Faculty of Engineering & Technology

Electrical & Computer Engineering Department

Advanced Computer Networks (ENCS5321)

Final Project: Task 1

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Section: 1

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1 The Complete Network Topology

Figure 1 shows the complete network topology, detailing all Autonomous Systems (ASes), subnets and router interfaces.

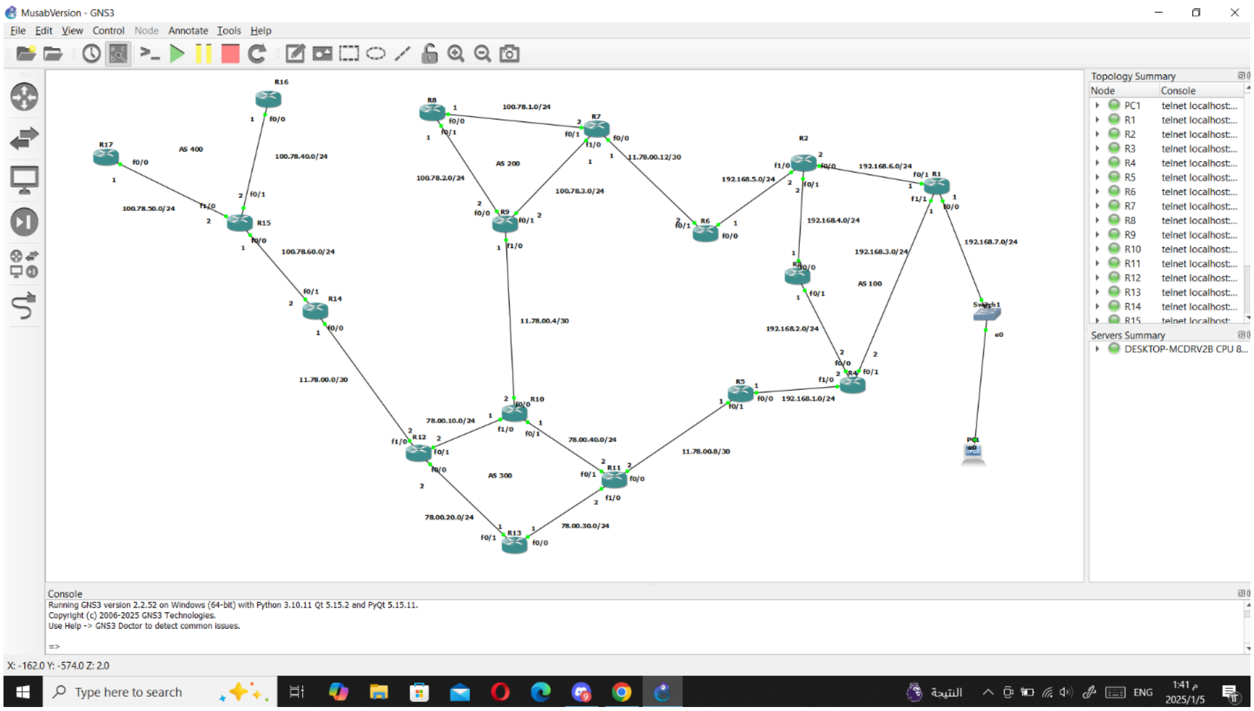

Figure 1: The Complete Network Topology

1200078 was the student id that was used for IP addresses.

As shown on Figure 1, the topology integrates multiple ASes to form a hierarchical and scalable design:

- AS100 (Enterprise Network)
  - Its IPs were already assigned by the instructor.
- AS200 (IX Provider)
  - Its subnets ids: 100.78.1.0/24, 100.78.2.0/24, 100.78.3.0/24.
- AS300 (Transit Provider)
  - Its subnets ids: 78.00.10.0/24, 78.00.20.0/24, 78.00.30.0/24, 78.00.40.0/24.
- AS400 (Enterprise Network)

- Its subnets ids: 100.78.40.0/24, 100.78.50.0/24, 100.78.60.0/24.

- The external connections between ASes:
  - Its subnets ids: 11.78.00.0/30, 11.78.00.4/30, 11.78.00.8/30, 11.78.00.12/30.

2 AS 400

2.1 IP Addresses Assignment

Figure 2 shows the assignment of IP addresses for R17 interfaces.

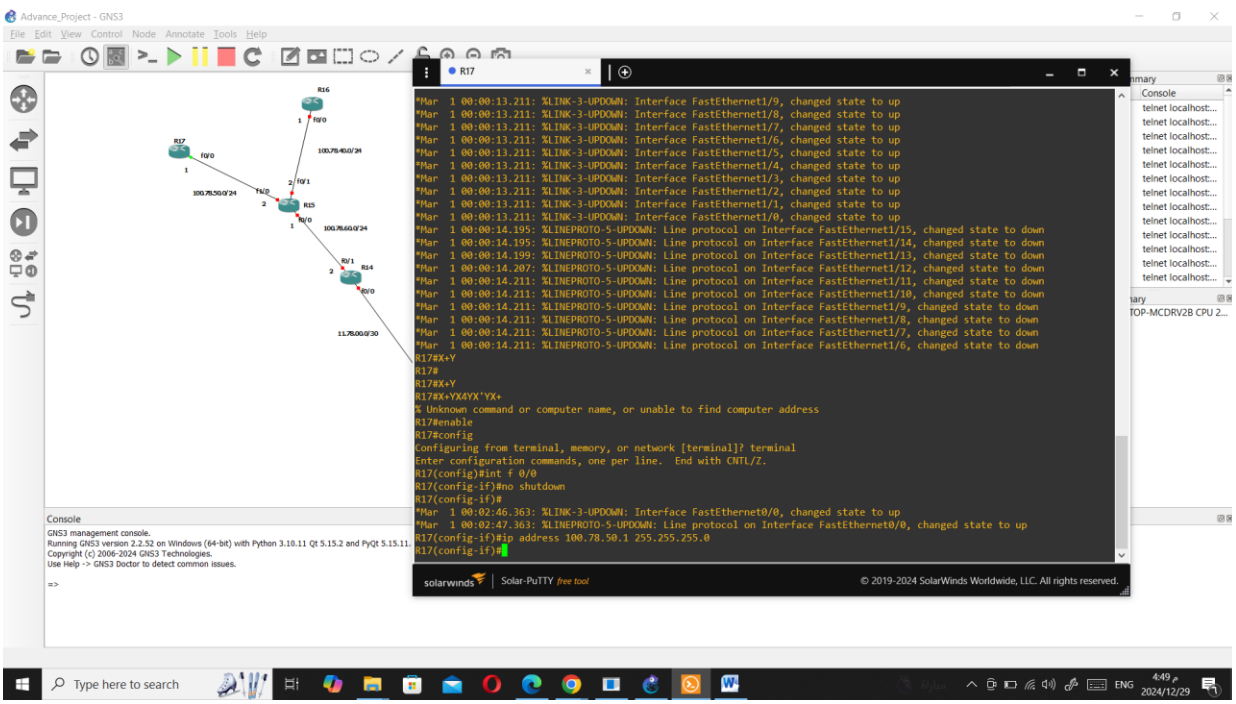

Figure 2: IP Addresses Assignment for R17

As shown on Figure 2, the IP address for Router R17's fast ethernet interface was successfully assigned and verified. The fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interface was brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interface is "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 3 shows the assignment of IP address for R16 interface.

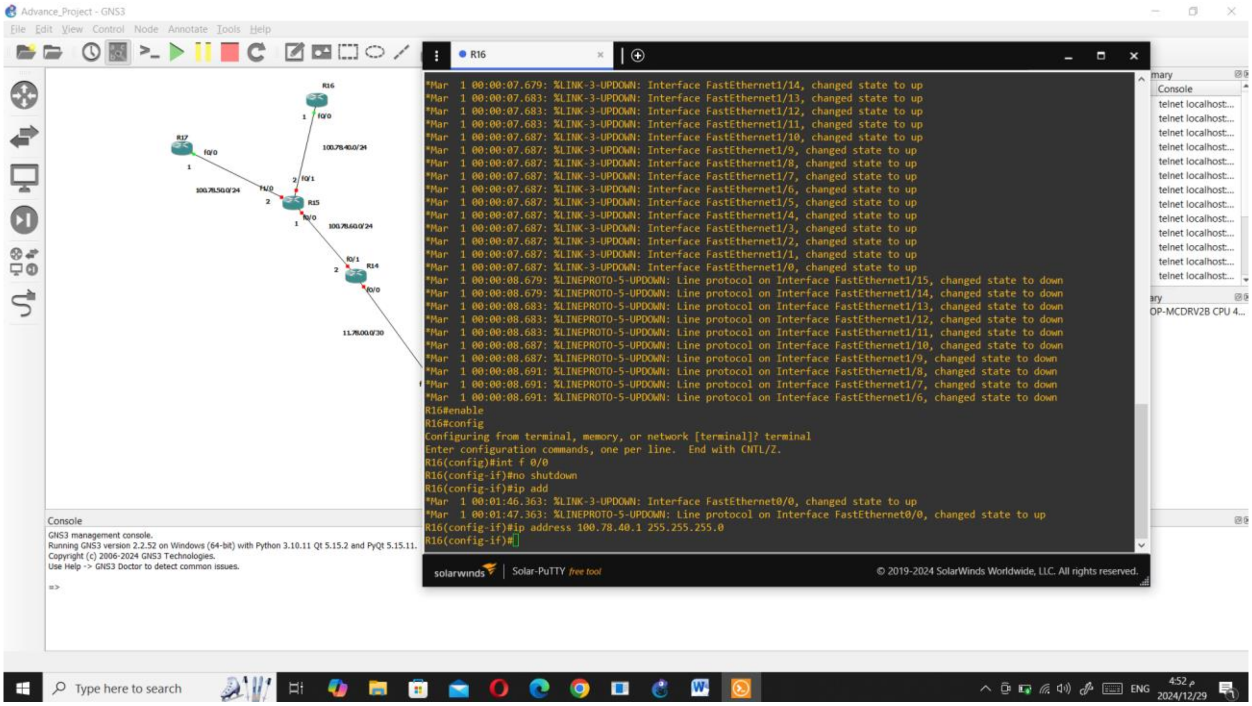

Figure 3: IP Addresses Assignment for R16

As shown on Figure 3, the IP address for Router R16's fast ethernet interface was successfully assigned and verified. The fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interface was brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interface is "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 4 shows the assignment of IP address for R14 interface.

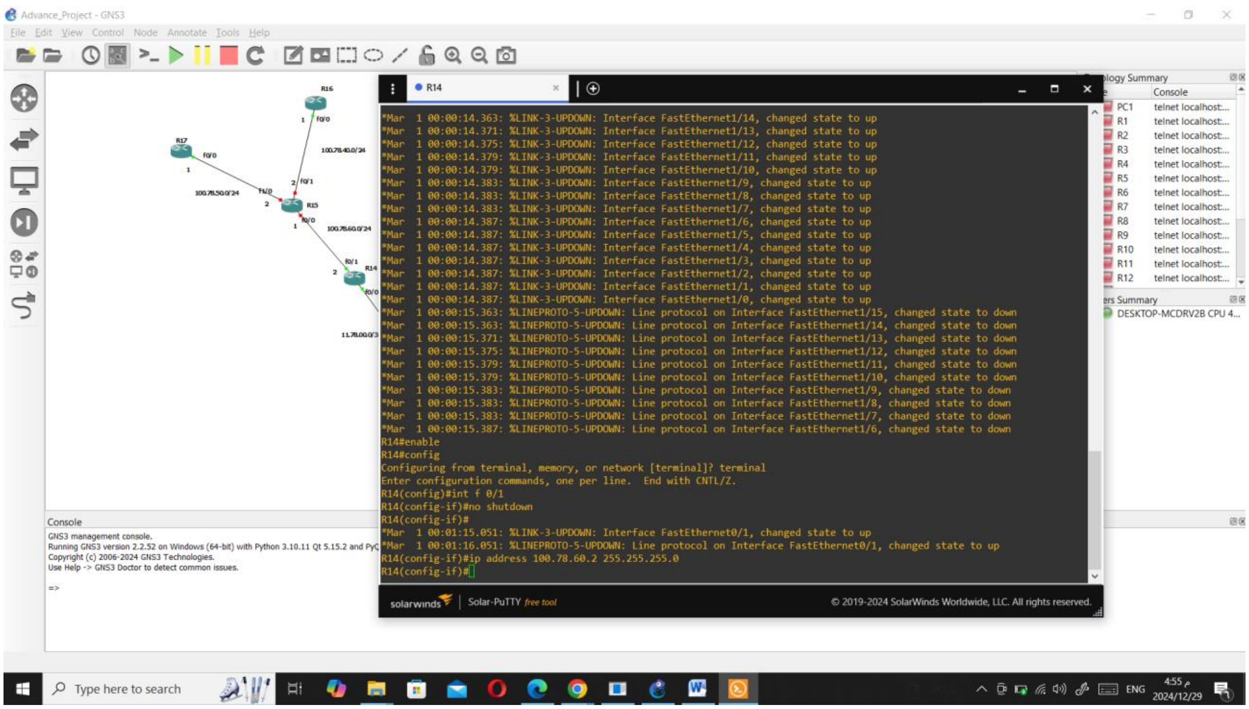

Figure 4: IP Addresses Assignment for R14

As shown on Figure 4, the IP address for Router R14's fast ethernet interface was successfully assigned and verified. The fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interface was brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interface is "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 5 shows the assignment of IP address for R15 interface.

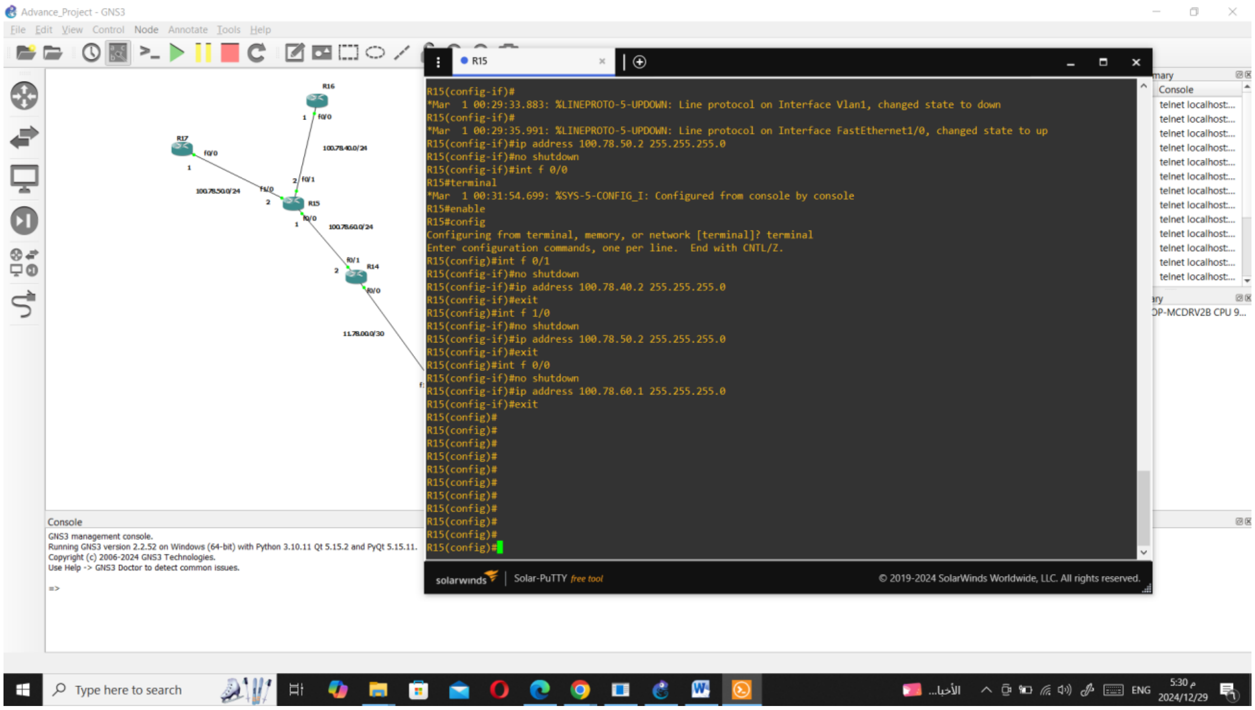

Figure 5: IP Addresses Assignment for R15

As shown on Figure 5, the IP addresses for Router R15 have been successfully assigned and verified. Each fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interfaces were brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interfaces are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

2.2 RIP Configuration

Figure 6 shows the RIP configuration on R17.

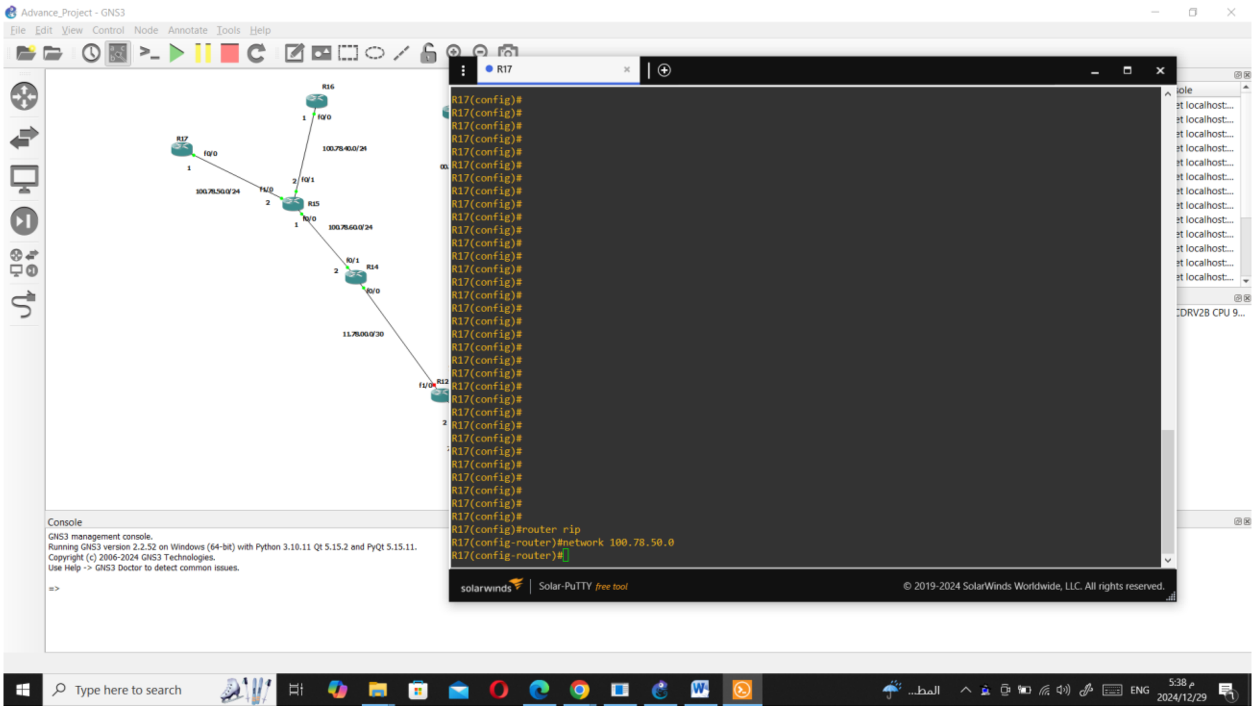

Figure 6: The RIP Configuration on Router R17

Figure 7 shows the RIP configuration on R16.

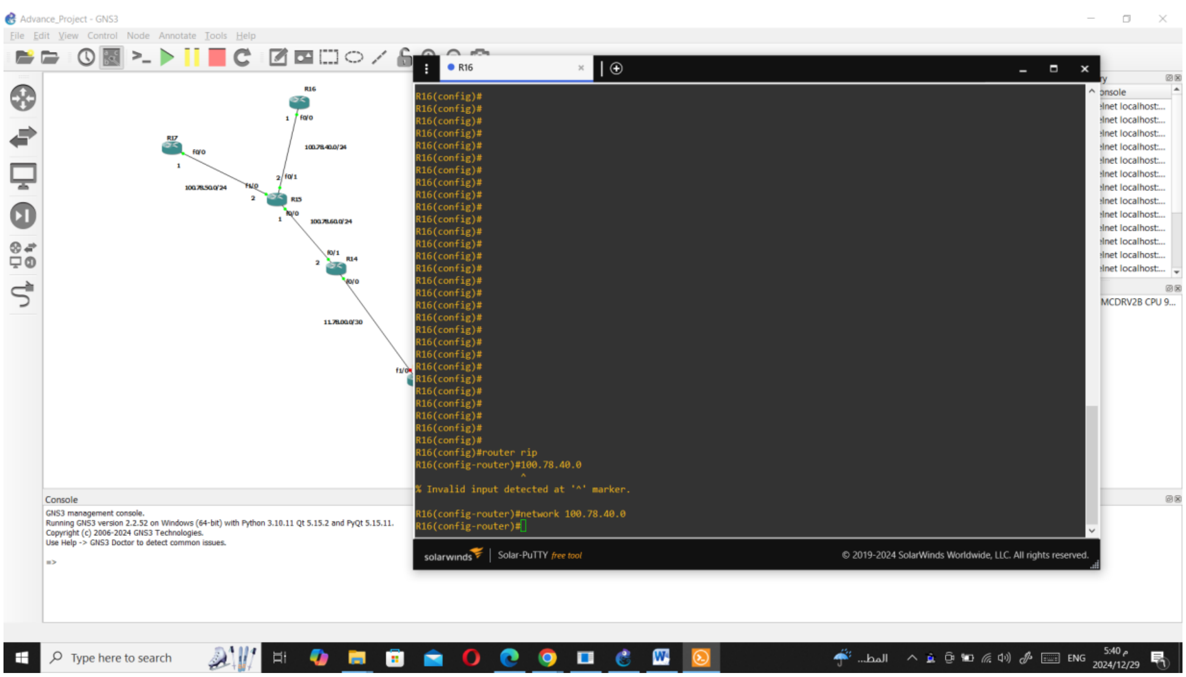

Figure 7: The RIP Configuration on Router R16

Figure 8 shows the RIP configuration on R14.

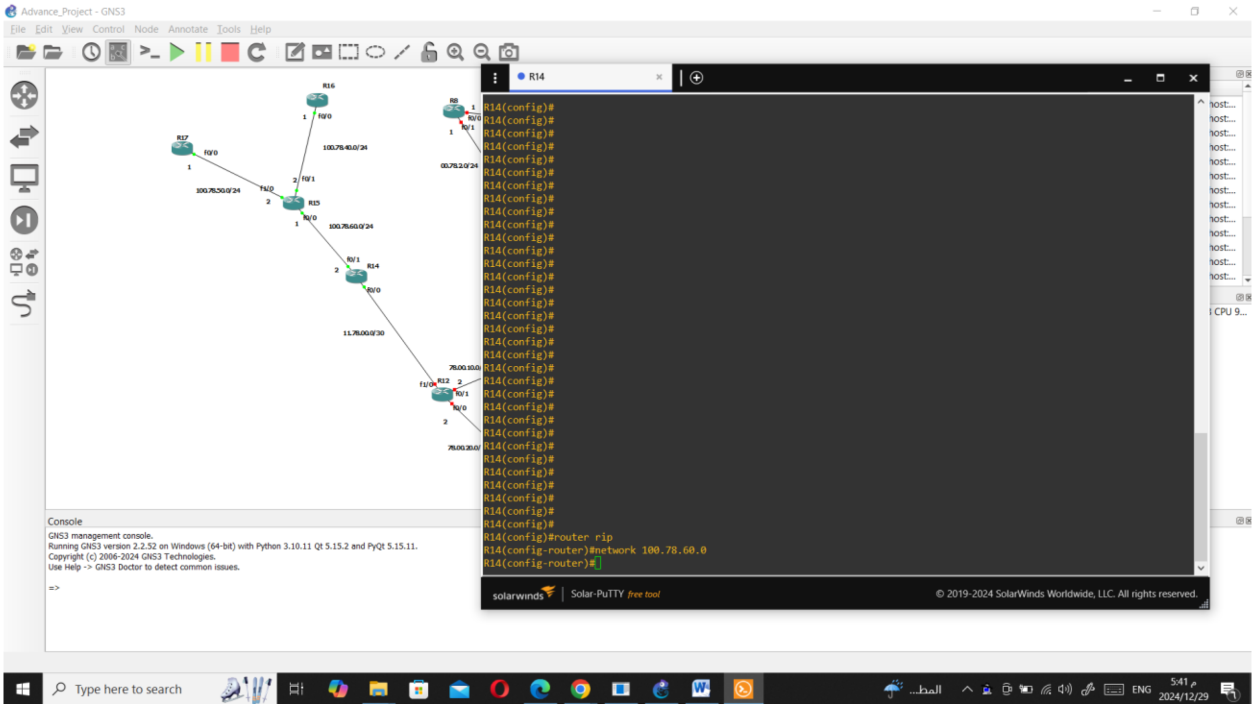

Figure 8: The RIP Configuration on Router R14

Figure 9 shows the RIP configuration on R15.

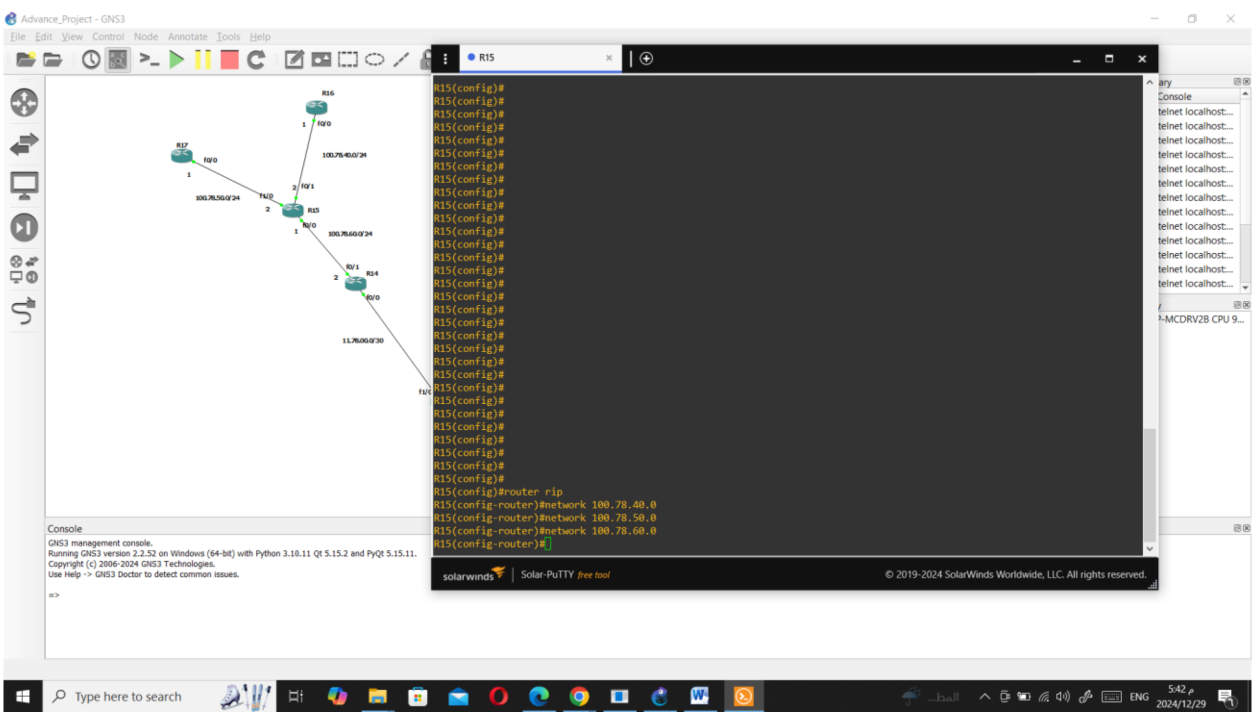

Figure 9: The RIP Configuration on Router R15

As shown on Figures (from Figure 6 to Figure 9), the RIP protocol was configured on Routers R17, R16, R14, and R15 to enable dynamic routing across the network. This configuration allows each router to share and receive routing information with its neighboring routers by advertising its directly connected networks, thereby ensuring efficient packet forwarding and optimal path selection.

3 AS 200

3.1 IP Addresses Assignment

Figure 10 shows the assignment of IP addresses for R8 interfaces.

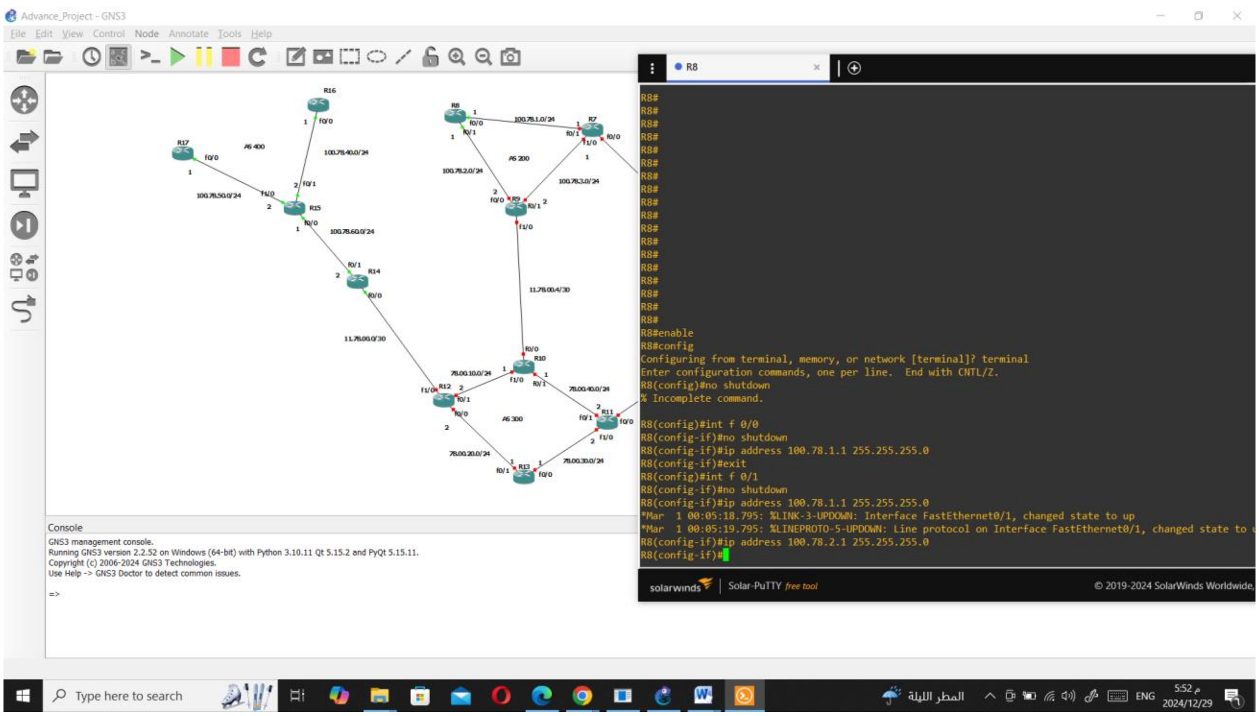

Figure 10: IP Addresses Assignment for R8

As shown on Figure 10, the IP addresses for Router R8 have been successfully assigned and verified. Each fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interfaces were brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interfaces are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 11 shows the assignment of IP addresses for R9 interfaces.

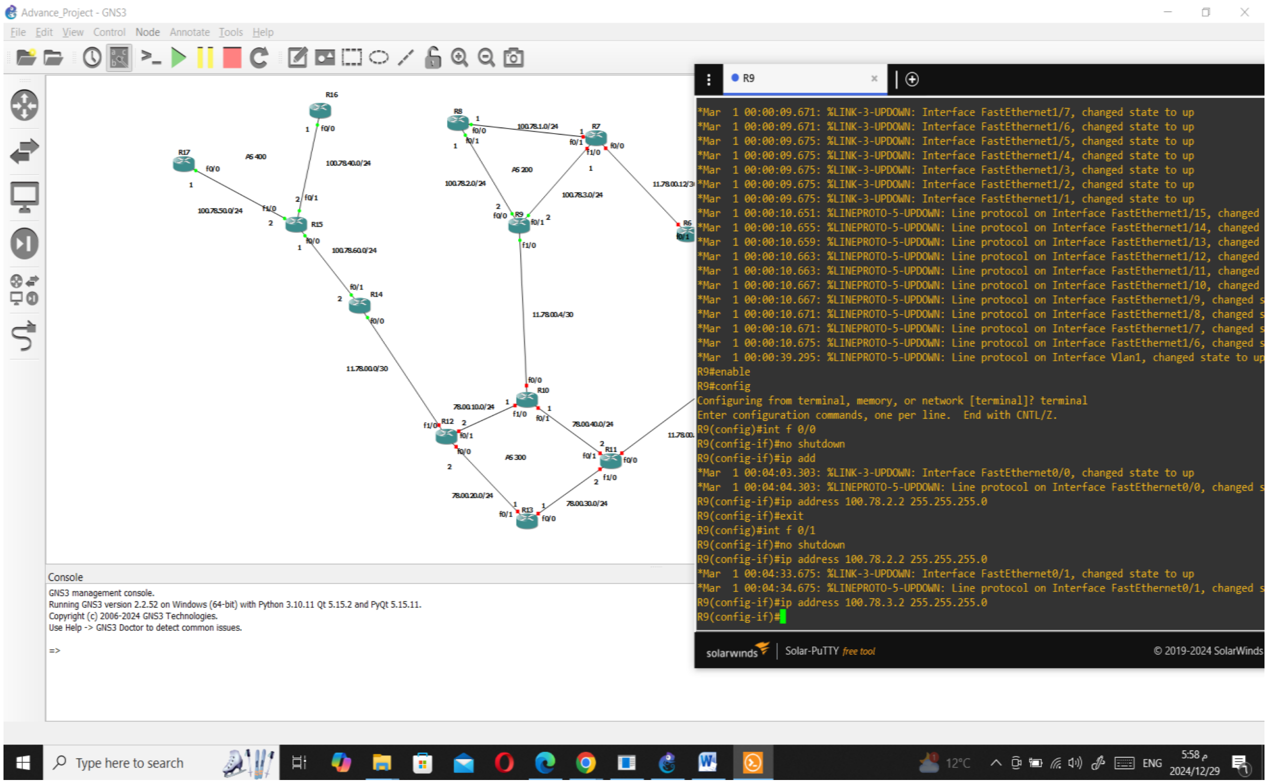

Figure 11: IP Addresses Assignment for R9

As shown on Figure 11, the IP addresses for Router R9 have been successfully assigned and verified. Each fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interfaces were brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interfaces are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 12 shows the assignment of IP addresses for R7 interfaces.

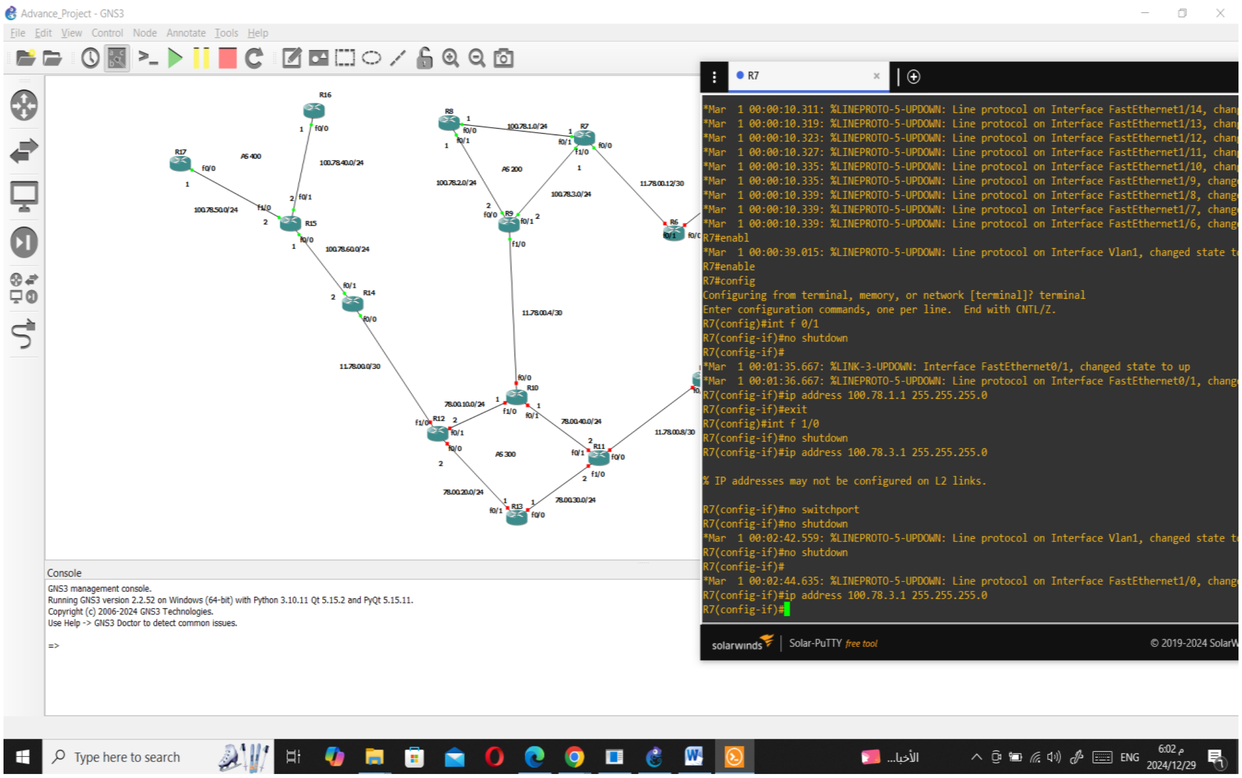

Figure 12: IP Addresses Assignment for R7

As shown on Figure 12, the IP addresses for Router R7 have been successfully assigned and verified. Each fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interfaces were brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interfaces are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

3.2 RIP Configuration

Figure 13 shows the RIP configuration on R8.

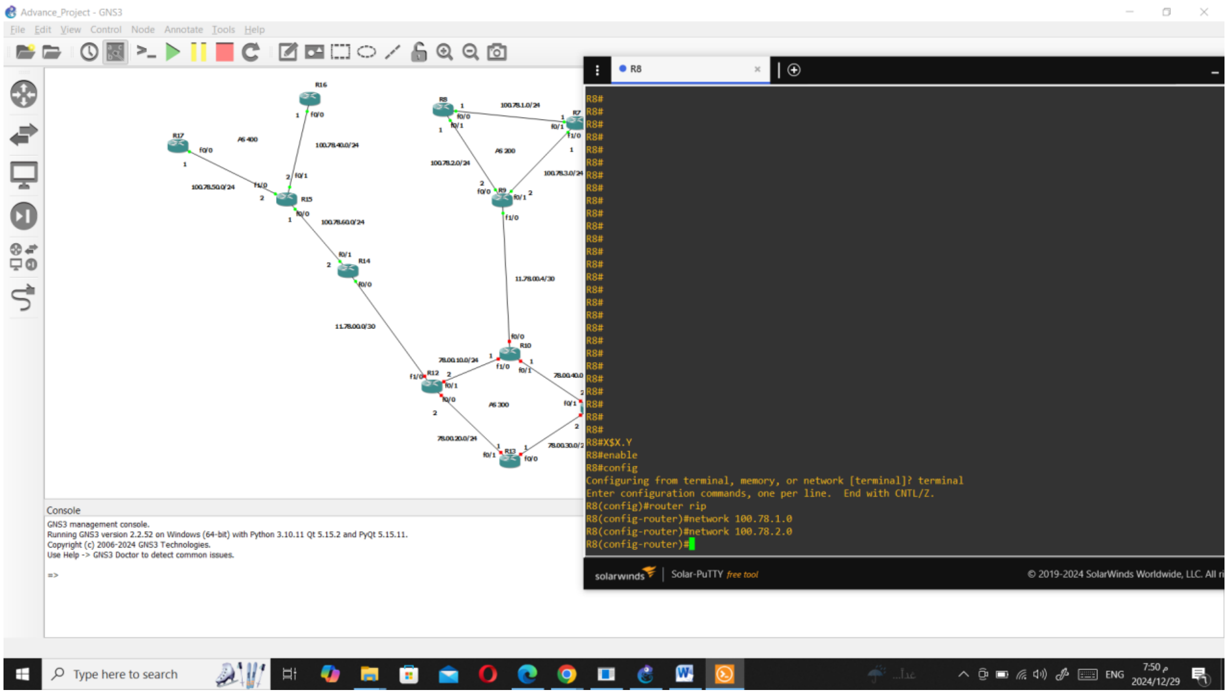

Figure 13: The RIP Configuration on Router R8

Figure 14 shows the RIP configuration on R9.

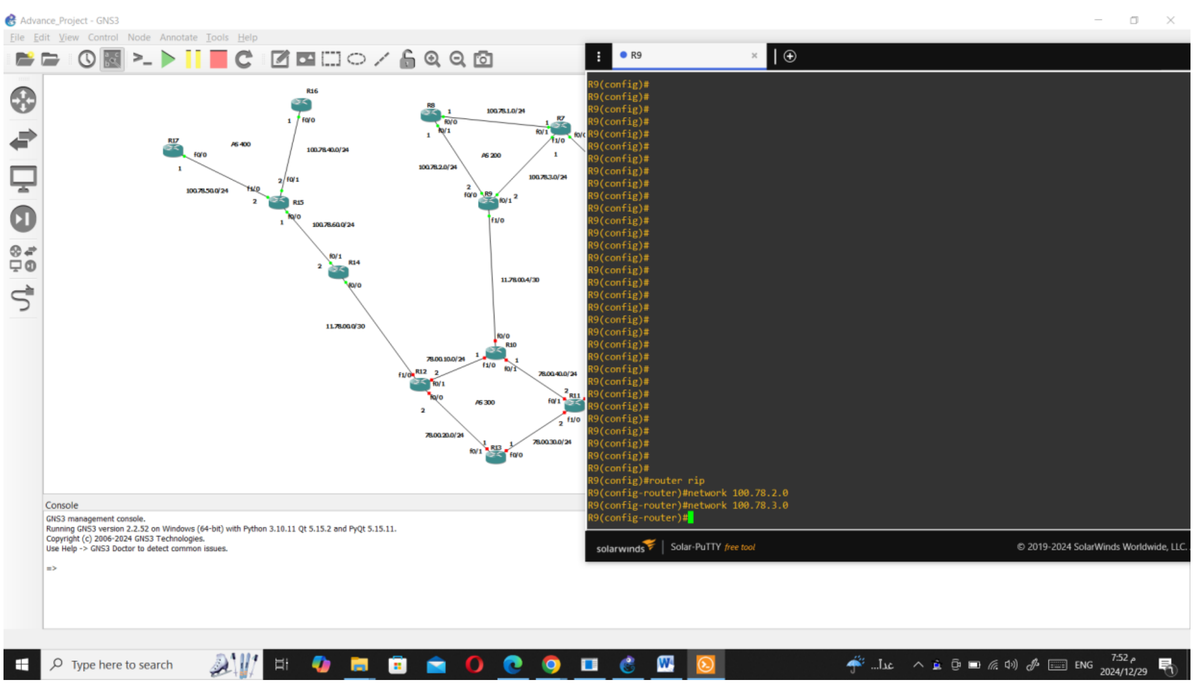

Figure 14: The RIP Configuration on Router R9

Figure 15 shows the RIP configuration on R7.

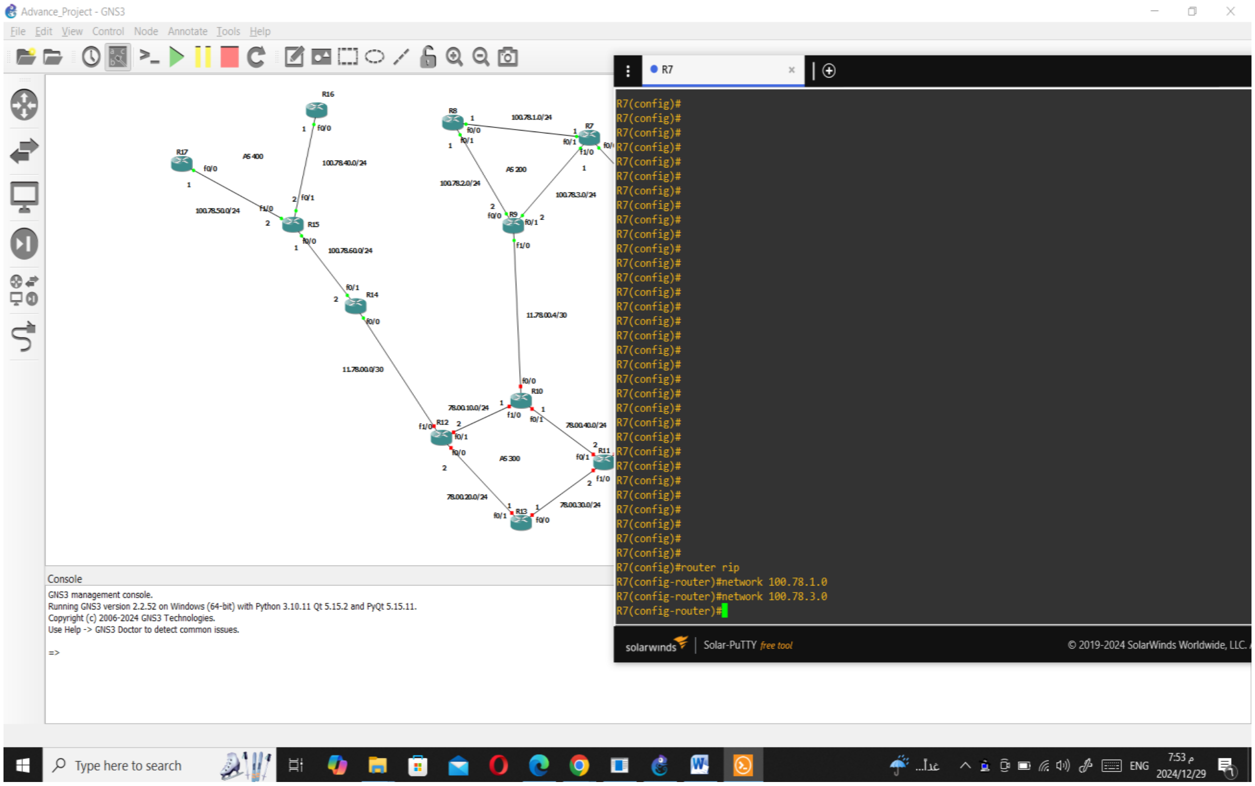

Figure 15: The RIP Configuration on Router R7

As shown on Figures (from Figure 13 to Figure 15), the RIP protocol was configured on Routers R8, R9, and R7 to enable dynamic routing across the network. This configuration allows each router to share and receive routing information with its neighboring routers by advertising its directly connected networks, thereby ensuring efficient packet forwarding and optimal path selection.

4 AS 300

4.1 IP Addresses Assignment

Figure 16 and Figure 17 show the assignment of IP addresses for R10 interfaces.

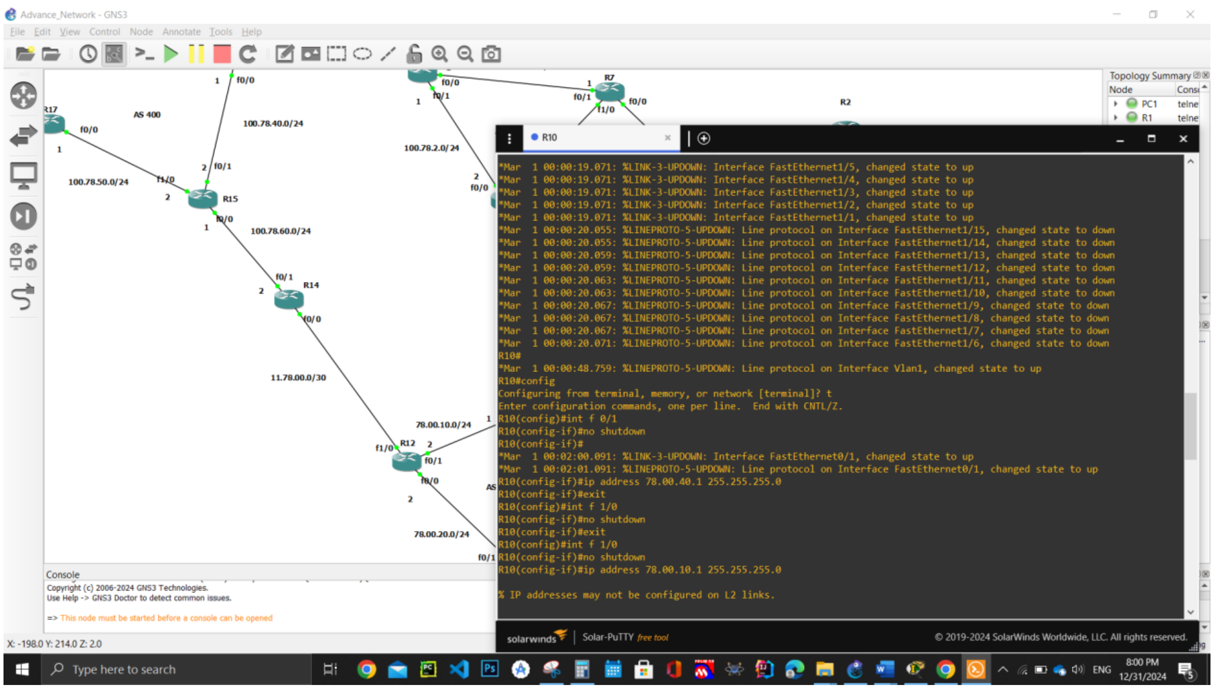

Figure 16: IP Addresses Assignment for R10-Part One

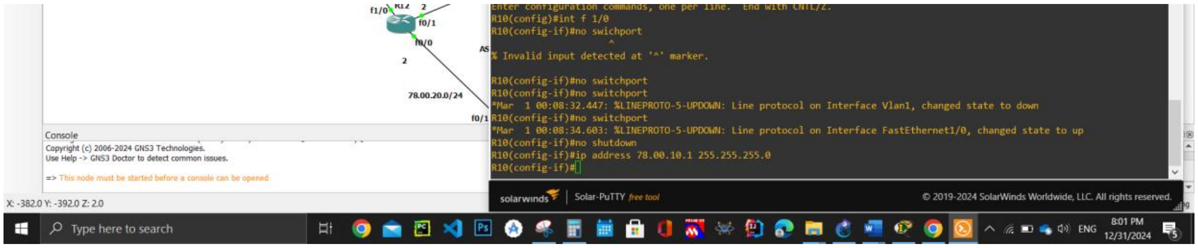

Figure 17: IP Addresses Assignment for R10-Part Two

As shown on Figures (Figure 16 and Figure 17), the IP addresses for Router R10 have been successfully assigned and verified. Each Fast Ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. For interfaces that initially did not respond to the no shutdown command, the no switchport command was applied to convert them from Layer 2 switch ports to Layer 3 routed ports. The no shutdown command was then reapplied on these interfaces, successfully bringing them to an operational state, as confirmed by status messages indicating they are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 18 shows the assignment of IP addresses for R11 interfaces.

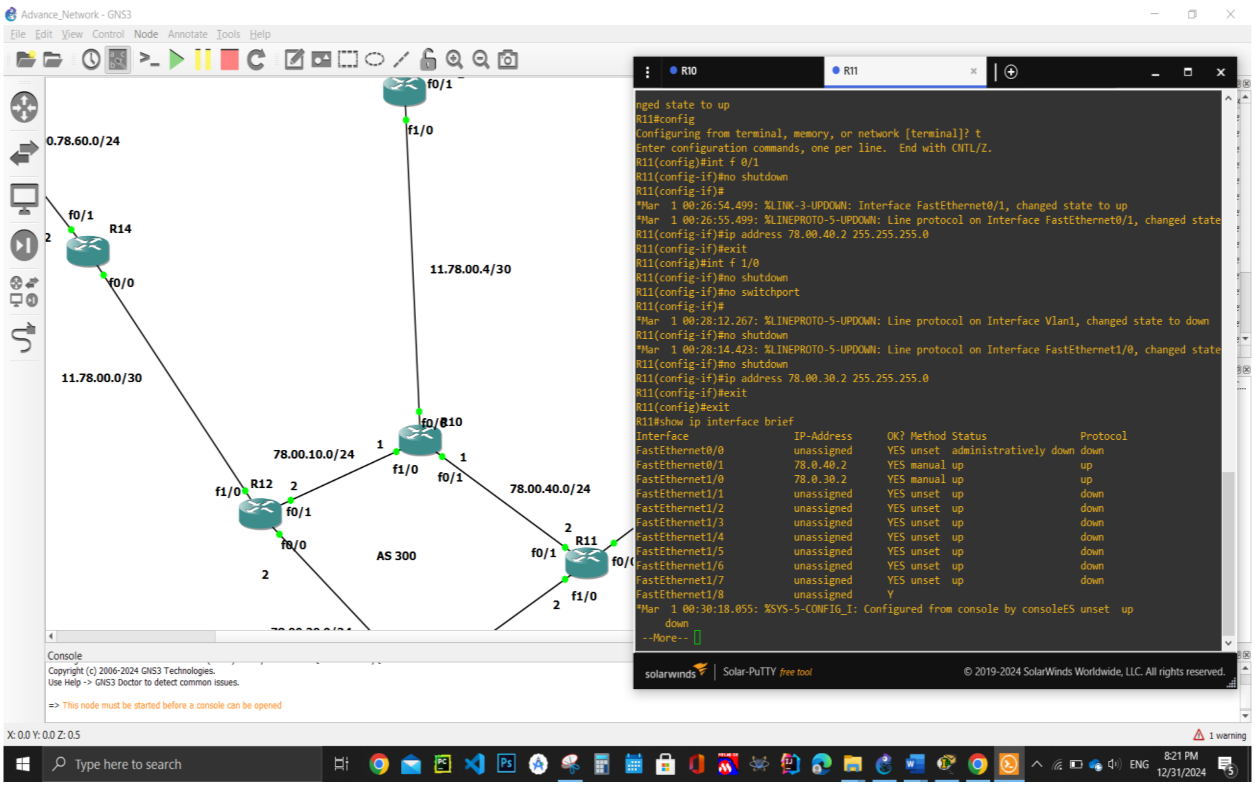

Figure 18: IP Addresses Assignment for R11

As shown on Figure 18, the IP addresses for Router R11 have been successfully assigned and verified. Each Fast Ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. For interfaces that initially did not respond to the no shutdown command, the no switchport command was applied to convert them from Layer 2 switch ports to Layer 3 routed ports. The no shutdown command was then reapplied on these interfaces, successfully bringing them to an operational state, as confirmed by status messages indicating they are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 19 shows the assignment of IP addresses for R12 interfaces.

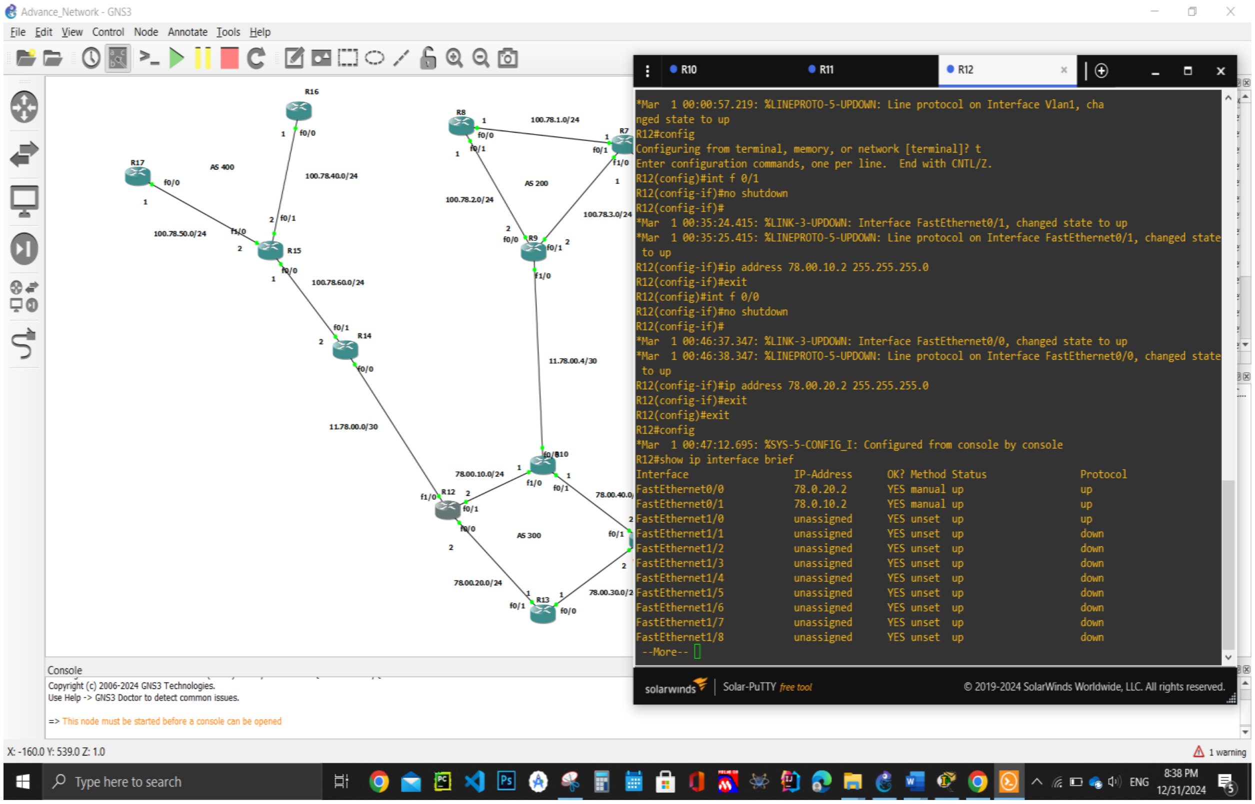

Figure 19: IP Addresses Assignment for R12

As shown on Figure 19, the IP addresses for Router R12 have been successfully assigned and verified. Each fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interfaces were brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interfaces are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 20 shows the assignment of IP addresses for R13 interfaces.

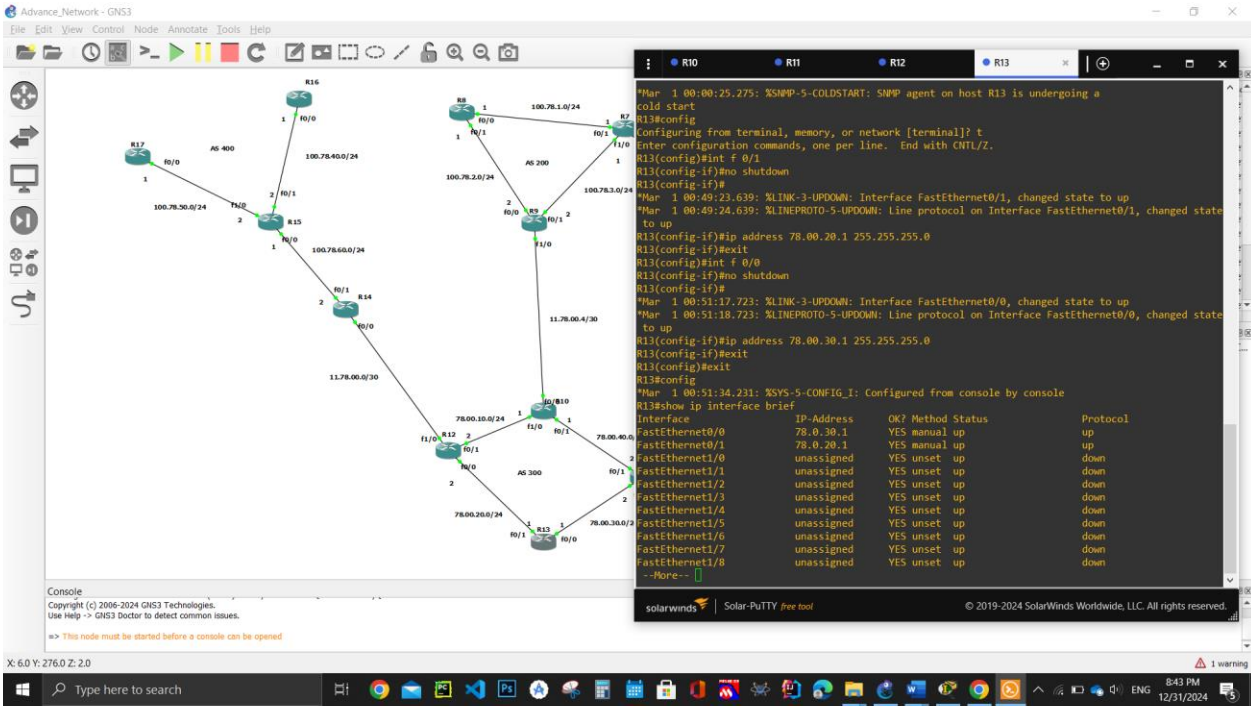

Figure 20: IP Addresses Assignment for R13

As shown on Figure 20, the IP addresses for Router R13 have been successfully assigned and verified. Each fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interfaces were brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interfaces are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

4.2 OSPF Configuration

Figure 21 shows the OSPF configuration on R10.

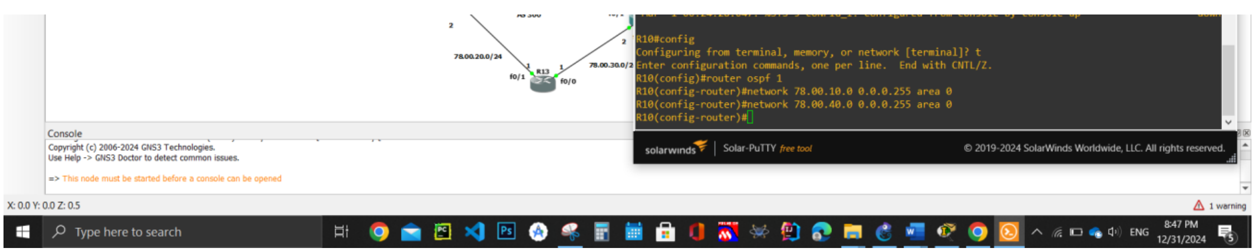

Figure 21: The OSPF Configuration on Router R10

Figure 22 shows the OSPF configuration on R11.

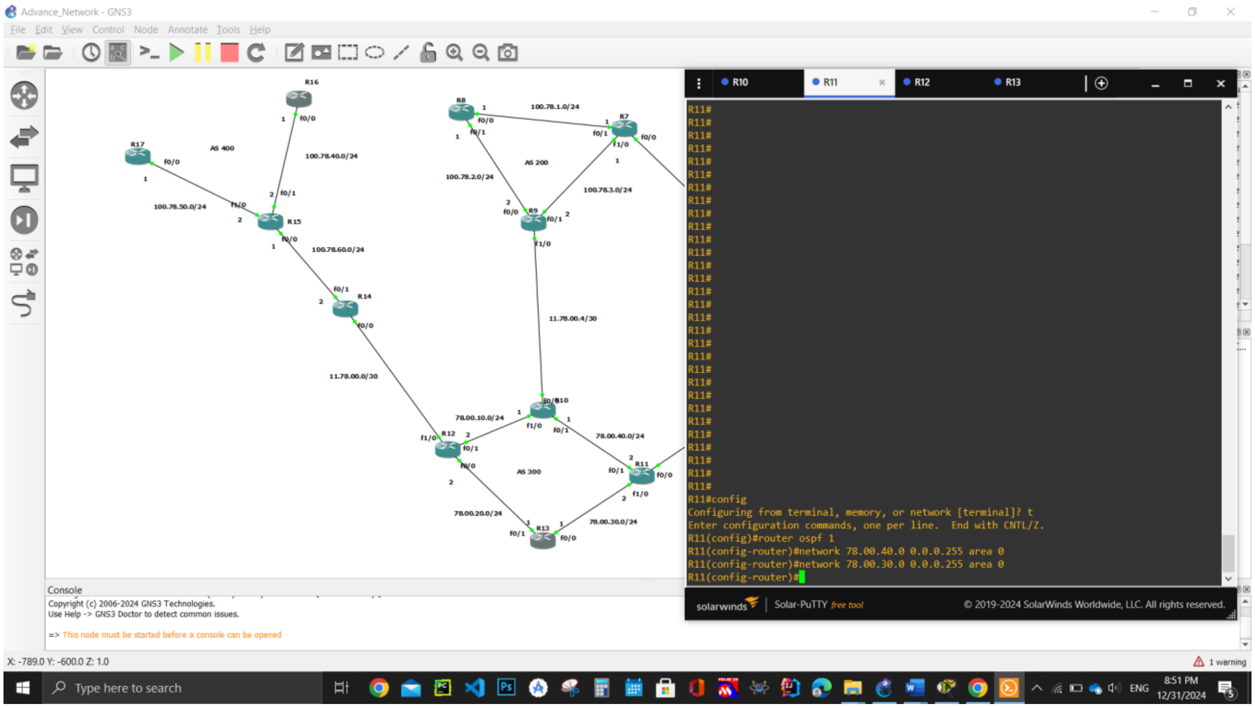

Figure 22: The OSPF Configuration on Router R11

Figure 23 shows the OSPF configuration on R12.

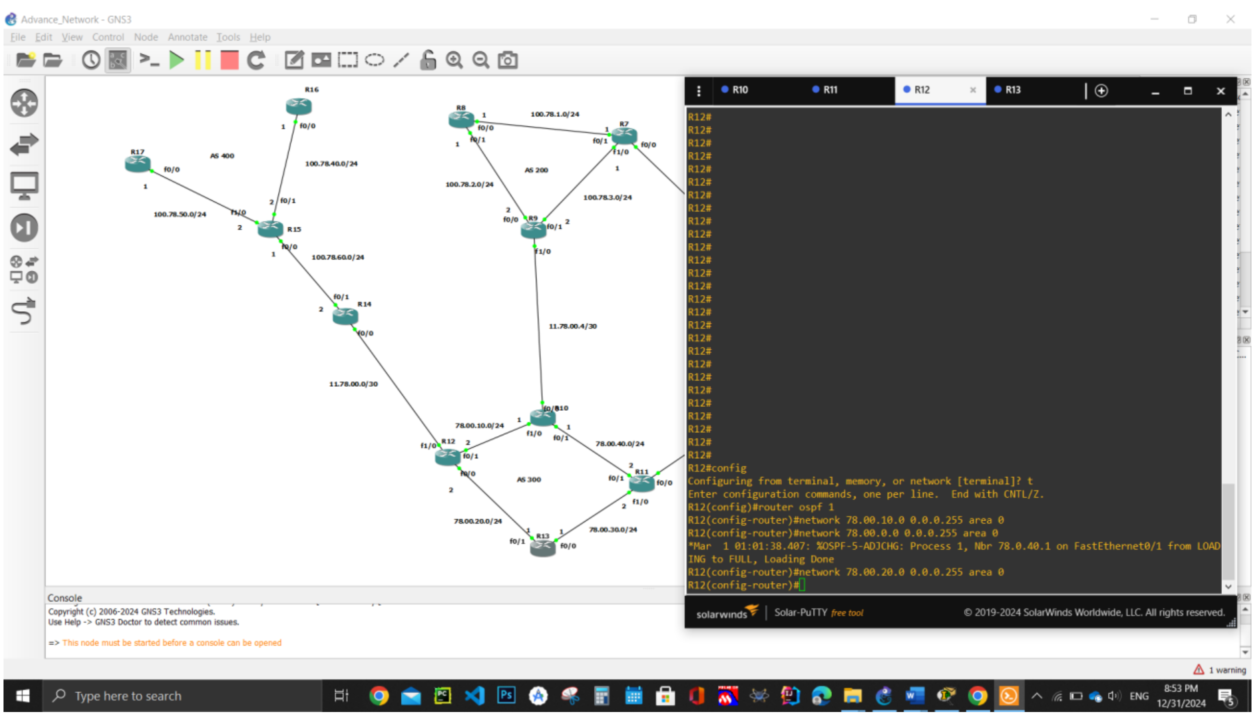

Figure 23: The OSPF Configuration on Router R12

Figure 24 shows the OSPF configuration on R13.

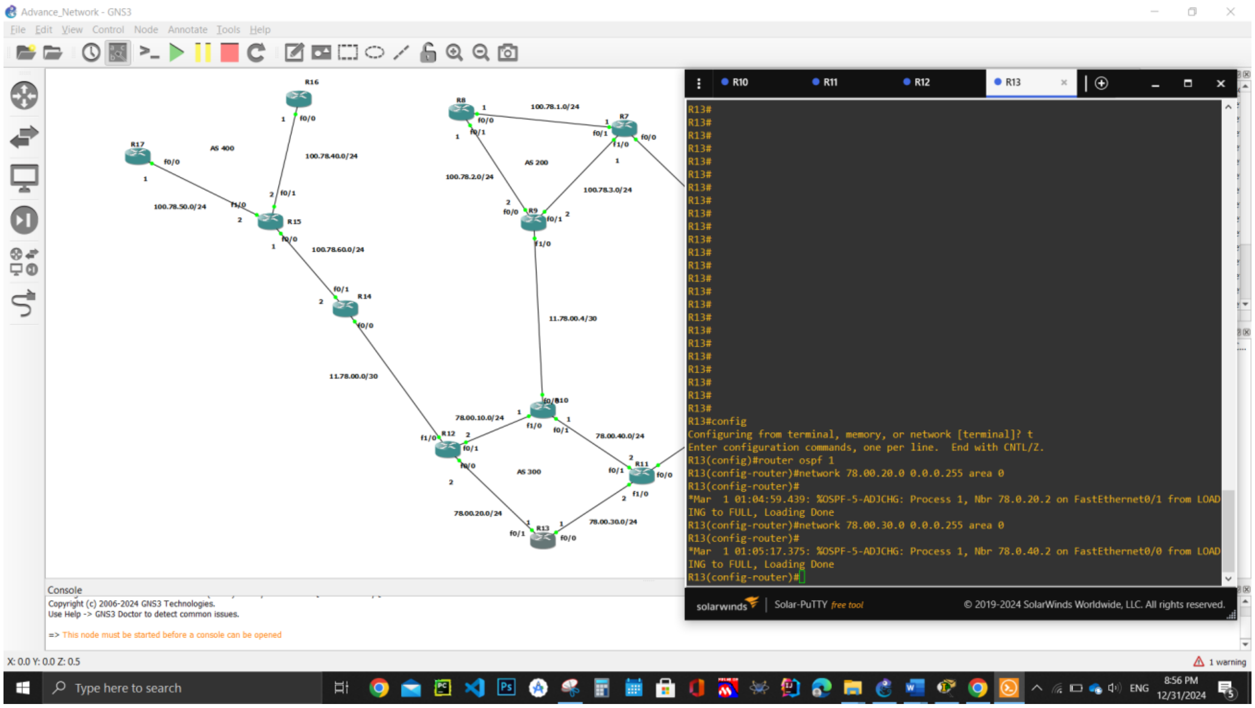

Figure 24: The OSPF Configuration on Router R13

As shown on Figures (from Figure 21 to Figure 24), the OSPF protocol was configured on Routers R10, R11, R12 and R13 to enable dynamic routing across the network. Each router was set up under OSPF process 1, with specific network statements used to advertise its directly connected subnets within OSPF area 0. This configuration allows each router to form OSPF adjacencies with its neighbors, ensuring the exchange of routing information and synchronization of link-state databases. The hierarchical design and the use of OSPF ensure optimal path selection, loop-free routing and high network reliability even in the presence of link failures.

5 AS 100

5.1 IP Addresses Assignment

Figure 25 shows the assignment of IP addresses for R1 interfaces.

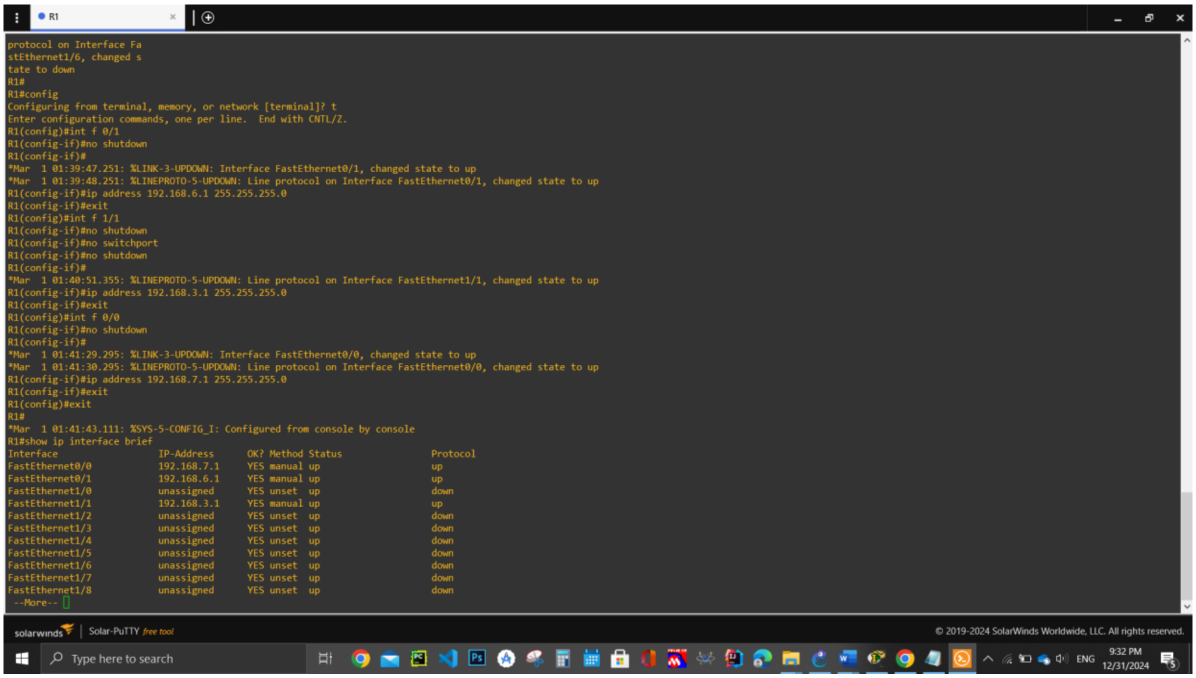

Figure 25: IP Addresses Assignment for R1

As shown on Figure 25, the IP addresses for Router R1 have been successfully assigned and verified. Each Fast Ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. For interfaces that initially did not respond to the no shutdown command, the no switchport command was applied to convert them from Layer 2 switch ports to Layer 3 routed ports. The no shutdown command was then reapplied on these interfaces, successfully bringing them to an operational state, as confirmed by status messages indicating they are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 26 shows the assignment of IP addresses for R2 interfaces.

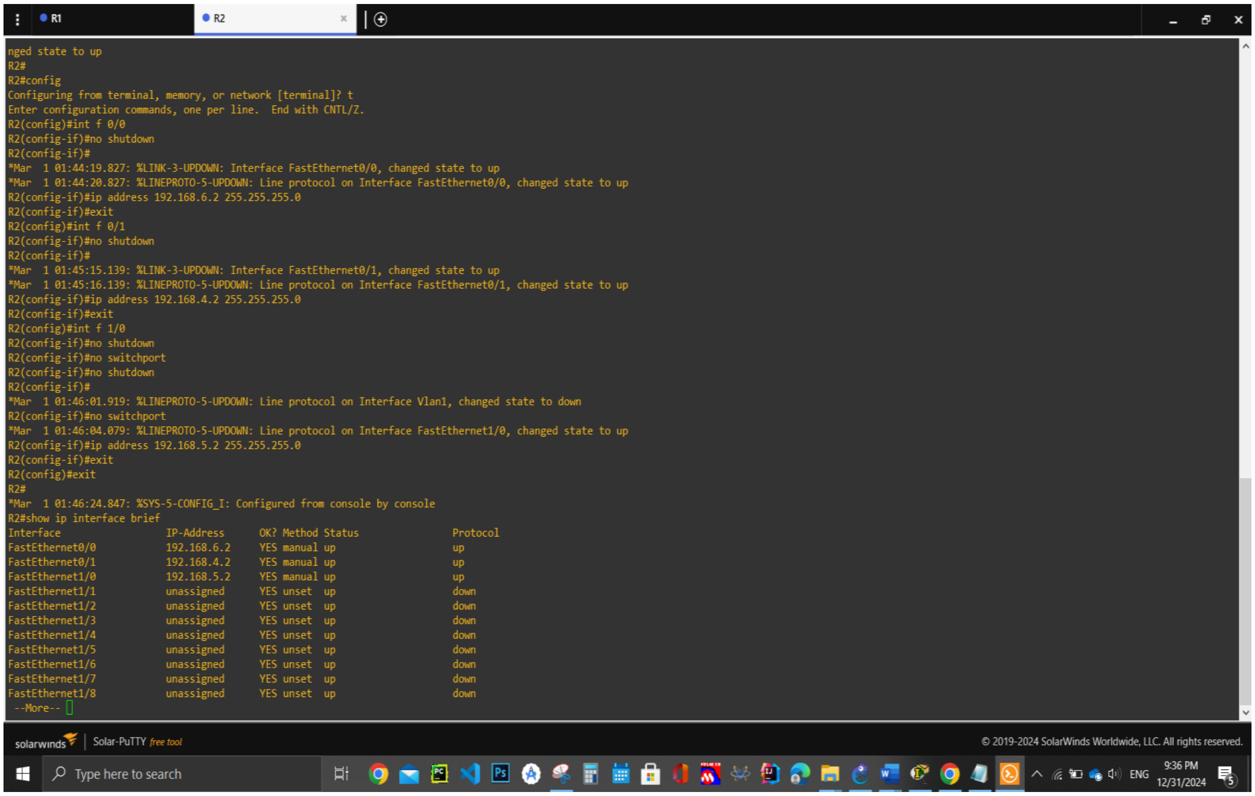

Figure 26: IP Addresses Assignment for R2

As shown on Figure 26, the IP addresses for Router R2 have been successfully assigned and verified. Each Fast Ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. For interfaces that initially did not respond to the no shutdown command, the no switchport command was applied to convert them from Layer 2 switch ports to Layer 3 routed ports. The no shutdown command was then reapplied on these interfaces, successfully bringing them to an operational state, as confirmed by status messages indicating they are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 27 shows the assignment of IP addresses for R3 interfaces.

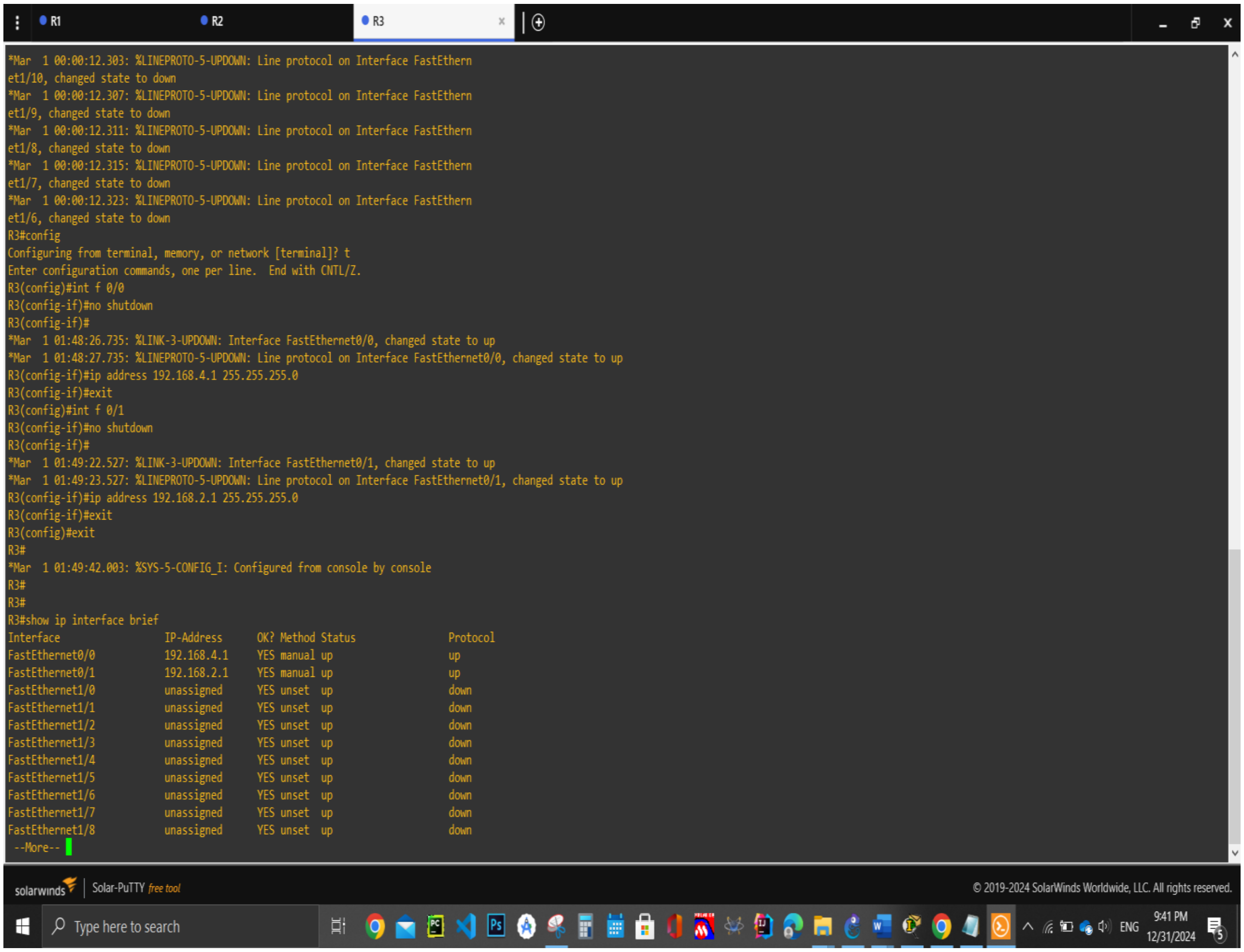

Figure 27: IP Addresses Assignment for R3

As shown on Figure 27, the IP addresses for Router R3 have been successfully assigned and verified. Each fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interfaces were brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interfaces are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 28 shows the assignment of IP addresses for R4 interfaces.

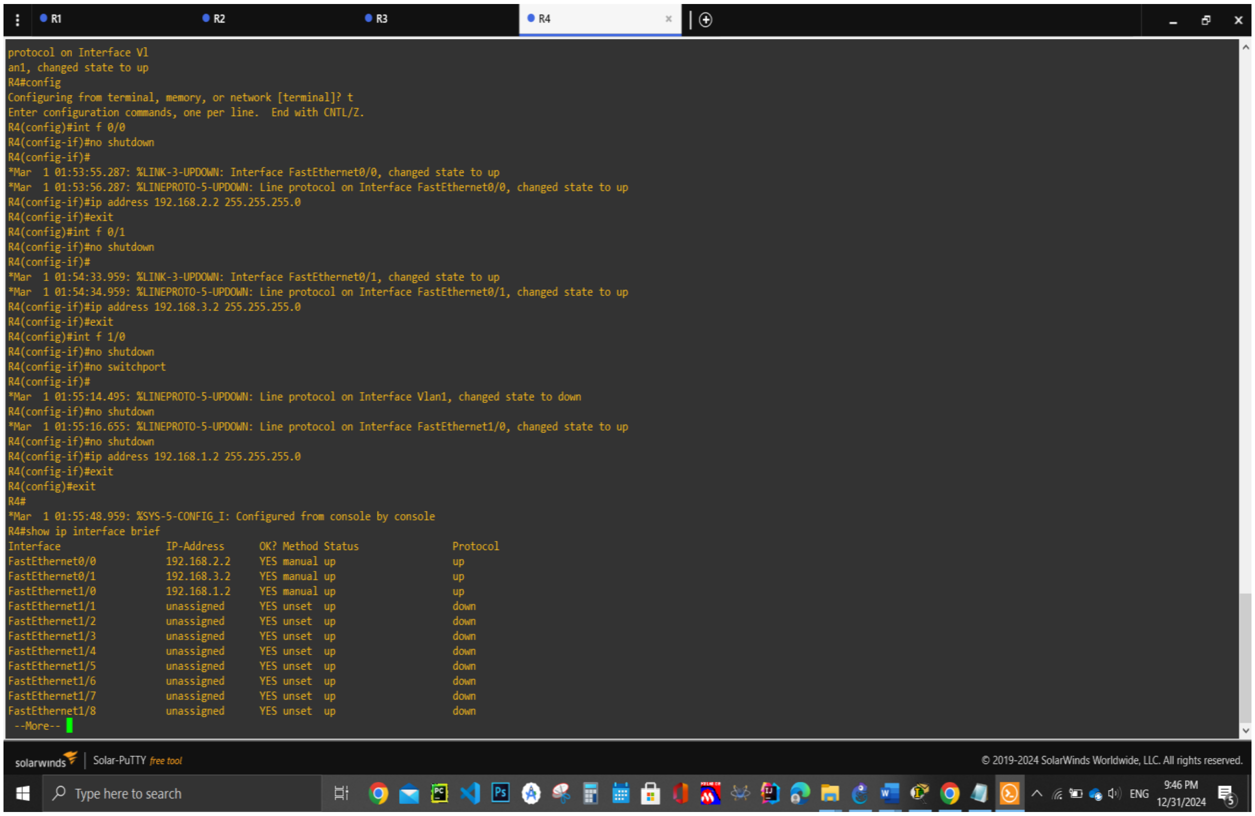

Figure 28: IP Addresses Assignment for R4

As shown on Figure 28, the IP addresses for Router R4 have been successfully assigned and verified. Each Fast Ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. For interfaces that initially did not respond to the no shutdown command, the no switchport command was applied to convert them from Layer 2 switch ports to Layer 3 routed ports. The no shutdown command was then reapplied on these interfaces, successfully bringing them to an operational state, as confirmed by status messages indicating they are "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 29 shows the assignment of IP address for R5 interface.

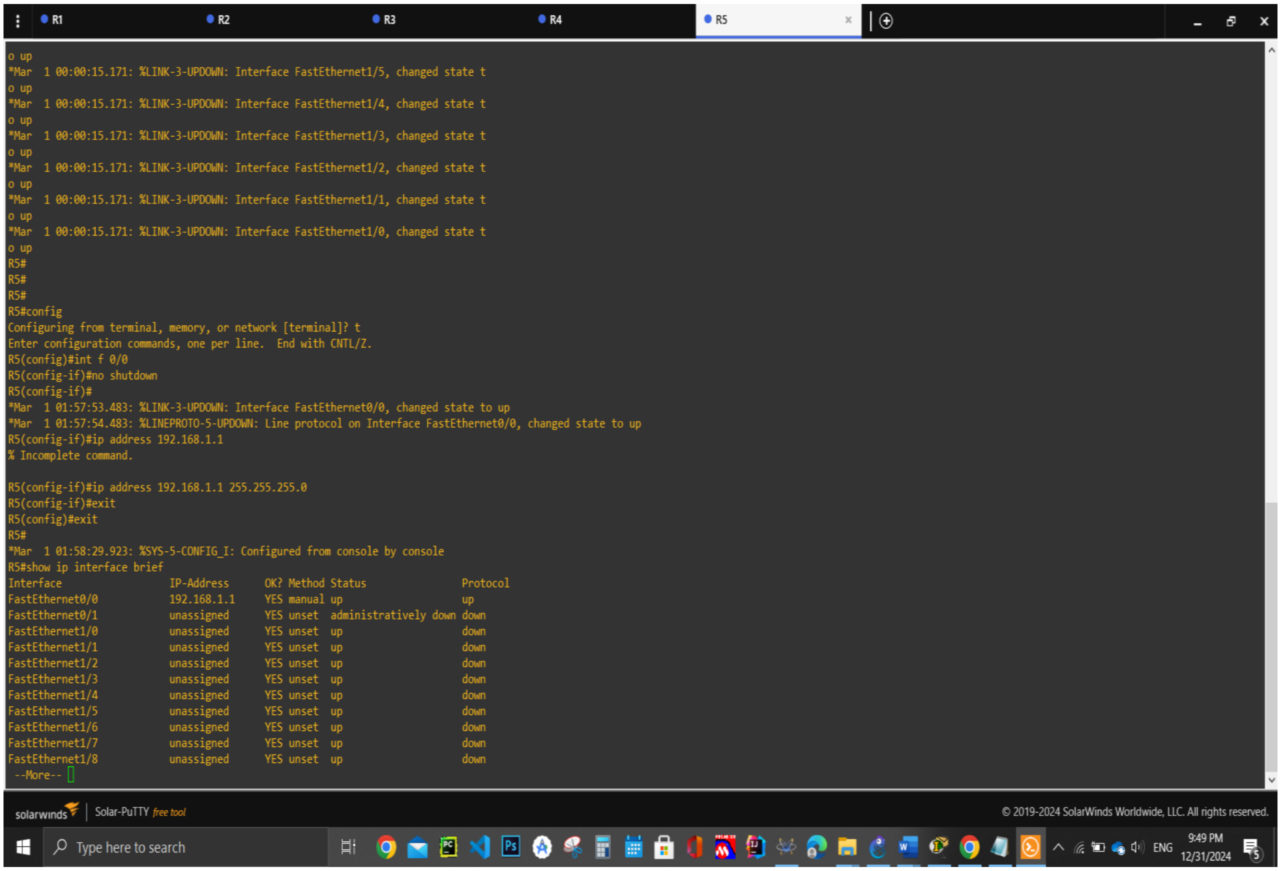

Figure 29: IP Addresses Assignment for R5

As shown on Figure 29, the IP address for Router R5's fast ethernet interface was successfully assigned and verified. The fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interface was brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interface is "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

Figure 30 shows the assignment of IP address for R6 interface.

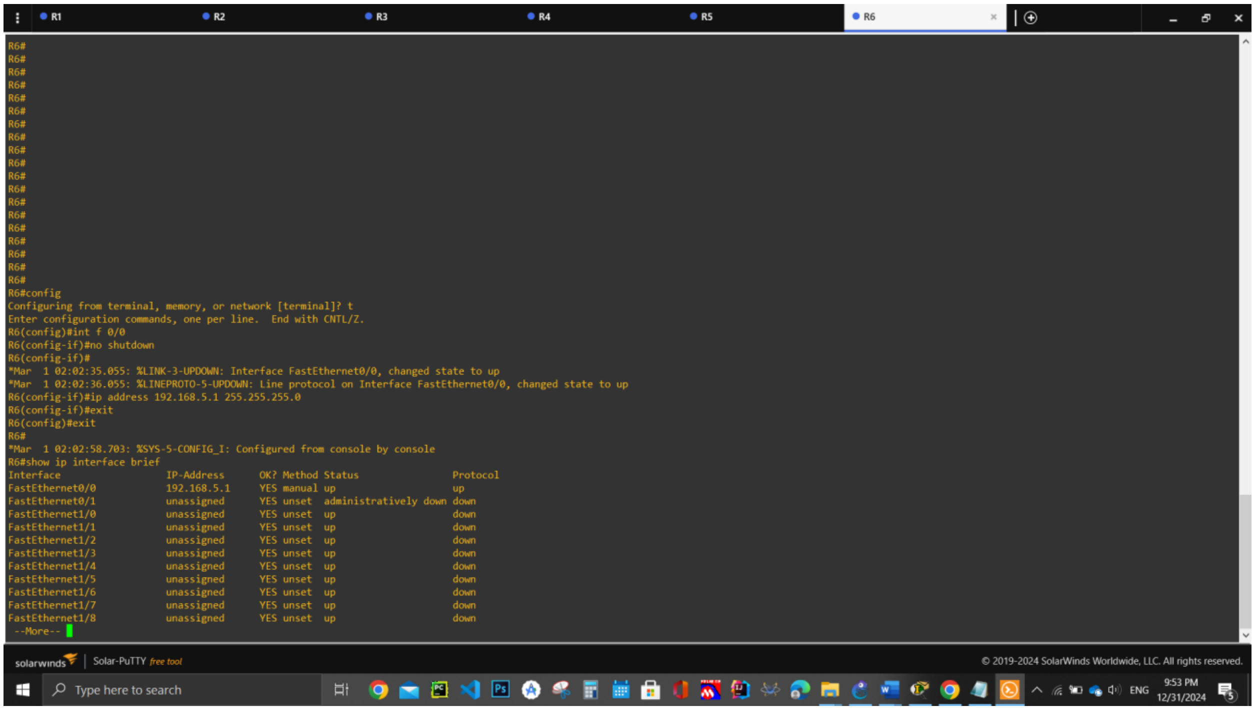

Figure 30: IP Addresses Assignment for R6

As shown on Figure 30, the IP address for Router R6's fast ethernet interface was successfully assigned and verified. The fast ethernet interface was configured with a unique IP address and a subnet mask of 255.255.255.0. The interface was brought to an operational state using the no shutdown command, as indicated by the status messages confirming the interface is "up." This configuration ensures proper connectivity within the network and forms the basis for enabling routing protocols, which is critical for inter-domain communication and efficient packet routing.

5.2 OSPF Configuration

Figure 31 shows the OSPF configuration on R1.

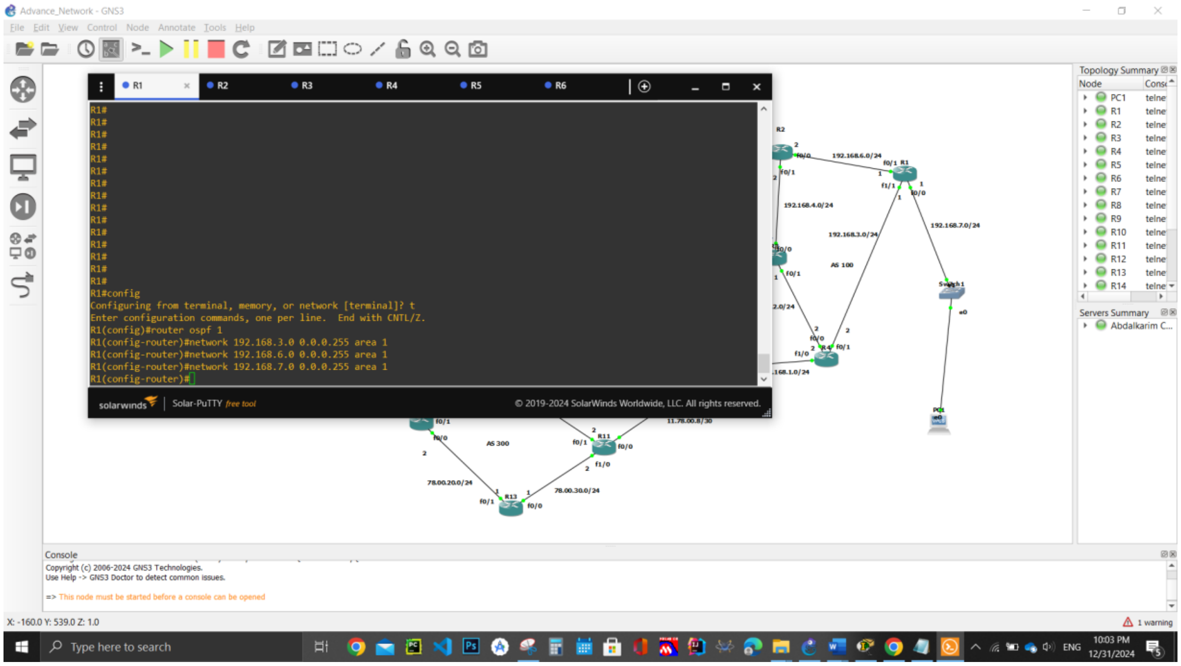

Figure 31: The OSPF Configuration on Router R1

Figure 32 shows the OSPF configuration on R2.

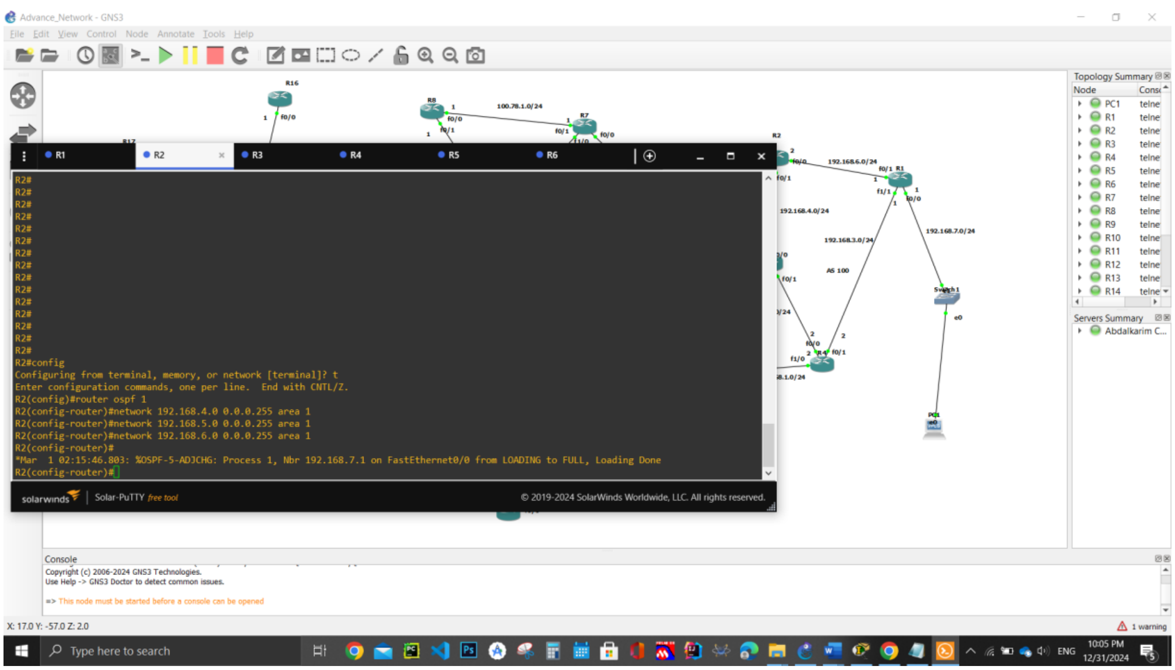

Figure 32: The OSPF Configuration on Router R2

Figure 33 shows the OSPF configuration on R3.

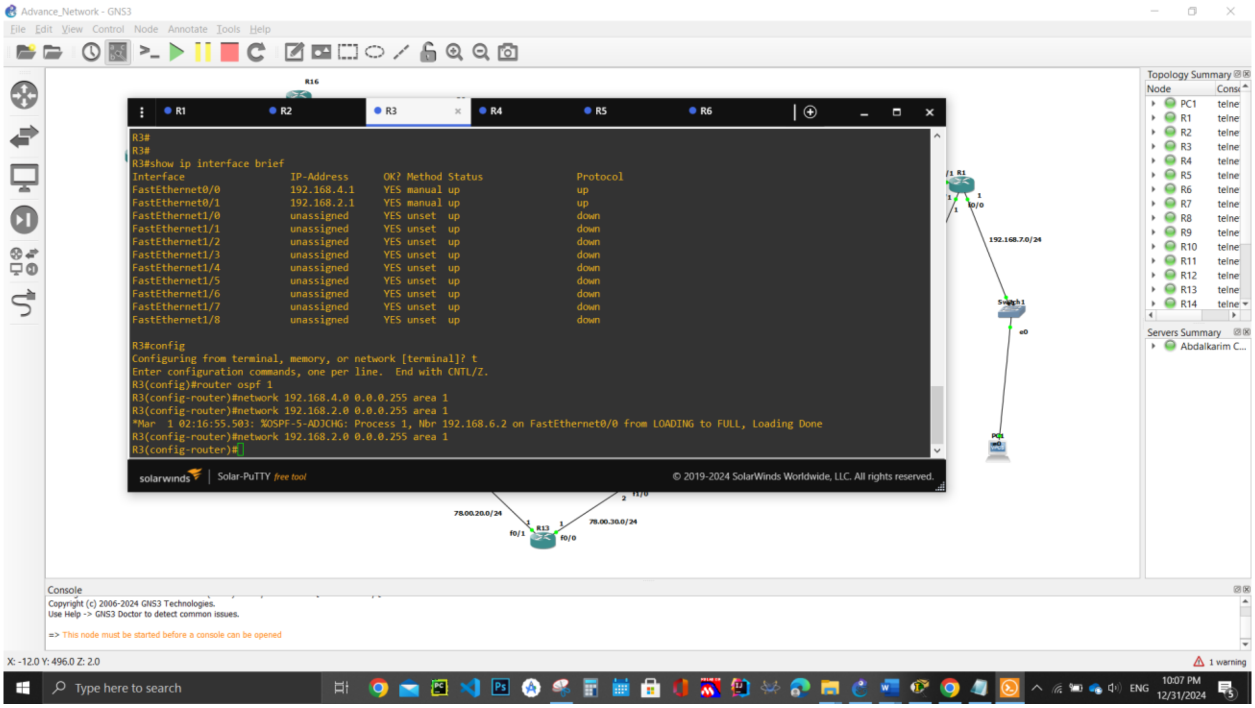

Figure 33: The OSPF Configuration on Router R3

Figure 34 shows the OSPF configuration on R4.

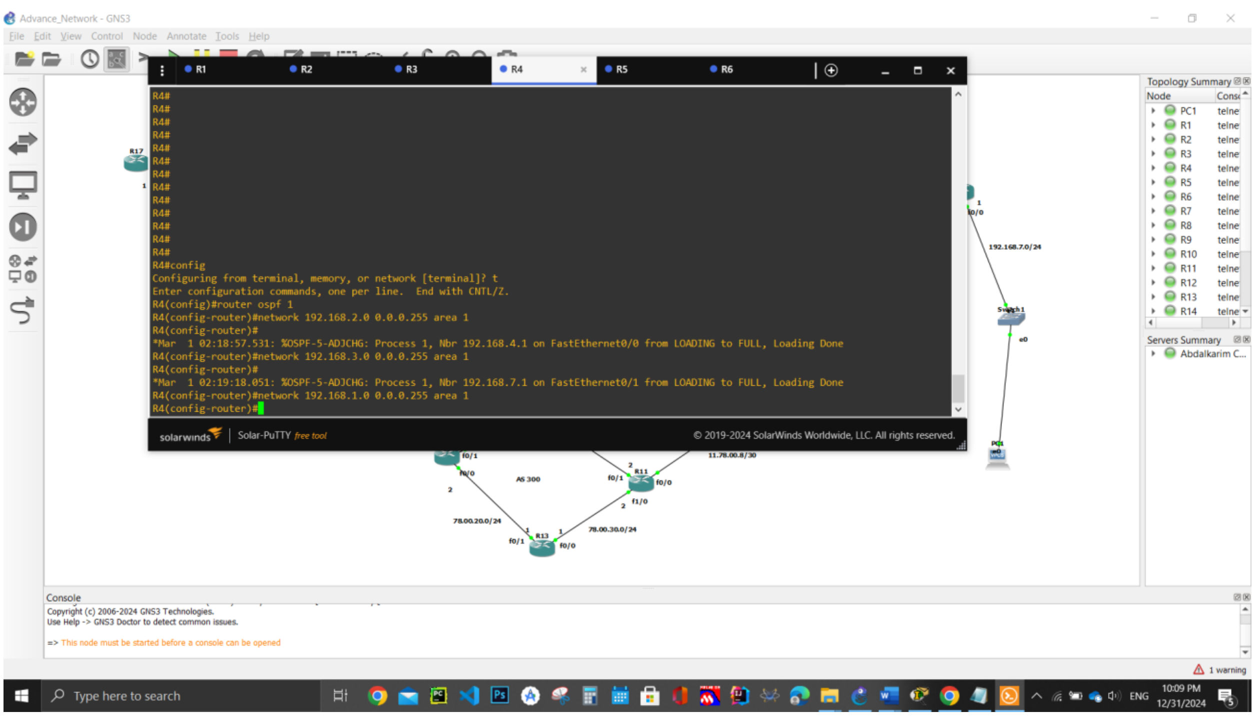

Figure 34: The OSPF Configuration on Router R4

Figure 35 shows the OSPF configuration on R5.

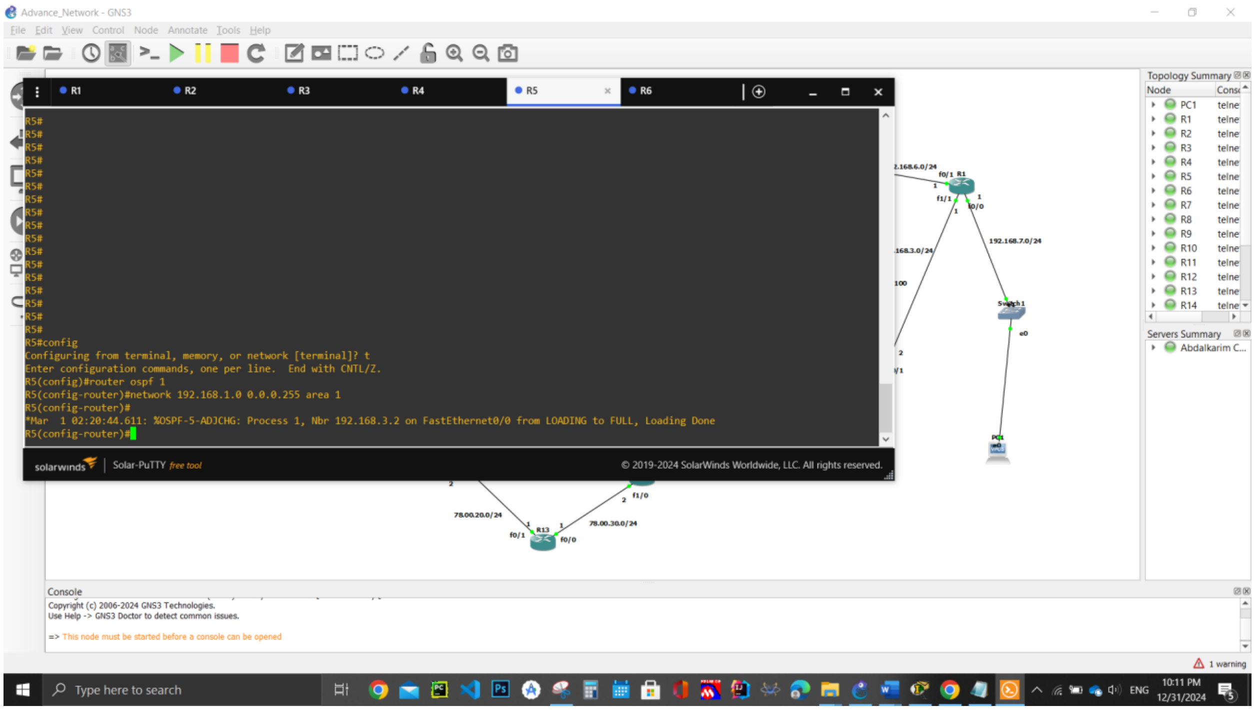

Figure 35: The OSPF Configuration on Router R5

Figure 36 shows the OSPF configuration on R6.

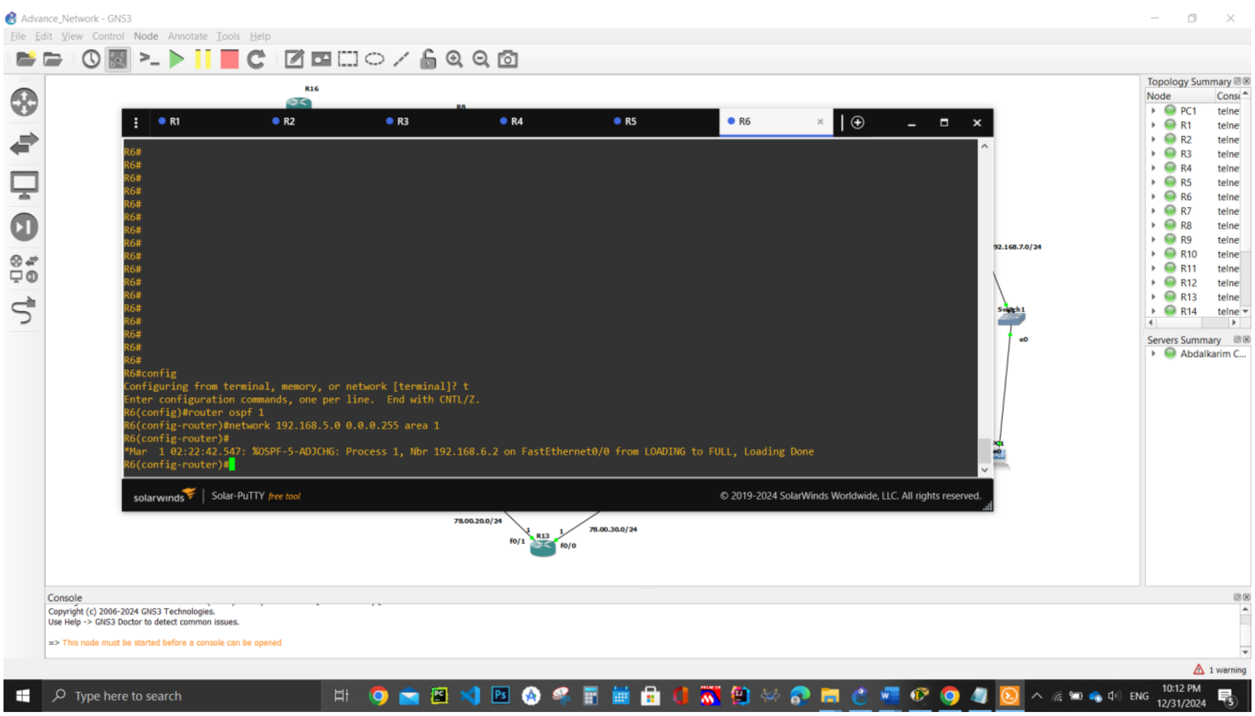

Figure 36: The OSPF Configuration on Router R6

As shown on figures (from Figure 31 to Figure 36), the OSPF protocol was configured on Routers R1, R2, R3, R4, R5 and R6 to enable dynamic routing across the network. Each router was set up under OSPF process 1, with specific network statements used to advertise its directly connected subnets within OSPF area 1. This configuration allows each router to form OSPF adjacencies with its neighbors, ensuring the exchange of routing information and synchronization of link-state databases. The hierarchical design and the use of OSPF ensure optimal path selection, loop-free routing and high network reliability even in the presence of link failures.

The following commands were used:

- show ip route: This command was used to display the routing table, which includes directly connected networks based on assigned IP addresses.
- write memory: This command was used to save the current running configuration to non-volatile memory (NVRAM) on a Cisco router. This ensures that the configuration was preserved after a reboot.
- write: This Command was used to save the configuration.
- show ip ospf: This command was used to check that the ospf configuration in a specific router.
- save: save command was used in PC to save the PC configuration.

6 BGP Configuration

6.1 eBGP Configuration

Figure 37 shows the eBGP configuration on router R12.

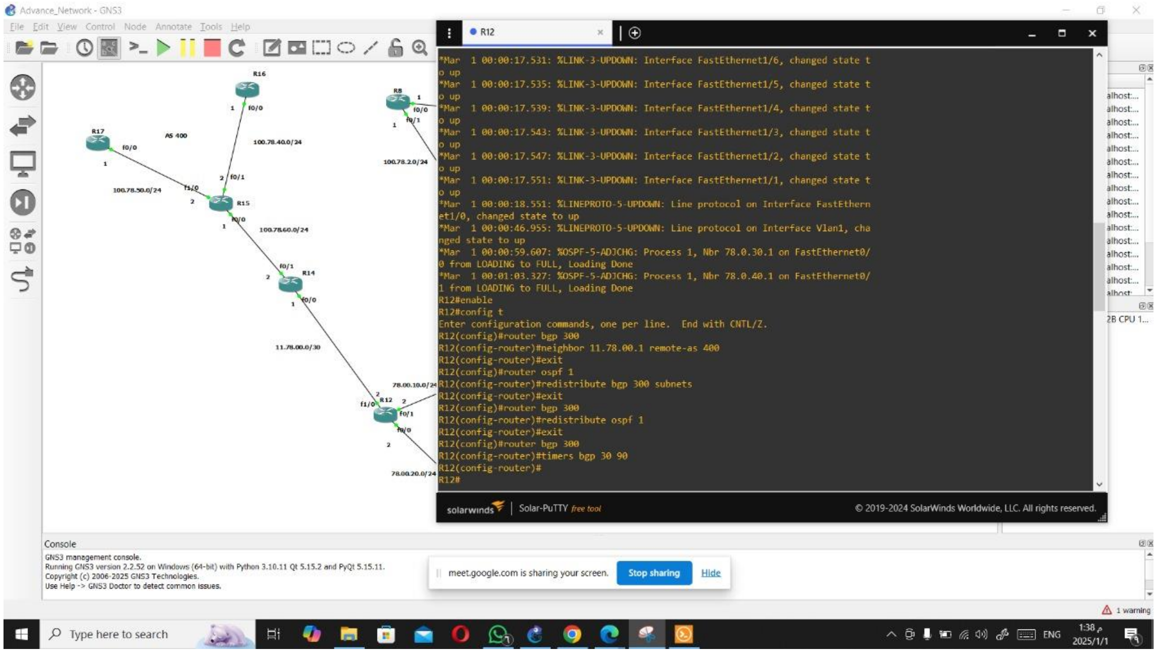

Figure 37: eBGP Configuration on Router R12

Figure 38 shows the eBGP configuration on router R10.

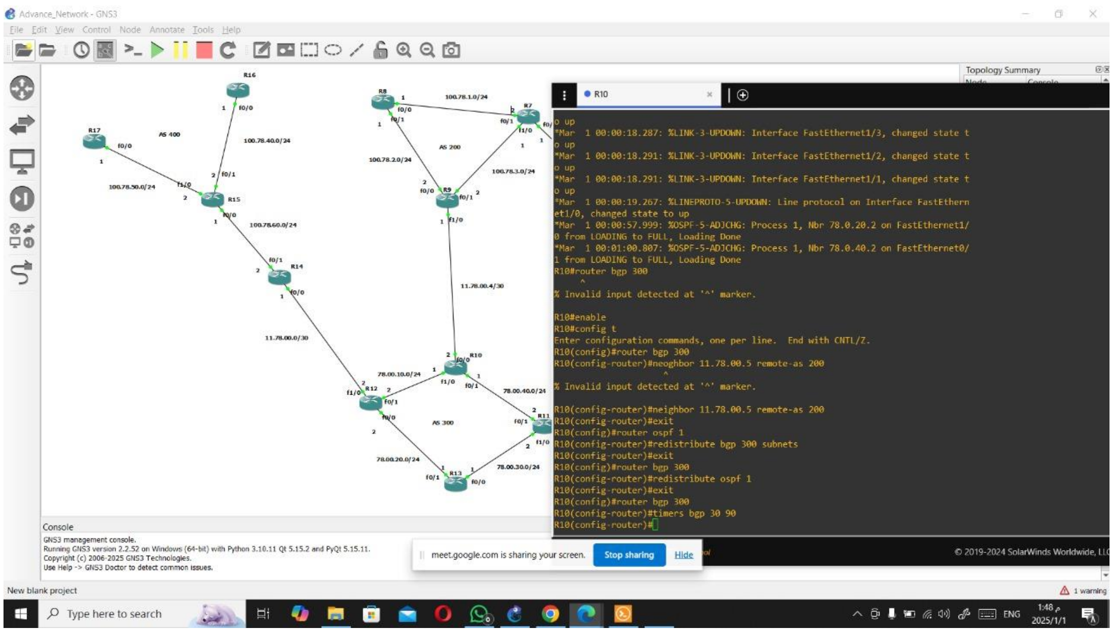

Figure 38: eBGP Configuration on Router R10

Figure 39 shows the eBGP configuration on router R11.

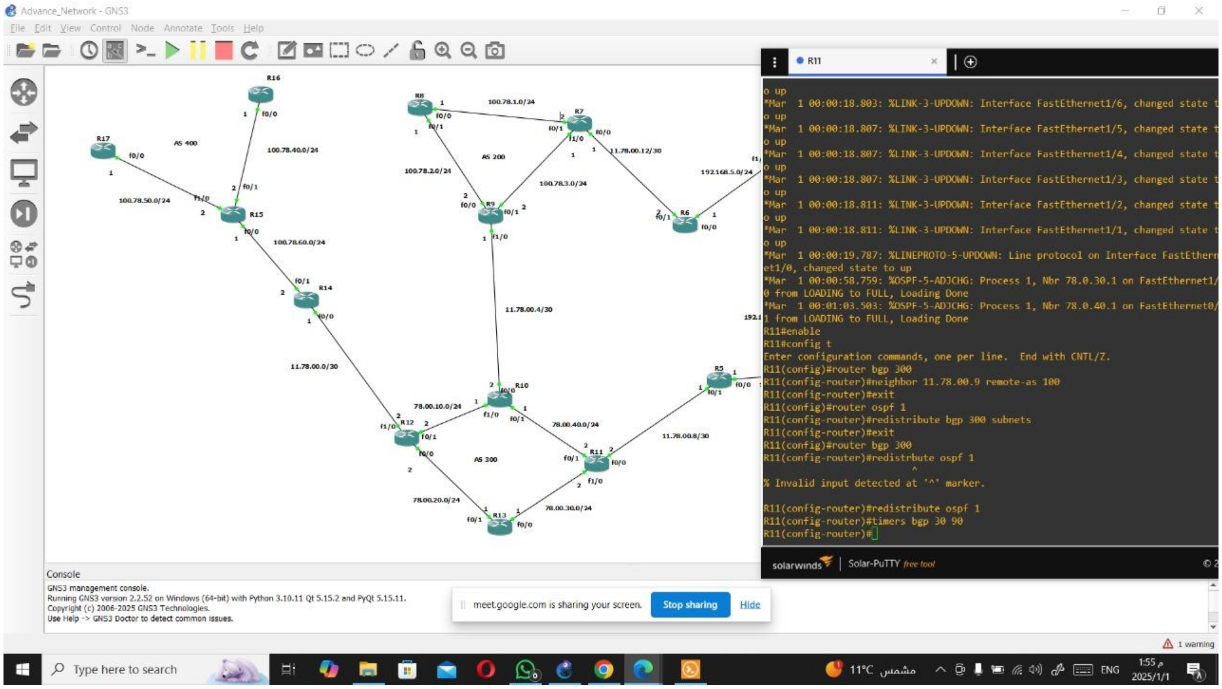

Figure 39: eBGP Configuration on Router R11

Figure 40 shows the eBGP configuration on router R5.

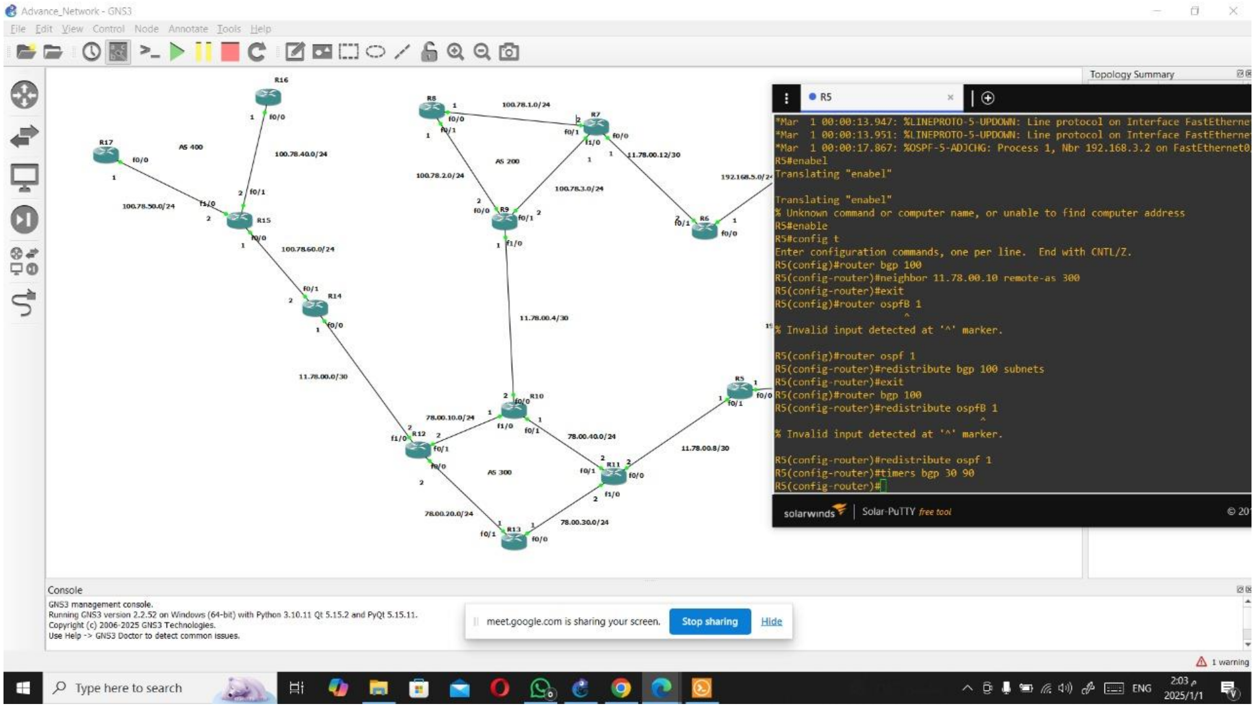

Figure 40: eBGP Configuration on Router R5

Figure 41 shows the eBGP configuration on router R6.

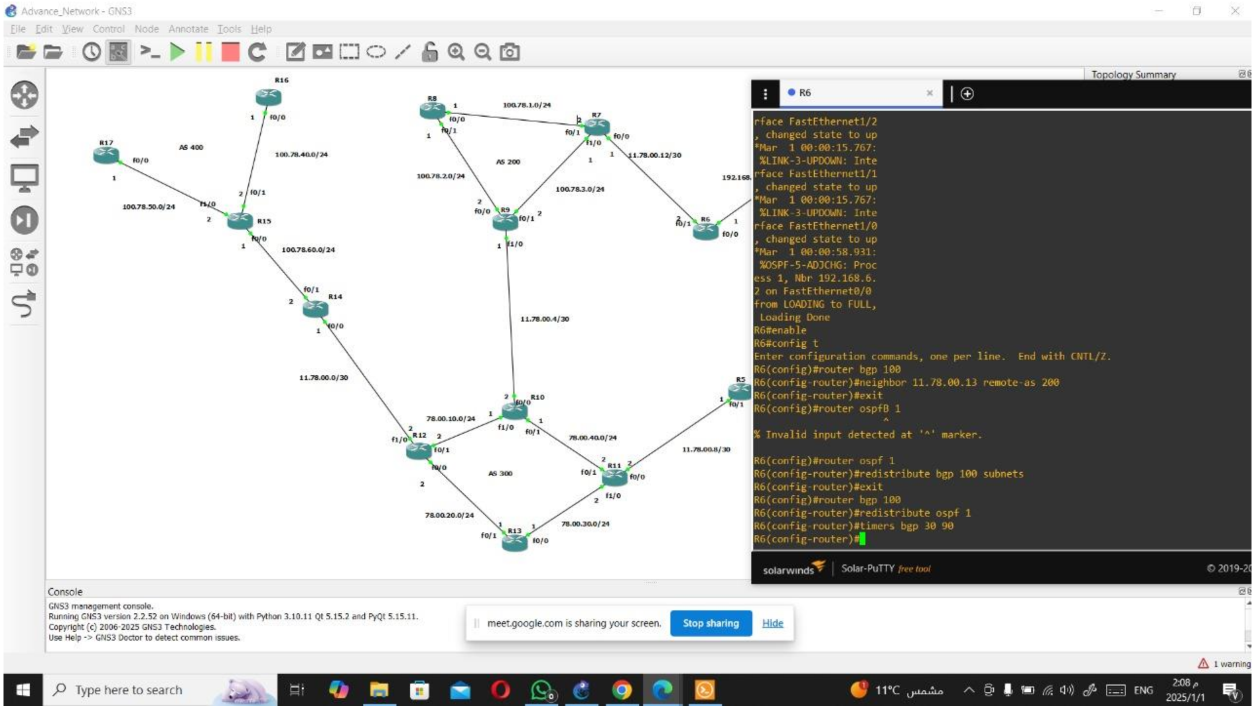

Figure 41: eBGP Configuration on Router R6

Figure 42 shows the eBGP configuration on router R14.

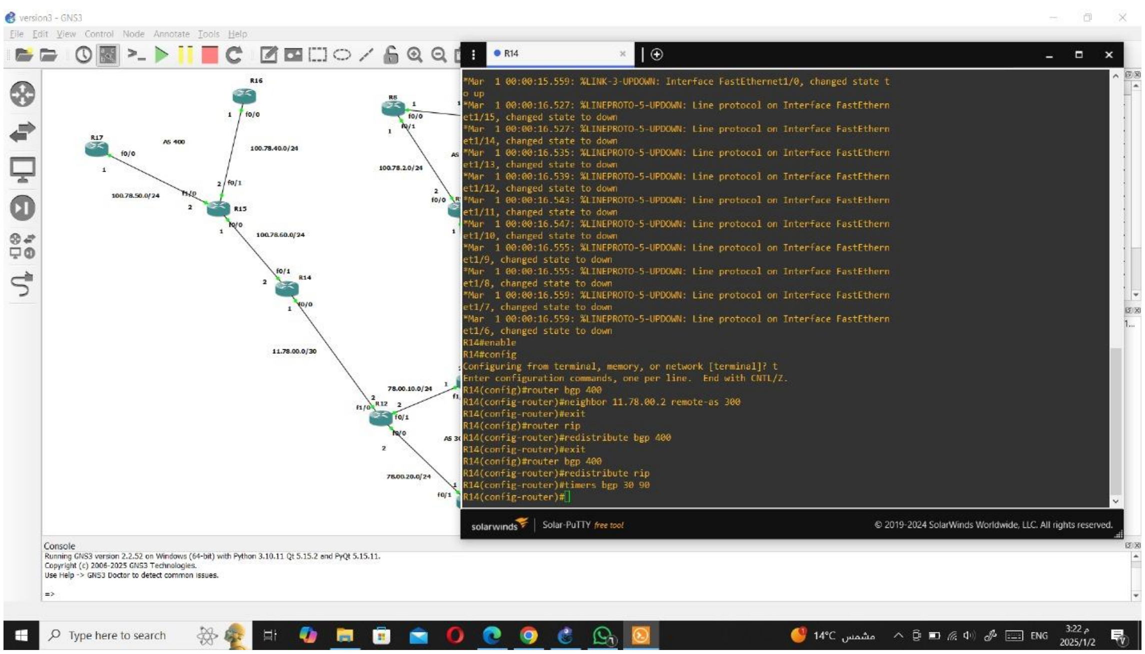

Figure 42: eBGP Configuration on Router R14

Figure 43 shows the eBGP configuration on router R9.

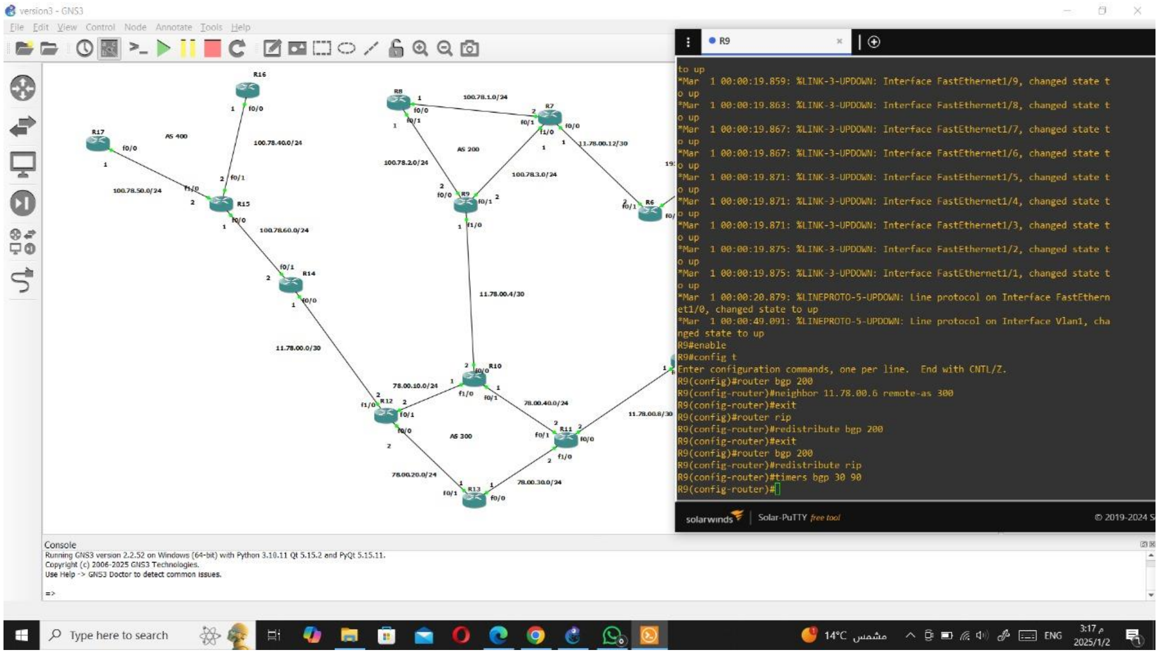

Figure 43: eBGP Configuration on Router R9

Figure 44 shows the eBGP configuration on router R7.

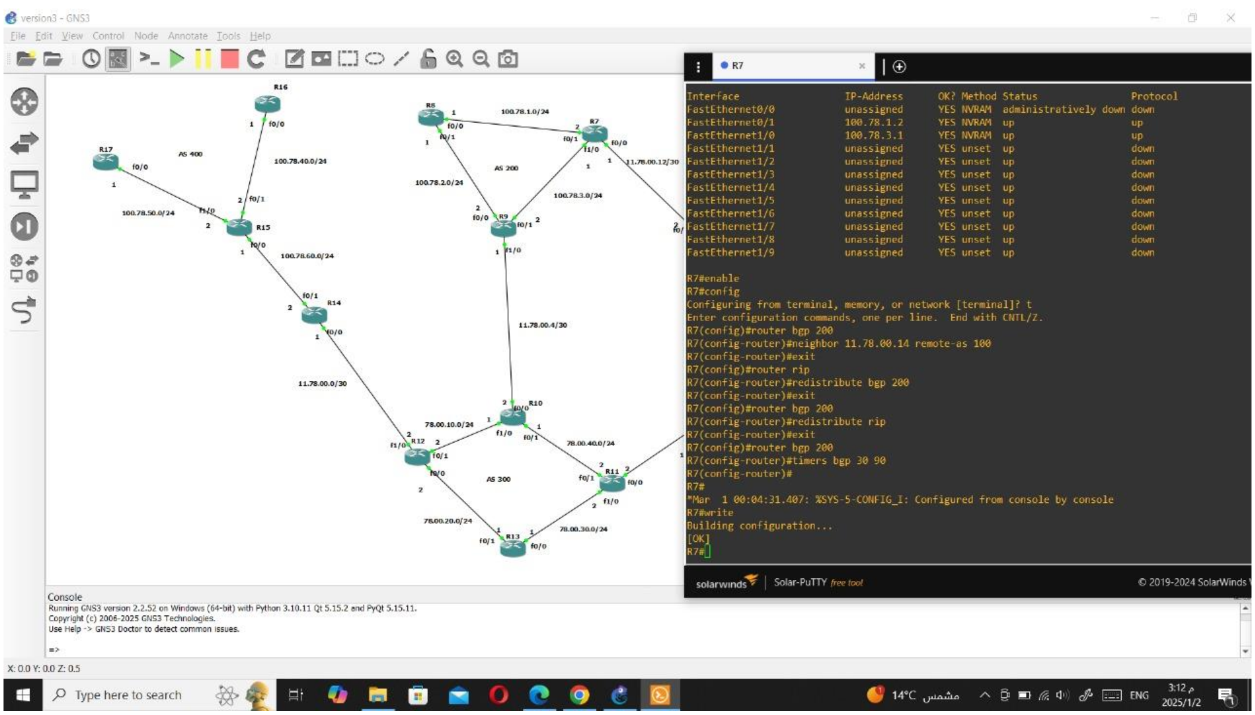

Figure 44: eBGP Configuration on Router R7

As shown on figures (from Figure 37 to Figure 44), eBGP was configured on Routers R12, R10, R11, R5, R6, R14, R9 and R7 with unique ASNs to enable external communication between autonomous systems. The neighbor command established eBGP sessions with directly connected peers, while the network command advertised local subnets into BGP. To ensure full connectivity, BGP routes were redistributed into OSPF and RIP using the redistribute bgp command, and OSPF and RIP routes were redistributed into BGP using the redistribute ospf and redistribute rip commands. Additionally, eBGP timers were configured using the timers bgp command to set the keepalive and hold times, with the smallest negotiated timer values being used between peers to maintain session stability. This integration ensured efficient and dynamic routing across the network while maintaining connectivity and reliability.

6.2 iBGP Configuration

Figure 45 shows the iBGP configuration on router R12.

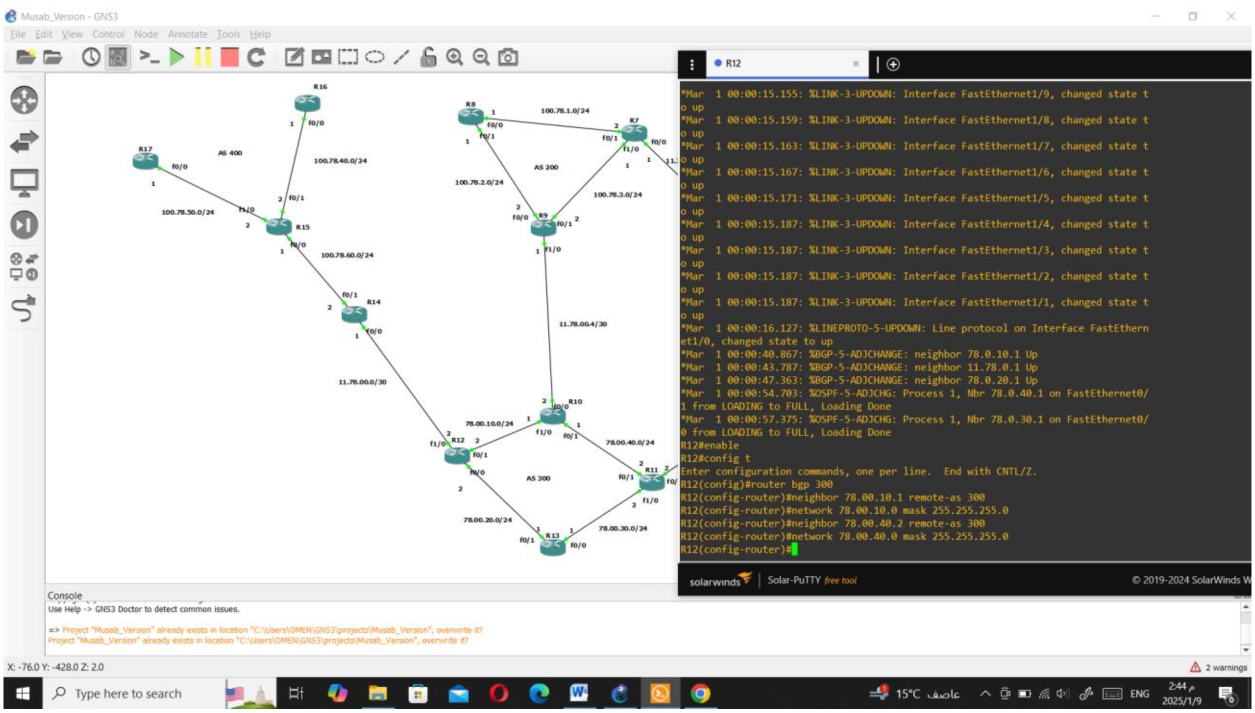

Figure 45: iBGP Configuration on Router R12

Figure 46 shows the iBGP configuration on router R11.

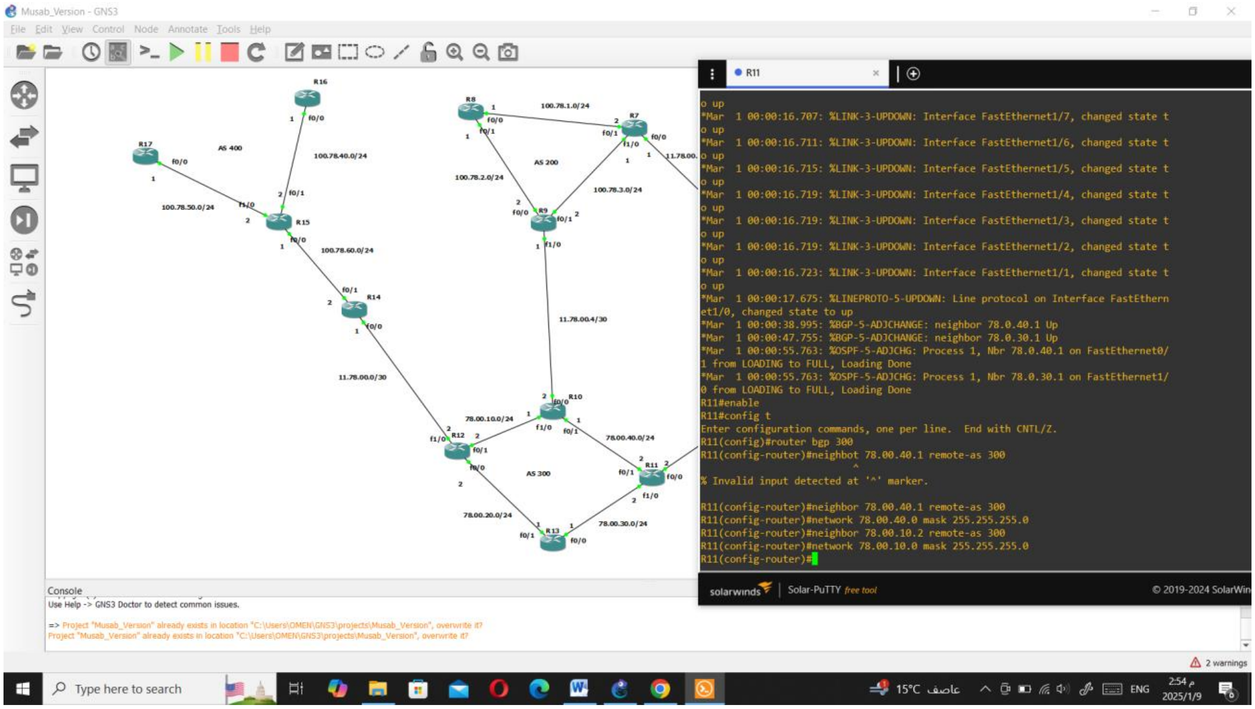

Figure 46: iBGP Configuration on Router R11

Figure 47 shows the iBGP configuration on router R10.

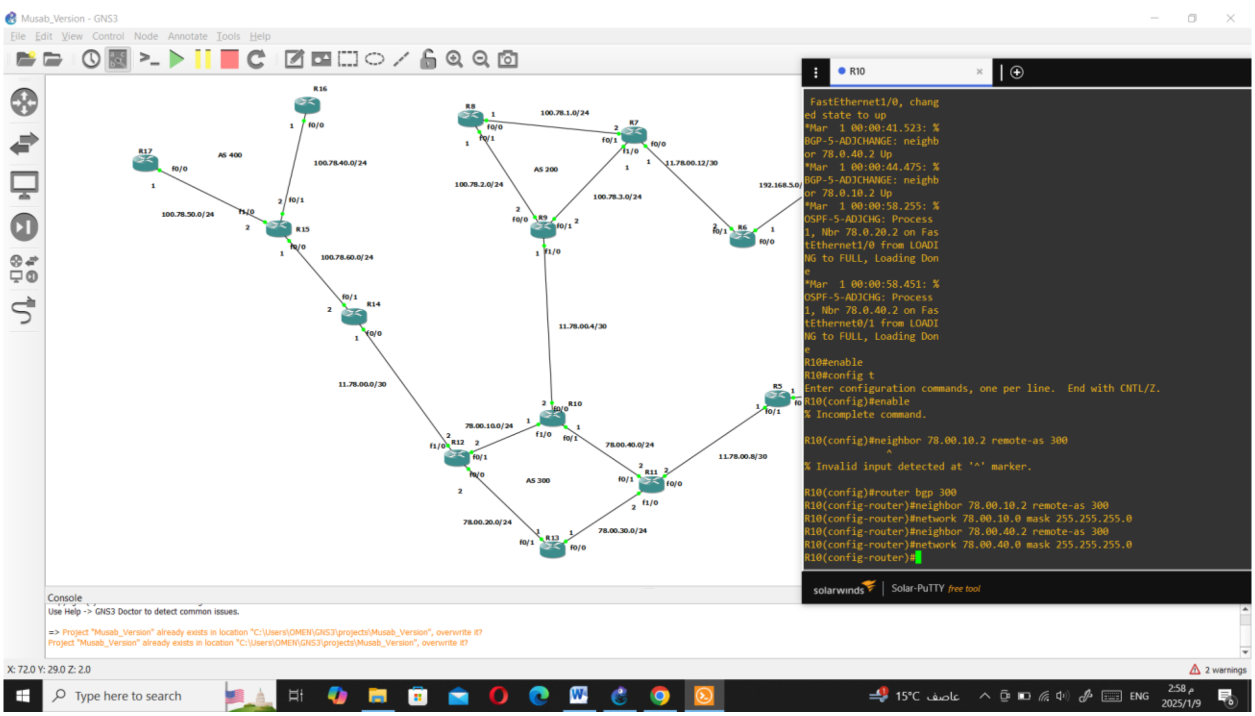

Figure 47: iBGP Configuration on Router R10

Figure 48 shows the iBGP configuration on router R7.

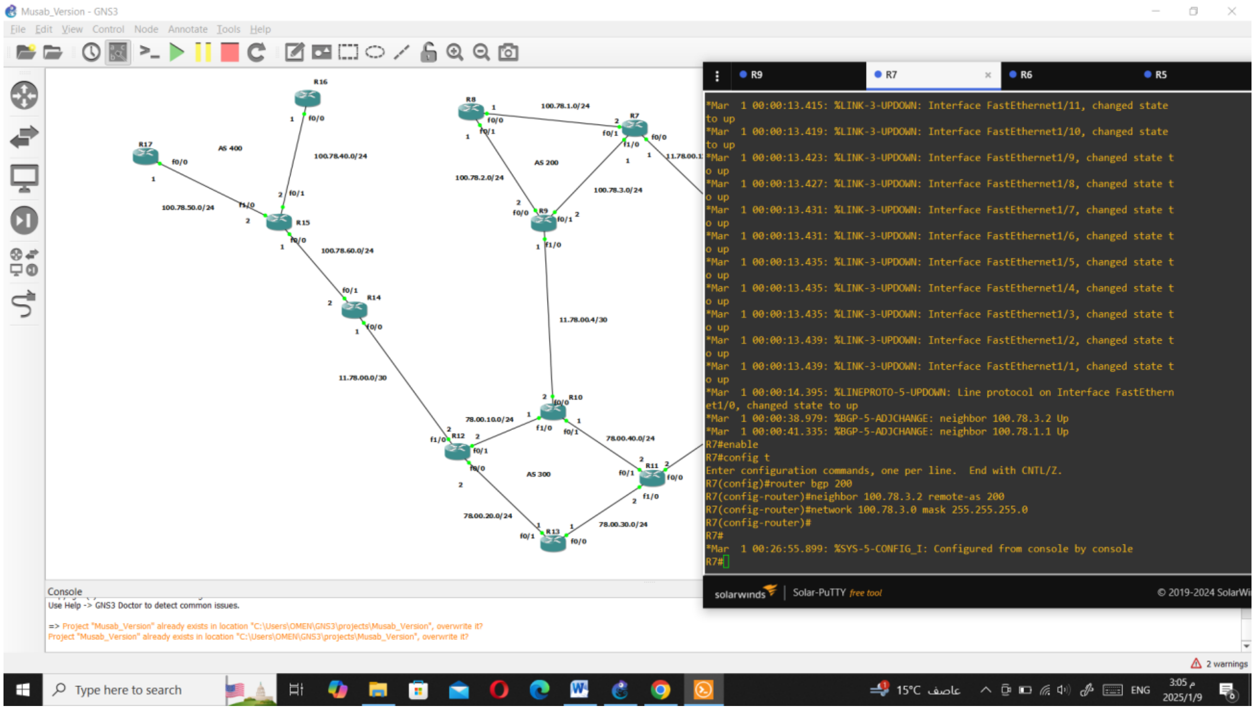

Figure 48: iBGP Configuration on Router R7

Figure 49 shows the iBGP configuration on router R9.

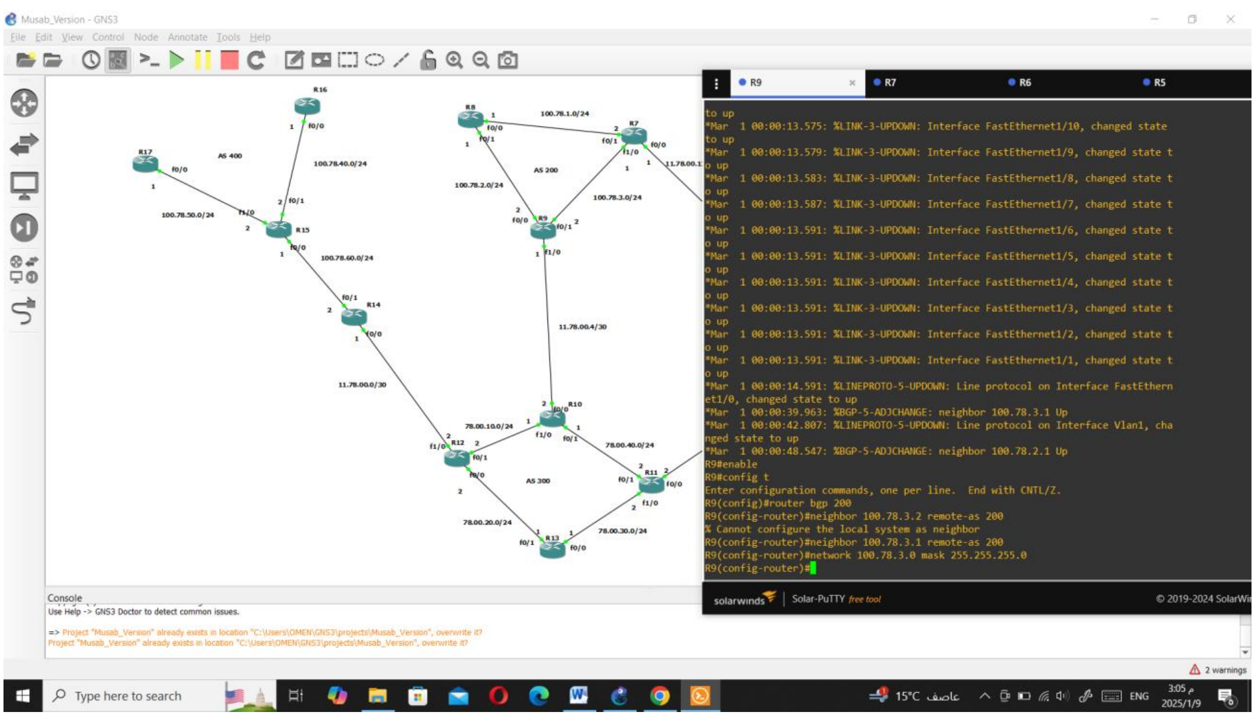

Figure 49: iBGP Configuration on Router R9

Figure 50 shows the iBGP configuration on router R5.

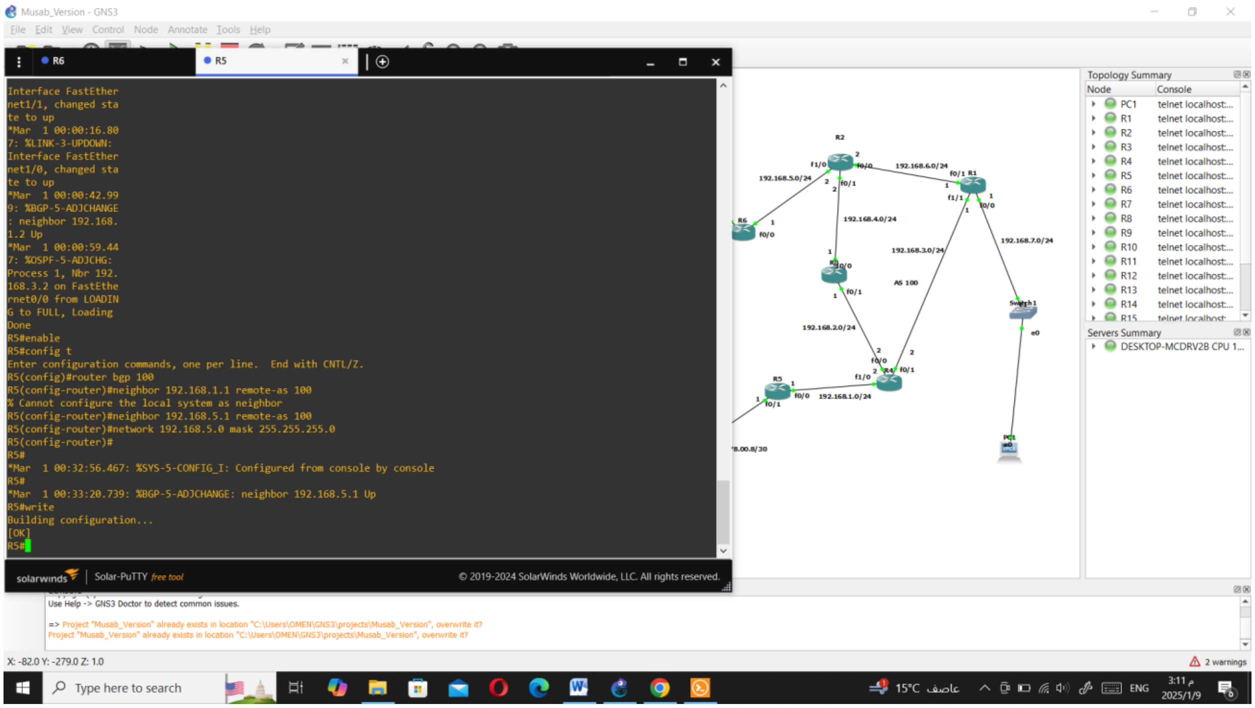

Figure 50: iBGP Configuration on Router R5

Figure 51 shows the iBGP configuration on router R6.

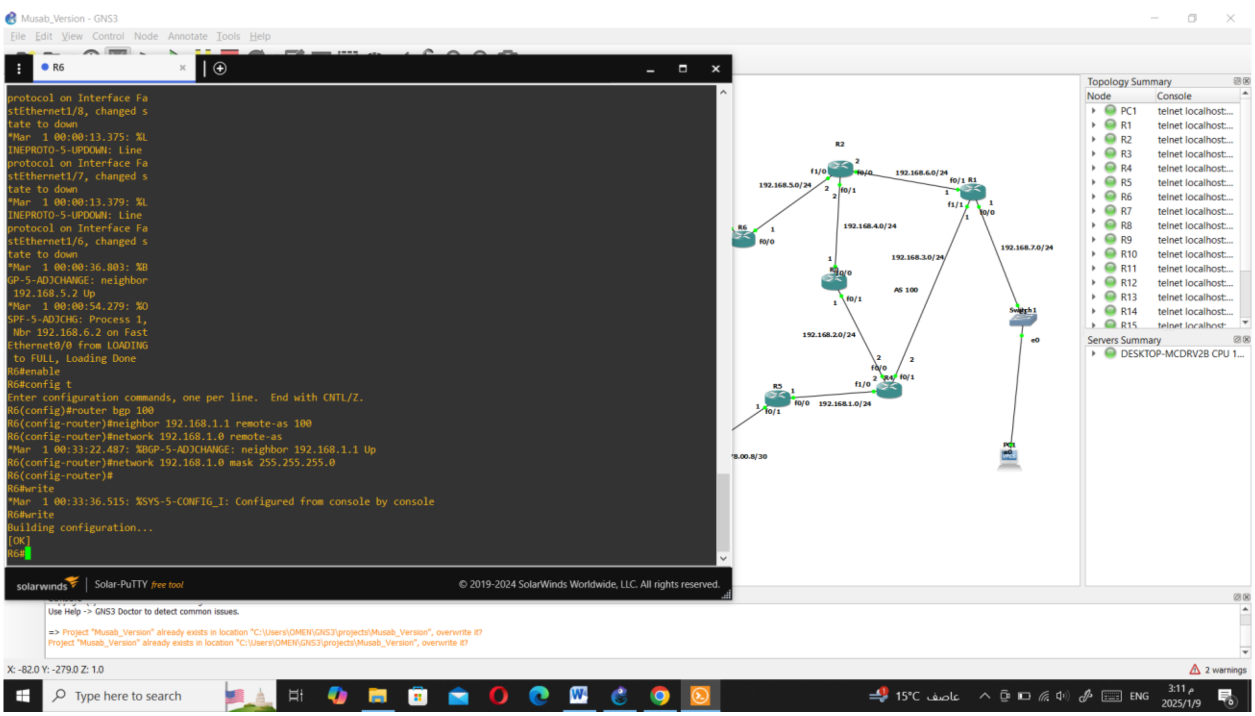

Figure 51: iBGP Configuration on Router R6

As shown on the figures (from Figure 45 to Figure 51), iBGP was configured on Routers within their autonomous systems to enable internal route exchange. The neighbor command established iBGP sessions using physical interface IPs directly, as loopback interfaces were not used. The next-hop-self command resolved next-hop reachability issues, while a full mesh topology was implemented using route reflection or confederation where necessary. IGPs like OSPF and RIP ensured physical interface reachability and routing consistency. This configuration provided efficient route dissemination and reliable internal connectivity.

7 Traffic Engineering

7.1 Influence Outbound Traffic Using Local Preference

Figure 52 shows the adjustment of the local preference value in the BGP configuration to influence outbound traffic. A higher value will prioritize the selected route, optimizing traffic flow within the network.

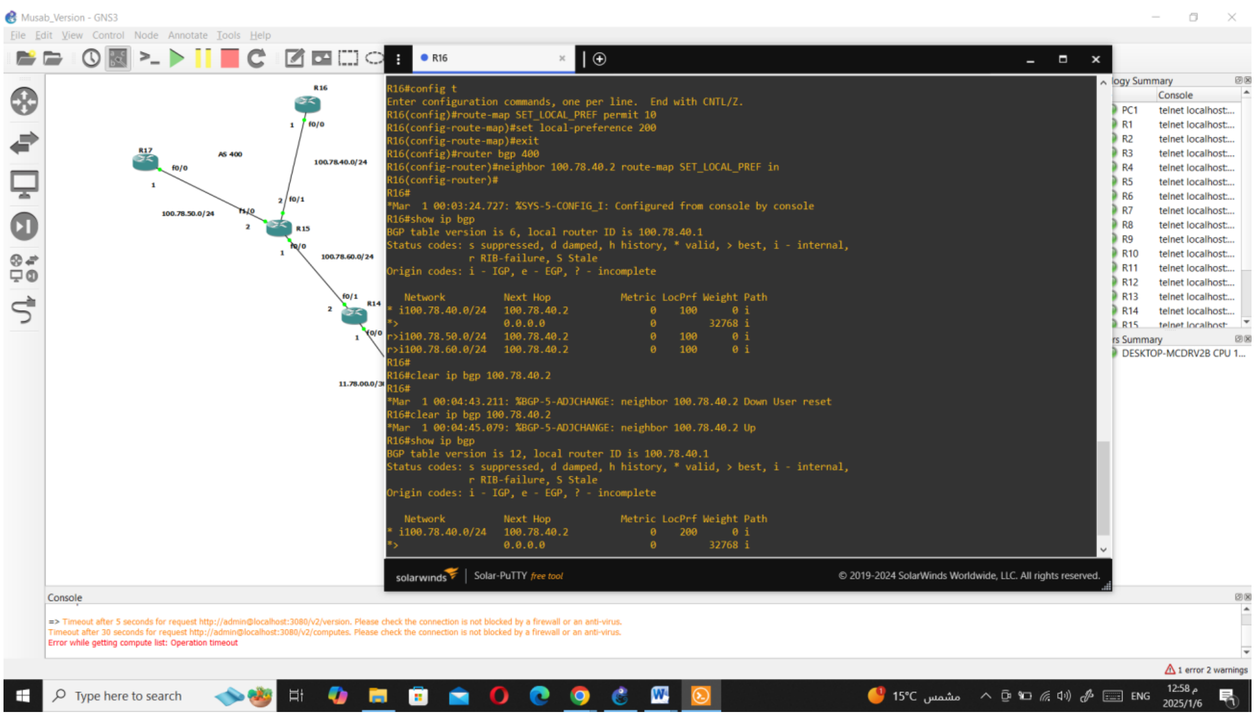

Figure 52: Influence Outbound Traffic Using Local Preference

7.2 Influence Inbound Traffic Using AS_PATH Prepending

Figure 53 shows that the AS_PATH prepending was applied to influence inbound traffic by increasing the length of the AS_PATH. This technique made the route less preferred, causing incoming traffic to be directed through alternative, more optimal paths.

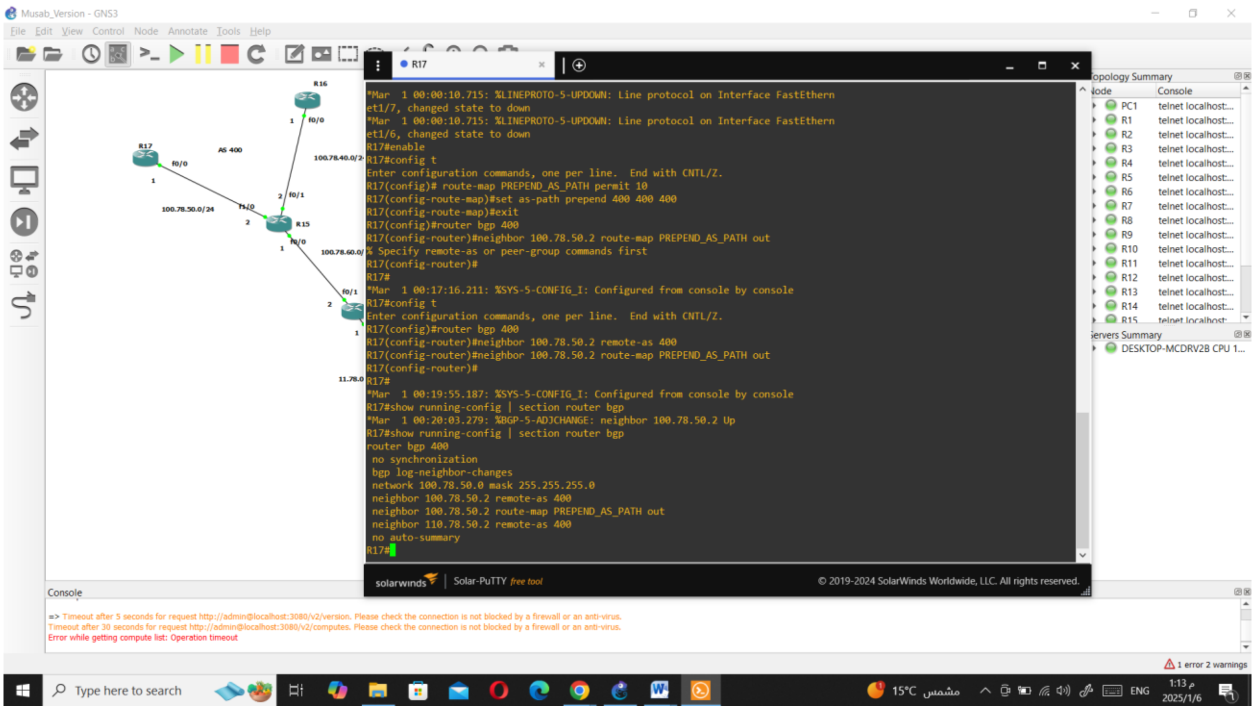

Figure 53: Influence Inbound Traffic Using AS_PATH Prepending

8 Routing Techniques

8.1 Route Filtering

Figure 54 shows how specific routes are filtered to control which paths are advertised or accepted in the network.

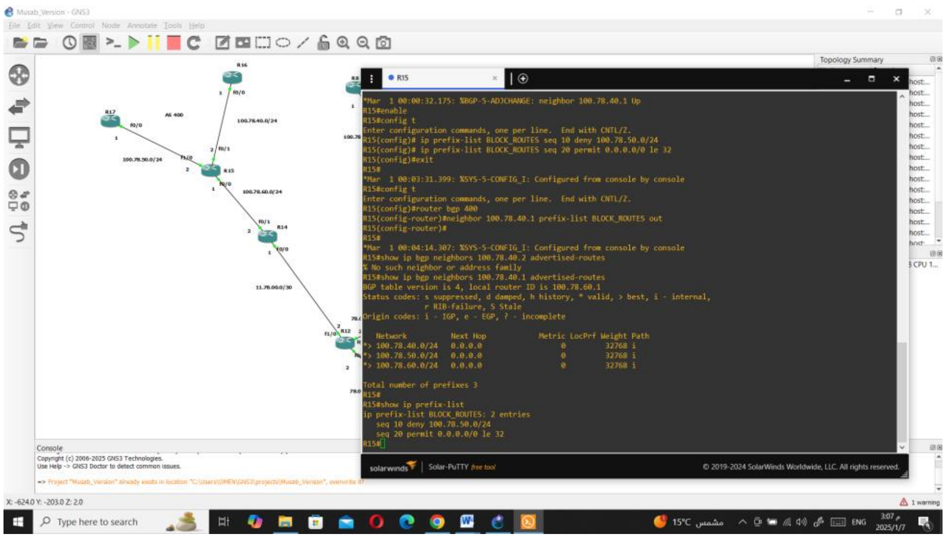

Figure 54: Route Filtering

8.2 Load Balance

Figure 55 demonstrates the distribution of traffic across multiple paths to ensure optimal resource usage and avoid congestion.

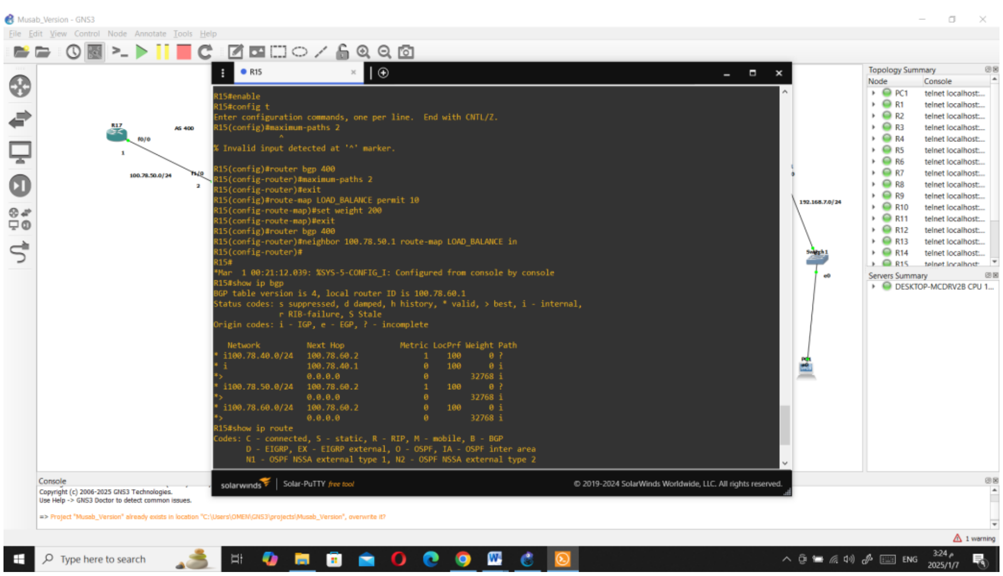

Figure 55: Load Balance

8.3 Policy-Based Routing

Figure 56 shows show traffic is routed based on defined policies, allowing for more control over specific traffic flows.

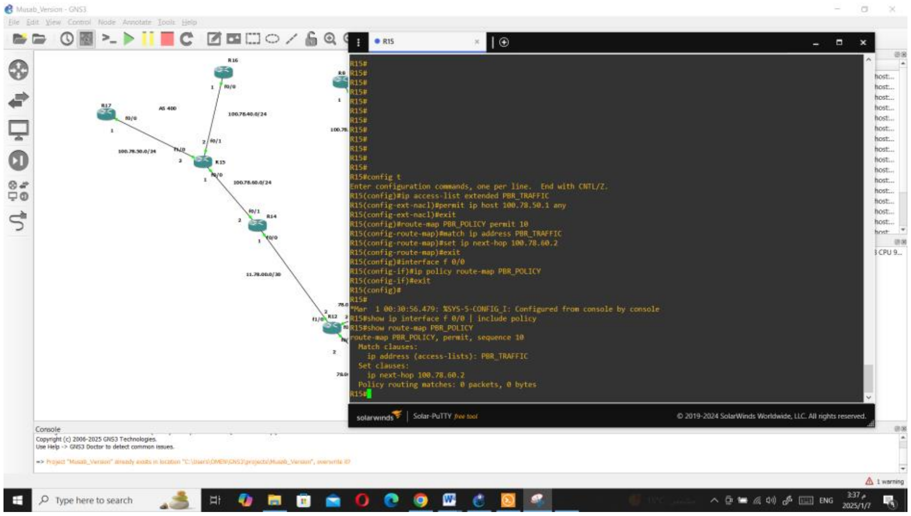

Figure 56: Policy-Based Routing

9 Ping Tests Between Different ASes and Within the Same AS

9.1 Ping in the same AS

Figure 57 shows the ping test within the same AS. It was done successfully, indicating that the network connectivity between devices in the same Autonomous System is stable and functioning as expected.

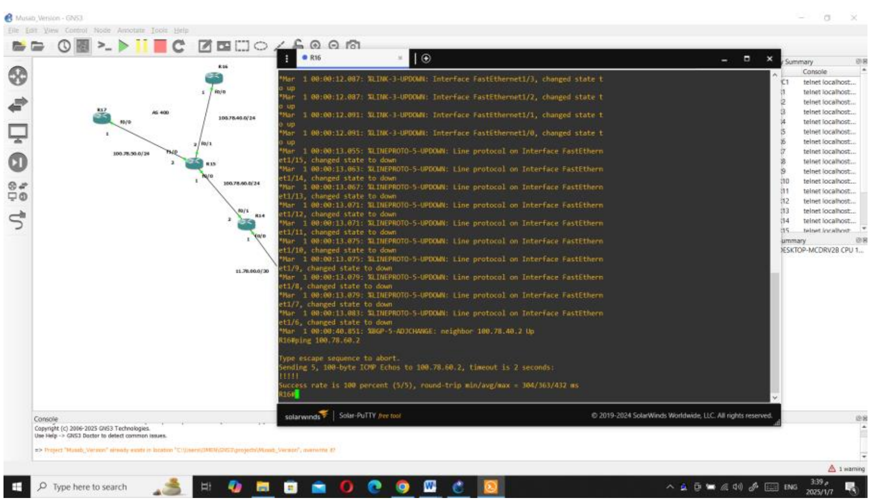

Figure 57: Ping in the Same AS

9.2 Ping between ASes

Figure 58 shows the ping test between ASes. It was done successfully, confirming proper inter-AS communication.

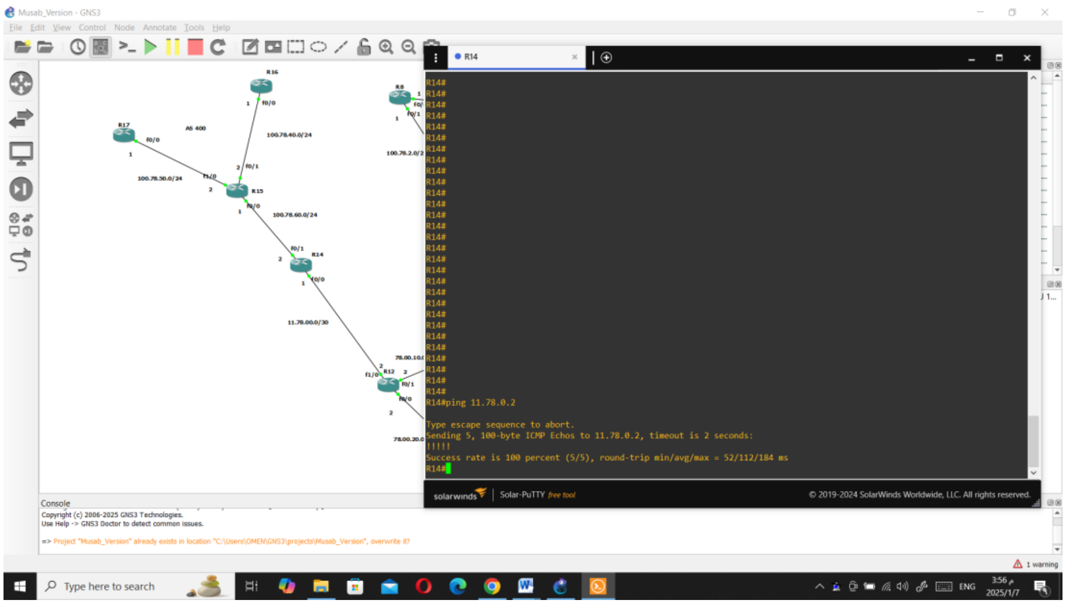

Figure 58: Ping between ASes

10 Conclusion

In conclusion, the implementation of various routing protocols, including OSPF and RIP, along with techniques like policy-based routing, load balancing, and route filtering, successfully optimized the network's performance and reliability. The ping tests, both within the same AS and between different ASes, confirmed stable connectivity and efficient routing. Address distribution strategies further enhanced network organization, ensuring seamless communication across different Autonomous Systems and within the same AS. These methods collectively contribute to a robust, scalable, and well-optimized network architecture.