Advanced Topics in Networking

Lab 3

Dynamic routing

Patryk Figiel

January 4, 2025

Contents

1. Goal of the lab

The goal of this lab is to configure a network with two ISP providers, ensuring full connectivity between all VPCs. This involves setting up dynamic routing protocols such as RIP v2 and OSPF, configuring NAT on routers that connect the VPCs, and verifying connectivity by performing pings. Additionally, the lab requires comparing the routing tables calculated using Dijkstra's algorithm with the results obtained in GNS3. Through this exercise, the lab demonstrates the practical implementation of routing and NAT techniques.

2. Preparations

In the preparations section, all the provided examples in the laboratory instructions were completed to gain practical knowledge of routing protocol configuration and operation. Additionally, a topology for RIP v2, OSPF, and BGP was configured to understand the functioning and differences of these protocols in practical scenarios.

3. The main task

3.1. Network Topology

The topology prepared for this laboratory is shown below:

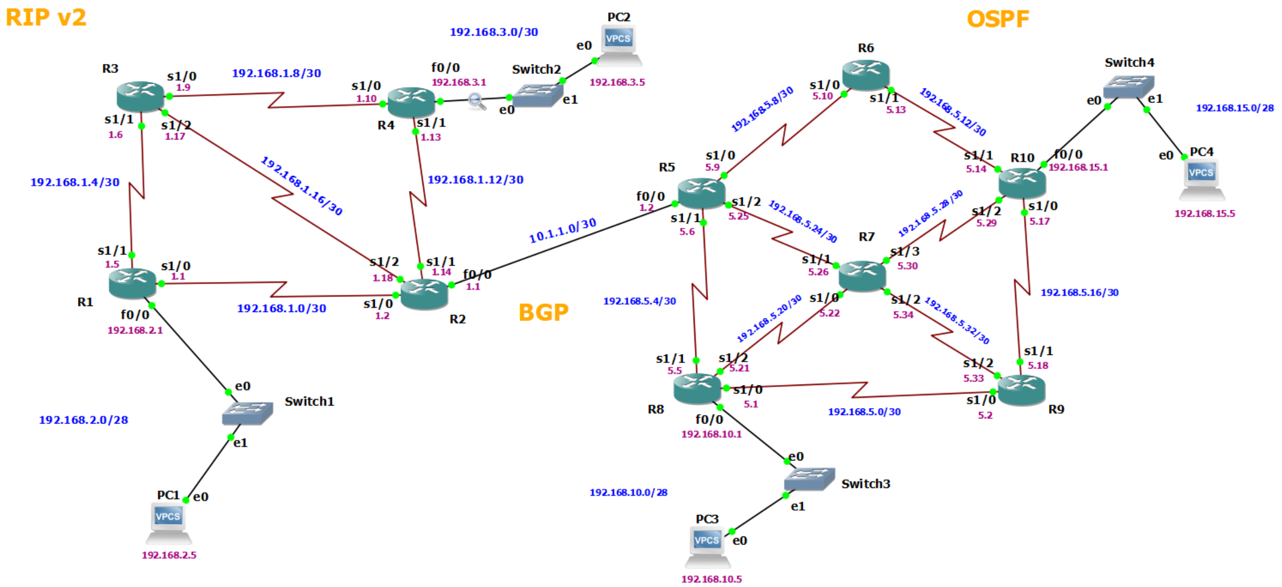


Figure 1. Network topology

3.2. IP allocation

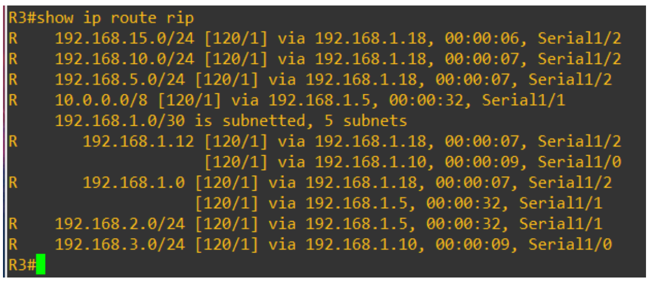
RIP v2 Network:
- 192.168.1.0/30 – between R1 and R2
- 192.168.1.4/30 – between R1 and R3
- 192.168.1.8/30 – between R3 and R4
- 192.168.1.12/30 – between R4 and R2
- 192.168.1.16/30 – between R3 and R2
- 192.168.2.0/28 – between R1 and PC1
- 192.168.3.0/28 – between R4 and PC2

BGP Network:
- 10.1.1.0/30 – between R2 and R5

OSPF Network:
- 192.168.5.0/30 – between R8 and R9
- 192.168.5.4/30 – between R8 and R5
- 192.168.5.8/30 – between R5 and R6
- 192.168.5.12/30 – between R6 and R10
- 192.168.5.16/30 – between R10 and R9
- 192.168.5.20/30 – between R8 and R7
- 192.168.5.24/30 – between R5 and R7
- 192.168.5.28/30 – between R7 and R10
- 192.168.5.32/30 – between R7 and R9
- 192.168.10.0/28 – between R8 and PC3
- 192.168.15.0/28 – between R10 and PC4

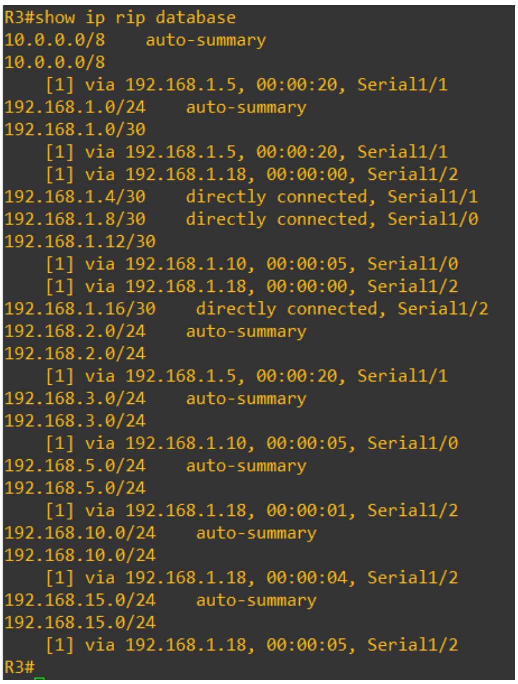
3.3. RIP protocol

The RIP v2 protocol was configured on all routers in the left section of the network topology. To set up RIP on the routers, network addresses were added using the appropriate commands, such as **network** [**network address**], and RIP v2 was enabled with the **version 2** command. The configuration was applied to each router, ensuring they could exchange routing information. Below are the RIP routing tables and the RIP database as viewed from the R3 router, reflecting the successful configuration and routing information exchanged among the routers.



```
R3#show ip route rip
R    192.168.15.0/24 [120/1] via 192.168.1.18, 00:00:06, Serial1/2
R    192.168.10.0/24 [120/1] via 192.168.1.18, 00:00:07, Serial1/2
R    192.168.5.0/24 [120/1] via 192.168.1.18, 00:00:07, Serial1/2
R    10.0.0.0/8 [120/1] via 192.168.1.5, 00:00:32, Serial1/1
     192.168.1.0/30 is subnetted, 5 subnets
R       192.168.1.12 [120/1] via 192.168.1.18, 00:00:07, Serial1/2
                     [120/1] via 192.168.1.10, 00:00:09, Serial1/0
R       192.168.1.0 [120/1] via 192.168.1.18, 00:00:07, Serial1/2
                    [120/1] via 192.168.1.5, 00:00:32, Serial1/1
R    192.168.2.0/24 [120/1] via 192.168.1.5, 00:00:32, Serial1/1
R    192.168.3.0/24 [120/1] via 192.168.1.10, 00:00:09, Serial1/0
R3#
```

Figure 2. IP routes



```
R3#show ip rip database
10.0.0.0/8    auto-summary
10.0.0.0/8
    [1] via 192.168.1.5, 00:00:20, Serial1/1
192.168.1.0/24    auto-summary
192.168.1.0/30
    [1] via 192.168.1.5, 00:00:20, Serial1/1
    [1] via 192.168.1.18, 00:00:00, Serial1/2
192.168.1.4/30    directly connected, Serial1/1
192.168.1.8/30    directly connected, Serial1/0
192.168.1.12/30
    [1] via 192.168.1.10, 00:00:05, Serial1/0
    [1] via 192.168.1.18, 00:00:00, Serial1/2
192.168.1.16/30    directly connected, Serial1/2
192.168.2.0/24    auto-summary
192.168.2.0/24
    [1] via 192.168.1.5, 00:00:20, Serial1/1
192.168.3.0/24    auto-summary
192.168.3.0/24
    [1] via 192.168.1.10, 00:00:05, Serial1/0
192.168.5.0/24    auto-summary
192.168.5.0/24
    [1] via 192.168.1.18, 00:00:01, Serial1/2
192.168.10.0/24    auto-summary
192.168.10.0/24
    [1] via 192.168.1.18, 00:00:04, Serial1/2
192.168.15.0/24    auto-summary
192.168.15.0/24
    [1] via 192.168.1.18, 00:00:05, Serial1/2
R3#
```

Figure 3. RIP database

In Wireshark set between R3 and R4, RIP v2 packets are visible between routers R3 (192.168.1.9) and R4 (192.168.1.10), with the destination set to the multicast address 224.0.0.9. This address is used by RIP v2 to exchange routing information between routers in the network, allowing R3 and R4 to share their routing tables. The packets contain routing updates, including network addresses, subnet masks, and metric information, as presented below:

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 268, returned sequence 246
2	0.288373	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 247, returned sequence 268
3	5.670034	N/A	N/A	CDP	321	Device ID: R4 Port ID: Serial1/0
4	10.557052	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 269, returned sequence 247
5	16.862793	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 248, returned sequence 269
6	19.221182	192.168.1.9	224.0.0.9	RIPv2	196	Response
7	20.951553	192.168.1.10	224.0.0.9	RIPv2	156	Response
8	20.988953	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 270, returned sequence 248
9	31.383841	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 271, returned sequence 248
10	34.030721	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 249, returned sequence 271
11	34.383010	N/A	N/A	CDP	321	Device ID: R3 Port ID: Serial1/0
12	41.519327	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 272, returned sequence 249
13	48.579045	192.168.1.9	224.0.0.9	RIPv2	196	Response
14	50.723307	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 250, returned sequence 272
15	50.905844	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 273, returned sequence 250
16	61.037732	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 274, returned sequence 250
17	64.183144	192.168.1.10	224.0.0.9	RIPv2	156	Response

Figure 4. Wireshark capturing packets

Finally, ping tests were executed to ensure that RIP protocol works correctly and hosts are reachable:

```
PC1> show ip

NAME        : PC1[1]
IP/MASK     : 192.168.2.5/28
GATEWAY     : 192.168.2.1
DNS         :
MAC         : 00:50:79:66:68:00
LPORT       : 20116
RHOST:PORT  : 127.0.0.1:20117
MTU         : 1500

PC1> ping 192.168.3.5

84 bytes from 192.168.3.5 icmp_seq=1 ttl=61 time=563.651 ms
84 bytes from 192.168.3.5 icmp_seq=2 ttl=61 time=206.297 ms
84 bytes from 192.168.3.5 icmp_seq=3 ttl=61 time=344.222 ms
84 bytes from 192.168.3.5 icmp_seq=4 ttl=61 time=216.602 ms
84 bytes from 192.168.3.5 icmp_seq=5 ttl=61 time=200.138 ms
```

Figure 5. Ping test from PC1 to PC2

3.4. OSPF protocol

The OSPF protocol was configured on all routers in the right section of the network topology. To set up OSPF, the OSPF process was initiated using the command **router ospf [process ID]**, and network addresses were assigned to OSPF areas using the **network [network address] [wildcard mask] area [area ID]** command. OSPF was enabled on each router, allowing them to exchange routing information. Below are the outputs of the **show ip ospf database** and **show ip route ospf** commands on router R6, reflecting the successful configuration and OSPF route exchange between the routers:

```
R6#show ip route ospf
     192.168.15.0/28 is subnetted, 1 subnets
O       192.168.15.0 [110/65] via 192.168.5.14, 00:56:39, Serial1/1
     192.168.10.0/28 is subnetted, 1 subnets
O       192.168.10.0 [110/129] via 192.168.5.9, 00:56:39, Serial1/0
     192.168.5.0/30 is subnetted, 9 subnets
O       192.168.5.32 [110/192] via 192.168.5.14, 00:56:39, Serial1/1
                     [110/192] via 192.168.5.9, 00:56:39, Serial1/0
O       192.168.5.4 [110/128] via 192.168.5.9, 00:56:39, Serial1/0
O       192.168.5.0 [110/192] via 192.168.5.14, 00:56:39, Serial1/1
                    [110/192] via 192.168.5.9, 00:56:39, Serial1/0
O       192.168.5.28 [110/128] via 192.168.5.14, 00:56:39, Serial1/1
O       192.168.5.24 [110/128] via 192.168.5.9, 00:56:39, Serial1/0
O       192.168.5.20 [110/192] via 192.168.5.14, 00:56:39, Serial1/1
                     [110/192] via 192.168.5.9, 00:56:39, Serial1/0
O       192.168.5.16 [110/128] via 192.168.5.14, 00:56:39, Serial1/1
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O E2    10.1.1.0/30 [110/1] via 192.168.5.9, 00:56:39, Serial1/0
O E2    10.0.0.0/8 [110/1] via 192.168.5.9, 00:56:39, Serial1/0
     192.168.1.0/30 is subnetted, 5 subnets
O E2    192.168.1.8 [110/1] via 192.168.5.9, 00:56:39, Serial1/0
O E2    192.168.1.12 [110/1] via 192.168.5.9, 00:56:39, Serial1/0
O E2    192.168.1.0 [110/1] via 192.168.5.9, 00:56:39, Serial1/0
O E2    192.168.1.4 [110/1] via 192.168.5.9, 00:56:39, Serial1/0
O E2    192.168.1.16 [110/1] via 192.168.5.9, 00:56:40, Serial1/0
O E2 192.168.2.0/24 [110/1] via 192.168.5.9, 00:56:41, Serial1/0
O E2 192.168.3.0/24 [110/1] via 192.168.5.9, 00:56:41, Serial1/0
R6#
```

Figure 6. IP routes

```
R6#show ip ospf summary

OSPF Process 10, Summary-address

    Not configured
R6#show ip ospf database

            OSPF Router with ID (192.168.5.13) (Process ID 10)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
192.168.5.13    192.168.5.13    1643        0x80000003 0x001D10 4
192.168.5.25    192.168.5.25    1715        0x80000005 0x00F601 6
192.168.5.33    192.168.5.33    1739        0x80000002 0x00FFD5 6
192.168.5.34    192.168.5.34    1682        0x80000003 0x005F01 8
192.168.10.1    192.168.10.1    1792        0x80000005 0x009FFC 7
192.168.15.1    192.168.15.1    1531        0x80000003 0x000357 7

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
10.0.0.0        192.168.5.25    1715        0x80000002 0x002F0A 65001
10.1.1.0        192.168.5.25    1715        0x80000002 0x00B56C 0
192.168.1.0     192.168.5.25    1715        0x80000002 0x00E2F8 65001
192.168.1.4     192.168.5.25    1715        0x80000002 0x00BA1D 65001
192.168.1.8     192.168.5.25    1715        0x80000002 0x009241 65001
192.168.1.12    192.168.5.25    1715        0x80000002 0x006A65 65001
192.168.1.16    192.168.5.25    1715        0x80000002 0x004289 65001
192.168.2.0     192.168.5.25    1715        0x80000002 0x00E9ED 65001
192.168.3.0     192.168.5.25    1716        0x80000002 0x00DEF7 65001
```

Figure 7. OSPF database

In Wireshark, OSPF packets can be observed between routers R5 (192.168.5.9) and R6 (192.168.5.10), typically using multicast address 224.0.0.5 for OSPF Hello packets. These Hello packets are exchanged between the routers to establish and maintain neighbor relationships. The packets contain OSPF Hello protocol data, such as router IDs, network masks, and the OSPF state, ensuring that both routers can successfully form an OSPF adjacency and exchange routing information, as seen below:

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 376, returned sequence 404
2	3.866994	192.168.5.10	224.0.0.5	OSPF	84	Hello Packet
3	4.107194	192.168.5.9	224.0.0.5	OSPF	84	Hello Packet
4	4.925572	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 405, returned sequence 376
5	9.995550	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 377, returned sequence 405
6	11.731155	192.168.5.9	224.0.0.5	OSPF	84	Hello Packet
7	13.131350	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 406, returned sequence 377
8	14.002933	192.168.5.10	224.0.0.5	OSPF	84	Hello Packet
9	20.472827	192.168.5.9	224.0.0.5	OSPF	84	Hello Packet
10	21.183831	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 378, returned sequence 406
11	22.835513	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 407, returned sequence 378
12	24.265042	192.168.5.10	224.0.0.5	OSPF	84	Hello Packet
13	30.406581	192.168.5.9	224.0.0.5	OSPF	84	Hello Packet
14	31.506798	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 379, returned sequence 407
15	32.331759	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 408, returned sequence 379
16	34.870260	192.168.5.10	224.0.0.5	OSPF	84	Hello Packet
17	38.492160	N/A	N/A	CDP	321	Device ID: R6 Port ID: Serial1/0
18	38.493442	192.168.5.9	224.0.0.5	OSPF	84	Hello Packet
19	41.270173	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 409, returned sequence 379
20	41.575417	N/A	N/A	SLARP	24	Line keepalive, outgoing sequence 380, returned sequence 409

Figure 8. Wireshark capturing packets

Similarly to the RIP network, ping tests were executed to check if all hosts are reachable in the network. An example is presented as follows:

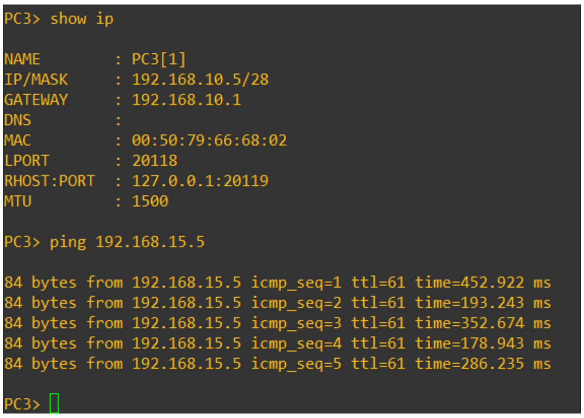


Figure 9. Ping test from PC3 to PC4

3.5. Connecting the whole network with BGP protocol

The BGP protocol was configured on routers R2 and R5 to facilitate routing between different Autonomous Systems (AS) and the exchange of routing information between different routing protocols. To configure BGP on R2, the BGP process was initiated using the command **router bgp** [**AS number**], and the neighbor relationship with R5 was established using the **neighbor** [**IP address**] **remote-as** [**AS number**] command. Additionally, RIP routes were redistributed into BGP using the **redistribute rip** command. On R5, BGP was configured similarly, establishing a neighbor relationship with R2, and OSPF routes were redistributed into BGP. Below are the outputs of the **show ip bgp neighbor** and **show ip route** commands on routers R2 and R5, reflecting the successful configuration and BGP route exchange between the routers:

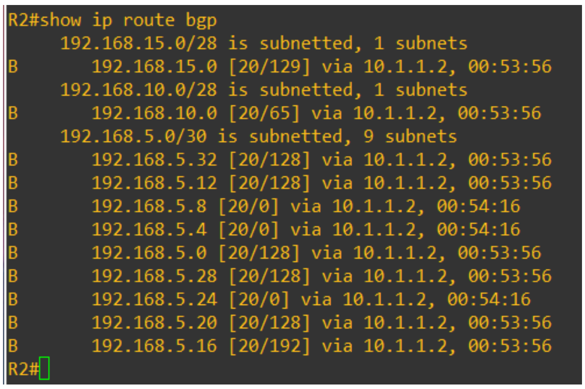


Figure 10. IP routes

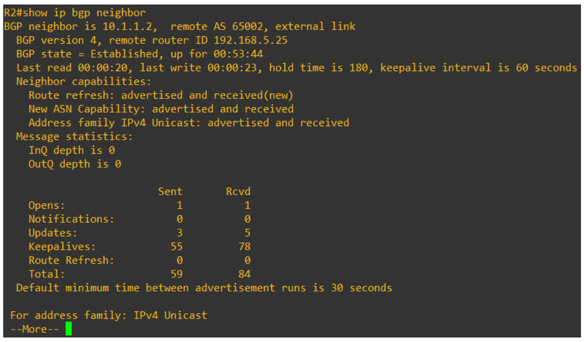


Figure 11. BGP neighbors

After that, it became possible to access every host in the entire network. The routers exchange routing information, and it is evident that every network is reachable from all routers. As an example, below are the routing tables for routers R4 and R9:

```
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    192.168.15.0/24 [120/1] via 192.168.1.14, 00:00:19, Serial1/1
R    192.168.10.0/24 [120/1] via 192.168.1.14, 00:00:19, Serial1/1
R    192.168.5.0/24 [120/1] via 192.168.1.14, 00:00:19, Serial1/1
R    10.0.0.0/8 [120/2] via 192.168.1.14, 00:00:19, Serial1/1
                [120/2] via 192.168.1.9, 00:00:12, Serial1/0
     192.168.1.0/30 is subnetted, 5 subnets
C       192.168.1.8 is directly connected, Serial1/0
C       192.168.1.12 is directly connected, Serial1/1
R       192.168.1.0 [120/1] via 192.168.1.14, 00:00:19, Serial1/1
R       192.168.1.4 [120/1] via 192.168.1.9, 00:00:12, Serial1/0
R       192.168.1.16 [120/1] via 192.168.1.14, 00:00:19, Serial1/1
                     [120/1] via 192.168.1.9, 00:00:12, Serial1/0
R    192.168.2.0/24 [120/2] via 192.168.1.14, 00:00:19, Serial1/1
                    [120/2] via 192.168.1.9, 00:00:12, Serial1/0
     192.168.3.0/28 is subnetted, 1 subnets
C       192.168.3.0 is directly connected, FastEthernet0/0
R4#
```

Figure 12. Routing table for R4

```
     192.168.15.0/28 is subnetted, 1 subnets
O       192.168.15.0 [110/65] via 192.168.5.17, 01:21:46, Serial1/1
     192.168.10.0/28 is subnetted, 1 subnets
O       192.168.10.0 [110/65] via 192.168.5.1, 01:21:56, Serial1/0
     192.168.5.0/30 is subnetted, 9 subnets
C       192.168.5.32 is directly connected, Serial1/2
O       192.168.5.12 [110/128] via 192.168.5.17, 01:21:46, Serial1/1
O       192.168.5.8 [110/192] via 192.168.5.34, 01:21:56, Serial1/2
                    [110/192] via 192.168.5.17, 01:21:46, Serial1/1
                    [110/192] via 192.168.5.1, 01:21:56, Serial1/0
O       192.168.5.4 [110/128] via 192.168.5.1, 01:21:56, Serial1/0
C       192.168.5.0 is directly connected, Serial1/0
O       192.168.5.28 [110/128] via 192.168.5.34, 01:21:56, Serial1/2
                     [110/128] via 192.168.5.17, 01:21:46, Serial1/1
O       192.168.5.24 [110/128] via 192.168.5.34, 01:21:58, Serial1/2
O       192.168.5.20 [110/128] via 192.168.5.34, 01:21:58, Serial1/2
                     [110/128] via 192.168.5.1, 01:21:58, Serial1/0
C       192.168.5.16 is directly connected, Serial1/1
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O E2    10.1.1.0/30 [110/1] via 192.168.5.34, 01:22:00, Serial1/2
                    [110/1] via 192.168.5.1, 01:22:00, Serial1/0
O E2    10.0.0.0/8 [110/1] via 192.168.5.34, 01:22:01, Serial1/2
                   [110/1] via 192.168.5.1, 01:22:01, Serial1/0
     192.168.1.0/30 is subnetted, 5 subnets
O E2    192.168.1.8 [110/1] via 192.168.5.34, 01:22:01, Serial1/2
                    [110/1] via 192.168.5.1, 01:22:01, Serial1/0
O E2    192.168.1.12 [110/1] via 192.168.5.34, 01:22:02, Serial1/2
                     [110/1] via 192.168.5.1, 01:22:02, Serial1/0
O E2    192.168.1.0 [110/1] via 192.168.5.34, 01:22:02, Serial1/2
                    [110/1] via 192.168.5.1, 01:22:02, Serial1/0
O E2    192.168.1.4 [110/1] via 192.168.5.34, 01:22:03, Serial1/2
                    [110/1] via 192.168.5.1, 01:22:03, Serial1/0
O E2    192.168.1.16 [110/1] via 192.168.5.34, 01:22:04, Serial1/2
                     [110/1] via 192.168.5.1, 01:22:04, Serial1/0
O E2 192.168.2.0/24 [110/1] via 192.168.5.34, 01:22:05, Serial1/2
                    [110/1] via 192.168.5.1, 01:22:05, Serial1/0
O E2 192.168.3.0/24 [110/1] via 192.168.5.34, 01:22:06, Serial1/2
                    [110/1] via 192.168.5.1, 01:22:06, Serial1/0
R9#
```

Figure 13. Routing table for R9

Below are presented ping tests from PC1 to PC3 and from PC4 to PC2:

```
PC1> ping 192.168.10.5

84 bytes from 192.168.10.5 icmp_seq=1 ttl=60 time=344.191 ms
84 bytes from 192.168.10.5 icmp_seq=2 ttl=60 time=379.321 ms
84 bytes from 192.168.10.5 icmp_seq=3 ttl=60 time=355.648 ms
84 bytes from 192.168.10.5 icmp_seq=4 ttl=60 time=301.116 ms
84 bytes from 192.168.10.5 icmp_seq=5 ttl=60 time=286.988 ms

PC1>
```

Figure 14. Ping test from PC1 to PC3

```
PC4> ping 192.168.3.5

84 bytes from 192.168.3.5 icmp_seq=1 ttl=59 time=446.555 ms
84 bytes from 192.168.3.5 icmp_seq=2 ttl=59 time=367.939 ms
84 bytes from 192.168.3.5 icmp_seq=3 ttl=59 time=362.146 ms
84 bytes from 192.168.3.5 icmp_seq=4 ttl=59 time=342.614 ms
84 bytes from 192.168.3.5 icmp_seq=5 ttl=59 time=351.042 ms

PC4>
```

Figure 15. Ping test from PC4 to PC2

3.6. NAT protocol

The NAT (Network Address Translation) protocol was configured on router R1 to enable translation of private IP addresses to public IP addresses. The NAT pool was created with the command **ip nat pool nat-pool 10.10.10.5 10.10.10.10 prefix-length 24**, and NAT was applied to the inside source using **ip nat inside source list 1 pool nat-pool overload**. Additionally, an access list was defined with **access-list 1 permit 192.168.2.0 0.0.0.15** to permit the translation of addresses within the 192.168.2.0/28 network. Below, the debug information for NAT statistics and translations is presented, showing that the private IP address 192.168.2.5 has been successfully translated to the public IP address 10.10.10.5.

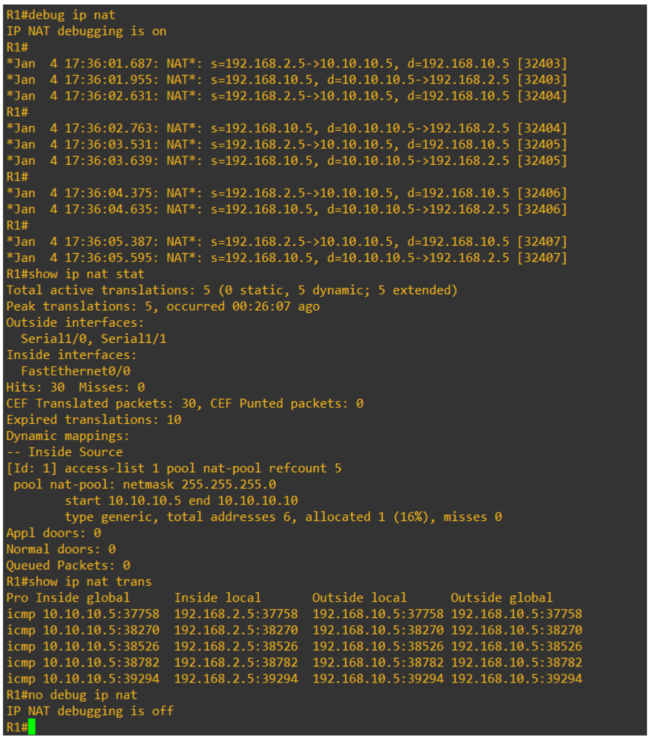


Figure 16. NAT debug informations

4. Summary

This lab focused on configuring and verifying dynamic routing protocols (RIP v2, OSPF, BGP) and implementing NAT for full connectivity across a multi-network topology. Routing tables, Wireshark captures, and ping tests confirmed proper protocol operation. All configurations were applied correctly, and NAT was successfully implemented. The lab was a success, with all objectives met. Additionally, all GNS3 configuration files are stored in a separate folder for easy access.