# Enhancing Students' Hands-On Skills of Wireless Technology Using Network Simulators

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## Abstract

This paper describes two well-known network simulators: Packet Tracer and Riverbed Modeler, and their core functionalities in the modeling of wireless networks. Labs were designed to aid students' in learning wireless communication technologies. We expected the labs to help students gain practical experience working with wireless networking configurations and enhance their understanding of different wireless network topologies. At the end of the semester, a survey was conducted to evaluate the learning environment, simulators, and labs' effectiveness. The results showed that most of the respondents had a very positive attitude toward the lab exercises. They also agreed that the simulators have successfully helped them develop their capabilities in creating and analyzing wireless networks in real world scenarios.

## Keywords

Network simulation; wireless communications; practical hands-on exercise; virtualization; technology education

## Introduction

In the field of wireless communication, students have to learn not only theoretical knowledge but also to practice realistic hands-on exercises. In general, two methods have been widely used to create a learning wireless network environment. One involves employing physical devices to accomplish with a wireless network[1] and the other is using simulators to mimic the behavior of the network devices[2]. With the increasing complexity of modern wireless communication systems, the first approach has become impractical and ineffective. In contrast, simulators provide an effective way to create an experimental environment in which a complex wireless network can be rapidly implemented and the topology can be easily changed.

Nowadays, there are a variety of simulators available on the market that can be used for learning wireless communication technologies, for example: NS-2, TOSSIM, EmStar, OMNeT++, J-Sim, ATEMU, Avrora, Packet Tracer, GNS3, and Riverbed Modeler[3-6]; each simulator offers different functionalities in studying, configuring, modeling, and testing wireless networks. Research has shown that the use of simulators is not only able to help students understand abstract network principles but can also improve students' practical skills when learning about wireless technologies[7].

In order to choose proper simulators for the class usage, two major factors have been taken into consideration, they are cost and popularity. Due to both Packet Tracer[8] and Riverbed Modeler[9] are free of charge for educational use and are widely used as research and educational tools, we adopted these two simulators in a mixed lecture/lab undergraduate wireless communications course to help the students learn concepts of wireless network technologies and protocols. Labs were developed based on the features of the simulators. The labs provided students with hands-on experience in terms of wireless network configuration, implementation, and performance evaluation.

In this paper, we first discussed the two simulators that were used in the class and then proceeded to introduce the designed labs. Lastly, we discussed the results of the survey that was carried out for evaluating the effectiveness of both simulators and labs.

**Simulation Tools**

Packet Tracer is a simulator that provides a powerful capability to create computer networks and mimic network behavior. It provides simulated devices with two interfaces, graphical user interface (GUI) and command line interface (CLI), for visualizing devices and entering configuration data. In the context of wireless network functionality, it provides a cell tower, a central office server, wireless routers, smartphones, and mobile devices. Along with the above devices, interfaces with wireless antennas can be added to a regular router in order to make it function as a wireless router. Beyond that, there is a sniffer tool that can be used to examine packets as they travel the network.

Moreover, Packet Tracer provides a very helpful tool "Activity Wizard" that can automatically evaluate students' practical skills and knowledge. The Activity Wizard allows instructors to create a complete network, an initial network, and activities that students need to complete. By following the activity instructions, students can configure the initial network to function as the complete network. When finished, the total number of completed activities will automatically be determined allowing the instructor is able to provide proper feedback to students.

Riverbed Modeler is a simulation tool that is built on C++ programs for implementing and modeling computer networks. It is comprised of a suite of protocols and technologies and features three hierarchical modeling abstraction editors (project, node, and process) to support different development levels. In the perspective of wireless network functionality, Riverbed Modeler delivers Wireless Local Networks (WLAN) based on IEEE 802.11 and ZigBee based on IEEE 802.15.4. After installation, it equips with examples of WLAN and Zigbee that comprise different scenarios. The examples not only demonstrate its supported features but also provide users with a chance to exercise their capabilities on how to configure wireless networks. Example scenarios include routing, roaming, Quality of service (QoS) analysis, channel interface, large wireless network modeling, Media Access Control (MAC) mode simulation, and co-existence of wireless standards.

In order to encourage academic users to use Packet Tracer, the software is available free of charge to Networking Academy instructors, students, alumni, and administrators who are registered Academy Connection users[10]. As for Riverbed Modeler, the company offers Riverbed Modeler Academic Edition for free through its University Teaching and Research Program[11].

The Academic Edition is a stripped-down version of Riverbed Modeler that has some restrictions, e.g., it has a limitation of the number of nodes and events in the simulation run; it cannot specify multiple seeds when running simulations; it only provides project editor; and it does not support certain wireless standards, such as Long-Term Evolution (LTE), Universal Mobile Telecommunications Service (UMTS), Worldwide Interoperability for Microwave Access (WiMAX).

**Lab Design**

The wireless communications course is a combination of lectures and labs. In order to help students understand key concepts of the course content lectured in class, labs have been developed using Packet Tracer and Riverbed Modeler. Since the course covered a broad range of topics dealing with wireless technologies but had limit time to conduct lab activities, we only focused on WLAN IEEE 802.11 protocols and its different wireless network topologies. Both Packet Tracer and Riverbed Modeler were acquired at no charge through Cisco Networking Academy and Riverbed University Teaching Program, respectively. They were installed in a number of virtual desktops within the desktop virtualization environment VMware View. With its remote desktop capabilities, both on-campus and distance education (DE) students were able to perform the lab activities anytime and anywhere, thus increasing the flexibility of students' learning.

**Packet Tracer Labs**

Labs were developed using the automated scoring and reporting tool, Activity Wizard, offered by Packet Tracer. In each lab, students were required to follow the given instructions to complete the necessary activities. In order to help students gain familiarity with the wireless network simulation on Packet Tracer gradually, the level of lab difficulty was provided to students from the easiest to the hardest.

In the first lab, we focused on the study of the configuration of a Linksys wireless router. A simple network was created and the network only included a Linksys WRT300N wireless router, one laptop, and one personal computer (PC). Students were asked to establish and verify connectivity among the network devices. The learning objectives of this lab are:

- Configure the wireless router for Internet connectivity
- Set up the network parameters
- Establish and verify connectivity of wired and wireless clients to the wireless router

In the second lab, the main goal was to study wireless security protocols, such as WEP, WPA, and WPA2. A more complicated network was created and the network included two routers, a switch, two PCs, a wireless router, and two laptops. Students were required to configure the wireless router and allow remote access to the wireless clients. The learning objectives of this lab are:

- Configure different security modes on network devices
- Add wireless capability to a PC by removing the Fast Ethernet network interface card (NIC) and then installing wireless interface

- Remotely manage the wireless router through the Internet web interface

In the third lab, wired and wireless networks were created. The wired network included a router, a switch, and two PCs. The wireless network included a cable modem, a wireless router, and two laptops. Students were asked to examine configurations of network devices and to select proper cables based on the configuration of devices. The learning objectives of this lab are:

- Select the appropriate cables to properly connect different wired and wireless devices
- Explore the physical view of the primary, secondary, and home networks
- Verify connections between network devices

**Riverbed Modeler Labs**

Three different network topologies were included in the labs[12]. They are Basic Service Set (BSS), Extended Service Set (ESS), and Independent Basic Service Set (IBSS). Each lab was divided into three phases: network creation, statistics collection, and result analysis. Lab manuals were provided to students so they could follow the steps to complete all the required activities. In order to help students gain confidence and knowledge about the usage of Riverbed Modeler, the labs scenarios started off easy and increasingly became more complicated.

In the first lab, a BSS WLAN was created and the network included a single access point (AP) and multiple wired and wireless devices. Students were asked to add the devices into the network and configure individual characteristics of the devices. The learning objectives of this lab are:

- Understand the technologies of IEEE 802.11 standard used in WLAN
- Configure individual characteristics of the wireless devices
- Observe the behavior of AP, fixed and mobile wireless devices in WLAN

In the second lab, an ESS WLAN was created that comprised of a central bridge connecting to four APs, a destination host, and a mobile wireless device. In the beginning of the lab, students were asked to configure the wireless device initially associated with AP1 then traveled in a clockwise direction to visit other three APs. Afterwards, a frequency-swept jammer was added in order to study the negative impact to the performance of the network. The learning objectives of this lab are:

- Simulate the behavior of roaming and handoff among APs
- Observe the data traffic of APs and wireless device in ESS
- Study the efforts of Denial of Service (DoS) attack to mobile devices

In the third lab, IBSS was studied and a wireless mobile ad-hoc network (MANET) was implemented. A set of mobile wireless devices were connected wirelessly to a gateway and each device was configured to move freely and independently in any physical direction. Students were asked to simulate five wireless routing protocols and compare their characteristics: Optimized Link State Routing Protocol (OLSR), Dynamic Source Routing (DSR), Ad Hoc On-Demand Distance Vector Routing (AODV), Temporally-Ordered Routing Algorithm (TORA), and Gateway Routing Protocol (GRP). The learning objectives of this lab are:

- Learn to implement a mobile ad-hoc network (MANET) using IEEE 802.11 standard
- Gain an understanding of different routing algorithms in wireless ad-hoc networks
- Evaluate and analyze network performance

**Student Assessment**

At the end of Fall 2016, a survey was conducted among 10 on-campus and 29 DE students who were registered in the course. The main purposes of the survey were to evaluate the labs' effectiveness and to discover students' comfort level with the two simulators. The survey was posted on the course management system Blackboard for students' access. In order to encourage students to participate in the survey, a 2-point incentive was offered on their final grade. In the end, a total of 28 out of 39 surveys were successfully received.

The survey was conducted by means of a questionnaire given to the students to complete. The questionnaire was carefully crafted so that only important questions regarding lab environment, simulation tools, and designed labs, were included. The first part of the questionnaire dealt with the lab environment. The second section concerned with Packet Tracer. The last section focused on Riverbed Modeler. The types of questions included in the survey were Likert-scale and open-ended questions.

Figure 1 showed the survey result of lab environment, which revealed that a large majority of respondents expressed a positive attitude towards the experimental environment. The respondents have expressed that VMWare View delivered a reliable access service that allowed students to access the virtualized workspace anytime and anywhere. It also showed that VMWare View provided a good platform to support networking simulators.
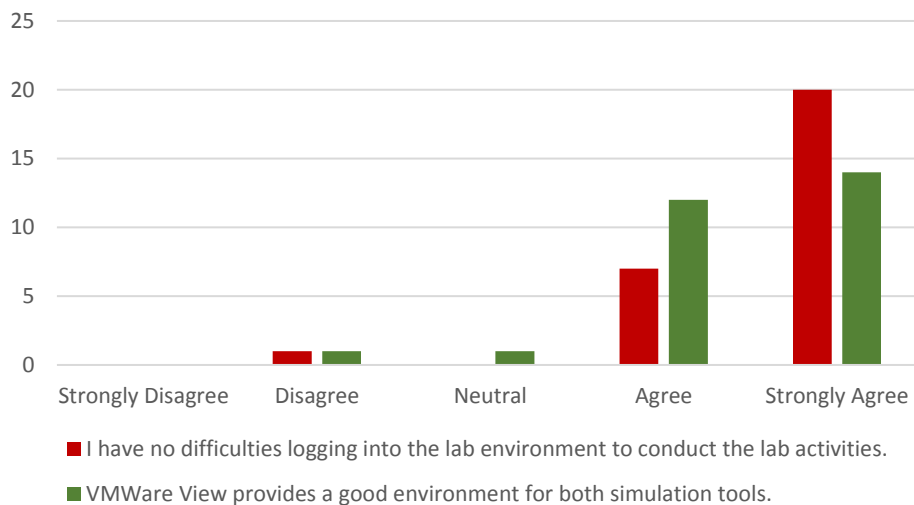


I have no difficulties logging into the lab environment to conduct the lab activities.

VMWare View provides a good environment for both simulation tools.

*Figure 1: Survey result of the lab environment*

Respondents were asked if Packet Tracer and Riverbed Modeler were good tools to strengthen analysis and learning knowledge of wireless communication technologies. 100% of the respondents and 76% of the respondents agreed that Packet Tracer and Riverbed Modeler were useful as a practical skill learning aid, respectively. In addition, almost all of the respondents (96%) agreed that Packet Tracer provided a good GUI. However, only 43% of the respondents

felt that the GUI of Riverbed Modeler was good. The possible reason to explain students' preference of the GUI toward Packet Tracer than Riverbed Modeler is familiarity. Our Information Computer Technology program provides many courses regarding wired computer networks, and Packet Tracer was widely used in those classes. This is the only course that uses Riverbed Modeler to simulate computer networks. Therefore, students were more familiar with Packet Tracer than Riverbed Modeler.
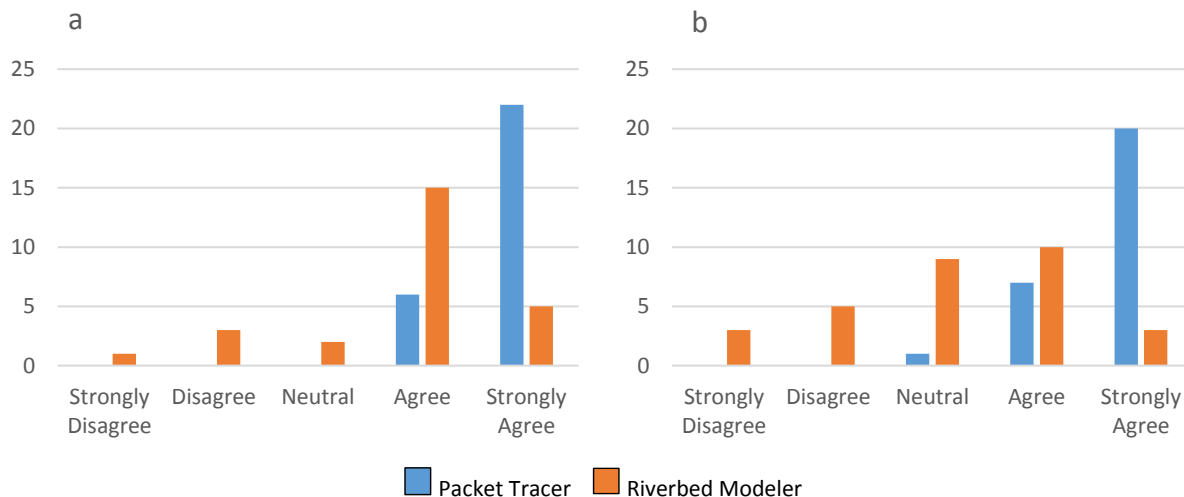


*Figure 2: Survey results of two simulators used in the course. (a) It is a useful tool in learning the knowledge of wireless communications (b) It has a good GUI*

Figure 3 showed the survey responses from the perspective of the lab design. In general, most of the respondents thought that Packet Tracer was easy to learn but Riverbed Modeler was not. As for the level of labs' technical difficulty, Packet Tracer was relatively low compared to that of Riverbed Modeler. Hence, it was more time-consuming to complete the lab activities of Riverbed Modeler than Packet Tracer.

Additionally, participants were asked to supply comments in the form of open-ended questions on what they liked best and what they most disliked about the two simulators. Most of the respondents indicated that Packet Tracer was easy to use and it had a good GUI design. However, some of the respondents also indicated that Packet Tracer lacked up-to-date wireless devices and did not have the ability to collect wireless data. In contrast, students believed that Riverbed Modeler was more powerful, because it was capable of collecting statistics and examining the signals from the perspective of individual devices and the entire network. However, too many settings and options have made Riverbed Modeler too complex and difficult to learn. Most of the respondents were overwhelmed with its complexity and did not fully understand how to interpret the simulation results.
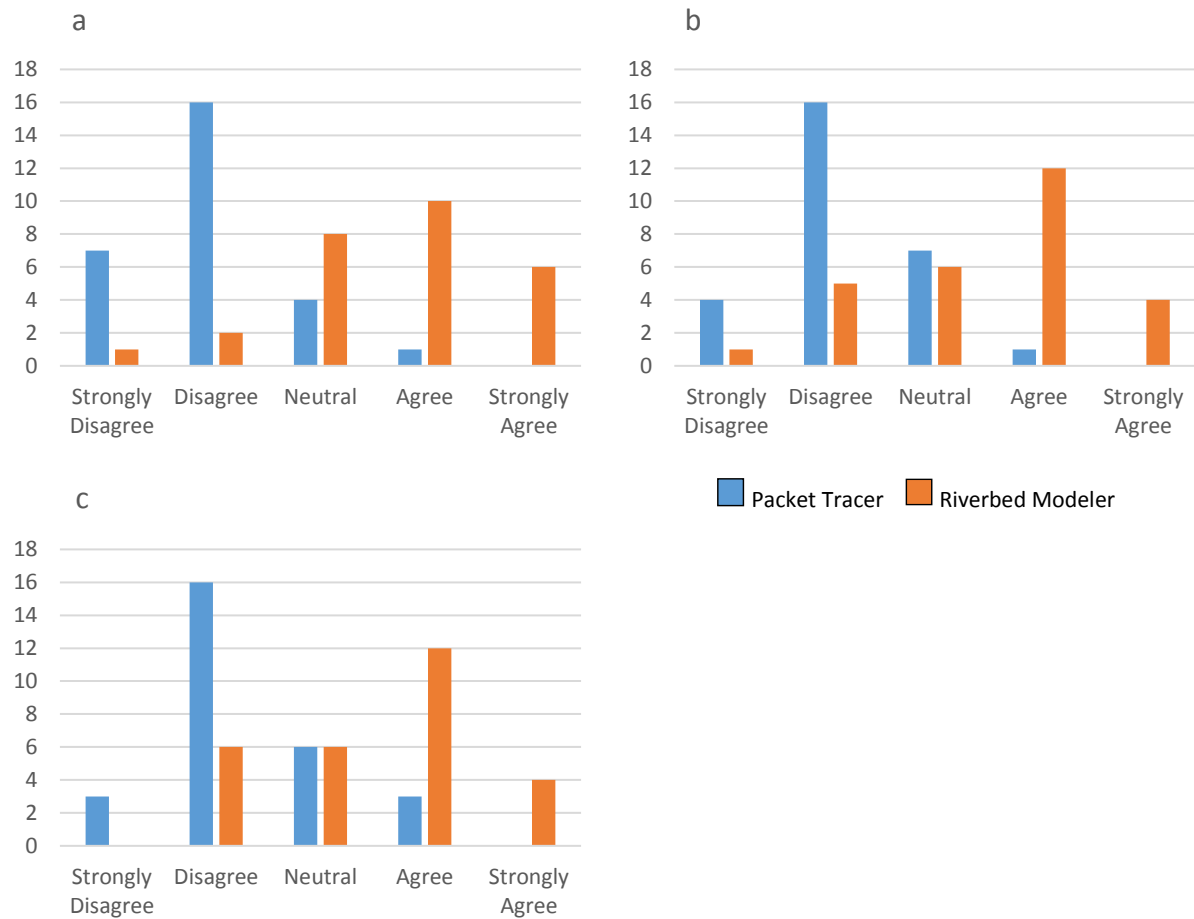
*Figure 3: Survey results from the perspective of the lab design. (a) It is difficult to learn (b) I would rate the technical difficulty of the labs as difficult (c) I spent excessive time working on the labs*

## Conclusions

Learning wireless communication technologies requires not only the understanding of theoretical knowledge but also experiential practice through hands-on experimentations. Simulators have been proven to be useful in aiding the educational process in teaching. This paper presented two simulators, Packet Tracer and Riverbed Modeler, which were used in an undergraduate wireless communications course. Both were capable of allowing students to create network topologies and then configure the associated devices. Labs were designed based on the features of the two simulators and detailed lab manuals were provided to help students develop their capabilities in creating and analyzing wireless networks in real world scenarios. The complete procedure offered students an opportunity to perform hands-on activities of three different network topologies (BSS, ESS, and IBSS) and therefore enhanced their theoretical knowledge of those networks. At the end of the semester, a survey was carried out to evaluate both simulators and lab effectiveness. Students perceived that the two simulators were useful tools that offered them the opportunity to conduct practical skills.

## Acknowledgements

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