Improving the Teaching of Computer Networks through the Incorporation of Industry based Training Courses

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Abstract—Computer networks are an integral part to the proper functioning of today’s society. They are also becoming essential components in almost all the software programs as well because of the need to get devices interconnected. As such, software engineers should be well prepared and able to use and integrate them. In this paper, we provide an overview of current Computer Networks teaching approaches at some current universities, and propose an updated curriculum based on the up-to-date approaches and our own teaching experiences. In particular, we describe our approach using the D-Link Baltija training courses, which are organized by the multinational company that makes network related products, to make the teaching more practical and up to today’s current developments. In addition, we propose extensions to the course, improvements that involve cooperation between remote institutions, namely Vytautas Magnus University (VMU) and Xi’an Jiaotong-Liverpool University (XJTLU), to improve hands-on experience.

Keywords—university teaching; computer networks; D-Link; Industry-University collaboration; Industry sessions.

I. INTRODUCTION

Computer networks are ubiquitous nowadays with this technology being integral part of today’s connected world. Moreover, their usage is becoming even more widespread and data demanding [2]. Therefore, computer scientists and engineers should know how they work and how to manage them as well as how to integrate them with other software and hardware components.

The field of Computer Networks changes constantly; therefore, teaching materials and approaches should change and be up to date, i.e. to adapt to novel, state-of-the-art technologies as well as novel educational approaches. One of the ways to improve the course is to look at the problems we encountered in everyday life by computer professionals. One of the sources of such information is information collected during industry organized training sessions, in our case the ones organized by D-Link Baltija. In this paper we analyze materials used at the Vytautas Magnus University (VMU) Computer Networks course and materials collecting in D-Link Baltija training courses from 2006.

The VMU course on Computer Networks [1] introduces the fundamental concepts of computer networking, classification, architecture and protocols, computer network design methods, implementation, the principles of data communications environments and technologies, security of the network and the management of communication networks development prospects. In 2012, the course has been updated based on the current trends in computer networks technologies and D-Link training courses results. Today, it is up-to-date and covers modern network technologies, it has theoretical and practical components. Practical sessions are based on network modeling with specialized software.

One of the first departments established at Xi’an Jiaotong-Liverpool University (XJTLU), a six-year old university in China created by a UK university and Chinese one, is the Department of Computer Science and Software Engineering. It offers a course on computer networks, named Internet Principles, where students learn networked computer systems in general and the Internet in particular. They should acquire the basic principles that govern the operation of networked systems, the design and organization principles of successful networks, and the key protocols and technologies that are used in the contemporary Internet. Given the success of the Computer Networks class in VMU, we at XJTLU want to emulate the results of including the D-Link training sessions into the provision of our Internet Principles course.

Most of leading technology-oriented universities have at least one computer network course. Most of them provide advanced courses at the graduate level as well. The courses in networking are quite similar at bachelor’s degree, however advanced graduate programs differ substantially: some are oriented toward network services programming, while others emphasize network hardware design or networking protocols.

In this paper we present an overview of general Computer Networks teaching approaches worldwide as well as in VMU and XJTLU in Section II. We discuss the D-Link Baltija training courses in Section III. and describe proposed curriculum in Section IV. Experimental evaluation is discussed in Section V. We conclude the paper in Section VI and present some future directions.
II. CURRENT APPROACHES

A. General Approaches

The Massachusetts Institute of Technology (MIT) is regarded as one of the best technology-oriented universities and can be considered as an example for others to follow. MIT has five computer networks courses (see Table 1).

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.857</td>
<td>Network and Computer Security</td>
<td>Undergraduate</td>
</tr>
<tr>
<td>6.263</td>
<td>Data Communication Networks</td>
<td>Graduate</td>
</tr>
<tr>
<td>6.829</td>
<td>Computer Networks</td>
<td>Graduate</td>
</tr>
<tr>
<td>6.973</td>
<td>Communication System Design</td>
<td>Graduate</td>
</tr>
<tr>
<td>18.996</td>
<td>Topics in Theoretical Computer Science: Internet Research Problems</td>
<td>Graduate</td>
</tr>
</tbody>
</table>

From the 5 courses [3][4][5][6][7], only 6.857 [3] is an introductory course for bachelor’s students, while the others are for master’s students and focus on different specialized areas of computer networking.

Similarly, Stanford University, has two courses related to computer networks: Introduction to computer networks (EE284) [8] and Advanced Topics in Networking (CS244) [9]. The first course is for the undergraduates and contains an overview of formation and transmission of frames, network structure and types, OSI model [10] levels and the Internet architecture. It is comprehensive enough to reveal the principles of network operation at a level close to the theoretical perspective. Because the lecture materials are not publicly available, we do not have the exact details. Nevertheless we are aware that there are practical tasks based on programming client-server application models. The second course (updated in 2012) is for postgraduates and focuses on higher-level protocols and shared architecture. Students are encouraged to take an analytical and research orientated work. Practical tasks require students to do programming activities.

Stanford and MIT focus on the active participation of the students in lectures, as the students are assessed taking into account their preparation and participation in discussions.

Carnegie Mellon University has two courses related to computer networks Computer networks: for undergraduates (15-441) [12] and for postgraduates (15-744) [13]. The first course is positioned as an introduction to computer networks with the goal to present the operating principles of modern networks and their development prospects. Last update to the course was conducted in autumn 2011. Practical classes are mainly composed of programming tasks. The second course partially overlaps with the first course on the basic principles of networks, but there is also different material which takes students in a deeper analysis and understanding of networks. It includes workshops which are tailored to the tasks used in the network simulator ns-2 [11]. Much attention is paid to the student’s projects, an important component of the course is to teach students to do independent research on the network related problems.

Cambridge University has one computer networks course [14] consisting of the several parts. The introduction of the course has information on Internet technologies in the broad sense. Topics on network applications, transport protocols, the network layers according to OSI model, and transmission level follow. The course ends with lectures on data centers. It is of particular interest to us that some fundamental concepts are left and taught at the end of the course. Although not much information about the practical components is publically available, NetFPGA platform [15] is used for simulating the behavior of network equipment.

B. Computer Networks Course in Vytautas Magnus University

The course on Computer Networks at Vytautas Magnus University (VMU) introduces the fundamental concepts of the computer networking, classification, architecture and protocols, computer network design methods, implementation, the principles of data communications and technologies, security of the network and the management of communication networks development prospects. It was updated and heavily revised in 2012, therefore the material is up-to-date with modern network technologies and market trends. The theoretical part provides information from foundations of the signaling in network transmissions up to the high level protocols and network applications. Practical sessions are based on the network modeling with specialized software – OPNET IT Guru Academic Edition [16]. The practical work contains tasks for network design, throughput testing and routing protocols.

C. Computer Networks Course in Xi’an Jiaotong-Liverpool University (XJTLU)

The only computer networks course in XJTLU focuses on the principles underlying data communication. It covers the different layers involved: presentation and application, transport, network, data link, and physical layer. It deals with network security issues such as public key encryption, cryptography, authentication and repudiation. Students, besides attending lecture, need to participate in labs where they put into practice what is discussed in class. They also have a coding project. We plan to either redesign this course or add a new one to expand our computer networks offering to students.

III. D-LINK TRAININGS

The D-Link Baltija [17] office organizes trainings since 2006 with focus to promote D-Link products. The second but more important task is to provide users with knowledge of using D-Link managed devices to their maximum capabilities. D-Link Baltija focuses on the audience with some theoretical and practical skills but lacking knowledge on how to implement network management features into complex production networks. A large percentage of participants come from the ISP segment. D-Link provides information on building efficient networks which in ISP case is a main source of company income.

A. Organization

Several types of trainings are organized and categorized as Marketing, Products, and Technological. Marketing, allows D-Link to introduce new features of new products. Network
technologies are not discussed in depth, only mentioned in the periphery. They often organize focus groups whose participants are mainly composed of people working in trade chain and also anyone interested in new products or features.

In products trainings D-Link presents their products and their usability features. These training sessions are illustrated with rich examples from production networks. However, network standards and performance are only mentioned. Such type of training is suitable for people who are interested in the theoretical foundations and operational protocol principles. The main audience is network administrators.

Technological trainings deal with the standards and their implementation and configuration. The material contains many configuration examples and realistic network scenarios. This category includes training on use and application of the wireless networks and switches. The primary target audience is network administrators working with enterprise networks and Internet service providers.

In 2012, in collaboration with the VMU, D-Link prepared and led some workshops. The material was based on the D-Link switch and firewall technology training with addition of practical tasks. The tasks were prepared with questions requiring self-study and deeper examination of standards. The training sessions encourage open thinking and what if situation analysis, rather than a simple repetition of the given task.

To evaluate effectiveness of the courses questionnaires are used, all the participants are interviewed, and their responses evaluated. After each session, D-Link provides participants questionnaires with five questions (see Table 2).

<table>
<thead>
<tr>
<th>No</th>
<th>Question</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The seminar was informative and provided useful insights.</td>
<td>To understand whether D-Link provides necessary and relevant information.</td>
</tr>
<tr>
<td>2</td>
<td>I have received detailed answers to my questions.</td>
<td>To estimate if the facilitator was able to understand participants’ questions and to provide meaningful answers.</td>
</tr>
<tr>
<td>3</td>
<td>Recommend others to visit this workshop.</td>
<td>To assess if participants see the workshop relevant to their colleagues.</td>
</tr>
<tr>
<td>4</td>
<td>The venue and time was right for me.</td>
<td>To determine how convenient the time and place are for the participants.</td>
</tr>
<tr>
<td>5</td>
<td>The training material has been carefully prepared and was accurate.</td>
<td>To evaluate D-Link’s ability to prepare a neat, accurate and understandable visual material.</td>
</tr>
</tbody>
</table>

Fig. 2. The five questions given to D-Link training participants.

Respondents are asked to grade each statement on a scale from 1 to 10 (with 10 being the highest). After each training D-Link Baltija analyzes all the answer. A number of the participants are D-Link customers and the nature of their business is known, so D-Link can roughly assess the qualifications and this information will help analyze answers and their importance.

B. Analysis

Over the last 3 years D-link Baltija organized 145 training sessions, which were attended by 1246 people. Evaluations of the response sheets gave an average score of 9.7 out of 10 for all the trainings. People were most interested in wireless and switching technologies trainings. These events had most participants and a lot of questions from participants. Those trainings provide information which can improve network operation for end users. It can be assumed that users are most interested in training sessions which give information and skills they can use in their work places.

IV. PROPOSED CURRICULUM

Based on the analysis in Sect II and III we propose the following tentative curriculum.

A. Theory

Based on D-Link Baltija training sessions and collected responses, it can be safely assumed that university courses can be improved. First of all, theoretical parts of the VMU computer network course must be more tied to the actual network standards. Students have to get not only theoretical knowledge but also learn actual standard, e.g. how they are implemented and what are the latest improvements.

Some suggestions for VMU network course improvement.

1. A section about optical cables and signaling should also include information about PON [19] networks and WDM [20].
2. Expanding the Wireless section with information about IEEE 802.11ac [21] standard and wireless security.
3. Addig information about STP evolution into RSTP (IEEE 802.1D-2004) and MSTP (IEEE 802.1Q-2005) as it currently cover only basic concept of STP.
5. Present sFlow [22] in addition to the already covered RMON (RFC2819) standard.

B. Practice

The undergraduate study program could be updated with practical work on the current network equipment that the industry uses. Students should be given opportunities to practically implement the theories discussed in lectures. It is recommended to include actual network problems and to allow students to perform deep analysis of the solutions to the problems. Since not everything needed for the practice is presented in the theoretical course, the material should include minimal theoretical introduction. Proposed practice tasks:

01 “Basic switch management commands”
02 “MAC, ARP entries and their management”
03 “802.1q VLAN. Asymmetric VLAN”
04 “Spanning Tree Protocol and loopback detection”
05 “Access Control List. Operation and applications”
06 “802.1x and other user identification methods”
07 “QoS, data priorities and their management”
08 “Routing basics in switches”
09 “Network firewalls - basic settings”
C. Collaboration Between Universities

We would propose the following collaboration between universities.

1. Practical task 10, Virtual Private Network (VPN) could be established among universities.
2. Students could collaborate on the selected practical tasks, and moreover, use VPN for communicating between the universities.
3. Teams created from students from different universities could be formed for certain tasks.
4. Joint distance lectures on the selected topics could be arranged.

We plan to start joint VPN practical tasks and several joint distance lectures, and move to establishing inter-university teams. Both VMU and XJTLU are keen to establish such a joint program.

V. EXPERIMENTAL EVALUATION

Only parts of the proposed approach were evaluated, i.e. the first two practice works were presented to students in the autumn semester in VMU (2012). That would be Basic switch management commands to get used to managing switches and see the information which it can provide about network status. Second practice is called MAC, ARP entries and their management. Students get acquainted with MAC and ARP management. Some problems are presented to students, such as MAC and IP address spoofing.

In spring of 2013 D-Link Baltija created and presented 11 practical training sessions open to the public. Some practical tasks are based on Switching Technologies in Modern Networks book [18]. Eight of them are based on switching technologies and three are based on firewalls. Full list can be seen in proposed curriculum of this document. VMU and D-Link network laboratory is used as a training location.

VI. CONCLUSIONS AND FUTURE PLANS

We proposed a novel approach for teaching Computer Networks course which includes industry relevant technologies and problems. Our approach is molded from practical experience of the training sessions offered by D-Link Baltija (Baltic). The course in our university was expanded not just to give theoretical and software engineer views on the computer networks, but to include a practical view of computer network administrators, both large and small, with all practical problems and day-to-day tasks.

We are planning to evaluate collaborative teaching in future, starting from establishing VPN between universities and joint distance lectures, and later on forming inter-university student teams to solve practical network tasks. Such collaborations among students will help them to understand how theories are implemented in actual networks. They will appreciate how the technology works in real scenarios and also potentially be able to identify some problem not addressed by current solutions. The idea is for the students to work remotely together and figure out the solutions to network issues from different networked sites.

We plan to improve course constantly, based on the results and changing world of computer networks. The authors are from two universities located at a far distance and are planning to establish a course jointly provided in two campuses. There are many challenges to overcome (e.g., language barriers, different semester schedules, class sizes), but we believe we can provide an enhanced learning experiences to students well aligned with the needs of today's networked world.

REFERENCES