Upgrading of a Data Communication and Computer Networks Course in Engineering Technology Program

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Upgrading of a Data Communication and Computer Networks Course in an Electrical Engineering Technology Program

Abstract

Data network communications is traditionally a course offered by computer engineering technology curricula, with the primary objective to introduce to the fundamental concepts in data communication and computer networks, as well as some level of hands-on component related to this area. Typical topics in such courses are the layered model of data communication, specifically the OSI seven-layered model, Internet routing, communication standards, protocols and technologies, and learning methods used to design the network and send data over the network in a secure manner. In the last decades, the data communication and applications have grown and become ubiquitous in both industry and people's everyday life, alongside with increasing data rates and emerging broadband technologies, i.e., Internet access technologies. The ability to connect with other computers, remote systems, and mobile devices is also contributing to the increased number of applications in our daily life. Consequently, courses related to computer networks become imperative for students in engineering technology programs, as they are essential in preparing the students for the level of technology required on the current job market. However, it is challenging to keep up in classrooms with today's industry requirements for graduates in terms of both content and hands-on activities. Firstly, the course content should be updated with emerging technologies, such as the Internet of Things (IoT), cloud computing, 5G, cybersecurity, etc. The knowledge of emerging communication technologies is crucial for student's awareness of new trends and to prepare them for the industry, especially telecommunication and Information Technology (IT) sectors. Secondly, the course should cover hands-on activities that are aligned with the theoretical upgrades introduced in the class. Such activities should include the use of network analyzer tools for network analysis and communications protocol development, as well as a network simulator to provide students with a technology development environment for network design, troubleshooting, and protocol modeling in a simulated environment. Following these considerations, this paper presents the way the Data Network Communications course was updated as part of an overall curriculum revision in an Electrical Engineering Technology program. The paper discusses the course topics, the course objectives, and the software tools introduced to support the hands-on activities in the class, including the Wireshark software tool, for network troubleshooting, profiling network traffic and analyzing packets. The paper also presents the way the course was received by students, as well as lessons learned after the first semester of offering it in the new format and the modifications planned for future semesters.

1. Introduction

Data communication, including data gathering, processing, and sharing, is one of the fields that seems to have exponential growth, and it grows much faster than any other field, mostly due to the fact that it became lately an underlying technology for so many other fields. Research and business alike are strongly dependent on the ability to access and process data. In addition, the ability to communicate with other computers and mobile devices through advanced data communication technologies led to significant changes in everyday life and businesses. The Internet has revolutionized data communications and created a digital ecosystem, which allows everyone to connect to each other easily [1-2]. People of any age have used the Internet at some level for either work or personal use, e.g., ordering food, online shopping, sharing a picture and a video, videoconferencing, online education, etc. From a business perspective, the expectations of companies, especially which have offices spread over a wide geographical area, have changed, as they cannot manage their daily operation or financial activity without the Internet. Being able to access information at a high data rate and in a secure manner is crucial for a company in this digital age. The huge pressure in the economy as well as in the society for highly qualified workforce in data communications and computer networks motivates the need of educational institutions to put a high emphasis on data network communications and computer networks courses. Such courses become imperative for students in electrical and computer engineering technology programs, as they are essential in preparing the students for the level of technology required on the current job market.

Courses in data communications and computer networks are offered in Computer Science, Electrical and Computer Engineering and Information Science departments. Such courses typically discuss the OSI seven-layered model, Internet routing, communication standards, protocols and technologies, network design and management, and security [3]. Programming and project assignments as part of the course can help students to understand and gain further insight into the theoretical lectures. According to the study [4], data communications and networking courses are divided into three categories: (1) The fundamental and general topics of computer networks using some practical examples, (2) Internet protocols, and (3) A set of programming and project assignments. The traditional approach to teaching data communications consists of lectures covering theoretical information and mathematical basis, and of laboratory sessions where students can understand better the communication process and how to program a communications protocol. It is very crucial to keep up in classrooms with today's industry requirements for graduates in terms of both content and hands-on activities. These changes place increased demands on departmental resources to offer new content. A computer networks course was discussed in [5-6], which combines the traditional, technical aspects of a computer science course with the business and information emphasis of a traditional information system course. The course is supported by a laboratory session providing the students with hands-on opportunities and activities. It is expected that the content can be extended easily with additional lectures. However, the hands-on activities are more challenging to keep up with the updates in the lectures since new equipment or instructor qualifications would be necessary.

A network simulation laboratory environment was developed for a data communications and networking course, called COMNET III, with several hands-on activities [7-8]. It is an object-oriented design, which allows building models by graphically selecting palette icons representing nodes, links, protocols and traffic, and positioning them on the screen using a mouse. According to this study, student comprehension and interest significantly enhanced with the COMNET III network simulator. A set of new laboratory exercises in the classroom was developed for class demonstrations as well as in the computer laboratory for practical work in computer networking at an introductory level [9]. The results showed that these helped students gain a better understanding of computer networking, and students with practical experience scored better in the final exam than those without practical experience. A classroom environment of computer network laboratory experiments was developed for an undergraduate course on computer engineering [10]. They emphasized the importance of giving attention to theoretical and fundamental knowledge in data communication and networking due to changes quickly. A project was proposed to improve the learning of students enrolled in the data communications courses through a problem-solving approach using OPNET, which is a software environment for modeling, simulating, and analyzing the performance of communications networks [11]. The project helped students to gain a better understanding of complex communications protocols and enable them to gain experience in designing and testing communication networks. Partov network simulation engine was used, which easily implement real network devices and observe how they interact with real Internet traffic, to help students acquire a deeper understanding of the networking concepts in a computer networks course [12].

This paper discusses how to improve the Data Communications and Computer Networks course as part of the Electrical Engineering Technology curriculum, with new lectures on emerging technologies and hands-on activities, including Wireshark [13]. The emerging technologies discussed in the revised version of the course include the Internet of Things (IoT), cloud computing, 5G, and cybersecurity. Wireshark is an open-source packet capture and protocol analysis software, and one of the reasons for choosing it as a class tool was that it is available for free.

2. The Computer Networks Course as part of the Electrical Engineering Technology Curriculum

Ever since the Electrical Engineering Technology (EET) program at Old Dominion University has started, it had offered two areas of concentration, Computer Engineering Technology and Electrical Systems, which are the traditional concentrations in an electrical and computer engineering technology program. While the concentration of the electrical system was offering a variety of courses in advanced electronics, communication systems, power systems or programmable logic controllers, the specialization in either one of the directions was done at the senior level through elective courses. This approach is probably the one followed by most of the programs. However, in 2018, after consulting with the industrial advisory board and in response to the trends in the industry, the program decided to divide the broader Electrical Systems

concentration area into four more specific areas of concentration, namely: Communication Systems, Embedded Systems, Mechatronics Systems and Power Systems. These four new areas of concentration were added to the previous Computer Engineering Technology, to a total of five areas of concentration that the program currently offers. The launch of the new concentration areas was very well received by the incoming students, as they seem to relate better to the more specific areas than to the previous general one. The structure of the curriculum still allows that decide at some point to change their area of concentration to do this with ease and without losing the course credits taken already. Since each direction still includes the requirement for two senior elective courses, courses that are required on one of the pathways may complete the elective requirements on a new pathway, allowing this way the flexibility for the students to change their focus if they come to this decision. The core curriculum for the Electrical Engineering Program, the courses that students on all the concentrations are taking, are in DC and AC circuits, electronic devices and circuits, digital and linear electronics, microprocessors, and programming. The specifics on each of the concentrations are as follows:

- *Computer Engineering Technology* – the hardware-oriented core curriculum is integrated with several courses in Computer Science, which also satisfy the requirements of a minor in Computer Science.

- *Communication Systems Technology* – requires students to take courses in principles of communication systems and wireless communications, and they can take additional courses in computer networks.

- *Embedded Systems Technology* – requires students to take additional courses in microprocessors and microprocessor-based design.

- *Mechatronics Engineering Technology* – requires students to take courses in PLCs, microcontrollers, power and communication systems. On this track, students also take four mechatronics related courses in Mechanical Engineering Technology, completing this way a minor in Mechanical Engineering Technology.

- *Power Systems Technology* – students take additional courses in power systems and machinery, alternative energies and smart grids.

With the development of new concentration areas within the Electrical Engineering Technology (EET) program, a large number of courses were revised and updated, and a series of new courses were introduced. The 400-level course Introduction to Local Area Networks was part of the EET curriculum long before the 2018 curriculum changes and the introduction of the new concentration areas. The focus was on the design, installation, and management of PC based local area networks, and topics included LAN/WAN concepts (local and wide area networks), network topology (Ethernet, token ring), client/server hardware, bridges and routers. However, before the curriculum changes, the course was not offered for a while. With the curriculum revision started in fall 2018, this was one of the courses that was fully revised and reintroduced. Being a 400-level course, it continues to serve as a senior elective course for all of the concentrations. The communications track includes a sequence of two required courses, a 300-400 levels sequence. It is the

concentration on which the computer networking course best fits as an additional course to the communication sequence. However, the course pre-requisites, as well as the structure of the course, are set such that any junior standing EET student may take the course. Many of the students on embedded systems or mechatronics pathways find this course to be a perfect choice for their elective requirements. Students on the computer engineering pathway may take an Internet-related course in the Computer Science department to fulfill their minor and concentration requirements, but the revised EET course on computer networking is a very good choice for them too.

Along with the Bachelor of Science degree in EET, the program also offers a minor in EET. In the previous curriculum model, the minor requirements included a group of four EET courses, with no alternatives. This model was changed recently and includes now two 300 level required courses along with two more courses that may be selected from a large list of 300 and 400 level EET courses. The computer networking course is one of the options for satisfying the EET minor requirements. The course variety in the new format of the minor is expected to appeal to more students from other areas, and the networking course is one of the courses to generate a lot of interest. The computer networking course was offered in the new format in spring 2019 and is offered again in spring 2020. It is to note that the enrollment in the second year of offering the course almost doubled.

3. The Data Communication and Computer Networks Course Description

The course on Data Communication and Computer Networks offered in the Electrical Engineering Technology program at Old Dominion University introduces students to the fundamental concepts in data communication and computer networks, as well as to some level of hands-on activities. It is offered as a three credits course, with the lab/hands-on component of the course included in the regular three lecture hours per week. While the course is still listed as "*Introduction to Local Area Networks*", which was the name of the course since it was introduced, the course name might change in the near future to adjust to the current content of the course. The course in the new format was delivered in hybrid web-based mode and was managed via Blackboard, which is a online learning environment and management system. Campus students are attending the course live in the classroom, while the lecture is broadcasted via WebEx and the distance students can attend live through online connections. Archive of the lecture recordings is available for all students. The pre-requisites for this course are only related to math and programming background and a specific course on *Principles of Communication Systems* is only recommended to be taken previously, but it is not a pre-requisite. Relaxing this requirement allows students from other majors to be able to register for this course and use it eventually to complete an EET minor. Since EET requirements in terms of mathematical background are up to Calculus I, the EET curriculum includes a 300 level course named *Advanced Technical Analysis* in which students are exposed to various background topics in math, such as integral and derivative calculations, ordinary differential equations, basic linear algebra including matrices and determinants arithmetic as well as solving linear systems, basic statistics and vector calculus. The math concepts are introduced, and the necessary calculations are presented both with hands-on calculations and with the use of

Matlab/Simulink. For EET students, this course is the pre-requisite for the computer networking course, while students from other engineering majors are expected to have the requirements satisfied through regular math and programming courses.

The current catalog computer networking course description is as follows: "*This course provides an overview of the local area networks (LANs), wide-area networks (WANs), and backbone technologies. This combines the fundamental concepts of data communications and networking with practical applications and emphasizes the OSI reference model and its relationship to traditional and next-generation LAN/WAN technologies. Hands-on activities using Wireshark are included."* The course is offered once a year, in spring semesters, and spring 2019 was the first time of offering the course in the new format with the use of Wireshark software. For future semesters the course description may adjust to follow eventual changes in the tools used in the class or the introduction of new material.

The course is delivered with the following course objectives:

- Understand the fundamental concepts of data communication and computer networking.
- Identify different types of network topologies, protocols, and computer networking trends.
- Understand the OSI and TCP/IP models for standards development.
- Analyze major multiplexing techniques and circuits, messages, and packet switching.
- Identify the elements of data communications equipment and describe their function.
- Understand the fundamentals of Internet technology and operation.
- Understand the role and functions of network management software and requirements to manage the day-to-day operation of networks.

For course assessment and grading, the following instruments are used: two in class tests and a final exam, random quizzes and a term project. For the term project, students are required to prepare reports at two intermediate times during the semester and a final report. The term project concludes with a final presentation.

3.1 Course Content

The content of the course on Data Communication and Computer Networks is aligned with the course objectives stated above. In the previous format, before current curriculum updates, the focus of the course was on local and wide area networks (LANs and WANs), with the whole presentation of the material under the OSI layered structure network model and the hands-on activities on PC based local area networks. In the new format, the core of the course is still on LAN/WAN and layered network structure, but additional topics such as backbone network technologies, Internet of Things (IoT), cloud computing, 5G, and cybersecurity were introduced to some level of details. For the hands-on activities the software package Wireshark was introduced. The course material covers three main modules, as shown in Figure 1: (1) Fundamental concepts of data communication and OSI-layered structure, (2) Network technologies, and (3) Network design and management. The course covers the layered model of data communication, specifically the OSI seven-layered model, Internet routing, communication standards, protocols and technologies, and learning methods used to design the network.

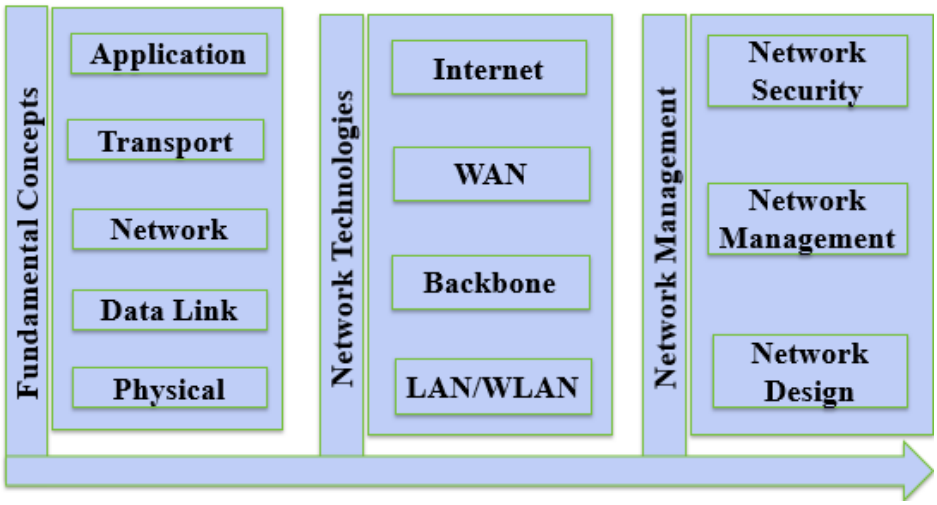


Figure 1. The course content with categories

The first part of the course focuses on fundamental concepts of data communication and layers of OSI model, including physical layer, data link layer, network layer, transport layer and application layer (the application, presentation, and session layers combined to follow the five-layers Internet model), and future trends in data communications and networking. The second part focuses on network technologies of various network types such as LAN/WLAN, backbone networks, WAN and Internet. It also covers the most commonly used network technologies (such as Switched Backbones, Routed Backbones, Virtual LANs), and discussed how to design and improve the performance of each network. The last part of the course discusses network design, network management and network security with practical examples such as technology design, end-user support, performance and fault management/analysis, risk assessment.

Several topics were introduced in the new format of the course in response to the advancement in communication technologies. The following topics were also discussed within the course material:

The Internet of Things (IoT) is a special networking scenario that has emerged in the last decade. The term Internet in IoT refers to the fact that these "things" are all connected to the broader Internet. The motivation of this topic was to introduce the students to IoT concepts, devices, and the importance of IoT in industry and everyday life, the current components of typical IoT devices and trends for the future. IoT concepts were presented along with the coverage of the Internet as one of the trend technologies.

Cloud computing is the on-demand technology services such as computing power, storage, and databases, which are provided by a cloud provider, such as Amazon Web Services (AWS), over the Internet. This topic was discussed in the class to familiarize the students with a new and growing field of cloud computing technologies and services. The cloud computing concept was presented along with the application layer, and key components of cloud computing, such as bandwidth, storage, etc., and cloud services, including Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) were discussed.

5G is the latest generation of cellar technology based on massive multiple-input and multiple-output (MIMO) and the use of millimeter waves and is currently in the developing stage. In the context of cellular technologies, students are briefed on the cellular concepts, the geographic distribution of base stations required to provide the services, and the reuse of frequencies. Concepts of multiplexing are also discussed. This topic was also presented along with the Internet portion of the course.

Cybersecurity is currently the most critical topic in data communication and networking. The motivation to introduce this topic in the course was to make students aware of the major threats in network security, how to conduct a risk assessment, how to ensure business continuity and how to prevent intrusion and cyber-attacks. The need for computer network security was discussed along with the means to deal with the problem. The cybersecurity topic was presented within the network security portion of the course.

3.2 The Hand-on Activities

-*Wireshark*

Engaging hands-on classroom activities are a big challenge for effective undergraduate engineering education due to a lack of knowledge in data computer networking and experience. In this revised format of the computer networks course, the hands-on activities were introduced using Wireshark software. The most challenging aspect of teaching the data communication concepts is the availability of many different software packages and many different Protocol Data Units (PDUs) that operate at different layers to successfully transfer a message. The activities in the course were designed to help students understand the fundamental of the data communication and networking concepts, such as layered network structure and communications protocols (specifically TCP/IP) and IP datagram format and fragmentation. These activities contributed to improved student engagement and class participation. Wireshark [13], formerly known as Ethereal, is a free network packet analyzer software, which allows a user to capture network traffic, decode packet protocols, define filters, analyze statistics and problems, import and export packets, interactively browse the network traffic. A typical Wireshark task includes following steps: (1) Browse Wireshark user interface with the main menu and toolbars, (2) Select a network interface (including Ethernet, Wireless LAN, Bluetooth, USB, and more) to collect the trace data, (3) Specify trace collection parameters such as duration, number of packets, filter, size of the file, output file name, etc., (4) Start the packet collection, (5) Analyze collected trace data in terms of packet header values, statistics or packet counts, etc., and (6) Stop the packet collection (optional). In the classroom, Wireshark and its GUI were introduced to the students in a short section of approximately 30 minutes in the second week of the semester. It included selecting a network interface from which the packets are to be collected, applying filters, collecting a live trace, viewing packet headers in the collected trace, and analyzing and viewing statistics of the collected trace data. Within the second section of about 45 min in the fourth week of the semester, it was discussed how Wireshark operates and its main components, including the packet capture, analyzer and statistics modules. In the fifth and seventh weeks, students performed several hands-on

activities in the class: (1) IP, Internet Control Message Protocol (ICMP), Address Resolution Protocol (ARP) in Wireshark: Collect live trace and examine IP, ICMP and ARP packet headers with ping and traceroute commands, --to be able to capture ARP packets, it is needed to execute the command "arp -d' to clear the arp cache--, (2) TCP in Wireshark: Collect a live trace and examine TCP headers and segments, (3) UDP in Wireshark: Collect a live trace and examine UDP headers and segments; and (4) HTTP in Wireshark: Analyze HTTP request/response statistics. Figure 2 shows a screenshot of the Wireshark GUI, while filtering "HTTP" packets with packet list, packet details and packet bytes.

Based on class immediate feedback, the hands-on activities with Wireshark tools helped students to better understand the concepts of data communication and networking protocols and layers, and gain knowledge and confidence in computer networks.

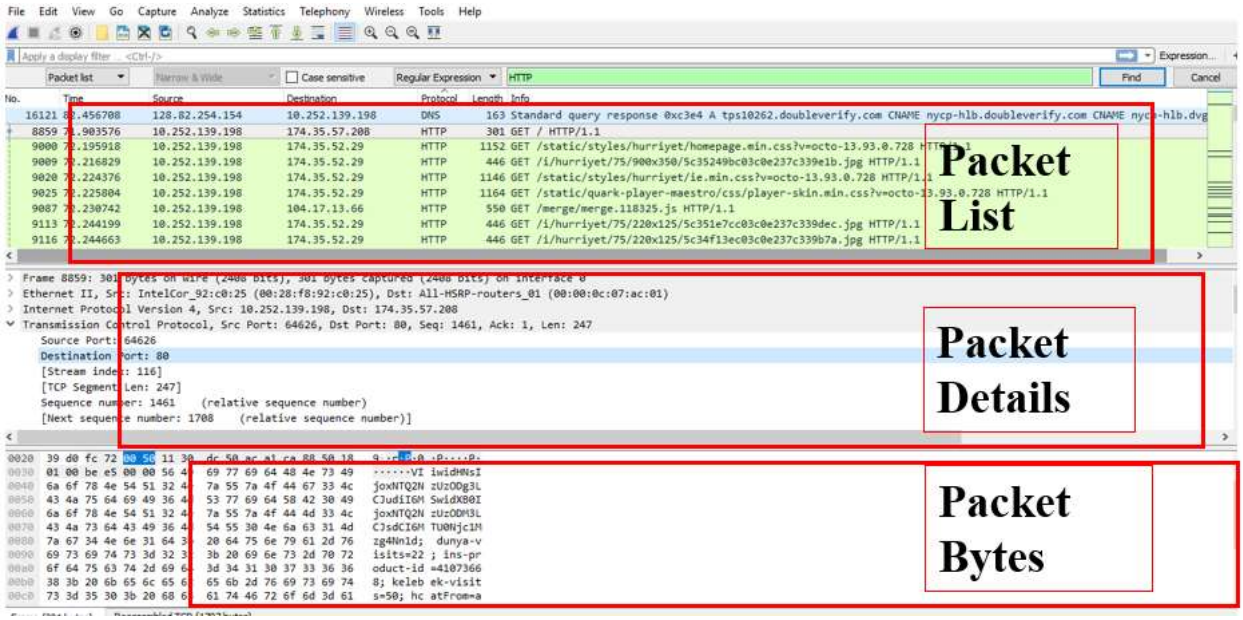


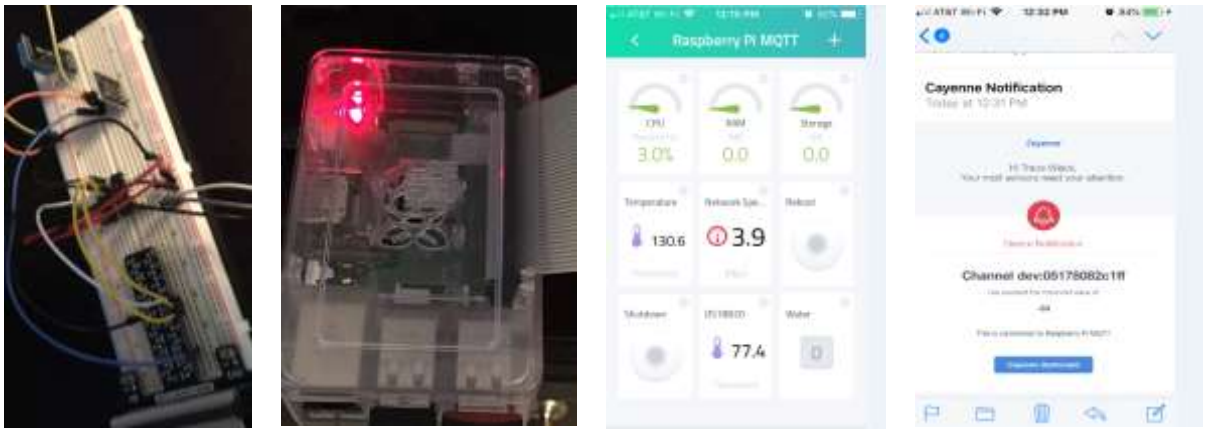
Figure 2. Filtering “HTTP” packets

3.3 The Term Project

The main objective of the term project is to extend student knowledge and research skills in addition to hands-on classroom activities. Several options were given to students for the term-project assignment including (1) Hardware and software development with Arduino or Raspberry PI for IoT applications, (2) Network design with network simulator, e.g., GNS3 or NetSim, and (3) Writing a term paper related to data communication technologies. Most students preferred to develop an IoT application, while some to write a term paper. For the IoT applications, students generally designed and developed home automation applications (home energy management, home security, or air quality) using IoT, which covers the software, hardware, sensors, protocols, and cloud architecture and platforms. Some examples of the projects implemented by the students: an IoT-based smart home hot water heater monitoring system, a cloud-based smart home automation server, and a Wi-Fi enabled home automation system. Some students wrote term

papers related to emerging communication technologies, and some topics selected were network security, future of protecting our networks, and electronic passport. It was interesting that within the first-semester cohort, no student chose for the term project the network design with a network simulator. The explanation for this may reside in the fact that students were willing to improve their hardware and software development skills, but they were reluctant to learn new software tools. The term project was scaffolded over the whole semester, and students were required to prepare a pre-proposal report, a mid-term report, and a final report. The semester ended with presentations of the term projects.

Among all the projects, an IoT-based smart home hot water heater monitoring system was the most comprehensive project, including hardware, software, cloud computing and IoT. The student completed several tasks: (1) Obtain the necessary components to build the project, (2) Search for various methods of interfacing among project components in terms of hardware and software, (3) Build the project and complete wiring, (4) Download the operating system and related software tools to the controller, i.e., Raspberry Pi, (5) Develop a software interface module for the Raspberry Pi and the water detection sensor, (6) Develop an app on a smartphone, (7) Test the water detection sensor alert on a smartphone, (8) Add more sensors to make the home fully automated, and (9) Test the overall system. According to the informal student feedback, the testing phase of the whole system is the most important. If one does not test the performance of the sensor and is assuming that the Raspberry Pi is correctly programmed, errors are highly probable to occur. Figure 3 shows project outcomes in terms of hardware and software.



(a) (b) (c) (d)

Figure 3. The project outcomes (a) Assembled project components and wiring, (b) Raspberry Pi hosting the operating system and related software tools, (c) An app on a smartphone, (d) The water detection sensor alert on a smartphone.

Most students provided positive feedback regarding the project assignment. They appreciated learning the theory and improving their knowledge through the project assignment and their software development skills.

4. Student Feedback

A student survey was administered through Blackboard at the end of the semester to get feedback from the students about the course in the new format and about the software used for the hands-on activities in the class. The responses were confidential. Ten students choose to participate in the survey. The overall response from the students was positive.

The first group of questions was related to the course structure and efficiency, and the results were as follows:

Question 1: *This course was useful in progress toward my degree and career*. 80% of the students agreed or strongly agreed, 10% were neutral, and 10% disagreed.

Question 2: *I think that the way the course was structured is adequate for both the online and campus delivery.* 80% of the students agreed or strongly agreed and 20% disagreed.

Question 3: *I think the class time was efficiently distributed between the lecture and the activity time, enough to cover the content of the course material.* 80% of the students agreed or strongly agreed and 20% disagreed.

Question 4: *This course met my expectations in terms of content and hands-on activities.* 70% of the students agreed or strongly agreed and 30% disagreed.

Question 5: *I consider that the course requires an adequate study time.* 80% of the students agreed or strongly agreed, 10% were neutral and 10% disagreed.

Question 6: *Which of the following factors influenced the most your engagement in the course?*
Project – 30%; Class activities – 20%; Quizzes – 40%; In-class tests – 10%; Final exam – 0%

Question 7: *Which of the following factors contributed the most to your learning of the course material?*
Project – 20%; Class activities – 0%; Quizzes – 70%; In-class tests – 10%; Final exam – 0%

Question 8: *This course increased my interest in computer networks.* 70% of the students agreed or strongly agreed, 10% were neutral and 20% disagreed.

Question 9: *This course helped me develop critical thinking skills related to computer networks.* 80% of the students agreed or strongly agreed and 20% disagreed.

The answers to these questions show that most students liked the course and found it useful, with 70-80% of the responding group finding the course useful and well structured. It is not much of a surprise that students do not consider exams in general and the final exam, in particular, to be engaging or contributing to learning. Instructors would disagree, probably saying that exams are expected to motivate the students to prepare for the class. The way questions 6 and 7 were formulated though, they ask the students to choose which of the instruments was more helpful and, in this context, the most surprising outcome came from the fact that class activities did not get the highest numbers. The students rated the quizzes to be the most engaging and most helpful in learning. Quizzes are still part of the testing portion of the course, but they were worth only 10% of the final grade. The exams all together were 70% with the final exam worth 40% (which may correlate with the 0% choices in the surveys) and the project was counted for 20% of the final grade. The quizzes, which are still putting pressure on the students to study the material, were the lower stake in the grade book and, as a result, the least pressure among the testing items was considered the most efficient instrument. While the hands-on activities may not be correlated well enough with all the parts of the material required for testing and as a consequence not to end up being highly considered to contribute to learning, it was expected to be considered the most engaging item, so the answers to question 6 were the most surprising. The answers for the project

were satisfactory since the project is narrowed to a specific topic for each student. In the future offerings of this class, questions 6 and 7 may be reformulated to rank among all the items instead of asking the students to pick one item. Also, from the instructor's perspective, it seems that the Wireshark network protocol analyzer was too complex for the undergraduate-level students, and this may have had an impact on their feedback even though they did not clearly state that.

Several questions in the survey were related to the Wireshark software used for hands-on activities in the class. The student responses were as follows:

Question 10: *Hands-on activities involving Wireshark software package --network protocol analyzer -- help me to understand the course material.* 40% of the students agreed or strongly agreed, 40% were neutral and 20% disagreed.
Question 11: *Wireshark software package --network protocol analyzer-- was easy to use and intuitive.* 60% of the students agreed or strongly agreed, 10% were neutral and 30% disagreed.
Question 12: *Hands-on activities involving Wireshark helped me to understand the layer structure of OSI model.* 60% of the students agreed, 20% were neutral and 20% disagreed.
Question 13: *Hands-on activities involving Wireshark helped me be successful in the class.* 30% of the students agreed, 40% were neutral and 30% disagreed.
Question 14: *I think that being familiar with Wireshark will help you later in the industry.* 50% of the students agreed or strongly agreed, 40% were neutral and 10% disagreed.
Question 15: *The layer of OSI model that I understood mostly with Wireshark was:*
Physical layer-20%; Data-link layer – 20%; Network layer – 40%; Transport layer – 10%; Application layer – 10%.

The answers to these questions show that students appreciated the Wireshark software package, but they were not overwhelmingly positive about it. Question 15 is useful for the instructor in revising the class activities.

The last question of the survey was a free answer question and was asking the students if they have any additional comments, questions or concerns. Some of the comments were only appreciative of the materials provided in the class or for the teaching style and only a few were more specific:

"This course was taken as an elective, but I think it was a great addition to my degree. At my current work we are always asking IT to perform certain task. Now that I understand the LAN a little better, I can ask the correct questions at work."
"I excel at things when learning using labs. I would like to see the addition of lab or two that involves configuring a switch and perhaps a wireless access point"
"I think utilizing Wireshark more often during the lectures would be pretty beneficial. I know we used it occasionally, but I don't feel we used it enough to be comfortable with it (at least for me). However, I don't think being fluent with Wireshark was necessary for this class structure."

We can see that there is a strong correlation between these free answers and the answers on the Wireshark related questions, in the sense that the students were positive about the package, but not necessarily enthusiastic.

5. Conclusion

The paper presents a case study of a revised course in data communications and computer networks in an electrical engineering technology program. The course was offered in hybrid mode (class and online students, with WebEx delivery of the course) and included both lectures and hands-on activities. The course content was updated to include introductions to newer technologies, such as Internet of Things (IoT), cloud computing, 5G, cybersecurity, but the major changes were the use of Wireshark software for class activities and the format of the project. The experience of the first semester of the course in the new format led to the conclusion that the use of Wireshark helped students better understand the OSI layered structure network model and Internet protocol, i.e., TCP/IP protocol, with real-world applications. During the hands-on activities, students improved their performance on how to read and interpret packet headers, and better understood DNS and DHCP routing. In addition to hands-on activities, the project assignment was an effective way to help students understand computer networks and communication technologies beyond the lectures. Informal feedback indicated that students enjoyed working on the project assignment, and they appreciated the flexibility of topic selection. Future updating of the course will focus on extending the hands-on activities. NetSim network simulator is proposed to be used in the following semester. This will create the opportunity to compare the efficiency and students' appreciation of different software packages.

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