



Sample network topologies using VLAN and implemented with GNS3 for educational purposes

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Abstract: This article is dedicated to the implementation of VLAN topologies for educational purposes implemented with the GNS3 specialized simulation system. Sample problems and solutions are at the heart of this paper and are intended, but not limited to, teaching and learning in the context of the laboratory sessions in Computer Networks and Communications at the Faculty of Mathematics and Informatics with University of Plovdiv Paisii Hilendarski with students majoring in the professional field of Computer Science. They can be used before, during and after lab classes for self-assessment and peer evaluation of students' knowledge, skills and competences.

Keywords: Computer Networks, Communications, simulation, VLAN, GNS3

I. Introduction

This article is a follow-up to a previous work [1] dedicated to the use of the specialized simulation system GNS3 [2] to implement virtual network topologies during laboratory sessions in Computer Networks and Communications (CNC) at the Faculty of Mathematics and Informatics with University of Plovdiv Paisii Hilendarski involving students majoring in the professional field of Computer Science [3][4][5][6]. GNS3 allows students to design, build and test computer networks in a risk-free environment. It is suitable for self-assessment and peer evaluation of students' knowledge and skills, e.g. to ascertain how well they have prepared for hands-on lab practicals at universities or vocational schools, for reinforcement of theoretical knowledge, as well as for a host of other didactic purposes [7][8][9]. In a previous publication we discussed some tasks related to the implementation of relatively simple network topologies involving one or several intermediary devices, e.g. one router and up to several switches, while configuring them resembles the settings involved in the most common implementations of home and office networks. Our examples used a Cisco router as a routing device. This requires acquainting trainees with some basic commands to be used for achieving the desired configuration. These commands can be referenced in Cisco's on-line manual [10][11]. The major didactic aim sought after is to teach students learn to configure networks, subnetworks, and to calculate network addresses [12]. This paper is dedicated to some assignments introducing students to the importance and operation of virtual local networks (VLAN).

II. Using VLAN

Virtual local networks (VLANs-Virtual LANs) can be used for dividing a certain network into logically separate segments [13]. They do not have their own physical infrastructure. One of the goals here is to reduce the size of broadcast domains. This type of networks allow to logically group physically separated network devices. Unicast, multicast, and broadcast packets belonging to a certain virtual network solely reach its members. The packets meant for devices outside the virtual network should pass through a router, therefore VLANs are connected using IP subnetworks. The transfer of traffic through VLANs is defined in the IEEE 802.1q standard. Identification of the frames of separate virtual networks is done via markers called tags (VLAN tags). A VLAN tag is 4 bytes (32-bit) long and is added to the header of the Ethernet frame between the source MAC and EtherType fields (Figure 1).

Figure 1 VLAN tag

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18 ...31
Destination address						Source address						VLAN tag				EtherType	Payload	
												0x8100		TCI				

The first two bytes (Figure 2) of the tag contain a protocol identifier (TPID - Tag protocol identifier) set to 0x8100. This identifier falls to the position of the EtherType field of a regular frame, which contributes to its

identification as a tagged frame. The second 2 bytes are denoted as TCI (Tag control information) and are allocated as follows:

PCP (Priority code point) - 3 bits to define priority with values ranging from 0 to 7;

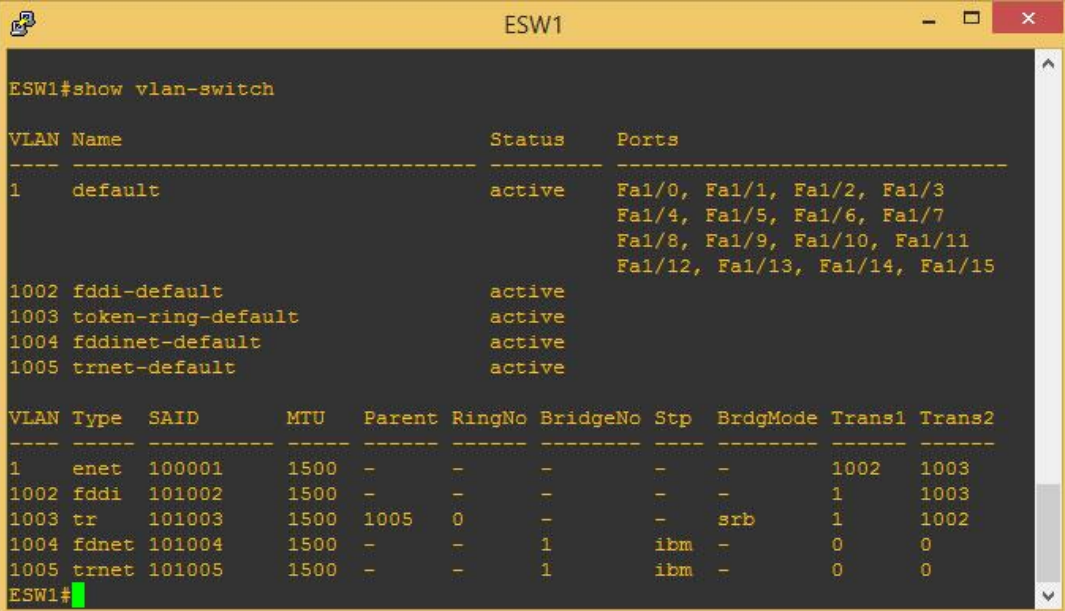
DEI (Drop eligible indicator) – 1 bit which is set to 0 for the Ethernet protocol;

VID (VLAN identifier) – 12-bit field for the VLAN number. The maximum value is $2^{12}=4096$. VLAN 1 is reserved and is set by default (Figure 3). Initially, the ports of each managed switch are members of VLAN 1 and it operates as an unmanaged one. A VID 0 tag means that the frame does not belong to any of the VLANs and carries only priority information. The last VLAN 4095 is reserved.

Figure 2 TPID and TCI

16 bits	3 bits	1 bit	12 bits
TPID=0x8100	TCI		
	PCP	DEI	VID

Figure 3 VLAN 1 is reserved and is set by default



```

ESW1#show vlan-switch

VLAN Name                Status    Ports
-----
1    default                active    Fa1/0, Fa1/1, Fa1/2, Fa1/3
                                           Fa1/4, Fa1/5, Fa1/6, Fa1/7
                                           Fa1/8, Fa1/9, Fa1/10, Fa1/11
                                           Fa1/12, Fa1/13, Fa1/14, Fa1/15
1002 fddi-default           active
1003 token-ring-default    active
1004 fddinet-default       active
1005 trnet-default         active

VLAN Type  SAID      MTU    Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2
-----
1    enet    100001    1500   -       -       -    -       -       1002  1003
1002 fddi    101002    1500   -       -       -    -       -       1       1003
1003 tr     101003    1500   1005    0       -    -       srb     1       1002
1004 fdnet 101004    1500   -       -       1    -       ibm     0       0
1005 trnet 101005    1500   -       -       1    -       ibm     0       0
ESW1#

```

VLANs are maintained by the manageable switches. Their MAC address table is different from the address table of regular L2 routers in terms of the additional column for VID of the VLAN. The address table of common routers has the following columns: **Port number**, **MAC address**, Age. It is thanks to this extra VID column that makes it possible to identify the members to be sent this particular frame from a specific VLAN.

Each port of the router can operate in one of the following modes:

access mode - when in this mode, the port belongs to one VLAN and the frames it serves are untagged;

trunk mode (tagged) - in this mode, the frames passing through the port are tagged. When a certain interface is configured as trunk, all frames of the separate VLANs passing through it are tagged. An exception is VLAN 1, which is referred to as native. There is a possibility to restrict the number of VLANs that can pass through the port

dynamic - in this mode the operation of the port is set dynamically depending on the configuration of its counterpart.

Task 1. Implement the topology of a LAN (Figure 4), complying with these requirements:

Use a Cisco c3725 router with an added module NM-16ESW;

Additional information: Module NM-16ESW supports 16 Fastethernet interfaces and adds the functionality of an L3 switch to the router. Its installation can be implemented during the initial import of the **image** file or after placing the router icon on the workplace pane and the relevant option from the Configure context menu is used. The slot used is slot 1.

At least four VPCS devices (PC1, PC2, PC3 и PC4), connected to ports of the NM-16ESW module;

The TCP / IP configuration settings of the computers will be set by a DHCP server.

Tips: In order that VPCS devices connected to different ports of the NM-16ESW module can share a DHCP server, they need to be grouped in a unified virtual network. By default, the module ports are members of VLAN 1, which satisfies the condition for such a network.

Solution:

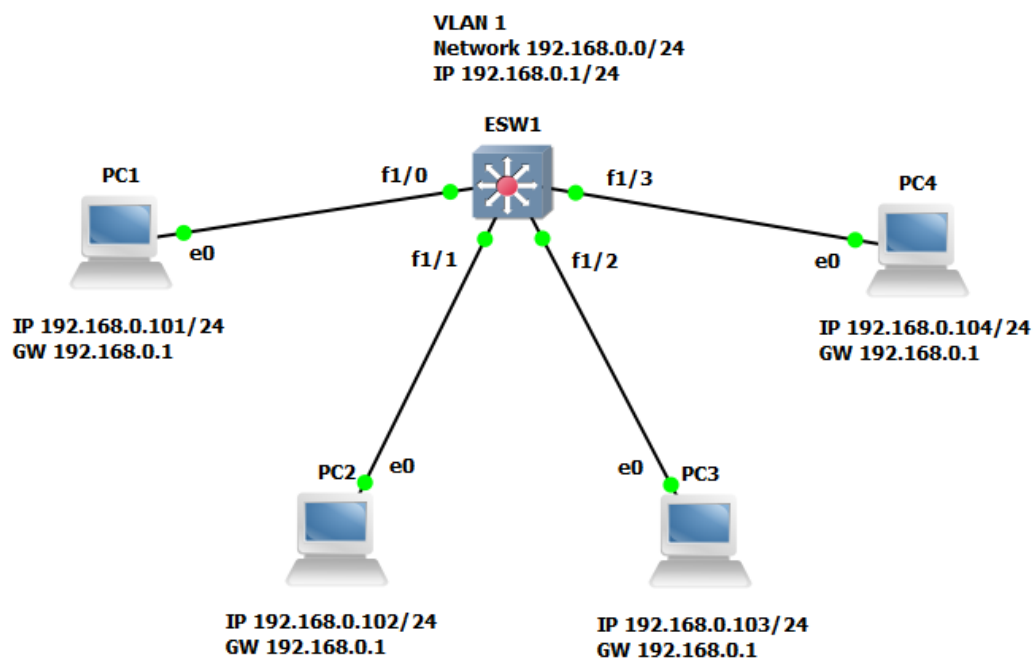
1. At least four VPCS (PC1, PC2, PC3 and PC4) are dragged from the device pane onto the workplace pane;
2. An EtherSwitch router 3725 (ESW1) is added. This is the name set during the initial setup of the **image** file of the Cisco router c3725, with an NM-16ESW module installed;
3. Use the contextual menu of the router and each VPCS to select the start option;
4. VPCS devices (PC1, PC2, PC3 and PC4) will be connected to selected Ethernet ports of the router using the link icon;
5. Use the router's console to input the following set of commands:

```

ESW1#configure terminal
ESW1(config)#ip dhcp pool pool_vlan1
ESW1(dhcp-config)#network 192.168.0.0 255.255.255.0
ESW1(dhcp-config)#default-router 192.168.0.1
ESW1(dhcp-config)#dns-server 192.168.0.1
ESW1(dhcp-config)#lease 1 12 59
ESW1(dhcp-config)#domain-name vlan1.com
ESW1(dhcp-config)#exit
ESW1(config)#ip dhcp excluded-address 192.168.0.1 192.168.0.100
ESW1(config)#interface vlan 1
ESW1(config-if)#ip address 192.168.0.1 255.255.255.0
ESW1(config-if)#no shutdown
ESW1(config-if)#exit
ESW1(config)#exit
ESW1#write
ESW1#copy running-config startup-config

```
6. In each computer's console, it starts the procedure for obtaining the TCP/IP configuration settings from the implemented DHCP server using the command: **ip dhcp**;
7. The physical connectivity among computers can be tested via the ping command.

Figure 4 Sample VLAN for simulation 1



Task 2. Implement the topology of a LAN (Figure 5), complying with these requirements:

Use a Cisco c3725 router with an added module NM-16ESW;

Additional information: The module was described in Task 1.

At least four VPCS devices (PC1, PC2, PC3 and PC4), connected to ports of the NM-16ESW module. Let half of these devices belong to one virtual network, while the other half belong to another one; Each virtual network will have its own IP addressing assigned by a DHCP server.

Solution:

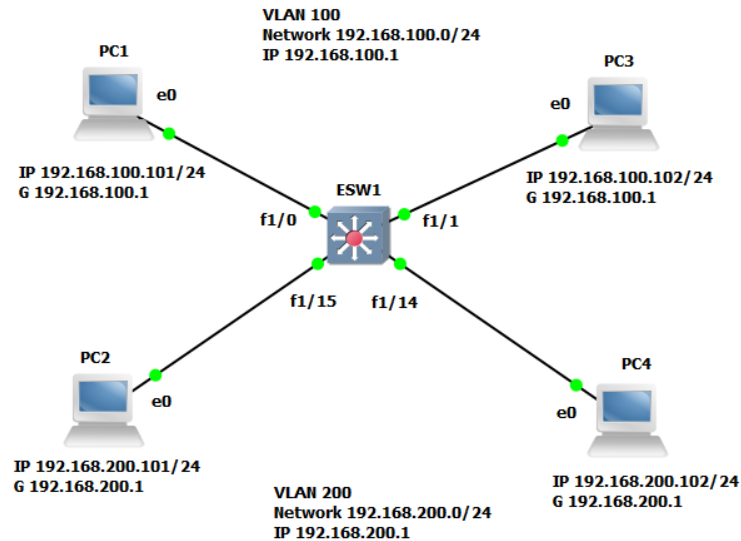
1. At least four VPCS (PC1, PC2, PC3 and PC4) are dragged from the device pane onto the workplace pane;
2. An EtherSwitch router 3725 (ESW1) is added;
3. Use the contextual menu of the router and each VPCS to select the start option;
4. VPCS devices (PC1, PC2, PC3 and PC4) will be connected to selected Ethernet ports of the router using the link icon. This solution involved the following pattern:
 - a. A virtual network VLAN 100 was built comprising the ports fastethernet1/0 (with connected PC1) and fastethernet1/1 (with connected PC3);
 - b. A virtual network VLAN 200 was built comprising the ports fastethernet1/14 (with connected PC4) and fastethernet1/15 (with connected PC2);
5. Use the router's console to input the following set of commands:

```
ESW1#vlan database
ESW1(vlan)#vlan 100 name vlan100
ESW1(vlan)#vlan 200 name vlan200
ESW1(vlan)#exit
ESW1#configure terminal
ESW1(config)#ip dhcp pool p1
ESW1(dhcp-config)#network 192.168.100.0 255.255.255.0
ESW1(dhcp-config)#default-router 192.168.100.1
ESW1(dhcp-config)#exit
ESW1(config)#ip dhcp pool p2
ESW1(dhcp-config)#network 192.168.200.0 255.255.255.0
ESW1(dhcp-config)#default-router 192.168.200.1
ESW1(dhcp-config)#exit
ESW1(config)#ip dhcp excluded-address 192.168.100.1 192.168.100.100
ESW1(config)#ip dhcp excluded-address 192.168.200.1 192.168.200.100
ESW1(config)#interface fastethernet1/0
ESW1(config-if)#switchport mode access
ESW1(config-if)#switchport access vlan 100
ESW1(config-if)#exit
ESW1(config)#interface fastethernet1/1
ESW1(config-if)#switchport mode access
ESW1(config-if)#switchport access vlan 100
ESW1(config-if)#exit
ESW1(config)#interface fastethernet1/14
ESW1(config-if)#switchport mode access
ESW1(config-if)#switchport access vlan 200
ESW1(config-if)#exit
ESW1(config)#interface fastethernet1/15
ESW1(config-if)#switchport mode access
ESW1(config-if)#switchport access vlan 200
ESW1(config-if)#exit
ESW1(config)#int vlan 100
ESW1(config-if)#ip address 192.168.100.1 255.255.255.0
ESW1(config-if)#no shutdown
ESW1(config-if)#exit
ESW1(config)#int vlan 200
ESW1(config-if)#ip address 192.168.200.1 255.255.255.0
ESW1(config-if)#no shutdown
ESW1(config-if)#exit
ESW1(config)#ip routing
ESW1(config)#exit
ESW1#write
ESW1#copy running-config startup-config
```

6. In each computer's console, it starts the procedure for obtaining the TCP/IP configuration settings from the implemented DHCP server using the command: **ip dhcp**;

- The physical connectivity among computers can be tested via the ping command.

Figure 5 Sample VLAN for simulation 2



III. Using trunk ports in a VLAN

The trunk port can transmit both tagged and untagged frames. Untagged frames belong to the native VLAN. Each trunk port has such a VLAN. If not assigned, the default one is used. In this example, the switch module NM-16ESW will be employed. This module is configured differently from the Cisco Catalyst switches. This will not have a significant impact in demonstrating the idea of trunk ports.

Task 3. Implement the topology of a LAN (Figure 7), complying with these requirements:

- Use two Cisco c3725 routers with an added NM-16ESW module;
- Communication between the two switch modules will take place via their ports number 15.
- At least two VPCS devices connected to each of the switch modules (ESW1 -> PC1, PC2, ESW2 -> PC3, PC4). Let PC1 and PC3 belong to VLAN 100, while PC2 and PC4 belong to VLAN 200;
- For IP addressing of the VPCS use static addresses as follows:
 - PC1-> ip 192.168.0.5/24
 - PC2-> ip 192.168.0.2/24
 - PC3-> ip 192.168.0.3/24
 - PC4-> ip 192.168.0.4/24
- The physical connectivity among computers can be tested via the **ping** command.

Solution:

- At least four VPCS (PC1, PC2, PC3 and PC4) are dragged from the device pane onto the workplace pane;
- Added are EtherSwitch router 3725 (ESW1) and EtherSwitch router 3725 (ESW2);
- Use the contextual menu of the router and each VPCS to select the start option;
- VPCS devices (PC1, PC2, PC3 and PC4) are connected to the relevant switch modules by the following pattern:
 - ESW1 (fa 1/1)-> PC1;
 - ESW1 (fa 1/0)-> PC2;
 - ESW2 (fa 1/1)-> PC3;
 - ESW2 (fa 1/0)-> PC4;
- The following virtual networks are set up for each of the switch modules:
 - VLAN 100, involving ports fa 1/1 on ESW1 and ESW2;
 - VLAN 200, involving ports fa 1/0 on ESW1 and ESW2;
- ESW1 and ESW2 modules will connect with each other via counterpart ports denoted fa 1/15. These ports will be modified as trunk ports;
- Use ESW1's console to input the following set of commands:

```
ESW1#vlan database
ESW1(vlan)#vlan 100 name vlan100
ESW1(vlan)#vlan 200 name vlan200
ESW1(vlan)#exit
```

- ```

ESW1#config terminal
ESW1(config)#int fa 1/1
ESW1(config-if)#switchport mode access
ESW1(config-if)#switchport access vlan 100
ESW1(config-if)#exit
ESW1(config)#int fa 1/0
ESW1(config-if)#switchport mode access
ESW1(config-if)#switchport access vlan 200
ESW1(config-if)#exit
ESW1(config)#int fa 1/15
ESW1(config-if)#switchport mode trunk
ESW1(config-if)#exit
ESW1(config)#exit
ESW1#write
ESW1#copy running-config startup-config

```
8. Use ESW's console to input the following set of commands:
 

```

ESW2#vlan database
ESW2(vlan)#vlan 100 name vlan100
ESW2(vlan)#vlan 200 name vlan200
ESW2(vlan)#exit
ESW2#config terminal
ESW2(config)#int fa 1/1
ESW2(config-if)#switchport mode access
ESW2(config-if)#switchport access vlan 100
ESW2(config-if)#exit
ESW2(config)#int fa 1/0
ESW2(config-if)#switchport mode access
ESW2(config-if)#switchport access vlan 200
ESW2(config-if)#exit
ESW2(config)#int fa 1/15
ESW2(config-if)#switchport mode trunk
ESW2(config-if)#exit
ESW2(config)#exit
ESW2#write
ESW2#copy running-config startup-config

```
  9. In the console of each computer, the **ip** command is used to assign the IP addresses as set forth in item 4 of the instructions to this assignment (Figure 6);
  10. The physical connectivity among computers can be tested via the **ping** command. (Figure 6).

**Figure 6 Testing the connectivity among computers**

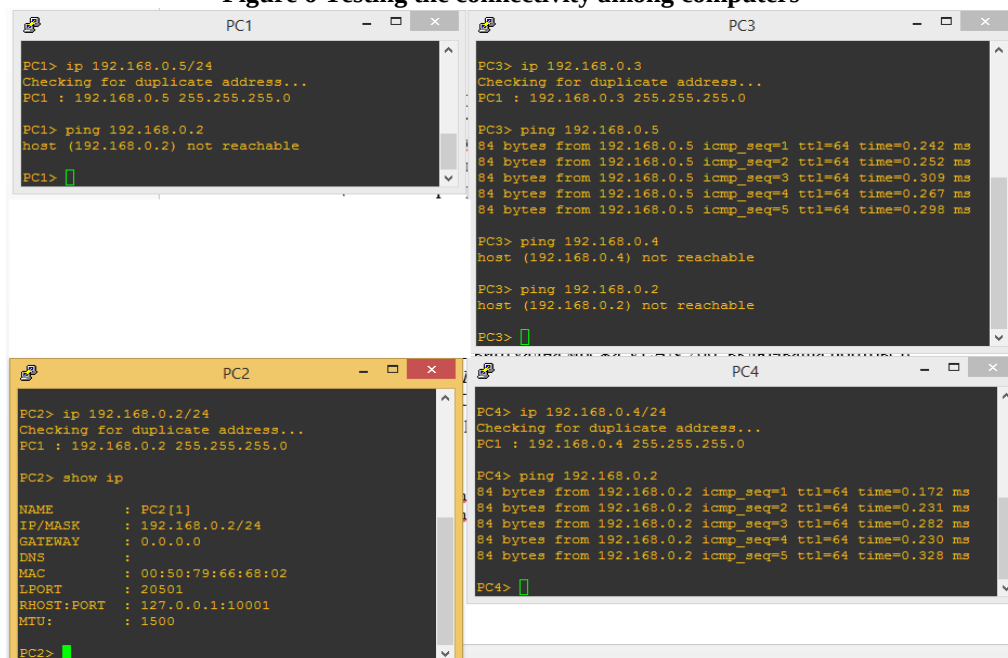
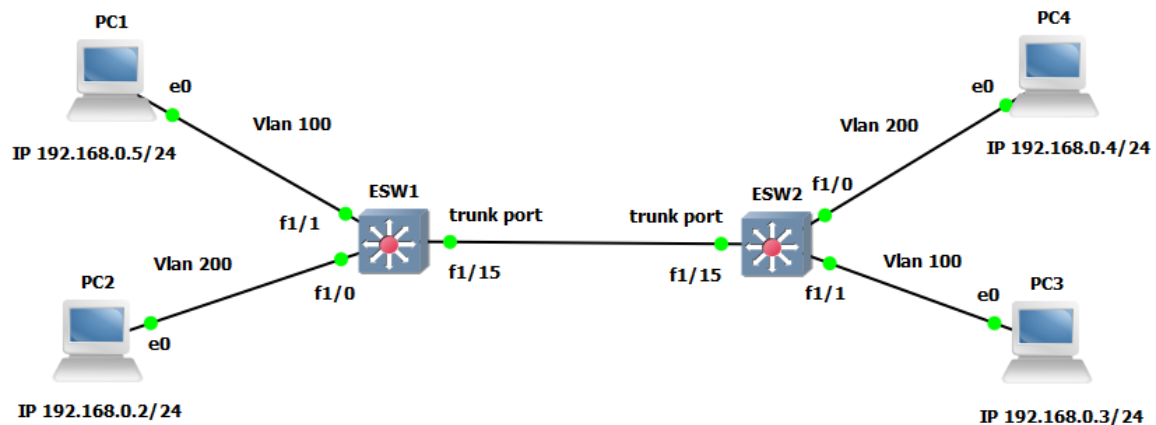


**Figure 7 Sample VLAN for simulation 2**

#### IV. Conclusion

The types of learning tasks presented in this paper can be implemented using network addressing different from the one in the solutions suggested. While the IP addresses of class C can be replaced with representatives of classes A or B, subnetworks can also be used. By way of example, other options for the network address 192.168.100.0 are: 192.168.100.0/25 and 192.168.100.128/25. In that case, to configure the router used, the ip subnet-zero command must be set to serve the first subnetwork (its address coincides with the standard network). From a teaching perspective, using simulations in teaching and learning CNC not only saves on valuable resources, but also offers more scenarios for reflection and critical thinking, thus setting the learning process in meaningful contexts resulting in reinforced skills related to subnetworks and addressing the devices students will need in real-life.

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#### VI. Acknowledgments

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