A New Online Laboratory-based Engineering Technology Course in Networks for the Industrial Environment

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Abstract

This paper describes the development of a new online graduate engineering technology course in advanced networks for industrial environments. The course is intended to provide an in-depth overview of high-performance wired and wireless networks for industrial control, communications, and computing. The emphasis is on understanding current and newly emerging network architectures, protocols, and technologies in terms of performance, network services, ease of implementation, maintenance, reliability, risk, and cost.

Introduction

High-performance data networks are one of the key enabling technologies in state-of-the-art industrial settings. It is essential that anyone interested in areas such as product improvement, industrial practices, engineering technology operation, etc. have a fundamental understanding of network protocols and hardware that may be needed in this environment.

This paper describes the development of a new online graduate engineering technology course in advanced networks for industrial environments at ******** University. The course is intended to provide an in-depth overview of high-performance wired and wireless networks for industrial control, communications, and computing. After completing the course students will be familiar with topics such as the OSI and TCP/IP protocol stacks and common network protocols such as Ethernet (IEEE 802.3),[1] Wi-Fi (IEEE 802.11[2]), Bluetooth,[3] ZigBee,[4] DPN3,[5] and CAN.[6] The goal is to enable students to make sensible decisions when selecting and implementing a network protocol for a particular industrial application.

Course Content

The course syllabus is shown in Figure 2. The course begins with an introduction to what network protocols are using the example of collision detection in the context of ordinary conversation. The use of this technique in first generation Ethernet is then described. Next, the importance of layered protocols is discussed and the DARPA, OSI and TCP/IP models are discussed. Circuit and packet switching are then compared with respect to performance, ease of implementation, and cost. Statistical methods and industry-standard CAD tools used in performance modeling are then described. The introduction concludes with a discussion of physical media, including copper wire, wireless, and fiber optic cable, with an emphasis on cost-performance tradeoffs.

The next four weeks are devoted to detailed descriptions of each of the layers of the TCP/IP protocol stack. A top-down approach is used, starting with the Application and Transport layers and ending with the Physical layer. The text for the course is *Computer Networking: A Top-Down Approach*[7] by J.F. Kurose and K.W. Ross, early advocates of the top-down approach.

Week	Topic
1	Introduction to network protocols and technologies, network topologies, the OSI

	and TCP/IP protocol stacks, circuit and packet switching, selection criteria
2	Network performance, throughput and latency, physical media
3	Application layer
4	Transport layer
5	Network (Internet) layer
6	Network Access layer
7	Ethernet
8	Some typical industry-specific networks (CAN, DPN3, etc.)
9	Wireless network protocols
10	Network security

Figure 2. Topics covered in the 10-week course.

Following the introduction a detailed description of each of the layers of the TCP/IP protocol stack is presented. A top-down approach is used, starting with the Application and Transport layers and ending with the Physical layer. Next, a number of network protocols used in industry are described in detail, beginning with Ethernet. Ethernet is not only ubiquitous in communications systems but is also widely used in industrial control, for example, to interconnect programmable logic controllers.

Next, several industry-specific network protocols are discussed, including CAN and DPN3. CAN (Controller Area Network) is a multi-master serial bus protocol originally designed to transmit short messages between microcontrollers in an automotive environment. Since its inception in 1986, its range of applications has expanded into such areas as industrial automation and medical equipment. DPN3 (Distributed Network Protocol) is an open standard intended to provide interoperability between computers and intelligent devices in the electric utility industry. The standard provides for an IP-based serial point-to-point link.

Wireless network protocols are then discussed in some detail, including 802.11, Bluetooth, and ZigBee. Bluetooth is becoming increasing useful in industrial applications as cable replacement, in wireless sensor networks, and as an interface to IP-based networks. ZigBee is a suite of protocols designed for low-power, low data rate RF mesh networks used to control consumer electronics, heating/cooling systems, lights, etc. It is finding increasing use in distributed control and monitoring in industrial settings.

The final topic is network security. Security is an important consideration in the industrial environment. Particular emphasis is places on securing email, Virtual Private Networks, and security in wireless networks. The networks previously described are compared in terms of performance and security features.

To provide hands-on experience with network protocols, experiments with two industry-standard modeling and evaluation tools, OPNET's IT Guru and Wireshark, are used. OPNET is a graphical network traffic simulator used for packet-level performance analysis of metrics such as throughput and delay. To use it components such as routers, hosts, servers, etc. are dragged from various menus and then connect them up in the desired topology. Figure 3 shows a typical screenshot of a network defined in this way. It shows three hosts connected through a local 100 Mb/s Ethernet switch to a cable that provides an Internet connection through a WAN to three remote servers. OPNET provides accurate models of real commercial devices—note in the figure that the model for a real, commercially available Linksys cable modem is being used. They also have models for all popular protocols and you can define your own devices or protocols in a high-level language such as C. You can choose the link speeds as well.

A variety of traffic patterns may be specified. For example, traffic may be generated with a random number generator using several statistical distributions such as normal or Poissonian for packet length and inter-packet time. The simulator can produce useful information such as average and instantaneous throughput, average or instantaneous delay, delay by priority, etc. Figure 4 shows the delay of individual packets as they are generated over time.

IT Guru may be freely downloaded for academic use and the students can run it on their own computers.

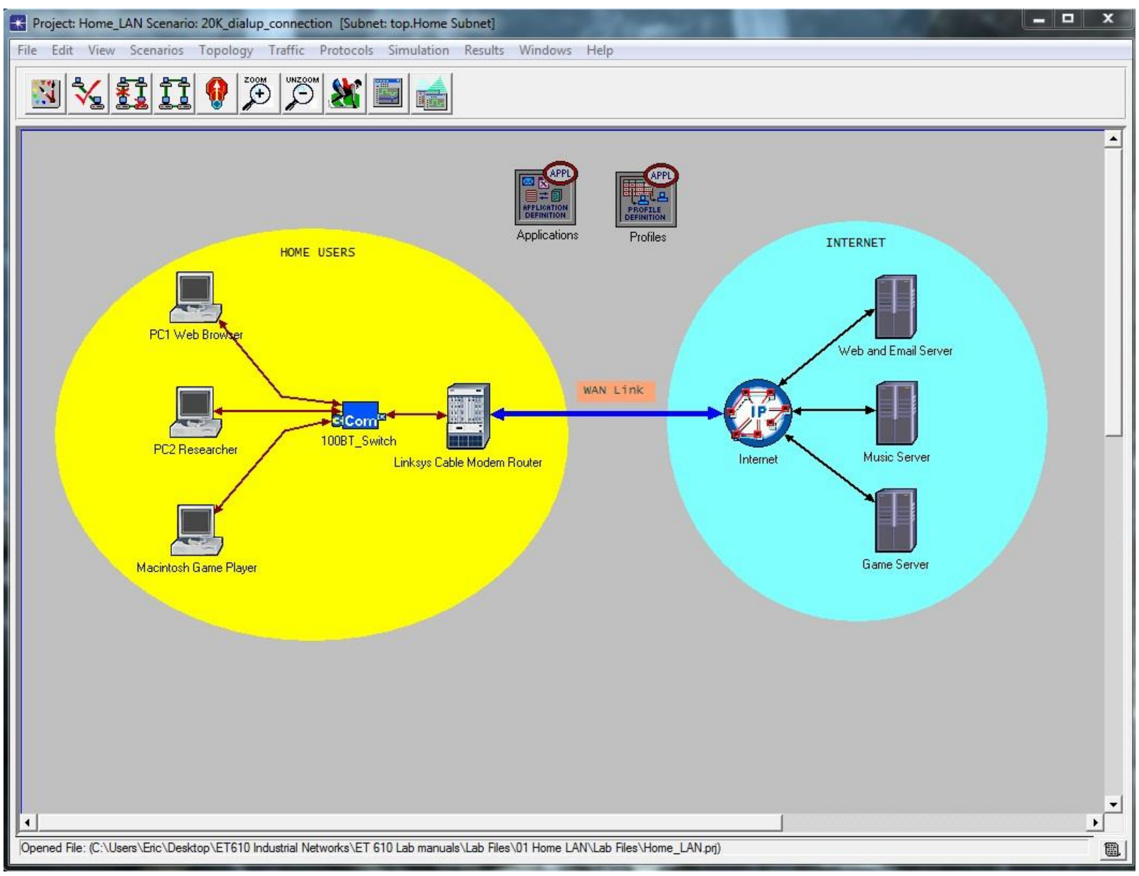

Figure 3. Typical OPNET screenshot.

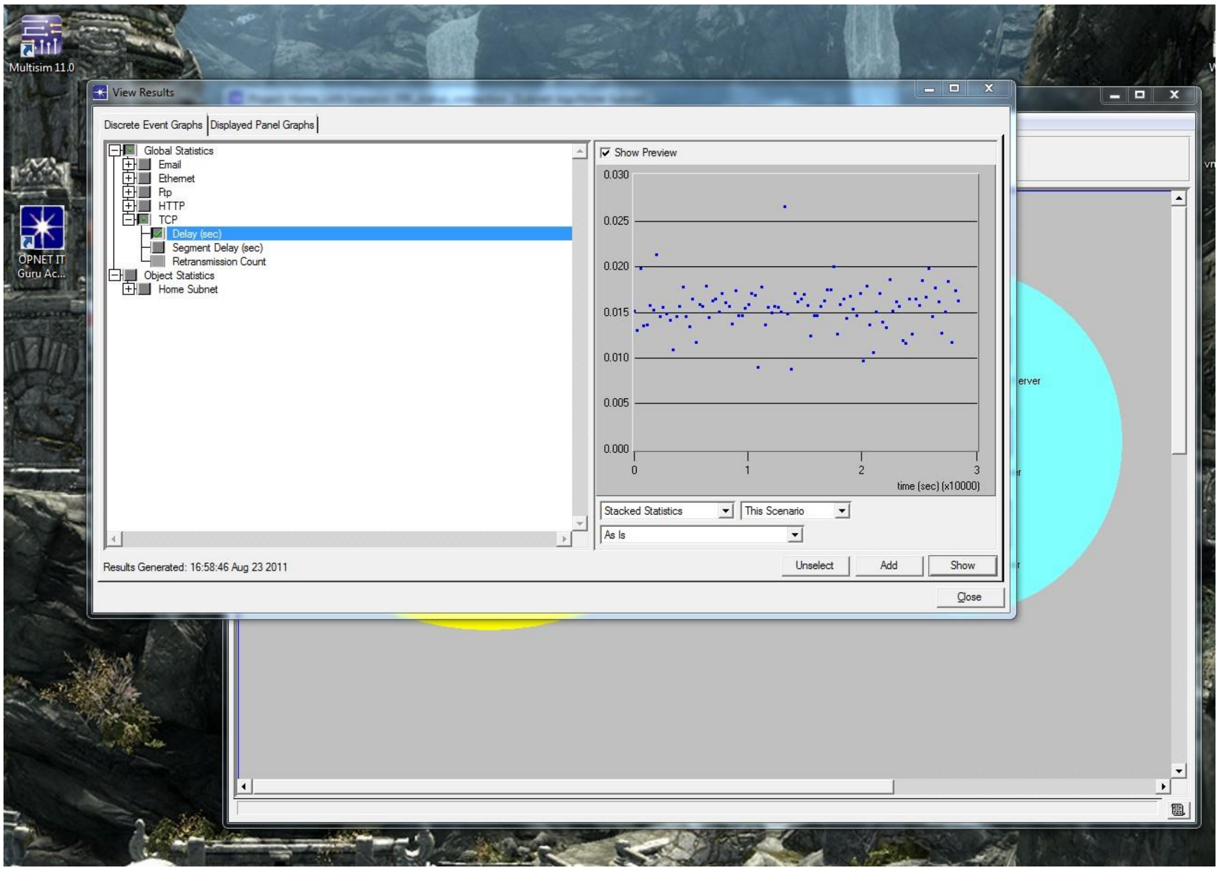

Figure 4. OPNET results showing individual packet delay over time.

Wireshark[37] is used to give the students hands-on experience with their own local area network. Wireshark is a GUI-based open-source protocol analyzer used for network troubleshooting and analysis. It can sniff out information such as source and destination addresses or the contents of packets at various network layers in the students' actual local network. Figure 5 shows a Wireshark screenshot showing the capture of packets corresponding to the request of a web page using the http protocol. The image shows the "Get" command, requesting the root document. The hostname is www.paleotechnologist.net.

Figure 6 shows the response from the host. It took about 300 ms for the request to go out (via a VPN connection), reach the webserver, and be processed and returned. Because Wireshark can capture a large amount of information quickly it is essential for the students to learn how to start it up, capture the needed data, and then shut it down quickly before some other process makes an Internet request. By clicking on the request, then the response, the student can see what information was exchanged.

The software may be freely downloaded by the students under the terms of the GNU General Public License, and versions are available for both PCs and Apple computers.

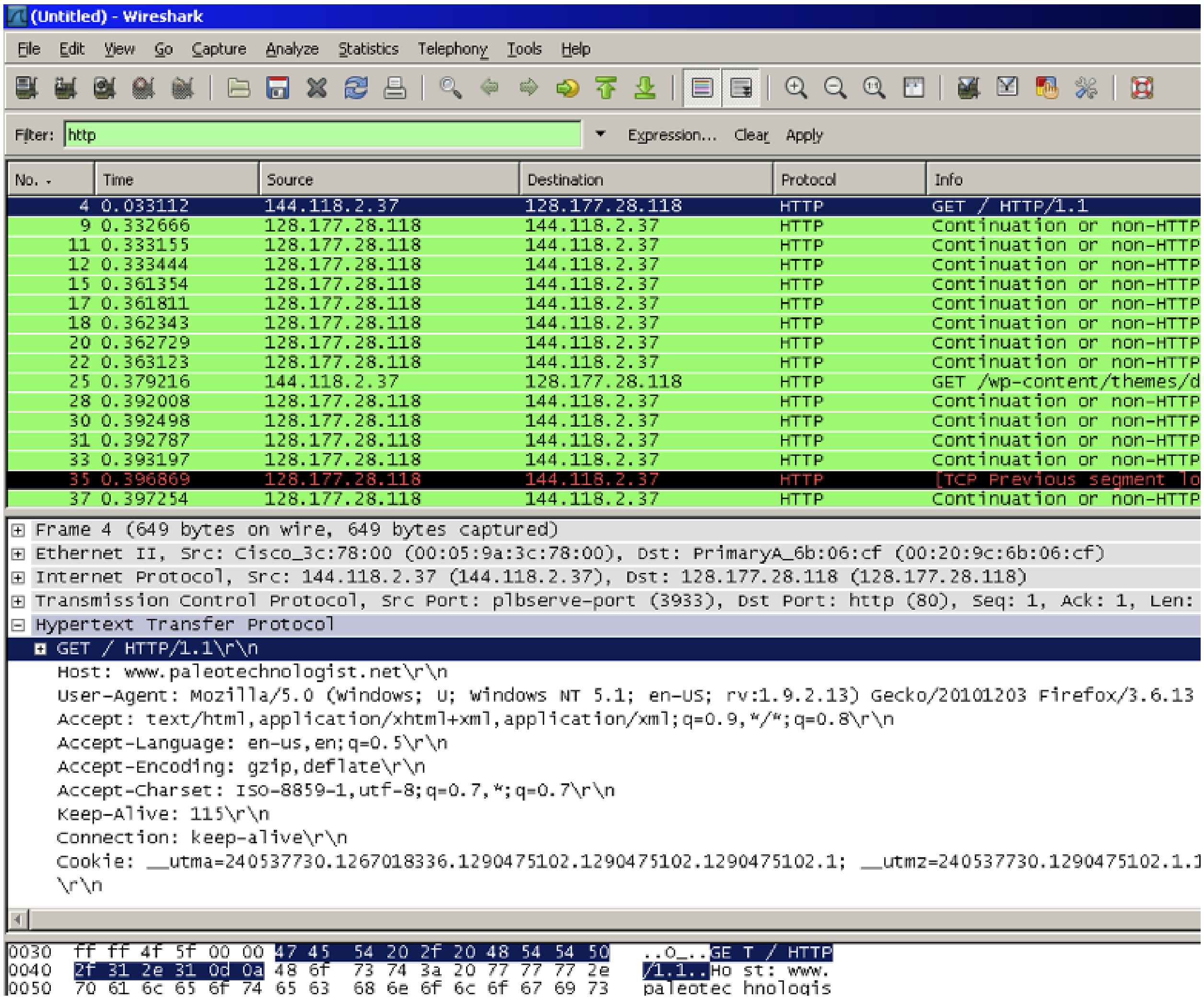

Figure 5. Wireshark screenshot for an HTTP request.

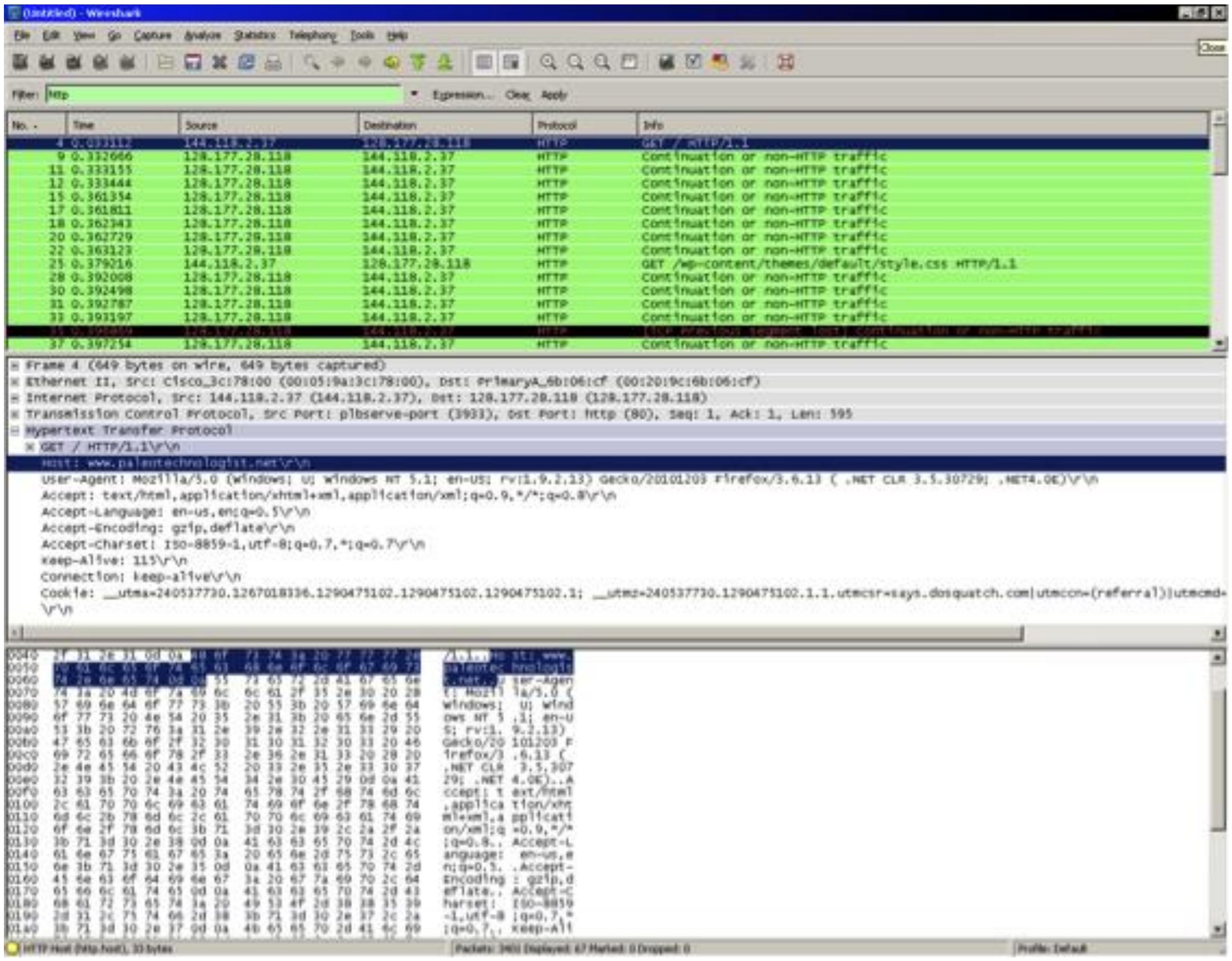

Figure 6. Screenshot of the response to the request from **www.paleotechnologist.net**.

Conclusions

This paper described a new online graduate engineering technology course in advanced networks for industrial environments. The course is intended to provide an in-depth overview of high-performance wired and wireless networks for industrial control, communications, and computing. The course uses a top-down approach to understanding layered protocols such as TCP/IP. The course includes topics aimed at the use of these networks in the industrial environment. These topics include performance/cost tradeoffs of various network topologies and industry specific network protocols such as ZigBee, CAN, and DPN, as well as common commercial networks that are finding their way into industrial applications such as Bluetooth and Wi-Fi. Hands-on experience in the online course is provided using the OPNET for performance modeling and simulation and Wireshark for network sniffing and protocol analysis.

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