Using OPNET Modules in a Computer Networks Class at Mercer University

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Abstract

The ability to simulate computer networks enhances the teaching of computer networks concepts. This paper describes three OPNET modules that have been developed for a Computer Networks class. The first module introduces students to OPNET, and how to build, test, and analyze network models. The context of this module is a company that has a local area network (LAN) on a first floor office building, and plans to add an additional network on another floor. In the second module, students develop models of a company's wide area network (WAN). The models are used to study how the performance of the network is affected by the different design decisions that are made to upgrade the network. The third module examines the effect of different network configurations on TCP (Transmission Control Protocol) congestion windows. This paper also discusses ways in which the OPNET modules have been developed so that students learn computer network concepts, and not just how to use OPNET software.

Introduction

OPNET (OPtimized Network Engineering Tools) is a comprehensive software environment for modeling, simulating, and analyzing the performance of communications networks (including the Internet). Recent articles [Cheng, 1 - Vukadinovic, 7] have described how OPNET has been used in teaching and research. OPNET features include object-oriented editors that mirror the structure of actual networks, and support of most network types and technologies. OPNET has become the industry standard tool for designing networks, and evaluating network performance under various test conditions. Hence, students will benefit from exposure to this product.

The Keck Foundation has awarded the Mercer University a three-year project to establish an Advanced Engineering Analysis Center that will be used to enhance the undergraduate experience in Mercer University School of Engineering (MUSE). The center has been equipped with OPNET Modeler 9.1.A installed on a Sun Microsystems SUN Blade 2000 server and nineteen SUN Blade 150 workstations.

ECE 455 (Computer Networks) is a computer networks class that is taught at the undergraduate (senior) level in the Department of Electrical and Computer Engineering, at MUSE. This course is aimed at introducing the students to various aspects of networks, such as protocols, implementation, and quality of service. In Fall 2003 semester, OPNET was introduced as a laboratory component of the class, and to aid in reinforcing many networking concepts. This paper describes three OPNET modules that have been developed for this class.

Configuring network models with OPNET usually requires many steps, and this can be overwhelming for new users. The approach that the author has taken in this class is to build a basic network model for each module. The basic models are stored in XML format. At the beginning of each lab, the respective network model is imported by the student into the student's project workspace. The student then performs analyses on the basic model. The next step involves modifications of the basic network model, and more analyses of the modified networks. This way the students can focus on learning computer network concepts, and gradually be introduced to learning the steps on how to build network models with OPNET.

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OPNET MODULES

Introduction to OPNET

This module introduces the students to OPNET, and how to use OPNET to build and analyze network models. In this lab, the basic model is a hypothetical company's LAN (local area network) on a first floor office building (See Figure 1). This XML format of the model is imported by each student into the student's respective workspace.

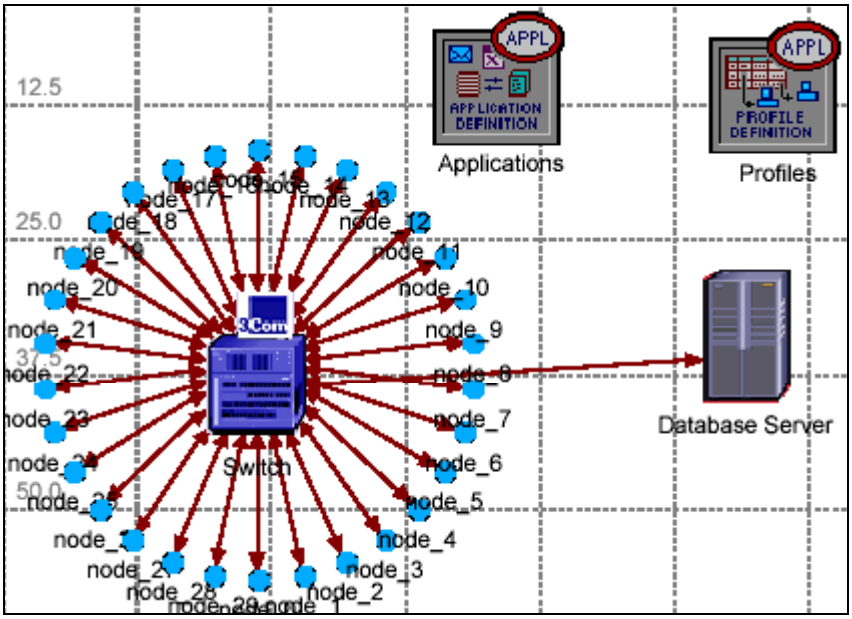

Figure 1 - First Floor Network

The 30 nodes represent workstations that are linked to a database server via a switch. The *Applications* object in the figure specifies the application traffic (e.g. database access, e-mail, web browsing, and file transfer) that can exist in the network. The *Profiles* object specifies the user profiles that can be modeled in the network. The user profile modeled in this network is database access (light) - workstations accessing the database server at a low rate.

The company plans to add an additional network on another floor. The students configure the simulator to collect the following statistics for the first floor network: the database server's Ethernet load and the entire network's Ethernet delay. After the first network's statistics are collected, the students expand the network model to include a second floor segment which consists of a 30-workstation star topology which is similar to the first network. The second floor network does not have a database server; it is connected to the first floor database server via a router. After the expanded network model is completed, students collect statistics (the database server's Ethernet load and the entire network's Ethernet delay), and compare them with previous statistics that were collected for the first network. The statistics are used in determining if the database server will be able to handle the additional load of a second network, and if the total delay across the final network will be acceptable once the second network is installed.

WAN Modeling

The basic model in this lab is a hypothetical company's WAN (wide area network). The company has subnets in its offices in Atlanta, Dallas, Denver, and Minneapolis. All the offices are connected to the Internet via 56K point-to-point protocol (PPP) links (Figure 2). The network model also includes profiles of the following types of users and

their locations: Engineers – Atlanta and Denver offices, Researchers – Minneapolis office, and Salespersons – Dallas office. The model makes use of the following profiles that have been defined by OPNET: engineers – light web browsing, light e-mail use, light telnet use, and light file transfer; researchers – heavy web browsing and light e-mail use. e-commerce customer – light web browsing; and sales persons – light database access, light e-mail use, light web browsing, and light file printing. The applications (e.g. web browsing) are supported by servers in the Atlanta office (Figure 3).

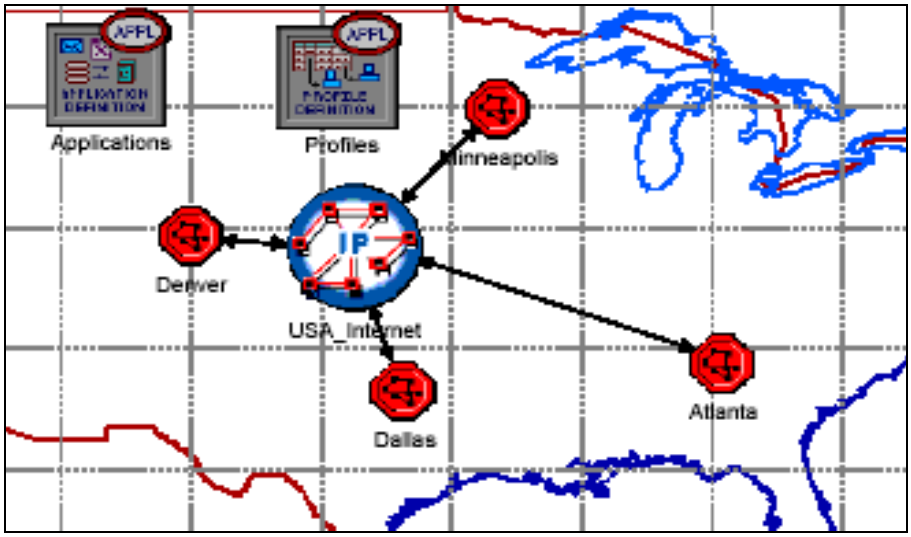

Figure 2 - WAN

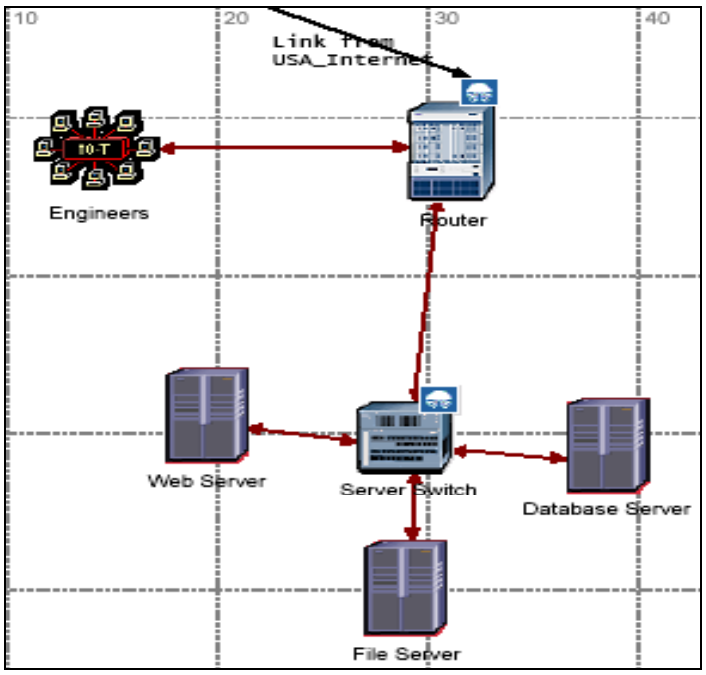

Figure 3 – Atlanta Office Subnet

Users of the company's network are experiencing high delays. The students create models of two upgraded networks. The first upgraded model replaces the 56K PPP links with DS-1 PPP links; the second upgraded model

uses DS-3 PPP links. The students run simulations for all three networks (56K, DS-1, and DS-3) in which the *HTTP Page Response Time* statistic is collected for each network. This is the average time it takes to retrieve an entire web page. A comparison of the data collected for each network is used to determine whether the company should upgrade to a DS-1 link or a DS-3 link.

Transmission Control Protocol (TCP)

Transmission Control Protocol (TCP) is a network protocol that provides reliable stream delivery and virtual connection service to applications. TCP congestion control algorithms allow a source to determine how much capacity is available in the network, so it knows how many packets it can safely have in transit. For each connection, the source maintains a congestion window in order to limit the amount of data that the source can have in transit at any given time. In this lab, the students study the effect of different network configurations on TCP congestion windows.

The basic network model in this lab consists of a FTP server located in Denver, CO, and a FTP client located in Chicago, IL. (Figure 4). The FTP client is connected to a router, and the router is connected to the Internet via a DS-3 PPP link. The FTP server is also connected to a router, and the server's router is connected to the Internet via a DS-3 PPP link.

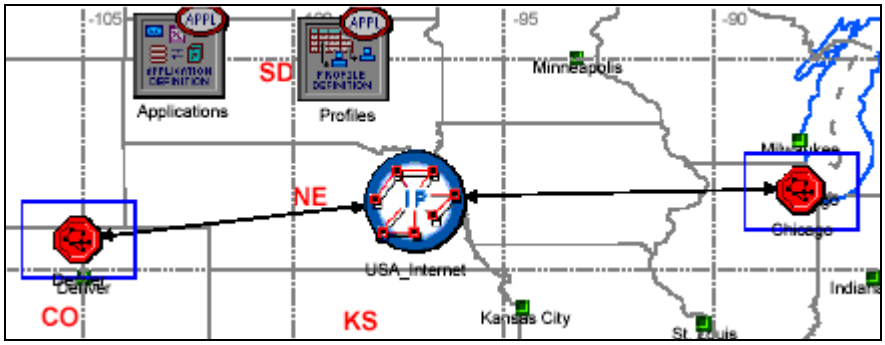

Figure 4 – Network Used to Study TCP

The basic network model represents a perfect network that does not discard packets. The students create two more network models. Each new model has an Internet packet discard ratio of 5%; the second new model also has an increase in the *receive buffer* of its FTP client. Each network model is configured to collect statistics for the FTP server's congestion window. Simulations are run and the students can see how discarded packets affect each network's TCP congestion window.

Students Comments

The students filled out a survey after completing the third module. Most students found the instructions in the modules to be easy to follow. They appreciated the exposure to an industry standard tool for designing networks. Some of the students suggested that more information be provided on OPNET software, and on why they had to follow certain steps in the modules.

Summary and Future Work

This paper has described three OPNET modules that have been developed for a Computer Networks class. The modules, which were developed using OPNET Modeler (version 9.1.A), have enhanced the educational experience of the students.

Future work includes improvement of the three modules in a way that takes the students suggestions into consideration, and the development of more modules, including modules on Ethernet and Token Rings. Student projects that use OPNET are also planned for the future.

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