DEPARTAMENTO DE ELETRÓNICA, TELECOMUNICAÇÕES
E INFORMÁTICA

LICENCIATURA EM ENGENHARIA DE COMPUTADORES E INFORMÁTICA

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REDES DE COMUNICAÇÕES II

LABORATORY GUIDE NO. 1:

VIRTUAL LANS + SPANNING TREE

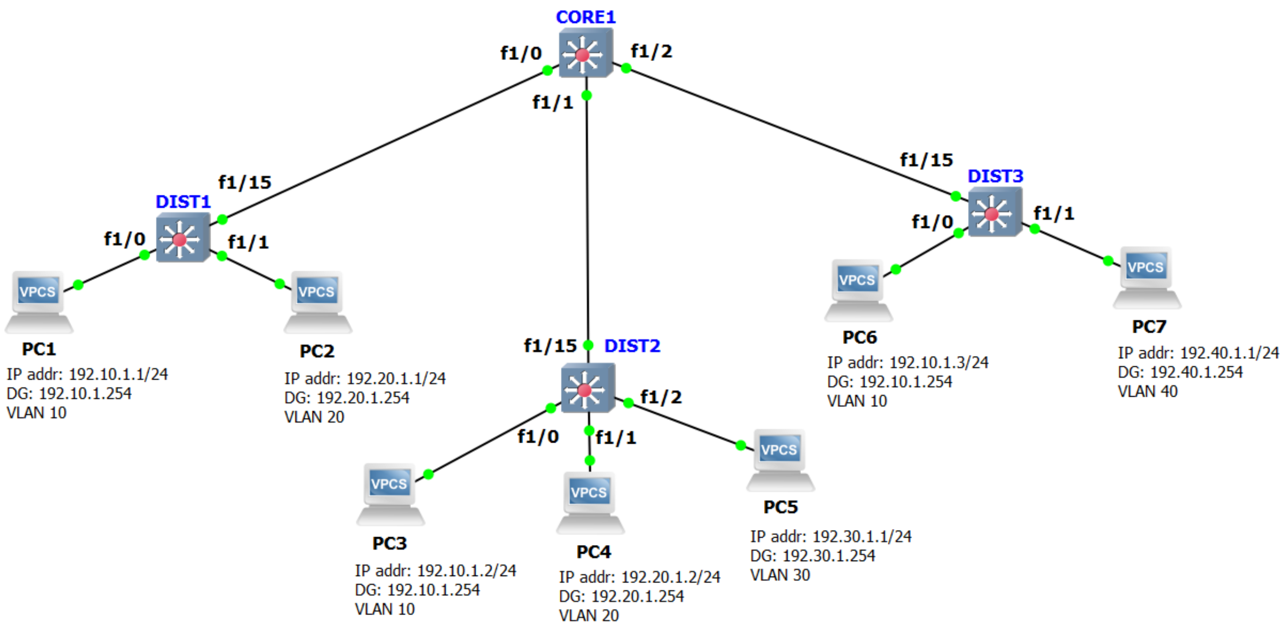
In this Laboratory Guide, all switches should be implemented as L3 Switches with the IOS image 12.4(21) of routers 3725 (provided in the elearning page of RC II) and with two network adapters:

- GT96100-FE, providing 2 FastEthernet routing interfaces: fe0/0 and fe0/1
- NM-16ESW, providing 16 FastEthernet switching interfaces: fe1/0, fe1/1, …, fe1/15

NOTE: Choose option "This is an EtherSwitch router" when defining the template of the L3 Switches.

1. Virtual LANs

Consider the following network setup composed of 1 core switch (CORE1), 3 distribution switches (DIST1, DIST2 and DIST3) and 7 PCs. Create a GNS3 template with all equipment and all links. Run the template and configure the IP and Default Gateway addresses of all PCs (let all switches on their default configuration and ignore by now the VLAN information of PCs).



Configuration of IP address and Default Gateway in PC1:

```
PC1> ip 192.10.1.1/24 192.10.1.254
PC1> save
```

Check the resulting configuration:

```
PC1> show ip
```

1.a. By default, all switches work as L2 Switches (all used interfaces are switching interfaces). Run the command `show vlan-switch` on each switch to check that all interfaces belong to the default VLAN 1.

1.b. Start a Wireshark capture in link DIST3-PC7. Execute a ping command from each PC to each IP address as specified next. Register the result of each ping and the packets captured in link DIST3-PC7 related to the executed ping. Justify the obtained results.

From:	To:	Result of Ping	Packets in DIST3-PC7 link
PC1	192.10.1.3	Ping Successful	ARP Request
PC1	192.10.1.10	Host not reachable	ARP Request 3x
PC1	192.20.1.2	Host not reachable	ARP Request (through Gateway IP) 3x
PC2	192.20.1.2	Ping Successful	ARP Request
PC2	192.30.1.1	Host not reachable	ARP Request (through Gateway IP) 3x
PC2	192.40.1.1	Host not reachable	ARP Request (through Gateway IP) 3x

Now, configure the switches to support all existing VLANs and the interfaces connected to the PCs in the VLANs specified in the figure. Configure also all links between switches as trunk links with 802.1q encapsulation supporting all VLANs.

Configuration of VLANs and trunk ports in switch DIST1:

```
DIST1# vlan database
DIST1(vlan)# vlan 10
DIST1(vlan)# vlan 20
DIST1(vlan)# vlan 30
DIST1(vlan)# vlan 40
DIST1(vlan)# exit
DIST1# configure terminal
DIST1(config)# interface f1/0
DIST1(config-if)# switchport mode access
DIST1(config-if)# switchport access vlan 10
DIST1(config-if)# interface f1/1
DIST1(config-if)# switchport mode access
DIST1(config-if)# switchport access vlan 20
DIST1(config-if)# interface f1/15
DIST1(config-if)# switchport mode trunk
DIST1(config-if)# end
DIST1# write
```

Check the resulting configuration:

```
DIST1# show configuration
DIST1# show vlan-switch
```

1.c. Start two Wireshark captures: one in link DIST3-PC7 and another in link CORE1-DIST3. Execute a ping command from each PC to each IP address as specified next. Register the result of each ping and the packets captured in the links related to the executed ping. In the analysis of the captured packets, register also the VLAN information in their 802.1q header. For each ping, justify the results and the differences with the results obtained in **1.b**.

From:	To:	Result of Ping	Packets in DIST3-PC7	Packets in CORE1-DIST3
PC1	192.10.1.3	Ping Successful	None	ARP Request & Reply, ICMP Packets
PC1	192.10.1.10	Host not reachable	None	ARP Request 3x
PC1	192.20.1.2	Host not reachable	None	ARP Request (through Gateway IP) 3x
PC2	192.20.1.2	Ping Successful	None	ARP Request
PC2	192.30.1.1	Host not reachable	None	ARP Request (through Gateway IP) 3x
PC2	192.40.1.1	Host not reachable	None	ARP Request (through Gateway IP) 3x

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

Na primeira situação (PC1 192.10.1.3) não se vê pacotes na captura DIST3-PC7, pois o ARP Broadcast é apenas transmitido na VLAN 10, o mesmo se aplica a outros exemplos.

Na quarta situação (PC2 192.20.1.2) só se vê um pacote ARP na captura DIST3-CORE1, pois o DIST2 responde ao ARP Request do CORE1 e assim fica aprendido na ARP Table as portas correpondentes que resulta no ping bem sucedido.

VLAN 20

PC2 192.40.1.1

802.1Q Virtual LAN, PRI: 0, DEI: 0, ID: 20

Colocar apenas CORE1 com routing pode originar congestionamento, pois comunicações que poderiam ser resolvidas no DIST1, DIST2 ou DIST3, são resolvidas no CORE1.
No entanto, de forma mais eficiente, podemos configurar todos os L3 Switches com routing para que comunicações dentro de apenas 1 L3 Switch seja resolvido nesse switch e comunicações para VLANs em switches diferentes resolvido no CORE1, diminuindo a change de congestionamento

2. Centralized Routing between VLANs

Copy the previous saved GNS3 template to a new template. In the new template, configure CORE1 as a L3 Switch to route the packets between the IP networks associated with all VLANs and following the default gateway addresses configured on the PCs.

Routing configuration of CORE1:

```
CORE1# configure terminal
CORE1(config)# ip routing           (to activate the routing function)
CORE1(config)# interface vlan10
CORE1(config-if)# ip address 192.10.1.254 255.255.255.0
CORE1(config-if)# no shutdown
CORE1(config-if)# interface vlan20
CORE1(config-if)# ip address 192.20.1.254 255.255.255.0
CORE1(config-if)# no shutdown
CORE1(config-if)# interface vlan30
CORE1(config-if)# ip address 192.30.1.254 255.255.255.0
CORE1(config-if)# no shutdown
CORE1(config-if)# interface vlan40
CORE1(config-if)# ip address 192.40.1.254 255.255.255.0
CORE1(config-if)# no shutdown
CORE1(config-if)# end
CORE1# write
```

Check the resulting configuration:

```
CORE1# show ip interface brief
```

Check the resulting IP routing table:

```
CORE1# show ip route
```

2.a. Check the IP routing table of CORE1 and justify it. Test the connectivity between all pairs of PCs. You should conclude that all PCs have connectivity between them (if not, there are configuration errors that must be identified and corrected).

2.b. What are the connections belonging to the broadcast domain of each existing VLAN? Why?

2.c. Start two Wireshark captures: one in link CORE1-DIST1 and another in link CORE1-DIST3. Execute a ping command from each PC to each IP address as specified next. Register the result of each ping and the packets captured in the two links related to the executed ping. In the analysis of the captured packets, register also the VLAN information in the 802.1q header. Justify these results.

From:	To:	Result of Ping	Packets in CORE1-DIST1	Packets in CORE1-DIST3
PC1	192.10.1.3	Ping Successful	ARP Request & Reply, ICMP Packets	ARP Request & Reply, ICMP Packets
PC1	192.10.1.10	Host not reachable	ARP Request 3x	ARP Request 3x
PC1	192.20.1.2	Ping Successful	ARP Request from PC1 & Reply ARP Request from CORE1 & ICMP Packets	ARP Request from PC1 & ARP Request from CORE1
PC2	192.20.1.2	Ping Successful	ARP Request from CORE1 & Reply ICMP Packets	ARP Request from CORE1
PC2	192.30.1.1	Ping Successful	ARP Request from PC2 & Reply ICMP Packets	ARP Request from PC2
PC2	192.40.1.1	Ping Successful	ARP Request from PC2 & ICMP Packets	ARP Request from PC2 & Reply & ICMP Packets
PC2	192.40.1.10	Timeout	ARP Request from PC1 & Reply CORE1 ARP Request from CORE1	ARP Request from PC1 & ARP Request from CORE1

RECALL FROM THEORETICAL CLASS – In this centralized routing setup, IP routing is centralized in CORE1 equipment. This approach has 2 advantages: (i) no need of IP routing in the distribution switches (L2 Switches are must less expensive than L3 Switches) and (ii) new PCs in any existing VLAN can be connected to any distribution switch with very little configuration (just configure the access mode and the VLAN ID of the interface connecting each new PC).

3. Distributed Routing between VLANs

Copy the GNS3 template saved at the end of Section 1 to a new template. In the new template, the aim is to configure the network routing with a distributed approach:

(a) VLAN 10 and VLAN 20 are end-to-end VLANs: configure CORE1 to route the packets from/to the IP networks associated with these VLANs
  - VLAN 20 reaches only distribution switches DIST1 and DIST2: remove VLAN 20 from the trunk connected to DIST3

(b) VLAN 30 is a local VLAN in DIST2: configure DIST2 to route the packets from/to the IP network associated with VLAN 30 and remove VLAN 30 from all trunks

(c) VLAN 40 is a local VLAN in DIST3: configure DIST3 to route the packets from/to the IP network associated with VLAN 40 and remove VLAN 40 from all trunks

(d) since there are now 3 switches (CORE1, DIST2 and DIST3) with the routing function activated, configure an interconnection VLAN (with a new associated IP network address) between them to allow IP routing between all existing VLANs.

Configure the new GNS3 template following the distributed approach described in (a)–(d). In (d), consider that VLAN 50 is the interconnection VLAN with the associated IP network 192.1.1.0/24. In this new VLAN 50, assign the IP addresses 192.1.1.1 to CORE1, 192.1.1.2 to DIST2 and 192.1.1.3 to DIST3.

Elimination of VLANs 20, 30 and 40 in the trunk CORE1-DIST3:

In CORE1:

```
CORE1# configure terminal
CORE1(config)# interface f1/2
CORE1(config-if)# switchport trunk allowed vlan 20,30,40
CORE1(config-if)# end
CORE1# write
CORE1# show configuration    (to check the resulting configuration)
```

In DIST3:

```
DIST3# configure terminal
DIST3(config)# interface f1/15
DIST3(config-if)# switchport trunk allowed vlan remove 20,30,40
DIST3(config-if)# end
DIST3# write
DIST2# show configuration    (to check the resulting configuration)
```

3.a. Check the IP routing tables of CORE1, DIST2 and DIST 3 and justify each routing table. Test the connectivity between all pairs of PCs using the ping command. Identify the pairs of PCs that still do not have connectivity between them and explain why.

3.b. What are the connections belonging to the broadcast domain of each existing VLAN? Why?

Now, configure in all switches with the routing function activated (i.e., CORE1, DIST2 and DIST 3) appropriate IP static routes to reach full network IP connectivity.

Configuration of IP static routes in DIST2 for the IP networks that are not directly connected to it):

```
DIST2# configure terminal
DIST2(config)# ip route 192.10.1.0 255.255.255.0 192.1.1.1
DIST2(config)# ip route 192.20.1.0 255.255.255.0 192.1.1.1
DIST2(config)# ip route 192.40.1.0 255.255.255.0 192.1.1.3
DIST2# write
```

3.c. Check the IP routing tables of CORE1, DIST2 and DIST 3 and justify each routing table. Test the connectivity between all pairs of PCs. You should conclude that all PCs have connectivity between them (if not, there are configuration errors that must be identified and corrected).

3.d. Start two Wireshark captures: one in link CORE1-DIST1 and another in link CORE1-DIST3. Execute a ping command from each PC to each IP address as specified next. Register the result of each ping and the packets captured in the two links related to the executed ping. In the analysis of the captured packets, register also the VLAN information in the 802.1q header. Justify these results.

From:	To:	Result of Ping	Packets in CORE1-DIST3	Packets in CORE1-DIST1
PC1	192.10.1.3	Successful	ARP Request & Reply, ICMP Request & Reply; VLAN ID: 10	ARP Request & Reply, ICMP Request & Reply; VLAN ID: 10
PC1	192.10.1.10	Unsuccesful	ARP Request	ARP Request
PC1	192.20.1.1	Successful	ARP Broadcast to gateway -> response -> ICMP request (VLAN 10 to 20) -> ARP to find VLAN 20 -> ICMP repley	ARP Request - VLAN 10
PC1	192.30.1.1	Successful	ARP Request & Reply, ICMP Request & Reply; VLAN 10	ARP Request - VLAN 10 ARP Request - VLAN 50
PC1	192.40.1.1	Successful	ARP Request & Reply, ICMP Request & Reply through VLAN 50	ARP Request - VLAN 10; ARP Request - VLAN 50
PC4	192.10.1.2	Successful	Nothing	Nothing
PC4	192.40.1.1	Successful	ARP Request & Reply, ICMP Request & Reply through VLAN 50	Nothing
PC5	192.40.1.1	Successful	ICMP Request & Reply trough VLAN 50	Nothing
PC5	192.40.1.10	Unsuccesful	ICMP Request through VLAN 50	Nothing

RECALL FROM THEORETICAL CLASS – In this distributed routing setup, IP routing is distributed between CORE1, DIST2 and DIST3 equipment. This approach has the advantage of being a more scalable solution, i.e., a larger number of distribution switches can be deployed without significant grow of the broadcast domains (avoiding their performance issues) and maintaining an equal routing effort among all equipment.

3.a)

```
CORE1#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

C    192.20.1.0/24 is directly connected, Vlan20
S    192.30.1.0/24 [1/0] via 192.1.1.2
C    192.1.1.0/24 is directly connected, Vlan50
C    192.10.1.0/24 is directly connected, Vlan10
S    192.40.1.0/24 [1/0] via 192.1.1.3
```

```
DIST2#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

S    192.20.1.0/24 [1/0] via 192.1.1.1
C    192.30.1.0/24 is directly connected, Vlan30
C    192.1.1.0/24 is directly connected, Vlan50
S    192.10.1.0/24 [1/0] via 192.1.1.1
S    192.40.1.0/24 [1/0] via 192.1.1.3
```

```
DIST3#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

S    192.20.1.0/24 [1/0] via 192.1.1.1
S    192.30.1.0/24 [1/0] via 192.1.1.2
C    192.1.1.0/24 is directly connected, Vlan50
S    192.10.1.0/24 [1/0] via 192.1.1.1
C    192.40.1.0/24 is directly connected, Vlan40
```

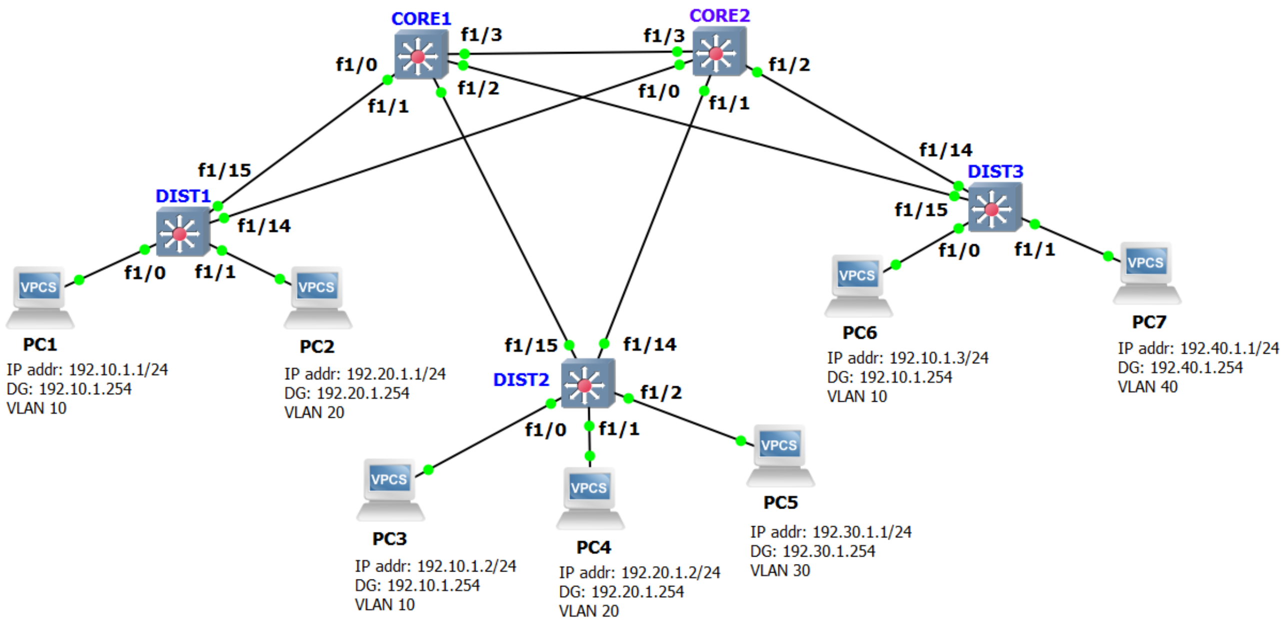
CORE1 é o único que consegue resolver pacotes vindos das VLANs 30 e 40 para VLANs 10 e 20.
Como ainda nao foram definidas static routes para as VLANs 30 e 40 conseguirem comunicar só é possível fazer pings entre as VLANs 10 e 20.

3.c)

Agora que os switches estão com routing ativo, estes, a partir da VLAN 50, consegues transmitir e receber pacotes vindos das VLANs 30 e 40, pois os pacotes têm um next hop para a VLAN 50, a VLAN 50 consegue comunicar com todas as outras VLANs a que lhe foi configurado route.

4. Redundant LANs with Spanning Tree

Copy the GNS3 template saved at the end of Section 1 to a new template (recall that there is no routing configuration between VLANs in this template). Before running the new template, add to the network configuration a new core switch (CORE2) with the new connections as shown in the next figure.



Run the new template, configure the new inserted links as trunk links and configure the new CORE2 to support all existing VLANs (i.e., 10, 20, 30 and 40).

4.a. Run `show vlan-switch` on each switch to check that all VLANs are end-to-end VLANs. ✓

4.b. Run `show spanning-tree bridge` on each switch to identify its *bridge ID* on each VLAN. ✓

4.c. Run `show spanning-tree brief` on each switch to identify the *port ID* and the *port Cost* of each interface belonging to each VLAN. A porta a que fica atribuido o block é decidida com base no ID mais alto (MAC) se o custo for igual.

4.d. The information displayed by the command `show spanning-tree brief` on each switch also enables the identification of the resulting spanning tree for each VLAN. Analyze:

(i) the ID of the *root bridge*, 32768
(ii) the state of each interface (*forwarding* or *blocking*) and
(iii) the ID of the *designated bridge* on each link and.

Justify the spanning tree of each VLAN based on the observed parameters in **4.b** and **4.c**.

4.e. Start two Wireshark captures: one in link DIST1-CORE1 and another in link DIST1-CORE2. Analyze the spanning tree packets, justify their content and confirm that they are periodically sent by the *designated bridge*. Analyze also the PVST packets and confirm that they support the implementation of a spanning tree for each existing VLAN. ✓

4.f. Shutdown the interface `f1/0` of CORE1 (simulating a link failure). Run `show spanning-tree brief` on each switch and analyze the resulting spanning tree for each VLAN:

(i) the ID of the *root bridge*,
(ii) the state of each interface (*forwarding* or *blocking*) and
(iii) the ID of the *designated bridge* on each link and.

Justify again the spanning tree of each VLAN based on the parameters observed in **4.b** and **4.c**.

Activate the interface `f1/0` of CORE1 (i.e., run `no shutdown` on the interface). Start a never-ending ping command at PC1 to PC6 (at PC1, run `ping 19.10.1.3 -t`). Start two Wireshark captures: one in link DIST1-CORE1 and another in link DIST1-CORE2.

4.g. Register in which captures the ICMP Echo Request and Echo Reply packets exchanged between PC1 and PC6 are observed. Justify the observations based on the spanning trees analyzed in **4.d**.

4.h. Shutdown the interface `f1/0` of CORE1. Register in which captures the ICMP Echo Request and Echo Reply packets are observed until the connectivity between PC1 and PC6 is restored. Justify the observations based on the spanning trees analyzed in **4.f**. Não aconteceu nada?

4.i. Activate again the interface `f1/0` of CORE1. Register in which captures the ICMP Echo Request and Echo Reply packets are observed until the connectivity between PC1 and PC6 is restored. Justify the observations.

Stop the two Wireshark captures and the never-ending ping command at PC1 (by insertion of `Ctrl+C`). Configure the routing between the different existing VLANs in the following way:

(a) configure CORE1 to route the packets from/to the IP networks associated with VLAN 30 and 40 ✓
(b) configure CORE2 to route the packets from/to the IP networks associated with VLAN 10 and 20 ✓
(c) configure an interconnection VLAN 50 (with the associated IP network 192.1.1.0/24) between CORE1 and CORE2 to allow IP routing between all existing VLANs (the new VLAN 50 must be included in the database of all distribution switches to become a redundant VLAN) ✓
(d) configure the appropriate static routes between CORE1 and CORE2 to reach full IP connectivity ✓

4.j. Check the IP routing tables of CORE1 and CORE2 and justify each routing table. Test the connectivity between all pairs of PCs. You should conclude that all PCs have connectivity between them (if not, there are configuration errors that must be identified and corrected). ✓

4.k. Start two Wireshark captures: one in link DIST1-CORE1 and another in link DIST1-CORE2. Execute a ping from PC1 to PC2. Register in which captures the exchanged ICMP Echo Request and Echo Reply packets are observed. Explain why the current spanning trees of the VLANs involved in this ping are not optimal.

4.l. What should be the optimal spanning tree for each VLAN? What changes in the spanning tree parameters (either *priority* values of the *bridge IDs* or/and *port Cost* values of interfaces) allow the setup optimal spanning tree for each VLAN? Configure these changes in the appropriate switches. Run the command `show spanning-tree brief` on each switch to verify that the resulting spanning trees are as required.

Configuration example of the *priority* value of CORE2 *bridge ID* for VLAN 10:

```
CORE2# configure terminal
CORE2(config)# spanning-tree vlan 10 priority 16384
CORE2(config)# end
CORE2# write
```

Configuration example of the *port Cost* value of CORE2 interface `f1/3` for VLAN 20:

```
CORE2# configure terminal
CORE2(config)# interface f1/3
CORE2(config-if)# spanning-tree vlan 20 cost 5
CORE2(config-if)# end
CORE2# write
```

DISTs:
conf t
interface f1/15
spanning-tree vlan 10 cost 39
spanning-tree vlan 20 cost 39
end
write

4.m. Repeat experiment **4.k** to confirm that the IPCM packets are now sent through the optimal paths.

4.e) – Justifique os pacotes Spanning Tree e PVST:
Os BPDU carregam informações (Bridge ID, Port ID, custo, timers) e são enviados periodicamente pelo designated bridge para atualizar a topologia. Os pacotes PVST permitem que cada VLAN tenha sua própria árvore, garantindo uma rede redundante sem loops.

4.f) – Justifique a spanning tree após a falha (shutdown de f1/0 em CORE1):
Com a falha, a topologia é recalculada: os caminhos de backup são ativados com base nos custos e Bridge IDs restantes, fazendo com que portas anteriormente bloqueadas passem para o estado forwarding para manter uma rede livre de loops.

4.g) Os pacotes ICMP de PC1 para PC6 passam pelo link DIST1–CORE2 porque a spanning tree para a VLAN em uso selecionou esse caminho como rota principal (as outras interfaces estão em bloqueio ou têm custo maior)

4.k) Os pacotes ICMP entre PC1 e PC2 estão a ser capturados apenas no link DIST1–CORE2. Isso ocorre devido aos valores de prioridade e/ou custo de porta não otimizados, resultando numa rota subótima.

4.L) nao sei responder