A Core System for a Web-based Virtual Computer Laboratory

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1. ABSTRACT

In a web-based e-learning environment, we expect the necessary knowledge and laboratory activities to be delivered to learners without requiring their on campus presence. Within this frame, our work focuses on designing a system that can serve in building web-based labs capable of delivering the required skills and hands-on training related to computer science field of study. The proposed architecture makes use of the current Virtualization and Virtual Network Computing (VNC) technologies to build the desired system. In this paper, we describe the design and show that it is capable of being a core for various types of scalable, modular, and easy to manage, configure, and access labs.

2. KEYWORDS

Virtualization, Virtual Network Computing, e-learning, open source, distance education.

3. INTRODUCTION

Our target is to introduce a system that can be used for delivering real experiences and problem solving techniques in fields of study related to computer science taking into consideration fulfilling the following points:

- The system should be able to provide activities akin to that of conventional lab.
- Enables access to the lab resources through generic and widely available software.
- Easy to manage and reconfigure.
- Ensures design modularity and scalability.
- Can serve as a start point for building various labs.
- Meet the requirements of the prevailing “cost reduction” strategy implemented in the different organizations.

Different approaches have been followed to design a lab activity that can be used in web-based e-learning systems; for example, one approached proposed to equip the currently available lab facilities with a remote access feature that enables learners to perform their tasks while not on campus [1]. Another approach proposed to use virtualization technologies available to build an environment that meets the specific requirements of one course [2]. We believe that the different approaches could meet one or more of the above mentioned targets; but, on another hand, our approach makes use of the previous work to propose an architecture that is similar in the general design concepts, but provides improvements that elevates the overall evaluation of the system.

The design we introduce in this paper makes use of two main technologies: Virtualization and VNC to achieve the targeted goals. With virtualization, it is possible to build and simultaneously operate a number of guest OSs with different configurations on one machine. Current virtualization technologies provide powerful tools for managing the environment variables besides the different guest OSs. VNC, on the other hand, enables web-based access to the lab activities. This is achieved by the implementation of a web-server residing on the target machine and communicating with the learner's web-browser.

The results we got from our work showed that our system, equipped with supporting tools, can be used as a base to deliver various lab activities in web-based e-learning environment.

4. SYSTEM DESCRIPTION

4.1. TECHNOLOGIES

The system is required to fulfill two basic functions: to provide a number of machines that will be used by learners to accomplish the assigned tasks during lab activities; and to enable web-based access to these machines.

Virtualization technology provides the tool to create a number of concurrently-running, still isolated, operating system instances (guest OSs) on one hardware host machine. In our system, we adopted Xen [4] to accomplish this task. Xen is an open source virtualization hypervisor that introduces powerful capabilities and tools for building and controlling the different instances of guest OSs, and is gaining increased interest in the virtualization community. Capabilities include the introduction of two technologies for building guest OSs, Virtual Machines (VM) in Xen terminology, which are Full-virtualization and Para-virtualization. Differences between the two can be realized in terms of performance indicators and host machine's hardware support and access in the guest OS. Another capability by Xen is the introduction of different networking customizable scenarios for the installed VMs. Such scenarios include Bridged Networking, Routed networking, and VLANS. Tools provided by Xen include command-prompt and GUI interfaces to handle the different tasks related to the VMs such as creation, booting, shutting down, plugging/unplugging devices besides many others. Xen hypervisor uses a number of configuration files to setup the virtualization environment and the network design on the host machine. By modifying these files, we can alter the behavior of Xen and enable the creation of more sophisticated network designs that meets our requirements. Creating a VM in Xen is relatively a simple task that can be performed through the virt-manager GUI interface. The installation process involves setting up the different parameters related to the VM such as: storage, memory, and the number of virtual CPUs. The VM's storage can be set up on a separate media or as a simple file on the host machine's file system. Using a file as storage for the VM enables the possibility of creating twin VM by simply copying the VM's storage and configuration files with some simple modifications that should be done in the configuration file.

VNC [5] technology is the tool we use for providing remote access to the different VMs installed in the system. Besides being an open source technology, VNC provides simple and OS independent yet secure access to the remote system through a client-server model. VNC server will reside on the target machine, the VM in our case, while the user will use the client software to get the remote machine environment on his/hers machine. The simplicity VNC introduces comes from the fact that the client software can be any web browser which the user will use to connect to the server on the opposite peer through preconfigured TCP ports; thus, access to the different VMs can be controlled through Access Control List (ACL) that resides on intermediating Firewall. VNC technology also provides a security model by which user privileges can be determined through configuration files on the accessed system. Configuration files also can be used to set up the environment which the learner can access such as desktop or terminal, for example.

4.2.IMPLEMENTATION

As shown in Figure 1, implementation has been done on a single server that has the following hardware architecture:

CPU is Intel Core2 Duo 6300 operating at 1.86GHz
RAM is 2GB
HDD is SATA 320GB
Mother Board is GIGABYTE GA-965G-DS3 with support for virtualization.

Xen virtualization hypervisor and VNC technologies are included in the distribution of Fedora Core 6; therefore, we used this distribution as the host OS (Dom0). As for the guest operating systems, we used Fedora Core 5 and 6 for full-virtualization installation and Para-virtualization installation instances respectively.

By default, Xen is configured to create a bridge "xenbr0" and connect all VMs' network interfaces to it. We kept the bridged network architecture in our

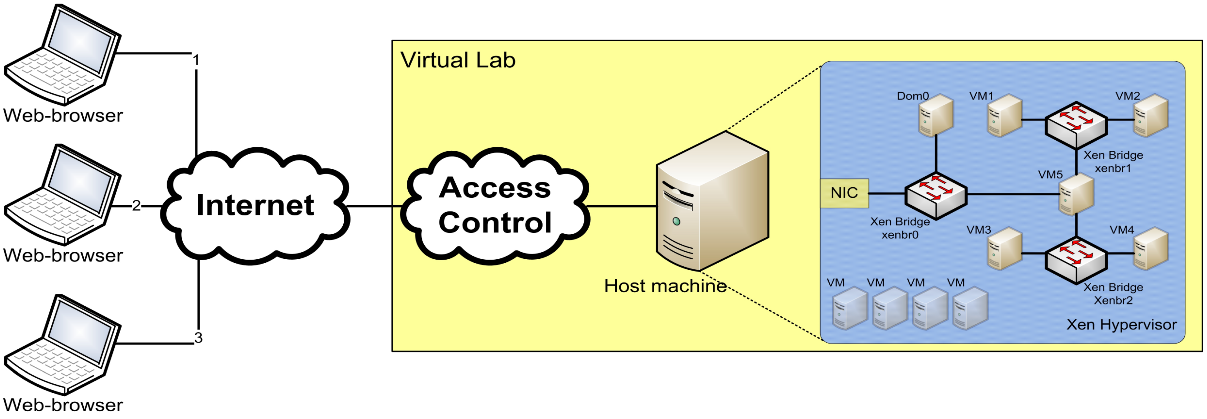


Figure 1 (Schematic of the web-based virtual computer laboratory)

design with some modification that we adopted in order to create more bridges to improve the network's design. The following lines show a portion of the script we used for creating the structure showed in Figure 1:

```
#!/bin/sh
dir=$(dirname “$0”)
“$dir/network-bridge” “$@” vifnum=0
“$dir/network-bridge” “$@” vifnum=1 netdev=dummy0
“$dir/network-bridge” “$@” vifnum=2 netdev=dummy1
```

Using the virt-manager for building a new VM will lead to creating a configuration file in which one network interface is attached to the VM and connected to the default bridge created in Xen network i.e. xenbr0. By altering the configuration file, we can attach more network interfaces to the VM and connect them to the different bridges available in the network as illustrated in the following lines which are taken from VM5 configuration file.

```
vif= [ 'type=ioemu, mac=xxxxxxxx, bridge=xenbr0',
        'type=ioemu, mac=xxxxxxxx, bridge=xenbr1',
        'type=ioemu, mac=xxxxxxxx, bridge=xenbr2', ]
```

Remote access to a VM involves carrying out some modification to the VNC configuration files and setting the password(s) for the users. VNC server configures a number of displays that remote users can connect to over TCP ports corresponding to them; for example display number X will be accessible through the TCP port 5800+X. A display in VNC also is characterized by “user name” that corresponds to a user defined in Linux system. By this way, the remote user connected to the VNC server's display will have the same privileges of one user defined in the system. The following listing shows portion of the file in which a number of displays are defined:

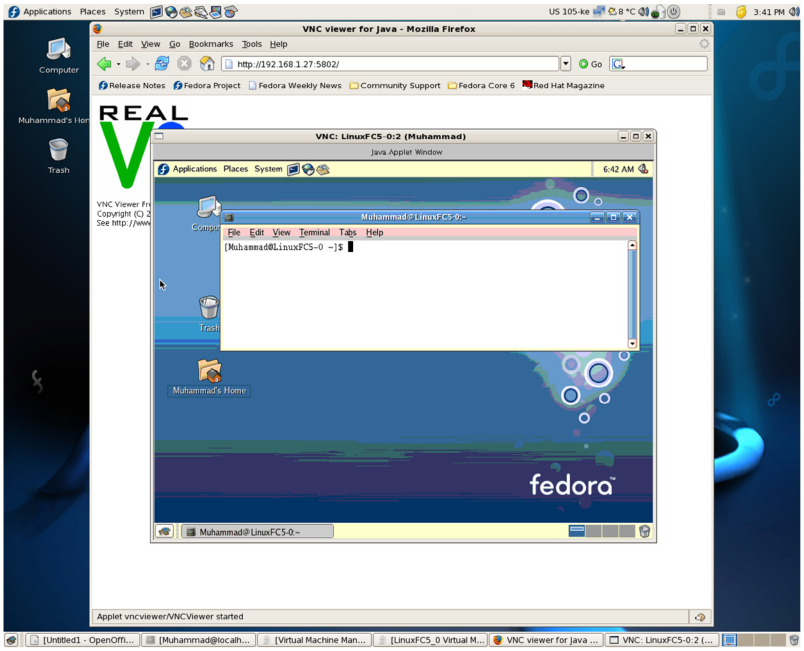
```
VNCSERVERS=”1:User1 2:User1 3:root”
VNCSERVERARGS[1]=”-geometry 800x600 -depth 24”
VNCSERVERARGS[2]=”-geometry 800x600 -depth 24”
VNCSERVERARGS[3]=”-geometry 800x600 -depth 24”
```

This file defines three displays through which learners will access this VM. We can note that one user name can be used for defining more than one display. Next step is to assign passwords for remote access; this is done by entering the command "vncpasswd" at the specified user command prompt. The environment the remote user will get can be defined in the file "xstartup". Uncomment the following two lines and the remote user will have access to the desktop environment.

```
unset SESSION_MANAGER
exec /etc/X11/xinit/xinitrc
```

Configured as previously mentioned, a VM now is ready to serve learners connecting through their web browsers. Figure 2 shows a snap shot of a learner's screen when logged into one VM.

The proposed structure can be configured in various scenarios to serve different training courses offered by the web-based e-learning system. For example, the sub-network formed by the VMs connected to one of the auxiliary bridges we created in the system can be used for delivering training in courses that do not involve networking concepts such as OS and application specific courses. A structure that involves the two auxiliary bridges connected by one VM will enable delivering training on networking concepts. VM in this case will act as a router between


Applications Places System
US 105-ke 8 °C 3:41 PM
VNC viewer for Java - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://192.168.1.27:5802/
Go
Release Notes Fedora Project Fedora Weekly News Community Support Fedora Core 6 Red Hat Magazine
Computer
Muhammad's Hor
Trash
REAL
VNC Viewer Fr
Copyright (C) 2
See http://www
VNC: LinuxFC5-0:2 (Muhammad)
Java Applet Window
Applications Places System
6:42 AM
Comput
Trash
Muhammad's Home
Muhammad@LinuxFC5-0:~
File Edit View Terminal Tabs Help
fedora
Muhammad@LinuxFC5-0:~
Applet vncviewer/VNCViewer started
[Untitled1 - OpenOffi...
[Muhammad@localh...
[Virtual Machine Man...
[LinuxFC5_0 Virtual M...
VNC viewer for Java ...
VNC: LinuxFC5-0:2 (...

```
[Muhammad@LinuxFC5-0 ~]$
```

Figure 2 (A sample of the learner's screen)

the two sub-networks and will be available for learners to reconfigure.

In order to meet the requirements of various training course aimed by the system, a number of preconfigured VMs have been created with the needed software packages installed. This set of VMs will reside in the system without being booted. When the instructor wants to activate one lab, the VMs that meet lab requirements will be booted and enabled for access on the system. The number of VMs assigned for one lab can be increased or decreased according to the number of learners making use of the lab activity at the same time.

5. RESULT

As a result of our work, a learner in a web-based e-learning environment is able to access a system that is designed to provide training and hands-on activities through his/her web browser.

6. CONCLUSION

In this paper, we presented our approach to designing a system that can serve in building modular, scalable, and easy to mange web-based lab environments suitable for delivering activities akin to those offered by conventional labs. The design can be used for various types of lab activities in computer science related field of study and can be scaled and reconfigured depending on instructors' preferences.

7. FUTURE WORK

Future work related to the proposed design will concentrate on the following points:

- Designing a tool with Graphical User Interface (GUI) for controlling the different VMs in the system. This tool will be used by instructors for activating all VMs involved in one lab activity for a certain period of time during which learners will be able to accomplish their task.
- Building the virtual lab platform which will be the learners' interface to the different activities available in the system. This platform will be used for authenticating the login of the learners to the system and for saving a record of each learner's usage of the system and the different activities he/she has taken.
- Exploiting the possibility of automatically detecting the progress of each learner in the assigned task.
- Establish the connection between the virtual lab system and any available Learning Management System LMS.

8. REFERENCES

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