DEPARTAMENTO DE ELETRÓNICA, TELECOMUNICAÇÕES
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LICENCIATURA EM ENGENHARIA DE COMPUTADORES E INFORMÁTICA

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REDES DE COMUNICAÇÕES II

LABORATORY GUIDE NO. 2:

INTERIOR GATEWAY IP ROUTING

Laboratory Guide No. 2

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

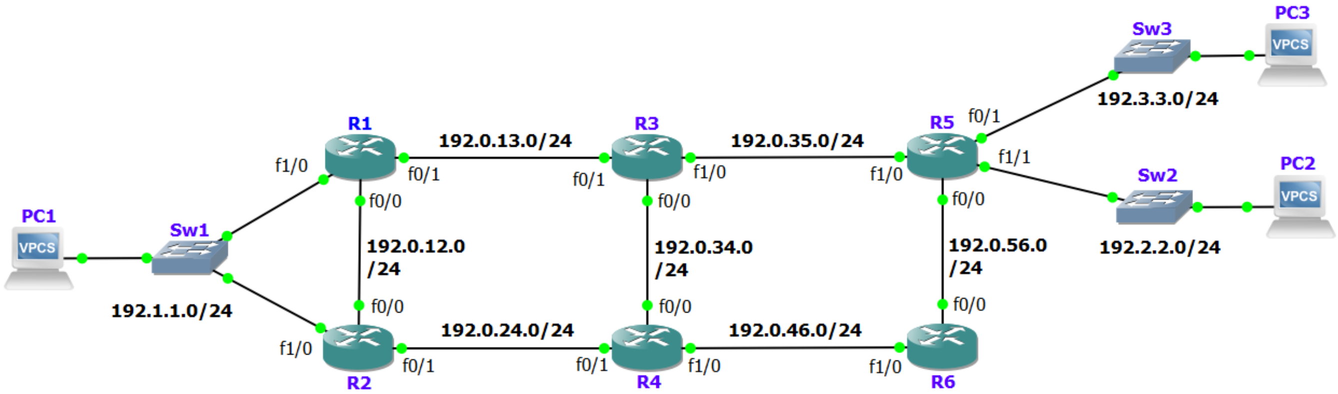
Consider the following network setup composed of 6 routers, seven IP transit networks (one IP network per point-to-point link between routers) and 3 stub networks (one IP network per each switch). Create a GNS3 template with all equipment and all links. Then, run the template.

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
```

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
```

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?

Depois de adicionar as networks no protocolo RIP, ambos os routers ficaram a conhecer networks que nao conseguiam acessar diretamente.
Com custo 1 em ambos. A network 192.1.1.0/24 é uma network de transito, pois esta tem um "caminho alternativo" para as conecções.

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.

O protocolo RIP para cada porta/network que comunica, envia todas as networks que conhece, excepto a network que está a ser usada para enviar o pacote. Isto acontece para todas as portas e este método chama-se SPLIT HORIZON

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?). O RIP usa UDP para comunicar a partir da porta 520. A origem é o router e o destino é multicast.

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

Os tipos de mensagens são RIP responses e têm periodicidade de 30 segundos.

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). O protocolo está configurado com split horizon por defeito, pois em cada RIP response na qual estava a ser enviado o pacote, nao era partilhado o IP dessa rede.

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? Ao colocar a porta F1/0 em passive mode, torna a network 192.1.1.0 como uma network stub

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. Não são capturados pacotes RIP na captura PC1-Sw1 devido à ativação do passive mode na porta f1/0. Deixa de haver comunicação do protocolo RIP a partir das portas f1/0 dos routers R1 e 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?

Sim, perdi a conectividade, pois a interface f1/0 do router R2 é a gateway do PC1. Se eu fechar essa porta, não há nenhum protocolo (VRRP off) para alterar a gateway de forma dinamica.

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) <u>in the interfaces `f1/0` of both routers R1 and R2</u> 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 <u>in all other routers (i.e., R3, R4, R5 and R6)</u>. Include all directly connected IP networks in the RIP process of routers R3, R4 and R6. On the other hand, <u>include only the networks 192.0.35.0/24 and 192.0.56.0/25 in the RIP process of router R5</u>.

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).

2.h) O VRRP funciona de forma a que um grupo de routers compartilhe um único endereço IP virtual que serve como o gateway padrão para uma LAN.
Um router no grupo é eleito como o master com base em sua prioridade, enquanto os outros atuam como backups. O master envia periodicamente mensagens de multicast VRRP para informar os backups de que ele ainda está ativo. Se os backups pararem de receber essas mensagens (por exemplo, se o mestre falhar), um deles — com a próxima prioridade mais alta — assumirá como mestre.
O roteador R1 e R2 foi configurado com uma prioridade de 120. Como resultado, R2 é o master (pois o seu IP é maior que o IP de R1) e é aquele que responde às solicitações ARP e manipula o tráfego para o IP virtual compartilhado (192.1.1.254).
Isso garante que, mesmo que o R2 ou sua interface associada falhem, a LAN continuará a usar o mesmo gateway padrão fornecido pelo R1 até que uma alteração seja necessária.

2.i) Ao desligar a interface f1/0 do R2, este deixa de conseguir comunicar com o Sw1. Como resultado disso, R2 deixa de enviar os VRRP Announcements, o router R1 detecta essa falha e toma controlo como master, ou seja, agora todos os pacotes direcionado para 192.1.1.254 passarão no router R1.

2.j) Ao voltar a ativar a porta f1/0 do router R2, este como tem uma prioridade mais alta que R1, volta a tornar-se o master.

2.k) Como a porta f1/0 do router R2 foi desativada, a porta f1/0 do route R1 passou a ser master. Os pings passaram a ser mandados para o router R1 e encaminhados para a porta f0/0 de R2.

2.l) As networks dos switches 2 e 3 só são conhecidas no router R5, pois não foi introduzido no router R5 as networks para o protocolo RIPv2.

2.m) Quando é configurado no router R5 como default-information route, este passa a gerar um anúncio de rota default (0.0.0.0/0) para todos os seus vizinhos RIP. Com isso, todos os routers recebem essa rota através das atualizações RIP e a instalam nas suas route table, apontando para R5 como o next hop para quaisquer destinos que não correspondam a uma rota específica.

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:

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.

3.d. What is the OSPF Router ID of R1 and of R2? Which router is the Designated Router and the Backup Designated Router 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
```

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?

3.g. Again, start two Wireshark captures: one in link PC1-Sw1 and another in link R1-R2. Do you capture any OSPF message in link PC1-Sw1? Why? The OSPF messages observed in link R1-R2 are equal to the ones observed in **3.d**? Why?

To analyze the LSAs (in this case, Router Link States and the Net Link States) database information, run on router R1 and router R2 the commands:

```
show ip ospf database
show ip ospf database router
show ip ospf database network
```

3.h. Verify that the information shown in both routers is the same (why?). Based on this information:
(a) justify the number of Router Link States and Net Link States,
(b) verify that the information represents the network topology associated with R1 and R2,
(c) verify who is the router advertiser of each LSA,
(d) verify that the default OSPF cost of each interface agrees with the costs of the IP routing tables.

Activate the OSPFv2 routing protocol in all other routers (i.e., R3, R4, R5 and R6). Include all interfaces in the OSPF process of routers R3, R4 and R6. On the other hand, include only the interfaces `f0/0` and `f1/0` in the OSPF process of router R5. Again, consider the interfaces in the OSPF Process No. 1 and in the backbone area (i.e., area 0).

3.i. 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?).

3.j. Check the Router Link State of router R5 (in one of the routers) and justify why the IP networks of Sw2 and Sw3 are not learned by the other routers.

Start a Wireshark capture in link R1-R2 and change to 3 the OSPF cost of interface `f1/0` of router R3.

Configuration of the OSPF cost on interface `f1/0` of router R3:

```
R3# configure terminal
R3(config)# interface f1/0
R3(config-if)# ip ospf cost 3
R3(config-if)# end
R1# write
```

3.k. Analyze and justify:
(a) the changes in the IP routing tables of router R1 and R2,
(b) the OSPF packets captured in link R1-R2 during the network changes.

Start again a Wireshark capture in link R1-R2 and, then, shutdown the interface `f1/0` of router R4 (simulating a link failure).

IMPORTANT NOTE ON OSPF CONCERNING THE AGE OF LSAs: Each LSA has an age, which indicates whether the LSA is still valid (once the LSA reaches the maximum age of 1 hour, it is discarded). During the aging process, the originating router of each LSA sends a refresh packet every 30 minutes (whether there has been a change in the network topology or not) to prevent the LSA from being discarded by all other routers. On the other hand, if an existing LSA is no longer valid, the originating router sends the LSA with an age of 1 hour so that the LSA is discarded by all other routers.

3.l. Analyze and justify:
(a) the changes in the IP routing tables of router R1 and R2,
(b) the OSPF packets captured in link R1-R2 during the network changes.

Change again the OSPF cost of interface `f1/0` of router R3 to the default value of 1 and activate the interface `f1/0` of router R4, to reach the network state of **3.i** and **3.j**.

Then, configure router R5 to announce itself to all other OSPF routers as the destination of a default OSPF route:

```
R5# configure terminal
R5(config)# router ospf 1
R5(config-router)# default-information originate always
R5(config-router)# end
R5# write
```

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

3.n. Analyze the IP routing tables of routers R1 and R2. Justify the new entries due to the configuration of the default OSPF route. Based on the type of external route (E1 or E2) inserted in the IP routing tables, explain their cost values in the two routers.

3.o. Run command `show ip ospf database` in any router (why?) and identify the new type of LSA associated with the external route.

Now, configure also router R6 to announce itself to all other OSPF routers as the destination of a default OSPF route, but with an external cost of 3:

```
R6# configure terminal
R6(config)# router ospf 1
R6(config-router)# default-information originate always metric 3
R6(config-router)# end
R6# write
```

3.p. Analyze the IP routing tables of routers R1 and R2 and check that they remain the same (why?). Run command `show ip ospf database` in any router to check how the LSDB was updated with this new default route.

Now, change the configuration of the default OSPF route announcement in router R6 to announce an external route of type E1:

```
R6# configure terminal
R6(config)# router ospf 1
R6(config-router)# default-information originate always metric-type 1
R6(config-router)# end
R6# write
```

3.q. Analyze the IP routing tables of routers R1 and R2. Justify the new entries on the routing tables due to the configuration of the E1 external route on router R6 and explain their cost values in the two routers.

Eliminate the configuration of the default route in router R6:

```
R6# configure terminal
R6(config)# router ospf 1
R6(config-router)# no default-information originate
R6(config-router)# end
R6# write
```

IMPORTANT: Save the current GNS3 template to be used as the initial setup of each of the following sections.

4. IP routing with different routing domains

Copy the previous saved GNS3 template to a new template. Next, the aim is to have 2 routing domains (one RIP domain and one OSPF domain) and one boundary router (router R3) connecting the two domains as illustrated in the next figure. To reach this setting, change the routing configuration of the routers in the following way:

Routers R4, R5 and R6:

- keep the current configuration (which includes the default OSPF route configured in R5)

Router R3:

- remove interface `f0/1` from the OSPF Process No. 1
- activate RIPv2 including only the directly connected network 192.0.13.0 in the RIP process

Routers R1 and R2

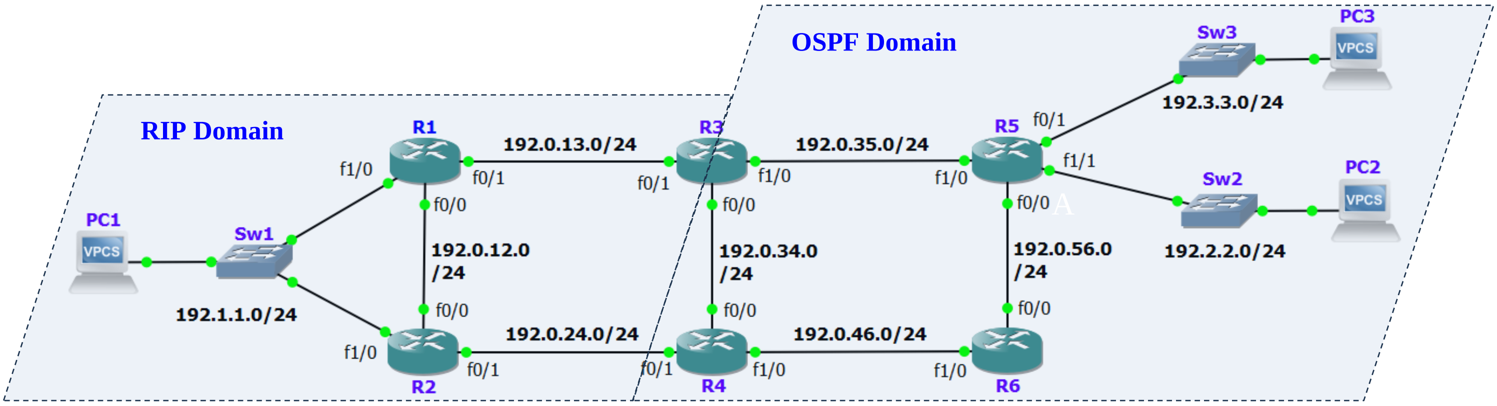
- eliminate the OSPF Process No. 1
- activate RIPv2 including all directly connected IP networks
- configure interfaces `f1/0` as passive-interfaces for the RIP protocol

Removal of interface `f0/1` from the OSPF Process No. 1 in router R3:

```
R3# configure terminal
R3(config)# interface f0/1
R3(config-if)# no ip ospf 1 area 0
R3(config-if)# end
R3# write
```

Elimination of OSPF Process No. 1 in router R1:

```
R1# configure terminal
R1(config)# no router ospf 1
R1(config)# end
R1# write
```



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

(a) a router in one domain only learns the remote IP networks of its domain and following the metrics of the domain's routing protocol,

(b) router R3 learns all remote IP networks including the default route towards router R5.

In router R3, redistribute the networks learned by RIP into the OSPF protocol:

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

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.

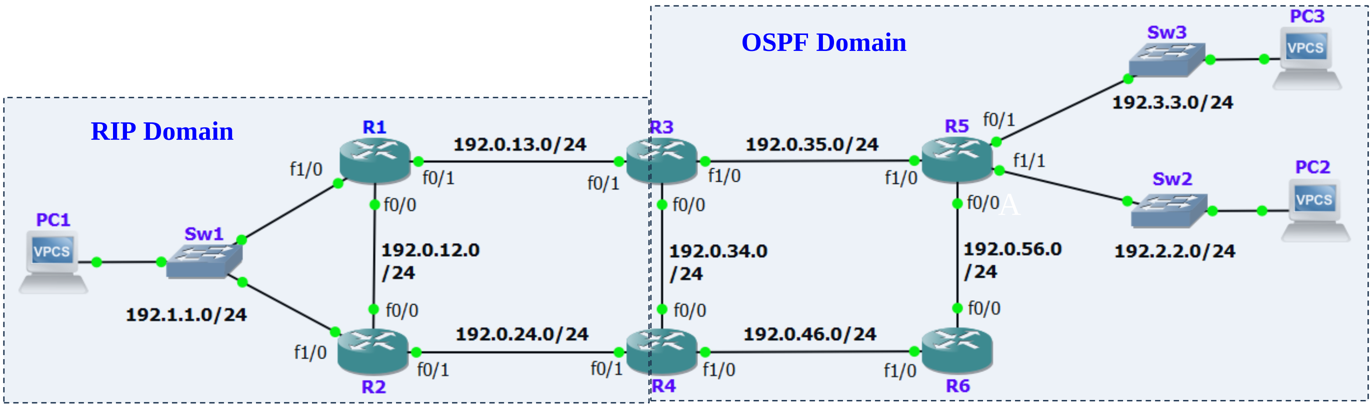
In router R3, eliminate the previous redistribution from OSPF into RIP and configure router R3 to announce itself to all other RIP routers as the destination of a default RIP route:

```
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
```

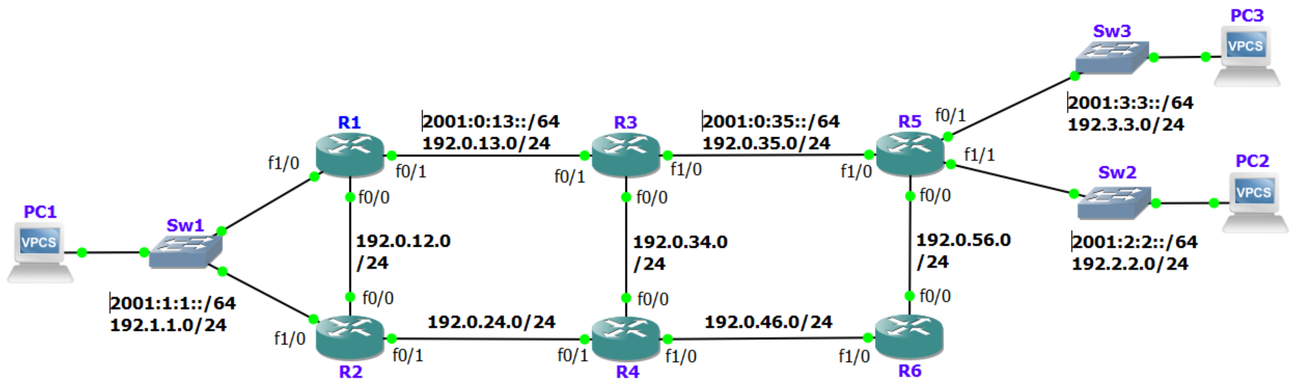
4.i. Check (through ping) that there is connectivity between all PCs. Analyze the IP routing table of all routers. Justify why now the routing solution is the desired one.

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.



IPv6 addressing configuration and routing activation in router R1:

```
R1# configure terminal
R1(config)# ipv6 unicast-routing
R1(config)# interface f1/0
R1(config-if)# ipv6 address 2001:1:1::1/64
R1(config-if)# interface f0/1
R1(config-if)# ipv6 address 2001:0:13::1/64
R1(config-if)# end
R1# write
```

Configuration of the IPv6 address in PC1:

```
PC1> ip 2001:1:1::100/64
PC1> save
```

Check the resulting configuration:

```
PC1> show ipv6
```

5.a. Check the IPv6 routing table of routers R1, R3 and R5. Verify that, on each router, its routing table includes the directly connected IPv6 networks and does not include any remote IP network.

Check the complete IPv6 routing table in router R1:

```
R1# show ipv6 route
```

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

```
R1# show ipv6 route | exclude L
```

5.b. Run the command `show ipv6 interface brief` on routers R1, R3 and R5 and check that besides the global IPv6 address, a link-local IPv6 address is also automatically configured to each interface.

Activate the OSPFv3 routing protocol in routers R1, R3 and R5. Include all IPv6 interfaces in the OSPF process of routers R1 and R3. On the other hand, include only the interface `f1/0` in the OSPF process of router R5. Consider the interfaces in the OSPF Process No. 1 and in the backbone area (i.e., area 0)

Activation of OSPFv3 in all IPv6 interfaces of router R1 with OSPF Process No. 1 and area 0:

```
R1# configure terminal
R1(config)# interface f0/1
R1(config-if)# ipv6 ospf 1 area 0
R1(config-if)# interface f1/0
R1(config-if)# ipv6 ospf 1 area 0
R1(config-if)# end
R1# write
```

Check the resulting configuration:

```
R1# show configuration
```

5.c. Analyze the IPv6 routing tables of routers R1, R3 and R5. Justify the OSPF entries that were added by the OSPFv3 protocol and their costs. What are the IPv6 addresses of the next-hop routers in the OSPF entries?

Now, configure router R5 to announce itself to all other OSPFv3 routers as the destination of a default OSPF route:

```
R5# configure terminal
R5(config)# ipv6 router ospf 1
R5(config-rtr)# default-information originate always
R5(config-rtr)# end
R5# write
```

5.d. Check (through ping) that there is IPv6 connectivity between all PCs. Analyze the IPv6 routing tables of routers R1 and R3. Justify the new entries due to the configuration of the default OSPF route. Based on the type of external route (E1 or E2) inserted in the IPv6 routing tables, explain their cost values in the two routers.

To analyze the LSAs database information, run on routers R1, R2 and R3 the commands:

```
show ipv6 ospf database
show ipv6 ospf database router
show ipv6 ospf database net
show ipv6 ospf database prefix
show ipv6 ospf database link
```

5.e. First, check that the IDs of the LSAs are based on the IPv4 addresses selected as Router ID by the routers. Verify also that the information shown in the routers is the same concerning the Router LSAs, the Net LSAs, the Intra Area Prefix LSAs and the AS External LSAs. On the other hand, the Link (Type-8) LSAs are different on different routers.

5.f. Then, based on the information shown, check that:

(a) there are 3 Router LSAs, one per IPv6 router
(b) there are 2 Net LSAs, one per transit network
(c) there are 3 Intra Area Prefix LSAs, one per global IPv6 prefix (each IPv6 prefix is announced by the Designated Router of the connection where the IPv6 prefix is used)
(d) there is 1 AS External LSA, corresponding to the configured default OSPF route
(e) the Link LSAs contain the link-local and global IPv6 prefixes of the router (where you see the information) and of its neighbor routers