DEVELOPMENT OF LABORATORY EXERCISES BASED ON THE OPNET NETWORK SIMULATING APPROACH

Ajay Kumar*
Graduate student, M.S. in Computer Science Program, Rivier College

Keywords: *OPNET IT Guru software, Networking lab, Ethernet, CSMA-CD, LAN*

Abstract

The primary purpose of this article is to discuss the laboratory exercises designed for using in the network-technology courses at Rivier College and analyze the lab results for the real-time networks and protocols. The labs have been developed in OPNET™ IT Guru Academic simulation environment, which is a network simulator that offers the tools for model design, simulation, and analysis.

1 Introduction

Different priorities and obstacles do not allow a small college to offer a variety of networks to its students and faculty for using them in the classrooms. As an option, they can use an invaluable tool, the OPNET™ IT Guru Academic software package [1] that offers all the tools for network model design, simulation and analysis at a reasonable cost. OPNET software can simulate a wide variety of different networks, which are linked to each other. One can just work from his/her PC to simulate different networks and study visually the impact of various factors (e.g., traffic load, bandwidth, data rate, etc.) on the network. With OPNET™ IT Guru, a sophisticated tool that provides analysis and modeling of network performance [2], users can study data message flows, packet losses, link failures, bits errors, etc. OPNET software is very user-friendly and easy to install.

The IT Guru's installation is straightforward and takes less than 15 minutes. The package has helpful documentation that is well laid out, easy to use, and includes a large number of examples and tutorials. In addition, the product is feature-rich and contains a steep learning curve. A network technician could find the product very useful in evaluating the effects of new applications and network changes without harming the production network.

2 Purpose

The purpose of this article is to discuss two laboratory exercises designed for using the OPNET™ IT Guru Academic software package (version 9.1). The following simulation cases will be discussed:

- Lab1: Ethernet (Aloha, CSMA-CD)
- Lab2: Switched Local Area Network (LAN).

3 Laboratory 1: Ethernet: A Direct Link Network with Media Access Control

3.1 Objective

This lab has been designed to demonstrate the operation of the Ethernet network. The simulation in this lab will help examine the performance of the Ethernet network under different scenarios.

3.2 Lab Overview

The Ethernet is a working example of the more general Carrier Sense, Multiple Access with Collision Detect (CSMS/CD) local area network technology [3]. The Ethernet is a multiple-access network, meaning that a set of nodes sends and receives frames over a shared link. The "carrier sense" in CSMA/CD means that all the nodes can distinguish between an idle and a busy link. The "collision detect" means that a node listens as it transmit and can therefore detect when a frame it is transmitting has collided with a frame transmitted by another node [4].

In this lab we set up an Ethernet with 14 nodes connected via coaxial link in a bus topology. The coaxial link is operating at a data rate of 10Mbps. lab is designed to explain how the throughput of the network is affected by the network load, as well as by the size of the packets.

3.3 Study of Traffic Characteristics

The simulation results are shown in Fig. 1. We have found non-monotonous relationship between the received (throughput) and sent (load) packets.

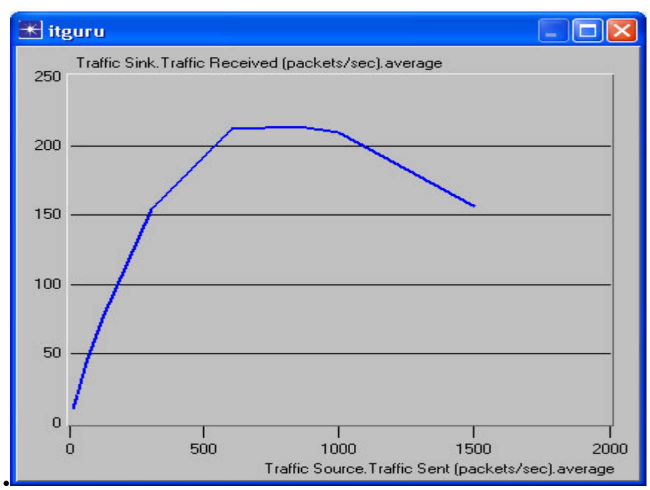

Fig. 1. Traffic received (throughput) vs. Traffic sent (load).

Initially throughput increases with offered load and reaches a maximum value. After the maximum load is reached, any further load only leads to decrease in the throughput. Therefore, in order to maximize the throughput in the network, the load must be chosen carefully. The fact is that, as the traffic on the network increases, more collisions occur causing retransmission of frames and consequently increasing their overall delay.

Increasing the number of packets (load) in the network also increases the length of the queues at each router. Longer queues, in turn, mean packets are delayed longer in the network, and, hence, the traffic received is dropped. At the same time too conservative approach leads to the drop again as it does not allow enough packets to being sent to keep the links busy.

In the Ethernet, collisions increase as the network is loaded, and this causes retransmissions and increases in load that cause even more collisions. The resulting network overload slows traffic considerably.

3.4 Analysis of Traffic Received

We have studied three variations of the previous simulation scenario: the coax_Q2a, coax_Q2b and coax_Q2c cases, for which the inter-arrival time attribute of the packet generation arguments has been set to the exponential factors of 0.1, 0.05, and 0.025, respectively.

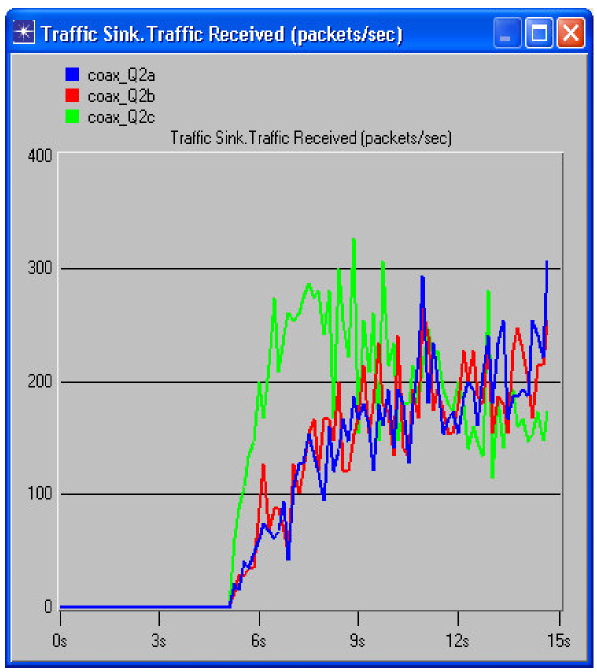

Fig. 2. Throughput Traffic Received vs. Inter-Arrival Time

The results of simulations are shown in Figure 2. We found that with decreasing the inter-arrival time the throughput (traffic received) increases till a certain maximum throughput is reached, and then decreases.

The Figure 3 shows the collision dynamics in the network, which is characterized by the average number of collisions. We found that, as long as the inter-arrival time is within a given limited range, the number of collisions remains small. Once the critical threshold is reached, the number of collisions increases dramatically.

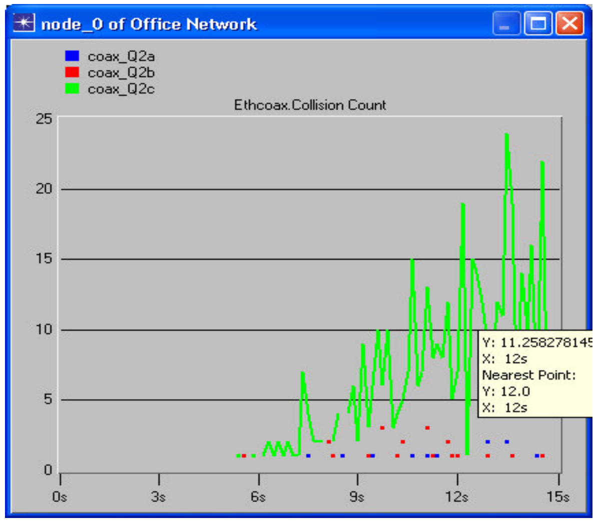

Fig. 3. Average Number of Collisions

3.5 Ethernet Scale vs. Its Performance

In this section, we study the effect of the number of stations on the Ethernet performance. The number of stations has been reduced from 30 (the original case, coax_Q2c) to 15 nodes (a new case, coax_Q3). The comparison of the node collision counts in these scenarios indicates that, as the number of nodes in the network increases, the number of collisions increases (see Fig. 4).

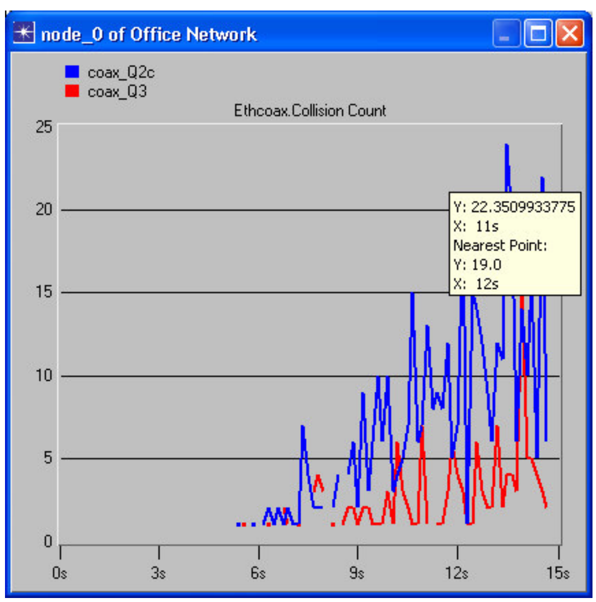

Fig. 4. Collision for a 15 node vs. 30 node cases

3.6 Packet Size Effects

We have studied the effect of the packet size on the throughput of the Ethernet network. The results shown in Figures 5 and 6 indicate that the throughput (traffic received) for the 512 byte packet (the coax_Q4 case) is greater than that one for the 1024 byte packets (the coax_Q2c case), although the bit rates are significantly different in both cases.

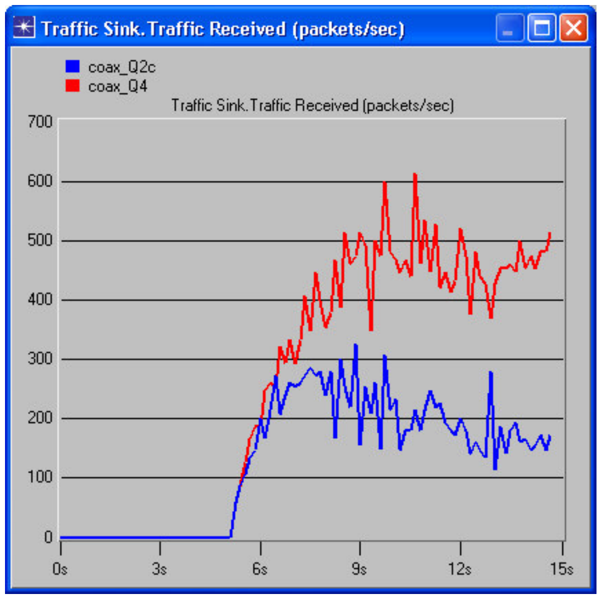

Fig. 5. Traffic Received (packets per sec)

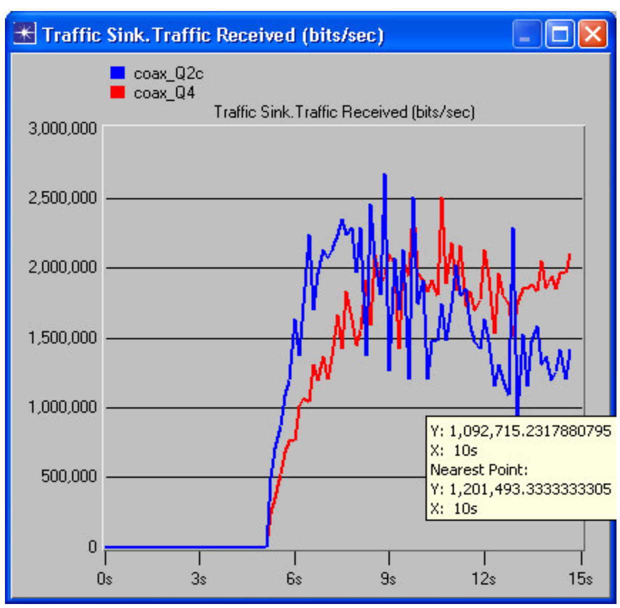

Fig. 6. Traffic Received (bits per sec)

4 Laboratory 2: A Set of Local Area Networks Interconnected by Switches

4.1 Objective

This lab has been designed to demonstrate the implementation of switched local area networks. The simulation in this lab will help examine the performance of different implementations of local area networks connected by switches and hubs.

4.2 Lab Overview

There is a limit on the number of hosts that can be attached to a single network and on the size of a geographic area that a single network can serve [3, 4]. Computer networks use switches to enable the communication between one host and another, even when no direct connection exists between those hosts [3].

The key problem that a switch must deal with is the finite bandwidth of its outputs [4]. If packets destined for a certain output arrive at a switch and their arrival rate exceeds the capacity of that output, then we have a problem of connection. In this case, the switch will queue (or buffer) packets until the contention subsides. If it lasts too long, however, the switch will run out of buffer space and be forced to discard the packets. When packets are discarded too frequently, the switch is said to be congested [3].

4.3 The Switch Role

The following study demonstrates why the adding of a switch makes a network perform better in terms of throughput and delay characteristics.

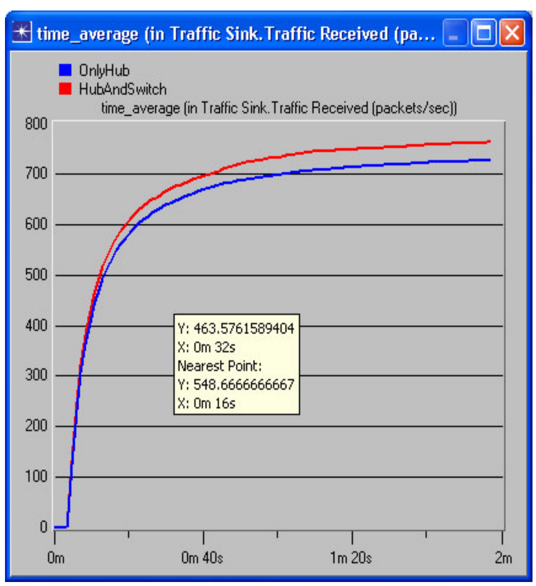

Fig. 7. Traffic Received (Throughput) for the Hub and Hub-and-Switch Cases.

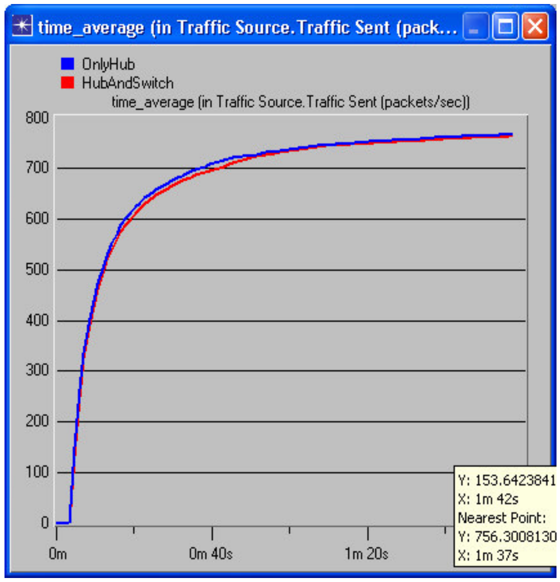

Fig. 8. Traffic Sent (Load) for the Hub and Hub-and-Switch Cases.

We have studied two cases: 1) Ethernet with the hub only, and 2) Ethernet with the hub and switch. The results shown in Figures 7 and 8 demonstrate that, although the traffic send is almost the same in both cases, the traffic received has improved in the Hub-and-Switch case. The second configuration makes network perform better in terms of throughput and delay characteristics.

With a switched network any user can be connected to each port directly [3]. Therefore, the bandwidth is shared only among a number of users in the workgroup (connected to the ports). Since this is the reduced media, the sharing of other portions of the bandwidth is available. Switches can also maintain multiple connections at one point [3, 4].

Switches normally have higher port counts than bridges and divide network into several dedicated channels independent ("parallel") from each other. These multiple independent data paths increase the throughput capacity of a switch. There is no contention to gain access, and LAN switch architecture becomes scalable. Another advantage of switches is that most of them are self-configuring. This property allows to minimizing the network downtime, although ways for manual configuration are also available [4].

4.4 Analysis of the Collision in the Switched LAN

The use of the switch makes it possible to reduce the collisions on the network. The communication procedures follow the certain rules. For example, when a peripheral device wishes to communicate, it sends the request for communication (a "message") that reaches the switch. If another peripheral device communicates already, two messages are found at the same time on the network. The message from the first host is taken at the beginning of a queue, and the second host waits for trying again to communicate a few milliseconds later.

Switches upon finding that the destination port is overloaded will send the *jam* message to the sender. Since the decoding of the MAC address is fast and the switch can, in very little time, respond with a *jam* message, collision or packet loss can be avoided [3, 4].

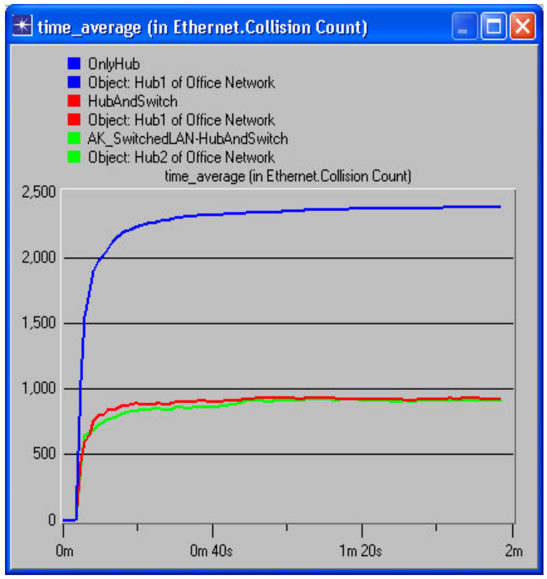

Fig. 9. Collision Counts for Various Ethernet Network Configurations.

The data shown in Figure 9 demonstrates that the network performance improves in LANs, in which LAN switches are installed, because the LAN switch creates isolated collision domains. Many LAN switch installations assign just one user per port [3]. By distributing users over several collision domains, collisions are avoided and performance improves.

4.4 Performance of Various Network Configurations

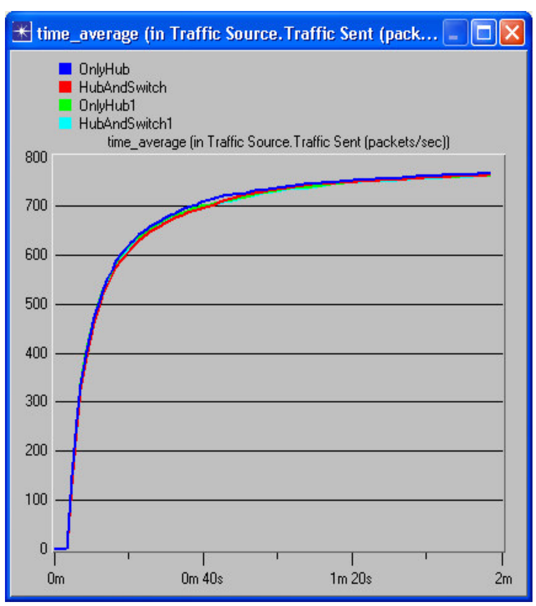

Fig. 10. Time Average in Traffic Sent

We have studied the network performances (in terms of delay throughput and collision count) for the following four network configurations:

1) The Only-Hub case: Hubs with out any switch
2) The Only-Hub1case: Hub is replaced by a switch
3) The Hub-and-Switch case: Two hubs and one switch
4) The Hub-and-Switch1 case: Two switches only

The Traffic Sent (load) parameters have been almost the same in all the cases (see Figure 10). We have found that there is a slight improvement in the network performance (Traffic Received characteristics) in all the cases with switches (see Figure 11).

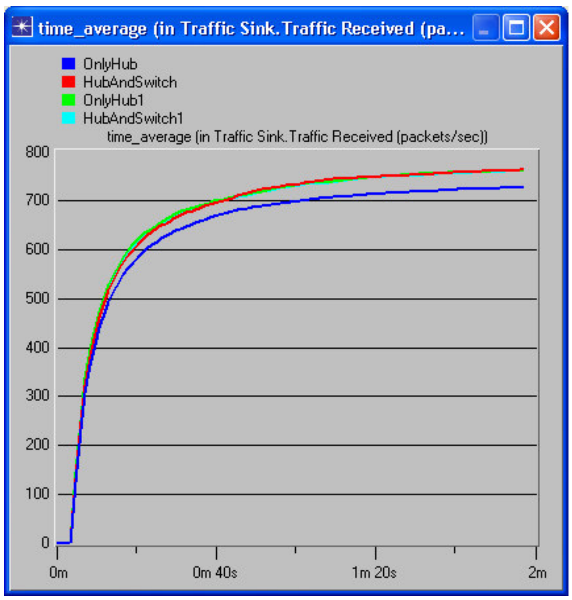

Fig. 11. Time Average in Traffic Received

The data shown in the Figure 12 demonstrates that the delay in the cases with the switches without hubs (the Only-Hub1, Hub-and-Switch, and Hub-and-Switch1 cases) is significantly less compared to the network configurations with a hub (the Only-Hub case). Particularly, when we replaced two hubs with switches the delay is almost negligible.

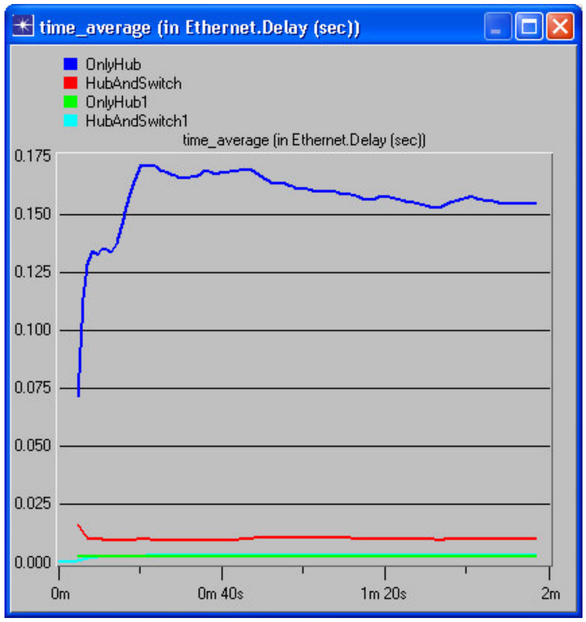

Fig. 12. Time Average Delay for Various Network Configurations.

5. Conclusion

This article consists of two laboratory exercises that cover a range of important topics in networking. The users are provided an opportunity to experience the behavior of different networks and protocols, as well as a tool for learning principles and procedures of network simulation by using the OPNET™ IT GURU Academic Modeler simulation environment. Nowadays, this is the most cost effective solution for colleges and universities to demonstrate the performance of different networks and protocols.

6. Acknowledgments

I would like to take this opportunity and thank the Department of Mathematics and Computer Science at the River College for giving me the opportunity to write an article on such interesting and challenging topic. Finally, I would like to give special thanks to Dr. Vladimir V. Riabov, Ph.D., associate professor of Computer Science, for all the support and help.

References

[1] IT Guru Academic Edition. OPNET Technologies, 2005. Retrieved October 1, 2005, from http://www.opnet.com/services/university/itguru_academic_edition.html.

[2] The World's Leading Network Modeling and Simulation Environment. OPNET Technologies, 2004. Retrieved October 1, 2005, from http://www.opnet.com/products/modeler/home.html.

[3] William Stallings. *Data and Computer Communications*, 7th Edition. Pearson Education, 2005.

[4] Larry L. Peterson and Bruce S. Davie. *Computer Networks: A System Approach*, 3rd Edition. Morgan Kaufmann, 2005.

* **AJAY KUMAR** was born in Bangalore, India. He received his B.S. in Mathematics, Physics and Chemistry from Bangalore University in India in 1991. After emigration to the United States in 1996, he worked as a consultant and software developer for Unisys Corporation. Ajay is currently a computer programmer/analyst at TradePoint Systems in Nashua. He passed the Oracle Certified Associate exams. Ajay is pursuing a M.S. in Computer Science at Rivier College.

