Fundamentos de Redes

Laboratory Guide no. 2

Objectives

- The Virtual LAN (VLAN) concept
- Analysis of the IEEE802.1Q VLAN protocol
- Interconnection of VLANs
- The Spanning Tree routing concept
- Analysis of the IEEE802.1D Spanning Tree protocol.

Duration

- 4 weeks

Note: In GNS3, a Layer 2 switch may me implement (i) with a basic device (Ethernet switch device) that does not have console and does not support the Spanning Tree Protocol, or (ii) with a switching module in a router (EtherSwitch router device). This guide will use the latter, **EtherSwitch router** as Layer 2 switch **using only the switching module ports** (e.g., F1/0 to F1/15).

Experiments with Virtual LANs

1.1. Set up the network shown in the following figure and configure all IP addresses with netmask 255.255.255.0.

In Switch 1, configure two VLANs in the following way:

a) ports numbered F1/5 to F1/8 belonging to VLAN 2 (must be created);

```
ESW1# vlan database
ESW1(vlan)# vlan 2
ESW1(vlan)# exit
ESW1# configure terminal
ESW1(config)# interface range F1/5 - 8
ESW1(config-if-range)# switchport access vlan 2
ESW1(config-if-range)# end
ESW1# write
```

b) all other ports belonging to VLAN 1 (the default/native VLAN).

To verify the VLAN associated with each interface, use the command:

```
ESW1# show vlan-switch
```

Configure VLAN 1 interface of Switch1:

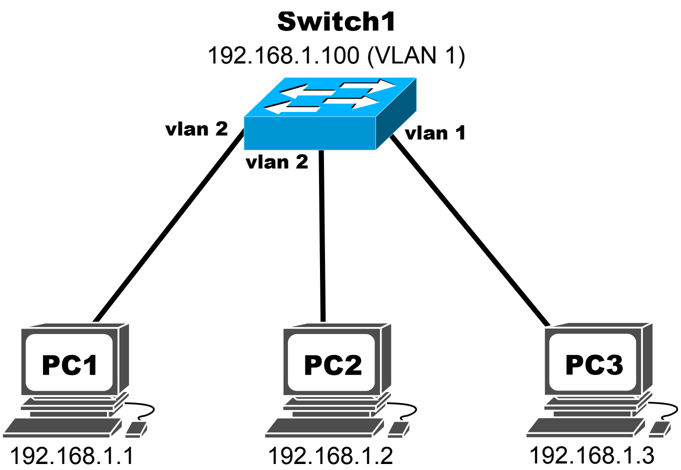
```
ESW1(config)# interface vlan 1
ESW1(config-if)# ip address 192.168.1.100 255.255.255.0
ESW1(config-if)# no shutdown
ESW1(config-if-range)# end
ESW1# write
```

In all PCs, configure the appropriate the IPv4 address.

For PC1:

```
PC-1> ip 192.168.1.1/24
```

Note: Cisco equipment have VLAN 1002 to 1005 by default (for proprietary protocols) that cannot be deleted.



Troubleshooting 1: When creating the VLAN, if a flash memory space error occurs, run the command

```
ESW1# erase flash:
```

to erase the flash, and after, create the missing VLAN.

1.2. Connect PC1 and PC2 to VLAN 2 ports and PC3 to a VLAN 1 port, as specified in the figure.

Troubleshooting 2: Verify if all the interfaces with connections are `up` with the command:

```
ESW1# show ip interface brief
```

if not, perform a `shutdown` followed by a `no shutdown` on the respective interface.

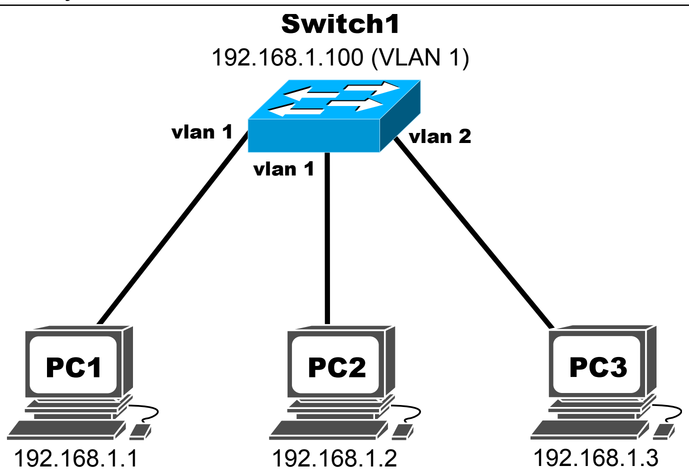
1.3. From each equipment run the ping command to check which pairs of equipment (including Switch 1) have IP connectivity. Verify that only equipment in the same VLAN has IP connectivity.

1.4. Start captures on the links PC1-Switch1 and PC3-Switch1 and set an appropriate filter to display ARP and ICMP packets. Run the ping commands specified in the following table. For each run, register the connectivity and the filtered packets. Justify the results obtained on each case.

Ping from:	**Ping to:**	**Connectivity (yes or no)**	**Packets (PC1-Switch1 link)**	**Packets (PC3-Switch1 link)**
PC2	Switch1	no	ARP Req (not answered)	Nothing
PC2	PC3	no	ARP Req (not answered)	Nothing
PC2	192.168.1.34	no?	ARP Req (not answered)	Nothing
PC3	Switch 1	yes	Nothing	ARP Req/Ans. 5 ICMP requests & replies
PC3	PC2	no	Nothing	ARP Req (not answered)
PC3	192.168.1.34	no?	Nothing	ARP Req (not answered)
Switch1	PC3	yes	Nothing	5 ICMP requests & replies
Switch1	192.168.1.34	no?	Nothing	ARP Req (not answered)

All worked according to the predicted

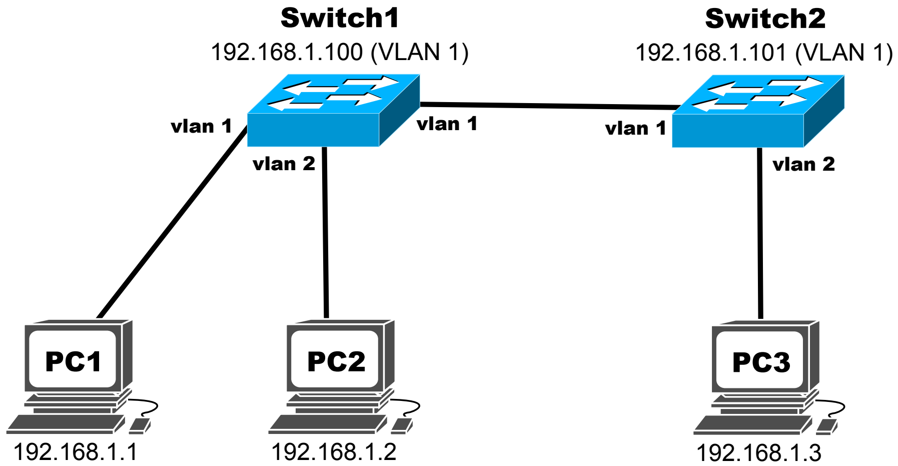
2.1. In Switch 1, change the connections in order to connect PC1 and PC2 to VLAN 1 ports and PC3 to a VLAN 2 port (as specified in the next figure). Using the ping command, register and justify the pairs of equipment (including Switch 1) that have connectivity. Once again, verify that only equipment in the same VLAN has IP connectivity.



2.2. Start new captures on the links PC1-Switch1 and PC3-Switch1 and set an appropriate filter to display ARP and ICMP packets. Run the ping commands specified in the following table. For each run, register the connectivity and the filtered packets. Justify the results obtained on each case.

Ping from:	Ping to:	Connectivity (yes or no)	Packets (PC1-Switch1 link)	Packets (PC3-Switch1 link)
PC2	Switch1	yes	Can't be done (L2 Switch)	Can't be done (L2 switch)
PC2	PC3	no	ARP req (not answered)	Nothing
PC2	192.168.1.34	no?	ARP req (not answered)	Nothing
PC3	Switch 1	no	Can't be done (L2 Switch)	Can't be done (L2 switch)
PC3	PC2	no	Nothing	ARP req (not answered)
PC3	192.168.1.34	no?	Nothing	ARP req (not answered)
Switch1	PC3	no	Can't be done (L2 Switch)	Can't be done (L2 switch)
Switch1	192.168.1.34	no	Can't be done (L2 Switch)	Can't be done (L2 switch)

3. Reconfigure the network as specified in the following figure. In the new inserted Switch 2, configure VLANs 1 and 2 in the same way as specified to Switch 1 in the previous experiments.

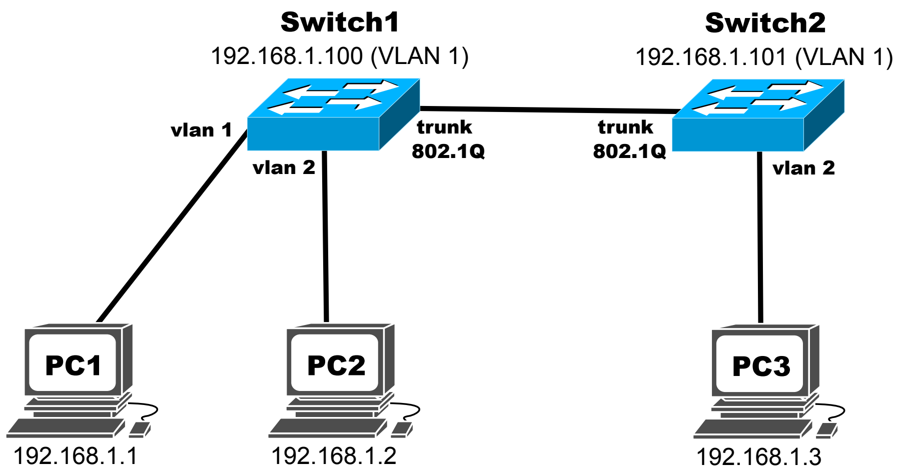


3.1. Start new capture on the link Swicth1-Switch2 and set an appropriate filter to display ARP and ICMP packets. Run the ping commands specified in the following table. For each run, register the connectivity and the filtered packets. Justify the results obtained on each case.

Ping from:	Ping to:	Connectivity (yes or no)	Filtered packets
PC1	Switch 1	yes	ARP requests & replies
PC1	Switch 2	yes	ARP requests & replies. ICMP Requests & Replies
PC1	PC2	no	ARP requests not answered
PC1	PC3	no	ARP requests not answered
PC2	Switch 1	no	nothing
PC2	Switch 2	no	nothing
PC2	PC2	yes	nothing
PC2	PC3	no	nothing

4. At both Switches 1 and 2, configure the ports connecting the switches as a trunk port (e.g., F1/15) in order to support both VLAN using the IEEE802.1Q VLAN protocol, as specified in the following figure.

```
ESW3(config)# interface F1/15
ESW3(config-if)# switchport mode trunk
```



4.1. Start new capture on the link Swicth1-Switch2 and set an appropriate filter to display ARP and ICMP packets. Run the ping commands specified in the following table. For each run, register the filtered packets and their VLAN ID value. Justify the results obtained on each case. For each case, compare these results with the ones observed in experiment 3.1.

VLAN ID	Ping from:	Ping to:	Connectivity (yes or no)	Filtered packets
N/A	PC1	Switch 1	yes	ARP requests
N/A	PC1	Switch 2	yes	ICMP requests & replies. ARPs
N/A	PC1	PC2	no	ARP
N/A	PC1	PC3	no	ARP. No ICMP!
0010 (2)	PC2	Switch 1	no	ARP
2	PC2	Switch 2	no	ARP
-	PC2	PC2	yes	NOTHING!
2 (both)	PC2	PC3	yes	ICMP requests & replies. ARPs

Format of the Ethernet frames with and without 802.1Q tags

Ethernet frame without 802.1Q tag

Destination Address (6 *bytes*)
Source Address (6 *bytes*)
Type / Length (2 *bytes*)
Data Field

Ethernet frame with 802.1Q tag

Destination Address (6 *bytes*)
Source Address (6 *bytes*)
8100h (2 *bytes*)
Priority (3 *bits*)
CFI (1 *bit*)
VLAN ID (12 *bits*)
Type / Length (2 *bytes*)
Data Field

5. Reconfigure the network as specified in the following figure where the Router routes packets between VLAN 2 and VLAN 3 (each one with its own network IP address).

In Switch 1, configure the VLAN in the following way:

a) ports numbered F1/0 to F1/4 belonging to VLAN 3 (must be created);

```
ESW1# vlan database
ESW1(vlan)# vlan 3
ESW1(vlan)# exit
ESW1(config)# interface range F1/0 - 4
ESW1(config-if-range)# switchport access vlan 3
```

b) ports numbered F1/5 to F1/8 belonging to VLAN 2;

c) all other ports belonging to VLAN 1 (the default/native VLAN).

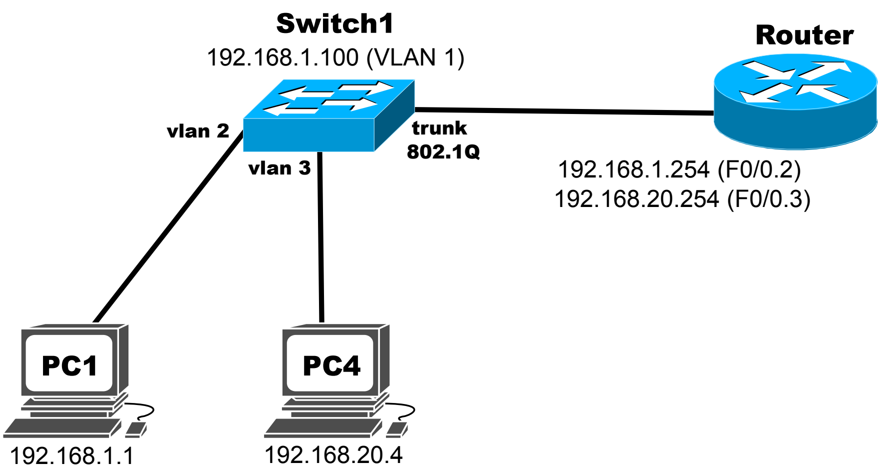
In the Router, create 2 virtual interfaces on interface F0/0, one for VLAN 2 (F0/0.2) and another for VLAN 3 (F0/0.3), with the given IP addresses:

```
Router (config)# interface F0/0
Router (config-if)# no shutdown
Router (config-if)# interface F0/0.2
Router (config-subif)# encapsulation dot1Q 2
Router (config-subif)# ip address 192.168.1.254 255.255.255.0
Router (config-if)# interface F0/0.3
Router (config-subif)# encapsulation dot1Q 3
Router (config-subif)# ip address 192.168.20.254 255.255.255.0
```

In both PCs, configure the appropriate the IPv4 address and Default Gateway address.

For PC1:

```
PC-1> ip 192.168.1.1/24 192.168.1.254
```



5.1. In order to verify the correctness of the configurations, check the IP connectivity between PC1 and PC4 with the ping command. Register and justify the IP routing table of the Router.

Use the command to view the IPv4 routing table:

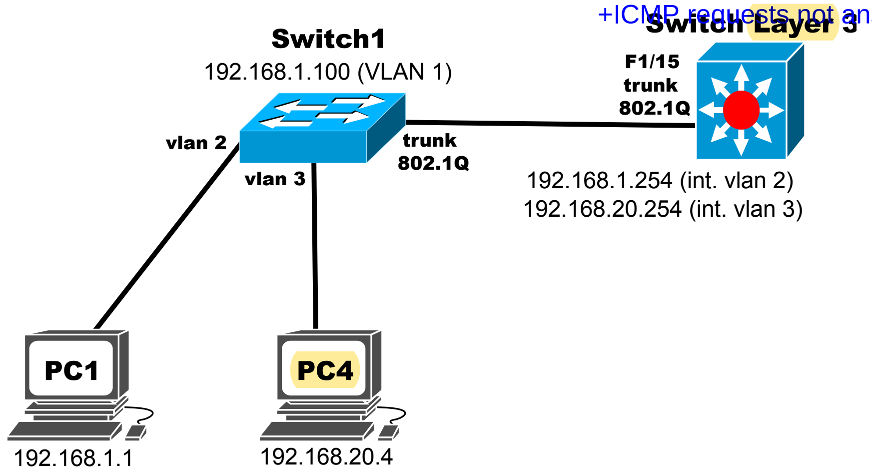
`Router# show ip route` 192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks

192.168.20.0/24 is variably subnetted, 2 subnets, 2 masks

5.2. Start new capture on the link Swicth1-Router and set an appropriate filter to display ARP and ICMP packets. Run the ping commands specified in the following table. For each run, register the filtered packets and their VLAN ID value. Justify the results obtained on each case.

Attention to paths between devices from different networks with the router in between!

Ping from:	Ping to:	Connectivity (yes or no)	Filtered packets	VLAN ID
PC1	Switch 1	no	ARP requests not answered	2
PC1	Router	yes	ARP + ICMP requests & replies	2
PC1	PC4	yes (router)	ARP + ICMP requests & replies	2 then 3
PC1	192.1.1.100	no	ARP req + rep & ICMP requ not answ	2
PC4	Switch 1	no	See note	
PC4	Router	yes	ARP + ICMP requests & replies	3
PC4	PC1	yes	ARP + ICMP req & repl & not answ	3 then 2
PC4	192.1.1.100	no	ARP requests not answered +ICMP requests not answered	3



5.3. Reconfigure the network as specified in the previous figure where the inter-VLAN routing is performed by a Layer 3 switch (GNS3 *EtherSwitch Router*).

Create VLANs 2 and 3 at the L3 Switch (VLAN2 and 3):

```
ESW1# vlan database
ESW1(vlan)# vlan 2
ESW1(vlan)# vlan 3
ESW1(vlan)# exit
```

Activate IPv4 routing (most times is active by default):

```
ESW1(config)# ip routing
```

Configure the ports that connects to Switch1 as trunk (802.1Q):

```
ESW1(config)# interface F1/15
ESW1(config-if)# switchport mode trunk
```

Configure the Switch L3 virtual (Vlan) interfaces:

```
ESW1(config)# interface Vlan 2
ESW1(config-if)# ip address 192.168.1.254 255.255.255.0
ESW1(config-if)# no autostate                          !forces the port to be always up
ESW1(config)# interface Vlan 3
ESW1(config-if)# ip address 192.168.20.254 255.255.255.0
ESW1(config-if)# no autostate                          !forces the port to be always up
```

Check the IP connectivity between PC1 and PC4 with the ping command. Register and justify the IP routing table of the Layer 3 switch.

C 192.168.20.0/24 is directly connected, VLAN3

C 192.168.1.0/24 is directly connected, VLAN2

Spanning Tree Protocol (STP)

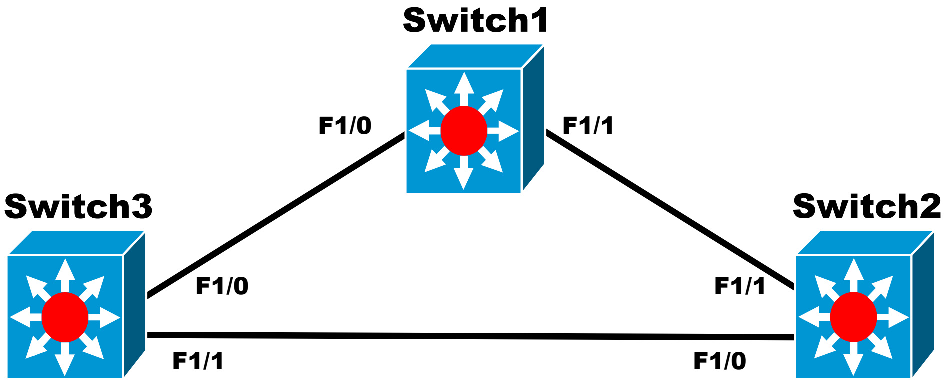
6. In GNS3 configure a network as specified in the following figure, using the connections of the switching module (ports F1/0 to F1/15) of the *"EtherSwitch Routers"*. Verify that all used ports belong to VLAN 1:

```
ESW1# show vlan-switch
```

Based on the result of command

```
ESW1# show spanning-tree vlan 1
```

check the configured *spanning tree* and register/identify the following information: MAC address of each bridge, priority of each bridge, *bridge IDs, root bridge*, *designated bridges* for each LAN, root port for each *bridge*, designated ports for each *bridge*, the root path cost of each *bridge* and the cost of all ports.



6.1. Start a capture in each LAN (SW1-SW2, SW1-SW3 e SW2-SW3). Analyse the BPDU/STP captured packets, register its contents and confirm their coherence with the results obtained in experiment 1. Which *bridge* is responsible for sending BPDUs in each local network?

Format of the configuration BPDU packets

<table>
<tr><th>#octets</th><th colspan="3"></th></tr>
<tr><td>2</td><td colspan="3">Protocol Identifier</td></tr>
<tr><td>1</td><td colspan="3">Version</td></tr>
<tr><td>1</td><td colspan="3">Message Type</td></tr>
<tr><td>1</td><td>TCA</td><td>Reserved</td><td>TC</td></tr>
<tr><td>8</td><td colspan="3">Root ID</td></tr>
<tr><td>4</td><td colspan="3">Cost of Path to Root</td></tr>
<tr><td>8</td><td colspan="3">Bridge ID</td></tr>
<tr><td>2</td><td colspan="3">Port ID</td></tr>
<tr><td>2</td><td colspan="3">Message Age</td></tr>
<tr><td>2</td><td colspan="3">Max Age</td></tr>
<tr><td>2</td><td colspan="3">Hello Time</td></tr>
<tr><td>2</td><td colspan="3">Forward Delay</td></tr>
</table>

6.2. Pause all *switches* and stop all captures. Now that you know the *Bridge ID* of the three switches, start a capture in the Ethernet network that interconnects the two switches with the higher IDs. Execute the following sequence of actions:

(i) Restart the *switch* with the highest *Bridge* ID, wait two minutes and analyse the sequence of captured BPDU/STP packets;

(ii) Restart the *switch* with the intermediate *Bridge* ID, wait two minutes and analyse the sequence of captured BPDU/STP packets;

(iii) Restart the *switch* with the lowest *Bridge* ID, wait two minutes and analyse the sequence of captured BPDU/STP packets.

Based on the results of the captures, explain the construction mechanism of the *spanning tree*.

6.3. Start a capture in all LANs (SW1-SW2, SW1-SW3 and SW2-SW3). Change the priority of one *bridge* in such a way that it becomes the *root bridge*.

```
ESW1# configure terminal
ESW1(config)# spanning-tree vlan 1 priority <value>
```

Analyse the captured BPDU/STP packets and explain the re-election process of the root *bridge*.

6.4. Start a capture in all LANs (SW1-SW2, SW1-SW3 and SW2-SW3). Change in the designated bridge of the network that is not connected to the root bridge the cost of its root port in such a way that it stops being the designated bridge, using the following commands:

```
ESW1# configure terminal
ESW1(config)# interface <interface>
ESW1(config-if)# spanning-tree cost <value>
```

Since there was a change in the *Spanning Tree* protocol parameters, the topology change notification mechanism is triggered. Let the capture last for a period of at least 1 minute after changing the port cost. Analyse the sequence of captured packets and verify if BPDU packets of the TCN type were sent and if there were any changes on the TC and TCA *flags* of the *Configuration BPDU* packets.

Format of the TCN (*Topology Change Notification*) packets

#octets	
2	Protocol Identifier
1	Version
1	Message Type

6.5. Start a capture on the Ethernet network that is not directly connected to the *root bridge*.

The bridge *Hello Time* parameter can be changed with the following commands

```
ESW# configure terminal
ESW1(config)# spanning-tree vlan 1 hello-time <value>
```

Execute the following sequence of actions:

(i) change the *Hello time* parameter of the *root bridge* to 6 seconds and, using Wireshark, verify the periodicity of the generated BPDU packets;

(ii) reassign the default value of the *Hello Time* parameter in the *root bridge*, change this parameter in the designated bridge of the PC network to 6 seconds and verify the periodicity of the BPDU packets that are sent.

What do you conclude about the effect of configuring the *Hello Time* parameter in different *switches* on the general functioning behaviour of the *Spanning Tree* protocol?

Extra (*Per-VLAN Spanning-Tree*)

7. Create VLAN 2 on the different *switches,* define all connections between *switches* as i*nter-switch*/*trunk* connections*.*

```
ESW1# vlan database
ESW1(vlan)# vlan 2
ESW1(vlan)# apply
ESW1(vlan)# exit
ESW1# configure terminal
ESW1(config)# interface f1/0
ESW1(config-if)# switchport mode trunk
ESW1(config)# interface f1/1
ESW1(config-if)# switchport mode trunk
```

Verify the state of each Spanning-Tree process in each one of the configured VLANs:

```
ESW1# show spanning-tree
ESW1# show spanning-tree vlan 1
ESW1# show spanning-tree vlan 2
```

Start a capture in all LANs (SW1-SW2, SW1-SW3 and SW2-SW3) and analyse the BPDU/PVST packets that were captured (namely the 802.1Q tag of the Ethernet frames).

Note 1: *Per-VLAN Spanning-Tree* (PVST) treats each VLAN as a separate network.

Note 2: For the native VLAN (1, by default) no 802.1Q tags are added.

7.1. Change the *root bridge* (by changing the *bridge priority*) only on VLAN 2:

```
ESW1# configure terminal
ESW1(config)# spanning-tree vlan 2 priority <value>
```

Verify the state of the *Spanning Tree* processes in each VLAN:

```
ESW1# show spanning-tree
ESW1# show spanning-tree vlan 1
ESW1# show spanning-tree vlan 2
```