

# Developing a Reconfigurable Network Lab

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## ABSTRACT

Providing adequate hands-on experience of a network is a major component of an Information Technology program. Course requirements, limited budgets, time intensive classroom setup, reconfiguration, and rapidly changing computing technology poses several challenges for most academic institutions. This paper examines designing a reconfigurable network lab to support multiple network courses. Our lab requires the use of equipment with various configurations while minimizing transition time between class periods for different course requirements or student projects.

The multipurpose lab can be utilized for hands-on student learning, simple instructor demonstrations, demonstrations of multi-tiered networks with real time analysis, and site-to-site intercollegiate network-based competitions. In the future, our lab will provide students visual real time feedback similar to a network operations center (NOC); exposing the impact of their efforts in administrating and configuring their network design.

This paper discusses strengths and weaknesses of the design and covers in detail the configuration of the classroom lab. Beneficial goals are to integrate software visualization tools, such as "Nagios" (a network monitoring tool) and virtual machines (for ease of operating system changes). The lab creates a multifunctional network classroom to facilitate education of cross discipline classes as well as focusing students with a deeper understanding of network science concepts. Our students will be able to apply their knowledge learned in the classroom during academic internships with industry. A more flexible lab means lower overall cost because of lab reuse and the ability to meet future needs.

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## Categories and Subject Descriptors

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Design, Standardization

## Keywords

Information Technology Education, Lab Design

## 1. INTRODUCTION

Rapidly changing computing technology poses several challenges for most academic institutions trying to remain current in their discipline while providing an adequate hands-on network learning environment. New efficient methods are required to continue an adequate network science education through hands-on based labs. Most institutions realize the value of a reconfigurable classroom because it minimizes the setup time of equipment, quality of teaching in the classroom and assists in the professional growth of faculty members through independent study.

Designing a lab that provides students with various hands-on experiences vary based on cost, personnel, space, and course requirements. There are labs that focus on hardware experiences or use a combination of hardware with simulated hardware [1, 2], but this solution does not address sharing of a laboratory with various courses. Virtual machine software is a recent approach to sharing laboratory space with multiple courses with limited interference [3,4,5].

Our design focuses on supporting multi-disciplined courses and minimizing the setup time of the equipment by mounting all the networking and computing hardware in racks co-located in the classroom. The physical movement of network equipment is decreased and flexibility is improved because all of the equipment is in close proximity to each other. Faculty members must strive to stay abreast of new instructional methods and technologies that affect the pedagogical situation. A rapidly reconfigurable lab with help our faculty meet future teaching needs.

## 2. LAB ENVIRONMENT

The network lab within the Network Science Center at the U.S. Military Academy is utilized by multi-disciplined courses (CS484-Computer Networks, IT382-Networked Systems

Management, and independent study for Cisco Certified Network Associate (CCNA) / Microsoft Certified Systems Engineer (MCSE) certifications). This equates two 51 one hour lab sessions in conjunction with additional 109 hours of lecture, and 24/7 access to the students with cipher lock access. The classroom lab is also used to support student preparation for our annual inter-collegiate Cyber Defense Exercise.

The classroom is designed to accommodate 18 students and is broken up into six rows with three students each (figure 1). Each student desk has a patch panel connected to the master patch panel in the rear of the room. Each student is provided a Keyboard, Video, and Mouse (KVM) switch connected to a desktop computer for accessing the academy network for supporting material and rack mounted computer in the rear of the room. The KVM switch addresses the issue of providing Internet access while protecting the campus network [6].



Figure 1. Lab Configuration

VMware workstation was chosen as our virtual machine client for several reasons, the main reason being the ability to take snapshots of the current state of the machine. This allows the students and instructors the flexibility to save different states of the machine and continue at will without discarding student’s work, which facilitates the building block concept of the courses. Running multiple virtual machines on the same physical box attached to separate physical network cards, (see figure 2) reduces the number of systems required for a network design. “The lab machines are never compromised and are always available for the next class” [7].

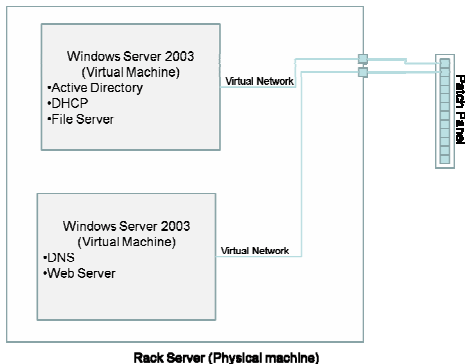


Figure 2. Computer Configuration

The overhead in time saved by utilizing these techniques is approximately 1/4 of the time of using Ghosting techniques. In addition, with the students integrated as part of the lab setup, resetting the lab can be completed in about 5 minutes. Integrating students into the lab configuration is beneficial to both the instructor in eliminating the two hours of pre/post class setup, but also gives the students hands-on experience in backing up and restoring network configurations.[8] Only one copy of the operating system ever has to be installed from scratch, because the Virtual Machine (VM) can be copied to create a new instance of the operating system.

Additionally, the ability to restore to a previous configuration via the VMware revert command enables students to quickly recover from failures [7].

The backbone of the network is comprised of Cisco 2621XM routers and 2950 – 24 and 2950-12 series switches. These are all interconnected with a series of patch panels giving the instructor flexibility in configuring various lab scenarios. The benefits of selecting these devices include the ability to implement Virtual Local Area Networks (VLAN) including trunking and dot1.q encapsulations which allows for a scalable network while minimizing network interfaces, but also enables CCNA practice labs. These devices also have module bays which can be supplemented with serial devices or other Ethernet modules to expand the capability and flexibility of the equipment.

### 3. COURSE OVERVIEW

While the network lab will be utilized by several multidisciplinary courses, we will focus on the Network Systems Management course. The main purpose of this course is to provide students hands on experience implementing network theory while examining security concerns at key areas of the network. The course is comprised of 40 hours per semester with almost half dedicated to hands on labs. Each lab is a building block for follow-on labs which culminate in a final hands-on network project. The course is comprised of the following sections:

#### Lab Series #0:

This series examines the IPV4 network space and introduces the Open Systems Interconnection (OSI) and Transmission Control Protocol (TCP) models. We cover both classful and classless network addressing. Variable Length Subnet Masking (VLSM) concepts show conservation of network space while demonstrating collision and broadcast domains. While we currently implement the IPV4 addressing, the equipment has the ability to implement the IPV6 addressing and we give an introduction to future capabilities of IPV6.

#### Lab Series #1:

Switching concepts include VLAN creation and management (figure 3). Securing the switch with complex passwords and discussing security concerns with telnet is demonstrated using Wireshark. Analyzing the physical addressing of the network is showing the flow of the TCP model is examined and discussed. They will implement trunking between switches with appropriate encapsulation and analyze traffic within the various VLANs. Students will be able to examine the benefits of separating the different collision domains.

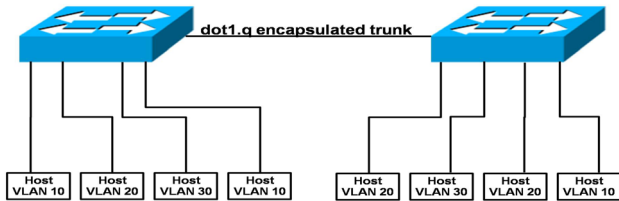


Figure 3. VLAN Lab

Lab Series #2:

This series covers routing concepts to include Open Shortest Path First (OSPF) and Routing Information Protocol (RIP) while integrating knowledge VLANs and implementing inter-VLAN routing. The metrics used by the different routing method are demonstrated when examining various network designs. Students will test redundant loops looking for broadcast storms and compare and contrasts the various routing methods.

Lab Series #3

Network management is demonstrated by illustrating network visualization software such as Nagios, INAV(see figure 4), and What's up Gold. Quality of service and IP convergence highlights challenges that network administrators will face as more capabilities are merged on to the network. We also introduce Access Control Lists (ACL) to control access to our network. Students will demonstrate their ability to manage their network through both limiting access to their network, and through controlling devices remotely.

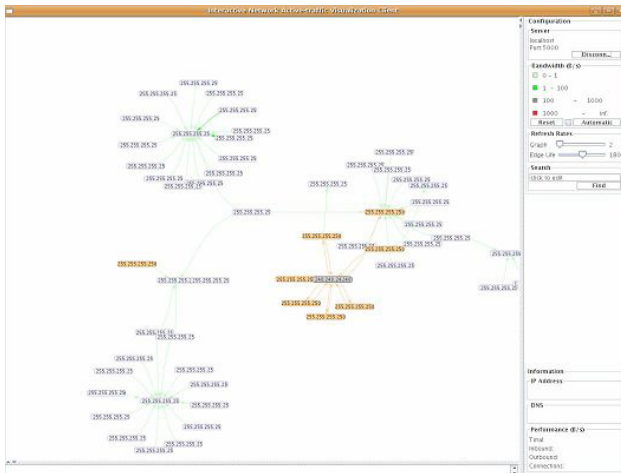


Figure 4. INAV Visualization [9]

Lab Series #4

Deploying the Windows domain demonstrates the implementation of Active Directory, Dynamic Host Configuration Protocol (DHCP), and Domain Name System (DNS) principles. Students will continue to use the network they have built to test the implementation of the domain for security, authentication, and authorization. They will use zone forwarding to examine the functionality of DNS. Finally they will create multiple DHCP pools to facilitate the VLANs they have created. Students will

build from their previous lab experience and now demonstrate how they can limit access from hosts on different VLANs.

Lab Series #5

The complete network integration will test their ability to stand up and secure a network from scratch using the principles given in lecture and lab. They will utilize multiple switches, routers, servers, and clients to demonstrate their understanding of network management. (See figure 5). This configuration allows for scalability of the individual labs and facilitates the implementation of all presented lecture material. Each team of students, normally three, can be given different routing protocols, such as OSPF or RIP Version 2 to configure as well as tasked to design multiple VLANs for security and minimizing broadcast domains. Students must demonstrate their ability to secure their network design by monitoring the visualization tools and creating ACL's to limit access to key network areas.

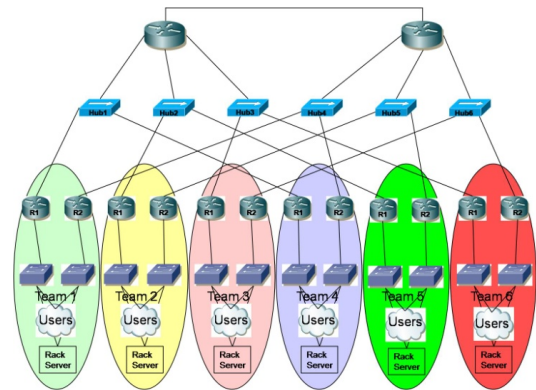


Figure 5. Example Network Topology

## 4. LAB INTEGRATION IMPACTS

There are numerous benefits from implementing a multi-disciplined lab:

- Eliminate manual, repetitive, and error-prone tasks
- Easy of integration with other existing applications / tools
- Pre-defined selection of virtual machines allows administrators to maintain control over the IT environment and minimize lab maintenance
- A lab utilized exclusively by CS/IT/EE students is a valuable recruiting tool.

Challenges to implementing this type of lab means allocating time to teach unfamiliar applications to students, how to properly integrate virtual machines, the use of network visualization tools and patching techniques.

## 5. CONCLUSIONS

Given all of these components, students can implement network designs as simple as setting up a single host to check connectivity to the router, or install a complete domain with multiple clients, while being able to visually see outages and general connectivity status.

The time saved in setup and tear down for resetting the room for the next class is reduced to ¼ of the time of previous setup / and tear down time. Integrating the students into the resetting of the class reinforces testing and integrating new configurations that are real world experiences, for example, the numerous patches to operating systems and network configuration changes that occur as their operational structure changes.

## 6. FUTURE APPLICATIONS

Although not integrated at the time of this paper, integrating a wider variety of Cisco internetworking hardware will allow a broader range of topics to be covered and the breadth of problems students can study. The capabilities of this reconfigurable lab facilitate faculty and student research in network science without impeding on current academic course requirements. This can also be expanded into the area of robotics research where the network can be configured to support homogeneous or heterogeneous robotic communication.

In terms of our pedagogical needs, the network lab should become the focal point for our students in the IT program because it provides them a usable environment in which they are eager to work. Last year our program had its first graduates and the lab should continue to attract more students due to various research and certification opportunities for both our faculty and students.

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