A REVIEW PAPER ON TEACHING COMPLEX COMPUTER NETWORK CONCEPTS

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ABSTRACT

The primary issue that arises while teaching computer networks to students is the high cost and small quantity of network devices available for use in the lab. These days, we can get around this restriction thanks to virtualization. In this study, we provide an approach that uses the Tool for virtualization VNUML-UM a publicly accessible Provides information on load balance, mobility and range to allow students to understand Complex computer networking concepts from practical applications. Over the last three academic years, we have conducted a few opinion polls with the pupils to confirm the value of employing the utilization of VNUML-UM virtualization tools in advanced computer education concepts. The outcomes demonstrate that our pupils believe the VNUML-UM facilitates a better understanding of the various concepts and their practical abilities. The kids' final grades, which are noticeably better than time, support this impression as well. To the extent of our understanding, this work offers the firsthand account of results on the utilization of virtualization to the teaching of sophisticated computer network concepts.

Keywords:— *Computer and data science education, virtualization software tools, virtual Laboratory, Educational Simulation, Computer Instructional Strategies and Networks.*

1. INTRODUCTION

When teaching both fundamental and sophisticated computer network concepts—such as load balancing, mobility, routing, and other issues—students must learn both the theoretical information and Ability to set up and follow events using international computers. Engineering courses help students gain these skills. through the creation of "laboratories" [1]. Smaller student groups ought to utilize these labs to provide them the most opportunity to experiment with the various network components and accurately acquire the necessary skills. However, the creation of intricate network topologies must be fulfilled in order to achieve this goal in actual laboratories (therefore referred to as labs), but it is also expensive (both financially and in terms of time).

Virtualization techniques [2], [3], that is enable very realistic network infrastructure simulation, have emerged as an alternate, effective, and affordable option to get around the aforementioned issues. Additionally, the incorporation of computer technology can assist learners in perceiving the enhancement of their educational experience [4]. Because of this, these tools have historically supported the teaching of several areas in computer science education [5, 6, 7, 8, 9, 10, 11, 12, 13, 14]. Specifically, a number of writers have effectively used virtualization to instruct students about network routing and basic network configuration [10], [11], [12], [15], and [16].

However, as far as we are aware, advanced computer network concepts like Mobility, load balancing and pressure are not met taught using virtualization tools. This paper outlines the approach and the instrument We developed

and implemented this concept in our Computer Networks course (as part of the Computer Science Engineering degree at the University of Murcia). This tool is provided by VNUML [18] and is known as VNUML-UM [17]. As far as we are aware, VNUML-UM is the first virtualization machine to enable instructions of such sophisticated contents. Furthermore, the effectiveness of our concept is validated not only by tracking the progression of students' grades throughout multiple courses, but also by the students themselves, as indicated by a few opinion surveys. The remainder of the document is structured as follows: The background information on virtualization and teaching is presented in Section 2. The Including computer and online courses we are using the VNUML-UM-based learning methodology for, is covered in Section 3. The VNUML-UM tool and a few scenarios created Our students' results can be found in Chapter 4.. The specific outcomes we have achieved by using the suggested methods are detailed in Section 5. Section 6 wraps up the report and provides an overview of some potential future research topics.

2. Virtual Network Lab

The benefits of virtualization approaches are explained in detail below, along with how they inspired the creation of virtualized network laboratories built around the VNUML-UM virtualization tool.

2.1 Qhia computer network virtualization

Teaching computer networking, a lot more computers may be needed than when teaching subjects like operating systems and system administration, where practicing with them usually only requires two personal computers, or PCs, to set up a scenario. This is especially true when teaching more complex concepts.

Table 1 Virtualization tool sib piv

	License	Topology configuration	Scenario execution	Type of virtualized hosts
Imunes	BSD	Configuration centralized in a single configuration file. Optional graphical configuration.	Graphical simulation or through command line interface	Virtual hosts run a specific FreeBSD kernel that cannot be extended
Velnet	Restricted (based on VMware Workstation)	Topology is configured through a graphical interface. Virtual machines can be only configured once they are started.	Graphical execution where each virtual host must be independently started/stopped.	Virtual hosts can be based on any operative system.
MLN	GNU GPL	Single configuration file containing both topology and virtual machines configurations.	Single command line parser to manage the virtual network scenario.	Limited set of specific file systems supported for virtual nodes.
Netkit	GNU GPL	Configuration is split across various files to specify the topology and virtual machines configuration. Optional graphical configuration (NetLab).	Execution is controlled through different command line programs for managing virtual hosts, scenarios, etc.	Virtual machines run a Debian GNU/Linux distribution that can be extended with new software.
Dynamips	GNU GPL	Configuration is specified in a single file to indicate topology and virtual machines configurations.	Tedious execution based on command-line interface commands.	Only supports de virtualization of Cisco routers.
NVLab	Not available	Configuration is specified through a Web interface that is saved in a server as a XML file.	Executed in the server and the user accesses by means of VNC and works manually with the nodes. Only accepts one user logged into the system. The tool has not been tested in a real environment.	Nodes based on Xen
VNUML	GNU GPL	Topology and virtual machines are configured in a single specification file by using a simple XML-based language. Optional graphical configuration (VNUMLGUI)	Simple execution through a command line parser that not only controls the basic interaction with the scenarios (start/stop) but also allows the automatic execution of commands in virtual machines.	Virtual hosts can run any customized UML kernel that can be extended with new utilities.

Utilizing labs with actual equipment has a few significant drawbacks. Especially education has to be Groups of students implement the work and the time students can spend on computer network scenarios is limited because there is only one structure where all the boys and girls working at the same time cannot work. On the other hand, Lab virtualization technology is great because it allows all students to use it a different network scenario Virtualization not only solves various issues seen in labs using actual equipment, but it also makes computer network tswvy easier to understand practically. First, students consider Liquidity would be best that they greatly value. Students can use computer network scenarios at home or at university as they can Nruab software virtualization on their laptops or PCs. Because they are not limited by the timeline that is set out Students can develop their applications using various physical devices in real laboratories and gain flexibility in computer interaction.. Second, virtualization provides more freedom. By defining the topology and its implications, teachers can create and classify the situations that students will deal with components, or students can design their own network topologies. Ultimately, virtualization enables for pupils to obtain practical expertise in creating, deploying, and administering Real topology tools they will encounter in their future work endeavors. In conclusion, virtualization is an effective tool that enables students to practice in an adaptable and practical setting, helping them to solidify the principles they have acquired in theoretical classes.

2.2 Virtualization tools for virtual network scenarios

At the moment, Qemu, Xen, WMware Server, Virtual Box thiab Kullanıcı Modeli Linux (UML) are a few popular virtualization solutions. However, these solutions don't offer a particular way to make The nature of using virtual networking is simple. This is the reason for projects like Virtual Networking for Immunities [19], Velnet [20], My Linux Network (MLN) [21], Netkit [22], Dynamips [23], etc. Network User-Mode Linux (VNUML) [18], have been launched in recent years with The goal is to simplify the deployment and configuration of virtual network infrastructure. One of the easiest is VNUML and potent tools available for Used in academic and scientific environments, according to a study on the subject published in [12]. Even if there are now Many virtualization tools (such NVLab[24]), VNUML is still the best option available today for Network scene virtualization (as seen in Table 1).

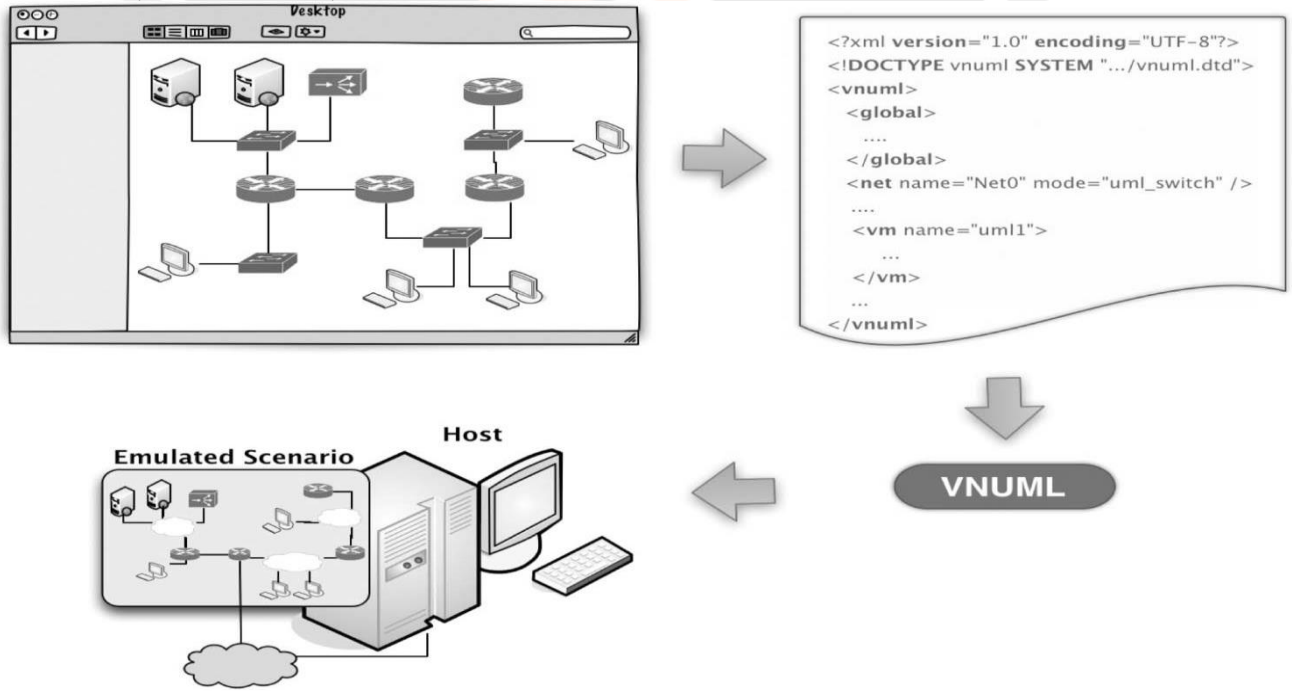

Figure 1. VNUML development stages.

Consequently, VNUML is a viable choice for Complex ideas about computer networks instruction. In fact, it allows us to perform virtualization on computers using a simple version of the Linux kernel and file system. Therefore, the configuration used in the virtualization program can be used without modification in the real

situation because the virtualized environment actually uses the same equipment as the real situation.In addition, the instrument exhibits strong performance, a manageable memory usage [25], and a superb virtualization grade.

Additionally, VNUML is simple to install, available under the You can use it directly from a Live CD or DVD under the terms of the GNU Public License. Most VNUML parsers, files, and XML data definitions (DTDs) are installed. During the installation process, two files needed for the virtual machine need to be installed: one that has the virtual machine's file system and another that contains the Linux kernel.

To test various virtual machine configurations, it actually permits Many system files and kernels are installed. The VNUML process consists of three steps (see Figure 1). The first step in Figure 1 is the user (teacher or student) design phase theoretically explains the network scenario. During this stage, the user describes the many components and elements that make up the network architecture, such as Routers, connections, computers and different IP addresses assigned to each equipment interface. The user creates a file containing the scenario definition in the VNUML language (second step in Fig. 1), which is predicated on a precisely defined XML DTD, during the implementation phase that follows. Yog tias VNUML graphical user interface tool is used to build the network architecture, this specification might be generated automatically [26]. Ultimately, the third step in Figure 1 shows how the Perl-written VNUML parser reads the scenario definition, and the fourth step shows how the virtual machines and topologies are integrated designated networks is automatically launched during work.

As illustrated in Figure 2, VNUML opens Each node has a window that simulates Linux console, via which users can communicate with virtual machines by configuring them appropriately, starting and terminating daemons and/or programs, running commands, etc. Also, program provides the ability to run various The commands on the virtual machine are listed in the database.

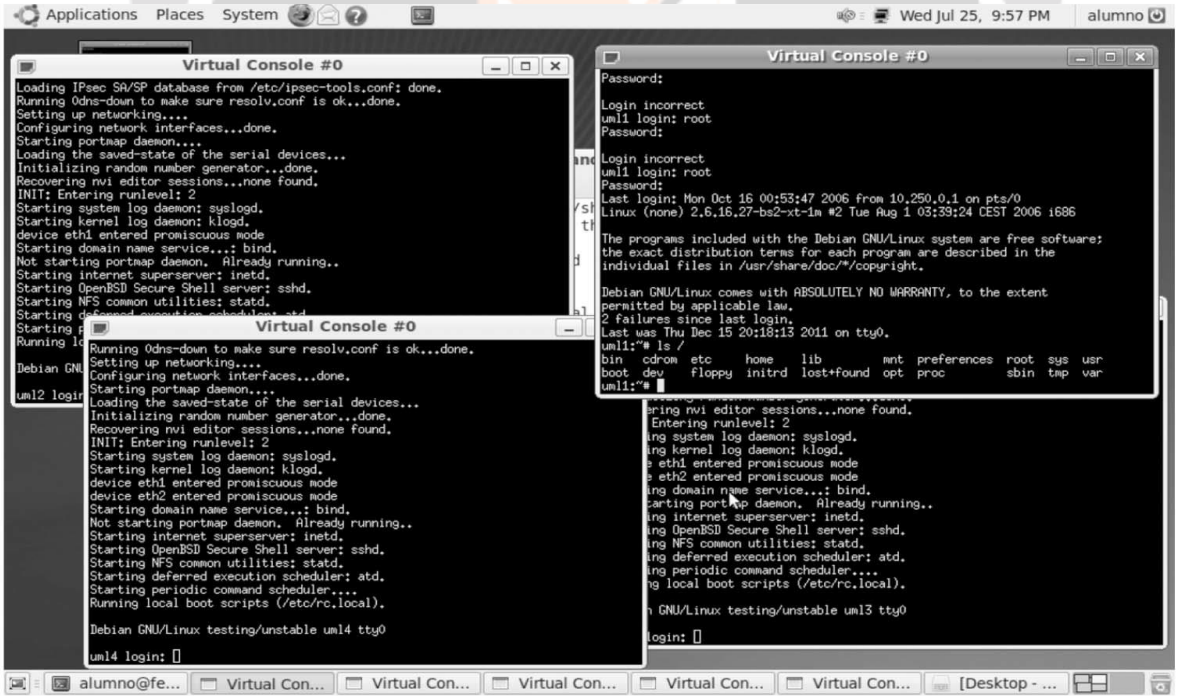

Figure 2. VNUML continued.

Moreover, VNUML enables the host—the actual machine used to run the simulation—to take part. It is a virtualized network architecture that can connect the simulated architecture to the real internet. Once we are done interacting with the topology, we can use the decoupler to terminate the simulation.

3 Computer Network Topics

We then explain the effectiveness of the computer networking discipline and the resources that will be needed to develop it.

3.1 Subject Description

Computer Networking course is held for two to four months each year and is the fourth course leading to a Computer Science Engineering degree**.** The ten units that make up the theoretical part of the subject (which has a workload equivalent to eight ECTS units—the European Credit Transfer System) includes the following topics: Routing and Mobility, High Capacity, Load Balancing, dynamic routing, Transmission Control Protocol (TCP) operation and support in IP versions 4 and 6. The performance has a load equal to four ECTS and its aim is to support the most important theoretical ideas by creating a computer network that must meet the requirements it has made objectives and find solutions to specific issues. Students must create and verify that their suggested solution functions correctly utilizing VNUML tool. Specifically, three key subjects are treated Performance includes product stability, IP mobility and availability, and efficiency.

These foundational concepts are created by assigning pupils to complete a variety of practical tasks. Courses are structured and important theoretical concepts are covered throughout the course. Our approach includes an explanation of the specific techniques students will use to build network components and how to configure these devices and the network topology.

3.2 Laboratory methods

We plan to hold one-hour laboratories throughout the school year to teach the hands-on portion of the course. These labs are designed to introduce students to the various tools and configuration options that can be used to solve real-world tasks through hands-on demonstrations. More specifically, the conference is divided into the following sections:

- Sessions 1, 2, 3, and 4.These lessons aim to help the learner become acquainted with the surroundings and to clarify the general usage of VNUML.
- Sessions 5, 6, and 7. During these lectures, instructors cover computer network architectures related to routing protocols in addition to explaining the software that implements dynamic routing protocols and specifics of its configuration.
- Sessions 8 and 9. During these courses, we go over the topologies and software that students can utilize to construct their real load balancing and high availability work.

In addition to these general sessions, we provide online tools that allow students to connect with instructors to clarify questions and expedite the learning process [27]. Generally speaking, laboratory sessions consist of no more than 15 groups (30 students) and are divided into three rounds on different days of the week to improve student comfort and instructional quality. Taking into account the three primary subjects the topic cover in the theoretical part (discussed in Section 3.1), we propose three practical works to deal with them:

- Practicalwork1: Computer network and routing design is the first practical task.In this practical assignment (which relates to sessions 5-7), students must build a network topology that is integrated by a number of companies that meet specific criteria. They then use various routing tools and configure several dynamic routing protocols (RIPv1, RIPv2, RIPng, OSPFv2, OSPFv3, and BGPv4) inside the network infrastructure to verify their design. Through this hands-on work, students gain a comprehensive understanding of the many routing protocols covered in the theoretical portion of the course, including IPv4/IPv6 address assignment, computer network design, and dynamic routing.
- Practical work 2: IPv6 auto configuration and mobility. Through this hands-on study, students can learn about several important auto configuration and IPv6 mobility concepts. The task specifically comprises of a sketch that describes how these elements are configured in actual circumstances. Because of this, the methodology we employ is predicated on the explanation of multiple steps that lead the student through the procedure and display the various configuration files and necessary commands. The student has to confirm that the scenario put out by the professor works, respond to a series of questions meant to elicit accurate comprehension, and carry out a number of desired adjustments and extensions.
- Practical work 3: Both load balancing and high availability. This practical activity, which is connected to sessions 8 and 9, suggests designing a load-balanced, highly available system that meets a number of precise specifications. In particular, it gives students the chance to engage

practically with a few theoretical ideas like load balancing, high availability, and computer network design. Students must specifically set up redundant routers (in accordance with the Virtual Router Redundancy Protocol, or VRRP), web servers, DNS, and web proxies employing load balancers and caches based on IP addresses or cookies.

It's vital to note that Practical Work 2 lacks related sessions because students can appropriately build the drawing and respond to the various questions by using the principles covered in sessions 1-4 and the theoretical portion. Lastly, we would like to point out that the VNUML-UM distribution is used to generate the various scenarios needed to complete the previously indicated practical exercises (see Section 4).

3.3 Students' Learning Process

This section summarizes the steps students need to take to gain the knowledge and skills needed in the course. The first exam was held one week after the start of the theoretical course. After the first session is completed, special sessions on practical activities will be based on the topics covered in the theoretical sessions. In these sessions, software that provides flexibility, automatic configuration, IPv6 mobility, high capacity and stability installed on the file system used by virtual machines was explained. In these lessons, the teacher specifically explains how to use programs to create and create multiple computer networks and how to set them up. We encourage learning in the process through class discussion. Therefore, we can reconcile many theoretical concepts with real-life applications. The aim of each performance is to create a computer network that follows a specific process related to some theoretical ideas introduced earlier. Students were divided into two groups to complete each task. After completing several laboratory-related practical tasks, students will do the following. First, they decide on the design of the solution and discuss what needs to be done. Once the design is approved, they often present the solution to the instructor for input before starting to develop the drug. This progress can be achieved in two ways: either during study hours that they can use at home or in the laboratory (at unscheduled hours), or during study tests performed every week that do not affect the time period. Regardless of the student's academic performance, teachers can educate students through meetings or virtual schooling. Design, configuration capabilities are key points for the development and selection of system development tools [28]. When a similar special competition is created, such as the formation of administrative policy in two autonomous systems, they cooperate by dividing certain tasks. Finally, they work together to create a final report that relates to the actual study. The purpose of this report is to reiterate their understanding of the system and explain and defend the various designs they have chosen for the system.

3.4 Students' Evaluation

There are two methods used to measure student learning outcomes in the computer networks course. Firstly, by a theoretical examination. However, they must also develop them through the assessment of the three practical works.

We differentiate between two sections in the theoretical exam. First, a test consisting of twenty multiple-choice questions, where you have to select one response from three alternatives. Our objective is to minimize the likelihood of guesswork by implementing a scoring criterion that RUIZ-MARTINEZ ET AL.: TEACHING ADVANCED CONCEPTS IN COMPUTER NETWORKS: For wrong answers, VNUML-UM VIRTUALIZATION TOOL 89 deducts points. This rule states that: 1 point is awarded for a correct response, 1/(number of choices–1) points are deducted for We have developed an improved VNUML distribution, known as VNUML-UM, based on VNUML version 1.7.3. This is offered as a teaching resource [17]. The basic VNUML kernel and file system files have been expanded in this installation to include the modules and software required to carry out the various practical tasks outlined in Section 3.2. It is noteworthy that certain tools found in VNUML-UM for load balancing, high availability, and IP-based mobility are strong enough to be utilized in professional settings. Consequently, VNUML-UM could potentially be applied to the expert design of networks. Actually, it has previously been demonstrated that VNUML may be used in professional testbeds [12].

Although there are more recent VNUML versions (1.8.9 and 1.9.0beta8), we have chosen to use version 1.7.3 in our labs. There are two factors at play. On the one hand, the number of virtual machines that can run in a single virtualized scenario is plainly limited by the fact that newer versions demand more RAM to launch a virtual machine than versions 1.7.

However, neither the techniques used in the practical portion of the subject nor the features developed in our virtualized situations are enhanced by the additional capabilities provided in the more recent versions of VNUML. Actually, the improvements made to the parser that starts the simulation—which has been shown to be stable already in version 1.7.3—and the simplification of the language used to define the virtualized network topology

have been the main goals of these most recent releases. Nevertheless, we have also created a customized version based on VNUML 1.8.9 for those possible customers with more capable labs. When a stable release of version 1.9 becomes ready, the same course of action is anticipated.

In terms of the virtual machines, VNUML-UM supports the filesytem version 0.4.1 of VNUML version 1.7.3 as well as the Linux kernel version 2.6.16.27. The Linux kernel version 2.6.29 and the file system file version 0.6.0 are compatible with VNUML 1.8.9. The VNUML project website has the original files for these versions [18].

The fact that VNUML's Linux distribution does not function in graphical mode is the root cause of the various issues encountered when creating this customized distribution. Consequently, installation is limited to programs that support command-line operation mode.

Although this feature makes it possible to run multiple virtual machines without consuming a lot of RAM, it restricts the range of tools that we may add to the system. We were forced to do a thorough search and analysis of the various tools that met this requirement as a result.

We also closely examined the dependencies and disk space needed for each tool's installation in order to reduce the size of the virtual machine file system file.

Our goal was to strike a balance between the needed disk space and the functionality offered when choosing which tools to install in the file system file. In actuality, we threw out a few tools since their functionality was the same as that of others and their size was a significant installation need. Following the installation and selection process, we evaluated each tool's functionality and performance, paying close attention to any memory requirements during use. Since we found certain tools that couldn't function with the virtual machine memory setup by default, this analysis was crucial. We therefore conducted a thorough investigation to identify the ideal setup that would enable a seamless virtual network scenario.

We could create a centralized system, a web-based system, or include this new distribution into a virtualized system that would stop students from installing the program using the VNUML-UM distribution. As a result, the new distribution serves as the foundation for all systems based on this capabilities. In our instance, we chose to utilize VNUML-UM in its current form rather than creating a centralized system since student-developed laboratories yield superior performance.

In our instance, we offered our students a virtualized solution based on NoMachine NX [30], which is essentially a remote desktop, in addition to the distribution and installation that were available in the labs. The students use the same VNUML-UM version installed on an Ubuntu operating system, which has the same functionality as the system in the laboratories, in this 90 IEEE TRANSACTIONS ON LEARNING TECHNOLOGIES, VOL. 6, NO. 1, JANUARY-MARCH 2013 solution.

Even while this technique allows access through a web browser without requiring the installation of software, its speed is worse due to the inadequate power of the several computers used to deliver this capability. Because of this, we chose to install the program on every lab computer, and students have generally favored this setting for using VNUML-UM in the NoMachine NX platform.each incorrect response, and no points are awarded in the event that the question is left unanswered [29]. These tests determine if the student has learned the fundamentals of the subject matter. To be able to solve the various problems in the second section of the exam, you must have this information. As a result, the student cannot take the second section of the theoretical exam and the exam is deemed unsuccessful if the mark is not 10 points or above. Second, there are three significant issues on the test that require students to apply the knowledge they have learned during the teaching-learning process.

Pupils are divided into groups of two, just as in the creation and assessment of the three practical works. Every group is required to create the three suggested useful works. Each practical task requires them to create and execute a planned network scenario using VNUML-UM. They also need to produce a report outlining how they resolved the practical task and providing rationale for the various choices they made.

Every group also gets an interview with a lecturer.

During this interview, each group member is assessed separately based on two factors: a written exam where students respond to questions regarding various problems that arose during the practical work; and by creating tests and modifications to the scenario they created using the VNUML-UM system.

The ultimate grade that the student receives is determined by the outcomes of the theoretical exam and the completion of the practical assignments. The practical assignments carry a 30% weighting, whereas the theoretical test carries a 70% weighting. Each practical task carries the following weight: For Practical Work 1, 20 percent is allocated to Practical Work 2, and 40 percent is allocated to Practical Work 3. Additionally, in order to move forward with the computation of the final mark, students must pass both the theoretical exam and the practical work, meaning they must receive at least five points out of ten in each.

4. VNUML-UM: CUSTOMIZED VNUML DISTRIBUTION FOR THE PRACTICAL LEARNING OF COMPUTER NETWORKS

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4.1 Tools Supported by VNUML-UM

Based on the functionality they offer, the tools in the VNUML-UM distribution can be divided into three categories: 1) tools for IP-based mobility; 2) tools for routing and computer network configuration; and 3) tools for high availability and load balancing. The various programs that are installed in VNUML-UM and the features that are offered are described in detail below

4.1.1 Tools for Routing and Network

Configuration. Due to its Linux foundation, the VNUML file system file comes with standard tools for managing IPv4 and IPv6, such as ifconfig, ping, ping6, traceroute, traceroute6, route, tcpdump, and others. To support the route advertisement (carried out by routers) that facilitates the IPv6 autoconfiguration process, the Router

Advertisement Daemon (radvd) is also provided.
The Quagga routing software (version 0.99.5), which implements the following protocols: RIPv1, RIPv2, RIPng, OSPFv2, OSPFv3, BGP-4, and BGP-4þ, is used by the VNUML project to support the various routing protocols. As a result, we are able to suggest useful exercises pertaining to outer gateway protocol (EGP) and inner gateway protocol (IGP). The setup of the various areas specified in the protocol standard is supported by the various OSPF versions.
Prefix-based and attribute-based filtering, private autonomous systems, prepending, BGP attribute modification, multihoming, and other features are also supported by the BGP implementation.

4.1.2 Tools for IP-Based Mobility

VNUML-UM uses the mobile IPv6 for Linux (MIPL) package to implement IPv6 mobility scenarios. This software uses the radvd daemon, which was previously discussed, to implement the mobile IPv6 protocol. Advanced features supported by MIPL include the usage of security settings (IPsec) and routing optimization between mobile and correspondent nodes.

4.1.3 Tools for High Availability and Load Balancing

In contrast to the previously indicated set of tools, which are already included in the file system file made available by the VNUML project [18], we have loaded the software required to create the load balancing and high availability procedures. The only program that may be installed is new software that supports command-line operation mode because the simulation's Linux virtual machines do not function in graphical mode. However, we have discovered a large number of solutions that enable this mode by offering high availability and load balancing features. The installed tools are listed below, categorized into various groups based on the particular capabilities they offer. Keep in mind that some tools could show up more than once if they have many uses:

- Tools for redundancy in networks. For this reason, we have installed vrrpd and keepalived, two separate utilities that enable the VRRP protocol for router redundancy. Additionally, load balancing between routers within a particular network can be accomplished via the VRRP protocol.
- Proxy DNS solutions such as DNRD, DNSProxy, dproxy, dnsmasq, and pdns allow you to monitor the availability of remote DNS servers and minimize the amount of DNS requests that are made to authoritative servers.
- Squid, DNS Balance, and DNRD are a few examples of local DNS servers that load balance, support multiple DNS forwarder servers, and include DNS resolution caches.
- Balance, balanceNG, pen, penbw, pound, haproxy, LVS, lvs-kiss, and keepalived are examples of TCP and Layer 7 load balancing.

4.2 Using the VNUML-UM Virtualization Tool

In this part, we discuss a number of considerations that should be made when teaching network-related concepts using the VNUML-UM distribution. First off, it's important to note that installing VNUML on the Ubuntu distribution is a rather straightforward and largely automated process.
To gain flexibility when working outside of university facilities, many student groups choose to install the VNUML-UM distribution found in [17] on their own computers at home. In addition, having used this virtualization program for a number of years, we can confirm that the latest editions have made the installation process simpler.
Permissions that must be given to students in order for them to utilize the various virtualization features and, in the end, create the practical exercises that are described in Section 3.2, are crucial to the operation of VNUML-UM. Administrators of the laboratories generally have a policy of not giving students root administrator access to their personal accounts.
When creating virtualized scenarios based on VNUML-UM that must communicate with the actual machine (host), this circumstance poses a challenge. The rationale is that some features (like the management network that helps launch the scenario by automatically running specific commands in the virtualized hosts) need administrator-level access in the host in order to do some configuration tasks. Our suggestion for resolving this issue is to utilize the sudo program, which is present in Linux systems. The administrator can utilize this utility to designate which scripts can be performed by non-administrator users with the same authority as an administrator.

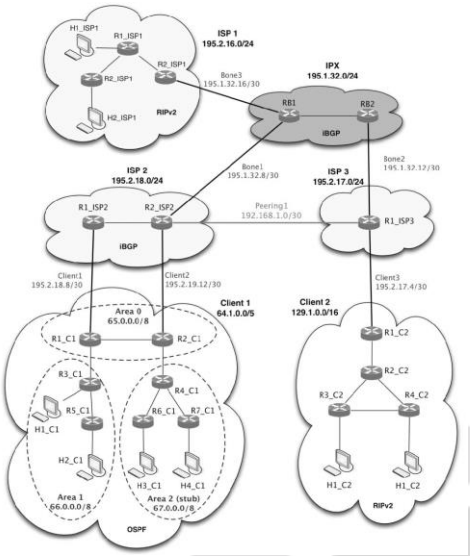

Fig. 3. Example of scenario for Practice 1.

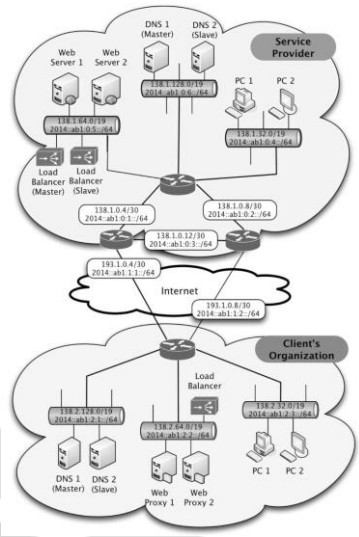

Fig. 4. Example of scenario for Practice 3.

Since our update file supports multiple parallel paths, it requires more disk space (about 800 MB) than the original file provided by the VNUML development team. However, it is this size that determines the value of the resulting software equivalents. Furthermore, the optimization of the write ensures that this size does not affect VNUML performance in virtualized network scenarios, since only changes to the database system files and a copy of the system files are stored for each virtual machine. from all Virtual Machine Share

4.3 Network Scenarios Created by VNUML-UM

We check the situation in the computer network as an example of the resources that VNUML-UM can provide for testing and analysis. give some examples The topology is created during the run. For example, Figure 3 shows the scenario topology of the scenario created in Exercise 1. In this case, there are many independent systems connected to different networks using a mixture of peering and transport configurations. We also found that the self-managed Client1 and Client2 systems are not created by the same management system. Rather, the former is divided into several OSPF areas, while the latter uses RIP as the routing protocol.
The situation that the students completed according to the instructions in Activity 3 is shown in Figure 4.
Each company will set up a primary DNS server and a backup DNS server for its DNS system. Service providers provide high-quality web services by providing the parallel resources needed across multiple web servers. These web services are accessed by users within the customer's organization; many web proxy servers have been set up to reduce traffic. and the 2011-2012 class. The results are based on the evaluation process described in Section 3.4. We also surveyed students to see if they found the different tools and activities useful in better understanding the various concepts covered in philosophy courses.

5.1 Analysis of Marks Obtained by Students

A comparison of the various grades that the students received for the three practical assignments during the various academic courses is shown in Table 2. The mark is displayed as a range of numbers from 0 to 10. A student is deemed to have passed a practical work if their mark is equal to or higher than five points. We can see a decline in the number of students enrolled in each course in the table. We would want to make it clear that this variance is the result of a transition period brought on by the degree's adaptation to the Bologna process and the European Credit Transfer and Accumulation System (ECTS). Pupils have the option of completing their coursework in accordance with the current degree or adjusting to the new one. The number of students studying this subject has somewhat decreased as some have chosen to enroll in the new degree.
Based on an examination of the grades students received for the various practical assignments, we have noticed considerable fluctuations in the first course (2009–2010), particularly in practical work 3.We can confirm based

on our expertise that these. Variations stem from the process of applying our methodology for the first time, which is prone to unforeseen issues and calls for repeated changes.

TABLE 2
Labs Marks

Course / Issue	2009-2010	2010-2011	2011-2012
Number of evaluated students	45	25	21
Practical Work 1			
Marks (7-10)	38	22	17
Marks (5-7)	7	3	4
Marks (<5)	0	0	0
Marks 7-10 (%)	84,4	88	81
Practical Work 2			
Marks (7-10)	45	25	19
Marks (5-7)	0	0	2
Marks (<5)	0	0	0
Marks 7-10 (%)	100	100	90
Practical Work 3			
Marks (7-10)	20	23	15
Marks (5-7)	25	2	5
Marks (<5)	0	0	0
Marks 7-10 (%)	44,4	92	75

We use students' ideas to solve different problems that we identified, especially in the first year. We also improved the documentation of many of the tools installed in VNUML-UM to include more practical examples and more tips for students.

These measures increased student performance in the following academic year (2010-2011). For example, the passing rate for 7th and 10th grades in Practical Exercise 3 increased from 44.4% in the 2008-2009 academic year to 92% in the 2011-2012 academic year.

We believe that the study results for 2010-2011 and 2011-2012 are more representative because they were obtained using a consistent method for solving different problems in the first year. In this case, we see that the children's performance is of a fairly high standard. More precisely, the percentage of students who scored between 7 and 10 in tasks 1, 2 and 3 was 85%, 95% and 84% respectively. Finally, it is worth noting that all students who completed the different tasks received a passing grade (~ 5 points).

This is because they can use VNUML-UM to check that their conditions are set correctly and to solve various problems that arise. Therefore, they will not provide teachers with a computer network scenario for evaluation until they are sure that it works as planned.

To determine whether our approach and the VNUML-UM tool help students understand computer communication, we also conducted a further analysis of students' performance in the theoretical part of the subject. In particular, we investigate the relationship between the theoretical and practical aspects of the course. The scores obtained by students who passed both parts of the theoretical test are shown in Table 3.

From the results, we can conclude that the percentage of students who passed the theoretical exam without completing the practical work is low (15.9%) for the class of 2009-2010, 18.2% for the class of 2010-2011, 16.7% for the class of 2010-2011 (2011-2012). As a result, over 81% of students who pass the requirement go on to complete practical work in addition to or before the theory exam.

TABLE 3
The connection between theory and practice

Problems related to student learning in the laboratory

Code	Question related to
Q1	Improvement of the understanding of network design
Q2	Better understanding of IGP
Q3	Better understanding of EGP
Q4	Consideration of VNUML as useful tool to understand network concepts
Q5	Better understanding of mobile IPv6 concepts
Q6	Better understanding of load balancing and high availability concepts

Marks (7-10)	4	2	1
Marks (5-7)	3	2	2
Passed (%)	15,9	18,2	16,7
Passed (7-10) (%)	9,1	9,1	5,5

Course / Issue	2009-2010	2010-2011	2011-2012
Theoretical part passed with practices passed			
Marks (7-10)	12	10	9
Marks (5-7)	24	8	6
Passed (%)	84,1	81,8	83,3
Passed (7-10) (%)	27,3	45,4	50
Theoretical part passed before passing practices			

Furthermore,In the most recent term, 20112012, the number of students who passed the theoretical course with g ood grades (7 to 10) increased from 27.3% in the previous year to 50%.indicating that our approach helps students master computer network principles.

Therefore, we conclude that both students saw the VNUMLUM project as successful and benefited more from it or the work created by the project completed the educational process. To verify this, we conducted a comprehen sive survey with the students. The results are shown in the next section.

5.2 Student comments about the layout

Further more to the findings drawn from the examination of the students' grades, we chose to conduct a survey to find out how the students felt and whether or not the many practical projects had improved their comprehension of the various theoretical ideas. In order to improve our work continuously, their feedback is crucial. In the 2009–2010 course, 15 students took part 10 students participated in this selection in 2010-2011. In the end, 2011–2012 had 20 players.Students were asked to evaluate the following points in the questionnaire regarding learning computer n etworking principles and using VNUMLUM in our laboratory (see Table 4). Question 1 (Q1) asked students wh ether participation in various international projects put more pressure on various theoretical concepts related to n etwork architecture..

To answer the second and third questions, you need to understand the internal (Q2) and external (Q3) routing protocols. Finally, Q5 and Q6 aim to determine how our methods and available data help explain some complex concepts such as mobility, balance, and volition (Q5). Each subject rated the behavior on a scale from 0 to 10, with 10 indicating that the behavior was rated well. Figu re 5 shows the students' evaluations for each question. The findings show that most of our students were interest

ed in how the internship could help them understand computerrelated concepts. Since virtualization has become a popular topic in this topic, as seen in Section 2, the first three questions (Q1Q3) need to be answered**.** VNUML UM is a useful tool for virtualizing scenarios involving computer networks.Explaining complex concepts, especi ally load balancing, availability, and implementation of IPv6. Based on the feedback, our students felt that the b alance of learning, mobility, and interest were more beneficial to VNUMLVM than network connectivity. Stude nts who completed the prerequisite course performed better on the thinking section, as shown in Table 3.

TABLE 4

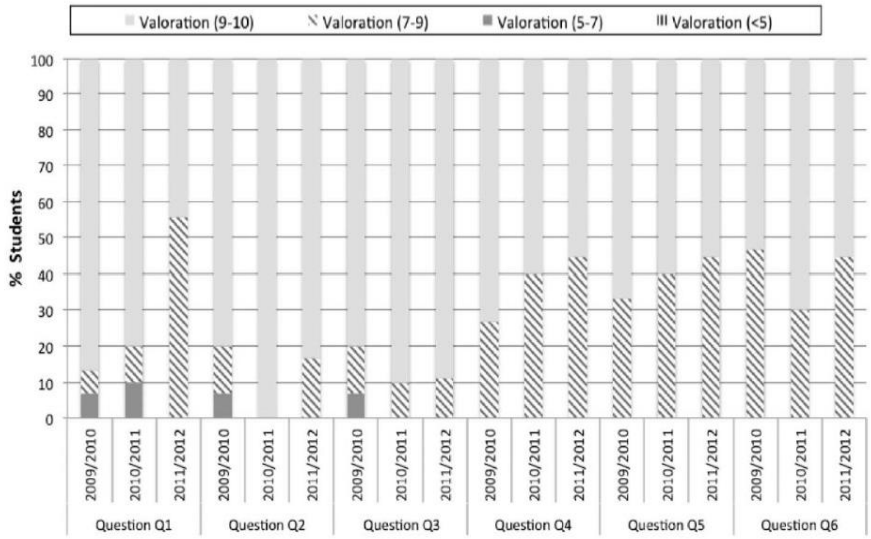

Figure 5. Check out current topics.

Table 5

Lake methods

Course Issue	2009-2010	2010-2011	2011-2012	2009-2010	2010-2011	2011-2012
Question Code	Q1	Q1	Q1	Q2	Q2	Q2
Mean	8.7	9.1	8.1	8.6	9.5	8.9
SD	0.8	0.6	1.9	0.9	0.5	2
CI	0.4	0.3	0.9	0.5	0.3	0.9
Question Code	Q3	Q3	Q3	Q4	Q4	Q4
Mean	8.6	8.9	8.8	8.4	8.5	8.5

SD	0.9	0.7	2	0.8	0.9	2
CI	0.5	0.4	0.9	0.4	0.6	0.9
Question Code	Q5	Q5	Q5	Q6	Q6	Q6
Mean	8.3	8.6	8.5	8.2	8.6	8.5
SD	0.9	0.5	2	0.9	0.7	2
CI	0.5	0.3	0.9	0.5	0.3	0.9

Finally, it is important to note that in addition to the information gathered from After careful analysis, directly heard from students. Generally speaking, they have informed us that they have been able to comprehend some topics that were previously too ethereal for them because of the actual work. This review has been verified by the unidentified viewpoints formed in the various courses.

6. Conclusion and next projects

Virtualization aids computer science education because it makes programs in student labs more accessible and manageable.Thus,far.It is always important to use virtualization in education in business management and teachi ng in computer networks,In this paper, we show how virtualization can be used to teach not only these important concepts but also many concepts related to computer networks, such as mobility, equity, and diversity. Specifically, we describe a novel teaching tool called VNUML-UM, The methods we use to teach these ideas incomputer and online courses and the different results we get,The met hods we use to teach these ideas in computer and online courses and the different results we get Our experience shows that the VNUMLUM classification is an effective tool for teaching the principles of comp uter communication. This contradicts the findings that the number of students who fail an exam increases when students submit their work on time or early and receive better grades.Another important factor supporting our ap proach is the students' perception of their own learning and how the device and laboratory in the sessions increa sed their knowledge of various computer systems. Another important finding is that our results show that the V NUMLUM classification, a virtualization tool, can be used to demonstrate higher computer connectivity principl es than known. Acknowledgements This work was partially supported by the Research Development Group Grant Program (04552/GERM/06).

REFERENCES

[1] I.A. Garcia, C.L. Pacheco, and J.N. Garcia, "Enhancing Education in Electronic Sciences Using Virtual Laboratories Developed with Effective Practices," Computer Applications in Eng. Education, http://dx.doi.org/10.1002/cae.20554, 2011.

[2] S. Nanda and T.-C. Chiueh, A Survey of Virtualization Technologies,Technical Report TR-179, http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.74.37, 2005.

[3] J. White and A. Pilbeam, "A Survey of Virtualization Technologies with Performance Testing," The Computing Research Repository,http://arxiv.org/abs/1010.3233, Oct. 2010.

[4] J. Keengwe and L.O. Anyanwu, "Computer Technology-Infused Learning Enhancement," J. Science Education and Technology,vol. 16, no. 5, pp. 387-393, June 2007.

[5] D. Dobrilovic and Z. Stojanov, "Using Virtualization Software in Operating Systems Course," Proc. Int'l Conf. Information Technology: Research and Education (ITRE '06), pp. 222-226, May 2006.

[6] A. Gaspar, S. Langevin, and W.D. Armitage, "Virtualization

Technologies in the Undergraduate IT Curriculum," IT Professional,vol. 9, no. 4, pp. 10-17, 2007.

[7] G.D. Steffen and H.I. Abu-Mulaweh, "Teaching Local Area Networking in a Secure Virtual Environment," Computer Applications in Eng. Education, vol. 18, no. 3, pp. 547-554, 2010.

[8] A. Gaspar, S. Langevin, W. Armitage, and M. Rideout, "Enabling New Pedagogies in Operating Systems and Networking Courses with State of the Art Open Source Kernel and Virtualization Technologies," J. Computer Small Colleges, vol. 23, no. 5, pp. 189-198, 2008.

[9] D. Dobrilovic, V. Brtka, I. Berkovic, and B. Odadzic, "Evaluation of the Virtual Network Laboratory Exercises Using a Method Based on the Rough Set Theory," Computer Applications in Eng. Education, vol. 20, no. 1, pp. 29-37, http://dx.doi.org/10.1002/cae.20370, 2012.

[10] D. Dobrilovic and B. Odadzic, "Virtualization Technology as a Tool for Teaching Computer Networks," World Academy of Science,Eng. and Technology, vol. 13, no. 13, pp. 126-130, Jan. 2006.

[11] L. Fa`brega, J. Massaguer, T. Jove´, and D. Me´rida, "A Virtual Network Laboratory for Learning IP Networking," Proc. Seventh Ann. Conf. Innovation and Technology in Computer Science Education (ITiCSE '02), pp. 161-164, http://doi.acm.org/10.1145/544414. 544462, 2002.

[12] F. Gala´n, D. Ferna´ndez, W. Fuertes, M. Go´mez, and J.E.L. de Vergara, "Scenario-Based Virtual Network Infrastructure Management in Research and Educational Testbeds with VNUML," Annals of Telecomm. - Annales Des Tcommunications, vol. 64, nos. 5/6, pp. 305-323, http://dx.doi.org/10.1007/s12243-009-0104-3, 2009.

[13] F. Gala´n and D. Ferna´ndez, "Use of VNUML in Virtual Honeynets Deployment," Proc. Actas de IX Reunio´n Espan˜ola sobre Criptologı´a y Seguridad de la Informaci (RECSI '06), pp. 600-615, Sept. 2006.

[14] M. Pollitt, K. Nance, B. Hay, R.C. Dodge, P. Craiger, P. Burke, C. Marberry, and B. Brubaker, "Virtualization and Digital Forensics: A Research and Education Agenda," J. Digital Forensic Practice, vol. 2, pp. 62-73, Apr. 2008.

[15] S.C. Nemesio, P. De Las Heras Quirs, E.M.C. Barbero, and J.A.C. Gonza´lez, "Early Experiences with NetGUI Laboratories," Proc. Simposio Internacional de Informa´tica Educativa (SIIE '06),Oct. 2006.

[16] R. Nabhen and C. Maziero, "Some Experiences in Using Virtual Machines for Teaching Computer Networks," Proc. IFIP 19th World Congress Education for the 21st Century - Impact of ICT and Digital Resources, D. Kumar and J. Turner, eds., vol. 210, pp. 93-104, http://dx.doi.org/10.1007/978-0-387-34731-8_11, 2006.

[17] A. Ruiz-Martı´nez, F. Peren˜ iguez, R. Marı´n-Lo´pez, P.M. Ruiz, and A.F. Go´mez-Skarmeta, "VNUML Kernel and Filesystem for Teaching Advanced Computer Network Concepts," http://ants.inf.um.es/arm/computernetworks/vnuml-um.html, 2013.

[18] VNUML Web Server, "Virtual Network User Mode Linux (VNUML)," http://www.dit.upm.es/vnumlwiki, 2013.

[19] "MUNES - An Integrated Multiprotocol Network Emulator /Simulator," http://old.tel.fer.hr/imunes, 2013.

[20] B. Kneale, A.Y. De Horta, and I. Box, "VELNET: Virtual Environment for Learning Networking," Proc. Sixth Conf. Australasian Computing Education (ACE '04), pp. 161-168, 2004.

[21] "My Linux Network (MLN)," http://ostatic.com/mln, 2013
.
[22] "Netkit," http://wiki.netkit.org/index.php, 2013.

[23] Dynamips, “Dynamips: Cisco 7200 Simulator,” http://www.ipflow.utc.fr/index.php, 2013.

[24] M. Wannous and H. Nakano, “NVLab, A Networking Virtual Web-Based Laboratory that Implements Virtualization and Virtual Network Computing Technologies,” IEEE Trans. Learning Technologies, vol. 3, no. 2, pp. 129-138, Apr.-June 2010.

[25] W.M. Fuertes and J.E. Lo´pez de Vergara, “A Quantitative
Comparison of Virtual Network Environments Based on Performance Measurements,” Proc. 14th HP Software Univ. Assoc. Workshop, July 2007.

[26] M. Blanc, “Virtual Network User Mode Linux (VNUML),”
http://sourceforge.net/projects/vnumlgui, 2009.

[27] J. MacDonald, Blended Learning and Online Tutoring: Planning Learner Support and Activity Design. Gower, Apr. 2008.

[28] C.M. Duh and L.R. Wen, “From Collaborative Argumentation to Knowledge Creation,” Proc. Conf. Information Management (ICIM), Feb. 2002.

[29] Y. Bereby-Meyer, J. Meyer, and O.M. Flascher, “Prospect Theory Analysis of Guessing in Multiple Choice Tests,” J. Behavioral Decision Making, vol. 15, no. 4, pp. 313-327, http://dx.doi.org/10.1002/bdm.417, 2002.

[30] “NoMachine NX Software,” http://www.nomachine.com, 2013.