Design and Evaluation of a Web-based Tool for Teaching Computer Network Design to Undergraduates

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ABSTRACT

Previous studies have shown that motivating students to learn about local area network (LAN) design can be difficult when presented in the traditional lecture format. To overcome this problem, a Web-based tool (“WebLan-Designer”) was developed as an aid to teaching and learning of LAN design at introductory level. WebLan-Designer provides a set of learning resources (tutorials, quizzes, network modeling, network design scenarios, key terms and definitions, and review questions and answers) and aims to assist undergraduate students in learning the basics of both wired and wireless LAN design. The tool is Internet-based and can be accessed at any time so that students can study LAN design at their own pace and convenience. This flexible learning approach contributes positively to distance education and e-learning using the World Wide Web. The effectiveness of WebLan-Designer was evaluated both formally and informally; positive student and peer feedback indicates that the design and the implementation of the tool has been successful and that using WebLan-Designer may have a positive impact on student learning and comprehension.

Keywords: Computer network education, interactive learning, teaching and learning, Web-based tool, WebLan-Designer.
INTRODUCTION

Almost all computer science (CS), computer engineering (CE), information systems (IS), and information technology (IT) curricula include some basic courses in local area network (LAN) design. Unfortunately, motivating students to learn about LAN design fundamentals can be difficult not only because students find the subject rather abstract when it is delivered using a traditional lecture format, but also because of inflexible on-campus teaching which does not provide students with enough opportunities to engage actively in the learning process (Gasparinatou & Grigoriadou, 2011). To overcome this problem, the authors have developed a Web-based teaching suite called WebLan-Designer that gives students an interactive and flexible learning experience in both wired and wireless LAN design.

The principles of LAN design are the subject of a number of widely used textbooks (Fitzgerald & Dennis, 2009; Forouzan, 2007; Kurose & Ross, 2010; Palmer & Sinclair, 2003). These scholarly texts normally include additional study material in the form of review questions and exercises aimed at helping students to understand the theoretical concepts and applications. However, prior research findings indicate that students engage better and learn more effectively if their networking courses are complemented by carefully designed learning tools and resources helping them to achieve the course learning objectives (Chang, 2004; Gotsis, Goudos, & Sahalos, 2005; Midkiff, 2005; N.I. Sarkar, 2006).

WebLan-Designer is an example of a Web-based system which provides a set of learning resources (including tutorials, quizzes, modelling, scenarios, key terms and definitions, and review questions and suggested answers) to undergraduate students in CS, CE, IS, and IT programmes; its objective is to support learning about LAN design fundamentals through a simulated hands-on experience. In general, the use of Web-based learning tools for developing flexible teaching and learning models in computer networks and related subjects has been
discussed extensively in the literature (Aller et al., 2005; Djordjevic, Nikolic, & Milenkovic, 2005; Garcia & Alesanco, 2004; Hanson et al., 2009; Wannous & Nakano, 2010). It is believed that pedagogical approaches such as experiential learning and simulation motivate students and help them become active learners who are able to construct their own knowledge effectively (Berglund, 2003; Chang, 2004; Chen, 2003; Gasparinatou & Grigoriadou, 2011; Sousa, Alves, & Gericota, 2010; Vargas et al., 2010).

The context for the design and evaluation of WebLan-Designer reported in this paper was provided by the teaching and learning environment at a New Zealand University (AUT University) where computer networks and LAN design fundamentals are taught both in the School of Computing and Mathematical Sciences, and the School of Engineering. WebLan-Designer serves as a student-centred self-paced learning tool as well as classroom teaching tool. This flexible learning approach to LAN design using WebLan-Designer has been applied for several years now in undergraduate computer networking courses in computer science and IT programmes at AUT University. Normally the scope of these courses includes extensive coverage of LAN media, topologies, protocols, wireless technologies, and various aspects of network design.

The main objective of this paper is to report on the development and evaluation of the WebLan-Designer and its usefulness as a teaching and learning tool in the field of computer networking. The study presented here contributes to the computer science education literature by emphasising strongly that the use of interactive and flexible learning experience using a Web-based tool has been crucial in motivating students to learn about LAN design fundamentals. The most innovative aspect of this paper is the development and evaluation of such a tool which may effectively complement both the lecture and tutorial content of an undergraduate computer networking course.
The rest of the paper is organized as follows. In the following section a background review of various network simulation tools is presented. Next, the architecture and features of WebLan-Designer are described, and the value of WebLan-Designer and the way it has been used in the classroom is highlighted. Finally, the system evaluation results are presented and discussed. The paper concludes with suggestions for future research and development.

BACKGROUND: A REVIEW OF SELECTED TOOLS

A wide variety of tools are available to support teaching and learning some aspects of computer network design. They range from simple animation, simulation and more specialized purposely built software packages. We have tested several of these tools for teaching and learning introductory computer networking courses. However, commercial software packages are a bit time consuming to learn, and often they offer a sophisticated network environment and powerful simulation capabilities which are not needed for an introductory networking courses (Fall & Varadhan, ; Zheng & Ni, 2003).

Among the non-commercial network simulation packages for modelling and performance evaluation of computer networks, ns-2 (Fall & Varadhan) is arguably one of the most popular network simulators. It is used widely by academic researchers and graduate students in computer science and computer engineering. Ns-2 is available at no cost and provides an environment for rapid model development. However, the package may be of limited use as a teaching and learning tool mostly because of its text-based interface that is not user-friendly.

Network modelling and simulation tools with a graphical user interface (GUI) may be better suited for use in classroom settings. Early examples include the commercial packages NETWORK II.5 and COMNET II.5 (Garrison, 1991), and NetMod (Bachmann, Segal, Srinivasan, & Teorey, 1991). The latter can be used for network modelling as well as for an in-
depth performance analysis of large interconnected LANs. The Layer-Module set (Diab & Tabbara, 1995) is another early system developed specifically as a teaching tool. It includes graphical animation and simulation of various network functions following the open system interconnection (OSI) model, accompanied by explanatory texts, figures, examples, demonstrations, and multiple choice revision questions. The more recently developed Web-based package called WebTrafMon can be used as a complement to network simulators as well as for traffic monitoring (Hong, Kwon, & Kim, 1999).

EMPOWER (Zheng & Ni, 2003), cnet (McDonald), and dlpjava (King) are network animators/simulators that can be used to illustrate the concepts of both wired and wireless networks. However, these packages require a degree of prior knowledge and proficiency, e.g., Unix/Linux experience (McDonald).

LAN-Designer (N.I. Sarkar, 2004) and LAN-Designer (N. Sarkar, 2005) are two easy-to-use Web-based tools for wireless and wired LAN modelling, respectively. However, the current versions of these tools offer limited functionality with respect to supporting classroom teaching and learning.

GloMoSim (GloMoSim), ViTAN (Fitzek, Seeling, Reisslein, Rugin, & Zorzi, 2004) and VANS (Shinohara, Hyashi, Hira, Kanazaki, & Nishio) are examples of well developed visual simulators for ad hoc networks. These tools have network animation and reconfiguration facilities and display simulation status, statistics and mobile hosts. However, students need to be familiar with network protocols and network configuration.

Finally, OPNET is a commercial package commonly used by both researchers and practitioners, especially for designing and modelling complex communication networks (OPNET Modeler). OPNET IT Guru and Modeler are available at no cost for educational use under the...
OPNET University program. However, the software maintenance cost associated with the academic version of OPNET is considerably high.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Key feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>NETWORK II.5, COMNET II.5, NetMod</td>
<td>Early packages, offer advanced modelling functions and a graphical interface.</td>
</tr>
<tr>
<td>The Layer-Module set</td>
<td>An early package that illustrates network design concepts. Suitable for teaching and learning, however it uses the OSI network model.</td>
</tr>
<tr>
<td>WebTrafMon</td>
<td>A Web-based tool for network traffic monitoring and review. Requires an extensive setup for use in the classroom.</td>
</tr>
<tr>
<td>ns-2</td>
<td>Offers advanced network modelling and simulation; has a non-friendly text based interface.</td>
</tr>
<tr>
<td>EMPOWER</td>
<td>A network animator that requires a significant prior knowledge on the subject of networking.</td>
</tr>
<tr>
<td>Cnet</td>
<td>A network simulator that enables experimentation with network protocols (data link, routing, and transport layers). Requires a basic knowledge of the Linux/Unix operating system.</td>
</tr>
<tr>
<td>dlpjava</td>
<td>A network simulator that can be used to enhance teaching data link protocols. It requires good knowledge of Java programming as well as a system set up.</td>
</tr>
<tr>
<td>WLAN-Designer, LAN-Designer</td>
<td>Web-based tools (prototypes) for illustrating the concepts of network design (wireless and wired LANs), but have limited functionality.</td>
</tr>
<tr>
<td>GloMoSim, ViTAN, VANS</td>
<td>Rich visual simulators for ad hoc networks, suitable for advanced computer network classes; students need to be familiar with the underlying protocols.</td>
</tr>
<tr>
<td>OPNET</td>
<td>It offers advanced modelling and simulation, but maintenance cost is high.</td>
</tr>
</tbody>
</table>
Table 1 lists the tools reviewed earlier along with their key features. Most of the existing tools are significantly demanding in terms of user prior subject knowledge and system setup. Additionally the network simulation packages may be far more complex and detailed than what may be required by courses at introductory level.

Ideally we would have liked to identify a relatively simple and easy to use tool that would provide an integrated suite to cover both wired and wireless networking, with sufficient functionality to facilitate student-centred learning. As none of the existing tools reviewed in this section fulfils our requirements we initiated a project to build a system meeting them. Following a design science approach (Vaishnavi & Kuechler, 2007) we designed, developed and evaluated WebLan-Designer - a Web-based tool for interactive learning and teaching LAN design fundamentals to students with a limited or no background in computer networking. The tool which is described in the next section is different in its goals and its capabilities compared to the existing tools reviewed: it aims to facilitate foundation knowledge acquisition. Once the students are familiar with the basic concepts of LAN design, they can be guided to use a more sophisticated tool such OPNET Modeler to advance their studies further.

WEBLAN-DESIGNER ARCHITECTURE AND FEATURES
Meeting the requirements identified above WebLAN-Designer was developed as a Web-based, and simple to navigate and use tool. It supports teaching and learning of wired and wireless LAN design, and contains a comprehensive set of learning resources. Organized into two tutorial suites, WebLan-Designer provides students with an opportunity to learn computer networking at their own pace and self-assess their level of learning achievement. The easy to use GUI allows
students to create their own learning path to fit in with their prior knowledge of computer networking and with their learning style and preferences.

The WebLan-Designer is currently hosted on a university Web server (http://elena.aut.ac.nz/homepages/Weblandesigner). The implementation involves the use of PHP (hypertext preprocessor scripting language) and MySQL database. The system contains both static and dynamic Web pages. Since its launch in 2005, it has been subjected to extensive tests for performance and robustness.

The high-level conceptual architecture of WebLan-Designer is shown in Fig. 1. The two tutorial suites (Wired LAN and Wireless LAN) have the same logical structure, each developed as a self contained module.

Fig.1. The Architecture of WebLan-Designer.
The homepage (Fig. 2) provides navigation to and within the identically organized modules and their components: Tutorial, Quiz, Modelling, Scenarios, Key terms and Review questions. The module components are described with some illustrative screenshots next.

Fig.2. WebLan-Designer Homepage.

**Tutorial**

The tutorial provides a sequence of learning tasks that help students develop incrementally their knowledge and understanding of LAN design. A student completing the wired LAN tutorial for example, will encounter and eventually master the following key networking concepts: server-based LAN design, network protocols, medium access control protocols (e.g., carrier sense multiple-access with collision detection, token passing), Ethernet and token ring networks, LAN topologies (bus, star, ring, mesh; logical and physical topologies), networking devices (hubs, switches, network interface cards), and switched-Ethernet. In the wireless LAN tutorial, students learn about infrastructure supported wireless networks and ad hoc networks. Each tutorial
includes a set of self assessment questions available at the point of commencing it, allowing the students to evaluate their current knowledge and focus on identified ‘gaps’ while taking a walk-through tutorial. After completing each tutorial the system provides feedback and a measure of the student’s achievement. The tutorials can be used either in an assigned lab/tutorial session supplementing the traditional lecture or outside the class time as self study mode.

In summary, the wired and wireless LAN tutorials are two important modules of WebLan-Designer which provide a walk-through tutorial in completing a set of learning tasks of wired and wireless LAN design. Each tutorial includes self assessment both at commencement and completion.

**Quiz**

Students can assess their knowledge of LAN design at any time by using the two interactive quizzes. Each quiz consists of a set of 25 multiple-choice questions with four possible answers; each question is designed to cover a key LAN design concept. At the end of a quiz session, the system displays scores such as the percentage of the correctly answered questions. It also provides feedback on incorrect answers. Figure 3 shows a screenshot of a quiz summary page.

A quiz can be used by the instructor to gauge the overall level of existing LAN design knowledge in their classes prior to starting the course. WebLan-Designer provides a user-friendly environment for quiz management and therefore instructors can easily update the two quizzes on a regular basis to suit their needs.
Modeling

The modeling engine of WebLan-Designer allows students to develop a LAN model by selecting the network components and the desired configuration. The student can experiment with various LAN topologies and channel access protocols. The system supports a number of physical and logical topologies for wired LAN modeling (e.g., physical and logical star, physical star and logical bus, physical star and logical ring, physical and logical bus, and physical and logical ring). For wireless network modeling, the system supports both ad hoc and infrastructure networks. LAN modeling is one of the most interesting features of WebLan-Designer because students can interact with the system and see their models on the screen. They can observe the topology and the way LAN components such as workstations, servers, and printers are placed on LAN media. “There are many ways of connecting up a network” - students can verify this statement by clicking on the ‘Refresh’ button on a LAN model (Fig. 4). Each time they refresh
the model, LAN components are placed on the media randomly reflecting the characteristics of a real network design.

An example of a wired LAN model generated by the system is shown in Fig. 4. The following configuration was selected.

**Topology:** physical and logical star; **Number of workstations:** 10; **Number of servers:** 1; and **Number of printers:** 1

Similarly, for a wireless infrastructure-based network, WebLan-Designer generated the valid wireless LAN model (Fig. 5) based on the following configuration.

**Topology:** infrastructure network; **Number of mobile workstations:** 10; **Number of Personal Digital Assistants (PDAs):** 8; **Number of printers:** 0.
Fig. 5. A system generated model of an infrastructure-based wireless LAN.

Scenarios

Each network scenario starts with a description of a realistic situation and includes a set of requirements to be met by a network model. The scenario is completed by providing a model satisfying the requirements. The eight small business scenarios (four wired and four wireless) allow students to examine a sample of backbone networks. By observing and analysing a network scenario and its solution, students can develop a better understanding of corporate-wide LAN design. Figure 6 shows one of the wireless LAN scenarios. The two additional challenging
network design exercises (with no model answers provided) for students to develop their problem solving skills. In the classroom, the instructor can provide feedback on the validity of student’s solutions.

**Key Terms**

More than 200 key terms and definitions related to wired and wireless networks are defined and arranged in alphabetical order in the two respective pages. Examples of key wired LAN key terms include: bus, star, mesh, and ring physical topologies, logical topology, medium access control protocols, carrier-sense multiple access with collision detection (CSMA/CD), token passing, file server, hubs, switches, routers, unshielded twisted-pair (UTP) category 5e, coaxial cable, optical fibre. Examples of wireless LAN key terms are ad hoc network, infrastructure network, wireless interface card, access point, wireless channel, carrier-sense multiple access.

![Diagram of a scenario-based wireless LAN design](image)

**Fig.6. Scenario-based wireless LAN design.**
with collision avoidance (CSMA/CA), modulation, demodulation, direct sequence spread spectrum (DSSS), frequency-hopping spread spectrum (FHSS). Both instructors and students may find these key terms and definitions are handy to brush up their networking skills.

**Review Questions and Answers**

A series of 40 review questions and their answers provided which can be used for revision and self assessment reinforcing student learning and achievement. The review questions are aligned with the content of the tutorials on wired and wireless LANs. Each review question is accompanied by a suggested model answer. A sample of three review questions and answers is shown in Table 2.

<table>
<thead>
<tr>
<th>Review question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the resources that can be shared in a network?</td>
<td>Files, folders, printers, CD-ROM towers, scanners, modem pools, routers, gateways.</td>
</tr>
<tr>
<td>Which physical device creates and destroys data frames on a network?</td>
<td>The network interface card (NIC).</td>
</tr>
<tr>
<td>Which shared medium access control protocol is prevalent in wireless LANs?</td>
<td>Carrier sense multiple access with collision avoidance (CSMA/CA).</td>
</tr>
</tbody>
</table>

**Useful Links and Feedback**

The ‘Useful links’ and ‘Feedback’ options on the main menu of WebLan-Designer complement the teaching and learning described above. The ‘Useful links’ page contains links to various resources such as simulation tools, textbooks, white papers and articles relevant to computer network design that would allow further exploration of LAN design concepts. Finally, the system
provides contact details so that users can send their feedback and suggestions for further improvement.

In summary, Web-LAN designer offers flexible and effective teaching and learning resources to help students to learn about LAN design fundamentals. It can be used in the classroom to enhance face-to-face learning by adding an online element to it; for off-campus the system provides support for self-paced independent student learning.

WEBLAN-DESIGNER: PRACTICE AND EVALUATION

WebLan-Designer has been extensively tested in the classroom and across multiple undergraduate programs (IT, IS, and CIS curricula) with students building knowledge about computer networking as active participating in the learning process.

In lecture sessions, the tool was used to demonstrate LAN design, liven-up the traditional lectures and let students become aware of its functionality. In tutorial sessions, students were assigned in-class tasks that included using WebLan-Designer. After gaining some basic knowledge, students were first asked to design a LAN based on a given scenario, and then to verify visually and interactively their own solution by engaging with the respective tutorial and the network modeller. Gradually students were introduced to the full spectrum of system capabilities and were encouraged to reinforce LAN design fundamentals further using the interactive quizzes, network design scenarios, key terms and definitions, and the review questions and answers.

Students can learn the material at their own pace and convenience because the system can be used outside the classroom (e.g., at home or in a computer laboratory). The system can also be
used for revision in preparation for the final examination. For independent study using WebLan-Designer students may use the suggested sequence of study shown in Fig. 7.

![Fig. 7. A suggested sequence of independent study.](image)

The authors have been using WebLan-Designer as an aid to enhance teaching and learning of LAN design for the last six years. As far as its performance and robustness are concerned, the system was first tested rigorously by the system developers, and then by end-users (instructors and students) at AUT University. The tool has been adopted by other lecturers/instructors in New Zealand and overseas, and their experiences of using WebLan-Design have been very positive. The easy-to-use GUI makes WebLan-Designer an ideal tool for undergraduate students exploring computer network design (no need for a user manual). Being active participants in the learning activities, students become increasingly motivated to learn more, and find the course more enjoyable (compared to student opinions about the previous course with no interactive component and no hands-on activities). The system has been evaluated extensively both formally by students (through a survey) and informally in discussions and personal communication with peers. The authors regularly seek feedback, for the purpose of improving the system further.
**Classroom Evaluation by Student Feedback**

A formal classroom evaluation of WebLan-Designer was conducted during Semesters 1 and 2 of 2006, across multiple streams of students taking two introductory level courses: eBusiness IT Infrastructure (2nd year students, Bachelor of Business), and Networking 1 (1st year students, Bachelor of Computer and information Sciences). The evaluation was facilitated by a member of the teaching team and the anonymity of the respondents was assured. Participation in the evaluation was entirely voluntary. Students were asked to complete a short questionnaire with six questions (Table 3). Following Ma, Andersson, & Streith (2005) the first five questions refer to the two fundamental and empirically validated determinants predicting an individual user’s intention to use new technology that are part of TAM (Technology Acceptance Model) – perceived usefulness, and perceived ease of use. Questions 2 and 3 measure the perceived usefulness of the tool as indicated by its two major characteristics (interactivity and rich resources) while questions 1, 4, and 5 measure its perceived ease of use (interface convenience, content flow, and navigation). Following Wixom and Todd (2005) who found that satisfaction was an indirect predictor of intention to use new technology, question 6 was added to investigate student satisfaction with the tool. A five point scale was used, with 1 as ‘poor’ and 5 as ‘excellent’. An open ended question asking students to reflect on their learning experiences was also included.
Table 3. Evaluation Questionnaire

<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>(QE1)</td>
<td>How convenient did you find the user interface of WebLan-Designer to use?</td>
<td>4.18</td>
</tr>
<tr>
<td>(QE2)</td>
<td>How useful did you find the interactive learning experience to be?</td>
<td>4.18</td>
</tr>
<tr>
<td>(QE3)</td>
<td>How useful did you find the learning resources to be?</td>
<td>4.20</td>
</tr>
<tr>
<td>(QE4)</td>
<td>How easy did you find WebLan-Designer to use and follow?</td>
<td>4.20</td>
</tr>
<tr>
<td>(QE5)</td>
<td>How easy did you find it to navigate through WebLan-Designer Web pages?</td>
<td>4.22</td>
</tr>
<tr>
<td>(QE6)</td>
<td>How effective (overall) was WebLan-Designer in helping you improve your understanding of LAN design concepts?</td>
<td>4.25</td>
</tr>
</tbody>
</table>

Forty undergraduate students (60% male and 40% female) from both “E-business IT Infrastructure” and “Networking 1” completed the questionnaire. The student age varied from 22 to 33 years for male students, and from 21 to 30 for female students. The survey results showed that the majority of the respondents found WebLan-Designer an easy-to-use and a useful tool providing excellent learning resources (Table 4). The evidence suggests that the tool has met the design requirements discussed earlier and second, that it may provide a valuable service to learners and teachers.

Table 4. Evaluation Results (N=40)

<table>
<thead>
<tr>
<th>Category</th>
<th>Question</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Use</td>
<td>(QE1)</td>
<td>4.18</td>
</tr>
<tr>
<td></td>
<td>(QE4)</td>
<td>4.20</td>
</tr>
<tr>
<td></td>
<td>(QE5)</td>
<td>4.22</td>
</tr>
<tr>
<td>Usefulness</td>
<td>(QE2)</td>
<td>4.18</td>
</tr>
<tr>
<td></td>
<td>(QE3)</td>
<td>4.20</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>(QE6)</td>
<td>4.25</td>
</tr>
</tbody>
</table>
The responses to the open ended question revealed that students felt they had learned considerably through the interactive learning activities provided. A typical comment is shown below:

“I like especially the LAN modelling part. Review questions and answers, and the network scenarios are very useful. Interactive learning through tutorials and quizzes ... A very useful resource good for learning and teaching ...”

Evaluation by Student Developers

WebLan-Designer was implemented (Web development and coding) by two final year undergraduate students specializing in software development. The student developers tested the robustness of the system and updated the system based on staff and student feedback. At the completion of the project, the students were asked to reflect on what they had learnt about computer network design while working on the project. This learning is evidenced in the students’ reflective statements, an example of which follows:

“I have learnt a lot through this experience ... WebLan-Designer. The resources/materials given to us allowed me to revise and strengthen my understanding about LAN design.”

Evaluation by Other Students

Students from other universities are using WebLan-Designer to learn about network design and to work out their assignments. They often provide feedback and suggestions for improvement (e.g., J. Wilhelm, personal communication, September 14, 2009). Some students have sent us the solutions of to the scenario-based exercises (A. Deore, personal communication, April 14, 2011). The comments about design, user friendliness and comprehensiveness of WebLan-Designer’s learning resources are particularly favourable.
...First I must commend your site, in its ease of use and explanations of terminology and key concepts.... Again, I commend your site, as it is more user-friendly than most dedicated software programs that I've seen. (J. Wilhelm, personal communication, September 14, 2009).

“... I was really impressed WebLan-Designer: a Web-based Software Tool to Enhance Teaching and Learning Wireless LAN Design ”. (Haider, University of Arkansas at Little Rock, USA; personal communication, August 24, 2005).

Evaluation by Peers in New Zealand

Peer feedback about WebLan-Designer was received at the two demonstrations arranged at two national conferences (N.I. Sarkar & Petrova, 2005; N.I. Sarkar & Petrova, 2006). The discussion during the conference presentations showed a high level of interest in using WebLan-Designer in the classrooms. Overall the peer comments were positive and constructive; some of the recommendations were implemented in the final version of the system.

Evaluation by Peers Overseas

Since the system was made available to the public through the Internet, a number of computer networking lecturers across the globe have started using WebLan-Designer in their classes or are planning to use it.

...I'd like to say that I ... would like to try the tool [WebLan-Designer] myself. I want to ask if accessing this tool is allowed for free, and would be very happy to receive any further details from you. (M. M. Jamous, personal communication, May 15, 2009).

The authors have received the following comments:

...I've noticed that the use of the WebLan-Designer Tool [was] very useful to the students to understand networking concepts. I've had a very positive feedback from them. And I'd like to
thank you for your bright initiative to create this tool. (V. Pimentel, personal communication, March 19, 2011).

The suggestions for further improvement of WebLan-Designer include expanding the system capacity (beyond 20 stations), adding an explanation to accompany a generated configuration model, providing a justification to the scenario examples, and even adding an automated subsystem capable of putting together a scenario solution based on generated configuration models. The authors will incorporate some of these suggestions in the next system upgrade.

**Comparison of Learning Improvements**

The authors attempted next to arrive at a quantitative measure of the possible impact of WebLan-Designer on student learning and comprehension. In three consecutive semesters (2005-2006) students were given an assessment test which consisted of 25 multiple-choice questions on both wired and wireless LAN design (see Appendix). The test was administered after students had been exposed to the concepts but prior to be given access to WebLan-Designer in class. Then, after the entire class had an opportunity to gain hands-on experience with the system and go through the same concepts again, the test was repeated and the results used to gauge the level of change in student learning and comprehension. A total of three groups of students participated with 11, 13, and 17 students respectively in each group.

The three groups showed similar patterns in terms of scores in the tests ‘before’ and ‘after’. The example below is from the last run (semester 2, 2006). The class consisted of 17 students, 11 males and six females. While the class was not a particularly large group, it was at least a diverse mix (domestic, international, and exchange students). The ‘before’ and ‘after’ tests were conducted among students having similar academic background, similar prior knowledge of the subject area (low), and who had been exposed to the same instructional class material.
The impact of WebLan-Designer on student performance was measured by comparing student scores in the first and the second runs of the test (Table 5). Defining ‘improvement’ as (‘score after’ - ‘score before’)/(100 - ‘score before’) in order to obtain a measure of learning achievement, it can be seen that students showed an improvement ranging from 13% to 75%, with two students showing no improvement. The average class improvement was 35%. It would be reasonable to attribute this improvement to the practical WebLan-Designer experience that students had between the two tests since no other form of instruction was given before the second test.

Table 5. Impact of WebLan-Designer on Student Learning and Comprehension

<table>
<thead>
<tr>
<th>Student</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement (%)</td>
<td>15.38</td>
<td>55.56</td>
<td>75.00</td>
<td>50.00</td>
<td>52.63</td>
<td>13.33</td>
<td>38.10</td>
<td>41.18</td>
<td>28.57</td>
</tr>
<tr>
<td>Student</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Improvement (%)</td>
<td>35.29</td>
<td>0.00</td>
<td>50.00</td>
<td>50.00</td>
<td>30.00</td>
<td>33.33</td>
<td>0.00</td>
<td>45.45</td>
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</tr>
</tbody>
</table>

Average improvement: 35.13%

The average class performance on each individual question in the test is shown in Table 6. The fraction of the students in the class who answered correctly (expressed as a percentage) each of the 25 questions in the test ‘before’ and ‘after’ they had experience with WebLan-Designer are shown in columns 2 and 3, 6 and 7, respectively. It can be seen that significant improvement was achieved in 13 out of the 25 questions (2, 4, 5, 6, 9, 10, 15, 17, 18, 20, 21, 24, 25): these were answered on the average above the pass mark of 50% in the ‘after’ test while they were answered on the average below the pass mark in the ‘before’ test. With respect to the rest of the questions the results indicate that further improvement was achieved in questions (1, 3, 8, 11, 13, 14) and in
questions (19, 23). However in the second case the pass mark was not reached, on the average. Finally the improvement in answering questions (7, 12, 16, and 22) was relatively low compared to the rest of the questions. The last two results can be explained in part with the fact the WebLAN-Designer does not address the related theoretical content to a significant degree. The results provide useful feedback for the instructor: they identify areas where misconceptions may have prevailed and indicate that additional resources and tuition may be needed (e.g., questions 19 and 23). The quizzes can also be modified in order to re-focus self-assessment and enhance its impact on learning.

Table 6. Student Performance on each Question in the Class Test

<table>
<thead>
<tr>
<th>Question</th>
<th>Percentage of class answering correctly</th>
<th>Improvement (%)</th>
<th>Question</th>
<th>Percentage of class answering correctly</th>
<th>Improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>1</td>
<td>94.1</td>
<td>100</td>
<td>100.00</td>
<td></td>
<td>18</td>
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<tr>
<td>3</td>
<td>88</td>
<td>100</td>
<td>100.00</td>
<td></td>
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<td>8</td>
<td>59</td>
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<td>71</td>
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<td>41</td>
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<td>100.00</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

Average score before: **37.9%**. Average score after: **62.4%**. Improvement: **47.05%**
**DISCUSSION AND CONCLUDING REMARKS**

WebLan-Designer has been developed and used in the classrooms to enhance the teaching and learning of LAN design fundamentals. The pedagogical approach underlying the use of WebLan-Designer as a tool to assist student learning and comprehension is aligned with the constructivist approach to teaching and learning as the tool provides students with a means to objectify network topology concepts (Chen, 2003). The flexibility of the Web based system enhances student experiences by introducing variation and stimulating interest and understanding (Berglund, 2003). Additionally the system supports student learning even for students who may differ in the level of prior knowledge they come with. While more experienced students can use quizzes and/or network scenarios straightaway, ‘beginners’ can focus on learning the fundamental concepts by going through the key terms and definitions first and then move on to network modeling. Regardless of the path taken students are provided with plentiful opportunities to identify their own learning needs and to construct new knowledge by internalizing the basic ideas and concepts of LAN design.

WebLan-Designer has been developed with simplicity in mind (as opposed to sophisticated) with a user-friendly graphical user interface. This simplicity allows students to use the system without any training or a special set up. It can be accessed at any time and provides walk-through tutorials on both wired and wireless LAN design so that students can learn about computer network design at their own pace. It features both knowledge building and self assessment capabilities and can support a variety of blended learning approaches that were found to be more effective compared to pure face-to-face models (Means, Toyama, Murphy, Bakia, & Jones, 2009).

We have been using the system for more than six years now in the classrooms to blend the face-to-face and on-line environments and engage students in a collaborative learning model. We
have found that the capability to tailor instruction to meet the individual’s specific needs and the opportunity to test and reflect on one’s progressively achieved level of understanding has been especially effective, as also implied in (Means et al., 2009); the evaluation and test results also suggest that WebLan-Designer can be used successfully as a teaching and learning tool.

This tool is available at http://elena.aut.ac.nz/homepages/weblandesigner/ so that students can learn about LAN design at their own pace and convenience. The system was evaluated by students and their responses to the questionnaire about WebLan-Designer were highly favorable. The students indicated that they had found WebLan-Designer easy to use and that it helped them to gain a better understanding of LAN design fundamentals. WebLan-Designer has a positive impact on student learning and comprehension. Results obtained have shown that the students scored better in the class test with WebLan-Designer experience.

We have been updating WebLan-Designer on a regular basis and the most recent update in quizzes management was in September 2011. WebLan-Designer can be used in other fields, such as computer engineering and management information systems. Currently, the system displays LAN diagrams involving up to twenty workstations, 10 mobile stations, 10 PDAs, four file servers, and four printers, which is adequate for current teaching and demonstration purposes. WebLan-Designer can easily be upgraded to accommodate any number of devices. The incorporation of TCP/IP networking is proposed as a future development. WebLan-Designer is available free of cost to faculty interested in using it to supplement teaching computer networking.

ACKNOWLEDGMENT
WebLan-Designer was funded by AUT through a contestable RELTS grant. An earlier version of this paper (WebLan-Designer: A Web-based System for Interactive Teaching and Learning LAN
Design) was presented at the 3rd IEEE International Conference on Information Technology: Research and Education (ITRE’05).
APPENDIX: Assessment test (maximum time allowed to complete is 25 minutes)

Please answer as many questions as you can. Thank you for your participation.

1. Which of the following statements about a LAN is true?
   A. A computer network which covers a relatively small geographic area
   B. A computer network which covers a relatively large geographic area
   C. A computer network which does not cover any geographic area
   D. None of the above

2. A network consists of the following basic components:
   A. Repeaters, hub, cabling, modems, application software.
   B. Fibre optic cabling, hub, workstations, multistation access unit
   C. Network operating system, cabling, network cards, workstation
   D. All of the above.

3. Which of the following statements about bandwidth of a channel is true?
   A. Greater the bandwidth, higher the data rate
   B. Greater the bandwidth, lower the data rate
   C. Lower the bandwidth, higher the data rate
   D. All of the above

4. Match the description of a LAN topology. A break in a cable anywhere on the network can disable the entire network:
   A. Ring   B. Bus   C. Star   D. Both A and B

5. A Star topology is usually cabled with which type of cabling?
   A. Thin coax  B. Thick coax  C. Fiber Optic  D. UTP

6. A television broadcast is an example of:
   A. Simplex transmission  B. Half-duplex transmission
   C. Full-duplex transmission  D. All of the above

7. Which one of the followings is not a channel access method for a LAN?
   A. CSMA/CD  B. Token Passing  C. CAMA/CA  D. Token ring

8. Which one of the followings is not a LAN topology?
   A. Star   B. Ring   C. Bus   D. Ethernet

9. Which of the following statements is true?
   A. A Hub is faster than a switch
   B. A Hub is slower than a switch
   C. A Hub can transmit data simultaneously from two or more sources
   D. All of the above

10. Which of the following statements about a computer network protocol is true?
    A. A protocol is a collection of rules for formatting, ordering, and error-checking data sent across a network
    B. A protocol is only required just before data transmission across a network
    C. Data transmission across the network can be success without a protocol
    D. All of the above

11. What is the bandwidth of a signal that ranges from 100 kHz to 10 kHz?
    A. 110 kHz  B. 90 kHz  C. 1.10 kHz  D. 9 kHz
12. The IEEE 802.4 is an example of:
   A. Ethernet LAN  B. Token Ring  C. Token Bus  D. Wireless LAN
13. Frequency is measured in:
   A. Bps  B. Mbyte  C. Mbits  D. Hertz
14. Terahertz is equivalent to:
   A. 1 trillion hertz  B. 1 billion hertz  C. 1 million hertz  D. 1 thousand hertz
15. Which one of the following statements about optical fibre cable is true?
   A. Higher bandwidth than UTP cable  
   B. Lower bandwidth than UTP cable 
   C. Same bandwidth as coaxial cable
   D. None of the above
16. Match the definition of a networking term: The block of data sent over an Ethernet network is called:
   A. Protocol stack  B. Frame  C. Cell  D. Subnet
17. The maximum recommended segment length in a thin ethernet (10Base-2) is:
   A. 100 feet  B. 185 feet  C. 100 metres  D. 185 metres
18. What does Wi-Fi stand for?
   A. Wired-Fiction  B. Wireless-Fitting  C. Wireless-Fidelity  D. Wired-Fix
19. What is the maximum theoretical speed of IEEE 802.11b?
   A. 12 Mbps  B. 54 Mbps  C. 22 Mbps  D. 11 Mbps
20. What is the maximum theoretical speed of IEEE 802.11a?
   A. 12 Mbps  B. 54 Mbps  C. 22 Mbps  D. 11 Mbps
21. Is Wi-Fi a secure network?
   A. Yes, better than wired networks
   B. No, worse than wired networks
   C. Yes, equal to wired networks
22. Does it cost more to set a Wi-Fi network than a wired network?
   A. Yes, a lot more than a wired network
   B. Yes, but not much more than a wired network
   C. No, the same
   D. No, a lot cheaper than a wired network
23. A wireless LAN is always requires an Access Point:
   A. False  B. True
24. A wireless LAN is better than a wired LAN because:
   A. It offers mobility  B. It offers high bandwidth
   C. It is more secure  D. Both A and B
25. The basic unit serviced by a base station is called:
   A. City  B. Cell  C. Town  D. Village
REFERENCES


