On Using Simulators and a Hybrid Approach for an Internetworking Technology Course

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This paper presents an implementation of a hybrid course in advanced computer network focused on internetworking technologies. Professional networking equipment is expensive and setting up a big enough networking laboratory can be costly. To overcome this problem, the course makes use of online and offline computer networks simulators that help the students to practice the concepts and skills required to obtain a certification in this field, even when they are at home. We discuss the advantages of each simulator we used and the role they played in our hybrid approach. Using this approach, half of our students obtained a certification. We believe that this is a practical approach, which can be easily replicated or improved by other colleges with similar courses or interests.

I. Introduction

An internetwork is a set of individual networks connected by intermediate networking devices to function as a single one. Internetworking refers to the industry, the products, and procedures that meet the challenge of creating and administering internetworks. The most known example of internetworking is the Internet, which is a network composed of individual networks also known as autonomous systems (AS). Each AS is own and administrated by private entities or enterprises. The Internet consists of every AS or enterprise network around the world and billions of end user devices connected using Internet service providers (ISPs) [1].

Implementing a functional internetwork involves many challenges in the areas of connectivity, reliability, network management, and flexibility. Engineers, network administrators, and technicians that understand the technologies, standards, and equipment to keep enterprise network operations running are in high demand. Companies such as Cisco, Juniper, and TestOut provide professional certification in this field. A certification in this area is earned by a person that passes a practical certification exam. The certification assures an individual's qualification to perform tasks and fulfill a job at a certain level; there are different certification levels.

An entry-level position in this field requires working knowledge of routing, switching, network applications, protocols, and services. The best way to learn about networking topics is by hands-on experiences. Setting up a personal training lab would require at least a couple of professional switches and a couple of professional routers, mounting racks, cables, and computers. A school would need several of these personal training labs. Hands-on labs with real equipment are great; however, their experience would be limited to the number of devices in the lab. Moreover, to try different realistic scenarios the equipment have to be reset every time, and sometimes rewired (change the connections), which is tedious and would add extra time to the learning process.

Network simulators are an excellent alternative to real equipment training. Simulators are way cheaper than real hardware, and most of them come with predefined labs dealing with network topologies and scenarios that allow students to configure and troubleshoot situations that are very similar to problems that a technician could face in a real case [2]. Additionally, some simulators grade the labs and provide feedback, which helps students to learn from their mistakes. Simulators can speed up the learning process since students do not need to reset and reconnect equipment to try a new lab. Moreover, simulators save the physical space required by hardware and cables.

In this paper, we present the details of the implementation of a hybrid course in advanced computer networks focused on Cisco internetworking technologies. In our course, students make use two different simulators. The course is hybrid and meets once a week in the classroom and once a week online. Besides the advantages mentioned above, each simulator offers different features and functionality that is exploited to learn various elements of the curriculum. The paper discusses the benefits of the simulators we used and the role they played in the hybrid approach. We have obtained very encouraging results with this course model. During the Fall 2015 semester, 50% of our course students received a certification. These students took a certification exam that requires at least 1210 points on a scale from 250 to 1600 points. The class' average grade in this exam was 1150 points, which is higher than the average nationwide (1036 points). We believe that this is a practical approach that can be easily replicated and adapted by other colleges with similar courses or interests.

The rest of the paper is organized as follows. In Section II we describe the details of our course, including the course learning outcomes. Section III introduces the network simulators we use and discusses their main features and advantages they offer. Section IV discusses the hybrid aspect of the course. Section V discusses how the course has been assessed and the results. Section VI concludes and presents future work. Finally, Section VII shows the list of references cited here.

II. About the course

The interconnection of each autonomous system is based on different technologies and underlying hardware. For example, each enterprise network connects to at least one ISP using wide-area network (WAN) links, which are leased permanent connections. The ISPs around the world also connect to each other. Moreover, their unification is possible thanks to a standard internetworking protocol called Internet Protocol Suite, also referred as the TCP/IP stack. Thus, these interconnected networks, going from the smallest home network to the enterprise network with thousands of devices, are all connected to the global Internet.

This course covers the technologies, protocols, and techniques used to connect a computer network with other networks. The covered topics include local area networks (LAN) and wide area networks (WAN) implementation, wireless networks implementation, network security, switching and routing configuration, advanced TCP/IP configuration, and network management. In particular, this the course focus on the content required to obtain an entry level certification such as the CENT/ICND1, ICND2 or CCNA certification from Cisco [3] [4] and the Switching

Pro or Routing Pro from TestOut [5] [6]. These certifications validate a person's ability to install, configure, operate, and troubleshoot medium-size routed and switched networks, using Cisco products.

Course Learning Outcomes

Upon completing this course, the student will be able to:

- Describe how networks function, identifying major components, function of network components, and the OSI reference model
- Identify switched LAN technology solutions to Ethernet networking issues
- Describe the reasons for extending the reach of a LAN and the methods that can be used, with a focus on wireless access
- Describe the reasons for connecting networks with routers and how routed networks transmit data through networks using TCP/IP
- Describe the function of WANs, the major devices of WANs, and configure PPP encapsulation, static and dynamic routing, PAT, and RIP routing
- Use the command-line interface to discover neighbors on the network and manage the router start-up and configuration

III. The computer network simulators

When deciding about a simulator for practicing switching and routing, there are many options. Four our course we considered Cisco's Packet Tracer [7] [8], Person's Network Simulator [9], Boson's NetSim [10], RouterSim' Network Visualizer [11], and TestOut's LabSim Switching and Routing Pro [12]. All of them have excellent features that can help an individual's preparation for the certification exam.

Our selection had to take into account the price and, more importantly, the software license; we wanted to be able to use it in our classroom. For example, we discarded Packet Tracer, since it is licensed to Cisco Network Academy students/teachers only. We also consider the GNS3 emulator, which is free; however, we discarded it because it does not provide switch support and the user has to provide copies of the Cisco IOS[1] to work, wich would require a license. The best matches for us are TestOut's LabSim Switching and Routing Pro and RouterSim' Network Visualizer. Table 1 shows a list of some of the features of this two simulators and compares them with real hardware.

TestOut's LabSim Routing and Switching Pro

Routing and Switching Pro is a courseware sold by TestOut. The courseware provides training material in a form of videos and fact sheets, labs, quizzes, and exam prep for preparing students for certification exams such as the Cisco's CCNA and TestOut's Routing Pro and Switching Pro. This courseware contains 82 preset labs; wich cover some of the most common network

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[1] Cisco IOS (originally Internetwork Operating System) is software used on most Cisco routers and Cisco network switches.

configurations found in the IT industry. Figure 1 shows an example of a lab that includes a network topology three host computers, two switches, and one router, the command line interface (CLI) is from the router. The courseware is powered by the company's network simulator called LabSim.

Table 1. Comparison of real hardware and the two simulators used in our course [13]

Feature	Real Hardware	TestOut's LabSim	RouterSim's Network Visualizer
Core function	As real as it gets	Simulates the functionality of the networking devices	Simulates the functionality of the networking devices
Command Line Interface (CLI) output generated by	Cisco IOS	Simulator	Simulator
Who defines the commands supported?	Cisco IOS	Simulator developers	Simulator developers
Cisco router support	Yes	Yes	Yes
Cisco switch support	Yes	Yes	Yes
Predefined lab exercises	No	Yes	Yes
Graded labs	No	Yes	Yes
Includes lectures	No	Yes	Yes
Includes video lectures	No	Yes	No
Includes quizzes	No	Yes	No
Allows to create new network topologies	Yes (limited by the number of devices)	No	Yes
Cross platform	N/A	Yes (Web Based)	No (Only Windows)
Portability (i.e. Laptop or mobile)	No	Yes (Web Based)	Yes (laptop)
Remote Access	Yes (telnet/SSH)	Yes (Web Based)	Yes (remote desktop)
License	N/A	Individual Per student	Individual Per computer (school license available)

LabSim is an online or web-based application that runs in the web browser on a PC or Mac, and some mobile devices. LabSim presents many advantages for both the students and the instructor. For example, LabSim allows our students to practice anywhere where they can access a computing device with a browser and Internet access. The preconfigured labs enable students to focus on learning how to configure the different network devices (hosts, switches, routers, etc.). Unfortunately, there is no way to create or modify the network topologies on these labs. The labs are graded after completion and provide adequate feedback. Users can repeat the labs and quizzes as much as they want. The students' grades and progress report are available anytime.
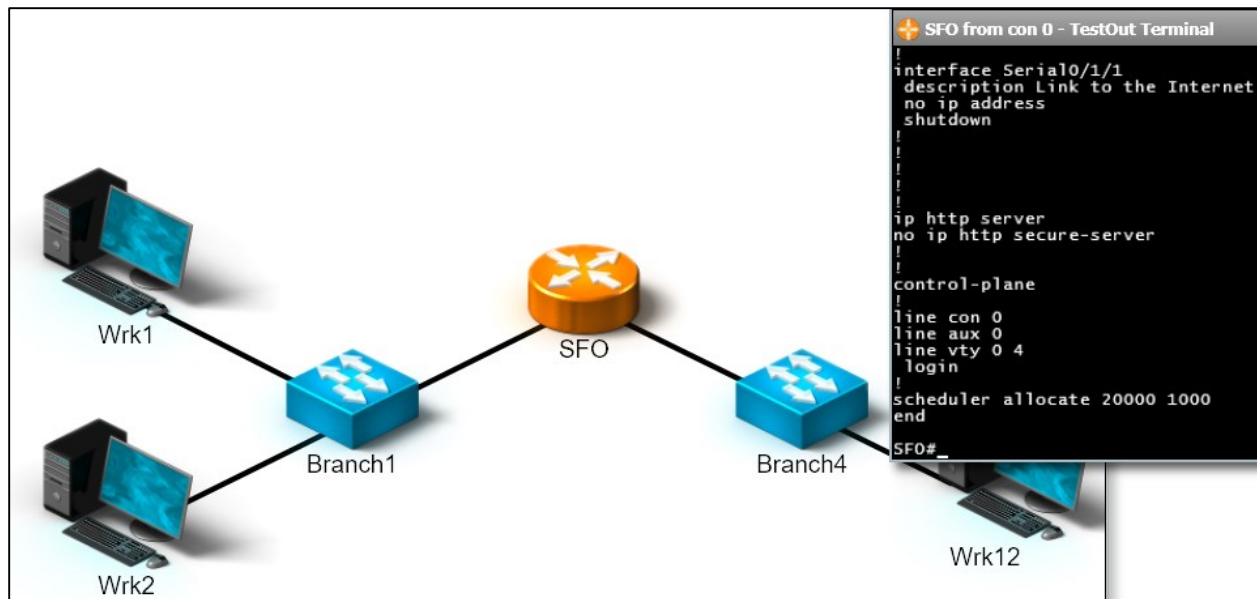
Figure 1. An example of a TestOut's LabSim lab scenario

The way it is licensed is per student. Thus, every student must have an account to access the course. TesetOuts provides special price for schools and special free access accounts for instructors.

RouterSim's Network Visualizer 8.0

The Network Visualizer 8.0 is a simulator where users can design, build, and configure their own network topologies with drag and drop design. It comes loaded with several pre-designed network layouts to choose. However, users can also create their own networks and labs. Users are empowered to build, test and preview any type of network and environment they want. This feature allows learners to experience how to connect different types of hardware interfaces such as Fast Ethernet and Serial Interfaces. Figure 2 shows an example of a user-defined lab that includes the view of a router's physical interface. The included predefined labs guide the learner step-by-step through the configuration process from the ground up. It provides real-world-like experience in configuring Cisco routing and switching devices within an internetwork. It grades the labs and provides excellent feedback. This simulator runs only on the Windows operating system.

The regular way it is licensed is per user and computer. That is, every computer where the software is installed must have a license, which is provided as a code by the company. You can uninstall the software from a computer and recover the license so that software can be installed on another computer. Negotiating with RouterSim to obtain a school license for multiple users per installation was easy; thus, we were able to install it in our school computer lab to be used by different students.
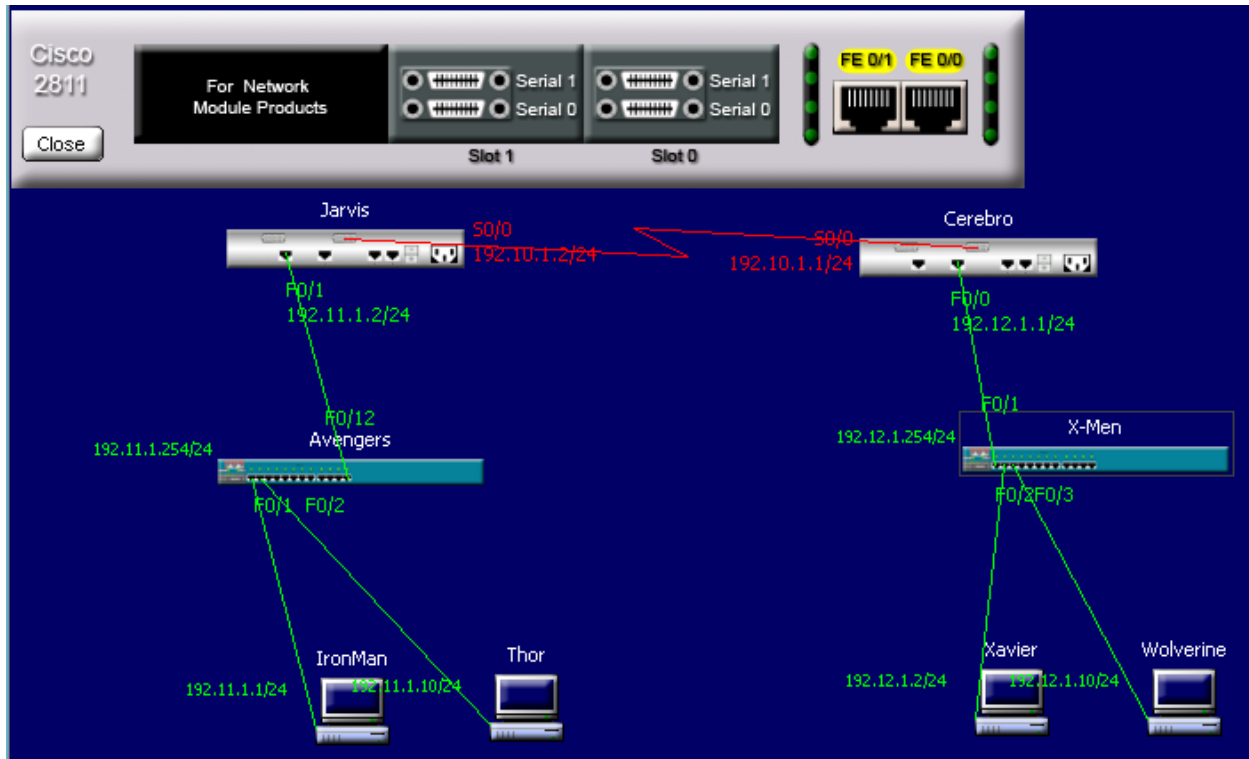
Figure 2. An example of a RouterSim's Network Visualizer user-defined lab scenario showing a router physical interfaces

IV. The course implementation: The hybrid model

Instead of a regular textbook, we adopted the TestOut's Switching and Routing Pro courseware. As it was mentioned in the previous section, this courseware is a complete training solution that goes beyond of what a book can offer. This software is based on a comprehensive training methodology that includes video, text, labs, quizzes and practice certification tests. It consists of seventeen chapters that include computer concepts, network devices and cables, fundamental and advanced LAN switching, IP v4 and IPv6, basic and advanced routing (RIP, OSPF, EIGPR protocols), WAN configuration and network management, and network security. The content and labs are delivered online; thus, it gives instant, anywhere access through most major browsers on both PC and Mac, and some mobile devices. The included hands-on labs let the students practice both hardware and software configuration tasks in a virtual environment.

The course runs in a 15 week semester with two sessions of 3 hours per week. One session we meet in the classroom and the other session is online. The online sessions are for students to work on the TestOut's content. TestOut's system has been essential in the implementation of this hybrid approach. TestOut provides free instructor accounts that include all the benefits the student accounts have. Moreover, instructor accounts provide class management and assessment tools so that instructor can focus on helping students learn, not on maintaining the course or the technology. TestOut provides integrated assessment tools that allow instructor and students to chart progress, identify learning deficiencies, and measure certification and job readiness. With

an instructor account instructors have access to a grading book that can generate progress of enrolled students, for the whole class or individually. The reports can show the instructor the time the students are spending on each topic, lab, or quiz. Also, the instructor can check the attempts per student for a given lab or quiz and their progressive grades.

In the in the classroom session, the instructor gives a short lecture to reinforce the concepts learned online followed by a weekly quiz. This weekly quizzes help to reinforce and verify that students are actually learning the content from the online material. After the quizzes, the students work in practical labs with the RouterSim's Network Visualizer simulator. This simulator comes loaded with preset labs designed to master the required concepts for the Cisco certification. In addition, as mentioned before, this simulator permits to create or develop your own networks or labs. This feature has been fundamental to our class. Thus, the in-class labs provide a different perspective on the concepts learned by the online labs of TestOut; they complement each other. In these labs, the student creates different network topologies and experiment by adding, removing, or replacing network components. For example, adding more computer hosts, changing one model of switch or router for a different one, changing the connections or type of physical interfaces (serial vs. Fast Ethernet), and more. In addition, the simulator provides a tool to analyze the network traffic; the tool can trace the packets sent through the simulated network. These labs are designed so that can be completed during the class time. To provide a grade for these weekly labs, we use the following policy:

- If successfully, completed the lab assignment: 100%.
- If made a legitimate attempt to complete the lab assignment: 75%
- If attended the lab, but made no effort to complete the assignment: 30%
- Did not attend the lab   0%

The course grading policy is the following:
- Online component: 40%
  - Quizzes: 20%
  - Labs: 20%
- In-class component: 60%
  - Weekly in-class quizzes: 10%
  - Networking Labs: 15%
  - Writing assignments[2]: 15%
  - Mid-Term Exam: 10%
  - Final Exam: 10%

For the online component of the course, the student can answer the quizzes or complete the labs with open notes at home. Every quiz has to be completed the night before the next class. The minimum passing grade is 80. Students can use as many attempts as needed to pass the quiz. In the same way, the online labs have to be completed to have the right to work on the in the classroom. Also, students have to pass all the quizzes to have the right to take the Mid-Term and

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[2] The class deals with written communication, a general education outcome. A discussion about this part is beyond of the scope of this paper.

the Final Exam. If for any reason, the student misses a class, it is h(er/is) responsibility to complete the corresponding the online reading assignments, quizzes, and labs.

Both the online and the in classroom components reinforce some essential soft skills. For example, the fact that the students learn about professional accreditations and the self-directed nature of online component promote an ability to engage in self-directed continuing professional development. In addition, having weekly deadlines with a high grade required as pass grade for their assignments encourages a commitment to quality, timeliness, and continuous improvement. One soft skill that is practiced in the classroom is time management. Students have to submit whatever they can achieve during the period assigned to the lab. We believe this helps the student to work against the clock, as in a certification exam.

V. Assessment and results

We assess the outcomes of the course with the TestOut's Switching Pro Certification exam. This Certification exam measures the students' ability to perform real-world tasks based on the topics listed in Table 2. The exam is timed; it is limited to 120 minutes, with about 14 questions or lab assignments that count for 45 tasks. The passing score is 1210 points, on a scale of 250-1600 points.

The Switching Pro Certification Exam is included in the cost of TestOut's Routing and Switching Pro courseware. The exam is online and it is scored immediately upon completion. Instructors have immediate access to student scores. Students receive score and pass/fail notification immediately after exam ends. Students who take and pass the exam can download a digital certification certificate. After some weeks, students will receive a hard copy by mail.

The results

During the Fall 2015 semester, 20 students were enrolled in the class. Table 3 shows the class' results from the certification exam and compares them with nationwide and statewide (New York) results. The majority of the students completed the exam in less than two hours; the average was 106 minutes, which is a little bit more than the national (92 minutes) but equal to the statewide. A couple of students stated that they could not finish the exam in the 120 minutes period. After that period, the system ends the exam, and the incomplete exams are graded according to the completed portion. Although only 50% of the students (10 students) obtained the certification, this percentage is a little bit higher than the nation and state rates (both 45%). The class average score is 1150 with a standard deviation of 303, and a median of 1180. The class average is higher than both the nation (1034) and state (1081) average. The highest score was 1540 points, only six students got a grade less than 1090 points, and only one student got less than 700 points (490 points, the lowest score in the class).

Table 2. Switching Pro certification objectives

Objective	Content
1 Switch Setup and Configuration	View switch configuration information. Configure switch hostnames and interface descriptions. Configure switch banners. Manage switch configuration files. Manage switch IOS files.
2 Switch Interface Configuration	View directly connected network devices using CDP. Manage the CDP configuration. Configure interface speed and duplex settings. View the status of switch interfaces.
3 TCP/IP Configuration	Configure switch TCP/IP settings. Troubleshoot LAN communications.
4 VLAN Configuration	View information about VLANs configured on a switch. Manage default VLAN configuration settings. Configure VLANs on a switch. Extend VLANs to multiple switches using trunking. Troubleshoot VLAN issues. Troubleshoot trunking issues.
5 InterVLAN Routing	Configure interVLAN routing. Troubleshoot interVLAN routing issues.
6 Spanning Tree Configuration	View STP configuration information. Manually configure a switch as a root bridge. Configure Rapid PVST+. Troubleshoot STP issues.
7 Switch Security	Restrict access to a switch. Configure switch passwords. Disable switch interfaces. Enable switch port security. Configure switch remote access using SSH.
8 EtherChannel Configuration	Configure EtherChannel using the following: PAGP LACP

Table 3. Results of our students compare to nation and state results

Statistics	Mean	Pass Rate	Completion Time
College (National)	1,034	45%	1:32
College (NY State)	1,081	45%	1:46
Our Students	**1,150**	**50%**	**1:46**

The results are encouraging, 70% of the students got a score greater than 1050 points. Most of the students in this course are seniors and can add their knowledge about internetworking technologies into their resume. Now, after graduation, half of the students will have one more credential that will help them to build their career path. The ones that were very close to the mark to get the certification are encouraged to retake the exam after a review.

VI. Conclusions

We presented an approach to teaching internetworking technologies in an advanced computer-networking course. This approach has two main features: i) it follows a hybrid approach, and ii) it make uses of online and offline computer network simulators. With the hybrid approach, one day the class met in the classroom for short lectures, some hands-on labs, and some short quizzes. The online simulator allows the students to practice different problem settings and scenarios.

The results of implementing this approach are very encouraging. Fifty percent of our students were able to obtain a certification in this field. Moreover, about seventy percent of the students got a grade grader than 1050 points, from exam scale of 250 to 1600, which shows that they have a real knowledge of the field. We expect the next generation of students maintains or improve these records. We also are looking to implement this approach on other courses in our programs. We believe that this is an inexpensive model, which can be adopted and implemented by other colleges with similar courses or interests.

VII. References

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