Educational Platform using Virtualization Technologies: Teaching-Learning Applications and Research Uses Cases

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Abstract— **Currently, the implementation of Virtualization Technologies (VT) is a proven solution that potentially provides maximum benefits and opportunities for industry and research. However, teaching-learning processes in higher education and in collaborative learning environments are just beginning to take advantage of VT. The work proposed in this paper focuses on the effective usage of virtualization platforms based on several educational applications and research use cases. As evidence of the validity of these solutions, we make a brief description of the existing experiences, which have been implemented within the university. The test results have shown features, strengths, weaknesses, as well as results related to how the teaching and learning processes have improved using virtualization technology.**

Index Terms—**Collaborative platforms, education, teaching-learning process, virtual network laboratory, virtualization technologies.**

I. Introduction

CURRENTLY, the implementation of Virtualization Technology (VT) (e.g., Xen, VMware, KVM, etc.) is a proven solution that potentially provides maximum benefits and opportunities for industry and research. However, teaching-learning processes in higher education and in collaborative learning environments are just beginning to take advantage of VT. University computer laboratories typically require multiple installations of software packages that must be done every semester, according to specific requirements of different subjects. In addition, software packages require better hardware features, especially in terms of processor and memory, which increases both energy consumption, and the need for investment in new hardware. Within this context, this research proposes the utilization of virtual computing platforms: First as an important option to provide economic platforms for research and experimentation. Second as a competitive strategy for hardware sharing and hardware investment reduction. Third, as an educational innovation to provide cost-effective platforms for teaching-learning processes. Furthermore, this technology reduces the risk of damage in real environments, as well as the cost of development and experimentation. This paper presents several research use cases and educational applications that precisely show how effective this technology can be.

Over the last years, we have researched and experimented with the advantages offered by VT in Education. The results of these experiments were useful to develop a set of solutions, related to the educational processes. As an evidence of the validity of these solutions, we make a brief description of the existing experiences both in educational applications and in research use cases, which have been implemented within the university: *i) Tests and software validation,* where several environments have been designed and deployed using Virtual Machines (VM), giving an experimental topology for pre-production testing; *ii) Networking services emulation*, such as multimedia emulation services in order to compare the results obtained in a real network, versus the same environment using virtualization platforms; *iii) Traffic analysis simulation*, in order to compare the results obtained through out simulation methods designed to determine the conditions under which network services presents degradation using virtualization platforms; *iv) Experimentation of vulnerabilities in Information Systems*, to conduct security risk analysis originated by a denial of service attack, a virus or an intrusion; *v) Cost-effective platform for teaching and learning processes*, based on VM, which enables training methods of configuration and installation of several network operating systems, configuration of network devices, deployment of services, etc.; *vi) Availability of user accounts on remote servers*, via remote terminal access to VMs destined to user applications or services in real networks; *vii) Multi-platform computer labs*, in the sense that multiple operating systems and specialized software can be used in the Computer Lab in order to optimize resources, without having to reinstall the software packages. Based on these use cases we have distilled also the features, strengths, weaknesses, as well as results related to how the teaching and learning processes have improved.

The main contribution of our research is the know-how transferring in order to create a collaborative teaching-learning platform using VTs to facilitate the exchange of best practices to maximize educational resources. According to each situation, we designed virtual network environments (VNE) [1] and then we implemented the topology for each application.

The remainder of this paper has the following organization: Section 2 presents our research uses cases using virtualization systems. Section 3 describes our experiences regarding of innovation strategies on education and learning. Then, the evaluation results are provided in Section 4. Section 5 discusses related work. Finally, Section 6 closes the paper with the conclusions and future work lines.

II. Research Use Cases

This Section describes some of the research use cases we have conducted by in the network virtualization scope. We started few years ago evaluating the main virtualization tools [2]. Then we selected the best tools that have enabled us to implement and validate some experiments that are detailed below. A point that is worth mentioning is the importance of research as a prominent activity, which has provided the necessary knowledge for the usage of this technology in teaching and learning processes.

A. *Networking services emulation*

An alternative to performing experiments in real networks is to use virtualization tools, which can be applied to tests if an application performs correctly in a concrete network topology. Several tools currently exist (e.g., VNUML [3], Netkit [4], KVM [5], VMware [6], Xen [7], etc) that allow deploying such VNE in single physical equipment. In these scenarios it is important to reduce the *overhead* introduced by the VT if application performance is going to be measured. In this light, in the work we have implemented a specific VNE to compare a real case with a virtualized system.

Within this context, this research use case proposes to implement a method to improve the results obtained in virtual network environments, trying to resemble those obtained in real environments. In particular, our main goal was to obtain a result as close as possible to a real case. These improvements will provide strategies to interact with real time applications and to ensure their service delivery in similar conditions before putting them into production. In addition, these enhancements could improve user perception.

To carry out this work, we have emulated a real network service, namely video-on-demand (VoD) over ADSL by means of the Xen virtualization tool [7]. Firstly, we designed and implemented the required test-bed to make the comparisons between virtual and real environments. Secondly, we adjusted the network environment parameters to emulate the operational aspects of the real environment. With these results, we have found new guidelines to adjust the emulation parameters in virtual network environments

In this experimental setup, the real environment is shown in Fig. 1. In this research we selected the VoD in an ADSL connection. Next we tested the emulation of the service conditions for streaming VoD versus a classic 1.2 Mbps ADSL connection. Finally we accomplished the experiments described following.

As a second step, to experiment the VoD service, we designed and implemented the VNE shown in Fig. 2. In this new environment, we installed and configured the Video LAN server in a VM located on one server in our laboratory at the University. On the other side we installed a VLC media player as a client on the same host, to display the video, especially given the need to handle a graphical environment and considering that Xen has limitations in such requirements. Then we fine tuned the link between Router 2 and Router 1 to make it similar to the case of an ADSL connection.

As shown in Fig. 2, the elements of the virtual environment can be mapped to some elements of the real ADSL environment in Fig. 1. (i. e., the Video LAN Server in each environment as well as the clients). Similarly, Router 1 maps to the home ADSL router, Router 2 maps to the ISP router, and Router 3 maps to the server router. Other routers could be also considered in the path between Router 2 and 3 if necessary.

The following procedure has been used to implement the proposed design in a virtual network environment: First of all we created the first VM and installed the guest OS, Linux Debian. Then, we cloned the first VM to the remaining VMs, in order to reduce the installation time. At this point, it should be noted that the routers depicted in Fig. 2 are VMs to which the functionality of routing devices was assigned. After this, we added virtual interfaces, configured IP addresses, routing and started services. Lastly, we created and executed the respective programs that automatically constructed and started the environment. As a final point, we installed the software for traffic monitoring both in the virtual network environment and the host. It is also worth mentioning that all tests were done using open source software.

B. *Traffic analysis simulation*

Currently there are at least three ways to achieve network dimensioning and comparative performance measurements. One alternative is to set up a mock network infrastructure in parallel, but this would require new equipment and hardware devices making it an expensive solution. The

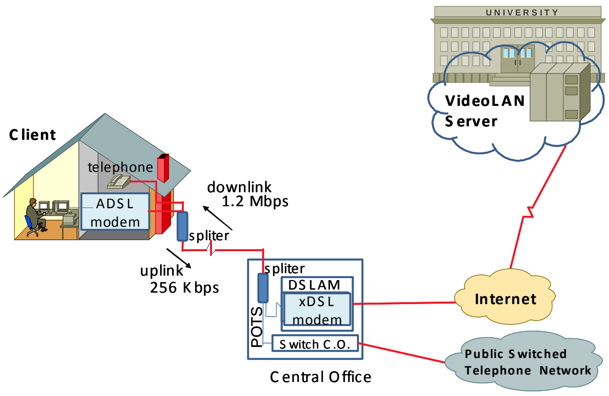

Figure 1. Testing environment of an ADSL connection

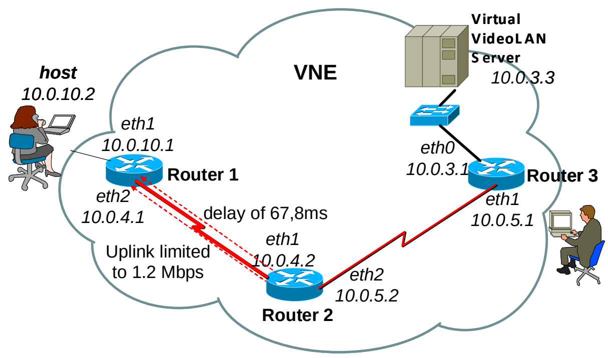

Figure 2. Virtual network environment used to emulate a VoD over an ADSL connection

other alternative is to use simulation tools, such as NS-2 [8] among others, which are used to evaluate the performance of networks. The third alternative is to use VT. In this research case we have evaluated the network performance using NS-2 as network simulation technology, and Xen as virtualization technology. In this instance, we have proposed the performance evaluation of IP networks, through a quantitative comparison of results obtained using virtualization vs. those obtained by simulation methods. To accomplish this we designed and implemented various test environments using the two technologies, setting the parameters that are related to network performance such as bandwidth, latency and packet loss.

The first experimental results illustrated that there are significant differences between the two technologies, when assessing the performance of the network, although testing was done on the same topology. Furthermore, the experiments using a different hardware base, keeping the same environment for both technologies demonstrated that the results in the case of simulation will remain exactly the same by repeating the tests. In contrast, in the case of Virtualization the results were different. This means that NS-2 maintains a constant behavior, while Xen, being an emulation of the network in real time generates an overhead on the underlying hardware in each experiment.

Regarding this issue, it was detected that *packet loss* is more difficult to control when NS-2 is used, (the presence of *packet loss* causes a reduction in performance when virtualization is applied). Therefore, when using VT in real network performance tests, packet loss is a key parameter that considerably affects the performance; in contrast with those results obtained when using simulation methods (see Fig. 3). The packets were injected through *Iperf* [9], whose report shows the number of lost packets over the total generated packet.

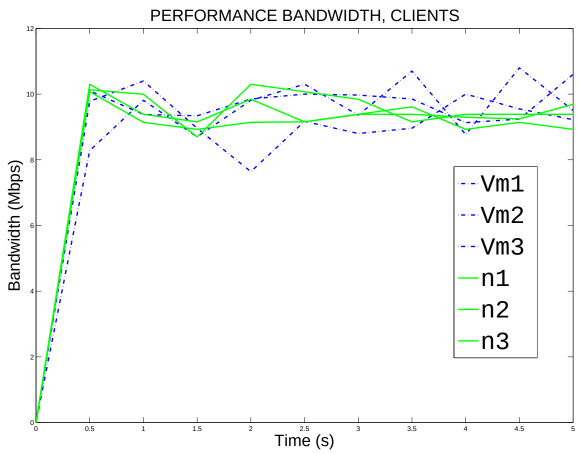

Figure 3. Comparison of the performance using NS-2 and Xen

Figure 3 shows the network behavior with both NS-2 and Xen. It illustrates the average measurement of the collected data, calculated from ten tests performed with each technology. The environment consisted of three clients (nodes) in a LAN. The algorithm used to generate traffic was UDP/CBR. The boundaries on experimentation were 10 Mbps sent rate and 0.300 ms delay. No more than 5 seconds have been plotted for better viewing (from the 60 seconds that the whole experiment lasts, since the behavior was similar). As can be appreciated the differences are significant but as explained above; their similarity is affected by the overhead produced in the virtualization layer and because of *packet loss* in the virtualized environment.

C. *Experimentation of vulnerabilities in Information Systems*

The major threats to network security are computer viruses, worms, Trojan horse programs, denial of service attacks, the unsolicited bulk messages flow known as Spam and a variety of types of attacks. Regarding with this issue it is important to encompass an experimental platform with the certain of not to damage the computer equipment. Also, from an educational point o view teachers must encompass a test infrastructure to divulge their knowledge of how to prevent network security attacks. On the other hand it is important that the student be able to test and identify the vulnerabilities and the types of attacks against network security.

One of the best ways to simulate network attacks is to configure test environments using VT or simply a VM. Within this context, we have the following experiences: i) Programming of several real attacks scripts against VMs. For example, scripts to insert malicious codes (i.e., computer viruses), modification attacks scripts such as changes, insertion, deletion, password discovered, kill processes, interrupt servers and breaking into computer systems; ii) A practical lab focused on understanding access attacks, Denial of services attacks and repudiation attacks; iii) A practical lab focused on port scanning (i. e., nmap or netsat Linux commands), because scanning computer systems for vulnerability is an important part of a good security program; and iv) Installing sniffers like Wireshark in order to perform traffic monitoring, and snort in order to install an instruction detection system.

III. TEACHING-LEARNING APPLICATIONS

Within the scope of education research, our experience described in section II has been the base to innovate the teaching and learning processes. This section describes some practical applications in the use of VT as a teaching-learning method. This is very important because it reveals the different opportunities that this technology offers within education. It is worth noting that we have focused on open source virtualization tools and have applied these in our university.

A. *Cost-effective platform for teaching and learning processes*

There are several advantages when using virtualization: reduction of infrastructure investment costs, central management, immediate creation of new VMs, efficient use of hardware resources, easy portability of VMs among physical servers, because they are simply contained in files. Furthermore, the most important advantage is that if one of the virtual computers is compromised by a fault, the real host and other VMs are unaffected. Lastly, VM technology supports complex guest operating systems and lets them share common hardware and special software applications installed on the physical host.

According to Dobrilovic [10], teaching computer network concept is hardly possible without having specialized network laboratories. VTs have been used to replace laboratory data networks and operating systems for practical teaching. Among the low-cost of teaching and learning using virtualization platforms, we have used virtualization to teach computer networks, installation and Operating Systems configuration, routing configuration, and network security attacks.

B. *Availability of user accounts on remote servers*

In order to provide an additional service to teachers and students of the university, we have planned user remote access to multiple servers located in the university laboratories. Within these servers, several Virtual Box and VMware Server VMs were set up. Microsoft Office, video and online chat messaging were installed on each VM as software of massive use.

The users were also able to access the Internet, and access to key applications and actual services in corporate networks. For this purpose, the Microsoft Remote Desktop (RDP) client, Linux rdesktop or any remote connection tools were used, since that they allow us to use graphical interfaces. Fig. 4 shows the application environment.

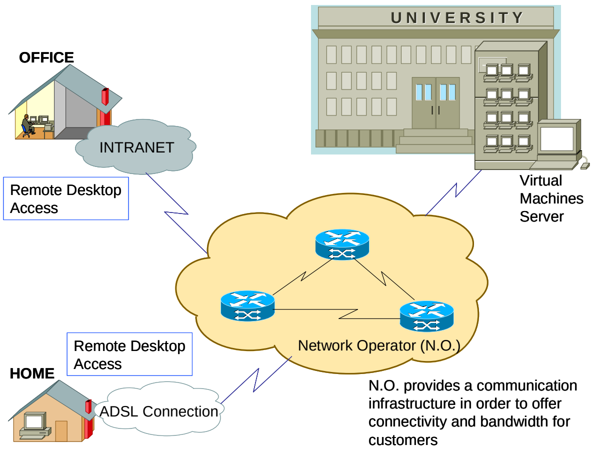

Figure 4. Testing environment of a remote desktop access.

During testing, we obtained the availability of user accounts on remote servers from their workplace, college or home. The work environment was a VM but running from the server located at the university. The user access was controlled because it required for each server its IP address and a port number. The teacher and students could access at any time (i. e., outside working hours/class). This can prevent the network overload because when users use the network at different times, overloading resources are less likely. Also, if there was any problem with any VM it was regenerated dynamically from a repository of VMs on a dedicated server. This in particular reduced the cost of server maintenance (backups, updates, etc.).

To conclude, it is worth mentioning that these experiments were conducted using VirtualBox and VMware Server virtualization platforms, which have interesting features for remote access to servers. These tools also facilitated the use of RDP viewing the virtual terminal running remotely. In contrast, multimedia applications consume bandwidth, so it is not suitable for slow speed connection.

C. *Multi-platform computer labs*

At present, typically, multiple installations of software packages must be done every semester, according to specific requirements of different subjects. In addition, software packages require better hardware features, especially in terms of processor and memory, which increases both energy consumption and the need for investment in new hardware. An alternative to solve this issue is to use virtualization tools, which can be applied in order to have without effort several multi-platform computer labs. Although VT does not resolve the need for better CPU and memory on computers, what we have got is CPU and memory sharing by installing multiple VMs images in a server. In our university, this was achieved through having several VMs, in which was installed several guest operating systems (e. g., Microsoft Windows, or any Linux distribution). Also, we have installed on each VM specialized software that each teacher needs to teach their classes. With this we achieve the effective management of muli-platform computer labs as an effective implementation using VT.

D. *Tests and software validation*

Virtualization platforms make possible the execution of tests and software validation, and provide facilities for the dimensioning of network services using Virtual Network Environments (VNE). In the particular case of the teaching and learning processes of the Software Engineering, it is critical to realize a test of software validation before putting the applications in production. Normally, computer laboratories do not provide an infrastructure similar to those that require a complex network for a business company. The virtualization tools provide a platform of software validation and testing, which can include multiple servers, different networks, and emulation of several clients. According to Dumitru and Lowery in [11], with this technology it is possible to create a virtual test environment, which basically is based on three key benefits of VT, such as: consolidation, isolation and replication.

Within this context, to test an e-commerce solution (i. e., online shopping software) as a final course project, the laboratory technicians have designed and implemented by means of VMs a client-server architecture of two logical layers (i. e., web server and data base server) and a physical layer (i. e., single physical host). In this experimentation platform, the pilot tests were conducted. Several users were responsible for testing alpha software, whose users in this context are called clients. They used a graphical user interface on each VM. Clients and servers were interconnected in a virtual network environment. The client requested the Web server to make a purchase. This call was transformed into an XML document that described and invoked a method name and formal parameters. This XML was sent using HTTP to the web server that was also a VM. Then the method on the server performed the operations, and interacted with the data that in turn were stored in the data base server (i. e., other VM). Finally, this method returned the result to the clients.

An important aspect in this test environment is the fact that these virtualized systems are completely transparent to the user and to other servers both virtualized or hybrids in the case of interacting with a physical server. Therefore, for practical purposes, when you use virtualization platforms for testing and software validation, this environment has the appearance and functionality of physical systems.

IV. EVALUATION RESULTS

To evaluate the utility of the application of VTs, an anonymous and voluntary survey was carried out after the end of the semester in August 2009. Three subjects such as: Local Area Networks, Operating Systems, and Networks Security were collected as a sample. The number of students surveyed was 42. The number of teachers was 8. The survey was planned for both teachers and students. It was addressed to identify features, strengths, weaknesses and key lessons learned in the implementation of virtualization in education. Fig. 5 shows the main results obtained. Due to space limitations, many questions that had no impact on the survey have been omitted.

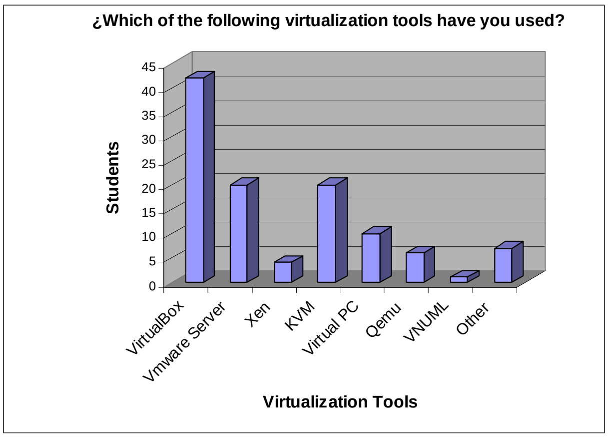

Figure 5. Preferences from the use of virtualization tools

As the Fig. 5 shows, most students and teachers use VirtualBox, VMware Server and KVM. This means that they have tested different virtualization tools. In addition, this means that they prefer virtualization tools which display graphical interfaces.

On the other hand, in this evaluation (for ease of presentation, see Tables I-III) we can observe that the opinions of both teachers and students about the use of these technologies are positive (e. g., ease of installation, ease of learning, available on the Web and technical support). Another important outcome is regarding to the weaknesses. Teachers and students agree with the difficulties related to more resource consumptions (e. g., CPU and memory), more hardware requirements (e. g., HD, NICS, I/O devices), more difficulty to connect to the external network and others. In conclusion, this is the fee for using this technology.

Finally, in the survey we have asked the teachers how the use of VT has improved the teaching and learning process.

TABLE I: ANSWERS TO THE QUESTION: ¿IN WHICH ASPECTS OF THE TEACHING-LEARNING PROCESS HAVE YOU USED VIRTUALIZATION PLATFORMS?

Aspects	Teachers	Students
Computer networks	40.10%	42.86
Configuration and installation of Operating Systems	80.38%	40.48%
Networks security attacks	20.16%	11.90%
Access to accounts on remote servers	12.20%	11.90%
Emulation of network services	03.06%	35.00%
Testing and software validation	12.20%	16.67%

TABLE II: ANSWERS TO THE QUESTION: ¿WHICH OF THE FOLLOWING DO YOU THINK ARE THE STRENGTHS OF USING VIRTUALIZATION PLATFORMS?

Strengths	Teachers	Students
Easy to install	90.02%	92.86%
Easy to learn	80.38%	71.43%
Available on the Web	80.16%	76.19%
Easy to deploy VNE	40.00%	49.14%
Technical support	22.28%	16.67%

TABLE III: ANSWERS TO THE QUESTION: ¿WHICH OF THE FOLLOWING DO YOU THINK ARE THE WEAKNESSES OF USING VIRTUALIZATION PLATFORMS?

Weaknesses	Teachers	Students
Resource consumptions	90.36%	40.48%
It is too slow	20.46%	35.71%
More hardware requirements	90.62%	69.05%
Difficulty to connect to the external network	22.04%	7.14%
Other	6.98%	2.38%

They response as follows: First of all is a cheaper option to learn some computer science topics. Second, it permits to have several guest operating systems in single physical host. Third, it enables software testing without risk of damage to the physical host. Forth, from the savings point of view, this technology reduces investment costs, energy savings, and reduced costs of experimentation.

V. RELATED WORK

There are some works that have implemented virtualization platforms in the teaching-learning process. Regarding with the teaching of computer networks, a first comparable research has been described by Galán et al. [12]. There, authors present an analysis and implementation of Computer Network Laboratories for the teaching-learning process through VNUML as a virtualization platform. In the same context, in [13] the authors address a description of an innovative design approach of a computer networks laboratory for efficient management. In addition, in [14] the researchers explore teaching dynamic routing protocols such as RIP and OSPF using Zebra within VMs. In [15] the authors present the virtualization of a computer network that includes the VM management, fault assurances, deployment of virtual infrastructure and network servers. Lastly, in [16] the researchers propose a computer network course for teaching TCP/IP networking. They present an environment that provides virtual laboratory remote access for students, remote laboratory management as well as creation and configuration of networking scenarios. Implementation of BGP-4 protocol scenario is also presented in this paper as a case study. However, we have exploited the VT aspects which are generally used in industry (e. g., consolidation, multiple platforms, and so on) in research and academic environments.

With regard to the use of VT in network security, the work proposed by Keller [17], explains the design of a virtual laboratory for conducting several experiments assessing vulnerabilities through intrusions and virtual servers that functioned as firewalls. In the same context in [18], authors using VMware VMs in the Intrusion Detection Lab as part of an ongoing effort to integrate virtualization technology into their network security curriculum. Compared with our experiences, we have dealt with various types of threats on the security network and we have built real hackers attacks scripts.

VI. Conclusions and Future Work

This paper has outlined some teaching-learning applications and research uses cases taking the advantages that VTs provide. For each case, explained above, it was necessary to design and implement a test environment, which in particular consists in a VNE (or just a single VM) deployed in single physical host. On the other hand, the convenience of VMs for networking emulation, networking security, and networking dimensioning were evaluated. In addition, this work has been intended to verify the functionality of several VTs in situations where the teachers and students can replace real environments with VMs. It is possible that the virtualization of resources may not exactly correspond to real resources in the network. Nevertheless this infrastructure allows making diverse experiments and let us to perform different type of matters inside of the university.

To validate the successful implementation of VT in education, a survey was developed, which results validated their use. Both the teacher and the student though positively about their use. In addition, in this survey we have identified several strengths such as: reduction of investment costs, ease of installation, ease of learning and energy savings. In contrast, some responses agreed on the need for more resources, enhanced hardware, and take into account more CPU and memory consumption.

Finally, in this work we exposed some experiences such as: test and software validation, cost-effective platform for teaching and learning process, availability of user accounts on remote servers, networking services emulation, traffic analysis simulation, and to end with experimentation of vulnerabilities in Information Systems. All of this represents the effective application of VT within research, teaching and learning process and it can become a collaborative platform to innovate higher education.

To finish, as future work and with the purpose of obtaining a major experimentation topology, we will explore how to create a collaborative environment based on VTs between universities of Ecuador, Spain, USA, Brasil and other countries.

Acknowledgments

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References

[1] W. Fuertes and J. E. López de Vergara, "An emulation of VoD services using virtual network environments". In Proc. GI/ITG Workshop on Overlay and Network Virtualization NVWS'09, Kassel-Germany, March 2009.

[2] W. Fuertes and J. E. López de Vergara, "A quantitative comparison of virtual network environments based on performance measurements", In Proc. 14th HP Software University Association Workshop, Munich, Germany, 8-11 July 2007.

[3] F. Galán, D. Fernández, W. Fuertes, M. Gómez and J. E. López de Vergara, "Scenario-based virtual network infrastructure management in research and educationnal testbeds with VNUML", *Annals of Telecommunications*, vol. 64(5), pp. 305-323, May 2009.

[4] M. Pizzonia and M. Rimondini, "NetKit: Easy Emulation of Complex Networks on Inexpernsive Hardware", In Proc. TridentCom 2008, Innsbruck (Austria), March 2008.

[5] Kernel Based Virtual Machine, [Online] http://www.linux-kvm.org/page/Main_Page.

[6] VMware, [Online] http://www.vmware.com/.

[7] P. Barham et al., "Xen and the Art of Virtualization,". In Proc. 19th ACM symposium on Operating systems principles. Bolton Landing, pp. 164-177, NY., USA, 2003.

[8] The Network Simulator ns2, [Online] http://www.isi.edu/nsnam/ns. Last verification, Sept. 2009.

[9] The Iperf, [Online] http://sourceforge.net/projects/iperf/.

[10] D. Dobrilovic, B. Odadzic, "Virtualization Technology as a Tool for Teaching Computer Networks", *International Journal of Social Sciences*, Spring 2006.

[11] A. Dumitru and J. Lowery, "Using Virtual Machines to Simulate Comples IT Environmenst", *Power Solutions*, pp. 22-26, Juune 2004.

[12] F. Galán, D. Fernández, J. Rúiz, O. Walid, T. de Miguel. "A Virtualization Tool in Computer Network Laboratories", In Proc. 5th International Conference on Information Technology Based Higher Education and Training (ITHET'04), pp. 209-214, Instanbul, May 2004. ISBN: 0-7803-8596-9.

[13] C. Caicedo, W. Cerroni, "Design of a Computer Networking Laboratory for Efficient Manageability and Effective Teaching". In Proc. 39th ASEE/IEEE Frontiers in Education Conference. W2F-1. October 2009.

[14] D. Dobrilovic, Z. Stojanov, B. Odadzic, "Implementing BGP-4 protocol scenario in VNLab open networking environment", In Proc. of 6th International Symposium on Intelligent Systems and Informatics. pp. 185-189. Serbia. Sept. 2008.

[15] N. Felde, T. Lindinger, L. Maximilians, H. Reiser. "Virtualizing an IT Lab for Higher Education Teaching". In Proc. GI/ITG KuVS Fachgespräch "Virtualisierung", 2008, pp. 97-104

[16] J. Keller and R. Naues, "Design of a Virtual Computer Security Lab", LG Parallelitat und VLSI. FernUniversitat in Hagen, 2006.

[17] J. Keller, R. Naues, "A Collaborative Virtual Computer Security Lab," e-science, In Proc. Second IEEE International Conference on e-Science and Grid Computing (e-Science'06), pp. 126, Los Alamitos, CA, USA, December, 2006

[18] P. Li, T. Mohammed, "Integration of Virtualization Technology into Network Security Laboratory", In Proc. 38th ASEE/IEEE Frontiers in Education Conference, Saratoga, NY, October, 2008.