

Virtual and Virtualization Technologies in Computer Networks Education

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Abstract—We discuss benefits of different virtual and virtualization technologies applied in higher education. Virtual worlds can be used in most courses, independently on the branch of science: learning materials can be presented in 3D virtual world where avatars representing users can access them, online events can be organized there etc. Virtualization technologies are applicable in technically-related courses, typically in courses of computer networks. Virtualization techniques allow students to access simulated hardware, software or network topologies and experiment with them. Both types of technologies extend possibilities of full-time and distance education with little technical requirements; educators have to reflect this situation.

Keywords—Computer networks, e-learning, higher education virtual worlds, virtualization

I. INTRODUCTION

OUR lives become more and more virtual: we communicate through e-mail and chat, we leave messages on social networks such as Facebook or Twitter, we share experiences and impression through photos and videos on YouTube, we shop online etc. Also higher and distance education is affected by availability of different virtualization technologies. Few years ago learning management systems (LMS) such as WebCT were the exclusive educational online platforms, today the wide range of innovative virtual technologies can make the educational processes more fluent and efficient: the learner can access large amount of electronic study resources, virtual hardware and software and can communicate with schoolmates and tutors anytime and anywhere. Technical requirements are low from the students' point of view: PC or notebook with

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online access and optionally installation of special browsers. From the educators' point of view, virtual and virtualization technologies extend possibilities of full time and distance education. Therefore it is important to develop corresponding educational scenarios. The objective of the paper is to explore the educational potential of virtual and virtualization technologies. We present the classification of technologies and we provide case studies from the authors' workplace.

II. VIRTUAL TECHNOLOGIES

There are two types of virtual technologies:

- *virtual worlds* (also digital, simulated, massively multi-user, collaborative worlds) in sense of audio-visual interactive simulated environments accessed by multiple users through an online interface,
- *virtualized hardware / software / network / data* etc. in sense of full or partial simulation of underlying hardware / hosting applications in an environment separated from the underlying operating system / creation of a virtualized network addressing space across network subnets / presenting data as an abstract layer, independent on underlying database structures and storage.

Both types of technologies are applicable in the educational context. Virtual worlds can be reused in all kinds of courses, virtualized resources are suitable namely for computer-science related courses.

A. Educational Virtual Worlds

The common characteristics of virtual worlds are

- space shared by all participants at once,
- pseudo-realistic or even photo-realistic 3D graphical user interface,
- interactions among users and with objects of the virtual world in real time,
- allowing the formation of in-world user groups (teams, coalitions, neighborhoods, etc.),
- the world's existence continuing regardless of whether individuals are logged in [1].

Classification of virtual worlds is presented by [2] where commercial, educational, social, entertainment, sport and simulation worlds are differentiated. Leading example of virtual world is SecondLife (SL) [3], commercial 3D virtual

social platform where users are presented by customizable human-shaped avatars who can ‘teleport’ to locations. Scripting languages are used for building interactive presentations. SecondLife is accessible online from June 2003.

There were about 20 million users in October 2010, about 700 educational institutions (including over 300 universities) provided courses in their virtual SL campuses or conducted research there [3]. Typically, universities use SL presentations for attracting new students, for providing language learning, historical field trips, simulations and role-playing games etc.

The main advantage of simulations and games is that situations can be replicated; different scenarios can be examined with reliably, efficiently and with low costs. Experimental SL training for medical students was described in [4], overview of medical ‘locations’ in SL is presented in [5].

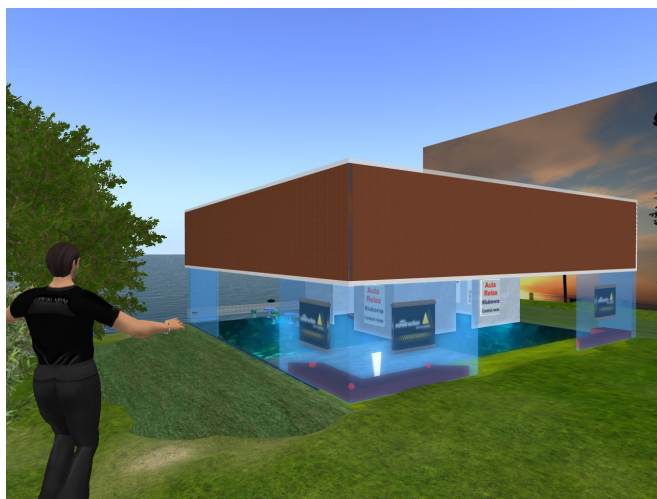


Fig. 1 Presentation of FIM UHK in SecondLife (screenshot)

Virtual worlds can be integrated with learning management systems and can be compatible with e-learning standards. SLOODLE [6] is a combination of Second Life and Moodle system. It allows storing data from virtual world activities and process them for the purpose of traditional e-learning course, i.e. user accounts in Moodle can be linked with avatars in SL, discussions among avatars can be archived in Moodle discussions, 3D modeling tasks can be defined in SL and then graded as assignments in Moodle etc. The compatibility with LMS like Moodle which is already used by the teaching staff makes the development of virtual world applications easier and more practical. Another example of integration of virtual world with suitable e-learning technology is OLIVE, enterprise-grade virtual world compatible with the Sharable Content Object Reference Model (SCORM) e-learning reference model [7]. The compatibility with all kinds of helps minimize the dependence of educational institution on particular provider of virtual world technology.

B. Virtualization and remote access

There are some papers such as the ones with references [8] and [9] that describe the types of remote laboratories architectures in existence. [10]

III. CASE STUDY

A. Laboratory aspects and equipment

For computer networks education at Faculty of Informatics and Management we dispose of one specialised laboratory with technical background. The laboratory of computer network was founded in 2007 as financed in FRVS project. The equipment consists of the following items:

- 10x PC DELL Optiplex 745 Intel Q965 chipset, Intel Core2Duo E6700, Radeon X1300PRO, SoundMAX, 4 GB RAM, 500 GB HDD, DVD-ROM, 20" LCD 2007WFP Flat Panel Monitor, keyboard, mouse,
- 9x ROUTER CISCO 2800,
- 9x SWITCH CISCO 2960,
- 3x LINKSYS WRT150N,
- structured cabling and other accessories.

The laboratory is used by:

- 160 students of Computer networks 2 course,
- 40 students of Computer networks 3 course,
- 30 students of Computer networks 4 course and by
- 20 students working on bachelor's thesis.

The Computer networks 1 course is theoretical course without needs of special equipment.

The laboratory with all its necessary technical equipment cannot be open freely to students all the day, therefore virtualization is the way how to allow students to study/work/participate distantly. Virtualized laboratory is cheaper and more efficient solution. To increase the student's laboratory time is possible using the scheduled remote laboratory access.

B. Requirements for remote access to laboratory

The first prerequisite for remote access to the virtual lab is the stability of all elements of the local network. Of course the smallest single component failure can have a major impact on the entire site (local network). This aspect will affect primarily the interest of other or next users [11]. The second major prerequisite is the stability of a virtualized environment, i.e. the technology used. Hence we need to choose the right virtualization software and debug it thoroughly in actual use in the locality. Another condition is focused on the hardware, especially the associated (connected) network elements (routers, switches), because each site must operate completely independently.

It is necessary to resolve access to the site this provide by that is managing the server, which will be operated using the open-source technologies (depending on the project) such as PHP, MySQL, Java, LDAP, etc.

C. Proposed solutions

The first way to solve the interconnection of two different ports is to use ASSSK-1, 2, which are developed by University of Ostrava. The primary advantage is in the modular facility. The disadvantage is mainly the impossibility of linking other ports than the standard 10BaseT. Therefore, it was also implemented the technology FPGA and the concept of VLANs, which allow connection of other devices 10/100/1000. [12]

Another way to connect all devices in the area is the use of Moxa cards. Moxa cards are devices that are placed under the management server and include several ports RS-232, typically 8, 16 This option, however, lacks flexibility, because you need to physically swap the entire topology in order to complete the exercise. This situation is illustrated in Figure 1.

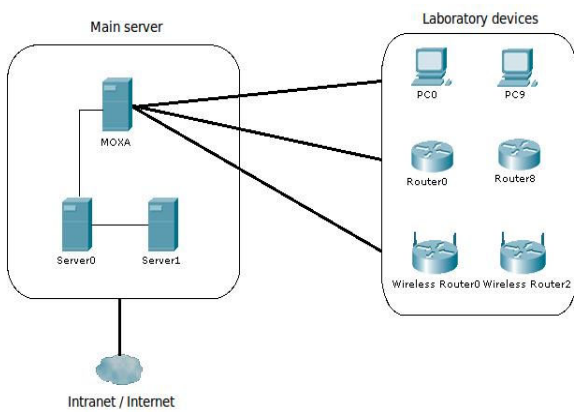


Fig. 1. A single area with MOXA solution

Part Laboratory devices, here are located all the facilities available in the LAN, all connected to a server that contains several MOXA multiport serial cards. Under Main site - the center of all the services that will provide the management server, such as: deleting the configuration, Apache, PHP, MySQL, etc.

D. A possible troubles

Deleting configurations - can be caused by a stored configuration of students who worked in the previous time, leaving the configurations that had "unknown" password, it is necessary to solve this situation, a sequence of commands that will ensure the cleaning of various network devices within the site, or to develop a feedback system that will watch every facility in network and identify what are the condition and they will send a cleaning sequences of commands which brings in the network device into a usable state [13].

Another possible difficulty may be the storage configuration by the user in the previous class created and will want to use again in the future. This can be solved in two ways. The first way is to store configuration on the server (the site) or using a second method. Where the applet will use remote access with two-way communication interception equipment between and a local network remote network element, may be recorded on

a local file. This can be a more efficient and complex solution than the first [13].

A threat can also arise in the communication transmission media, where users can be under attack from the third site. So we can use secured technologies such as IPSec, HTTPS. Another important aspect of security is to use the password authentication method, e.g. type of LDAP servers, RADIUS and so on.

E. Virtual laboratory of computer networks

The purpose of this case study is to introduce a virtual laboratory project, and in particular the use of various virtualization technologies in its design and solutions. This project aims to design and implement e-learning system to support teaching of computer networks. That project primary provides an interactive environment for creating and configuring virtual network topologies based on elements of the brand Cisco Systems inc. which is leading technological company in networking industry. Cisco has created its own courses, that teach general networking theory and include practical exercises based on its own product-line. It makes Cisco platform ideal for this project. Cisco academies have own laboratories with physical hardware, where students do exercises. But the laboratories can't be available for students 24/7. That is the reason for using virtualization.

Project consist of several partial applications arranged into architecture layers.

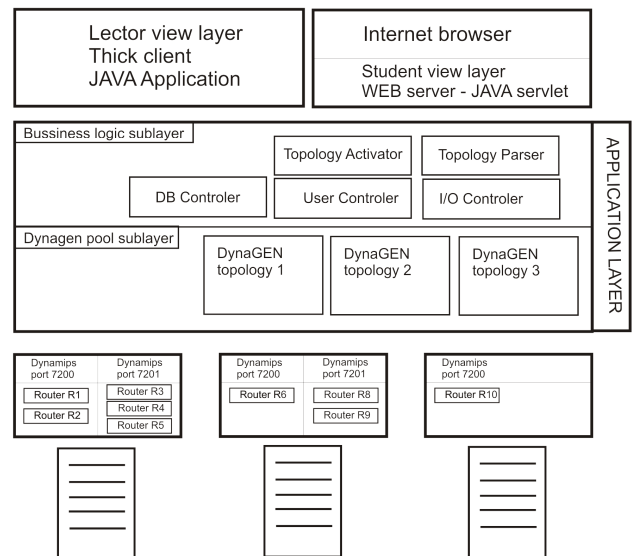


Fig. 2. Architecture of virtual laboratory solution

The layer that ensures virtualization of devices is based on Dynamips/Dynagen emulation toolkit. Dynamips is Cisco router emulator. Reference [14] shows that it emulates 1700, 2600, 3600, 3700, and 7200 hardware platforms, and runs standard IOS images. IOS (Internetwork Operating System) is software integrated in multitasking operating system that contains routing, switching and telecommunication services used in Cisco network devices. Single process of Dynamips is able to emulate more than one device. It makes troubles in

case of performing emulation on 32-bit operating systems. There are limits in maximum assigned memory per process. Reference [15] shows that 32-bit Windows systems has 2GB limit and by reference [6] 32-bit Linux systems has 3GB limit. There are few ways how to deal with this problem:

- *Using only 64-bit system* - This is the most straightforward solution but it also requires 64-bit support in physical hardware.
- *To run more than one Dynamips process on 32-bit system* - Running more Dynamips processes is possible. In that case processes are listening on different network ports and together shares system resources. This solution is usable only if there are not any network based restrictions that causes failing connection. This approach is used in Virtual laboratory project.
- *To use para/virtualized operating system* - There are lot of virtualization tools like as VirtualBox, VMware, Xen, KVM, that can provide virtualized operating systems with assigned as much memory they are limited per process and on them run Dynamips emulator. Reference [6] shows brief overview about different approaches to virtualization and its types. Further it describes why the paravirtualization technique is more efficient in terms of performance. Paravirtualization approach uses Xen. Against previous two methods there are some overhead costs. On the other hand Xen provides some extra services like as real-time virtual machine migration to less busy physical servers in situations when some running topology become inactive. It's some kind of load balancing. can be used as one of possible improvements of Virtual laboratory project.

Dynagen is text based front end for Dynamips. It allows to easy create and work with virtual network topologies by:

- *Defining topologies into configuration file* with simple syntax, which facilitate its generation by upper layer, that contains business logic of virtual lab application.
- *Controlling of multiple Dynamips servers simultaneously* which allows to distribute large topologies across several physical servers.
- *Providing management of emulated devices* is important mainly for providing input/output configuration interface of virtual device to upper layer of application and through it to users.

Set of Dynagen processes is in this design architecture contained in the application layer as its lower sublayer. It is important to realize that one instance of Dynagen means one specific active topology. Therefore communication between the business logic sublayer and the dynagen pool sublayer have to be reliable, robust and real-time.

Business logic sublayer provides to user functionality and behaviour of application resulting from Use Case model and Requirements model that are both parts of analysis of this project. There are two user roles in application, student and lector role. Lector can create / update / delete / activate / deactivate virtual network topologies. In case of creation business logic sublayer parses created topology XML from Lector view layer and generate script for Dynagen and save it. If topology have to became to active state script is loaded from

database and Dynagen process is started. Next there is determined what other topologies are active and how many physical servers are designed for processes of emulator Dynamips. By the results are on servers started instances listening on particular network ports so that the distribution of load is approximately same per server.

Lector also have to assign one or more virtual devices to the specific student. Business logic sublayer also takes care about access control to the specific device.

Lector view layer is thick client platform independent application with GUI determined for interactive drawing and creating network topology. It parses topology drawing to XML data format and send to the Application layer, specifically to the business logic sublayer.

Student view layer consist of web application that provide simple web interface where students have to be registered and logged. They can list topologies they are atteded in and let see one of those topologies. They can see simple diagram of whole topology and through simple Java Applet can configure assigned emulated devices. This topology page is completed by simple chat through which can communicate with other students configuring some devices in the same topology.

IV. CONCLUSION

Between the main benefits of the remote access to computer networks laboratory belongs the increase the student's laboratory time using the scheduled laboratory access. The virtual laboratory is a cheaper way of the extension of the laboratory. One of the main contributions of this paper has been discussion about benefits of different virtual and virtualization technologies applied in higher education and to show a remote and virtual laboratory solution.

REFERENCES

- [1] *Virtual Worlds Review*. URL: <http://www.virtualworldsreview.com> (accessed 2010-10-20)
- [2] W.J.Teahan. *Artificial Intelligence – Agents and Environments*. BookBoon, 2010, ch.2.
- [3] *SecondLife homepage*. URL: <http://secondlife.com/> (accessed 2010-10-20)
- [4] J.Weicha, R.Heyden, E.Sternthal et.al. *Learning in a Virtual World: Experience With Using Second Life for Medical Education*. In: Journal of Medical Internet Research, 2010, Vol.12, No.1.
- [5] B. Meskó: *Top 10: Virtual Medical Sites in Second Life!* URL: <http://sciencereview.com/2007/06/17/top-10-virtual-medical-sites-in-second-life/> (accessed 2010-10-20)
- [6] *SLOODLE homepage*. URL: <http://www.sloodle.org/moodle/> (accessed 2010-10-20)
- [7] *OLIVE homepage*. URL: www.saic.com/olive/ (accessed 2010-10-20)
- [8] H. Benmohamed, A. Leleve, P. Prevot. *Remote Laboratories: New Technology and Standard Based Architecture*. In: Int. Conf. on Information and Communication Technologies: From Theory to Applications. 2004, pp101-102.
- [9] S.K.Esche, C.Chassapis, J.W.Nazalewicz et al. *An architecture for multi-user remote laboratories*. In: World Transactions on Engineering and Technology Education (UICEE), 2003, Vol.2, No.1.
- [10] J.Lloret, J.M.Jimenez, J.R.Diaz et al. *A remote network laboratory to improve university classes*. In: Proc. of the 5th WSEAS/IASME international conference on Engineering education, Heraklion, Greece, 2008, pp299-304.
- [11] P.Němec *Virtual network laboratory*. Master's thesis, Faculty of Electrical engineering and Computer Science, VŠB-TU Ostrava, 2005 (in Czech)

- [12] P.Grygárek, M.Milata, J.Vavříček. *The Fully Distributed Architecture of Virtual Network Laboratory*. DCS Technical University of Ostrava, 2007.
- [13] P.Grygárek. *The experience of deploying virtual laboratory of PC networking and next phase and development. Collection of technologies for e-learning*. FEL ČVUT, Praha, 2006.
- [14] *The network configuration generator for Dynamips*. URL: <http://dynagen.org/> (accessed 2010-10-20)
- [15] *Memory Limits for Windows Releases*. URL: [http://msdn.microsoft.com/en-us/library/aa366778\(VS.85\).aspx](http://msdn.microsoft.com/en-us/library/aa366778(VS.85).aspx) (accessed 2010-10-20)
- [16] P.Bargam et al. *Xen and the art of virtualization*. In: Proc. of the nineteenth ACM symposium on Operating systems principles. Bolton Landing, NY, USA, 2003, pp. 164 - 177