APPLICATION OF COMPUTER NETWORK SIMULATION SOFTWARE IN VIRTUAL ENVIRONMENT

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Abstract:

The development of information technologies enabled interactive teaching and the application of various software in education. The paper analyzed problems observed in the standard way of teaching in the field of computer networks. The aim of this paper is to prove that the application of computer network simulation software in teaching can improve the understanding of the materials in the field of computer networks. A comparative analysis of three computer network simulation software (Cisco Packet Tracer, GNS3 and OPNET) was performed regarding of use of these software in teaching. It is shown why Cisco Packet Tracer is the best solution for entry-level education in this area. By creating a simple computer network using Cisco Packet Tracer software, the necessary initial theoretical knowledge of computer networks is presented. It has been shown that the application of computer network simulation software cannot replace the classical form of teaching but represents good support in mastering complicated theoretical concepts in the field of computer networks.

Keywords:

Computer networking, computer network simulation, Cisco Packet Tracer.

INTRODUCTION

The intensive development of information technologies directly affects changes in the educational system. These changes imply greater use of interactive teaching, as well as the use of appropriate software that enables the simulation and visualization of complicated theoretical concepts which improves the understanding of the material [1].

Based on the recommendations of leading international organizations dealing with education, teaching in the field of computer networks represents a very important segment of the education of experts in the field of informatics and computing [2]. Due to the complexity of the computer networks concept, the sole study of theory in this field can not enable students to solve practical problems. The effectiveness of teaching mainly depends on the laboratory conditions in which its practical part is performed [3]. Conducting laboratory exercises with real network equipment is practically unfeasible due to the high cost of the equipment, its rapid development and the frequent need for upgrades. Real laboratories have limited access to the simultaneous work of many students.

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For the above reasons, the application of computer network simulation software is the best complement to theoretical teaching in this area.

This paper provides an overview of software that can be used in teaching in the field of computer networks. A comparative analysis of three software was performed: Cisco Packet Tracer, GNS3 and OPNET. An explanation is provided as to why Cisco Packet Tracer is the best choice for learning the basic principles of computer networks. The basic features of this software are presented and a detailed procedure for creating a computer network is explained.

2. ADVANTAGES OF USING COMPUTER NETWORK SIMULATION SOFTWARE

Computer network simulation is the process of creating a virtual version of a physical network. The application of computer network simulation software enables students to better understand the basic principles of computer network operation. Students have the opportunity to experiment with different network technologies and protocols, as well as to test different network management scenarios and strategies. For example, students can simulate network outages or package loss to analyse how the network performs in such situations. Also, they can analyse how the increase in the number of computers in the network affects the performance of the network, and how the IP addressing of computers, sub-netting or super-networking, etc. is done. These experiments can help students to learn by way of practical examples of how network management works and how the network can be optimized with the aim of achieving better performance.

Using some of the computer network simulation software, students are enabled to work in a virtual environment, simulate real network scenarios and test network performance. Most software provide the ability to set up and configure various network devices, which enables students to gain practical experience in working with the equipment.

The use of these software also allows teachers to create various simulations and scenarios related to specific topics that are theoretically covered during classes.

3. COMPUTER NETWORK SIMULATION SOFTWARE OVERVIEW

There are a lot of computer network simulating software. Some of them are developed exclusively for academic purposes and can not be used to simulate complex computer networks. On the other hand, there are also commercial software which are very complicated for use in teaching and do not provide appropriate displays of simulation results that would help students understand the operation of computer networks. Some of the most popular software that can be used in class are: Cisco Packet Tracer, GNS3 and OPNET. The main advantages and disadvantages of each of the mentioned software will be described.

3.1. CISCO PACKET TRACER

Cisco Packet Tracer is free software developed by Cisco Systems. This software contains detailed models of Cisco network equipment and is used to simulate computer networks. It has an interface that is very easy to use. It is intended for pupils, students and professors as a tool for learning and understanding the basic principles of computer networks.

Using this software, it is possible to configure various network devices, such as routers, servers, wireless access points, etc. Users can test their configurations and analyse how different network protocols behave in a real environment. It is also possible to connect network devices in different ways and to simulate different network scenarios [4].

Cisco Packet Tracer supports protocols of all levels of the TCP/IP reference model, such as IPv4, IPv6, OSPF, EIGRP, BGP, FTP, SMTP, HTTP, DNS, DHCP and others [5]. Cisco Packet Tracer enables one to create virtual computer networks (VLANs), configure security policies, including VPN (Virtual Private Network) and firewall configuration.

This software supports recording the created network session and its delayed playback. This allows the possibility of the processes and events that took place in the network to be analysed again, which positively affects the mastering of material from this area.

Cisco Packet Tracer is a good choice for all those who want to master the basics of computer networks and gain initial practical experience in this area. The downside of this software is that it is only limited to simulating Cisco devices, so it is not suitable for more complex network scenarios. Also, it does not contain all the features that are available in a real Cisco environment.

3.2. GNS3 (GRAPHICAL NETWORK SIMULATOR 3)

GNS3 is free and open-source software. It is often used in advanced computer networking courses. This software allows students to simulate various network configurations and scenarios with many components. The software supports the use of various types of network equipment including Cisco, Juniper and MicroTik [6]. GNS3 can be used to create a variety of network topologies, including networks with multiple routers, servers, and other network components. This software supports various types of operating systems, including Cisco IOS and Juniper JUNOS [3]. GNS3 is available for Windows, Mac and Linux platforms.

Using GNS3, students are enabled to create virtual network environments, as well as to simulate different scenarios in virtual network conditions. This is possible because GNS3 supports integration with virtual environments such as VMware, VirtualBox and Docker.

GNS3 has many advanced features and allows users to create very complex and realistic network configurations. The disadvantage of this software, from the aspect of use in teaching, is that it is not as easy to use as Cisco Packet Tracer. It takes more time to learn and use it in comparison to other computer network simulation software.

3.3. OPNET (OPTIMIZED NETWORK ENGINEERING TOOLS)

OPNET was developed as a tool for research and development of computer networks. It is used in a variety of industries, including telecommunications, transportation, energy, military, and others [7]. It is also used in advanced courses and in research in the networking industry. For teaching purposes, a specialized free version of the OPNET IT Guru - Academic Edition software is used. This version is used in over 500 universities around the world [3]. This version of the software is designed to complement specific lab exercises to teach fundamental networking concepts.

OPNET enables the examination of an existing network to find and eliminate errors, check the network configuration before it is built, and plan the durability and capacity of the network, plan the development of applications and other issues related to network technology [2]. OPNET enables performance analysis of network protocols and applications, such as bandwidth, latency, packet loss, and other parameters. Also, this software enables the automatic generation of scenarios for testing network performance and simulating different scenarios.

One of the advantages of OPNET is that it supports different types of network technologies, including wireless and fixed network technologies such as LTE, WiMAX, ZigBee and others. There is also the possibility of integration with other simulation tools, such as MATLAB and Simulink, which allows performing highly complex network performance analyses [2].

OPNET is quite expensive software and complex to use. Its use requires a certain amount of knowledge of network technology and the simulation concepts. However, OPNET is a powerful tool for simulation and analysis of computer networks and provides deep insights into the performance of network systems.

4. SELECTED SOFTWARE FOR SIMULATING COMPUTER NETWORKS COMPARISON

Selected software for simulating computer networks can be compared according to several criteria, such as: complexity, functionality, availability, the necessary level of initial knowledge, etc. A comparative analysis based on the mentioned criteria led to the conclusion that Cisco Packet Tracer is the best choice for use in teaching by students who are just getting to know the basics of computer networks.

When we analyse the complexity of the mentioned software, Cisco Packet Tracer stands out for its simplicity of operation. This software is best suited for beginners who are new to computer networks and are not familiar with complex network configurations. It has an interface that is very easy to use.

When analysing software functionality, Cisco Packet Tracer stands out for its large number of preconfigured network elements and devices. This enables students to easily create different network configurations and experiment with different network scenarios.

In terms of availability, Cisco Packet Tracer is available on various platforms including Windows, MAC OS, and Linux, which makes it accessible to a wide range of users. This software is free to download and use, making it available to all schools and colleges.

5. THE CISCO PACKET TRACER PROGRAM WORKING ENVIRONMENT

The graphical environment of the Cisco Packet Tracer program is very simple and contains options that are characteristic of most application programs. The upper toolbar contains the *File, Edit, Options, View, Tools, Extensions, Window* and *Help* menus. For educational use, it is very important that within the *File* menu, by selecting *Open Samples*, one can access many typical network scenarios created. Network scenarios are divided into five areas, namely: *Networking, Infrastructure Automation, Cybersecurity, IoT* and *Programming*. On each predefined network scenario, it is possible to make various changes (for example, adding cards to modular routers and switches) and to perform network performance analysis.

This program supports the display of logical and physical workspaces. This is particularly important for teaching applications. The logical desktop shows the logical network topology, while the physical desktop allows students to see how the created network looks in space and how devices are physically connected and organized into sectors.

In the lower palette of this program, there are tools for selecting network devices. Devices are divided into the following categories: Routers, Switches, Hubs, Wireless devices, Connections, End devices, WAN Emulation, Custom Made Devices, and multi-user connections. Additionally, in the lower palette, it is possible to choose between two operating modes: real-time or simulation operating mode. Both modes have equal importance in teaching. The application of real operation mode allows students to get a feel for network device performance in practice. Application of the simulation work model allows students to control the time intervals of data transmission through the network.

6. CREATING A SIMPLE COMPUTER NETWORK

Creating a simple computer network consists of several stages: selecting network devices, configuring network devices and checking the created connections. Supposedly it is necessary to create a computer network whose topology is shown in Figure 1 and the addressing scheme is given in Table 1 [8].
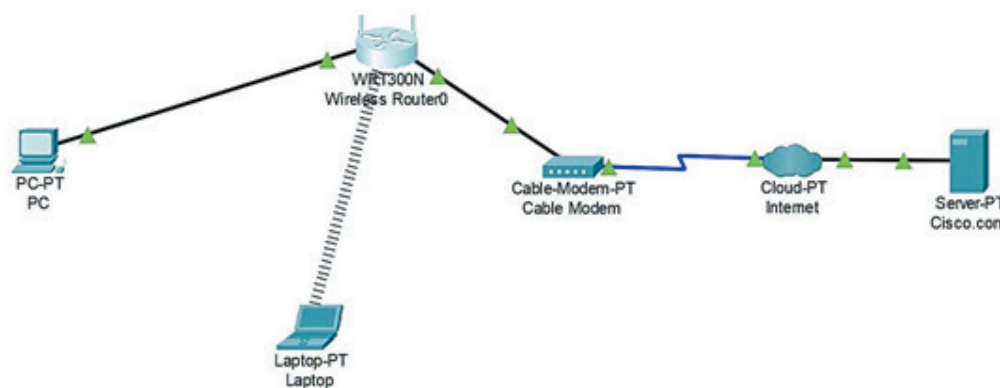

Figure 1 - Simple computer network.

Table 1 - Addressing Table [8].

Device	Interface	IP Address	Subnet Mask	Default Gateway
PC	Ethernet0	DHCP		192.168.0.1
Wireless Router	LAN	192.168.0.1	255.255.255.0	
Wireless Router	Internet	DHCP		
Cisco.com server	Ethernet0	208.67.220.220	255.255.255.0	
Laptop	Wireless0	DHCP		

6.1. SELECTION OF NETWORK DEVICES

Creating a computer network begins with selecting network devices and placing them in the workspace. After network devices are selected, their labels can be changed. By clicking on the device in the workspace opens a window in which the *Config tab* should be selected. The name of the network device can be changed in the *Display name* field. During IP addressing, it should be ensured that the addresses are within the permitted range. The most commonly used range in LAN networks is 192.168.0.0 – 192.168.255.255. The computer in this example is assigned the address 192.168.0.1. The Default Gateway address is set later, i.e. after setting the network address to which the computer will belong. After that, the DNS server address is set.

The next step is to connect the network components. A copper straight-through cable is used to connect the PC and the wireless router. The same cable is used to connect the wireless router and the cable modem. A coaxial cable is used to connect the cable modem and the Internet Cloud. Next, a copper straight-through cable is also used to connect the Internet cloud and the server.

6.2. CONFIGURING NETWORK DEVICES

The next stage in creating a computer network is configuring network devices. By clicking on the wireless router located in the workspace, it is necessary to select the *GUI* tab to see the configuration options of this router. After that, it is necessary to select the *Wireless tab* and change the *Network Name (SSID)* in the resulting field. Setting the network name is shown in Figure 2.
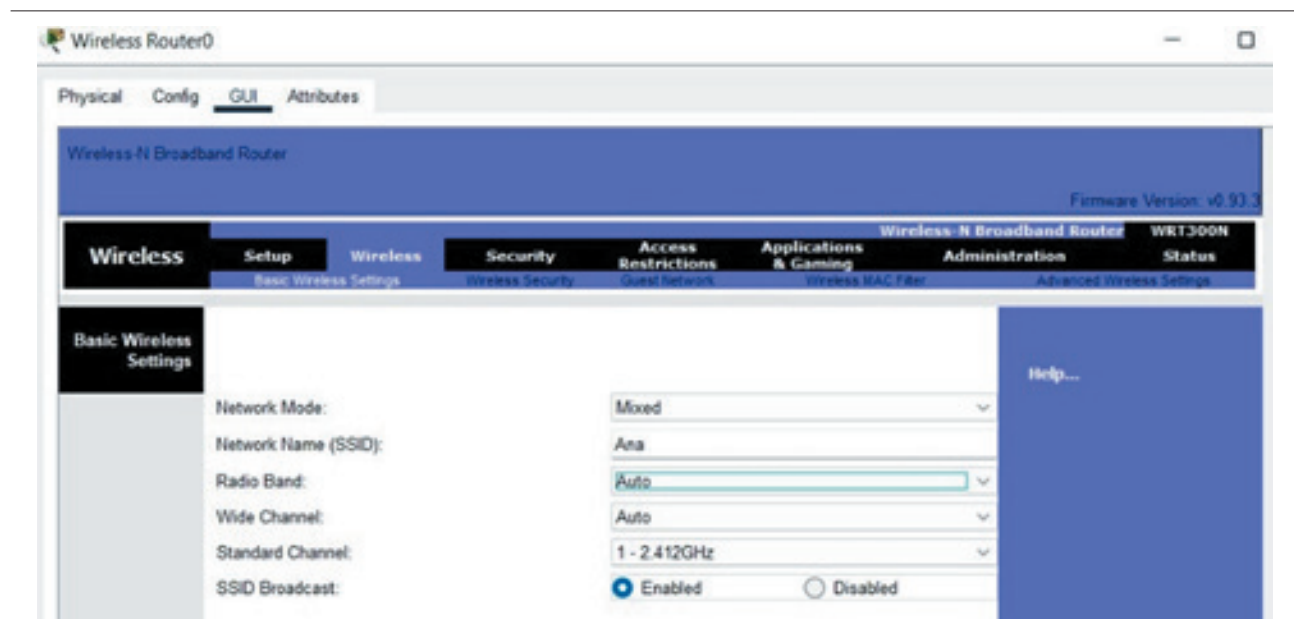

Figure 2 - Setting the Network Name.

Next, in the *Setup tab* under the settings for the DHCP server, it is necessary to check whether the *Enable* button is turned on and set the static address of the DNS server to 208.67.220.220. Save the settings by clicking *Save Settings*. The IP address of the router is 198.168.0.1 and the subnet mask is 255.255.255.0. The DHCP Server is activated and the starting address is 192.168.0.100. The maximum number of user addresses is 50, therefore the range of IP addresses is from 192.168.0.100 to 192.168.0.149. The static address of DNS1 is 208.67.220.220.

To create a wireless connection between the laptop and the wireless router, it is necessary to change the configuration of the selected laptop. By clicking on the laptop in the workspace, a list of modules is obtained under the *Physical tab*. Firstly the laptop should be turned off by clicking the power button. Then it is necessary to remove the installed Ethernet copper module by simply dragging the module to the part of the window where there is a list of modules. Next, it is necessary to install the WPC300N wireless module by simply dragging it toward the laptop. After installing the module, it is necessary to turn on the laptop. When the wireless module is installed it is necessary to connect the laptop to the network.

By clicking on the laptop, in the *Desktop tab*, the *PC Wireless* icon should be selected. When the Wireless-N Notebook Adapter display appears, select the *Connect tab*. Next is to check if the network that was created appeared in the list of wireless networks. You need to select that network and click on the *Connect tab*. It is necessary to select that particular network and to click on the Connect tab. At that moment, the indicator will appear in the workspace signalling that the laptop and a wireless router are connected through a wireless connection.

The next step is to configure the PC. Firstly, it is necessary to click on PC, and then in the *Desktop tab*, the *IP Configuration* option should be selected. Within this window, it is necessary to select the DCHP radio button in order for the PC use DCHP to receive an IPv4

address from the wireless router. The *IP Configuration* then closed. Next click on the PC to open the *Command Prompt* window as shown in Figure 3 and use the *ipconfig/all* command to check whether the PC has received an IPv4 address from the 192.168.0.X range.

The next step is to configure the Internet cloud. Two modules are necessary for the correct operation of the network, PT-CLOUD-NM-1CX module for cable modem connection and module PT-CLOUD-NM-1CFE for copper Ethernet connection. These modules are added within the Logical tab. After that, it is necessary to select the Cable option in the Config tab under the Connections menu. In the first drop-down menu, select Coaxial, and in the second drop-down menu, select Ethernet.

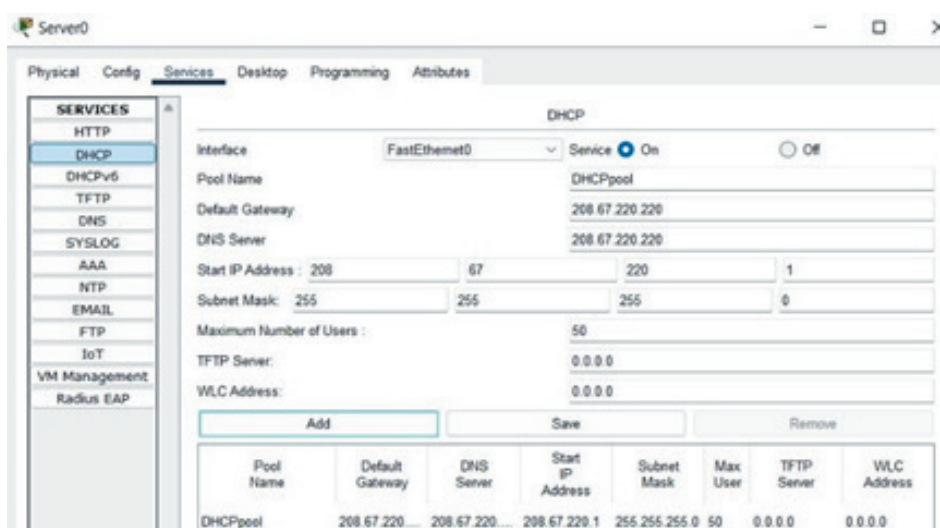Figure 3 - Ipv4 address control using the ipconfig/all command.

Figure 4 - Configuring DHCP server.

The last thing to configure is to make the server work as a DHCP server. Within the Service tab of the server shown in Figure 4, the DHCP option should be selected and the following parameters should be set: Pool name: DHCP pool; Default Gateway: 208.67.220.220; DNS Server: 208.67.220.220; Starting IP Address: 208.67.220.1; SubnetMask: 255.255.255.0; Maximum number of users: 50.

Then it is necessary to configure the DNS server to provide the domain name to IPv4 address resolution. This is done by selecting DNS in the *Service tab* and entering the following parameters: Name: Cisco.com, Type: A Record; Address: 208.67.220.220.

It is also necessary to make global settings and select *Settings* in the *Config tab* and enter the following parameters: Gateway: 208.67.220.1; DNS Server: 208.67.220.220.

Finally, it is necessary to adjust the FastEthernet settings of the Cisco server under the FastEhernet option located in the *Config tab*. Enter the following parameters: IP Configuration: Static; IP Address: 208.67.220.220; Subnet Mask 255.255.255.0

6.3. CHECKING THE OPERATION OF THE CREATED NETWORK

It is necessary to check whether the PC receives an IPv4 address from DHCP. By selecting the PC´s *desktop*, the Command Prompt icon should be clicked. After the *ipconfig /release command, the ipconfig /renew* command should be entered. If the network is configured correctly, the PC should get an address from the 192.168.0.X range. The connection to the Cisco server is checked with the *ping* command. The response to the specified network commands is shown in Figure 5.

Figure 5 - Checking the created network with ipconfig/renew and ping commands.

7. CONCLUSION

The application of computer network simulation software in teaching has great potential to improve the quality of education. Each of the network simulation software has its advantages and disadvantages. The decision as to which software is best to use for educational purposes depends on the needs of the course, the level of education of the students, available time and budget. Here, a comparative analysis was made out of three software: Cisco Packet Tracer, GNS3 and OPNET. It is shown that Cisco Packet Tracer software is the best choice for the initial level of education in the field of computer networks.

To create a simple computer network shown in this work, only basic knowledge of the characteristics of network devices, how to connect and configure them, the concept of IP addressing, as well as basic network commands was necessary. This means that the virtual network laboratory is not a basic tool, but only a support in overcoming the complicated theoretical concepts in the field of computer networks.

It is very important to include computer network simulation software in the educational program, to support students in their use and to create a special teaching plan. Future research should analyse how much the application of computer network simulation software helps students to improve their understanding of the material in this area.

7. REFERENCES

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