UTILIZING OPEN-SOURCE TOOLS IN THE NETWORKING LABORATORY

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Abstract

Hands-on engineering applications bring real world experiences to students as well as reinforce the basic concepts. Computer networking is a challenging yet fun subject to teach as well as to learn. Primary reasons for this include its conceptual complexity and ever-changing technical jargon. Mastering its fundamental concepts from textbooks alone is difficult for students, particularly in introductory classes. Practical laboratory exercises provide students with opportunities to apply what they have learned into real-world settings. This helps underscore important concepts and aids in fortifying concept applicability in various settings leading to more active and more participative learning experiences. In this paper we show the evolving set of networking laboratory exercises using open-source software packages. Open source is affordable, real-world, evolutionary, and made for networking. It is also shown that these exercises will be competency-based and mapped to ABET 2000 a-k criteria.

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1. INTRODUCTION

The goal of this paper is to show the evolving development of a set of competency-based laboratory exercises using various open-source network software packages to enhance learning by students enrolled in computer networking classes. These exercises will provide students the hands-on experience they need to better understand networking concepts using live data from the Internet, while also complementing existing laboratory set-ups. Even though free networking software is readily available, it is not typically incorporated into undergraduate computer engineering/technology or computer science teaching curricula as comprehensively as one would like [1-4]. Networking courses typically focus on theory, simulation and hardware applications, or some combinations of these to impart knowledge. However, Internet-available freeware, typically used by networking professionals, can be used as a valuable resource to supplant the use of theory, simulation and/or hardware applications in developing, and teaching through, an integrated networking curricula. The purpose in this approach is to do just that; that is, to create a learning environment that inspires active learning through the use of real and live networking concepts through the use of freeware available on the Internet as part of integrated networking curricula. This goal was accomplished by creating laboratory exercises that will parallel networking and data communications topics in light of Bloom's taxonomy on learning styles and the ABET 2000 a-k criteria [5-6].

There are potential limitations of using freeware programs (e.g., lack of support, potential changes in the source software, potential changes in operating systems or

network protocols, etc). The goal, however, is to develop freeware-based exercises that can overcome these limitations, for instance, those that are sufficiently generic and can be used independently of a particular networking platform (e.g. Windows or Linux-based). These exercises are designed utilizing progressive layers of problem complexities and corresponding learning competencies such that students will be able to chart their own pathways to learning starting with retrieval from memory and progressing through connecting prior knowledge to new learning, applying new learning to problem solutions, and then analysis and evaluation of complex networking problems. This approach is also designed to foster creativity in students through Internet searches to find the most appropriate freeware program(s) to complete a given exercise, to compare programs against one another along various criteria (speed, cost, ease of installation and use, etc.) and to develop insights into needed program capabilities in solving a particular networking problem. Finally, all of the products (and byproducts) of the work is posted on the web to help disseminate these experience in developing and teaching through networking freeware.

Freeware is already in use in various commercial networking environments in serving various needs, for example, in monitoring and troubleshooting a network, providing toolkits of programs to use when problems arise, and so on. However, there is a need in engineering programs to use freeware in creative and meaningful ways in networking curricula.

The following are the goals of the ongoing evolutionary computer networking laboratory website organized by Lawrence Technological University and Wayne State University:

(1) Infuse Internet-based free-ware networking exercises into existing networking curricula. A major goal of the project is to develop competency-based freeware exercises for educators and students, such as open source networking software downloaded from the Internet that will inspire active learning environments in the teaching of networking curricula. These exercises will be used as supplements to teaching with hands-on live data and will be sufficiently generic that students will be able to use them under many operating platforms. When used in conjunction with the accompanying vignettes and lecture notes in the website, they will enhance experiential learning, and do so comprehensively. To make this effort challenging and theory-based, learning objectives were generated for each exercise based on Bloom's Taxonomy and ABET 2000 a-k Criteria. Specifically, the following have been addressed: (a) define the criteria with which to measure outcome achievements, (b) design assessment tools, (c) apply these tools to the outcomes, and (d) demonstrate that outcomes are achieved.

(2) Develop topical vignettes and lecture notes to accompany each exercise along with a website. The reality-anchored, learner-based situational vignettes to accompany the exercises have been generated to give the student the opportunity to construct her own interpretation of the merits of the freeware programs she will be using, nearly custom-tailoring learning to the individual student. Used in conjunction with the lecture notes and exercise instructions we will place on the website, these vignettes will inspire critical thinking and help formalize student learning. In addition, challenging exercise extensions from the vignettes to motivate students into higher levels of learning.

(3) Foster the creation of new on-line courses in the computer networking area. Many faculty who prefer to offer on-line courses find it difficult to do so for those courses that have laboratory components that meet at laboratories on campus. Since the Project is based on the use of competency-based exercises downloaded from the internet, it will help eliminate the need for on-site meetings on campus, easing completion of exercises at the student's leisure, and their dissemination at anytime, from anywhere in the world.

DETAILED PROJECT DEVELOPMENT

Computer networking is a fast-changing field and instructors can struggle to stay on top of the material, as well as making it relevant and interesting for students. Mastering its fundamental concepts from textbooks alone is difficult for students, and a primary goal is active or participative learning. This will underscore important concepts and aids in fortifying concept applicability in various settings leading to more active and more participative learning experiences [10-13].

Completed surveys indicate that many educators use network simulators in their networking curricula to help students master concepts. Simulators such as OPNET or Predictor can be invaluable tools in achieving this purpose as they are frameworks novice students can use in designing a proposed network, planning for future growth, testing the viability of proposed changes to a network, performing what-if analyses around the reliability of key components in a network, and investigating the possible effects of losing a component from a network [14,15]. An important limitation of these simulators, however, is that they do not allow opportunities for hands-on work with live

networks. An alternative approach is the use of hardware laboratories equipped with devices such as routers, switches, modems, wireless technologies and the like that provide actual hands-on network training. A weakness of this approach, however, is that a well-equipped networking laboratory is expensive to establish and maintain. The third model used is teaching through theory only. While this approach allows for extensive discussion of concepts in the classroom, it does not involve hands-on experimentation, a key ingredient in fortifying student learning. In the final model, both hardware and simulation packages are used simultaneously. While this approach provides the benefits associated with the use of hardware and simulation packages discussed earlier, it also suffers from the same hardware cost weaknesses.

Developed Computer Networking Laboratory Assignments

1. **Linux Operating Systems**
   In this laboratory exercise, students are asked to download and create boot disks for different versions of the Linux operating systems. Connection to the Internet through Linux is the major criteria, although other features and criteria are applicable. If possible, students will also find a version small enough to fit on a floppy disk or CD.

2. **Live Packet Capture and Decoding**
   In this laboratory exercise, students are asked to download open-source protocol analyzer programs from the Internet. This exercise will capture live packets on the network and students will decode all the fields for different protocols.

3. **IP Addressing and Subnetting**
   In this laboratory exercise, students are asked to download different open-source IP address and subnet calculation programs from the Internet. They will be given IP addressing and subnetting exercises to be done by hand first, then verified using the programs downloaded.

4. **Ping, Ipconfig and Traceroute Analysis programs**
   In this laboratory exercise, students will be asked to utilize the DOS, Windows, and Linux based ping, ipconfig and traceroute programs for network analysis. They will be asked to download several of each variety of programs. Students will compare the different flavors of these programs.

5. **Cyclic Redundancy Code (CRC) Lab**
   The CRC technique is one of the most used techniques for error detection in data communications. Using this technique, the transmitter circuit appends an extra n-bit sequence to every frame called Frame Check Sequence (FCS). The FCS holds redundant information that helps the receiver circuit to detect errors in the frame. In this laboratory exercise, students download an open-source cyclic redundancy calculator programs from the Internet.

6. **Winhexcom**
   In this laboratory exercise, students are asked to use a dual channel hexadecimal, ASCII, and ANSI protocol analyzer for RS232, RS422, or RS485 full- or half-duplex synchronous and asynchronous protocols. Students are asked to debug protocols using many ports.

7. **Encryption/Decryption of Messages Over Live Networks**
   In this laboratory exercise, students utilize the RSA algorithm to generate their own private and public keys. They share the public key with their lab partners. Then, they encrypt a message in binary number format at send it to their partners. The partners will then decrypt the message using the keys. Each member of the group encrypts and decrypts the message using the algorithm.

8. **Network Security**
   In this laboratory exercise, students download security programs [other than firewalls] for network security. These programs include spyware removal programs, automatic encryption programs, and anti-virus programs. They make a spreadsheet that compares these programs on the basis of efficiency, cost, behavior, and ease of use.

9. **Statistical Email Filtering**
   In this laboratory exercise, students install and evaluate Bayesian-probability based email filter systems. They compare the email filters based on criteria: effectiveness based on probability detection, ease of use, cost, and GUI. Bayes' established probability theory is directly applicable to email sorting and text classification. They attempt to break the filters in order to find out how the probability systems work.

10. **Remote PC Access**
    In this laboratory exercise, students download and install various remote PC access programs. They evaluate the programs base on program installation and features, and demonstrate its use through: telephone cable, Ethernet straight, Ethernet crossover, and/or RS232. The programs will have different operating system bases.

SAMPLE DETAILED LABORATORY EXERCISE

"Live Packet Capture and Decoding"

Laboratory Example: In the "Live Packet Capture and Decoding" laboratory exercise, students are asked to work in groups of two, each student working at a separate computer. Each student is first asked to find the IP address and exchange the IP address information with his/her partner. Then they are asked to download an open-source packet capture program (such as ethereal) into their respective computers [16]. They then start the live capture and send "ping" commands to each other, before stopping the program. Even in this short amount of time, the capture program collects large amount of data from the network. The students are then asked to scan this information, and find the ping command they sent to each other by locating the "Sender's IP Address" and the "Receiver's IP Address". Once they find the particular ping command they sent, they are asked to decode the command, identify all the fields in the packet, such as start of frame delimiter, destination and source address, field length, data field, frame check sequence, and so on. A valuable byproduct of this exercise the excitement students feel by experiencing the interplay between seeing the "live" packet that they send, and learning about all the fields which are explained in the lecture. Another exciting byproduct is the fact that because each group is encouraged to use a different packet capture program, they get to compare their findings; for instance, they see that some programs are easier to use than others, or give more useful information when compared to others.

Dr. Ece Yaprak, is an Associate Professor of Engineering Technology at WSU. Her academic interests are in digital design and computer networking. Her research has led to seven NASA and one U.S. NAVY faculty fellowships and three NASA grants. Her professional experience at General Electric, the Ford Motor Company, and several NASA Laboratories and the US Navy SPAWAR Center help her blend real world experience into her teaching. She has won two teaching awards in the College of Engineering. She has developed distance-learning classes. She has been serving on the Curriculum Committee of the NSF-funded Greenfield Coalition, and through that experience, has worked with the design and implementation of reality-based learning activities. She is responsible for curriculum development in the digital and networking curricula of her Division, and is an IEEE/TAC ABET program evaluator.

Dr. Lisa Anneberg, an Associate Professor of Engineering at LTU, has developed and teaches a computer networking course. She has been involved in curriculum development in the Computer Engineering area at LTU, and is an active member of LTU's assessment committee. She has been teaching in LTU's outreach programs such as DAPCEP, and the 2+2+2 Program for High School Engineering Preparation. She was awarded SAE [Society of Automotive Engineers] Teetor Award in 1996 for teaching excellence. She is also an IEEE/TAC ABET program evaluator.

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