

Sample network topologies for educational purposes implemented with GNS3

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Abstract

This paper presents sample problems and solutions on virtual network topologies for educational purposes implemented with the specialized simulation system GNS3. They are meant for teaching and learning purposes related to 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 are suitable for self-assessment and peer evaluation of students' competences and can be used before, during and after lab classes.

Keywords: Computer Networks, Communications, simulation, GNS3

1. Introduction

GNS3 (GNS3.com., 2015) is a simulation environment that can be used as a free virtual laboratory to adequately prepare university students for real life. Available for Windows, Linux and Mac, employed by leading organizations from all over the globe, regularly updated to keep pace with the fast developing computer networks and communications (CNC), it enjoys over 10 million downloads and a community of 2

million registered members worldwide. This article discusses the application of GNS3 to implement virtual network topologies for the teaching and learning purposes in laboratory sessions in (CNC) for Computer Science majors at the Faculty of Mathematics and Informatics (FMI) with University of Plovdiv Paisii Hilendarski. Related previous experience has been shared in (Stoitsov, G., &Garov, K., 2013), (Stoitsov, G., &Garov, K., 2010a), (Stoitsov, G., &Garov, K., 2010b) and (Stoitsov, G., 2012). The goals underlying the application of such software have been outlined in another publication (Stoitsov, G., &Aneva, St., 2014) illustrated by sample network topologies of home or office types, as well as by topologies involving three core groups of learning tasks with regard to the used routing protocol:

1. problems requiring the use of the RIPv1 routing protocol;
2. problems involving static routing;
3. problems requiring the use of the OSPF routing protocol.

Solving such problems is related to the skill to set the TCP/IP configuration parameters of the devices and interfaces involved. Building such types of skills can be enhanced by means of some basic topology problems related to configuring networks and calculating network addresses, especially in the process of acquiring initial knowledge in the field of addressing supported by the TCP/IP protocol stack. The topologies presented here contain 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. The outcomes expected of trainees are geared towards their abilities to:

- cite the addressing corresponding to different levels;
- recognize the structure of IPv4 addresses (Stoitsov, G., 2010);
- configure networks, subnet works and calculate network addresses.

The selected network simulation medium providing students with opportunities to build and configure the assigned virtual topologies is GNS3.

2. GNS3 as a simulation medium for network topologies

GNS3 is a popular and rapidly evolving simulation medium allowing the development and testing of virtual network topologies. It uses various emulators (also called "virtual machines") which execute the actual software on an intermediary or client device. GNS3 can emulate devices of the following types:

1. Machines supported by Oracle VirtualBox, Qemu or VMWare. These are in fact machines of i386, x86-x64 architecture, and as for Qemu - SPARC and ARM. Generally, Qemu also supports some other architectures, but they are not covered by GNS3 yet. They can be installed additionally, though;
2. Regular (not „smart“) Ethernet switches and hubs;
3. ATM and Frame Relay switches;
4. ATM bridges;
5. Juniper routers (JunOS operating system);
6. Allied Telesis routers (AW+ operating system);
7. Pseudo terminals through the VPCS subroutine;
8. Various Cisco products;
 - Routers of the 1700, 2600, 2691, 3600, 3700, 7200 series.
 - EtherSwitch routers;
 - IDS sensors;
 - PIX and ASA firewalls;
 - IOU smart switches.

The pseudo terminals, which the VPCS subroutine offers, can only accept settings via DHCP or manually, as well as perform ping and traceroute. This makes them useful for achieving our aims for basic diagnosis which does not consume a lot of resources (as opposed to a "full-featured" virtual machine), but not for more complex exercises such as filtering of HTTP requests, testing speed limits, etc.

Intercepting packets is possible via a command on the desired device and in particular its network adapter whose sent and received packages will be analysed. GNS3 is set to collect information which can be viewed via the Wireshark program either in real time or at a later stage.

The chosen simulation environment adequately prepares the students for real life - GNS3 is a free virtual lab which is available for Windows, Linux and Mac and has been downloaded well over 10 million times. Moreover, it enjoys a community of over 2 million registered members and is used by leading organizations worldwide. It is updated on a regular basis and stays in tune with the fast evolving CNCs. Students can design, develop and test computer networks in a risk-free environment, as procurement and physical availability of the hardware involved is not necessary (Lambadaris, I., n.d.), (Theunis, J., Leys, P., Potemans, J., VandenBroeck, B., & Vande Capelle, A., n.d.), (Expósito, J., Trujillo, V., & Gamess, A. 2010). It fosters reflection and is suitable for self-assessment and peer evaluation of students' competences, 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.

3. Implementing relatively simple networking topologies

3.1 Using an L2 switch as a central device

Task 1. Build the topology of a LAN (Figure 1) consisting of four or more computers and a switch as a central device supporting the L2 technology.

Solution:

1. At least four VPCS (PC1, PC2, PC3 and PC4) are dragged from the device pane onto the workplace pane;
2. An Ethernet switch (SW1) is added which is automatically started;
3. The start option is selected using the contextual menu of each VPCS ;
4. The VPCS devices are connected to selected Ethernet ports of the switch via the link icon;
5. From the same menu, the console for each computer is started and it is used to set the TCP/IP configuration settings. The small number of computers implies the use of a Class C private network. An example of such network is 192.168.0.0 with standard subnet mask of 255.255.255.0. The commands for each of the computers are as follows:
 - PC1 - **ip 192.168.0.1 255.255.255.0;**
 - PC2 - **ip 192.168.0.2 255.255.255.0;**
 - PC3 - **ip 192.168.0.3 255.255.255.0;**
 - PC4 - **ip 192.168.0.4 255.255.255.0;**
6. The command **show ip** is used to display the configuration settings that have been entered;
7. The physical connectivity between the computers, e.g. between PC1 and PC3, can be tested using the ping command: **ping 192.168.0.3**. The console of PC1 is set.

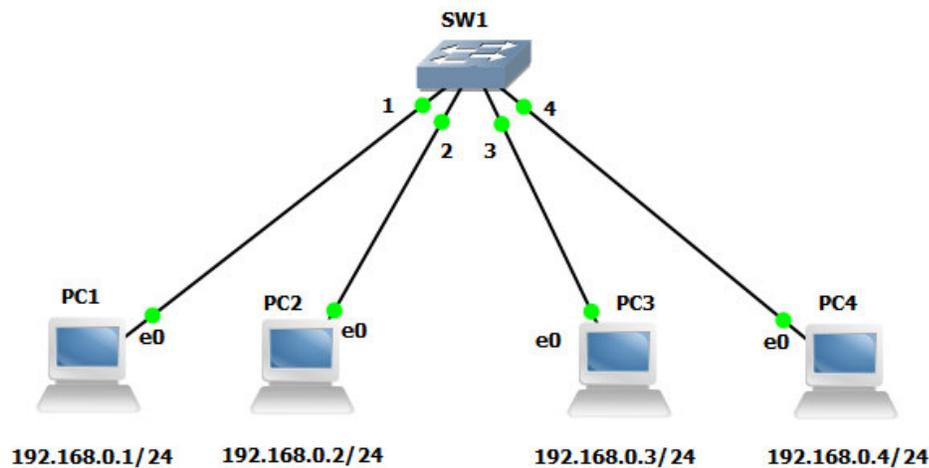


Figure 1. Sample topology 1.

Task 2. Build the topology of a LAN (Figure 2), consisting of two L2 switches with at least two computers connected to each of them

Solution:

1. At least four VPCS (PC1, PC2, PC3 и PC4) are dragged from the device pane onto the workplace pane;
2. Two Ethernet switches (SW1 and SW2) are added which are automatically started;
3. The start option is selected using the contextual menu of each VPCS ;
4. The VPCS devices are connected, two by two, to selected Ethernet ports of the relevant switches via the link icon. For instance, PC1 and PC2 are connected to SW1, while PC3 and PC4 are linked to SW2;
5. The console is started for each computer and is used to set the TCP/IP configuration settings. The small number of computers implies the use of a Class C private network – 192.168.10.0/24. The commands for each of the computers are as follows:
 - PC1 - **ip 192.168.10.1 255.255.255.0;**
 - PC2 - **ip 192.168.10.2 255.255.255.0;**
 - PC3 - **ip 192.168.10.3 255.255.255.0;**
 - PC4 - **ip 192.168.10.4 255.255.255.0;**
6. The physical connectivity among computers can be tested via the **ping** command.

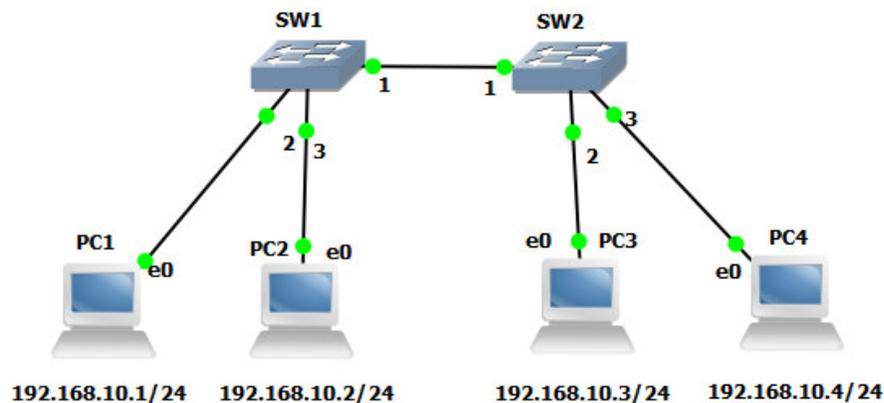


Figure 2. Sample topology 2

3.2 Using Cisco routers

Programmable routers offer great opportunities in the implementation of network topologies (Stoitsov, G., & Rangelov, V. 2014). The examples provided here consider topologies featuring a Cisco router with a simulation file that functions correctly in the test environment. It simulates a router of the C3725 series, which is sufficient for the implementation and configuration of a network topology for teaching and learning purposes. Information on the commands applied in the simulation model of the selected router can be seen on Cisco's website (Cisco Systems, Inc., 2015), (Cisco Systems, Inc., 2010). They are not the subject of this article, but rather a means to achieve the goals set.

Task 3. Implement the topology of a LAN (Figure 4) complying with these requirements:

1. A c3725 Cisco router will be used.

Additional information: According to specifications, it contains the module GT96100-FE, which supports 2 FastEthernet interfaces in slot 0, denoted FastEthernet0/0 and FastEthernet0/1. By default, these ports are defined as switched off (administratively down). Reference can be made on the router's console using the command: **show interfaces**.

2. The FastEthernet0/0 port will be connected to a switch providing access to at least three VPCS devices (PC1, PC2 and PC3) to the router.
3. The TCP / IP configuration settings of the computers will be set by a DHCP server.

Solution:

1. At least three VPCS (PC1, PC2 and PC3) are dragged from the device pane onto the workplace pane;
2. An Ethernet switch (SW1) is added which is automatically started;
3. A c3725 (R1) Cisco router is added;
4. The start option is selected using the contextual menu of each VPCS ;
5. The VPCS devices are connected to selected Ethernet ports of the switch via the link icon;
6. The router's console is used to input the following set of commands. They are meant to assign an IP address 192.168.0.1 to interface fa0/0 and to define the DHCP pool pool_r1, covering addresses 101 through 254 of network 192.168.0.0/24;

```
R1#configure terminal
R1(config)#interface fa 0/0
R1(config-if)#ip address 192.168.0.1 255.255.255.0
R1(config-if)#no shutdown
```

```
R1(config-if)#exit
R1(config)#ip dhcp pool pool_r1
R1(dhcp-config)#network 192.168.0.0 255.255.255.0
R1(dhcp-config)#default-router 192.168.0.1
R1(dhcp-config)#dns-server 192.168.0.1
R1(dhcp-config)#lease 3 12 59
R1(dhcp-config)#domain-name test.com
R1(dhcp-config)#exit
R1(config)#ip dhcp excluded-address 192.168.0.1 192.168.0.100
R1(config)#exit
R1#write
R1#copy running-config startup-config
```

7. For each computer, the console is started to set the command: **ip dhcp**. It starts the procedure for obtaining the TCP/IP configuration settings from the implemented DHCP server. As an example, the console output for PC1 is shown on
8. Figure 3;

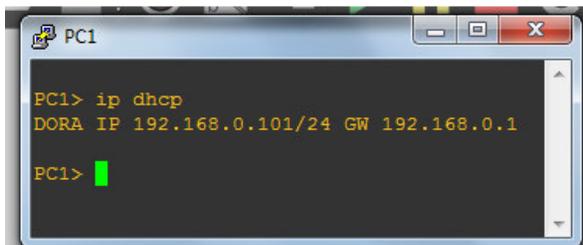


Figure 3. Console output for PC1

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

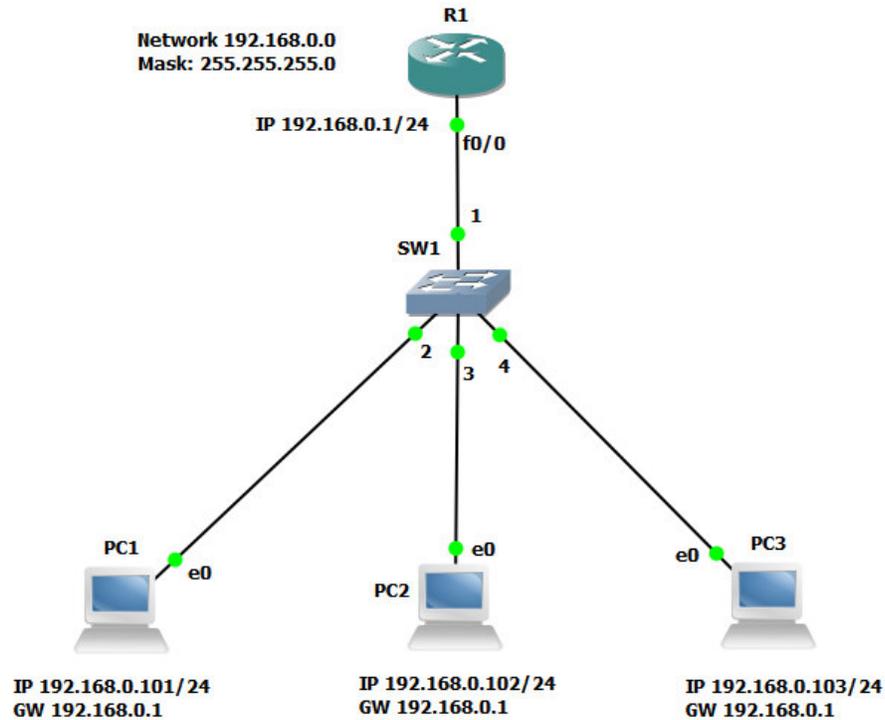


Figure 4. Sample topology 3

Task 4. Implement the topology of a LAN (Figure 6), complying with these requirements:

1. A c3725 Cisco router will be used.

Additional information: According to specifications, it contains the module GT96100-FE, which supports 2 FastEthernet interfaces in slot 0, designated as FastEthernet0/0 and FastEthernet0/1. By default, these ports are defined as switched off (administratively down). Reference can be made on the router's console using the command: **show interfaces**.

2. The FastEthernet0/0 port will be connected to a switch providing access to at least three VPCS devices (PC1, PC2 and PC3) to the router;
3. The FastEthernet0/1 port will be connected to VPCS device (PC4);
4. Each of the two ports of the router will build a separate network. The TCP / IP configuration settings of the VPCS devices will be set by two DHCP servers. One DHCP will be responsible for the devices connected to port FastEthernet0/0, while the other will take care of the devices linked to FastEthernet0/1.

Solution:

1. At least four VPCS (PC1, PC2, PC3 and PC4) are dragged from the device pane onto the workplace pane;
2. An Ethernet switch (SW1) is added which is automatically started;
3. A c3725 (R1) Cisco router is added;
4. The start option is selected using the contextual menu of each VPCS ;
5. VPCS devices (PC1, PC2, PC3) will be connected to selected Ethernet ports of the switch using the link icon, while PC4 will be linked to FastEthernet0/1 of R1;
6. The router's console is used to input the specified set of commands for:
 - assigning an IP address of 192.168.0.1 to interface fa0/0;

- assigning an IP address of 192.168.1.1 to interface fa0/1;
- defining DHCP pools pool_r1 and pool_r1_2, comprising the addresses from 101 to 254 of networks 192.168.0.0/24 and 192.168.1.0/24q respectively;

```
R1#configure terminal
R1(config)#interface fa 0/0
R1(config-if)#ip address 192.168.0.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface fa 0/1
R1(config-if)#ip address 192.168.1.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#ip dhcp pool pool_r1
R1(dhcp-config)#network 192.168.0.0 255.255.255.0
R1(dhcp-config)#default-router 192.168.0.1
R1(dhcp-config)#dns-server 192.168.0.1
R1(dhcp-config)#lease 3 12 59
R1(dhcp-config)#domain-name test.com
R1(dhcp-config)#exit
R1(config)#ip dhcp excluded-address 192.168.0.1 192.168.0.100
R1(config)#ip dhcp pool pool_r1_2
R1(dhcp-config)#network 192.168.1.0 255.255.255.0
R1(dhcp-config)#default-router 192.168.1.1
R1(dhcp-config)#dns-server 192.168.1.1
R1(dhcp-config)#lease 3 12 00
R1(dhcp-config)#domain-name test.com
R1(dhcp-config)#exit
R1(config)#ip dhcp excluded-address 192.168.1.1 192.168.1.100
R1(config)#exit
R1#write
R1#copy running-config startup-config
```

7. For each computer, the console is launched to set the command: **ip dhcp**. It starts the procedure for obtaining the TCP/IP configuration settings from the implemented DHCP server. As an example, the console outputs for PC1 and PC4 are shown on
8. Figure 5;



Figure 5. Console outputs for PC1 and PC4

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

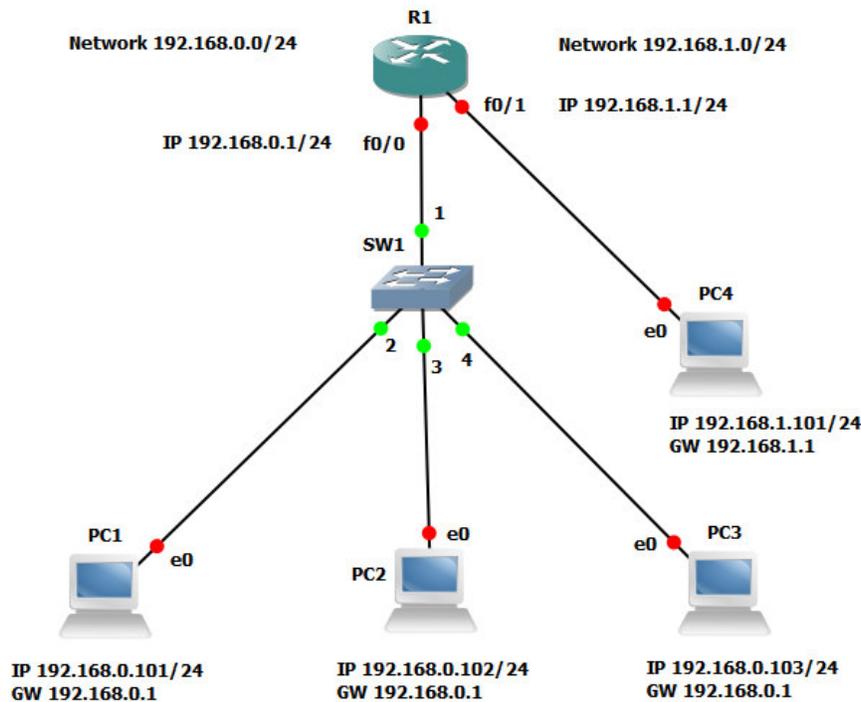


Figure 6. Sample topology 4

4. Conclusion

The types of problems presented in this work can be implemented via network addressing other than the one suggested in the example solutions provided herein. The IP addresses of class C can be replaced with representatives of classes A or B, while subnetworks can also be used. For instance, alternatives of the network address 192.168.100.0 are: 192.168.100.0/25 and 192.168.100.128/25. Should such scenarios be followed, 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). Such an approach would provide additional problems for reinforcement of skills related to subnetworks and addressing the devices.

The application of simulation software is a suitable approach offering the build-up of real-life skills of trainees, albeit in a virtual environment. So far, over 20 sample topologies have been implemented within the domain of problems considered herein, which is sufficient enough for laboratory practicals in Computer Networks and Communications at University of Plovdiv Paisii Hilendarski.

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