DEPARTAMENTO DE ELETRÓNICA, TELECOMUNICAÇÕES E INFORMÁTICA

LICENCIATURA EM ENGENHARIA DE COMPUTADORES E INFORMÁTICA

ANO 2024/2025

REDES DE COMUNICAÇÕES II

LABORATORY GUIDE NO. 2:

INTERIOR GATEWAY IP ROUTING

In this Laboratory Guide:

- all routers should use the IOS image 15.1(4) of routers 7200 (provided in the elearning page of RC II) and with two network adapters:
  - C7200-IO-2FE in slot 0, providing 2 FastEthernet routing interfaces: `f0/0` and `f0/1`
  - PA-2FE-TX in slot 1, providing 2 FastEthernet routing interfaces: `f1/0` and `f1/1`
- all switches should use the basic Ethernet Switch available in GNS3

1. Initial network setup

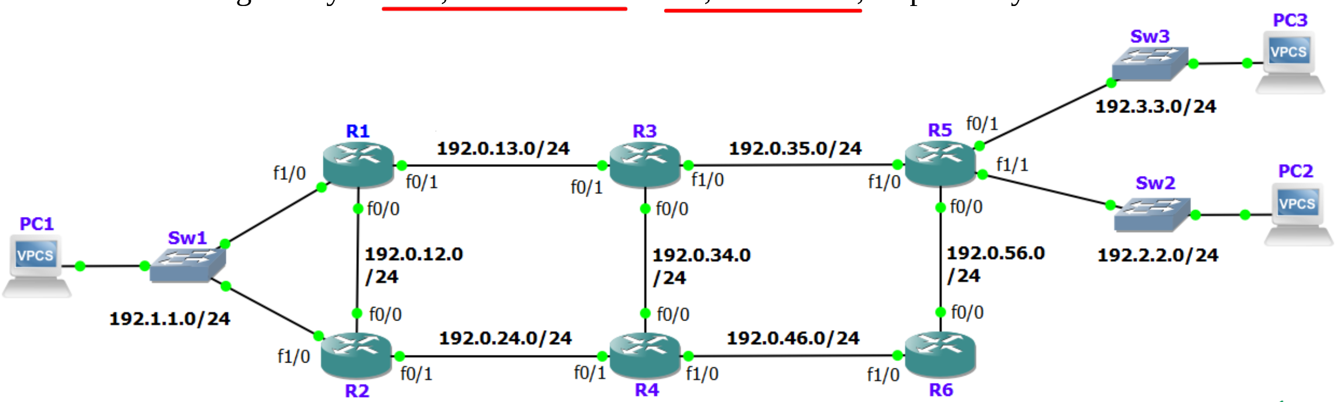
Consider the following network setup composed of 6 routers, seven IP transit networks (one IP network per point-to-point link between routers) and 3 stub networks (one IP network per each switch). Create a GNS3 template with all equipment and all links. Then, run the template.

On each interface of each router:

- configure an IP address (following the IP network addresses in the figure) with the host part of the address given by the number of the router name (for example, interface `f1/0` of router R3 is configured with the command `ip address 192.0.35.3 255.255.255.0`)
- activate the interface (command `no shutdown`)

Then, on each PC, configure its IP address (following the IP network addresses in the figure) and the IP address of its default gateway in the following way:

- the host part of the IP address is equal to 100 for all PCs (for example, PC1 with 192.1.1.100)
- the default gateway of PC1, PC2 and PC3 is R2, R5 and R5, respectively.



Configuration of IP address and default gateway in PC1:

```
PC1> ip 192.1.1.100/24 192.1.1.2
PC1> save
```

Check the resulting configuration:

```
PC1> show ip
```

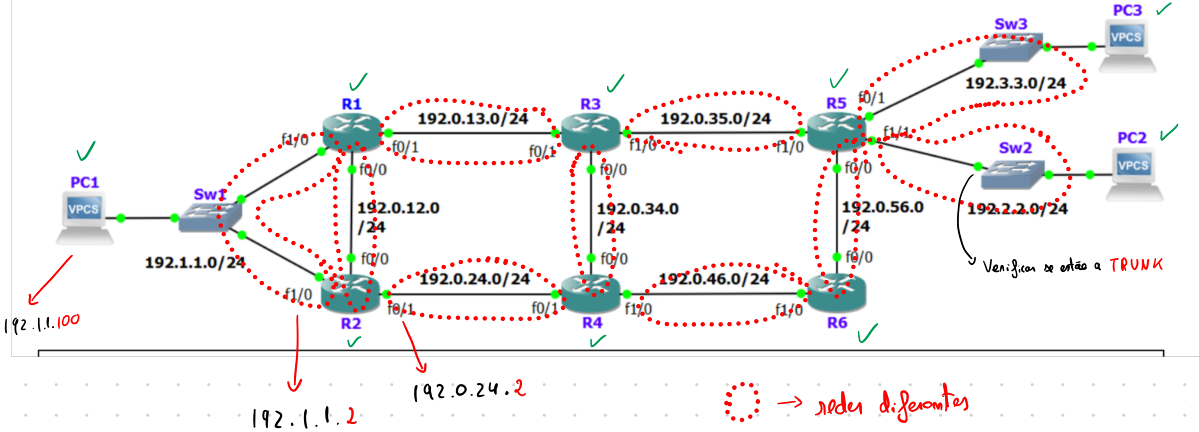
Check the IP routing table of each router. Verify that, on each router, its routing table includes all directly connected IP networks and does not include any remote IP network (if not, there are configuration errors that must be identified and corrected).

Check the complete IP routing table in router R1:

```
R1# show ip route
```

Check the IP routing table in router R1 without the Link IP addresses:

```
R1# show ip route | exclude L
```



Rotas do R2

```
R2# show ip route | exclude L
       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
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       + - replicated route, % - next hop override

Gateway of last resort is not set

      192.0.12.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.0.12.0/24 is directly connected, FastEthernet0/0
      192.0.24.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.0.24.0/24 is directly connected, FastEthernet0/1
      192.1.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.1.1.0/24 is directly connected, FastEthernet1/0

R2#
```

Ligada ao R1

Ligada ao R4

Ligada ao SW

2. IP routing based on RIP version 2

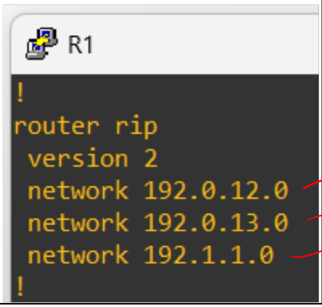
Activate the RIPv2 routing protocol only in routers R1 and R2. On each router, include all directly connected IP networks in the RIP process.

Activation of RIPv2 in router R1:

```
R1# configure terminal
R1(config)# router rip
R1(config-router)# version 2
R1(config-router)# network 192.1.1.0
R1(config-router)# network 192.0.12.0
R1(config-router)# network 192.0.13.0
R1(config-router)# end
R1# write
```

Check the resulting configuration:

```
R1# show configuration
```



"f0/0"
"f0/1"
"f1/0"

2.a. Analyze the IP routing tables of the routers. Justify the new entries that were added by the RIP protocol in all routers. Is the network 192.1.1.0/24 a transit or a stub network?

Start two Wireshark captures: one in link PC1-Sw1 and another in link R1-R2. Wait until you have at least a total of 6 RIPv2 messages on each capture.

IMPORTANT NOTE ON MULTICAST FRAMES FORWARDING IN A SWITCH: By default, an Ethernet frame for a multicast address is treated by a Switch in the same way as a frame for the broadcast address: the frame is forwarded by the Switch to all ports, except the incoming port.

Based on the observed RIPv2 messages in the two captures:

2.b. Check that RIP runs over UDP (what are the port numbers?) which runs over IPv4 (what are the origin and destination IP addresses?).

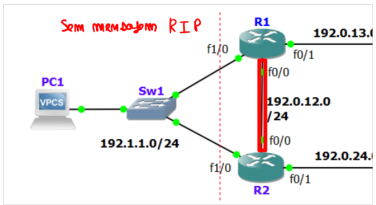
2.c. Check the type of observed RIP messages and how periodically they are sent by each router.

2.d. Analyze the distance vector sent in the RIP Response messages by each router on each link (is the protocol configured with or without split-horizon?) (justify each network and associated metric of each announced distance vector).

Configure the interfaces `f1/0` of both routers R1 and R2 as passive-interfaces for the RIP protocol.

Configuration of a passive-interface for RIP in router R1:

```
R1# configure terminal
R1(config)# router rip
R1(config-router)# passive-interface f1/0
R1(config-router)# end
R1# write
```



2.e. Analyze the IP routing tables of the routers. Justify again the entries added by the RIP protocol. Is the network 192.1.1.0/24 a transit or a stub network?

2.f. Again, start two Wireshark captures: one in link PC1-Sw1 and another in link R1-R2. Do you capture any RIPv2 message in link PC1-Sw1? Why? Analyze and justify the distance vector sent in the RIP messages observed in link R1-R2.

Start a never-ending ping command at PC1 to the address of the interface `f0/0` of router R2 (at PC1, run `ping 19.0.12.2 -t`). Shutdown the interface `f1/0` of router R2 (simulating a link failure).

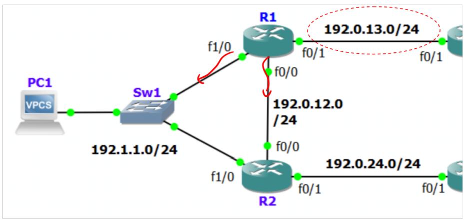
2.g. Did you lose the connectivity in the ping command? Why?

2.a)

```
R2# show ip route | exclude L
       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
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       + - replicated route, % - next hop override

Gateway of last resort is not set

      192.0.12.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.0.12.0/24 is directly connected, FastEthernet0/0
R     192.0.13.0/24 [120/1] via 192.1.1.1, 00:00:35, FastEthernet1/0
                    [120/1] via 192.0.12.1, 00:00:06, FastEthernet0/0
      192.0.24.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.0.24.0/24 is directly connected, FastEthernet0/1
      192.1.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.1.1.0/24 is directly connected, FastEthernet1/0

R2#
```

código do RIP

custo



Stop the previous never-ending ping command (by inserting `Ctrl+C`) and activate the interface `f1/0` of router R2 (i.e., run `no shutdown` on the interface).

Configure the Virtual Router Redundancy Protocol (VRRP) in the interfaces `f1/0` of both routers R1 and R2 to provide a virtual default gateway address 192.1.1.254 to the LAN of Sw1. Do not change the default VRRP priority value of the interfaces. (IMPORTANT: you must also change the default gateway address of PC1 to 192.1.1.254).

Configuration of VRRP in an interface of router R1:

```
R1# configure terminal
R1(config)# interface f1/0
R1(config-if)# vrrp 1 ip 192.1.1.254
R1(config-if)# vrrp 1 priority 120   (to change the default value 100)
R1(config-if)# end
R1# write
```

Start a Wireshark capture in link PC1-Sw1 and do not stop until it is explicitly requested.

2.h. By analyzing the VRRP messages, explain how VRRP works and what is the current master virtual default gateway.

2.i. Shutdown interface `f1/0` of router R2 (simulating a link failure). Analyze the VRRP messages and identify the resulting master virtual default gateway.

2.j. Activate the interface `f1/0` of router R2. Analyze the VRRP messages and identify the resulting master virtual default gateway.

2.k. Stop the Wireshark capture in link PC1-Sw1. Start a never-ending ping command at PC1 to the address of the interface `f0/0` of router R2. Run the following steps:

(a) shutdown the interface `f1/0` of router R2,
(b) wait for 15 seconds,
(c) activate again the interface `f1/0` of router R2.

Stop the never-ending ping command in PC1. What happened to the connectivity of the ping command in step (a) and step (c)?

Activate the RIPv2 routing protocol in all other routers (i.e., R3, R4, R5 and R6). Include all directly connected IP networks in the RIP process of routers R3, R4 and R6. On the other hand, include only the networks 192.0.35.0/24 and 192.0.56.0/25 in the RIP process of router R5.

2.l. Analyze the IP routing tables of all routers. Verify that each router always selects the next-hop neighbor routers providing the minimum cost paths to each known remote IP network. Verify also that the IP networks of Sw2 and Sw3 are only known by router R5 (why?).

2.m. Configure router R5 to announce itself to all other RIP routers as the destination of a default RIP route. Analyze the IP routing tables of all routers. Justify the new entries on the routing tables due to the configuration of the default RIP route.

Configuration of router R5 as the destination of a default RIP route:

```
R5# configure terminal
R5(config)# router rip
R5(config-router)# default-information originate
R5(config-router)# end
R5# write
```

2.n. Check (through ping) that all pairs of PCs have connectivity between them (if not, there are configuration errors that must be identified and corrected).

Stop running the GNS3 template and save a copy. Then, run again the template and eliminate the RIP protocol in all routers (to use this template in the next task, keeping the configuration of the VRRP).

Elimination of RIP in router R1:
```
R1# configure terminal
R1(config)# no router rip
R1(config)# end
R1# write
```

3. IP routing based on OSPF version 2

Activate the OSPFv2 routing protocol in all interfaces of routers R1 and R2. Consider all interfaces in OSPF Process No. 1 and in the backbone area (i.e., area 0).

Activation of OSPFv2 in all interfaces of router R1 with OSPF Process No. 1 and area 0:
```
R1# configure terminal
R1(config)# interface f0/0
R1(config-if)# ip ospf 1 area 0
R1(config-if)# interface f0/1
R1(config-if)# ip ospf 1 area 0
R1(config-if)# interface f1/0
R1(config-if)# ip ospf 1 area 0
R1(config-if)# end
R1# write
```
Check the resulting configuration:
```
R1# show configuration
```

3.a. Analyze the IP routing tables of the routers. Justify the new entries that were added by the OSPF protocol in all routers. Is the network 192.1.1.0/24 a transit or a stub network?

Start two Wireshark captures: one in link PC1-Sw1 and another in link R1-R2. Based on the observed OSPF messages in the two captures:

```
16 26.035208    192.1.1.1    224.0.0.5    OSPF    90 Hello Packet
```

3.b. Check that OSPF runs over IPv4 (what are the origin and destination IP addresses?). ✓

3.c. Check the type of observed OSPF messages and how periodically they are sent by each router. ≃ 20 seg

3.d. What is the OSPF Router ID of R1 and of R2? Which router is the Designated Router (R1) and the Backup Designated Router (R2) on each observed network? How is reliability guaranteed by the content of these messages?

3.e. Run on router R1 and router R2 the commands:

```
show ip ospf interface brief
show ip ospf neighbor
```

```
Interface    PID   Area         IP Address/Mask    Cost  State Nbrs F/C
Fa1/0        1     0            192.1.1.1/24       1     DR    0/0
Fa0/1        1     0            192.0.13.1/24      1     DR    0/0
Fa0/0        1     0            192.0.12.1/24      1     DR    0/0
R1#
```

```
R2#show ip ospf neighbor

Neighbor ID     Pri   State          Dead Time   Address        Interface
192.1.1.1         1   FULL/DR        00:00:38    192.0.12.1     FastEthernet0/
0
```

and verify that the information shown by these commands confirms your conclusions in **3.d**.

Configure the interfaces `f1/0` of both routers R1 and R2 as passive-interfaces for the OSPF protocol.

Configuration of a passive-interface in router R1:
```
R1# configure terminal
R1(config)# router ospf 1
R1(config-router)# passive-interface f1/0
R1(config-router)# end
R1# write
```

3.f. Analyze the IP routing tables of the routers. Justify again the entries added by the OSPF protocol. Is the network 192.1.1.0/24 a transit or a stub network?

4.b. Analyze the IP routing table of all routers. Check that the IP routing table of the routers in the RIP domain do not change (why?). Check which type of external routes are inserted in the routers of the OSPF domain and what are their external cost values.

In R3, redistribute all individual networks learned by OSPF into RIP with an external cost of 1:

```
R3# configure terminal
R3(config)# router rip
R3(config-router)# no auto-summary
R3(config-router)# redistribute ospf 1 metric 1
R3(config-router)# end
R3# write
```

4.c. Check (through ping) that there is connectivity between all PCs. Analyze the IP routing table of all routers. Check that the IP routing table of the routers in the OSPF domain do not change (why?). Justify how the networks of the OSPF domain are learned in the routers of the RIP domain.

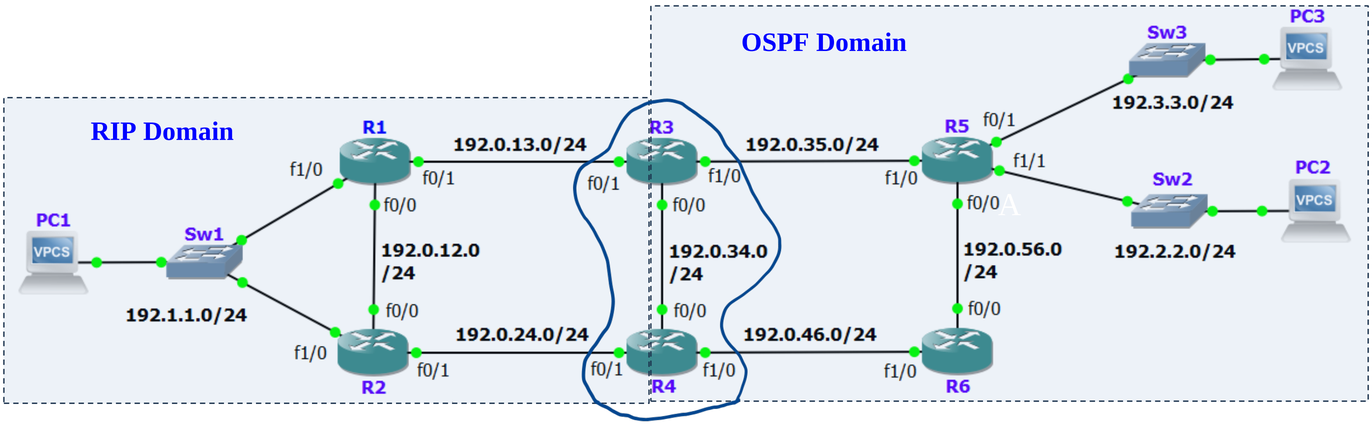
In router R3, eliminate the previous redistribution from OSPF into RIP and configure router R3 to announce itself to all other RIP routers as the destination of a default RIP route:

```
R3# configure terminal
R3(config)# router rip
R3(config-router)# no redistribute ospf 1 metric 1
R3(config-router)# default-information originate
R3(config-router)# end
R3# write
```

4.d. Check again that there is connectivity between all PCs. Analyze the IP routing table of all routers. Check that the IP routing table of the routers in the OSPF domain do not change (why?). Justify how the routers of the RIP domain forward the IP packets for networks outside their domain.

4.e. Compare the two previous routing solutions (the one in **4.c** with the one in **4.d**). In practice, what is the one that you would recommend?

Next, the aim is to have two boundary routers (R3 and R4) between the two domains as in the figure.



To reach this setting, first eliminate in router R3 the redistribution of RIP into OSPF and the announcement of the default RIP route:

```
R3# configure terminal
R3(config)# router ospf
R3(config-router)# no redistribute rip subnets
R3(config-router)# router rip
R3(config-router)# no default-information originate
R3(config-router)# end
R3# write
```

Then, change the configuration of router R4 in the following way:

- remove interface `f0/1` from the OSPF Process No. 1
- activate RIPv2 including only the directly connected network 192.0.24.0 in the RIP process

4.f. Analyze and justify the IP routing table of all routers. and justify why:

Configure both routers R3 and R4 to announce themselves to all other RIP routers as the destination of a default RIP route.

4.g. Analyze the IP routing table of all routers. Check that each router in the RIP domain learns a default route towards the closer default route destination. Check that the IP routing tables in the OSPF domain do not change.

Configure both routers R3 and R4 to redistribute the networks learned by RIP into the OSPF protocol using an external route of type E1 and external metric 1.

Redistribute RIP into OSPF using type E1 and external cost 1 in router R3:

```
R3# configure terminal
R3(config)# router ospf 1
R3(config-router)# redistribute rip subnets metric-type 1 metric 1
R3(config-router)# end
R3# write
```

4.h. Analyze the IP routing table of all routers and check that the routing solution is not ideal:

(a) some routing paths from the boundary routers (R3 or R4) to the remote IP networks in the RIP domain are first routed through the OSPF domain,
(b) the routing paths from the routers in the OSPF domain to the networks in the RIP domain are not the shortest paths.

Change in both routers R3 and R4 the RIP administrative distance from its default value (which is 120) to 100 (making its value lower than the administrative distance of OSPF).

Configure the RIP administrative distance in router R3:

```
R3# configure terminal
R3(config)# router rip
R3(config-router)# distance 100
R3(config-router)# end
R3# clear ip route *
R3# write
```

4.i. Check (through ping) that there is connectivity between all PCs. Analyze the IP routing table of all routers. Justify why now the routing solution is the desired one.

5. IPv6 routing based on OSPF version 3

Copy the GNS3 template saved at the end of Section 3 to a new template (recall that this template has OSPFv2 running in all routers for IPv4 routing). Run the template and configure the global IPv6 addresses as specified in the next figure (IPv6 routing is supported only by routers R1, R3 and R5).

Like in IPv4 addressing, use the number of the router name as the host part of the IPv6 addresses in the routers' interfaces (for example, interface `f1/0` of router R3 is configured with the IPv6 address `2001:0:35::3/64`) and use 100 as the host part of the IPv6 addresses of the PCs (for example, PC1 is configured with the address `2001:1:1::100/64`).

You need also to activate the IPv6 routing in routers R1, R3 and R5.

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R1 | R3 | R5

PC3 VPCS

PC2 VPCS

```
*Mar 17 17:13:28.427: %OSPF-5-ADJCHG: Process 1, Nbr 192.1.1.2 on Fa
R1#show ipv6 route
IPv6 Routing Table - default - 7 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static rou
       B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS su
       D - EIGRP, EX - EIGRP external, NM - NEMO, ND - Neighbor Disc
       l - LISP
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
OE2 ::/0 [110/1], tag 1
     via FE80::C803:39FF:FE68:6, FastEthernet0/1
C   2001:0:13::/64 [0/0]
     via FastEthernet0/1, directly connected
L   2001:0:13::1/128 [0/0]
     via FastEthernet0/1, receive
O   2001:0:35::/64 [110/2]
     via FE80::C803:39FF:FE68:6, FastEthernet0/1
C   2001:1:1::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:1:1::1/128 [0/0]
     via FastEthernet1/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
R1#show ipv6 int brief
FastEthernet0/0            [up/up]
    unassigned
FastEthernet0/1            [up/up]
    FE80::C801:3AFF:FE18:6
    2001:0:13::1
FastEthernet1/0            [up/up]
    FE80::C801:3AFF:FE18:1C
    2001:1:1::1
FastEthernet1/1            [administratively down/down]
    unassigned
R1#
```

Ligações

solarwinds Solar-PuTTY free tool

17:15
17/03/2025