2006-1987: USING NETWORK ANALYZERS FOR ENHANCEMENT OF COMPUTER NETWORKS TEACHING

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Using Ethereal and IT GURU for Enhancement of Computer Networks Teaching

Introduction

This paper describes a course and laboratory in computer networking for students in the Electrical and Computer Engineering Technology (ECET) program at The University of Cincinnati. Teaching a computer networking course for engineering technology students can be a challenge because of the breadth of topics spanning electrical engineering, computer science and computer engineering which encompasses abstract concepts such as encapsulation and layered models.

In our computer networking class, we set up a weekly lab which accounts for almost the same amount of time as the lecture. The outcome of this curriculum is designed to have students benefit from a better understanding of fundamental concepts in addition to gaining hands-on experience. However, we have struggled on how to set up the lab and what type of resources to include.

In the past, our department has purchased networking equipment such as routers and switches to establish the networking lab. We have faced the problems such as the cost to equip and maintain the lab while at the same time only limited topics can be explored through the lab equipment. In order to find a new pedagogical approach to provide students with hands-on experience to help students understand the concepts well, I have done some research and found that both Professor Kurose, Ross [2] and Matthews [1] have proposed the idea of using a software called Ethereal, which is a network packet sniffer, to observe the sequence of messages exchanged between two protocol entities so that students may see network protocol in action. Ethereal labs can help students understand different networking protocols well, although it cannot provide students experiments on how to implement, manage and conduct performance analysis for networks under different scenarios.

For the reasons stated above, I have adopted the Ethereal and network simulation software, OPNET IT GURU to develop my lab exercises for the computer networking class which gives an extensive introduction to computer networking concepts and focuses on concepts, principles and protocols and covers all aspects of networking. Students attending both the lecture and lab classes will obtain a better understanding of the fundamentals of data transmission, packet transmission and internetworking protocols and gain the skills to design and analyze computer networks by using these Softwares we introduced in the lab class. This paper will describe the lab exercises together with the feedback from students. The main goals of the lab are to:

- To develop a clear understanding of the network layer concept
- To explore the packet encapsulation and fragmentation issues
- To explore the packet, datagram and frame format characteristics
- To visualize different protocols in action
- To explore reliable transmission mechanisms

- To gain hands-on experience to conduct network design, implementation and network performance as well as trouble shooting skills

Ethereal and OPNET IT GURU

The concept of layering, protocol, packet and encapsulation may be taught through programming. However, students can understand these concepts well if they are able to see protocol in action by observing the sequence of message exchanges between two protocol entities, by delving down into the detail of protocol operation and causing protocols to perform certain actions and then observing these actions and their consequences [2]. This can be done in a real network environment, provided that we have all necessary equipment. This can also be completed in simulated scenarios which allow greater flexibility to investigate all aspects of protocol operations. The latter approach will allow students run various network applications in different scenarios.

Ethereal may be used to observe the messages exchanged between executing protocol entities is basically a packet sniffer which passively copies ("sniffs") messages being sent from and received by a computer. The structure of Ethereal is illustrated in Fig.1 [2].

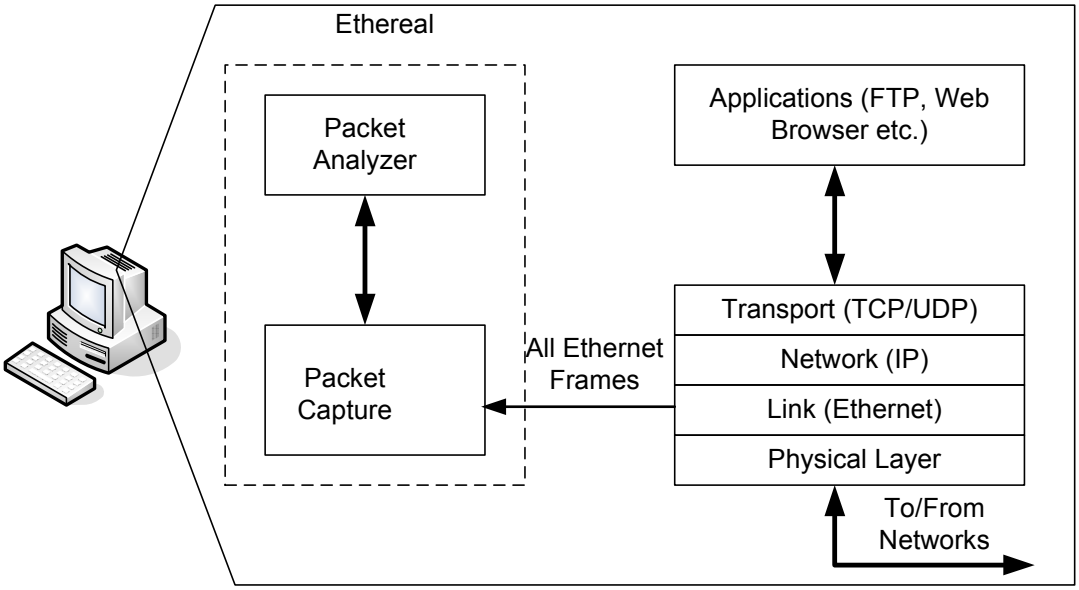

Fig.1: The structure of Ethereal.

Ethereal also has the ability to display the contents of the various protocol fields of these captured messages. The Ethereal is used by network professionals around the world for troubleshooting, analysis, software and protocol development, and education. Its open source license allows talented experts in the networking community to add enhancements. Ethereal runs on all popular computing platforms, including UNIX, Linux, and Windows.

The main features of Ethereal include [4]:

- Data can be captured "off the wire" from a live network connection, or read from a capture file
- Live data can be read from Ethernet, FDDI, PPP, Token-Ring, IEEE 802.11, Classical IP over ATM, and loopback interfaces (at least on some platforms; not all of those types are supported on all platforms)
- Captured network data can be browsed via a graphical user interface program.
- Captured files can be programmatically edited or converted via command-line switches to the "editcap" program.
- 750 protocols can currently be dissected.

The Ethereal labs are good for students to investigate component-wise each part of the network, However, Ethereal can not provide students hands-on experience on how to design, maintain, implement, configure and analyze a network. Traditionally, our lab allows a few students to wire, configure and investigate the performance of router and switches, the scope of the lab topics are limited. Recently, I found the lab manual using OPNET IT GURU Academic Edition to develop lab exercise [3].

OPNET IT Guru is a product of OPNET. It provides network modeling, simulation and analysis features. It has also been widely used for research and professional network design because it has the ability to provide a virtual network environment that models the behaviors of small scale to large scale networks (e.g., from a small office-based local area network to the global Internet). By working in the virtual network environment, IT managers, engineers and systems planners and operation staff are empowered with knowledge to more effectively analyze the systems performance, diagnose difficulty problems, and validate changes before they are implemented and plan for future scenarios including growth and failure [4].

Therefore, I will be using both Ethereal and OPNET IT GURU in my laboratory class to develop lab exercises so that students may know how to implement, manage and analyze a networking as well as to gain a better understanding of the protocol operation. The lab exercise below is based on these two software platforms.

Pedagogical Design

Our lecture class follows the integrated approach [4] that combines the best of top-down and bottom-up schemes in teaching networking. We begin with an introduction of computer network application, followed by the introduction of data transmission, packet switching networks and internetworking. I adopted this integrated approach because it is better to have students be able to use both Ethereal and OPNET IT GURU earlier to explore the underlying principles and application as well. The idea behind this pedagogical approach is to have students to explore the details of packet switching networks, i.e., the formats of packet, encapsulation, and fragmentation and experience how to build any virtual networks and test its performance. We have 7 lab exercises that have been tailored-according to topics from [1] and [2] and have been trialed in the fall quarter 2005 in our computer networking course. Each lab is conducted as a three hour session, held weekly for 7 weeks in our networking laboratory at ECET department. The following lab exercises describe the lab contents.

Lab Exercises

Lab 1: Introduction to Ethereal

Ethereal is one of the packet sniffers which can captures ("sniffs") messages being sent/received from/by a computer and stores and/or display the contents of the various protocol fields in these captured messages as well. Running passively, a packet sniffer only observes messages being sent and received by applications and protocols running on a computer, but never sends packets itself. A packet sniffer receives a copy of packets that are sent/received from/by application and protocols executing on a machine. In packet switching networks, messages exchanged by higher layer protocols l are encapsulated in link-layer frames (assumed Ethernet here); therefore, all upper layer protocols are encapsulated within an Ethernet frame. By capturing all link-layer frames, the packet analyzer module can restore each layer's packet content. In other words, the packet analyzer can visualize the message exchanged.

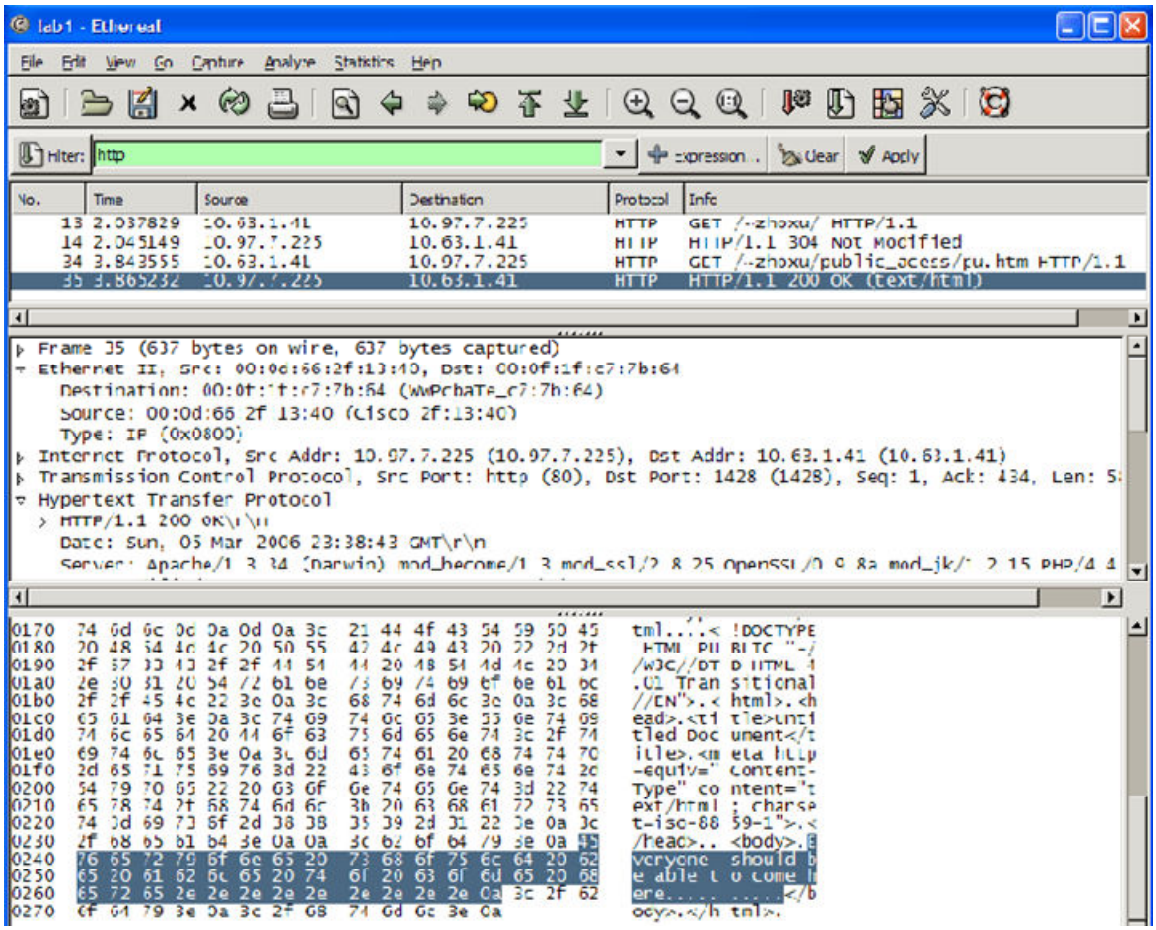

Fig. 2: Display of an HTTP message.

This lab has students to learn how to build the software (if they want to install it on their own computers) and explore different functions it provides. Students will be asked to capture packets while browsing several specific websites and then use this software to visualize the messages

transmitted across the network interface. Fig. 2 shows one of captured packets when browsing the tested webpage on which "everyone should be able to come here" displays. Students will be able to examine the detailed header information of the http message together with the content of the message. By expanding the header and packet content, we can see that HTTP message ("everyone should be able to come here") is carried inside of a TCP segment, which is carried inside of an IP datagram, which is carried inside of an Ethernet frame; The contents of the Ethernet frame (header as well as payload) are displayed in the packet contents window. Students show great interests in seeing the details of the message. At the same time, we emphasize the importance of encryption for communication over networks.

Lab2: Exploring the Ethernet Frame using Ethereal

In this lab, we explore reasons for Ethernet's success and we will use Ethereal to investigate Ethernet protocol. The first part of this lab, we assign some reading assignments to the students, and have them read the documentation from the Ethernet site (http://www.ethermanage.com/ethernet/ethernet.html) and the Ethernet FAQ (http://www.ethermanage.com/ethernet/enet-faqs/ethernet-faq.html) or any other source to help them to understand the following issues (1) how do the frame formats differ? (2) Why do they differ i.e. the reason for the change? (3) What is Ethernet channel capture? (4) Can one 10 Mbps, 100 Mbps Ethernet interface on the same 100 Mbps LAN? Will the 10 Mbps interfaces slow the LAN? (4) What are reasons for the success of Ethernet?

After they capture the data from the Ethernet interface, have students to examine the frame format and specifically, let them know how to find the Ethernet address of the source computer, destination address in the Ethernet frame and examine the frame type as well as the content of the message. The lab allow students see a live network data Ethernet frame is assembled by hardware addresses, frame type and payload as illustrated in Fig. 3.

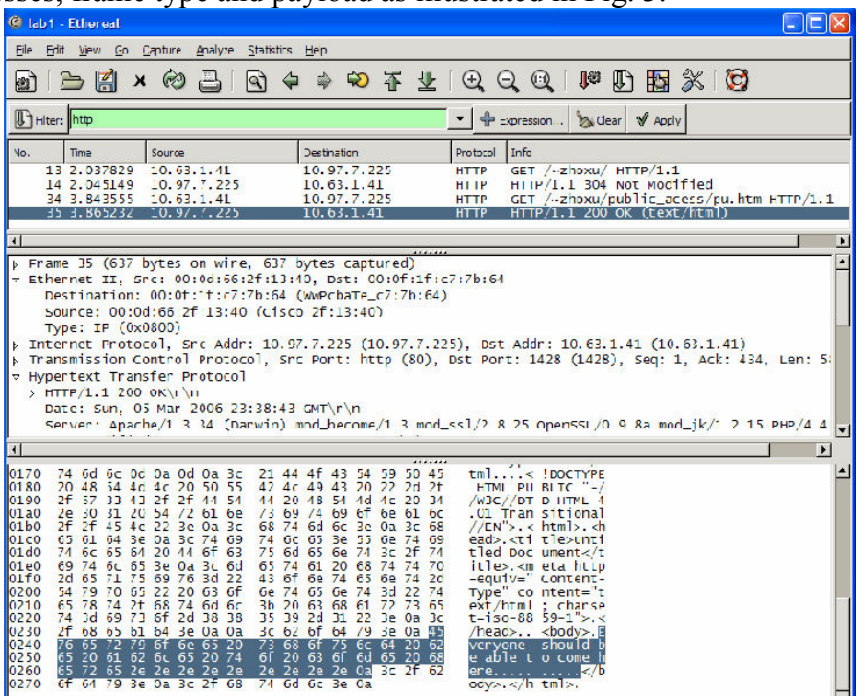

Fig. 3 Illustration of frame format used with Ethernet.

Lab 3: How to use OPNET IT GURU to Analyze Network Performance

This is the introduction of OPNET IT GURU. The objective of this lab is to learn the basics required to use OPNET effectively, including creating projects, building models, choosing statistics, managing scenarios, and viewing results. Students will be required to follow the tutorial provided by the software. Then, the students are required to use OPNET to simulate the throughput of a shared Ethernet network under different traffic load. Fig. 4 shows the created virtual Bus Ethernet by using OPNET IT GURU.

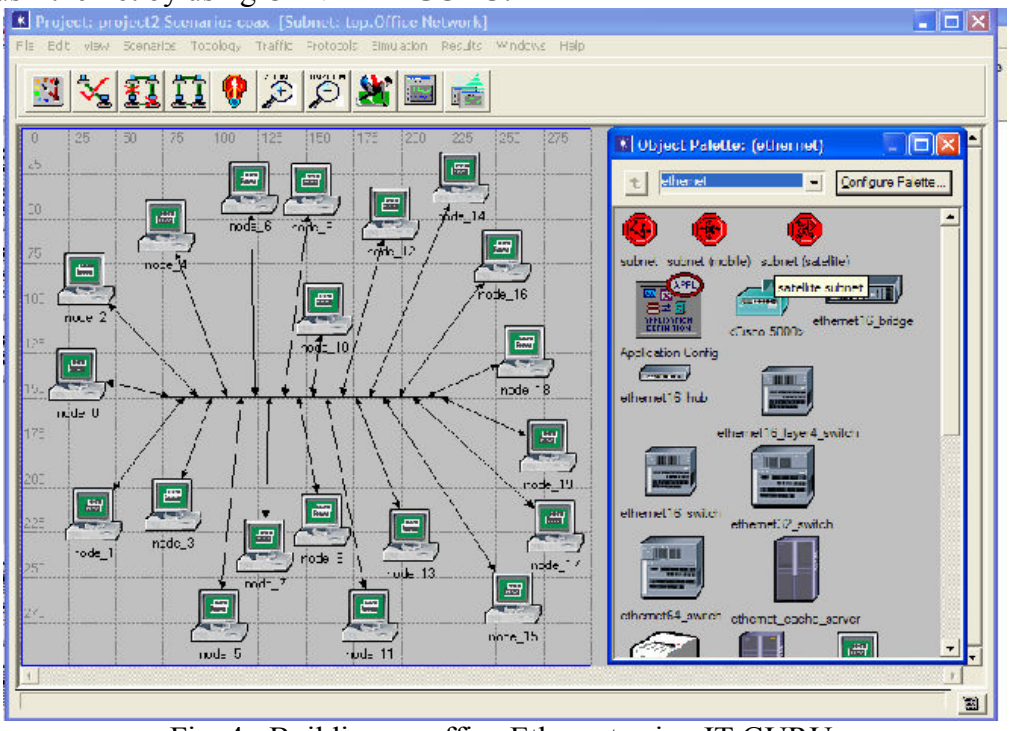

Fig. 4: Building an office Ethernet using IT GURU.

Once the virtual network is built and network nodes are configured, students will be able to run the simulations and check the network performance plots such as throughput and delays.

Lab 4: Use OPNET IT GURU to Compare Networks Connected by Switches and Hubs

Now continuing from lab 3, students will use OPNET IT GURU to simulate the local area networks connected by HUBs or switches. By conducting this lab, students will learn why a LAN connected by HUB has limited throughput and how switches help to increase the throughput and how the throughput of a switches is restricted by the processing speed.

Lab 5: Examine the ARP in Action

This lab will ask students to use Ethereal to examine the address resolution protocol in action. First, a reading research assignment require student to read RFC 826 (ftp://ftp.rfc-editor.org/in-notes/std/std37.txt) which contains the in-depth details of the ARP protocol, which is used by an

IP device to determine the IP address of a remote interface. Then, the students will try different URL and see how the ARP message exchanged.

Lab6: Examine IP Protocol, Fragmentation and Encapsulation in Action
Investigate the IP protocol, focusing on the IP and investigate the various fields in the IP datagram and study IP fragmentation in detail. By using the *pingplotter*, students can change the ICMP packet size to examine packet fragmentation in details.

Lab 7 Demonstrate TCP Performance using Different Congestion Control Mechanism
After reading the Transmission Control Protocol: IETF RFC number 793 (http://www.ietf.org/rfc/rfc0793.txt?number=793, students will conduct the lab to investigate the congestion control algorithms implemented by the transmission Control Protocol (TCP). Students will study TCP's use of sequence and acknowledgement numbers and they'll look at TCP's receiver-advertised flow control mechanism. They will investigate the performance (throughput and round-trip time) of the TCP connection between the client and the server.

Benefits of Lab Exercise and Students' Feedback

After one trial run of the networking course during the Fall 2005, we have assessed the educational value of the lab exercises through feedback from students. Our results show that most of students did not have the prior knowledge concerning computer networking concepts. They found that these labs are very interesting and easy to follow. In the course evaluation, students responded the question "What were the most effective aspects in the teaching of this course?" with "USING VARIOUS SOFTWARE PROGRAMS ON LIVE NETWORKS TO ELABORATE ON LECTURE MATERIAL". They consider the lab necessary for them to understand protocols, message, and datagram and frame format and they are well motivated by lab exercises. The following is a typical feedback from a student regarding Lab 6--"This lab helped to clarify how the trace route function works, by seeing the TTl field increment by one for each new echo request. The lab also furthered my understanding of the IP datagram frame format by looking at the header in depth. We were able to see how every field in the header remained the same except those that show fragmentation for an IP datagram".

In addition to help students understand the concepts, details of packet formats, these lab exercises provides the following main benefits

- Hands-on experience with OPNET IT GURU to construct different computer networks and conduct network performance analysis
- Hands-on experience with Ethereal to trouble-shoot and diagnose networks.
- Unlike programming exercises, students have more time to understand and analyze, rather than the time on programming debugging.
- Students have a better understanding on networking concepts

Conclusion

A series of lab materials has been tailored according to [1]] [2] [3] which can let students observe protocols in action and run various networks in a virtual environment. Feedbacks show

that these lab materials can motivate student's interest in networking, help them gain hands-on experience on how to construct networks and conduct performance analysis.

Reference

1. J. Matthews, "Computer Networking: Internet Protocols in Action", John Wiley & Sons, Inc. 2005
2. J.F.Kurose and Keith W. Ross, "Supplement to Computer Networking: A Top-Down Approach Featuring the Internet", 3rd edition.
3. K. Brown and L. Christianson, "OPENT Lab Manual to Accompany Data and Computer Communications", Prentice Hall
4. D.E. Comer, "Computer Networks and Internets with Internet Applications", 4th Edition, Pearson Prentice Hall, 2004.
5. Online resource, www.opnet.com
6. Online resource, www.ethereal.com