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Teaching Networking Labs With Virtualized Server Infrastructure.

Sergey Butakov
SolBridge International School of Business, butakov@solbridge.ac.kr

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Sergey Butakov
SolBridge International School of Business
Daejeon, South Korea
butakov@solbridge.ac.kr

Abstract:

Practical experience is considered a vital part of university level courses in the Information Technology and Information Systems areas. A practical component of computer networking related courses, especially at the Enterprise Integration level, requires multiple servers to be studied by the students. Many of such servers may be incompatible with each other and it may be required that they be installed on different platforms. This issue leads to increasing capital and operational expenses for the networking. The main goal of this paper is to share the experience of developing infrastructure for networking courses using virtualization technologies. The experience can be especially valuable to startup institutions or institutions in developing countries where resource constraints are a problem.

Keywords: Virtual Labs, Educational Simulations, Network operating systems, Open Source

I. INTRODUCTION

Practical experience is considered one of the major components of computer-related education (Longo and Bochicchio, 2009) and in particular, in Information Systems (IS) and Information Technology (IT) education (Curricula, 2005). Hands-on experience with networking technologies is highlighted in the 2008 IT curricula recommendations as a part of a networking component of the program (Curricula IT, 2008). The IT infrastructure component of the latest ACM/AIS recommendations for IS program also suggests extensive practical training on network configurations, network applications, and security (Curriculum IS, 2010). Extensive practical training requires the appropriate infrastructural support. The 2002 IS curricula recommendations clearly identify laboratory recommendations stating the need for specialized laboratories: "…Specialized laboratories are needed for advanced students where group and individual projects are developed.…" as well as a need to update them: "… All computing systems should be kept current. A plan should exist to continuously upgrade and/or replace software and equipment in a timely manner. The rate of change in technology suggests a rapid replacement cycle, with some technologies reaching obsolescence in less than 12 months.…" (Curriculum IS, 2002).

The IS curricula 2010 echoes its predecessor repeating similar requirements and adds the suggestion to use simulation tools to emulate real systems starting from the workstation level up to complex enterprise-level networks (Curriculum Guidelines IS, 2010). Some courses recommended for a core IS program, such as Enterprise Architecture or IT Infrastructure, require extensive experience with business applications, communication technologies and security applications. Typical topics in these courses and software systems required to support laboratory components are listed in Table 1.

Many of these servers may not be compatible with each other and may require installation on different hardware platforms and/or different Operating Systems (OS). Such incompatibility leads to the increasing number of physical servers required to fulfill teaching needs, demand additional technical support and therefore, increases cost of the program.

One option to reduce the number of the required hardware devices is implementation of multi boot systems. This solution is reportedly used by many schools. For example, the University of New Hampshire (Blezard, 2007), the University of Delaware (Dyar & Timmins, 2007) and the

University of California, LA (Ahn, 2008) use dual boot systems to reduce the need for multiple desktops in the computer labs used by students. A multiboot configuration also looks like a good option for servers because most of the major server level OS supports multi boot. Multi boot has the following main advantages: (i) it is easy to implement and (ii) all the resources of the physical box areavailable to the currently loaded OS. If multi boot is implemented on the server side then one physical server can be used to work with a number of different software servers mentioned above. But multi boot has its own disadvantages: (i) a new OS should be installed for any new server required and (ii) only one OS can run on one physical box at the same time. The latter is a major drawback of a multi boot configuration for the purposes of teaching Enterprise Integration topics.

Table I. Course topics and software systems

Topics	**Software systems**
Communication Technologies	• web server, • mail server, • instant messaging server, • enterprise portal
Security Technologies	• directory server, • authentication server, • certificate authority/center
Business Applications	• Customer Relationship Management (CRM) system, • Enterprise Resource Planning (ERP) system
Enterprise Integration	• all of the above (ideally), • directory service

Virtualization technology looks to be a much better option as it allows many platforms to run simultaneously and therefore reduces the number of physical servers required to support lab teaching. Virtualization was reportedly implemented in many university labs, but mostly on a desktop level (Denk & Fox, 2008; Dyar & Timmins, 2007). This paper focuses on the server virtualization for university IT labs. Based on the list of topics to be covered by lab components in a typical IS program (Table I) we offer the summary of our experience in deploying virtual servers in Linux environment and suggest a set of downloadable ready-to-deploy solutions for server components of a networking lab.

The following sections discuss pros and cons of virtualization technologies for server applications, describe the implementation of virtualization technology in the lab, provide a general description of the minimal required infrastructure, and finally give the download links to the set of ready-to-deploy virtual machines suitable for labs.

II. VIRTUAL TECHNOLOGIES IN A NETWORKING LAB OF MATERIAL

As mentioned above, the necessity to develop intensive hands-on experience with networking technologies for IS / IT majors sets relatively high requirements for hardware to be used in student labs. For example, teaching Enterprise Integration topics assumes that a number of software servers will be used simultaneously. Such a set could include for example, the following items on different OSs:

- Server 1 (OS: Microsoft Windows Server 2008): Active Directory for directory and authentication services.
- Server 2 (OS: SUSE Linux): Apache with Sugar CRM as an example of web server with intranet corporate application.
- Server 3 (OS: Fedora Linux): Zimbra communication solution from Yahoo for email, instant messaging and collaboration.
- Server 4 (OS: Sun Solaris): Oracle database.
- Server 5 (OS: CentOS Linux): Dimdim web conferencing server as another application server.

All five platforms should run at the same time simulating the configuration of IT services required by a typical Small/Medium Business (SMB) environment. In industrial-wide practice, compatibility issues on such platforms lead companies to install separate physical boxes for many of the services required for company operations. As recent marketing surveys show, SMB extensively upgraded and expanded the infrastructure. For example, SpiceWorks indicates that 45% of SMB companies have plans to buy server(s) in the next 6 months (Scholz, 2009). Of course, one of the key factors supporting this trend is that companies have to plan for the highest possible workload and most of the hardware platforms are under loaded out of peak time. Khanna et al. indicate that only 10 to 35 percent of the hardware capacity is used by the average company (Khanna et al., 2006). HP reports the typical average workload to be under 30 percent of physical server capacity (Padala et al., 2007). Microsoft estimates these numbers even lower: "… server workloads consume on average only five percent of total physical server capacity ..." (Microsoft, 2010). With the recent developments of virtualization technology in mass market server/desktop processors, the industry tendency is to move multiple servers into a virtual environment. Major IT industry leaders recognize this virtualization trend in SMB environment (Creeger, 2008). VMWARE estimates that 40 percent of American companies have implemented virtual technologies with 8:1 ratio, which means on average eight virtual platforms have been consolidated on one hardware platform (VMWARE, 2010). Such a trend not only reduces the capital expenses but also saves running expenses reducing energy consumption. Though energy savings in large data centers through virtualization are argued by many CIO's, they generally agree that in an SMB environment virtualization reduces energy bills (Creeger, 2008). Considering this tendency for SMB companies and therefore on the job market virtualization technologies should to be introduced to students.

Virtualization of university labs infrastructure is also a trend for many schools around the world. For example, Kuehn reports on the experience of installing desktops in a lab at Stanford University using Apple's Mac physical platform (Kuehn, 2008). Denk & Fox report on using virtual desktops accessible through the web at State University of New York Geneseo (Denk & Fox, 2008). Li reports virtualization to be implemented on the desktop level to teach a number of IT related courses at East Carolina University (Li, 2010). Implementation of virtual machines on a desktop level allows schools to save on the hardware and improves the efficiency of lab deployment, utilization, and maintenance. There are some reports that outline virtualization on the server level. Stewart et al. describe a virtual lab based on VMware and VirtualBox technologies and tailored for network security teaching (Stewart et.al., 2009). Other authors also show positive experience of teaching system administration and network security on the virtualized infrastructure (Wang, Hembroff, and Yedica, 2010; Stackpole et.al., 2008). The following main advantages of virtualization have been reported for university computer labs: OSs run at the same time, easy ways of rolling back the "guest" OS (Kuehn, 2008), access to software on different operation systems, possibility to provide web access to lab facilities through remote terminal connection (Denk & Fox, 2008).

Kuehn have also mentioned some disadvantages in virtualization technology implementation on the desktop level: "complicated setup, limited graphics acceleration, and incompatibility due to indirect hardware access, some performance loss, and heavy memory requirements" (Kuehn, 2008). If we check this list across the requirements for virtualized server infrastructure we will see that these disadvantages do not affect the server level implementation. Graphic acceleration is the last problem to worry about for servers. Most of the server OSs including major Windows Server and Linux distributions are compatible with popular hypervisors such as XEN or VMware; and most of the physical servers currently come with a substantial amount of RAM by default.

The problem of a complicated installation can be mostly solved by packing up and distributing preconfigured virtual machines with the required servers installed. They can be distributed as a set of virtual appliances that are already integrated with each other. After downloading these appliances the lab administrator needs only to change basic network settings in order to adjust the systems for the current environment. Of course, this way of distribution is only appropriate for Free Open Source (FOS) systems. For example, from the list of servers for the integration lab provided in the beginning of this section, only three servers including Sugar CRM, Zimbra and Dimdim fall into FOS category and can be distributed as virtual machine images based on a compatible free Linux distribution.

In addition to the advantages mentioned above for the desktop environment, the implementation of virtualization technologies for servers in a computer lab provides the following benefits:

- Rich set of applications running on a limited infrastructure: the set of 3-5 servers can run on a single physical box.
- High portability: the virtual appliances can be moved relatively easily to a new hardware/hypervisor environment.
- The solution initially comes with zero software costs as it could be based completely on FOS software. Of course, proprietary software can be added later if licenses are available for the particular institution or laboratory.
- Students develop hands-on experience with virtual technologies and become better prepared for the latest trends in the job market.
- Students can be introduced to a variety of OSs including different distributions of the Linux.

III. USER TRIALS

The proposed solution for using virtualized server environment to teach application layer component of network labs was extensively tested at SolBridge International School of Business. The minimalistic hardware set for the laboratory classes consisted of one server based on the Intel® Core™ 2 Quad platform with 4 GB of RAM, one 4 ports network switch, and three desktop PCs as clients. As it can be seen from the description such a configuration is relatively inexpensive and can be considered affordable for most of the institutions even in the developing world. OpenSUSE Linux was used as a host operation system for XEN hypervisor and 4 Virtual Machines (VMs) were configured as fully virtualized guest OSs. Table 2 provides details on the topics that were taught in this user trial. It differs slightly from the list provided in Table 1 because some services were excluded due to lack of lab time assigned in the course.

Table 2. Covered topics and implemented software

Topics	Software systems
Communication Technologies	web server, mail server, instant messaging server,
Security Technologies	directory server, authentication service

Topics	Software systems
Business Applications	Customer Relationship Management (CRM) system
Enterprise Integration	directory service

Table 3 provides lists of implemented services and configuration of virtual machines. The set of these tools had been showing reasonable performance with 2-3 clients working with one virtual server. The only proprietary software implemented was Microsoft Windows Server 2008 which was used to introduce students to Active Directory technology. In the circumstances, where license for Microsoft Server product is not accessible, it can be substituted by free OS with a directory/authentication service. For example, OpenLDAP running on OpenSUSE may fulfill such a role by making the lab software described in Table II totally free. Total storage size required for the configuration should be above 50GB (total for VM image size column in Table 1) which looks reasonable because currently most of the manufacturers offer ~70GB HDDs as a minimal option for servers. The total size of compressed virtual machines is slightly higher than 6GB and would fit on two DVDs and therefore can be easily distributed even in the environment where broadband Internet access is limited.

Table 3. Configuration of virtual machines

Service	**RAM allocated**	**VM image size**	**VM image compressed**	**Operation system**	**Application**
Host system, network routing	512 MB	8 GB*	~4GB**	Open-SUSE	Hypervisor, network bridge
Directory and Authentication	1GB	15 GB	n/a***	Windows Server 2008	Active Directory
Email and communication	1GB	15GB	~3GB	Fedora 11	Zimbra free ed.
CRM, web server	512MB	6 GB	~1.5GB	Open-SUSE	Sugar CRM, Apache
Web conferencing	1GB	8GB	~1.8GB	CentOS 4.5	Dimdim

* Disk space required for OpenSUSE, the host OS
** Size of OpenSUSE DVD distro
*** not applicable because image cannot be distributed over the web

Graphical description of the virtual network configured for the proposed set of software is displayed in the Figure 1. As can be seen from the figure after the host system installation is completed, the administrator has to only download and install virtual appliances, configure static addresses on the virtual network, and setup the following services on the host OS: DNS, DHCP, routing and firewall. In our experience this virtual network configuration can also be a part of the laboratory work for students in the IS infrastructure class. The set of software services represented in Figure 1 can be considered as a sufficient simulation of a typical infrastructure for an SMB environment.

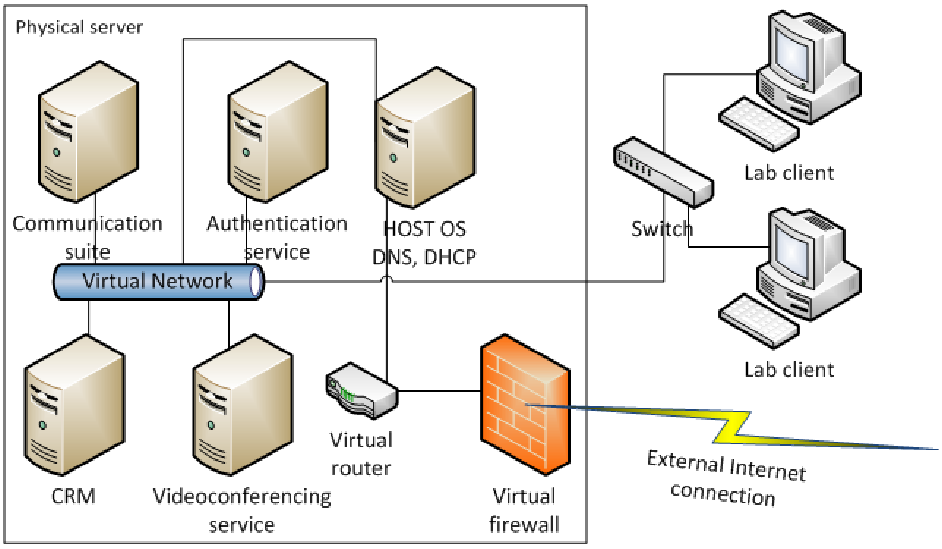

Figure 1. Virtual and physical networks in the trial setup.

IV. CONCLUSION

The proposed configuration of virtual servers and network settings can fulfill the basic requirements for teaching network based services and applications. It can be run on a minimal hardware infrastructure to provide a quick start for a network applications lab. From the IS curriculum point of view, the provided set of virtual appliances can support teaching of a wide variety of topics including, but not limited to, Communication Technologies, Security Technologies, Business Applications, and Enterprise Integration. All the software used in this configuration (except Microsoft Windows Server 2008) can be distributed as FOS for noncommercial use making the proposed virtualized lab solution highly portable. The preconfigured VMs for servers described above can be downloaded from the authors' web site (http://virtualservers.solbridge.info/) and easily configured on the XEN platform with minimal changes in the network settings. The additional benefits of proposed infrastructure implementation include exposing students to virtualization technologies and extensive use of FOS. Modest hardware requirements along with free software create a good opportunity to use the configuration as described in this paper in institutions in developing countries as well as in startups in developed countries.

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ABOUT THE AUTHOR

Dr. Sergey Butakov is Assistant Professor and Chief Communications Officer at SolBridge International School of Business, Daejeon, South Korea. He has several awards for research and teaching from universities in Russia, Nigeria and South Korea. Dr. Butakov authored and co-authored more than 30 publications. In 2001 – 2004 he served as principal researcher in two projects funded by Russian Foundation for Basic Research and the last five years he participated in a number of industry and university funded research projects. He is interested in network infrastructure monitoring and development, text search, plagiarism detection, software development, and artificial intelligence.