.0
PC>ping 192.19.1.131

Pinging 192.19.1.131 with 32 bytes of data:

Request timed out.
Reply from 192.19.1.131: bytes=32 time=15ms TTL=125
Reply from 192.19.1.131: bytes=32 time=3ms TTL=125
Reply from 192.19.1.131: bytes=32 time=2ms TTL=125

Ping statistics for 192.19.1.131:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
Approximate round trip times in milli-seconds:
    Minimum = 2ms, Maximum = 15ms, Average = 6ms

PC>
```

Figure 18: Ping from PC1 to PC4

4.Conclusion

In conclusion, After we finished this experiment we became able to configure and verify IP routing with Cisco routers, and we learned exterior gateway protocol, also we learned interior gateway protocols, Autonomous systems and Dynamic routing BGP, and we became able to configure BGP Timers in routers.

5.References

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