Computers & Education 70 (2014) 233–244

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Evaluating a computer-based simulation program to support wireless network fundamentals

T.J. Mateo Sanguino*, F.A. Márquez Hernández, C. Serrano López

Department of Electronic Engineering, Systems and Automatics, University of Huelva, Huelva, Spain

ARTICLE INFO

Article history:
Received 24 June 2013
Received in revised form
13 August 2013
Accepted 14 August 2013

Keywords:
Engineering education
IEEE 802.11 modeling
Wi-Fi simulator
Wireless network design

ABSTRACT

Formal learning on networking basics can reduce motivation and expectations for students who aim to become future professionals on wireless networks. To address this shortcoming, this paper presents an educational methodology to enhance learning by conducting cases studies on Wi-Fi network design. The proposed methodology is supported by a new educational simulation tool, namely WiFiSim, aimed at the generic study of IEEE 802.11-based WLANs in a disciplined way. The interest of this tool, which has been developed by the authors, lies in its ability to simulate realistic and customizable WLAN environments, high interactivity and user-friendly interface, and intuitive and easy-to-interpret 3D graphic results. These help students in wireless network modeling and deployment with improved reach and realism. In order to validate this basis, we tested WiFiSim under different simulation conditions. As a result, the teaching experience has demonstrated the effectiveness of the followed methodology and significantly reduced the gap between theory and practice.

1. Introduction

The optimal design and deployment of WLANs requires a clear understanding of a fair number of theoretical and practical concepts on telecommunication equipments. Before the future engineer faces the use of real hardware systems, simulators can be used with this purpose (Vasudevan, 2005). However, applications need to achieve a high degree of realism and simulation capability. This means that models need to include a physical description of the environment where the network will be deployed (e.g. complex Wi-Fi scenarios, high presence of obstacles, 3D spatial representation, etc.), as well as a definition of the physical features and operational parameters (type of Wi-Fi technology, medium access control, WLAN card, etc.). In practice, applications can partially satisfy simulation needs resulting in a limitation especially for those tools intended to be used for educational purposes (Xiaomei, 2008).

With the aim of facilitating training and learning of students, we propose an educational computer-network tool namely WiFiSim (Wireless Fidelity Simulator). The educational tool was devised to study the media access control and physical layer specifications for implementing WLAN communications in the 2.4 GHz band. To this end, we have followed two complementary strategies. On the one hand, simulate the behavior and protocol operation of the IEEE 802.11 standard widely used in Wi-Fi networks. On the other hand, assist students in wireless network modeling and design with a realistic approach. Nevertheless, simulations must achieve these goals without detriment of educational purposes, i.e. improving knowledge, usability, and real usefulness. These objectives comprise the research problem covered herein.

In order to validate this basis, we started a research project with the initiative of a group of teachers at the Department of Electronic Engineering, Computer Systems and Automatics at the University of Huelva (UHU), Spain. In a preliminary study, the authors presented the WiFiSim tool used in a networking course as part of an ongoing teaching project (Mateo Sanguino, Serrano López, & Márquez Hernández, 2013). We found that the educational simulator improved the students' results of both theoretical and practical works in general. We also found that the users' opinion of about WiFiSim was given as fairly positive and satisfying.

* Corresponding author.
E-mail address: tomas.mateo@diesia.uhu.es (T.J. Mateo Sanguino).

0360-1315/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compedu.2013.08.015

The present paper completes the previous work providing a broader analysis on how different courses of students perceived the WiFiSim's usefulness. In addition, we include a comparative study on the academic results over a total of six years, since we have regularly used simulation tools in our teaching. This allowed the teachers identify students' real problems and propose new educational challenges. With this aim, this paper proposes a teaching methodology to conduct case studies on the modeling and design of WLANs in a disciplined way. From the results, we discuss how the academic results on wireless networks were influenced and their implications in engineering education.

This paper is organized as follows. Section 2 contributes a brief discussion on tools about wireless networks used in academic fields. Section 3 presents the educational project and the main simulation capabilities of WiFiSim. Section 4 proposes a teaching methodology on WLAN design, while its subsections challenge the application in different simulation environments. Section 5 analyzes the impact of WiFiSim on the teaching and learning of Computer Science. Finally, the paper discusses the results obtained. Because of the paper contains a large amount of acronyms, a nomenclature for easier reading is given at the end.

2. Related work

Choosing a simulator to study optimal wireless-network design can become an arduous task due to the large number of existing tools, which involves highly time-consuming familiarization (Chandrashekar & Janes, 2009). Although many technical details are difficult to compare, reference (Karsten & Reineck, 2008) contributes an overview of different tools and simulation environments, highlighting their respective pros and cons. The work by this author helps on the evaluation and analysis of different tools in which the applications' quality is set according to different metrics and simulated scenarios. One of the most cited tools in the literature devoted to the study of different aspects of networking is undoubtedly ns-2 (now known as ns-3) (Henderson, Roy, Floyd, & Riley, 2006; Issariyakul & Hossain, 2008). The wide support for wireless networks includes the ad-hoc and the infrastructure modes, different spatial models, as well as different link and network layer protocols of the OSI stack.

Aimed at teaching, the University of Western Australia uses Cnet as an educational tool that allows experiencing diverse protocols of link, network and transport layers in mixed networks including WAN, LAN, and WLAN (McDonald, 1991). The main advantage is that Cnet proves a very interesting teaching tool, since it allows students to implement their own algorithms and, thus, extend the functionality of the simulator (Stallins, 2010). Also devoted to the study of networks, the OMNeT++ tool arose at the Technical University of Budapest (Varga & Hornig, 2008). Due to its generic architecture and flexibility, it is currently being used in other specific fields such as queues or hardware architectures. One of the main advantages of OMNeT++ is that, thanks to its modular architecture, simulations and models can be easily integrated into the user's graphic applications (Meyer, Odaker, & Hummel, 2010). Although it is not properly a network simulator, it is gaining popularity as a scientific tool and it is supported by a large developer community.

On the other hand, SWANS represents a scalable simulator with ability to form wireless network topologies by means of independent components (Barr, Haas, & Renesse, 2005). Its performance, although similar to that of ns-3, allows much larger network simulations. However, as its main disadvantage, SWANS was designed for the simulation of ad-hoc networks and thus includes no support for the infrastructure mode. Besides it currently only supports the IEEE 802.11b specification. More recently, Pythagor and Panvotis tools arose with the only aim of studying wireless networks (Vassis, Kormentzas, Rouskasa, & Maglogiannis, 2005; Vassis & Kormentzas, 2008). As main features, both tools support different types of physical layer, speed rate, and combined operation of IEEE 802.11 b/g nodes. Their lack of support for the IEEE 802.11n specification is among their main drawbacks. Finally, other noteworthy examples of educational simulators include QualNet – formerly GloMoSim© – (Zeng, Bagrodia, & Gerla, 1998) and OPNET™ (Flores Lucio, Paredes-Farrera, Jammeh, Fleury, & Reed, 2003), among others. However, these are either non-commercial or only available applications under academic licenses.

This article describes a new educational simulation tool devoted to the generic study of the IEEE 802.11 standard. The developed tool aims to improve various aspects of the above mentioned applications. The truly distinguishing issues of WiFiSim compared to others are: a) capability to simulate the 802.11a/b/g/n family commercialized until the present time; b) capability to simulate complex environments by including obstacles between devices to obtain a more realistic result than other tools; c) high usability and interactivity by implementing customizable devices on the WLAN; and d) 3D graphic results more intuitive and easier-to-interpret than programs based on command lines.

3. Educational project development

"Networking" is an annual subject that has been taught for 9 years in the 4th course of the Computer Science degree at the UHU. The academic program comprises a total of 96 h of classroom attendance in each semester, including 26.5 h of theory and 26.5 h of lab practices. It also requires a total of 90 h of non-presence work by students. In short, theory on wireless networks is taught at the end of the first semester. This period includes two classroom sessions aimed at studying theoretical concepts on wireless networks (boxes with continuous lines in Fig. 1), and two problem-solving sessions on the IEEE 802.11 protocol (dashed-line boxes in Fig. 1); each session takes 90 min, respectively. In addition, theoretical concepts on wireless networks are also trained during four lab sessions of 90 min. On the one hand, an optional practice aimed at working with real Wi-Fi systems is proposed to students. This involves capturing real WLAN traffic using monitoring applications (i.e. Ethereal or Wireshark) with the aim of validating the WiFiSim's reliability. On the other hand, a compulsory practice aimed at discovering potential problems on WLAN design is conducted by students. With this purpose, we put forward the case study explained in Section 4.

The mandatory nature of the subject and the considerable technological level that it contains are usually a hard obstacle for students working in this field. In fact, this subject conceals hard concepts on protocols together with highly specific terminology riddled with acronyms and specifications. For this reason, formal learning in networking courses can be hard and reduce motivation for those students who intend to relate theoretical and practical concepts to achieve future professional usefulness (Grasso & Burkins, 2010); i.e. modeling and designing Wi-Fi networks, identifying and solving real problems, undertaking projects of spam engineering, as well as getting to know all aspects related to network operation (medium access control, protocols, etc.). The analysis of this situation led the team of teachers who coordinates the subject to the conviction that we should accomplish the commitment of offering both an attractive subject and university