Getting skills in configuration and management of communication network elements using the DiP software and hardware complex

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Abstract. The article focuses on the problems of engineering education in a technical higher educational institution in particular on acquiring practical skills in configuration and management of communication network elements. This became possible through the creation of a software and hardware complex for studying the operation of optical lines and switching equipment, which will allow students who major in Information and Communication Technologies and Communication Systems, and others like it, to obtain theoretical, and most importantly, practical skills in modeling and operating networks of various levels of complexity. The configurations presented in the article are not reference or basic - they are given for an example and awareness of things, since for each network solution, individual parameters and technologies are applied.

Today, one of the most important problems is that students of technical universities lack or have little experience handling the target equipment. Therefore, when studying technical disciplines, it is essential to give students the opportunity to gain knowledge not only with the help of theory, but also directly with practice using equipment.

When studying various disciplines related to the practical implementation of methods and information transfer methods today, most often one resorts to computer modeling, since on the one hand it is easier and more economically profitable. However, at the same time, students do not have practical skills in working with communication network equipment. It was to solve this problem that this hardware and software complex was created and guidelines were developed with a detailed and step-by-step description of the network segments used, such as switches, routers, base stations and personal computers and their configuration.

According to the professional standard 06.018, approved by the Ministry of Labor and Social Protection of the Russian Federation dated October 31, 2014, a communications engineer must have a certain list of knowledge and skills [1]. For example, one of the job functions of a communication engineer is to measure parameters and to check the communication equipment quality. To provide a specialist with such necessary skills as mastering the skills of instrumental measurements used in the field of communication and analysis of measurement results, it is necessary to use simulated communication lines [1]. This is an example of one labor function, and there are many functions of that kind.
Certainly, a student can do industrial practice at communication enterprises. Except specialists are working there with real communication lines, therefore, they will not be allowed to perform any actions with the working equipment for teaching students, because an inexperienced student, by chance, can leave an entire apartment building without the Internet, or maybe an entire area.

If theoretical knowledge can be obtained at lectures, as well as from educational literature, then practical skills cannot be obtained in full at the university due to the lack of a modern laboratory base that would imitate the operation of modern communication networks.

When creating the hardware and software complex, it was decided to make the operation of the equipment as close as possible to the operation of real information and communication networks.

Figure 1 shows a schematic diagram of a three-tier hierarchical model that is used in many networking solutions.

![Figure 1. Three-level hierarchical model diagram.](image)

Core level - here, high-speed and fail-safe forwarding of large amounts of traffic without causing delays. At this level, routers are used with the configuration principle - VLAN (one or more) per node of the Distribution level.

Distribution level - this is where user traffic is routed between VLANs and filtered. Switches with routing functions (L2/3) and with the principle of configuration are often used: VLAN of each service per one node of the Access level.

Access level - users themselves physically join the access level. Here L2 switches (sometimes L2/3 +) are used with the configuration principle: VLAN services per user port + control VLAN per access device.

Based on the above, it was decided to create an Access layout in the form of a rack with FOCL equipment, which would simulate the existing FOCL and meet all the basic requirements of the network. To implement the two upper levels (Core and Distribution), a Cisco communication rack is used.

Cisco equipment is often used to create networks in real telecom operators, both small and medium and large. Figure 2 shows a block diagram of the hardware and software complex.

The communication rack (figure 2), used to give students practical skills, consists of various types of devices, including: two types of switches (managed and stand-alone), two-generation Catalyst series routers, and two IP telephony base stations of the 7912 series. All devices, except IP telephony base stations, operate on the basis of the Cisco IOS operating system, which can be controlled using a terminal, or using the CiscoNetworkAssistant utility.
When creating an Access model, it was necessary to be guided by the following requirements:

- The physical line (these are the cable sections) should not have a ring structure, since it is necessary to terminate the lines at one end of the cable in order to ensure convenient placement of the cable and couplings;
- The line must end at one optical distribution frame for 24 ports, which provides ease of transportation of the rack, due to the minimum number of splices on the crossbar;
- The optical line (this is the length traveled by light through the fibers of the cable) must have a ring structure and must be terminated with two adjacent ports on the same cross for the convenience of measurements.

Since the real communication line is geographically dispersed on a certain scale, it was decided to use a cable of short length, but at the same time with a large core, thereby organizing various optical routes.

The task was set: using the available sections of multicore cable (170 m, 180 m, 205 m, 300 m), to design a ring or linear splicing scheme for several optical routes of various lengths for the rack.

Thus, there are two types of cable - twenty-four-fiber (170 m) and sixty-four-fiber (180 m, 205 m, 300 m), so it is theoretically possible to obtain the maximum length of the optical path equal to $170 \times 24 + 180 \times 64 + 205 \times 64 + 300 \times 64 = 47920$ m. It turns out that having a total cable length of only $855 \times 170 + 180 + 205 + 300$, due to the fact that the cable is multicore it is theoretically possible to obtain a fiber-optic link length of about 50 kilometers.

The most optimal optical path lengths for measurements and calculations related to kilometric attenuation were chosen: 1 km, 1.5 km, 5 km, 10 km, and 15 km.

To implement these conditions, using the certificates of cable products, a diagram of the distribution of optical fibers on couplings was developed, shown in figure 3.

As a result of repeated empirical calculations and design and survey work, it was possible to obtain the routes as close as possible to the desired ones (table 1). Deviations from the specified initial lengths are due to the physical length of the cable sections and the small capacity of the lead-in distribution frame (24 ports).
To study the effect of the welding joint and various optical outlets on the optical path, it was also decided to include two crosses in the rack, which are simultaneously welded without couplings. As a result, a communication line was obtained from a DOTS-P-24 cable 200 meters long, terminated on crosses with various pigtailed adapters (such as SC-SC and FC-FC), which allows simulating communication lines of various lengths.

The work of the hardware and software complex is divided into two interrelated parts - theoretical and practical. In the theoretical part, students study the principle of operating the network devices, methods of their connection and principles of building networks of small and medium-sized offices. The practical part is designed to consolidate knowledge empirically and gain skills in working on a laboratory rack with Cisco network equipment.

The methodology created for working with a hardware and software complex will help students build awareness of how to configure Cisco equipment in a three-tier network model. To gain theoretical knowledge and skills in setting up equipment, as well as creating networks for small and medium-sized offices, the Cisco Packet Tracer software package is used, in which all devices that are part of a real rack are presented as a virtual model. Students are encouraged to independently create a virtual model using the capabilities of the Cisco Packet Tracer program. In addition to switching devices, the list of devices contains terminal terminals of various types (computers, phones, tablets, laptops, etc.). To consolidate the acquired skills, students are invited to perform these laboratory works on real equipment, in our case it is a Cisco rack.

All training is divided into several stages. Each stage clearly shows and explains how a network of one level or another is designed, connected and configured.

For example, the first theoretical stage clearly shows how a local network is created from a simple switch and several computers. It is necessary to assemble a network, connect all computers to the switch, configure the computers, assign an IP address to each computer manually, and check the operation of the network. Figure 4 shows the switching diagram of an elementary single-segment network.

| Length | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 1 |
|--------|---|---|---|---|---|---|---|---|
| 110    | 710| 480| 800| 260| 410| 780| 2670|   |

Table 1. Laboratory rack simulation.
Figure 4. Elementary one-segment network.

Then practical work using the Cisco rack can be carried out. It should be noted here that when working with equipment “not from the box”, difficulties may arise, for example, the inability to gain access to privileged mode or it is necessary to reconfigure the equipment again to work in the new network. Therefore, before directly creating an elementary local network, students need to learn how to reset equipment to factory settings and initial user settings, in a specific case, these are: set the equipment name, access password, as well as set up a message that will be seen by everyone who logs on to the system. This message is called message of the day or MOTD banner.

Figure 5. Login with customized banner.

The next stage of work is to get acquainted with the STP, RSTP protocols, their principles of operation, as well as configure remote access to Cisco equipment. STP is a network protocol designed to automatically remove cycles (switching loops) from the network topology at the link level in Ethernet networks [6]. Later, several modifications of the STP protocol appeared (here, only RSTP is considered), differing in some features in the operation algorithm, in speed, in relation to VLANs and a number of other issues, but in general they solve the same problem in similar ways. All of them are commonly referred to as STP protocols. Currently, STP (or similar) is supported by almost all but the most primitive Ethernet switches, both real and virtual.

In the switches used, STP is configured initially, so there is no need to enable it. The purpose of working with the protocol is that, in addition to theory, students can also clearly see how this protocol behaves in a real network, as well as switch to one of its modifications RSTP and compare the results obtained on the speed of these protocols.

Figure 6. Scheme used.

Further, students are invited to configure remote access to existing equipment (in a specific example, switches), that is, to provide the ability to remotely configure using PCs connected to the equipment. Initially, all the necessary settings are set directly through the terminal using a console cable: a local account is created, the privilege level of this account and the password for the account are set.
It is proposed to consider two protocols for remote access to equipment via a personal computer: Telnet and SSH. To work with these protocols on a PC, the PuTTY client program is used.

Telnet is a network protocol for remote access that does not use encryption and therefore is vulnerable to attacks when used on the Internet or local area network [7].

SSH is a network protocol that is equal in functionality to Telnet, but provides strict confidentiality and security of data over an unsecured network, such as the Internet or local area network [7].

The third step is the main part of all subsequent stages of this software and hardware complex, which is an integral part of all subsequent work. Here the network protocol DHCP and its subsequent configuration for small and medium-sized offices are considered. At this stage, students will receive not only theoretical knowledge about the DHCP protocol, but will also be able to configure this protocol on their own at the Cisco laboratory rack.
Dynamic Host Configuration Protocol (DHCP) is a dynamic host configuration protocol that allows network devices to automatically obtain an IP address and other parameters required to operate on a TCP/IP network [7]. This is necessary in cases where the computer and users often change places, physically and logically. Assigning them a static IP address every time is difficult and not always justified. Thus, using DHCP greatly simplifies the assignment of IP addresses to various devices and to administer all assigned addresses from one server.

When working with the hardware-software complex, the student will receive such compulsory skills as: Setting up, adjusting and testing communication equipment (software part); Testing of equipment, development of operating modes, control of design parameters of communication equipment; Carrying out measurements of parameters and checking the quality of the communication equipment (measuring the line with an optical tester, reflectometer, detecting a break on the line, which was specially made for this purpose); Carrying out repair and restoration work (the student will be able to determine where the damage is on the line, at this rack it is necessary to determine with the help of instruments on which coupling there is a bend); Selection and use of appropriate test and measurement equipment (tester and reflectometer); Using hardware software when configuring it (configuring switches); Analysis of the results obtained (determine the line operability by reflectograms); Drawing up working documentation of various kinds, etc.

Thanks to the created hardware and software complex, it is possible to study, adjust and install both optical access lines and multi-level transport networks. Moreover, the rack is made of elements directly used in production (pigtails, crosses, couplings, optical cable), and the laboratory work itself will be performed using optical equipment (power meters, optical reflectometer, optical tester), which is a significant gain for students.

With the help of the developed methodology for the hardware and software complex, students can acquire at least basic knowledge in setting up network equipment, client stations, as well as other devices participating in the functioning of the network. The developed hardware and software complex enables graduates majoring in "Information and Communication Technologies and Communication Systems", and others like it, to apply the knowledge gained while performing these works in the future, in professional experience.

References

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