Virtualization Technologies in the Training Future IT Specialists to the Subject "IP Telephony"

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Abstract: The application of virtualization technologies to train future IT specialists in IP telephony has been considered in the article. Requirements for students' professional training in the field of IP telephony have been defined. The components of the network training laboratory for training IP telephony have been determined. Modern approaches to the application of virtualization technologies have been analyzed. Features of using virtualization technologies for learning IP telephony have been determined. The analysis of modern virtualization technologies has showed the prospects of using native virtualization as a basis for creating a virtual training laboratory using VirtualBox software. The conducted pedagogical experiment has confirmed the effectiveness of using the developed virtual laboratory and repository of virtual hosts for training IP telephony to future IT specialists. Virtual machines increase student mobility, they can be exported and moved to another computer, and there the virtual machine can be started immediately. This is a significant advantage of virtualization during the SARS-CoV-2 pandemic, when students have to study remotely. Each student can have his own virtual laboratory.

1 INTRODUCTION

Training of future IT specialists is not possible without the application of modern learning technologies, including information. The general trend in the world is to equip higher education institutions with modern software and hardware. Today there is a rapid development of hardware and software, the emergence of new and improvement of old hardware platforms (Pavlenko and Pavlenko, 2021). It causes a constant lag of the educational process from today's requirements, and complicates the adaptation of higher education institutions and the growing demands of society to the quality of training in the field of information technology.

This problem becomes more noticeable in the training of future IT specialists in the discipline of "IP telephony in computer networks". To prepare them, it is necessary to ensure the solution of the following issues:

- mastering the knowledge and skills related to the various operating systems installing, functioning and exploitation, taking into account network interaction, both in local and global networks;
- mastering the knowledge and skills related to the installation, debugging, operation and exploitation of IP telephony software, taking into account network interaction, both in local and global networks.

One of the ways to solve a certain problem is the introduction of virtualization technology in the educational process.

The analysis of approaches to the application of virtualization for training future IT professionals shows the lack of a single concept of its implementation and application. The design and implementation of virtualization technologies requires the solution of many organizational, methodological and technical problems.

The development and application of virtualization technologies in various fields of computer science are reflected in (Balyk et al., 2019; Holovnia, 2020; Khomenko et al., 2020; Lunsford, 2009; Osad-

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chyi et al., 2020; Ray and Srivastava, 2020; Stefanek, 2017; Yan, 2011; Yuan and Cross, 2014; Yuan et al., 2012).

The problem of using virtualization in the teaching of information technology was considered in (Chamberlin et al., 2017; Barrionuevo et al., 2018; Khomenko et al., 2020; Korotun et al., 2020; Markova et al., 2019; Merzlykin et al., 2017; Segeč et al., 2019; Soler, 2011; Yuan et al., 2011, 2013).

The problem of using virtualization in the training IP telephony to future IT-specialists was considered in (Abubakr et al., 2019; Kaul and Jain, 2020; Moravcik and Kontsek, 2019; Rendon Schneir and Plückebaum, 2010; Setiawan et al., 2017).

The *aim* of the article is to analyze the possibilities of using existing virtualization technologies to train future IT specialists in IP telephony in computer networks.

2 REASONING FOR CHOOSING A VIRTUALIZATION SYSTEM FOR LEARNING IP TELEPHONY

Training of future IT specialists in accordance with the state standard of higher education involves the formation of a number of professional competencies: the ability to use operating and intelligent systems in solving practical problems, taking into account the protection of information in computer systems and networks; ability to use programming languages and software engineering in solving problems and tasks of social and professional nature; ability to analyze, debug, use and develop human-machine interaction based on computer architecture and organization.

They are formed during the study of a number of professional-oriented disciplines, one of which is "IP telephony in computer networks".

In accordance with the purpose of the study, we will consider virtualization technologies and identify prospects for their application to train future IT professionals in IP telephony in computer networks.

The study of "IP telephony in computer networks" uses two Asterisk servers based on Debian or Ubuntu Linux and at least two client personal computers with Windows operating systems and IP telephony software installed as a network training laboratory. This hardware and software are necessary to model the network interaction of IP telephony clients and servers using SIP, IAX2, H.323 protocols. One of the areas of a network laboratory development and implementation for the study of IP telephony is the application of virtualization.

The concept of virtualization appeared in the 1970s. It was understood as the transfer of physical resources of a computer into a virtual one with the help of specialized software, abstract layers allow creating several virtual machines on one physical machine, each virtual machine being able to work with its operating system (Drews, 2006).

Virtualization, as a concept, is used for two technologies that are fundamentally different: resource virtualization and platform virtualization. Resource virtualization, in contrast to platform virtualization, has a broader meaning and combines a large number of different approaches aimed at improving the usability of users with information systems in general. In our study, we will build on the concept of platform virtualization, as related technologies are evolving and are effective in achieving the goals of training future IT professionals.

Platform virtualization is understood as the creation of software systems based on existing hardware and software complexes. A system that provides hardware resources and software is called a host, and the systems it simulates are called guest systems. There are several types of virtualization platforms, each of which has its own approach to the concept of "virtualization". They are mainly determined by how full the hardware simulation (Barr et al., 2010).

We will consider virtualization with full emulation. This approach completely virtualizes all the hardware while keeping the guest operating system unchanged (Han and Jin, 2011). This allows you to simulate different hardware architectures. For example, you can run virtual machines with guest systems for x86 processors on platforms with a different architecture. Examples of software for complete simulation are: Bochs, Pearpc and QEMU.

The main disadvantage of this approach is that the simulated hardware significantly slows down the performance of the guest system, which makes interaction with it very inconvenient. Therefore, such products should not be used as a basis for developing a virtual training laboratory to study "IP telephony in computer networks" discipline.

Let's consider paravirtualization as a basis for the development of a virtual training laboratory for the study of the "IP telephony in computer networks" discipline. While using paravirtualization, the hardware is not simulated, a special software interface (API) is used to interact with the guest operating system at the level of RAM pages.

This approach requires modification of the guest system code. A significant number of hardware and software developers have doubts about the prospects

of this approach to virtualization (Babu et al., 2014), because today all decisions of hardware manufacturers regarding virtualization are aimed at systems with native virtualization. In addition, it should be noted the difficulty of deploying new instances of virtual machines for users. Therefore, the use of paravirtualization software in learning IP telephony in computer networks is impractical. Examples of paravirtualization are Xen, L4, TRANGO, WindRiver and XtratuMhypervisors.

We will consider partial (native) virtualization in the context of our study. In this case, only the required amount of hardware to run an isolated virtual machine is simulated (Li, 2010). This approach allows you to run guest operating systems designed only for the same architecture as the host.

In this way, multiple samples of guest systems can be run simultaneously, allowing you to simulate a computer network with IP telephony servers and clients on a single personal computer. This type of virtualization can significantly increase the speed of guest systems compared to full emulation and it is widely used today.

Beside this, the distribution of already established guest systems among users is quite simple and possible only on the basis of copying files. Disadvantages of this type of virtualization include the dependence of virtual machines on the architecture of the hardware platform, but for the "IP telephony in computer networks" discipline we use operating systems and software for x86 architecture. Examples of products for native virtualization: VMware Workstation, Virtualbox, Parallels Workstation and others, including server solutions (VMware Server, Microsoft Virtual Server, VMware ESX Server, VirtualIron and Microsoft Hyper V).

We will consider the virtualization of the operating system level and identify opportunities for its use to train future IT professionals in IP telephony in computer networks. The guest system, in this case, shares the use of one kernel of the host operating system with other guest systems (Yan, 2011). The virtual machine provides an environment for applications that run in isolation. This type of virtualization is used in the organization of virtual hosting systems, when you need to support multiple virtual client servers within one instance of the kernel.

This technology allows you to isolate each virtual system and deprive them of the ability to influence each other. Examples of operating system layer virtualization include: iCoreVirtualAccounts, Linux-VServer, LXC, OpenVZ, ParallelsVirtuozzoContainers, FreeBSDJail and sysjail.

We will consider virtualization of the application level. This type of virtualization involves the creation of separate containers for software isolation. The container includes all the necessary elements for the correct operation of the software: registry files, configuration files, user and system objects. As a result, the user receives an application that does not require installation on a similar platform.

Transferring the software to another computer will create a virtual environment for it, and the virtualization program resolves conflicts between the software and the operating system and other applications. Examples of such an approach are: Thinstall, Altiris, Trigence, Microsoft ApplicationVirtualization (App-V). Using application-level virtualization to train IP telephony to future IT professionals is impractical, due to the need to create a computer network model with separate servers and workstations rather than software.

So, we can affirm that one of the best solutions for the introduction of virtualization in the methodology of teaching IP telephony discipline in the computer networks will be the technology of native virtualization. This can be explained with the ability to use virtual machines in independent and classroom work of students, easy export of ready-made solutions and the ability to create a complex network infrastructure among downloaded virtual machines.

Let's consider the problem of choosing the specific software for native virtualization in order to use it to teach IP telephony in more detail. Let's analyze the possibility of using one of the three popular solutions for virtualization in the workplace: VMware Workstation, Parallels Workstation and VirtualBox.

VMware company is one of the best known in the high technology industry. It develops effective software in the field of virtualization. Their implementation of server software is widely used in virtual data centers and personal computers in business and industry.

VMware has two types of desktop software: VMware Workstation and VMwarePlayer. Every virtual client supports and works with virtual machines flawlessly. But the Workstation option has more features, namely: support for two monitors, integration of the Unity interface, and most importantly the ability to create virtual machines. The Player version only allows you to run and execute previously created virtual machines.

Teaching IP telephony in computer networks involves students creating their own virtual machines, so VMwarePlayer software cannot be used due to the existing restrictions on creating new virtual machines.

VMware Workstation functionality allows you to use it on computers running Windows and Linux op-

erating systems. The wizard for installing and debugging new virtual machines is simple and intuitive, and the default settings for specific operating systems are selected quite well. This allows students not to spend a lot of study time mastering software management skills.

Unity virtual interface integration allows you to include virtual machine elements directly into the host operating system interface. That is, icons and windows from a Windows virtual machine will work with icons and windows from the Ubuntu operating system. However, the use of Unity leads to a significant slowdown of virtual machines and complicates their use.

Parallels company is developing a software product for PC virtualization – Parallels Workstation. It solves the main task of virtualization – the simultaneous launch of multiple operating systems on a single computer running Windows or Linux. This product uses features designed for professionals in the field of local and online applications, software testing professionals and web designers. It can also be widely used for educational purposes.

During Parallels Workstation development the requirements for the product by IT specialists were considered. This software can work with more than 25 major operating systems – both 32-bit and 64-bit. High performance of Parallels Workstation is compatible with Intel VT-x2 virtualization technology and the use of a hypervisor.

However, owing to Controlled Native Execution (CNE) technology, Parallels Workstation allows you to run guest operating systems on older computers whose processors do not have hardware support for virtualization. Parallels Workstation's professional user interface offers many options for creating and configuring virtual machines, but an untrained professional will not be able to quickly create and install a virtual machine, making it difficult to use Parallels Workstation to teach IP telephony in computer networks.

VirtualBox is open source software, i.e. free of charge. Individual commercial functional elements are downloaded in the form of plug-ins. VirtualBox combines features of solutions for both servers and workstations. The first includes technologies of "balloon" dynamic redistribution and reduplication of RAM in a virtual machine on 64-bit hosts, iSCSI support, GUI-free mode and an efficient method of remote access to virtual machines through a shared RDP-server (VRDP, VirtualBox Remote Display Protocol). The second is high-quality support for USB equipment, including USB 2.0, as well as 2D and 3D acceleration in virtual machines due to the resources of the host graphics adapter.

VirtualBox can provide virtualization in a purely software mode or by using hardware support in modern processors. It uses disassembly of guest OS code and a number of other techniques, combining them.

While creating new virtual machines, the developers of VirtualBox managed to protect their users from possible problems and the need to understand the technical details. In most cases, it is sufficient to agree with the default settings, adjusting only the necessary and obvious of them, say, the amount of RAM.

In this case, the program will to some extent control the correctness of the selected parameters and, if necessary, make corrections or issue appropriate warnings. It is no coincidence that all the most subtle settings and actions can be performed exclusively from the command line, which, of course, requires the user to have some understanding of what is happening. These features are very convenient to use while creating and debugging virtual machines when learning IP telephony in computer networks.

As one can see from table 1 VirtualBox software supports multiple operating systems, allows you to connect up to 36 network adapters to a virtual machine and is distributed free of charge. All this points to the benefits of using VirtualBox as the main virtualization tool in the development of a network lab for training future IT professionals in IP telephony in computer networks.

3 REPOSITORY OF VIRTUAL MACHINES FOR TEACHING IP TELEPHONY

The content of the discipline "IP telephony in computer networks" involves a series of laboratory work:

1. Installing Asterisk and Free PBX.
2. Basic configuration of the IP telephony server.
3. Configure Asterisk to work with the SIP protocol.
4. Configure the Asterisk dial plan.
5. Calls management in Asterisk.
6. Voice services and menus in Asterisk.
7. Integration of Asterisk into the organization corporate network.

Two servers and several clients are required to perform laboratory work. Virtual hosts in the VirtualBox environment are created as servers. One core, 512 MB of RAM and 10 Gb on the virtual HDD are allocated for the Virtual Server. The client virtual

Table 1: Features of VMware Workstation, Parallels Workstation and Virtualbox.

Feature	VMware Workstation	Parallels Workstation	VirtualBox
Supported host operational systems	Windows, Linux, Mac OS X	Windows, Linux, MacOS X	Windows, Windows Server, Linux, Mac OS X, Solaris, OpenSolaris, FreeBSD
Guest operational systems	DOS, Windows, Linux, FreeBSD, Solaris	DOS, Windows, Linux, OS/2	DOS, Windows, Windows Server, Linux, OpenBSD, FreeBSD, OS/2, Solaris, OpenSolaris, others
Network adapters	before 4	before 5	before 36
Virtual disk controllers	IDE or SCSI	IDE (before 4)	IDE or SATA (before 32 disks) or SCSI
USB support	Yes	Yes	Yes
3D acceleration	Limited	No	Yes (OpenGL)
Remote access to the virtual machine	Limited	No	Built-in RDP server
Remote USB support	No	No	Yes
Shared folders	Yes	Yes	Yes
Open software	No	No	Yes
License cost	Workstation for Windows/Linux approximately $199	Workstation for Windows/Linux - $49.99	Free of charge

hosts configuration has 1 Gb of RAM and Windows 7 Home and LinuxMint 18 operating systems.

The server virtual hosts have the Ubuntu 18.04 and AsteriskFreePBX 15 operating systems installed.

Client virtual hosts have software for IP telephony using the SIP protocol – LinphoneDesktop 4 (https://www.linphone.org). This program is open and free. It works in Windows, Linux and MacOS operating systems.

Two IP telephony servers are required to simulate the interaction of server hosts on the Internet. Client hosts are used to test IP telephony features on users' devices (figure 1).

A set of virtual machines for application in VirtualBox has been prepared for each laboratory work. The developed virtual machines are placed on the internal server of Berdyansk State Pedagogical University. Students can download the required images of virtual machines to perform lab work at any time.

4 THE RESULTS OF THE EXPERIMENTAL RESEARCH OF VIRTUALIZATION TECHNOLOGIES INTRODUCTION IN TRAINING OF IP TELEPHONY

The introduction of virtualization technologies in the training of future IT specialists involves conducting experimental research. The purpose of the pedagogical experiment is to test the research hypothesis: the use of virtualization technologies to teach IP telephony to future IT professionals will help increase the level of knowledge acquisition and skills in the field of IP telephony and computer networks.

The offered methodological approach to the application of virtualization technologies for training IP telephony of future IT-specialists should provide the solution of the following tasks:

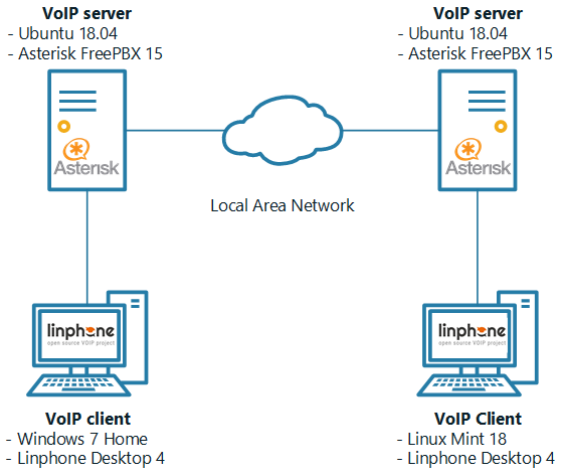

Figure 1: Virtual laboratory of IP telephony.

- software application for virtualization of servers and clients of IP telephony;
- systematic solution of debugging software problems and IP telephony protocols with the use of native virtualization;
- training time increasing to work with a network laboratory for the study of IP telephony.

Students of Berdyansk State Pedagogical University studying in the specialties 015 Professional Education (Computer Technologies) and 015 Professional Education (Digital Technologies) were involved in the experiment. The plan of the experiment provided for the creation of control and experimental groups. The experimental group consisted of 35 students and the control group of 39 students accordingly. Selection for control and experimental groups was carried out immediately before the study of "IP telephony in computer networks" discipline.

Classes in the control group were conducted using a hardware network laboratory. The method of conducting classes in such a laboratory provided for the organization of students' access to the equipment according to the schedule.

The organization of the educational process in the experimental group involved the application of virtualization technologies using the VirtualBox software and the developed repository of virtual machines. Virtual machines were organized according to the educational tasks of the discipline and were configured to perform specific practical tasks for setting up network software for IP telephony.

The success of the pedagogical experiment was insured by the use of such research methods that guarantee a reliable result. The following methods of pedagogical research were chosen: pedagogical observation at all stages of the experiment, tests, analysis of laboratory work, analysis of test results in the experimental and control groups.

The experiment studied the dynamics of the knowledge acquisition level and skills development in the field of IP telephony technologies and computer networks. The experimental technique involved the use of virtualization technologies at all stages of learning:

- while studying new material, as a system for demonstrating the features of setting up technologies and protocols of IP telephony;
- in consolidating the studied material, as a mean of developing skills in the field of IP telephony;
- in independent work, as an environment for the implementation of a professionally-oriented project to configure IP telephony servers in the corporate network of the enterprise.

Two tests were conducted to test the effectiveness of the virtualization technology implementation. The first test was conducted at the beginning of the study of the discipline. The purpose of this test was to determine the readiness of students of control and experimental groups to study IP telephony and covered the issues of installation, configuration and administration of server operating systems and networks. The test consisted of fourteen basic level tasks and three advanced tasks.

The second test was conducted at the end of the study of "IP telephony in computer networks" discipline. It consisted of ten basic tasks and five advanced tasks.

A comparison of students' knowledge acquisition level and skills development in the field of network technology and administration of server operating systems at the beginning of learning "IP telephony in computer networks" discipline revealed similarities in the levels of knowledge acquisition and skills of students in control and experimental groups.

A comparison of the results obtained after studying the discipline "IP telephony in computer networks" revealed differences between the levels of knowledge acquisition and skills formation in the control and experimental groups.

Table 2 shows the results of control works at the beginning and at the end of the experiment in the control and experimental groups.

Comparative analysis of tests results allows us to conclude about the positive dynamics of the knowledge acquisition level and skills in the field of IP telephony in both groups. In the experimental group the dynamics is more pronounced: a 14% increase in the share of students who coped with the task from 75 to 90% of the total (5% in the control group), a 19% de-

Table 2: The results of tests hold at the begging and at the end of the experiment.

	Before the experiment		After the experiment	
	Control group	**Experimental group**	**Control group**	**Experimental group**
Whole results of the test				
Managed with the test (%): including	90	94	90	94
• more than 90% from the whole work volume	5	9	10	14
• from 75 to 90% from the whole work volume	13	20	13	34
• from 50 to 75% from the whole work volume	62	65	67	46
• less than 50% from the whole work volume	20	6	10	6
Tasks of advanced level				
A part of students that have done:				
• more than 50% of the tasks of advanced level	5	14	5	54
• less than 50% of the tasks of advanced level	13	17	26	29
• those, who haven't reached the tasks of advanced level	82	79	69	17

crease in the share of students who coped with tasks from 50 to 75% of the total number of tasks (in the control group increased by 5%) (figure 2).

The share of students in the experimental group who coped with more than 50% of advanced tasks increased by 40% (in the control group the indicator hasn't changed). Statistical parameters of the experimental results are shown in table 3.

Analysis of the data in table 3 allows us to say about the positive dynamics in both groups, but in the experimental group the dynamics is more pronounced: the average score for the control work increased by 1.57 (in the control group by 0.85). In the Experimental Group, the median sample increased by 2 points. In the control group, the median increased by only 1 point.

Let's test the hypothesis of a normal sample distribution. We use Pearson's criterion for this. We formulate working hypotheses:

- H_0 – the empirical distribution is a subject to the normal distribution law,
- H_1 – the empirical distribution is a subject to another distribution law.

The results of the hypothesis test are shown in table 4.

Since it was found that all distributions obey the normal law, Student's criterion was chosen for further comparison of the samples (table 5). This will help to determine whether the level of knowledge acquisition and skills development in the field of IP telephony differ in the control and experimental groups. For this purpose working hypotheses were formulated:

- H_0 – levels of knowledge acquisition and skills development in the field of IP telephony of the two groups do not differ.
- H_1 – levels of knowledge acquisition and skills in the field of IP telephony in the two groups are different.

The obtained results indicate that at the level of significance $\alpha = 0.05$ the levels of knowledge acquisition and skills formation in the control and experimental group before the experiment coincide and differ after the experiment.

So, the results of the pedagogical experiment indicate that the research hypothesis has been confirmed, namely, the use of virtualization technologies to teach IP telephony to future IT specialists helps to increase the level of knowledge acquisition and skills in the field of IP telephony and computer networks.

5 CONCLUSIONS

Virtualization technologies were created primarily for the software applications development and testing.

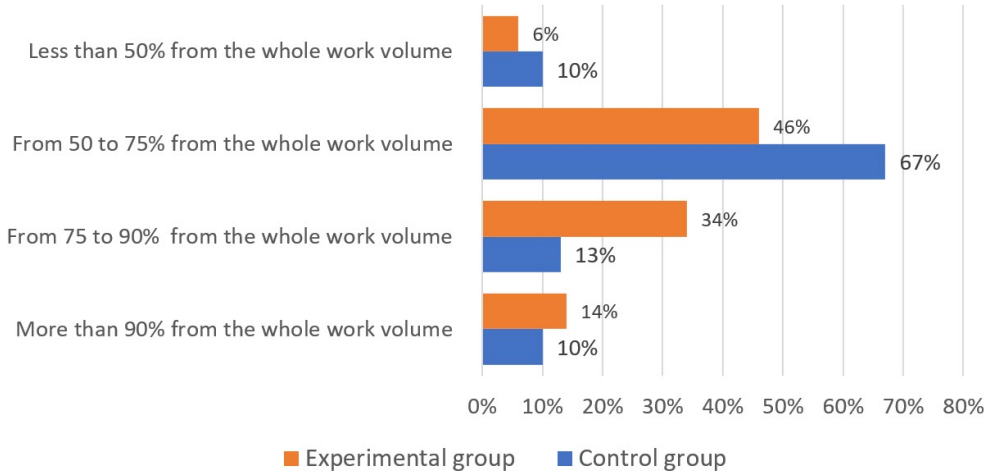

Figure 2: The results of test hold at the end of the experiment.

Table 3: Statistical parameters of knowledge acquisition levels and skills formation in IP telephony in the control and experimental groups before and after the experiment.

Parameters	**Control group before the experiment started**	**Control group after the held experiment**	**Experimental group before the experiment started**	**Experimental group after the held experiment**
Sample volume	39	39	35	35
Average	12.85	13.46	13.70	15.03
Median	12	13	13	15

Table 4: The results of testing the hypothesis of the sample distribution normality.

Group	**Before the experiment**		
Control group	$\chi^2_{empirical}$ 16.64	$\chi^2_{critical}$ 19.68	Accepted hypothesis H_0
Experimental group	$\chi^2_{empirical}$ 17.60	$\chi^2_{critical}$ 18.30	Accepted hypothesis H_0
	After the experiment		
Control group	$\chi^2_{empirical}$ 12.56	$\chi^2_{critical}$ 18.30	Accepted hypothesis H_0
Experimental group	$\chi^2_{empirical}$ 9.96	$\chi^2_{critical}$ 19.68	Accepted hypothesis H_0

Table 5: The results of statistical test of hypothesis.

Before the experiment		
$t_{empirical}$ 0.8	$t_{critical}$ 1.99	Accepted hypothesis H_0
After the experiment		
$t_{empirical}$ 2.3	$t_{critical}$ 1.99	Accepted hypothesis H_1

But in the field of education it is possible to use them in the training of future IT professionals.

The study has demonstrated a number of advantages from the introduction of virtualization in the educational process using VirtualBox, in the discipline of “IP telephony in computer networks”:

- the ability to support different operating systems in order to provide support and simultaneous launch of different operating systems to establish network interaction for the implementation of IP telephony service;
- the ability to isolate potentially dangerous steps of the operator or software products. In this case, the virtual machine acts as a laboratory stand, which is fully controlled by the student;
- the ability to create the necessary hardware configurations for the implementation of network interaction in the study of the discipline of IP telephony in computer networks. As a part of the lab-

oratory workshop, it is necessary to use the specified hardware configurations while checking the performance of Asterisk servers in certain conditions. It can also be used to perform various practical simulations of software and hardware;

- virtual machines application provides significant opportunities for setting up IP telephony servers, you can create repositories of ready-to-use virtual machines with guest operating systems set up according to the needs of a specific laboratory task, and use for training purposes. The developed virtual machines can be used for experimental research in the field of IP telephony, because in case of damage to the system, its recovery from the saved state takes little time;
- a significant advantage for learning IP telephony in computer networks using virtual machines is the ability to run several virtual machines connected to a virtual network on one host at the same time. This feature provides significant capabilities for creating virtual network models among multiple systems on a single physical computer;
- Virtual machines increase student mobility, they can be exported and moved to another computer, and there the virtual machine can be started immediately. This is a significant advantage of virtualization during the SARS-CoV-2 pandemic, when students have to study remotely. Each student can have his own virtual laboratory;
- while using virtual machines in the training of IP telephony control over the creation of backups, creating snapshots of virtual machines and recovery from failures significantly increase.

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