Building a Sustainable ICT Remote Access Lab through Student Lab-Worker Projects

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Abstract

This paper details the experiences of a paid undergraduate student lab-worker project that involved building, troubleshooting, and maintaining a quarter million-dollar network infrastructure used to deliver remotely accessible information and computer technology (ICT) labs. The infrastructure, known as the Academic Network Operations Center (ANOC), provides 24/7 remote-lab access to more than 500 students in 20 graduate and undergraduate courses annually. The assembly and ongoing maintenance of the ANOC by student lab-workers makes the project cost effective and also provides opportunities for the student lab-workers to apply their classroom knowledge and skills to meaningful work experience within the College. Using a case study approach, this paper provides details on the processes, procedures, and policies implemented at the department and college level to make these types of student managed remote labs a viable alternative for higher education institutions.

Keywords

Undergraduate laboratories, undergraduate projects, experiential learning, remote lab, technology management

Introduction

Higher level education and professional certifications are critical to career success within the ICT profession. After completing their degree and earning certifications, students are expected to apply their skills and knowledge immediately as they enter the post university work environment. Lab work allows students to apply classroom learning to practical implementation, and develop non-technical social and teamwork skills.[1, 2] However, meaningful hands-on experience is difficult for distance education (DE) students unable to participate in on-campus courses due to physical distance, disability, or professional reasons.[3, 4] When access to on-campus laboratories is not an option, remote-access labs provide students with a venue to develop practical skills employers expect of ICT graduates.

Developing, building, and sustaining the infrastructure to provide remote-access labs is extremely resource intensive beyond the initial cost of the equipment, requiring continuous maintenance, troubleshooting, and updating.[1] With shrinking university budgets, the financial and information technology (IT) staff resources required to develop and sustain a remote-access lab infrastructure are not always available. The case study approach for this paper describes the experience gained at East Carolina University, describing a student lab-worker project implemented to build and sustain a remote-access lab infrastructure to provide face-to-face and DE students a high quality, hands-on lab experience. The benefits of the project were twofold: 1) IT staff resources and financial costs are reduced as student workers carry much of the daily laboratory workload of maintaining the infrastructure, and 2) student lab-workers obtain real world, hands-on experience that goes beyond the typical structured course laboratory assignments.

The remainder of the paper is organized as follows: first, details of the ANOC design, funding, and implementation are discussed, second, details on student-worker staffing and supervision are provided to support sustainability of the virtual lab are discussed. The paper finishes with a summary and avenues for future work.

ANOC Design and Implementation

The ANOC is a complex remote access ICT lab environment that consists of more than 120 network infrastructure devices and a virtual machine environment that supports 10 undergraduate and graduate ICT courses. As many as 500 students each year rely on the ANOC to complete more than 120 hands-on labs via 24/7 access from anywhere in the world with Internet access.

Laboratory design

At the heart of the ANOC are two NDG Netlab+ network appliances that provide web-based lab access and equipment administration and management.[5] Network devices such as routers, switches, firewalls, and virtual machines are logically grouped and physically interconnected into equipment pods as shown in Figure 1. Pods may be reserved and accessed as a single resource by students to perform labs. The exact devices and interconnections within a pod can be customized to suit the needs of individual courses.

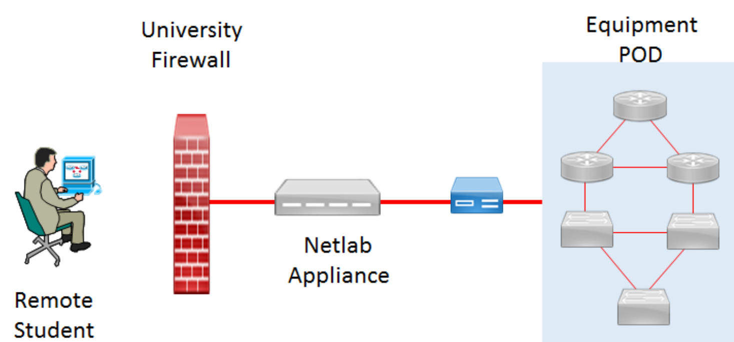

Figure 1. Conceptual Virtual Lab Infrastructure

The design and setup stage of the project required the students to review the lab materials for each of the 10 courses supported by the ANOC. The students worked in close coordination with faculty to design each pod to ensure it met all requirements for each course lab assignment. Capacity considerations required enough copies of each pod to support the number of students in any given course; thee pods per 24 students in a lab course was used. For some courses, stock pod designs implemented in the Netlab+ appliance were used. Other courses required custom pod designs to meet specific lab configurations.

After pod designs were complete, the student lab-workers developed a list of equipment already on-hand and a list of new equipment required to build enough copies of each pod. Once the new equipment list was complete, the student lab-workers presented the purchase recommendations to the faculty for drafting a purchase request. Table 1 shows the complete component inventory required for the control and data plane.

Table 1. ANOC Hardware Inventory

Control Plane							
Access Servers	**Qty**	**Control Switches**	**Qty**	**ASA Firewalls**	**Qty**	**PDUs**	**Qty**
Cisco 2911 ISR	6	Cisco Catalyst 2960	12	Cisco 5510	6	AP7900	8
Data Plane							
Routers	**Qty**	**Switches**	**Qty**				
Cisco 2911 ISR	12	Cisco Catalyst 3560	18				
Cisco 2811 ISR	13	Cisco Catalyst 2960	11				
Cisco 2801 ISR	10	Cisco Catalyst 2960x	15				
Cisco 2801 ISR	10	Cisco Catalyst 2960x	15				
Cisco 1941 ISR	6	Cisco Catalyst 2950	12				

Once all equipment arrived onsite, student lab-workers unboxed, inventoried, and then assembled the equipment into pods. The pod assembly process required physically installing the equipment into server racks, and running all cables for lab data and control planes. Once all physical layer connections were made, the pods were then configured logically within the Netlab appliance for device management and interfacing the VMware virtual environment. The hardware provided for a total of 20 equipment pods to be built. Figure 2 shows one row of assembled racks with pods in the ANOC.

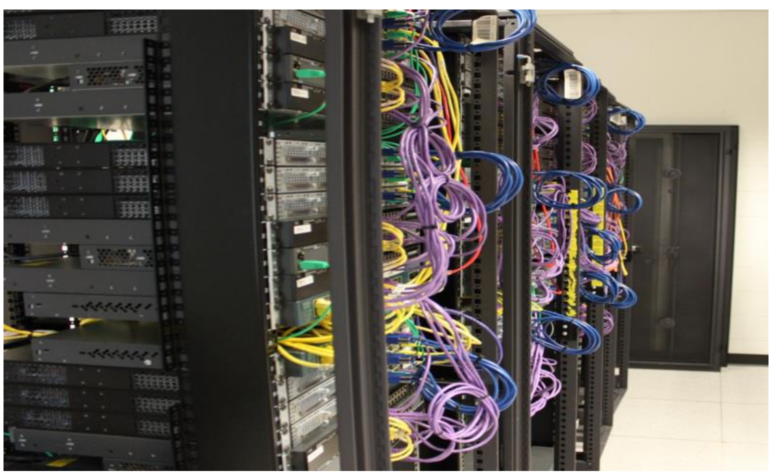

Figure 2. Pod Assembly Infrastructure

Laboratory Funding

Four main categories of funding support were needed for the ANOC project, two for the implementation project and two for lab sustainability. Implementation funds were required for the initial equipment purchase and student labor for equipment set-up and debugging. Ongoing funding support is then needed for annual license and housing expenses, along with anticipated equipment replacement for obsolete technology. Potential sources for financial support include lapsed salary budget dollars, university technology fees, historically present one-time, end of year budget surpluses, departmental budgets, and individual course fees.

For this project, the main source of implementation funds for capital equipment came from lapsed salary dollars and student technology fees. Lapsed dollars are money that is initially budgeted for faculty lines, but not spent because the position is not staffed. Student technology fees are collected from all university students and apportioned by the university based on individual department needs. One-time, end-of-year money is occasionally present, but this source cannot be relied upon and has a limited time frame for request submission. An alternative student funding support may be available from the federal work study program through the Office of Student Financial Aid. While the funding programs have their own specific application, eligibility, and selection processes, they have similar contract policies that define maximum number of hours the student can work, the scheduling of hours around student classes, hourly pay, submission of timesheets, and general ethical expectations.

For this case study, a departmental budget commitment made possible hiring as many as three part-time undergraduate student workers to work within the ANOC in a given semester. Student workers are paid at different grade levels depending on experience and their assigned role. New student workers with little experience, typically a sophomore, start at $8.00 an hour as an apprentice and learn on the job from upperclassmen with a pay range of $9.00 – 10.00 per hour. The most senior student worker is typically assigned the role of student supervisor, and is paid $12.50 an hour. Students are limited to a maximum of 20 hours per week.

ANOC Implementation Project

The ANOC project began in the summer term of 2015, and the remote access lab was required to be fully operational by the start of the 2016 fall semester. Initial assembly of the ANOC was the most resource intensive part of the project in terms of both student lab-worker hours and equipment expenditures. Three student lab-workers were hired to work 20 hours per week for both summer terms and the following fall semester. The scope of work and short timeline of the equipment assembly phase of the project meant that no entry-level student lab-worker was employed as there was no time available for on-the-job training.

Each of the 120 labs support by the ANOC needed to be tested, and any issues resolved prior to the beginning of the fall semester. The student lab-workers maintained a documentation log throughout the project for all corrective actions taken and the final logical and physical lab topologies for future reference. A documentation change revision process policy was also implemented.

Critical to the success of the implementation project was recruiting undergraduate students who were self-motivated, quick learning, and technically competent. The solution for the ANOC project was development of a competitive process that required applicants to participate in a formal application and interview process. In addition, a letter of recommendation was required from at least one full-time faculty. Minimum eligibility requirements for grade point average were set above those required by the Office of Student Financial Aid. All applicants were required to participate in a formal application and interview process.

ANOC sustainability

Sustaining the ANOC consists of ongoing maintenance, troubleshooting reported issues, updating software, adding new capabilities and equipment, documentation, and training new student lab-workers. This phase of the project is not as resource intensive as the initial development and building of the infrastructure, so fewer full-time student lab-workers are needed. During this phase two student lab-workers are employed, one senior student paid full-time as student lab-supervisor and an apprentice paid part-time at hours per week to receive on the job training. Having an entry level apprentice provides a means to hire students that receive on-the-job training from senior student lab-workers. This provides ready replacements when a senior student lab-worker leaves the project or graduates. Student lab-supervisors may also be assigned the same functions as the regular lab-worker, i.e. they do not just have an administrative role. The student position hierarchy is generally established based upon class ranking and credentials of the student, as shown in Table 2.

Table 2. ANOC Student Staffing Requirements

Student Lab Position	Qty	Min GPA	Standing	Certification(s)
Supervisor	1	3.2	Junior or Senior	CCNA or RHCT
Worker	2	3.0	Enrolled in 3000 level course	CCNA or RHCT
Apprentice	1	3.0	Enrolled in 2000 level course	

Summary and future work

Successful implementation and completion of the ANOC project has proven that a large scale remote access lab environment can be developed, maintained, and sustained through a well-organized student lab-worker project, saving significant financial and staffing resources. During implementation, students gained valuable technical and soft skills. Comments of the student lab-workers attest to the value of participating on the project:

"Experience was gained many times solving compatibility issues between Netlab and some of the newer Cisco switches. When these compatibility issues arose, it was the student-worker's responsibilities to find solutions and solve the problem, using whatever resources necessary." ICT undergraduate student lab- worker.

"This project enabled development of problem solving skills by applying the knowledge attained in classes and exhausting that knowledge, searching online and through forums, working through issues, and accurately diagnosing problems." ICT undergraduate student lab-worker.

After successful implementation, student-workers in the ANOC continue to gain trouble-shooting and problem solving experience. Each semester, new student lab-workers are hired onto the project to continue it forward to provide both sustainability and scalability of the remote-access lab infrastructure.

The proven success of the ANOC project building a sustainable ICT remote-access lab has led to a planned expansion of the project to include remote access labs for our College's Industrial Engineering Technology program (IET). In this next phase of the project, student lab-workers from the IET program will assist the ICT student lab-workers to add industrial network devices and industrial process automation and control machinery.

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John Pickard is an assistant professor at East Carolina University and teaches information and computer technology and network management in the College of Engineering and Technology. He holds a PhD in Technology Management from Indiana State University and an MBA in Business Management from Wayland Baptist University. His current industry recognized certifications include: Certified Cisco Network Professional, EMC Information Storage and Management, IPv6 Forum Certified Engineer (Gold), IPv6 Forum Certified Trainer (Gold). His research interests include; distance learning, Industrial Internet of Things, Internet protocols, and distributed network monitoring.

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