AC 2010-2188: FLEXIBLE CIS LABORATORY ENVIRONMENT EMPLOYING MULTI-BOOT AND VIRTUAL COMPUTING

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Flexible CIS Laboratory Environment Employing Multi-boot and Virtual Computing

Abstract

This work describes an innovative flexible multipurpose laboratory environment designed to support a large variety of laboratory exercises in a Computer Information Systems (CIS) curriculum. The environment employs multi-boot and virtual computing. Although it may be ideal to have separate labs for each course, this is often not feasible, and a single set of computers has to be used in different ways throughout the day; perhaps with networking, programming, PC repair, server administration, security, web design, operating systems and other courses all sharing the same resources. Virtual computing allows a single workstation to host many different operating system (OS) instances all running on a uniform, stable, base OS. This is an ideal environment for a flexible lab. However, some software, like EnCase and other computer forensics applications, is unable to function properly within a virtualized environment, usually because more direct access to hardware is required. In these situations, workstations can be configured to use dual or multiple booting to start up the desired OS for a course without interfering with other courses. This combination of technologies is successfully implemented to support many of the CIS courses at our institution. The success of this laboratory environment is assessed and evaluated through Faculty discussions as well as student performance on standardized certificate examinations. Results demonstrate an effective multi-course CIS laboratory environment.

Introduction

Computer Information Systems (CIS) and Computer Science (CS) programs are constantly adapting to new technologies and software to keep current and competitive. Consequently, these programs have a large number of laboratory courses requiring that students spend numerous hours in labs honing computer skills. Space requirements, hardware requirements, and software requirements including maintenance are often considered bottlenecks in program expansions, or just in keeping these programs current. When limited space or funds confine the lab environment, a stable, yet flexible, laboratory environment that can quickly be configured for new or updated courses becomes a necessity.

CIS, CS, and other technology-based programs rely heavily on computer laboratories to serve as the major resource for implementing active and project-based learning in a university setting. The literature reviewed shows positive results such as increased student enthusiasm towards their programs of study, perceptual and actual increases in students' knowledge, and development of design and team skills[1-5]. Furthermore, "scaffolding" is a method claiming that new knowledge is assimilated best when it is linked to previous experience[6, 7]. The discussed multipurpose laboratory was developed with the benefits of active learning and scaffolding in mind.

A number of educators in CIS, CS, Computer Engineering Technology (CET), and Computer Engineering (CE) developed computer laboratory environments for their courses, often under budgetary constraints. Usually, these environments serve one course[8, 9]. This work describes a complex computer environment serving most of the technical courses in a CIS program.

Lab Environment and the Curriculum

The CIS program required many labs that involved disassembling computers, packet-sniffing, OS installations, drive scanning, and malware behavior testing that our Information Technology Services (ITS) department could not support. So, in desperation, we set up what has now evolved into our CIS multi-purpose lab supporting ten courses, four to six each semester. In addition, the student Association for Computing Machinery (ACM) club wanted to have network game nights, so the CIS lab also fulfills that role. This lab is administered by a faculty member with assistance from one or two students. There was a plan to hire an outside part-time administrator, but this was not realized due to budget cuts.

Hardware Architecture

This section describes the hardware implementation on the part of the flexible laboratory environment. Estimated prices are shown where possible. As shown in Figure 1, the laboratory consists of the following equipment:

- 24 WinXP student workstations ($800 each)
- WinXP Instructor Workstation with dual monitors for running PowerPoint in presentation mode ($1000)
- Pilot workstation (currently testing Windows 7) ($800)
- Windows Server 2003 Server in back room ($1400)
- Gaming Server administered by the ACM Gaming Coordinator
- Laser Printer ($200)
- Ceiling-mounted projector ($600)
- Computers for PC Architecture students to disassemble and reassemble (stored in back room on shelving) (most are donated or previous lab equipment)
    - 8 tower workstation
    - 8 mini-desktop workstations
    - 4 notebooks
    - Large plastic bins with Keyboard/Mouse/tools/anti-static packaging to hold parts
    - Miscellaneous demo equipment
- Switches, Routers, and an Access Server for Routing class to configure (stored in back room in wheeled racks)
- A wireless access point with a panel antenna mounted on the front wall for configuration in several classes ($350)
- 6, 5-port Gigabit switches ($40 each)
- 1, 24-port unmanaged Gigabit Ethernet switch ($200)
- Cisco PIX firewall (approximately $500 for newer ASA 5505 since PIX are no longer supported)
- KVM (Keyboard/Video/Mouse) switch ($70)
- Backup RAID – 512MB+512MB in RAID 1 configuration ($250)

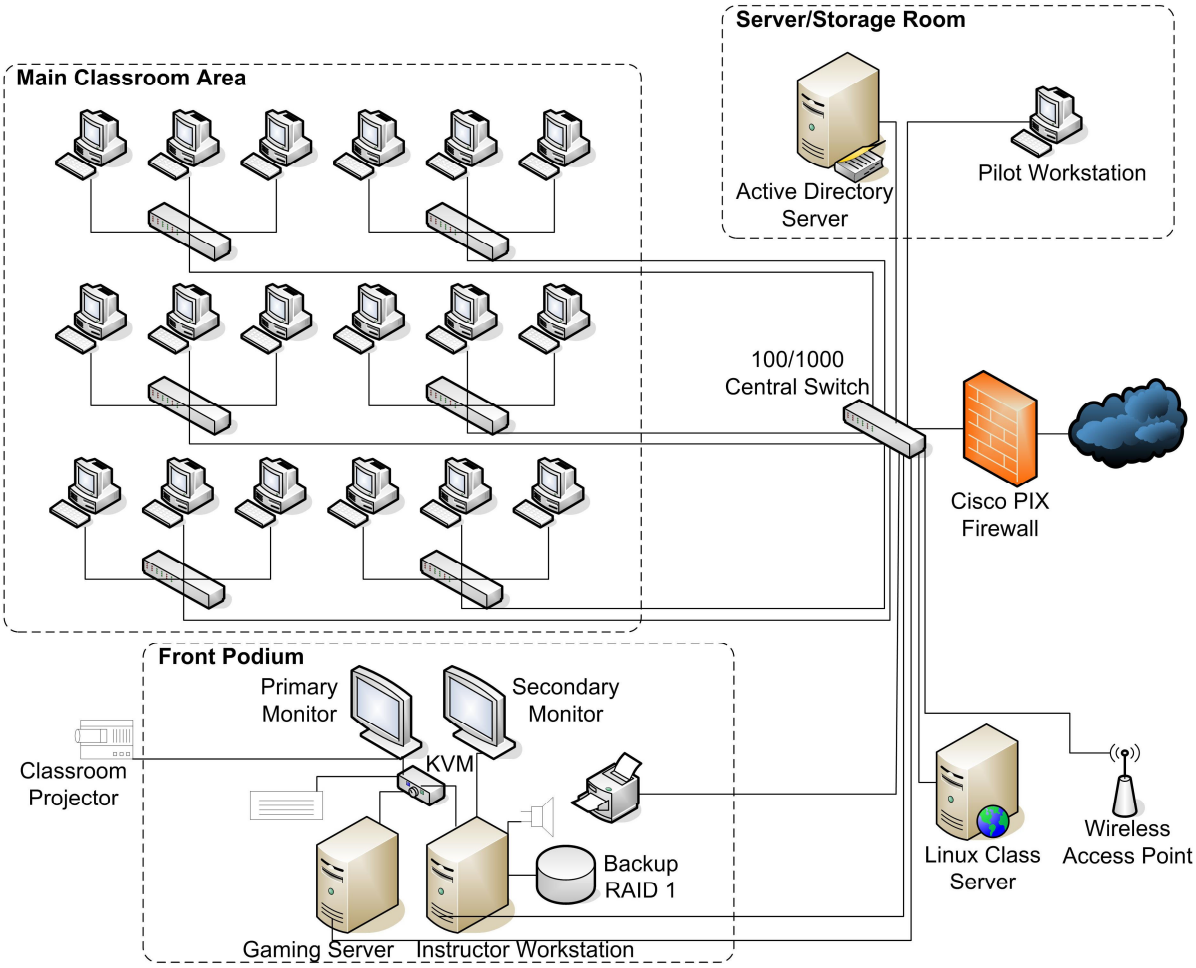

Figure 1. Hardware Architecture for the Flexible CIS Lab

In order to support the Virtual Machines, each workstation has 4 GB of RAM, and the Windows Server 2003 Server has 4 GB. This has proven to be the most important hardware requirement.

Since ACM game night also occurs in this lab, the workstations have upgraded graphics cards, but they are not upgraded as often as the students would like.

The Instructor Workstation has several partitions and shared folders over an internal hard disk drive (HDD) and an external redundant array of independent drives (RAID) including:

- System/Boot partition for Windows XP
- 'Class Materials' share for students to get files required for their classes
- 'Admin Files' administrative share with utilities
- 'Temp Storage' for students to use for uploading materials

- Backups

The workstations have the following partitions:

- Main lab Windows XP partition (50 GB)
- Virtual Machines (VM) partition with all the virtual hard drives (80 GB)
- Computer Forensics bootable Windows XP partition (40 GB)
- ACM Gaming bootable Windows XP partition (not accessible from other OSs, 100 GB)
- Student Backup partition for backing up their custom virtual machines. This must be located on a different physical HDD than the VM partition in case of failure. (35 GB)

The Windows Server 2003 server has:

- Windows System/Boot partition
- RAID 5 with backup storage of all VMs and Ghost images of workstation partitions
- Preboot eXecution Environment (PXE) for network booting of workstations

Software

The workstations and instructor currently run Windows XP. Windows Vista was overly resource-heavy and we chose not to upgrade, instead we are waiting for Windows 7.

Our CIS program has an MSDN subscription, which provides all of our OSs and more at an annual cost of $320 after the first year (http://msdn.microsoft.com/en-us/academic/bb250623.aspx). Our MS Office, Antivirus, and Ghost software is provided through our university licensing at no direct cost to us.

Table 1 lists the courses supported in the lab with specialized software and virtual machines (VMs) configured for each course.

Table 1. Software Environment

Supported Course:	Software Installed:
PC Architecture - CIS 185	Students create a new VM and install Windows 7 Preinstalled Windows XP, Vista, and/or Windows 7 for lab practice
Network Concepts – CIS 289	Preinstalled Windows XP, Vista, or Windows 7 for setting up peer-to-peer and client/server networks Organizational Unit on AD server for user and group creation (see Figure 2)
Intro to Web Development – CIS 311	Port forwarding through firewall allowing student access to Professor's own server for HTTP, FTP, and SSH

Linux – CIS 315	Empty VM for Linux installation and configuration Preinstalled and preconfigured Linux VM on Instructor Workstation for use during class
IT Security – CIS 360	Four preinstalled VMs: Windows XP (client) Windows Server 2003 (server) Two Linux (one for client and one for server)
Network Systems Administration – CIS 401	Empty VM for Windows Server 2003 installation and configuration (or per textbook instructions) VM on Server running the Forest Root server for this class
Linux Network Administration – CIS 402	Empty VM for Linux server installation and configuration Preinstalled Linux VM for client
Computer Forensics – CIS 462	Separate bootable partition with miscellaneous forensics software including EnCase (per textbook)
Routing and Wireless Networks – CIS 491	Cisco router simulation software (http://www.routersim.com/) ($179 per license, but bulk discounts are available)
Robotics with LEGO Mindstorms – CIS 491	Mindstorms software
General Lab Software	Office 2007 Internet Explorer, Firefox, and Chrome browsers Anti-virus software Norton Ghost with PXE server on Server 2003 server AB Tutor Control (Classroom Management Software - http://www.abconsulting.com/html/Tutor_Control.html) ($312) Student Response Network (Virtual clicker software - http://studentresponsenetwork.com/) ($125) Stu's QuizBoxes on Instructor Workstation (Jeopardy game software http://quizboxes.com/) Adobe Reader Certification Practice Questions (varies with budget) ISOs of installation CDs for XP, Vista, Win7, Linux

The Windows Server 2003 server has the following roles and responsibilities:

- Domain Controller
- DHCP Server
- DNS Server (redirects Internet requests through OpenDNS Basic - http://www.opendns.com/)
- Print Server
- GhostCast Server
- VM Forest Root Server for CIS 401

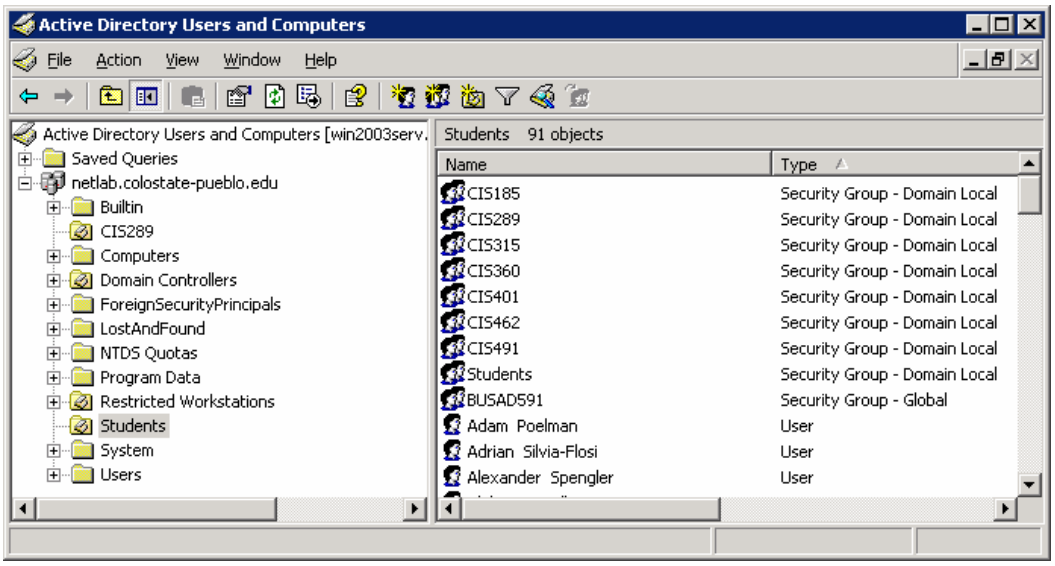

Figure 2. Windows snapshot of Active Directory User and Computers

In our Active Directory (AD) structure shown in Figure 2, notice the CIS 289 Organizational Unit (OU) and the Students OU with groups for each class. At the beginning of each semester, classlists output from the institutional database are used to edit a batch file for the creation of all student accounts and add them to the appropriate groups.

Currently our students use a terminal server administered by ITS for their programming courses. We are looking at moving some of these into our lab as well by installing Virtual Studio and a Java compiler. However, this would limit the times students could work on labs since they can access the lab only during regular work hours when no other classes are scheduled.

Norton Ghost paired with a pilot workstation and a PXE server for booting workstations directly into Ghost over the network allows reasonably quick workstation reconfiguration. After the pilot workstation is configured as desired, an image is taken and saved to the server's RAID, the 24 workstations are booted to Ghost, and finally GhostCast is used to reimage all the workstations simultaneously.

Implementation Results

We tried to use VMWare instead of VirtualPC, but due to errors with some labs that couldn't be corrected we switched back to VirtualPC. However, the current version that works on XP does not allow VMs to access USB drives, so students have a more difficult time saving their results. We have begun to look at VirtualBox (http://www.virtualbox.org/) as another alternative for some or all of the VMs in the lab.

One semester, we switched a class, CIS 360, over to web-based labs available from the textbook publisher. Although students appreciated the ability to do the labs outside of class on their own time from campus or from home, and the professor appreciated the grading features, the labs proved to be too slow and susceptible to time-outs with the students unable to access the labs later to experiment. Students decided that even with the problems with the in-house lab, this lab was preferable to the online alternatives.

The ability to run several courses each semester in the multi-purpose lab has been invaluable. Students crave the labs and often ask why we do not provide more hands-on experience in the classes. However, students are intolerant of downtime and tend to be harsh if a lab does not go perfectly smoothly often punishing the faculty member in charge during student evaluations. The lab environment development can take 10 hours/week, depending on the quality of student help available. It also requires constant upkeep. Finally, upgrades are major undertakings that must be completed during breaks.

Student and Faculty Performance Results

Student evaluations administered by the University often indicate students' satisfaction with the presented CIS lab environment. Student comments like:
"Hands on and additional research outside of the book helped to reinforce the concepts of the class,"
"The labs helped to solidify the concepts presented in class,"
"I liked the labs. It made what we were learning make sense. Having hands-on experience and a visual were very helpful,"
"The hands on labs were great!" and
"Use now at work," are often present in student evaluations. In addition, students' desire for more labs, and sometimes student frustrations when labs do not go as smoothly as expected are also present.

Faculty are satisfied with the laboratory. The ability to modify at will, add software without having to wait a month for ITS, and get inside the computers is extremely helpful in content delivery and timely hands-on experiences. Laboratory courses described in Table 1 are successfully offered. Student pass rates on standardized certification examinations are also good.

There are also financial benefits to this approach. Hardware costs are reasonable since we can shop around for the best value unconstrained by the ITS limitation. The space savings are considerable. Instead of one lab with some accompanying storage space, at least four separate lab rooms would have been required.

Cost Analysis

Where available, costs are listed alongside the lab item for both hardware and software. Since some software is available through our University licensing, we are able to keep costs down significantly. A lab similar to ours can be put together for about $28,000 with a recurring annual cost of $320 for the MSDN subscription. Not included in this amount are the optional physical switches, routers, and other equipment used by any routing classes, since the simulation software alone may be enough for smaller programs. The largest price variability will be seen in purchasing the firewall, as University guidelines will determine what must be used.

Conclusions & Future Plans

A flexible CIS laboratory environment employing multi-boot and virtual computing is described in sufficient detail for implementation. An almost entire CIS laboratory curriculum can be supported by such an environment. Major benefits are: flexibility, space savings, equipment cost savings, and an increase in student learning through practical experiences in a familiar laboratory learning environment. However, our experience shows that such integral laboratory environments might be prone to malware, thus needing the best anti-malware software available. In addition, lab development requires considerable faculty time. While faculty and students appreciate such an environment, some students may be frustrated by minor lab difficulties.

Future developments for the described laboratory environment include: upgrading the main partition to Windows 7, replacing Virtual PC with VirtualBox to get better performance for Linux or all VMs, incorporating Student Response Network in other classrooms without workstations by utilizing iPod touches and iPhones as an alternative to traditional clickers, installing a new gateway with integrated anti-virus and remote access (http://www.untangle.com/), and updating the firewall (PIX is no longer supported).

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