# SUNY FREDONIA CAMPUS NETWORK SIMULATION AND PERFORMANCE ANALYSIS USING OPNET

**Junaid Ahmed Zubairi & Mike Zuber**
**Department of Mathematics and Computer Science**
**State University of New York College at Fredonia, Fredonia, NY 14063**
zubairi@cs.fredonia.edu, zube7270@fredonia.edu

## ABSTRACT

SUNY Fredonia campus has recently migrated to switched Ethernet subnets and Gigabit Ethernet backbone. We are studying the performance of the time sensitive applications on campus network under varying load conditions using OPNET. This paper presents a few results and talks about planned work in future. We developed a model of the campus network in OPNET. Once the network simulation model was ready, we obtained Ethernet delay, traffic statistics and other interesting data. Next, we ran interactive voice across the network to determine if our department and campus network can handle such demanding applications under varying load conditions. In future, it is planned to implement new innovative algorithms for handling real-time speech traffic over the existing IPv4 network and obtain results via OPNET simulations.

## INTRODUCTION

SUNY Fredonia is a small college having about 5,000 students in the SUNY system located by the shores of Lake Erie near the city of Buffalo. Due to the increased use of computers in classes, labs and faculty offices, the campus network has experienced tremendous growth in the volume of traffic. Fredonia campus has recently migrated to switched Ethernet subnets and Gigabit Ethernet backbone to ease congestion. The college has invested in high-end routers and additional links to the Internet. Users have seen an improvement in the performance of overall network.

Now a days, two dominant trends in computing are increase in the power and capacity of machines and increase in networked applications. The applications over the network are using graphics, animations, images, voice and other multimedia streams. All such data requires high bandwidth to serve the users without performance degradation. The type of traffic on the network is changing from the best effort data traffic to delay bounded media streams and interactive speech. This change has prompted us to investigate if the current network would be able to support VoIP (Voice-Over-IP) or videoconferencing type applications. We have defined a research project to study and analyze the performance of the campus network. This project is comprised of two parts. The first part deals with performance quantification of the campus network by simulated testing. The second part is concerned with implementing innovative algorithms over the existing IPv4 networks for improving the real-time speech traffic. Using various testing techniques, we aim to quantify the performance of the campus network, isolate potential hot spots in the network and evaluate the suitability of the campus network for multimedia applications.

The time-sensitive applications such as multimedia multicasting, real-time speech and tele-medicine need certain delay constraints to be fulfilled by the network. For "on-time" transmission, the network should provide an upper limit on the delay. Various service levels and QoS parameters have been defined for cell-based and packet-based networks[1,2,3,4,5]. The latest version of IP i.e. IPv6 defines a 4-bit priority field in the header enabling a source to identify the desired delivery priority of its packets, relative to other packets from the same source. The priority values are divided into two ranges. Values 0-7 have the source applying congestion control, e.g. TCP. Values 8-15 are used to identify the traffic that does not back off on facing congestion. For such traffic, the lowest Priority value (8) is used for those packets that the sender is most agreeable for being discarded under conditions of congestion for example video traffic. The highest value (15) is used for those packets that the sender is least agreeable to have discarded for example audio traffic[6]. Most of the networks are packet-based and the service-sensitive protocol IPv6 has been introduced very recently. It will take at least 5 years for the Internet to migrate to IPv6. During this time, rigorous simulated studies must be conducted to extract the actual performance of IPv6 on different types of Ethernet as well as in a hybrid Ethernet-ATM network.

Using network performance benchmarking software on Linux workstations, analysis of the performance of real Ethernet-ATM network under varying load conditions has been done and reported elsewhere[7,8]. This provides some initial results and helps us in developing traffic simulation platform for Ethernet-ATM network for experimental purposes through OPNET network simulation systems.

**CAMPUS NETWORK MODELING WITH OPNET**

In this section, we describe our efforts to model the SUNY Fredonia campus network and to simulate high-quality voice traffic between clients while monitoring various things such as delay variation, dropped packets and total bytes sent.

One of the problems that we ran into when first familiarizing ourselves with OPNET was the need to make custom models. Our campus makes extensive use of the Cisco product line, with the 2924 switch making up the majority of our client-end connections. However, there were no 2924 in the model library. Fortunately, when it came time to model the campus, the "Create Custom Model" functionality came handy.

Reaching the goal of modeling the campus was relatively easy, thanks to our Network Manager Bruce Wilger and Vice President of Academic Information Technology Ms. Karen Klose. Our campus is broken down into 2 parts: Academic and Residential. Academic consisting of academic and administrative buildings. Residential is the housing for students. With some minor exceptions, all the wiring consists of various speeds of Ethernet (10, 100, Gigabit, and T-1's for Internet) and almost all of the hardware consists of Cisco switches and routers.

Once we discovered the layout of the campus and the kind of hardware used, the next step was to see if that hardware existed in OPNETs model library. Which, of course, it didn't. Our campus uses the following Cisco products

1924 / 2924
5500 / 5505 / 5509
6509
3640 ( 4-bay multiservice access router)
(* Models on the same line denote that they are in the same series)

Of the models listed above, only one was already modeled in OPNET, the 5500. So, with that in mind, our next task was to create the models that didn't already exist and place them in our own palette. After discovering the "Create New Model" menu item creating new models with information from the Cisco website was a snap. However, that ease-of-use came with a price: Modeler saw all of the ports as being 10/100/1000-enabled. This wasn't really a problem, just so long as we paid close attention to what we were connecting to these devices. Another snag we ran into was the number of ports on the Cisco hardware being modeled. The 5500 series, for example, can be configured with different number and types of ports. However, once you created a new switch with n-ports, you were stuck: that model would always have that many ports. We picked a number that was within the products specs while not being too ridiculously high.

Now armed with a decent and fairly accurate palette, we could set out to model the campus, which wasn't difficult, just tedious. What we did was make every building its own subnet. Academic and residential buildings were handled in a slightly different manner from one another. It is known that about 35-40% of all students living on campus are using Ethernet connections. We also knew the maximum capacity of all the buildings. So, with that info, we took 40% (worst case) the capacity of the given dorms and made that many clients. We used the pre-made "Ethernet Client" model and configured it for heavy browsing, light ftp and light e-mail usage, figuring this configuration to represent the average use of a computer on an academic campus. Most wiring closets in the dorms contain 1924's and some are with 2924's. All clients were connected to their respective switches with 10Mb copper. From that point, the dorms are basically broken down into groups of 4 and then, using fiber, the 1924/2924's are connected to 5505's using their 100Mb uplinks. There are 3 5505's, one for each group of 4 dorms, and we have 12 dorms. These 5505's are connected to the sole 6509 on campus located in Maytum using Gigabit Ethernet. The 6509 has a connection to the 3640 that provides the campus with Internet access using multiple T-1's with POPs in Rochester and Buffalo.

On the academic side, things get a little more complicated. As far as the dorms are concerned, they were basically carbon copies of each other. Academic buildings weren't so easy. But at the same time, the idea was the same: Ethernet client machines connected to 1924's and 2924's (far more 2924's this time around) with 100Mb copper connections where applicable, 10Mb copper in other cases. 1924's and 2924's were, in most cases, uplinked to 5505's or 5509's using Fast Ethernet. There were other cases where a given 1924 or 2924 would just be connected directly to the 6509 in Maytum using 100Mb fiber. The "Create LAN" wizard came in handy more times that we could count.

Maytum Hall is the heart of the campus LAN. It is where the router resides (which connects us to the outside world). It is where the 6509 is located (which all things

Ethernet eventually end up connecting to on campus) and it is also home to many servers used on campus. While in the model there are many NT/Unix servers located in Maytum Hall, only two are currently configured for running the school's mail services. These are two UNIX boxes that are running e-mail, ftp and remote login services (and are configured as such in the simulation). As far as other servers are concerned: Thompson Hall has an NT box that is running as an HTTP server. Fenton Hall South has about 10 to 12 UNIX boxes (the SGIs) running remote login and ftp and 3 Linux servers serving two subnets for departmental services. These are all modeled.

**EXPERIMENTS CONDUCTED**

(1) Computer Science lab simulation for voice traffic between two clients

(2) Overall campus network simulation with our typical load for determining top statistics i.e. potential congestion points.

(3) Overall campus network simulation with new proposed configuration to see if the congestion will be eased.

(4) Campus network simulation with main links between potential voice clients loaded with 50 percent background utilization.

(5) G.711 Voice application between two clients in Fenton South and McGinnies Hall under normal load conditions

(6) G.711 Voice application between two clients in Fenton South and McGinnies Hall with all switch links loaded with 50 percent background utilization

**RESULTS AND COMMENTS**

The diagrams of simulated CS lab and Campus network are shown in Figure 1 and Figure 2. A session of high quality speech traffic between two workstations was conducted in the CS lab. The results show that the network performance is very good as the voice packets experience a consistent delay ranging between 0.6ms and 0.7ms and the delay variation is within 20-40 nanoseconds. Since the traffic is contained within the CS lab, not much variation in network performance for high quality speech can be found.

For campus network, we have conducted experiments 2,3,4,5 and 6. We have 2031 client computers in the simulated network. The Ethernet workstations are all configured for light ftp and email load and heavy web browsing representing the typical use of machines in our academic environment. Simulated network traffic exceeds the actual measured traffic on the campus network therefore we are simulating "worse" case behavior. For average load, we found that the Gregory5500 switch serving ResNet and Fenton5505 serving the South Fenton Hall are handling the most traffic, as shown in Figure 3. The future plan of campus

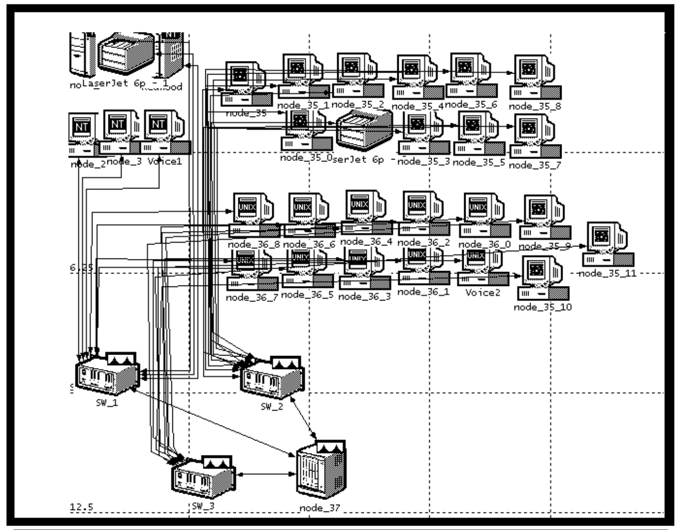



**Figure 1 The Simulated Computer Science Lab Network**

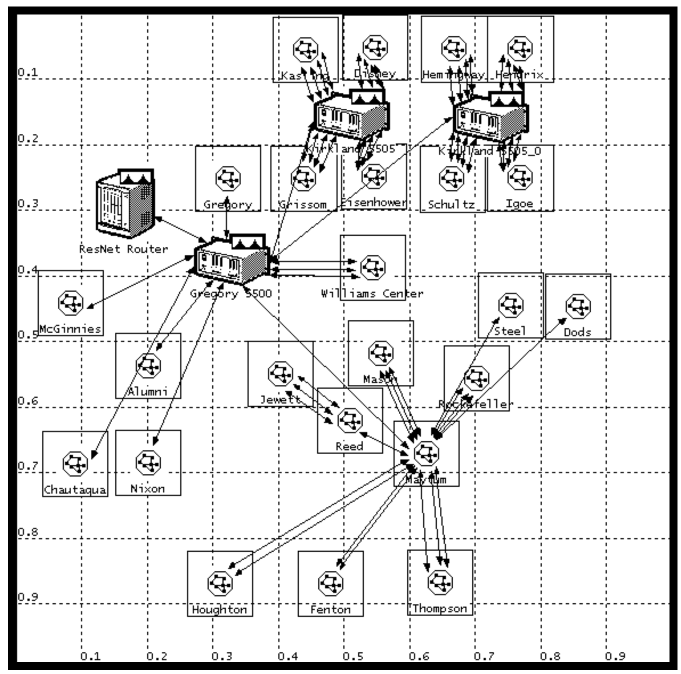
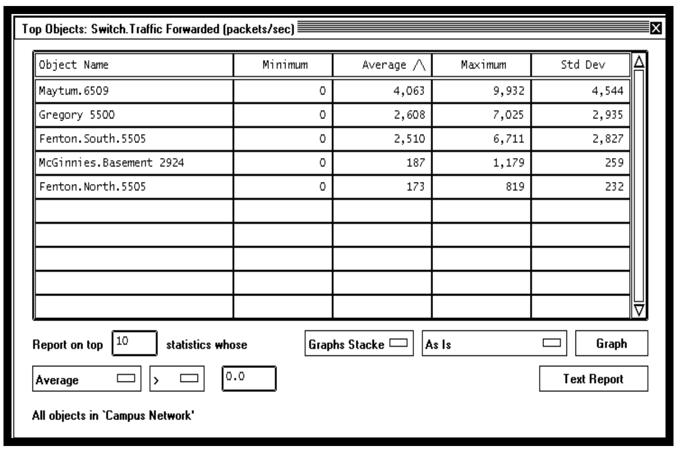



**Figure 2 The Simulated Campus Network**

network may ease this situation by adding more switches and uplinks to Maytum6509 from these buildings. Our Network Manager agreed with the findings of the simulation and presented his own solution for future. He proposed routing the other two 5505 switches of ResNet directly back to the 6509 in Maytum via Gigabit Ethernet. That would evenly spread the ResNet traffic across three Gigabit trunks vs. one. That would take 2/3 of the load off of the Gregory 5500. This solution was also simulated with OPNET and found to be successful in eliminating congestion. The results after implementing the solution are shown in Figure 4. It can be seen that the number of packets forwarded has dropped significantly for Gregory5500 switch.



Top Objects: Switch.Traffic Forwarded (packets/sec)

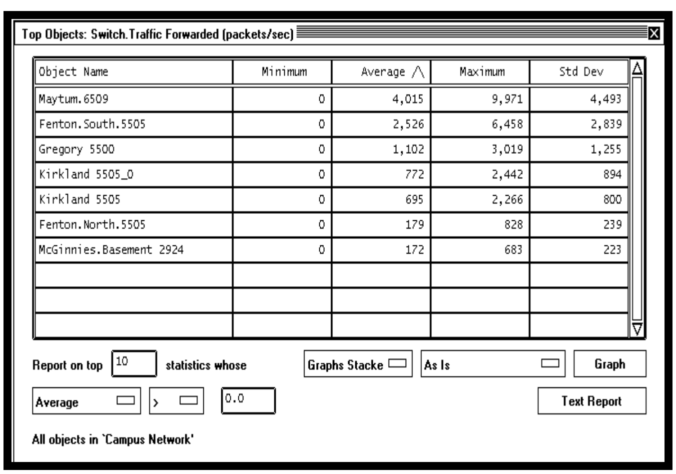
| Object Name | Minimum | Average | Maximum | Std Dev |
|---|---|---|---|---|
| Maytum.6509 | 0 | 4,063 | 9,932 | 4,544 |
| Gregory 5500 | 0 | 2,608 | 7,025 | 2,935 |
| Fenton.South.5505 | 0 | 2,510 | 6,711 | 2,827 |
| McGinnies.Basement 2924 | 0 | 187 | 1,179 | 259 |
| Fenton.North.5505 | 0 | 173 | 819 | 232 |

Report on top 10 statistics whose Graphs Stacke As Is Graph

Average > 0.0 Text Report

All objects in `Campus Network'

**Figure 3 The Top Traffic Statistics for Typical Load**



Top Objects: Switch.Traffic Forwarded (packets/sec)

| Object Name | Minimum | Average | Maximum | Std Dev |
|---|---|---|---|---|
| Maytum.6509 | 0 | 4,015 | 9,971 | 4,493 |
| Fenton.South.5505 | 0 | 2,526 | 6,458 | 2,839 |
| Gregory 5500 | 0 | 1,102 | 3,019 | 1,255 |
| Kirkland 5505_0 | 0 | 772 | 2,442 | 894 |
| Kirkland 5505 | 0 | 695 | 2,266 | 800 |
| Fenton.North.5505 | 0 | 179 | 828 | 239 |
| McGinnies.Basement 2924 | 0 | 172 | 683 | 223 |

Report on top 10 statistics whose Graphs Stacke As Is Graph

Average > 0.0 Text Report

All objects in `Campus Network'

**Figure 4 Top Traffic Statistics on Simulating Proposed Changes**

For voice application, we configured a client machine in McGinnies Hall to set up interactive voice connection with another machine in Fenton South. The simulation was conducted for typical campus load and then it was conducted again with all the intermediate switch links loaded with 50 percent background traffic. The delay variation and other statistics in both cases are shown for the machine in McGinnies Hall in Figure 5 and Figure 6. Under typical load, the packet delay variation does not exceed 60ns and the Ethernet delay is within 2ms. However, when the switch links are loaded with 50 percent background traffic, the Ethernet delay goes above 3.5ms and the packet delay variation for voice application increases to a maximum of 300ns. This is only for a single voice call and the situation will deteriorate if more calls are started at the same time.

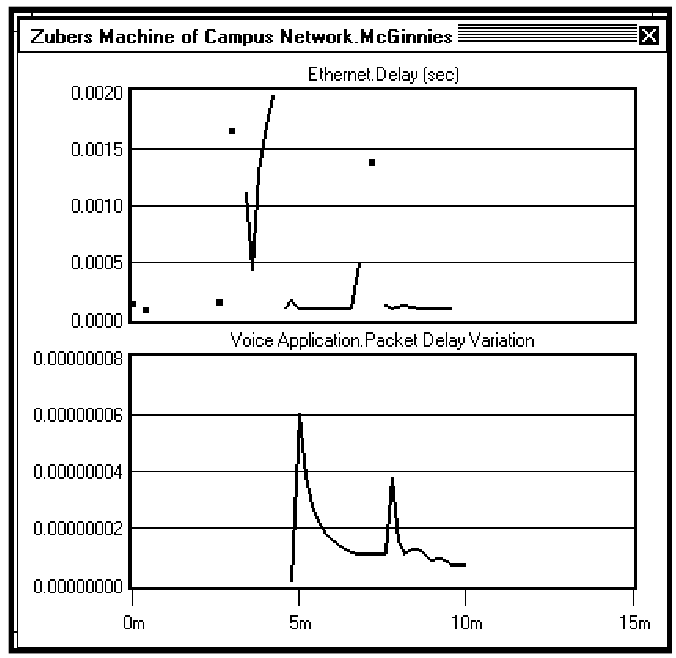



**Figure 5 Voice Application Performance Under Typical Load**

## CONCLUSION

We are working to evaluate the performance of SUNY Fredonia campus network under typical load conditions and also for time-sensitive applications such as voice over IP. We have presented a few results for network behavior under typical and heavy load conditions showing some potential bottleneck points. Two client machines were configured for interactive voice in two different subnets to pass the traffic through the core campus network. The results show very good performance under typical load conditions. However, the delays and delay variations increase under loaded conditions. More experiments are needed to ascertain the capacity and readiness of the campus for deploying voice over IP in a major way.

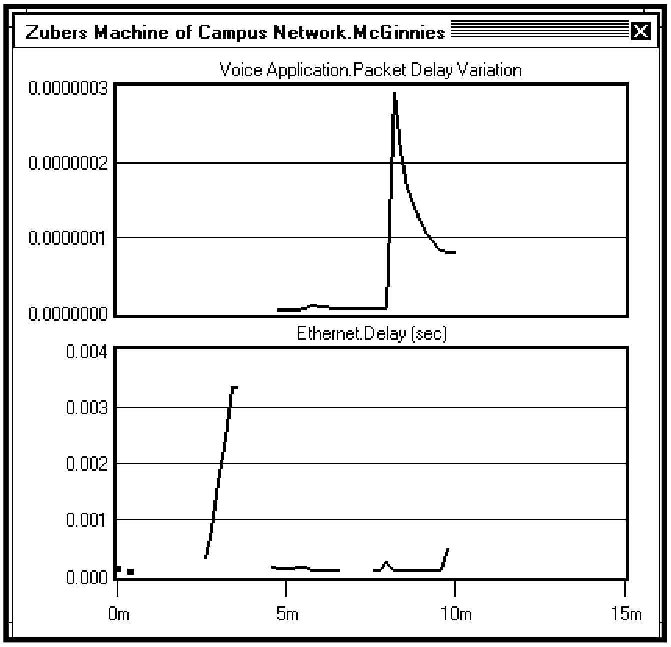



**Figure 5 Voice Application Performance Under Typical Load**

## REFERENCES

1. R. Onvural, *"Asynchronous Transfer Mode Networks: Performance Issues"*, Artech House, 2nd edition, 1995

2. U. Black, *"ATM: Foundations for BroadBand Networks"* Prentice Hall, 1995

3. L. Zhang, S. Deering, D. Estrin, S. Shenker and D. Zapalla, *"RSVP: A New Resource ReSerVation Protocol"*, IEEE Network, Sep. 1993

4. *"Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers"* in IETF RFC 2474 http://www.ietf.org/rfc/rfc2474.txt

5. *"An Architecture for Differentiated Services"* in IETF RFC 2475 http://www.ietf.org/rfc/rfc2475.txt

6. W. Stallings, *"IPv6: The New Internet Protocol"* IEEE Communications Magazine, vol. 34, no. 7, (1996) pp. 96-108

7. S. Al-Irhayim, J. A. Zubairi and W. H. Hassan, *"ATM Deployment Issues In A BroadBand Heterogeneous Campus Wide Network"* in Proc. IEEE MICC and ISPACS, Kuala Lumpur, Malaysia, November 1997, pp S14.3.1-S14.3.6.

8. J. A. Zubairi and A. Jantan, *"ATM-Ethernet Network Performance Analysis"* in Proc. IEEE National Conference on Telecommunication Technologies, Universiti Putra Malaysia, Kuala Lumpur, Dec 1998, pp 25-28.