Using OPNET to teach students computer networking subject

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(Received 13 / 4 / 2008 , Accepted 15 / 12 / 2008)

Abstract

Teaching introductory networking poses a challenge ,It is difficult to teach data communications because it require complex, stochastic processes which are not visible to students and hard for them to understands .The traditional way to teaching data communications consists of lectures, where the Queing's theoretical, mathematical basis is presented, and laboratory sessions where students are taught how to program a communications protocol in the hope that this will enable them to better understand the communication process or connect actual network which is very expensive and time consuming. These ways are not ideal because a verbal or text-based description does not convey the process of data communications adequately. Having students do programming an assignment is very time consuming and hence many students are unable to get beyond the mechanics of programming to a full understanding of the communication process. This paper show laboratory exercises for use with data communication and networking courses. All laboratories are developed in OPNET Modeler 9.1 simulation environment which is a network simulator that offers the tools for model design, simulation, data mining and analysis.

Keywords: OPNET, Teaching, Networking subject, simulation.

1. Introduction

As networking systems have become more complex and expensive, hands-on experiments based on networking simulation have become essential for teaching the key computer networking topics to students. The simulation approach is the most cost effective and highly useful because it provides a virtual environment for an assortment of desirable features such as modeling a network based on specific criteria and analyzing its performance under different scenarios with no cost [1].

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 [2] 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. The student 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 [3], 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.

The laboratory exercise of this paper has been implemented by The students through the use of OPNET simulation Program in there data communication and computer networking course at technical college of Mosul. The students need little knowledge about Queuing theory , line displine how the Discrete Event Simulation works ,some basic traffic models and statistical approaches where these subjects are there syllabus course), after install the OPNET software .The Students then work under supervision in small groups (three or four students). For each LAB exercise the students, implement the Labs, analysis results with there teachers , and report writing of the lab experiment in there Group , this both help us and them to assess the efficacy of the simulation experiments in enhancing student learning, through several questions to test the students' understanding of relevant basic concepts From the students' lab feedback, we found that the OPNET labs benefit students in deep understanding of complicated details of actual systems, encourage active learning (group of students after ending the semester be able to design a huge computer network for technical college and evaluate the performance of their design [4].This paper show some of results of the exercise LABs as graph and (or) a table of the values of some of the simulation parameter

2. System Requirements

To install OPNET in your PC you need [4]

- Intel Pentium III, 4 or compatible
- 256 MB RAM
- 400 MB disk space
- Display: 1024 x 768 or higher resolution, 256 or more colors
- The English language versions of the following operating systems are supported:
- Microsoft Windows NT (Service Pack 3, 5, or 6a; Service Packs 4 and 6 are not supported)
- Windows 2000 (Service Pack 1 and 2 are supported but not required)
- Windows XP (Service Pack 1 is required)

3. The purpose of using OPNET

OPNET is the best network simulator to meet teaching goals for the following reasons:

- OPNET is much easier to use. It provides a very convenient Graphic User Interface (GUI) and is very easy to learn [1].
- OPNET provide quality of documentation [5]
- OPNET meets all the needs for use in a different data communications course [9].
- OPNET is also suitable for use in research [5]

- OPNET can be used to model the entire network, including its routers, switches, protocols, servers, and the individual applications they support. A large range of communication systems from a single LAN to global inter-networks can be supported [1].
- OPNET software (with model source code) is available for FREE to the academic research and teaching community. Students can download and install OPNET IT Guru Academic Edition at home [1].
- The OPNET's discrete event engine for network simulations is the fastest and most scalable commercially available solution. It usually takes just a few minutes to complete simulations of most lab experiments [1].
- OPNET has a large user community. OPNET software is used by major fortune-500[9]

Companies, service providers, and government organizations worldwide. Students who Have experiences with OPNET simulator will have much better future employment opportunities in industry [1]. In addition to previous reason OPNET uses models that are specified in terms of objects, each with configurable sets of attributes. This allows for flexible definition of new objects with programmable characteristics and behavior in order to address the wide scope of systems that are presented in the course. Models are hierarchical to naturally parallel the structure of actual communication networks. The hierarchical approach allows for deep nesting of sub networks and nodes and large networks can be efficiently modeled. Stochastic and/or deterministic models can be used to generate network traffic. Performance evaluation and trade-off analysis require large volumes of simulation results to be interpreted and OPNET includes a tool for graphical representation and processing of simulation output. Simulation runs can be configured to automatically generate animations of the modeled system at various levels. These are used to help the student visualize how the network operates while working. Simulation results can be plotted as time series graphics, scatter plots, histograms, and probability functions [5].

4. Knowledge needed from student to be able to design and simulate a communication network

There are some basic communication building blocks that the students must understand before they are able to design and simulate a communication network. A basic understanding of queuing theory is required of students because it plays an important role in the design of computer communication networks and systems [5].

5. OPNET overview

OPNET's IT Guru provides a Virtual Network Environment that models the behavior of an entire network, including its routers, switches, protocols, servers, and individual applications. By working in the Virtual Network Environment, IT managers, network and system planners, and operations staffs are empowered to diagnose difficult problems more effectively, validate changes before they are implemented, and plan for future scenarios including growth and failure [6].

OPNET is a discrete network simulator which contains a comprehensive development environment supporting the modeling and performance evaluation of communication networks and distributed systems [1].

6. Modeling Methodology

OPNET Modeler is based on a series of hierarchically related editors that directly parallel the structure of actual networks. The modeling structure is consist of group of editors as following [7]

6.1 Network Editor (project editor)

The first editor is Network Editor (Project editor), which graphically represents the topology of a communication network. Networks consist of node (switch/router, server etc.) and links model (Ethernet, ATM, FDDI etc.). It is possible manage complex network with unlimited sub network nesting such as country, city, building, floor etc... Network editor provides geographical context, with physical characteristic of the networks [7]. From this editor, user can create a network model using models from the standard library, collect statistics about the network, run the simulation, and view the results see figure (1) [8] .

6.2 Node Editor

The Node Editor is used to define the behavior of each network object. Behavior is defined using different modules, each of which models some internal aspect of node behavior such as data creation, data storage, etc. Modules are connected via packet streams or statistic wires see figure(2). A single network object is typically made up of multiple modules defining its behavior [8].

6.3 Process Model Editor

The Process Editor is used to create process models, which control the underlying functionality of the node models created in the Node Editor. Process models are represented by finite state machines (FSMs), and are created with icons that represent states and lines that represent transitions between states see figure (3). Operations performed in each state or for a transition are described in C or C++ code blocks [8].

6.4 Link Model Editor

The Link Model Editor is used to create new types of link objects. Each new type of link can have different attribute interfaces and representation see figure (4). Comments and keywords can also be specified for easy recognition [8].

6.5 The Path Editor

The Path Editor is used to create new path objects that define a traffic route. Any protocol model that uses logical connections or virtual circuits such as MPLS, ATM, Frame Relay, etc can use paths to route traffic see figure (5) [9].

6.6 Packet Format Editor

The Packet Format Editor is used to define the internal structure of a packet as a set of fields. A packet format contains one or more field each, represented in the editor as a colored rectangular box see figure (6). The size of the box is proportional to the number of bits specified as the field's size [9].

6.7 Probe Editor

The Probe Editor is used to specify the statistics to be collected during simulation. While this can be done in the Project Editor, the Probe editor can be used to set additional characteristics of each probe. There are several different types of statistics that can be collected using different probes, including global statistics, link statistics, node statistics,

Attributes statistics, and several types of animation statistics see figure (7) [8].

6.8 The Simulation Sequence Editor

In the Simulation Sequence Editor an additional simulation constrains can be specified. Simulation sequences are represented by simulation icons, which contain a set of attributes that control the simulation's run-time characteristics see figure (8) [9].

6.9 Analysis Tool

Although simulation results can be viewed in the Project Editor, the Analysis Tool has several useful additional features. You can, for example, create scalar graphs and parametric studies, define templates to which you apply statistical data, create analysis configurations for application of statistical data, and create analysis configurations that can be saved and viewed later see figure (9)[8].

7. OPNET Labs

In this paper a set of labs is shown with appropriate screen captures from OPNET IT Guru Version 9.1 (OPNET IT Guru 9.1 is downloadable free for educational use). They are appropriate for someone who is at the introductory to intermediate level with networking technology [13]. They provide a way of learning features of OPNET in addition to being hands on review of some aspects of standard networking theory [13]. They are written in a generic way they are intended to be worthwhile anywhere from advanced curriculum to fundamentals.

7.1 M/M/1 Laboratory Exercise

Through this Exercise the students introduced to the M/M/1 queuing model to gain a basic understanding of how queuing models play an important role in communication networks. An M/M/1 queue consists of a first-in-first-out (FIFO) buffer with packets arriving randomly in accordance with a Poisson process, and a processor, called a server, which retrieves packets from the buffer at a specified service rate see figure (10)[5]. The three parameters that are examined are: packet arrival rate, packet sizes, and service capacity. The task of the students is to construct an M/M/1 queue model to allow an analyst to observe the performance of the queuing system with varying packet arrival rates, packet sizes, and service capacities. The students run simulations that will measure average delay (waiting time) experienced by packets in the queue, number of packets in the queue at any one time and average number of packets in the queue over time, and then analyze the results. This is done through design a process model that will count and present the number of packets received over time from any number of packet sources [١].

The components of a process model include a finite state machine diagram with embedded C statements, and various blocks containing code for variable declarations, macros, constant, and function definitions. The finite state machine diagram represents the functional flow of the process with an easily interpreted diagram of states and transitions. Events and conditions determine the migration from state to state through transitions [10]. Figure (11) shows a generic representation of a simple finite state machine. Each circle represents a state; the arrows between states represent transitions. The student can manipulate the system and show different case of result for example traffic received as seen in figure (12). Table (1) shows the results of M_M_Q (Queuing Disciplines) for multiple executions [10].

7.2 ETHERNET laboratory Exercise

Through this Exercise the students introduced to demonstrate the implementation of ETHERNET network . The simulation in the lab will help students examine the performance of the ETHERNET network under different scenarios. In this lab, students will set up an ETHERNET network with 18 nodes connected in a Bus topology. Students will learn that the throughput of Ethernet drops when the load is very high due to the increasingly frequent collisions that are occurring as the network reaches saturation as seen Figure (13). Table (2) shows the results for multiple executions for transmit and receive packets [5].

7.3 Token Ring Laboratory Exercise

Through this Exercise the students introduced to demonstrate the implementation of a token ring network. In the lab students will set up two token ring networks with 14[1] and 20 nodes both connected in a star topology, as seen in Figure (14 a) and (14b).The Students will study how the utilization and delay of the network are affected by the network load as well as the THT as seen in figure (15) and number of connected nodes.

7.4 Routing Information Protocol Laboratory Exercise

Through this Exercise the students introduced to explores the Routing Information Protocol (RIP), as seen in Figure (16). Students configure and analyze the performance of the RIP under different scenarios. Experiments illustrate the count-to-infinity problem in the distance vector routing protocol. The student can compare the number of Updates between any Routers in scenarios Lab as seen in figure (17).Also they could obtain the IP Addresses of the interface [1].

7.5 TCP simulation Laboratory Exercise

Through this Exercise the students introduced to demonstrate the functioning of TCP, and particularly the four algorithms used for congestion control: slow start, congestion avoidance, fast retransmit and fast recovery. The lab provides a number of scenarios to simulate and compare these algorithms [9].The student can show different results from this Lab for example sent segment sequence number as seen in figure (18).

7.6 Hubs versus Switches in Small Business LAN Laboratory Exercise

Through this Exercise the students introduced to demonstrate a compare performance of pure hub LAN with switched LAN in a tiny network. The students will create two scenarios. In one scenario there are five workstations that connect to a web server via a hub. Relevant performance statistics will be collected at both the workstations and the server. The same will be done in a second scenario except that instead of a hub it will be a switch facilitating the connection between server and workstations [13]. The student can show different results from this Lab for example Collision Count for the different scenario uses as seen in figure (19). Table (4) shows the results of various executions.

7.8 Wireless Network Laboratory Exercise

Through this Exercise the students introduced to design a simple radio network with a mobile jammer node and two stationary communications nodes, and then demonstrate the differences in the SNR of the network when the stationary nodes use an isotropic or directional antenna. This is done through a set of tasks the students must perform it : Use the radio link, mobile node , and antenna Pattern Editor to create a directional antenna pattern , define the trajectory of a mobile node ,execute parametric simulations ,and use the time controller to step through time values and relate node positions and results[3]. The student can show the result of bit rate and throughput for both isotropic and directional antenna as seen in figure (21).

7.9 Extra Laboratory Exercise

Through OPNET™ IT GURU Academic Modeler simulation environment the students can introduced to huge exercise , we cannot mention all these exercise through this paper ,so we mention some of these such as , ATM ,FDDI ,Token Bus , and Frame Relay Etc.

8 Conclusions

Simulation offers significant advantages as a basis for academic projects in computer networking. Because many unimportant details can be abstracted away, and also because simulations can be completely repeatable, it is possible to address the same concepts more quickly than is possible with actual networks. An important complement to classroom lectures is laboratory experiments. In networking, this often implies programming, protocol design, experiments and measurement. Simulation has an important role here since it allows students to examine problems with much less work and of much larger scope than are possible with experiments on real hardware. Therefore students will come to understand networking theory much better than if they learn only from reading and lectures. This paper shows that OPNET™ IT GURU Academic Modeler simulation environment is the most cost effective solution for colleges and universities to demonstrate the performance of different networks and protocols. Also this paper shows that the students will benefit from the OPENT simulation laboratory in many ways. The OPNET simulation labs reinforce the networking theory taught by regular lectures. The open design of the labs encourages active learning. In addition, students gain the knowledge of modeling and simulation technique for performance evaluation of networking systems.

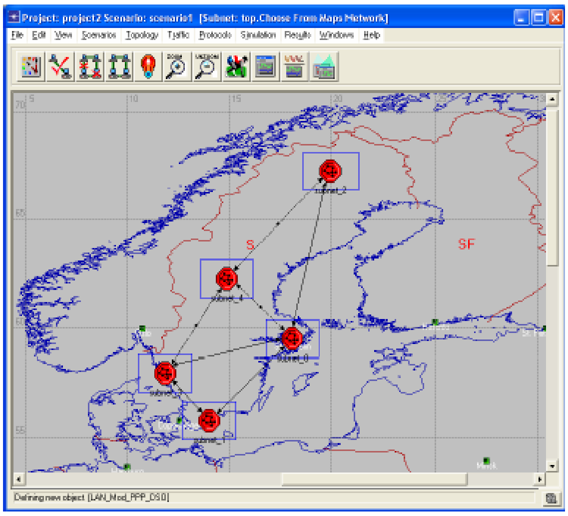


Fig. (1) a network model built in the Project Editor

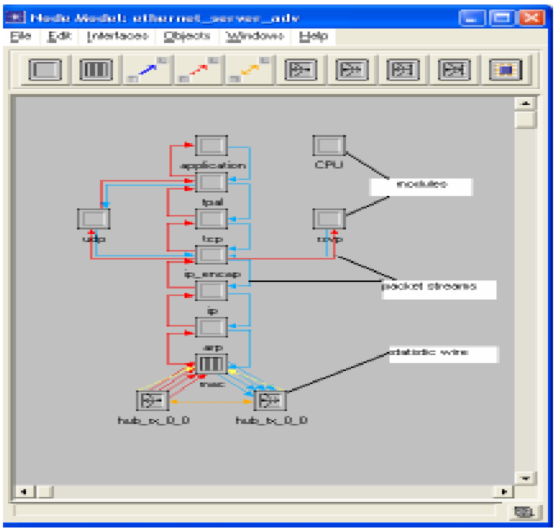


Fig. (2) Node editor

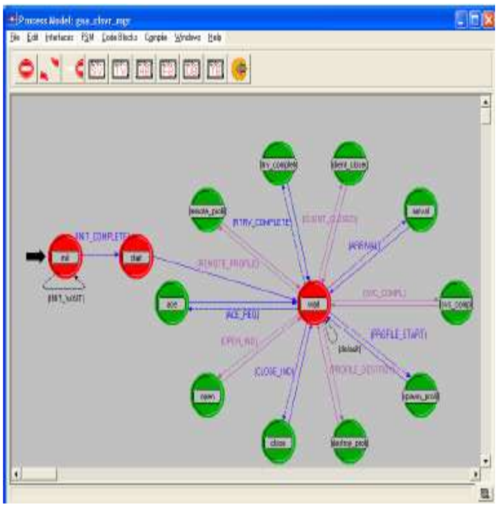


Figure (3) Process editor

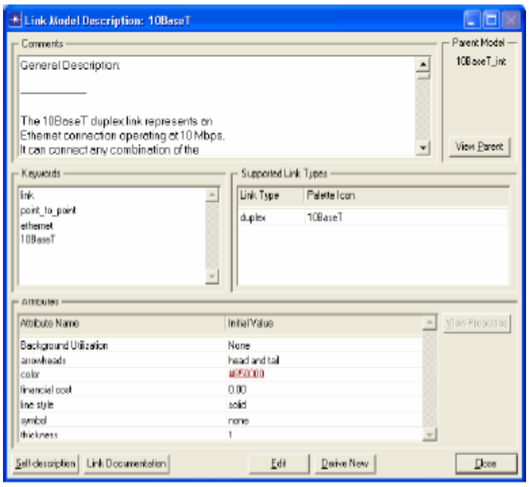


Figure (4) link editor

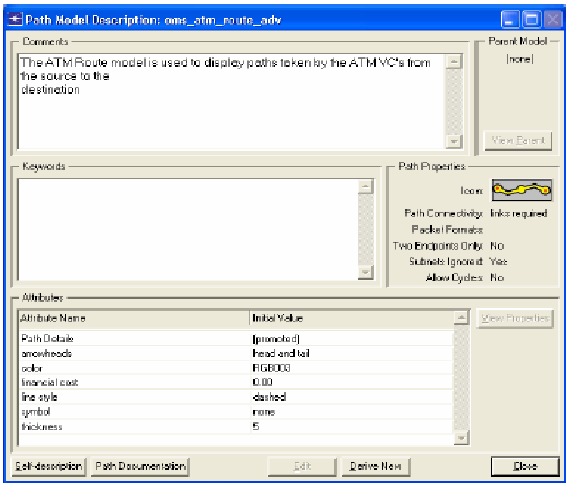


Figure (5) Path Editor

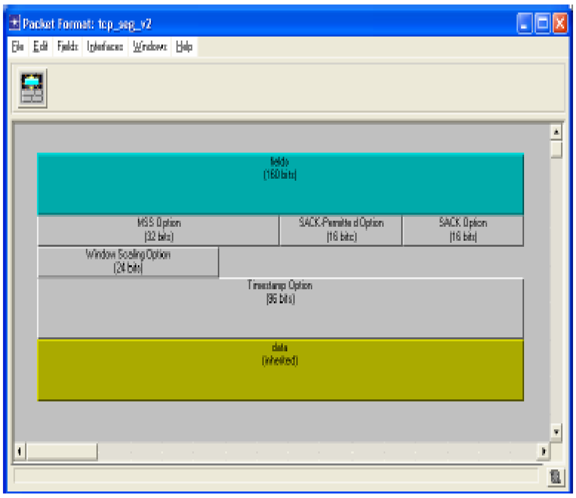


Figure (6) Packet format editor

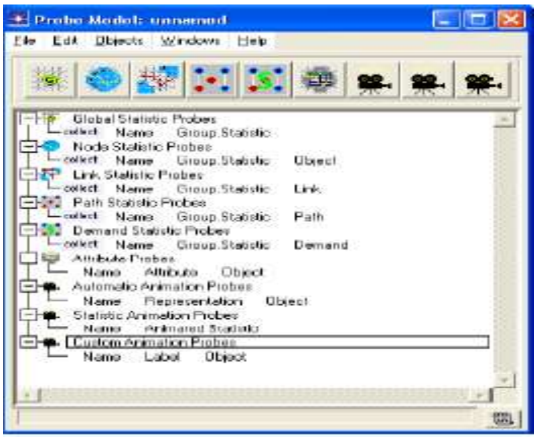


Figure (7) Probe Editor

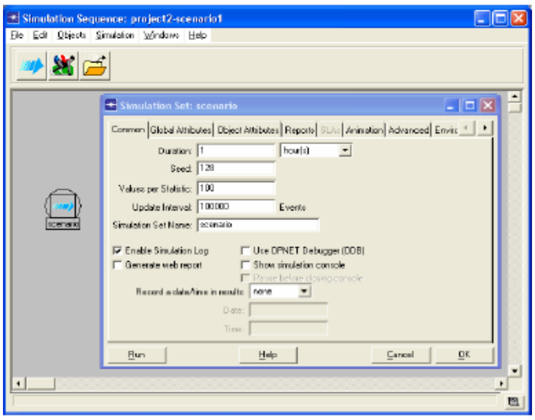


Figure (8) Simulation Sequence Editor

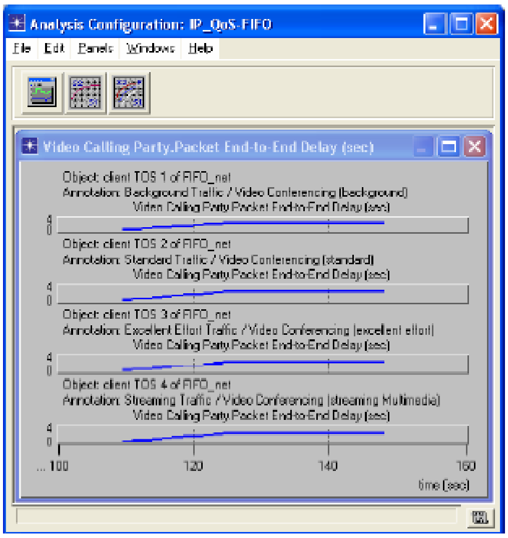


Figure (9) Analysis Tool

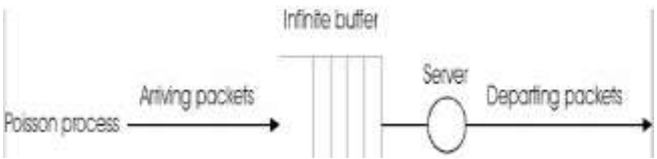


Figure (10) M/M/1 Queue System

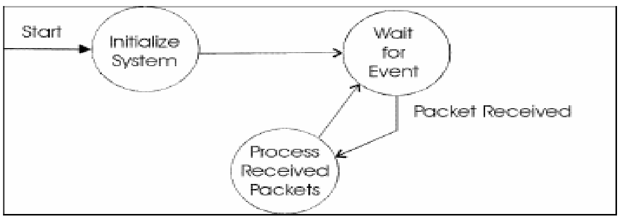


Figure (11) Example Finite State Machine

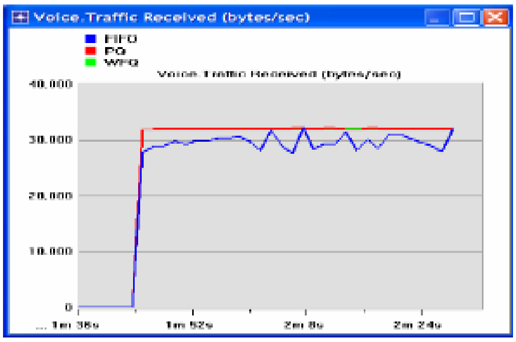


Figure (12) Result for M/M/1 Lab "

Traffic received "Packet/sec"

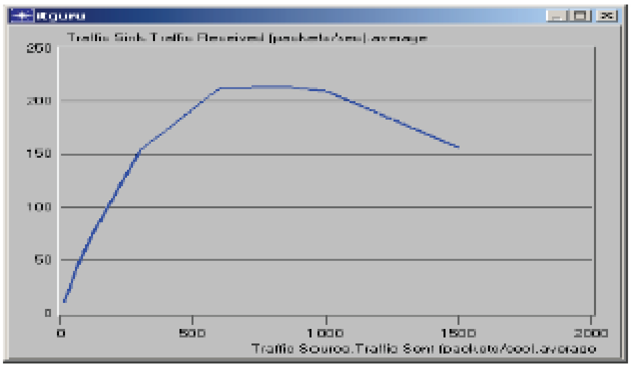


Figure (13) ETHERNET LAB "Traffic Send Vis Traffic received "Packet/sec"

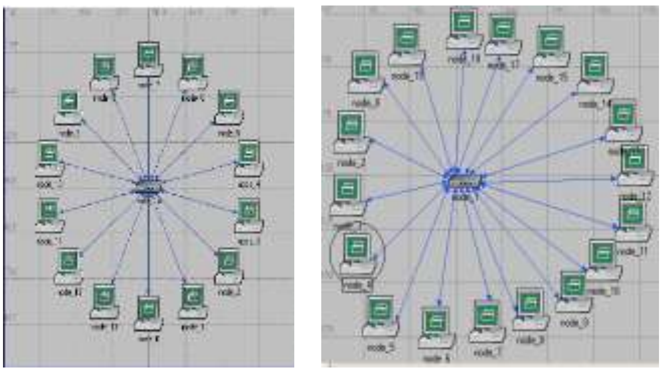


Figure (14a and 14b) Token ring network, Star topology

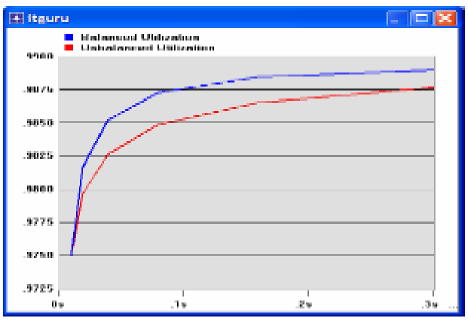


Figure (15) Result for Token ring node =14 LAB "Utilization

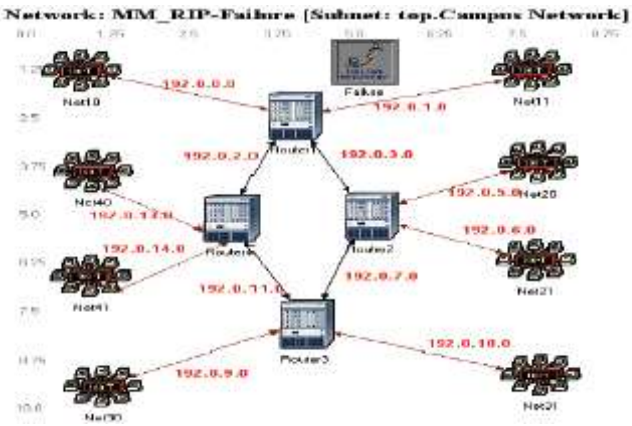


Figure (16) RIP Routing Example

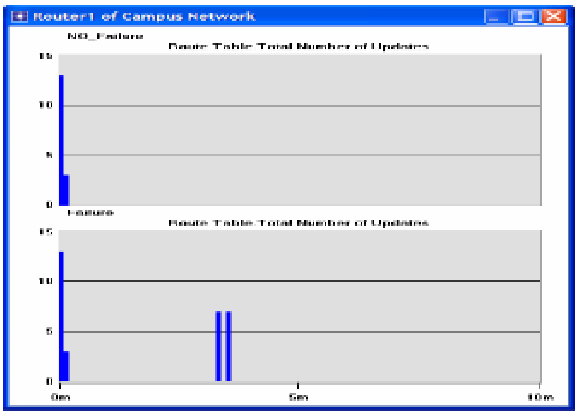


Figure (17) Result for RIP LAB "Total number of Update"

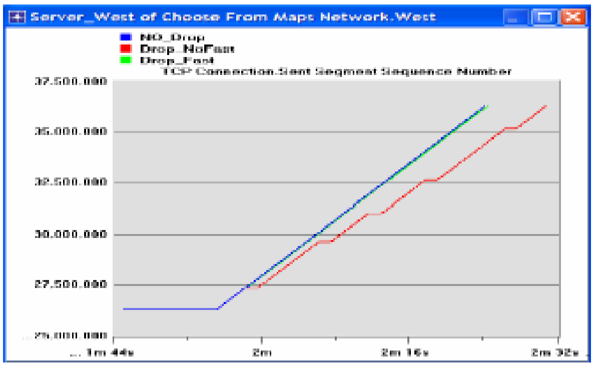
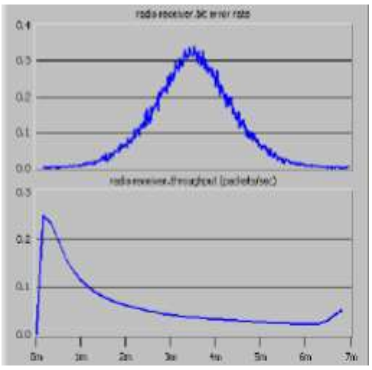


Figure (18) Result for TCP LAB "sent segment sequence number"



Figure(20) wireless network lab result "bit rate and throughput isotropic antenna"

Table(1) Results of M_M_Q (Queuing Disciplines)

Time (sec)	FIFO: Voice. Traffic Received (bytes/sec)	PQ: Voice Traffic Received (bytes/sec)	WQF: Voice. Traffic Received (bytes/sec)
0-103.5	0	0	0
105	8042.7	15893.3	15872
106.5	8512	15978.7	16021.3333
108	10624	16000	16000
109.5	10283	16021.3	15829.3333
111	11371	16021.3	15466.6667
112.5	11861	15978.7	15509.3333
114	10197	16000	15530.6667
115.5	11712	15978.7	15744
117	10517	16021.3	15722.6667
118.5	10795	15978.7	15552
120	10773	16042.7	15957.3333
121.5	11520	15957.3	15658.6667
123	10453	16000	15658.6667
124.5	11456	16021.3	15722.6667
126	11029	16021.3	15680
127.5	10048	15957.3	15786.6667
129	10965	16042.7	15872
130.5	10197	15978.7	15722.6667
132	10923	16000	15680
133.5	9834.7	15978.7	15552
135	10837	16042.7	15146.6667
136.5	10496	15978.7	15104
138	9770.7	16021.3	15850.6667
139.5	11157	16000	15957.3333
141	10475	15978.7	15872
129	10965	16042.7	15488
130.5	10197	15978.7	15445.3333
132	10923	16000	15125.3333
133.5	9834.7	15978.7	15445.3333
135	10837	16042.7	15616
136.5	10496	15978.7	15872
138	9770.7	16021.3	16021.3333
139.5	11157	16000	16000
141	10475	15978.7	15829.3333
142.5	10411	15957.3	15466.6667
144	11776	16021.3	15509.3333
145.5	9920	16021.3	15530.6667
147	10688	16000	15744
148.5	10475	15978.7	15722.6667
150	#N/A	#N/A	#N/A

Table (2) Result of ETHERNET

Traffic Sent (p/s)	Traffic received (p/s)
15.42592	10.68926
31.43263	20.68409
65.67845	43.1393
124.2403	75.37506
307.1176	154.103
600.7513	212.2655
850.1197	213.9721
1000.527	209.9608
1506.476	156.234

Table (3) Result of Token Ring LAB

THT (Sec)	Utilaization (balanced)	Utilaization (unbalanced)
0.01	0.974018	0.974106
0.02	0.981159	0.978907
0.04	0.984978	0.982025
0.08	0.987173	0.984344
0.16	0.988377	0.986227
0.32	0.989077	0.987572

Table (4) Results of Hubs versus Switches in Small business LAN Laboratory Exercise LAB

Time (sec)	Only Hub: Collision Count.	Hub & Switch. Collision Count	Hub2.Collision Count
0	0	0	0
1.2	0	0	0
2.4	0	0	0
3.6	0	0	0
4.8	1065.5	503.5	443.5
6	1554.667	611.3333333	662.6666667
7.2	1746	814.5	763
8.4	1891.6	824.4	794.4
6	1554.667	611.3333333	662.6666667
7.2	1746	814.5	763
8.4	1891.6	824.4	794.4
9.6	1976	894.6666667	847
10.8	2021.714	888	837.8571429
12	2062.5	928.25	863.25

References

1. Jinhua Guo, Weidong Xiang, and Shengquan Wang, Reinforce Networking Theory with OPNET Simulation,Journal of Information Technology Education, Volume 6, 2007
2. IT Guru Academic Edition. OPNET Technologies, 2005.
3. The World’s Leading Network Modeling and Simulation Environment. OPNET Technologies, 2004.
4. Mohammed O., Huda M., Ahmed A., Razan alani. ,Design of a computer network for technical college using OPNET , graduated project
5. Michael W Dixon ,Terry W Koziniec Using OPNET to Enhance Student Learning in a Data Communications Course , Informing Science , June 2002
6. Basics of OPNET IT Guru Academic Edition, OPNET Technologies, 2008

7. Dolejš Ondrej ,OPNET modeler - networks simulation ,,Department of Control Engineering ,Czech Technical college.
8. Mohammad Muslim ,Gigabit Ethernet Network Design Using Opnet ,M.Sc Thesis ,Department of Computer Science, Lamar University, ,2001
9. Tommy Svensson ,Development of laboratory exercises based on OPNET Modeler , M.Sc Thesis, Dept. of Telecommunications and Signal Processing , Blekinge Institute of Technology, , June 2003
10. Tanenbaum, A.S Computer Networks,., Prentice-Hall International Inc., Englewood Cliffs, NJ, 1999.
11. William Stallings., Data and Computer Communications, 7th Edition. Pearson Education, 2005.
12. Larry L. Peterson and Bruce S. Davie Computer Networks: A System Approach, 3rd Edition. Morgan Kaufmann, 2005.
13. Ranjan Kaparti ,OPNET IT GURU: A tool for networking education ,MSCIT practicum paper, REGIS UNIVERSITY

استخدام برنامج OPNET لتعليم الطلبة مفردات شبكات الحاسوب

ميادة غانم حموشي[١] ، رزن عبد الجواد العاني[٢]

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[٢] *الكلية التقنية موصل ، الموصل ، العراق*

(تاريخ الاستلام: ١٣ / ٤ / ٢٠٠٨ ، تاريخ القبول: ١٥ / ١٢ / ٢٠٠٨)

الملخص

يشكل تعليم أساسيات الشبكات تحديا، ومن الصعب تعليم اتصالات البيانات لأنها تتضمن عمليات ديناميكية معقدة وهي ليست مرئية الى الطلاب ومن الصعوبة عليهم فهم فكرتها. الطريقة التقليدية لتعليم اتصالات البيانات تشمل مجموعة محاضرات وهذه المحاضرات تتضمن نظريات الطوابير وقواعد رياضيية ، وجلسات مختبرات عملية حيث يقوم الطلاب ببرمجة اتفاقيات اتصالات البيانات على أمل أن هذه العملية ستمكنهم من فهم اتصالات البيانات بشكل كافي أو أن يقوموا بربط شبكات حقيقة وهذه العملية مكلفة ومستهلكة للوقت .وهذه الطرق لَيسَت مثاليَة لأن الوصف الشفوي والتوضيح النظري لا يوضحُ عمليةَ اتصالات البياناتِ بشكل كافي.وقيام الطلاب بهذه المهام عملية استهلاكية للوقت، ولِذلك العديد مِنْ الطلابِ غير قادرين على أَنْ ينظروا ما بعد ميكانيكية البرمجة ليصلوا إلى فَهْم كامل لعمليةِ الاتصال. يقدمُ هذه البحثِ تمارينَ مختبرِ لاستعمالها في مادة اتصالات البيانات ويعَرْض ببصيرةَ كيفية عمل وتصرف الشبكة الحقيقية. كُلّ المختبرات منفذة في بيئة برنامج المحاكاة OPNET Modeler 9.1 وهو عبارة عن محاكي شبكة والذي يَعطي الأدوات من أجل التصميمِ النموذجيِ، المحاكاة، تُتَعَقُّبُ وتحليل بيانات.

الكلمات الدالة: المحاكاة، شبكات الحاسوب، طرق تدريس.