ViRo – the Online Support Tool for IP Network Oriented Courses

J. Uramová, M. Kubina, P. Segeč, P. Palúch*
* University of Zilina, Faculty of Management Science and Informatics, Žilina, Slovakia
{Jana.Uramova,Milan.Kubina,Pavel.Segec,Peter.Paluch}@fri.uniza.sk

Abstract— **Education of IT technology experts is not limited to providing theoretical knowledge, rather, it should also facilitate obtaining practical hands-on experience. It is advantageous to provide these practical experience opportunities with the help of supporting tools available not only during main classroom exercises but also through other voluntary activities beyond the student laboratory exercises. The article provides the feature analysis of a new didactical supporting tool, the Virtual Router (ViRo). ViRo shall be used to leverage and enhance the delivery of university study topics in the field of networking technologies and computer networks. The tool will allow students to deepen their practical configuration skills in designing and management of computer networks and network elements in an online internet-accessible environment.**

Keywords – **education, computer networks, knowledge**

I. INTRODUCTION

Nowadays, demands on the knowledge level of network professionals are increasing not only from the theoretical point of view, but especially in terms of practical knowledge. This creates a need to provide appropriate educational resources allowing a simple access to information and interactive elements, facilitating a better understanding of particular study topics. New trends in information and communication technologies (ICT) offer new resources and tools that may be usefully utilized in the learning process in the form of complementary solutions supporting common forms of learning as well as enabling new forms of distance education even running in real time.

Education of ICT experts, as an addition to the up-to-date theoretical content, should allow the acquisition of necessary and highly desired practical skills. In the field of network technologies, the quality of teaching and learning is greatly enhanced by using modern and highly accessible laboratories equipped with the necessary technology. By working with the technology, students can verify and apply the acquired theoretical knowledge on real-life professional equipment. This approach, however, brings the need to build a laboratory or laboratories in the location of education, often with high set up costs. In addition, students' access to laboratory facilities is often limited to a few hours a week, during the time of laboratory exercises by the teaching schedule. The specified time is often inadequate for the student to fully understand the theoretical and practical aspects of network communication on real network communication devices.

This article analyzes the characteristics of a tool that would solve the problem of limited access to facilities in which students would be able to practice the configuration and management of devices in complex topologies and thereby improve their practical knowledge in the field of computer networks. The ViRo didactic tool can be used to support the teaching of subjects in the field of network technologies and computer networks.

Students will be able to acquire and deepen practical configuration skills in the design and management of computer networks and other network components on-line via the internet using this tool. The tool will be used to support educational for teaching courses Computer network 1, 2 at the Faculty of Management Science and Informatics and Faculty of Electrical Engineering at the University of Žilina.

II. ANALYSIS OF AVAILABLE SOLUTIONS

Currently, there is a number of applications available using which the students can put their knowledge and practical skills to test. These tools are significantly different in the functionality provided, from the simplest ones offering only very limited opportunities to the most complex. In the next section we mention only the most common and most complex solutions.

A. Packet Tracer

Packet Tracer (PT), developed by Cisco, is a self-paced, visual, interactive teaching and learning tool implemented in a form of computer networks simulation software [2] primary focused at CCNA level knowledge. PT allows the creation of complex topologies and subsequent work with them. The tool is freely available to students of academies involved in the Cisco Networking Academy program. PT offers a unique combination of realistic simulation and visualization experiences, complex assessment and activity authoring capabilities, and opportunities for multiuser collaboration and competition [3]. Packet Tracer excels in easy and intuitive control (see Fig. 1), the short time required to create the topology and the subsequent testing and configuration using a user-friendly graphical environment. PT disadvantage is its limited functionality and occasional issues with network simulation fidelity. This is due to the fact that the program does not use a real image of the router or switch operating system (IOS - Internetwork Operating System), but only functions implemented by application developers.

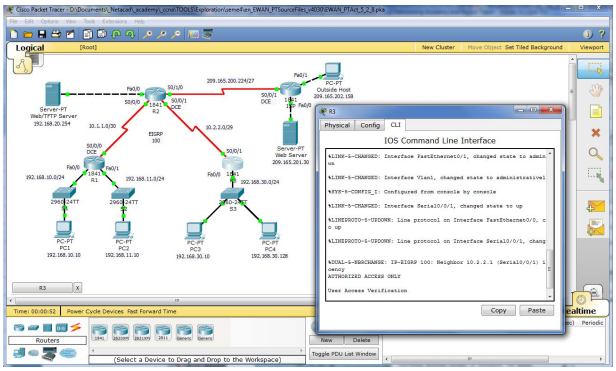

Figure 1. Packet Tracer logical and configuration interface view.

B. *Boson NetSim*

Boson Nets [4] is a simulation program similar to PT. It consists of three parts: Boson Lab Navigator is used to navigate in the list of generated configurations; Boson Network Designer allows creating custom network topologies; Boson NetSim is an application performing the actual simulation. The software focuses on simulation of the operations of Cisco devices. This simulator is primarily intended for those interested in CCNA and CCNP certification.

The program provides a number of preconfigured network topologies, which can be solved by user, or the user can create his/her own topology using 47 different devices. The program also contains instructions and procedures for dealing with these topologies. The disadvantage of this program, similarly to what we mentioned for PT, is that it is only a simulator. The program does not offer the full functionality of the devices. Boson NetSim (see Fig. 2) lags behind the PT program, in visual aspect, operation and supported CLI (Command Line Interpreter) commands.

C. *Dynamips/Dynagen and GNS3*

Another tool is open-source emulator of Cisco devices - Dynamips and its extension - Dynagen. Dynamips [5] is a multiplatform emulator of MIPS processors (MIPS - Microprocessor without Interlocked Pipeline Stages) and hardware environment. It was created by Christopher Fillot, originally for the purpose of emulating Cisco 7200 series routers on a standard PC by running the real IOS (Internetwork Operating System) in a virtual machine. The development and expansion concluded to its present form whenin addition to 7200 series, Dynamips also supports 3600 series routers (models 3620, 3640 and 3660) , 3700 series (models 3725, 3745) and 2600 series (models 2610, 2650XM, 2691).

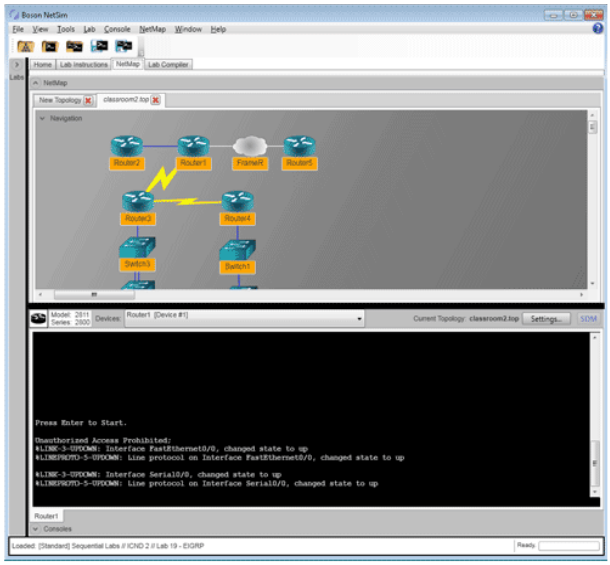

Figure 2. Boson NetSim [4].

Dynagen is a front-end for use with the Dynamips Cisco router emulator. It uses an INI-like configuration file to provision Dynamips emulator networks. It takes care of specifying the right port adapters, generating and matching up NIO descriptors, specifying bridges, frame-relay, ATM switches, etc. It also provides a management CLI for listing devices, suspending and reloading instances, determining and managing idle-pc values, performing packet captures, etc. [6].

The main difference between these instruments is that Dynamips emulates the hardware of supported router platforms in the form of a virtual machine and runs the real Cisco IOS in these virtual machines. Hence, the fidelity and accuracy of the emulation is unparalleled, as the IOS functions and features are not emulated, rather, the real IOS is being run inside a virtualized environment that emulates router hardware. The disadvantage is the need to purchase appropriate IOS licenses, since IOS is not a free software. A suitable addition is to use the Graphical Network Simulator GNS3, which is a graphic interface for Dynamips and Dynagen (see Fig. 3). Its main advantage is that it combines a user-friendly environment and the look reminiscent of Packet Tracer with the possibilities offered by Dynamips.

D. *Evaluation*

All of the analyzed tools are designed to run on the user side – user equipment (the student). Comparing their features and functionalities for the needs of ViRo tool, Dynamips seems to be the best option. The reason for selecting this particular tool is that, unlike the other solutions, it is an emulator which provides functionality of real devices. It is platform-independent and is able to function as a client/server application. Since the tool is demanding on the performance of the computer it runs on, we expect the integration of the tool into the client/server architecture, where the performance of the hosting device

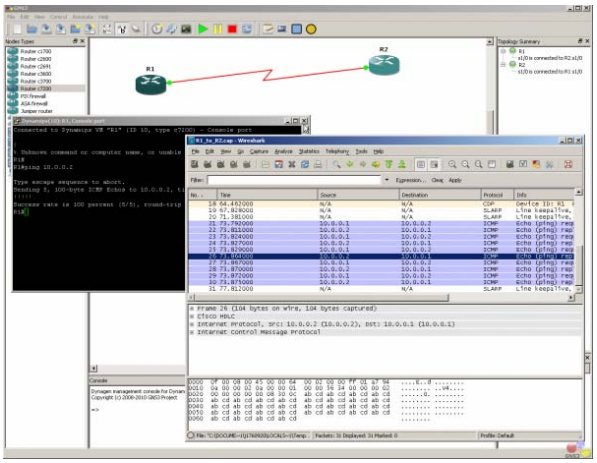

Figure 3. Graphical Network Simulator - Gns3 [7].

(server on which the tool will be operated) can be guaranteed, managed and secured.

III. ViRo tool

A. Motivation

Currently there is a lack of specialists in IT technologies on the labor market. IT specialists prepared by a university should be both theoretically and practically capable specialists who are able to translate their theoretical knowledge into practical skills in the field. We educate IT networking professionals at our Department of InfoCom Networks at Faculty of Management Science and Informatics as well as at the Department of Telecommunications and Multimedia at Faculty of Electrical Engineering at University of Žilina. Our courses are practically oriented and are highly sought for by our students. On the other hand, this high interest and resulting high loading of laboratories forces us to strictly observe the schedule of practical laboratory exercises where network devices are located. As a result, it is difficult to provide students with overtime for deepening practical configuration skills beyond the scope of the lesson.

To support the acquisition and reinforcement of skills and fundamental knowledge in the design, implementation and management of computer networks, there is a range of different simulators and emulators, some of which are described in our paper. With these tools, the user can perform simulation of complex computer networks and their components on a single PC. The big disadvantage of these tools is usually only a partial ability to simulate the behavior and configuration of real network devices. Some simulation tools are charged, are usually platform-dependent, and put increased demands on the hardware of system on which they operate.

One of these tools is the Dynamips, distributed under the GNU GPL, which is not a simulator, but rather an emulator of network device hardware, allowing to work directly with the network operating system of Cisco routers known as IOS. Its biggest advantage is the accuracy provided by virtualization, as the emulated devices are running the original IOS. A disadvantage is the relatively high demands on computing power of the system on which emulator works (depending on the amount of network elements in the topology).

Our main intention is to use the features of Dynamips/Dynagen in our ViRo tool and to provide students with access to this educational tool without imposing additional schedule demands. A prerequisite is, of course, a working Internet connection and a student's desire to learn and to work.

ViRo tool will use client/server architecture available on-line via the internet and offered through a web interface. We plan to build a community portal extension allowing the sharing of knowledge in order to build the knowledge base in this area. We take it a goal to create, keep and maintain community links of our students and in the wider context of network specialists themselves.

B. Goals

The goal of ViRo is to provide on-line, internet-accessible educational tool that allows students, regardless of their software and hardware options, remote access to a using network server. The server will be implemented with freely distributed and platform independent simulator of computer networks (Dynamips/Dynagen).

The management interface tool will provide a number of functions available through the internet and fully functional simulator of computer networks for the users. ViRo tool requires no additional installation of other software on the client computer. The tool provides the user with a laboratory environment that emulates the real network topology with which students work on practical exercises during the Computer networks courses implemented at two faculties of the University of Žilina, Faculty of Management Science and Informatics and Faculty of Electrical Engineering. The solution offers a number of advantages, such as the central management of network topologies and sets of exercises, management of operating systems for network elements, transfer of computing performance requirements of the simulations to a powerful and centrally managed network server, management of server load and use, process, personnel and time management, communication with real network, etc.

C. Features and requirements analysis

The general requirements that the ViRo tool should fulfill are:

- Accessibility of the tool via the Internet.
- Security.
- Simple, user-friendly operation.
- Extensibility application of new elements.

The whole system should provide the following functionality:

- The ability to log-in only for registered users, to prevent the unauthorized use.
- User accounts management – create, delete, block accounts, create user groups and assign users to them, create access rules
- The allocation of privileges to perform various activities within the application (creation of topologies, etc.).
- Creation of new topologies, and use of existing ones.
- Editing an existing topology.
- Deleting an existing topology.
- Saving unfinished topologies and the ability to continue the configuration later.
- Booking available topology for selected time slot in the week with guaranteed maximum booking time.
- Cancelling bookings.
- Administration of booking.
- Start/Stop a booked topology.
- Starting a topology without an appointment if the server has still available capacity.
- Managing system resources.
- Tracking the system.

In terms of the diversity of requirements for the system and its use, we assume three types of users for ViRo tool – student, teacher and administrator. Each type of users

should be able to use the functionality mentioned above, depending on authorization defined for their particular type. (See Fig. 4).

Functionalities of the user of the student type include:

- Edit personal profile
- Access to the list of available and booked topologies within the week.
- Booking the chosen topology for a particular day and a particular time slot.
- Cancel booking before booked date.
- Start a booked topology and working in the particular time slot.
- Save unfinished work on topology.
- Restore saved unfinished topology.

User of the teacher type has available all the options for the student, and in addition, teacher's options are supplements by other options, such as:

- Create a new topology.
- Edit, delete, and enable/disable existing topology.
- Add new users.
- Edit and delete existing users.
- Assign user permissions and assign users to the user groups.
- View the list of currently running simulations and all upcoming bookings.
- Cancel a booking for some reason (eg. maintenance of the system), or stop running simulation.

The administrator type, as its name suggests, describes the user who will manage the whole system. Unlike the group Student/Teacher, an administrator does not use the system but provides the functionality and management for the smooth functioning of the tool. The basic tasks of the administrator will be:

- Manage web features.
- Manage content.
- Configure the portal.
- Manage users and permissions.
- Manage system resources and file system.
- Troubleshoot.
- System maintenance.

Communication of a user with the system will be performed using a web interface, i.e. tool will be implemented as a web application. For this reason, as mentioned earlier, it is our aim to build a community portal extension allowing the sharing and the distribution of knowledge in the field of computer networks management within the CCNA and CCNP. Community portal allows creating guides, sample topologies and results in the form of articles or blogs. It can offer also other methods of communication in the form of discussion forums and communication channels.

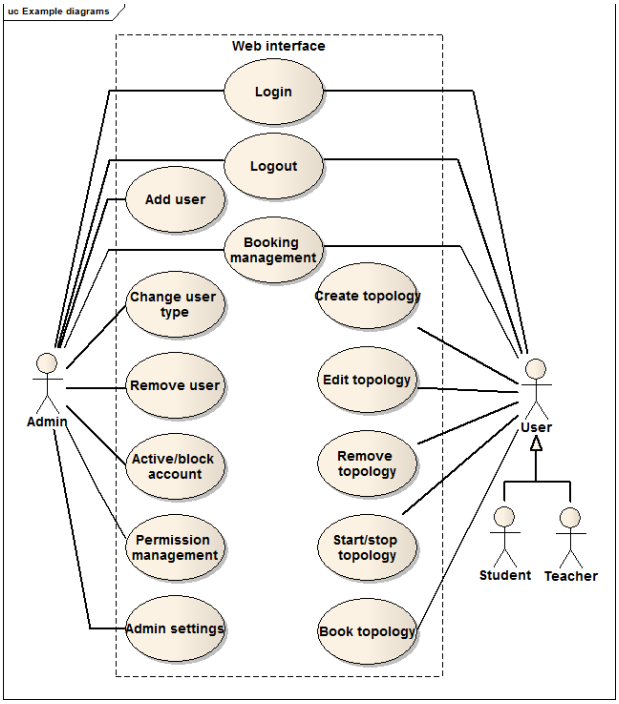

Figure 4. ViRo use case diagram.

D. *Basic technical design of proposed solution*

Based on theoretical and experimental analysis of functionalities and options for tool Dynamips and Dynagen, and taking into account all the requirements for the application resulting from the analysis, we propose the structure of the application ViRo as shown in Fig. 5. It is a solution built on the GNU/Linux operating system. In terms of memory consumption of the tool Dynamips, we will use a 64-bit version because of the possibility of using more than 4GB of RAM by a single process. The core of the application consists of Dynamips simulation program which will provide virtual device emulation. Dynamips will be extended by Dynagen extension to facilitate startup of topologies.

Web interfaces provide communication between the user and the functionality provided by the server. The interface will be designed as web portal from which users will have access to all the application options. A database running in MySQL database system will be created to store the data used by web interface and by applications Dynamips and Dynagen. Communication with individual virtual devices will be accomplished by a Java applet - Java Telnet Application, accessible directly from the web. Since the range of requirements for the application is very wide, we plan to use Content Management System (CMS) that provides basic functionality such as logging, user management and more.

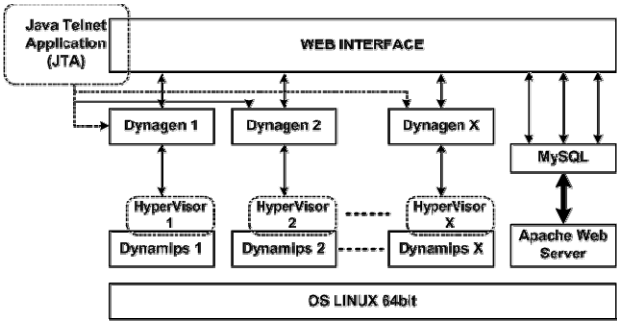

Figure 5. ViRo tool architecture.

IV. Conclusion

The ViRo tool will offer the opportunity for students and teachers to work easily and comfortably with virtual topologies. The tool will provide an interface for teachers to create a new topology or edit existing ones, and make them available to students who will then be able to work with them and thus improve their practical skills in the field of computer networks. The tool will also offer a reservation system which ensures a guaranteed number of work hours for each student. It will be possible to change the settings, such as the length of the blocks, the number of guaranteed hours, etc., in the system as needed. The tool will be fully extensible for new features according to user needs.

Acknowledgment

This work is supported by the KEGA project 060ŽU-4/2012 „VirRo - on-line nástroj na podporu vyučovania predmetov z oblastí IP sietí a komunitný znalostný portál/VirRo - online tool supporting education of IP networking courses and community knowledge portal“.

References

[1] K. Kleinová, P. Feciľak, F. Jakab, Z. Szalay: *Transforming Vocational Education in Slovakia*, 9th IEEE International Conference on Emerging eLearning Technologies and Applications, Stará Lesná, The High Tatras, Slovakia, 27. - 28.10.2011, Slovakia, IEEE, 2011, 9, pp. 199-204, ISBN: 978-1-4577-0050-7

[2] Packet Tracer 5.0 Datasheet, available at: http://tinyurl.com/yjc46k6.

[3] J. Janitor, F. Jakab, K. Kniewald: *Visual Learning Tools for Teaching/Learning Computer Networks*, The Sixth International Conference on Networking and Services ICNS 2010, LMPCNA 2010: The Second International Workshop on Learning Methodologies and Platforms used in the Cisco Networking Academy, Cancun, Mexico, 7-13 March 2010, Cancun, Mexico, IEEE Computer Society, 2010, pp. 351-355, ISBN 978-0-7695-3969-0.

[4] NetSim Network Simulator – The Cisco Network Simulator and Router Simulator, available at: http://www.boson.com/netsim-cisco-network-simulator

[5] Dynamips Cisco router emulator, available at: http://www.ipflow.utc.fr/index.php/Cisco_7200_Simulator

[6] Dynagen – The network configuration generator for Dynamips, available at: http://dynagen.org/

[7] Graphical Network Simulator - GNS3, available at: http://www.gns3.net/