

## ***Building Model for the University of Mosul Computer Network Using OPNET Simulator***

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### **Abstract**

This paper aims at establishing a model in OPNET (Optimized Network Engineering Tool) simulator for the University of Mosul computer network. The proposed network model was made up of two routers (Cisco 2600), core switch (Cisco6509), two servers, ip 32 cloud and 37 VLANs. These VLANs were connected to the core switch using fiber optic cables (1000BaseX). Three applications were added to test the network model. These applications were FTP (File Transfer Protocol), HTTP (Hyper Text Transfer Protocol) and VoIP (Voice over Internet Protocol). The results showed that the proposed model had a positive efficiency on designing and managing the targeted network and can be used to view the data flow in it. Also, the simulation results showed that the maximum number of VoIP service users could be raised upto 5000 users when working under IP Telephony. This means that the ability to utilize VoIP service in this network can be maintained and is better when subjected to IP telephony scheme.

**Keywords:** Computer network, Simulation, OPNET, Campus, VoIP.

**إنشاء نموذج لشبكة الحاسوب في جامعة الموصل باستخدام برنامج المحاكاة التطبيقي (أوبنت)**

### **الخلاصة**

إن الهدف من هذا البحث هو بناء نموذج لشبكة الحاسوب في جامعة الموصل باستخدام برنامج المحاكاة التطبيقي (أوبنت). أحتوى نموذج الشبكة على موجهي شبكة من نوع سيسكو، ومبدل رئيسي من نوع سيسكو، ومخدمان، وغيمة انترنت و37 شبكة محلية افتراضية. ربطت الشبكات المحلية الافتراضية إلى المبدل الأساسي باستخدام القابلات الضوئية. استخدمت ثلاثة تطبيقات لاختبار أداء نموذج الشبكة وهي بروتوكول نقل الملفات، وبروتوكول نقل النصوص التشعبية، ونقل الصوت عبر بروتوكول الانترنت. وقد أظهرت نتائج البحث إن النموذج المقترح له كفاءة جيدة من ناحية محاكاة عمل شبكة الجامعة وإدارة أداؤها وإمكانية استخدام النموذج المقترح لاستعراض سير البيانات المنتقلة عبر هذه الشبكة. كما أظهرت نتائج المحاكاة أن عدد مستخدمي خدمة الصوت عبر بروتوكول الانترنت يمكن زيادته إلى 5000 مستخدم عند العمل تحت نظام الاتصال الهاتفي عبر الانترنت، ودل هذا على إمكانية استخدام خدمة الصوت عبر بروتوكول الانترنت في شبكة الجامعة بشكل جيد عند العمل تحت النظام المذكور سابقاً.

**الكلمات الدالة: شبكة الحاسوب، المحاكاة، أوبنت، الجامعة، الصوت عبر بروتوكول الانترنت.**

## Introduction

Computer networks have extremely become important in our present days. Majority of universities are using them as a best means of communication with all universities, scientific research institutes and researchers around the global. Besides, most universities have nowadays provided their entire curriculums online; thus, allowing students to have them without any difficulties<sup>[1,2]</sup>.

Any computer network is actually in need of design and maintenance. To make this easy for computer network administrators, it is better for them to design a network model utilizing simulation tools<sup>[3]</sup>.

There is a growing literature on computer network modeling. For example B. Rodiers<sup>[4]</sup> made a model in OPNET modeler of the computer network at the K.U. Leuven University in Belgium. His study showed how the OPNET modeler tool can be used for the simulation of the backbone network.

Jinhua Guo et al<sup>[5]</sup> reinforced networking theory with OPNET simulation. Xinjie Chang<sup>[6]</sup> focuses on network modeling with OPNET. He mentioned that there are two forms of network simulation; analytical modeling and computer simulation. The analytical modeling is by mathematical analysis that characterizes a network as a set of equations. The main disadvantage is its over simplistic view of the network and inability to simulate the dynamic nature of a network. Thus, the study of a complex system always requires a discrete event simulation package, which can compute the time that would be associated with real events in a real-life situation.

L. Breaslu et al<sup>[7]</sup> give a comparative study of two well-known network simulators, OPNET modeler and Ns-2, providing a guide to

researchers undertaking packet-level network simulators.

Junaid A. Zubairi and Mike Zuber<sup>[8]</sup> developed a model of the campus network in SUNY Fredonia campus with OPNET. They obtained ethernet delay, traffic statistics and other interesting data.

Making use of the abovementioned studies, the present study aims at making a model for the University of Mosul computer network, and diagnosing its ability to use the VoIP application and finding which of the VoIP schemes is the better to use.

This work can be considered the first step to get a model at similar environments and conditions of the real-life network.

## Description of Computer Network in University of Mosul

The computer network in the University of Mosul establishment has begun in 90's and has witnessed wide expansions in terms of coverage area and number of users since then. This network gives various services to its clients, such as internet browsing, e-mail services, chatting, etc.

The network span area is about (2km\*3km) and consists of the following components (as shown in Figure 1):

**Satellite dish:** it is a two-way data communication device (uploading and downloading); the upload speed is about one-tenth of the 40 Mbps download speed.

**Modem:** it is used to modulate and demodulate the signals from-to the satellite dish.

**Router (Cisco 2600):** it is used to make decisions regarding the best path for the delivery of data on the network.

**Outside switch (Cisco 2950):** it is used to increase the number of the ports connected to the router. This will give

the ability to expand the number of real IP addresses provided from the internet provider. Actually, there is no configuration provided to this switch.

**Core switch (Cisco 6509):** it is the core of the university computer network backbone. All main switches in the network are connected to the core switch through fiber optic cables.

**Five servers:** they are connected to the core switch, and are as follows:

**Domain server:** this server has windows 2003 server system. It is responsible of joining other computers at the University of Mosul to its domain to make control of them. It also provides some services, such as active directory, DNS(domain name server), DHCP(dynamic host configuration protocol).

**Exchange server.**

**Symantec antivirus corporate edition server.**

**Filtering server.**

**VBulletin.**

**VLANs (Virtual Local Area Networks):** each main switch connected to the core switch represents a VLAN. These switches can be either Cisco switch 3750 or Cisco switch 2950. There are six core fiber optic cables (single mode KSA made) running from the remote colleges to the core switch room, connecting the core switch with the main switches of the colleges.

### **OPNET Simulator**

OPNET provides a comprehensive development environment for the specification, simulation and performance analysis of communication networks. A large range of communication systems from a single LAN to global satellite networks can be supported. Discrete event simulations are used as the means of analyzing system performance and their behavior.

The key features of OPNET are summarized here as follows:

**Modeling and Simulation Cycle:** OPNET provides powerful tools to assist users to go through three out of five phases in a design circle (i.e. the building of models, the execution of a simulation and the analysis of the output data).

**Hierarchical Modeling:** OPNET employs a hierarchical structure for modeling. Each level of the hierarchy describes different aspects of the complete model being simulated.

**Specialized in communication networks:** detailed library models provide support for existing protocols and allow researchers and developers to either modify these existing models or develop new models of their own.

**Automatic simulation generation:** OPNET models can be compiled into executable code. An executable discrete-event simulation can be debugged or simply executed; thus resulting in output data<sup>[3, 5, 6]</sup>.

### **Building the Proposed Computer Network Model**

The proposed network model was made up of two routers (Cisco 2600), core switch (Cisco6509), two servers, ip 32 cloud (to represent the internet) and 37 VLAVs (switches in the VLANs are Cisco2948). These VLANs, in turn, were connected to the core switch using fiber optic cables (1000BaseX) as shown in Figure 2.

In this proposed model, a subnet was created for each VLAN. Thirty-seven subnets were implemented representing thirty-seven main buildings in the university. Each subnet contained a main switch (Cisco 2948) and more than one hub connected to the main switch. With each hub, a number of computers were connected to. Every building contained 100 computers

which were, in turn, connected to the hubs using (100BaseT) cables, as shown in Figure 3.

VLANs were used to define logical units to those people of the same administrative service, research group, classrooms, etc. This made it available for users of the same unit to connect to the network from geographically distributed locations spread at remote areas inside the university.

After connecting the nodes, their configuration must be selected by editing the attribute of each node. The supported VLANs (VLAN1-VLAN38) were defined in the core switch as follows:

VLAN1 was a default VLAN that the servers and the computers in each building can access, so that any computer in a specific building can access the VLAN that belongs to this building, in addition to the VLAN1.

The connection between the computers that lied in the same VLAN was through the VLAN itself. The ports were configured as 'access' ports except the port connected to the core switch should be 'trunk' to allow access to other VLANs through the trunk port in the core switch.

To ensure proper connection between the computers in the network, each computer was addressed with an IP of class B, with the subnet mask (255.255.255.0). This subnet mask, in turn, allowed 254 subnets. Each subnet had 254 IP addresses and each VLAN had a subnet up to 254 addressable nodes.

All the VLANs were connected to the core switch. Only at this stage, there can be a data transfer between all the nodes connected to the core switch.

The objective of the network model was not only to establish connections between the computers, but

also to provide them with an internet access. ip32 cloud which is one of the OPNET facilities was added to represent the internet. A router links between the core switch and the ip32 cloud.

The router must have an IP address for all the connected ports. The port facing the core switch was set with an IP address of the same subnet used for VLAN1, and the port facing the internet was given an IP address of the subnet between the internet itself and the router.

Another router was also connected with HTTP server to the other side of the ip32 cloud so as to ensure both the downloading and uploading of the data when using any computer in any building.

To test the network model, applications were added using the 'application definition' and the 'profile definition', both of which were available in the OPNET toolbox. These applications were FTP, HTTP, and VoIP. Three scenarios were created for this test. As for the logical connection between the nodes, they could be tested using the data flow analysis.

### **Choosing the Setting of Application Definition and the Profile Definition**

To model any application in OPNET, both the 'application definition' and the 'profile definition' ought to be used [6, 9]. Application attribute directly defines many parameters, such as E-mail, FTP, HTTP and VoIP applications. For instance, in this work, the VoIP application has to be set. The voice destination, type of the used decoder and the voice frames per packets were the main variables in this application.

In the PCM (pulse code modulation), the CODEC being used is

(G.711). It samples (20 msec) of voice per packet; therefore, 50 such packets were needed to be transmitted per second. Each packet should contain 160 voice samples in order to give 8000 samples per second. For every packet of size 160 bytes, headers of additional protocol layers were added. These headers include RTP, UDP, IP and any other required headers.

Once the application has been defined, the profiles of this application must be entered. The profiles define the way in which workstations or the source of application will implement this application. Profile is basically a collection of applications that can be configured to control their start and end times in addition to their repeatability.

In the case of the previous example, the voice profile parameter can be defined as follows:

The 'start time offset' defines the starting time offset relative to the simulation start time. Since the capacity of the network is not defined yet, the profile of the application (Duration) must continue to the end of the simulation.

In this profile, the application adds a single call every second (Inter-repetition time and the repetition pattern). This profile was applied to every node that calls the VoIP application. Other applications configuration (FTP, HTTP) were thus set following the same procedure.

After creating the network model, statistics can be chosen related to any node (object statistics) or to the network as whole (global statistics).

The simulator can be configured with the desired period of time. The results of simulation will be in accordance with this configuration and will show the network functionality for the given time. The results of the

network performance can be viewed for a day or a week in much less time.

## Results and Discussion

After creating the network model and choosing the statistics, the simulator should be run to test the proposed model of the computer network, then to view and analyze its results. Three tests have been implemented, they are as follows:

### *FTP Test*

The profile name of FTP application was added to some computers and specified the FTP server as their destination. This was done to test the traffic sending and receiving among these computers and the FTP server.

Here FTP service was used only and changed its page size to (10 Mbyte) for the 'high FTP', then the network was run so as to get the results. Figures (4, 5, 6, and 7) show the responses of the network model of FTP test in different cases. As can be seen in these figures, the responses had zero values at the beginning, and then were increased because the network should have enough time to recognize, and hence communicate the network components and devices. This might take few seconds.

As for Figure 8, it shows the server delay for 'high FTP' in which the maximum delay was equal to (0.78 msec), the minimum delay was (0.68 msec) and the delay average was about (0.73 msec).

### *HTTP Test*

HTTP service was used with page size (566 Kbyte for heavy http). This size was taken by calculating the size of yahoo's page after downloading it. The users were assumed to have an identical web behavior and have equivalent Yahoo web page characteristics which, in turn, involved the number of the flash

objects which was 1, the number of image objects which was 17, the number of java script objects which was 4 and the number of style sheet documents which was 1.

The profile name of HTTP application was added to some computers to specify the HTTP server as their destination. Again, this was done to test the traffic sending and receiving among these computers and the HTTP server, and then the simulation was run to get the results. Figures (9, 10, 11, and 12) show the responses of the network model for HTTP test in different cases, and Figure 13 represents a heavy HTTP server delay whereby the maximum delay was equal to (0.85 msec), the minimum delay was (0.67 msec) and the delay average was about (0.76 msec).

#### **VoIP Test**

To illustrate the benefits of the designed network model, a more detailed study was performed on VoIP application. The quality of a VoIP call depends on the end-to-end delay, the jitter and the packet loss<sup>[10,11,12]</sup>.

The VoIP application was activated in some computers to test the sending and receiving traffic among these computers and the end-to-end delay time. In this scenario, VoIP service was used with PCM (pulse code modulation) (G.711 scheme as an encoder, and SIP as a protocol) as shown in Figures 14, 15.

The average network delay was (0.7 msec) as shown in Figure 16, while the jitter and the packet loss were limited. Thus, one can conclude that the integration of VoIP would cause no problem for the proposed computer network.

Then, the scenario was duplicated to use the IP Telephony as VoIP service (G.729 scheme as an encoder, and SIP as a protocol). This was done for

comparing between the two schemes and to discover which one of them is appropriate. The average network delay was (0.5 msec) when using the IP telephony as shown in Figure 17.

The simulation results showed that the maximum number of the users could be raised up to 600 simultaneous calls when subjected to the PCM (pulse code modulation) (64Kbps, with silence suppressed) and 5000 when working under IP Telephony (8Kbps with silence) as shown in Figures 18,19.

#### **Conclusions**

This paper shows how the OPNET simulator tool can be used for the simulation of the campus computer network at Mosul University.

As can be seen from the figures of FTP and HTTP, the responses had zero values at the beginning, and then got increased because the network should have enough time to recognize and communicate the network components and devices; therefore, this may take few seconds.

The server maximum delay for high FTP and HTTP servers were equal to (0.78 msec, 0.85 msec) respectively, while the average network delay for VoIP was (0.5 msec) when working under IP telephony scheme. As can be seen, the change of the server delay was thus small in all of these cases.

Since the simulation results showed that the maximum number of the users could be raised up to 5000 users when working under IP Telephony, this means that the ability to utilize VoIP service in this network can be maintained and is better when subjected to IP telephony scheme.

The present proposed model that represents the actual university computer network is in need of additional real measurement to be done on Mosul University network so as to

ensure excellent correlation between the modeled network, on the one hand, and the actual network, on another. Then, additional applications can be studied, such as videoconference and security. Finally, the OPNET simulation environment offers a very useful tool for designing and managing Mosul University campus network or any other identical network.

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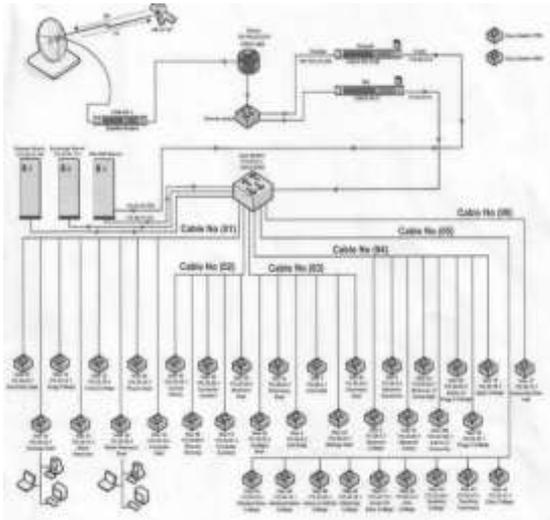


Figure (1) University of Mosul Computer Network Diagram

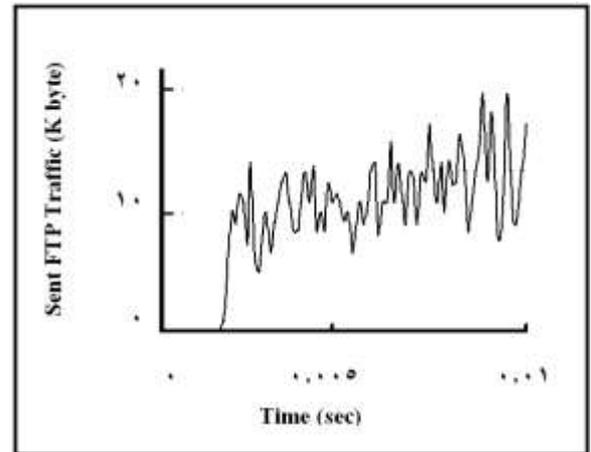


Figure (4) Sent FTP Traffic (Kbyte/ sec)

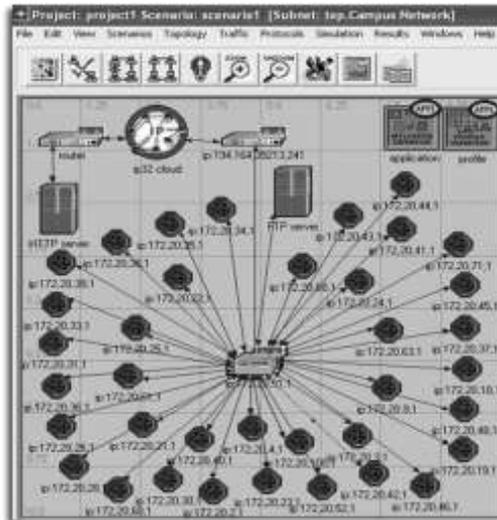


Figure (2): Network Model Implemented with OPNET

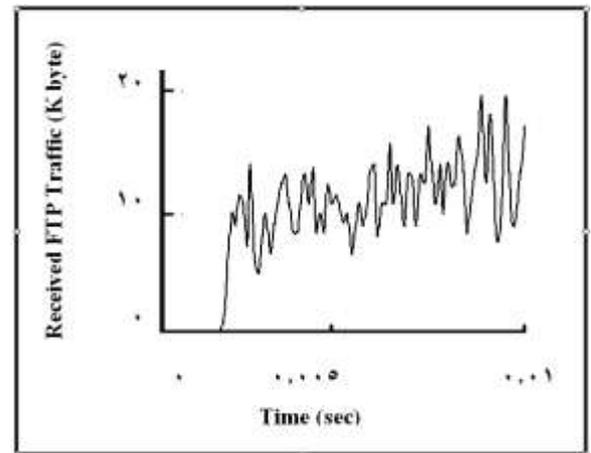


Figure (5): Received FTP Traffic (Kbyte/ sec)

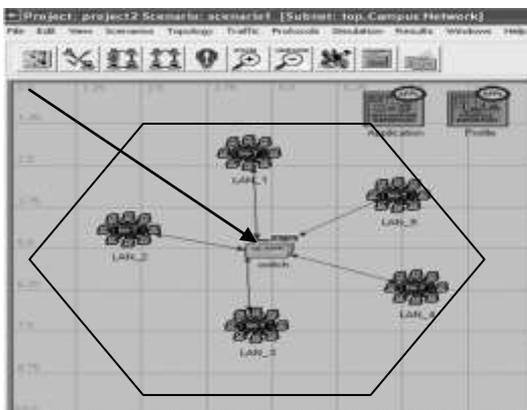


Figure (3) Contents of Each VLAN (Subnet) Implemented with OPNET

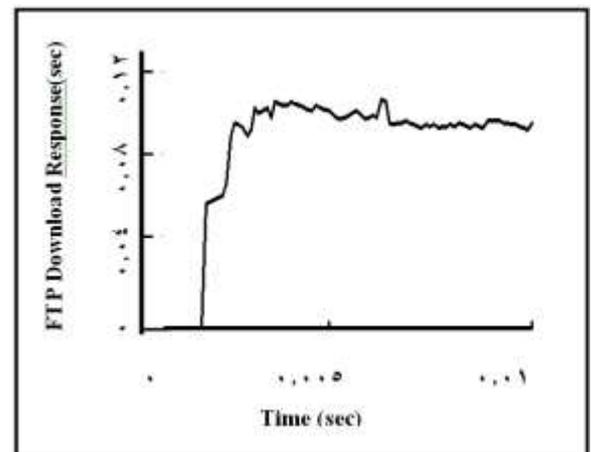


Figure (6): FTP Download Response Time (Sec)

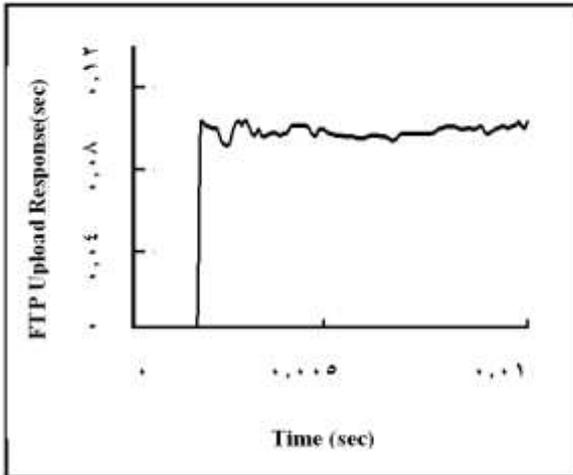


Figure 7: FTP Upload Response Time (Sec)

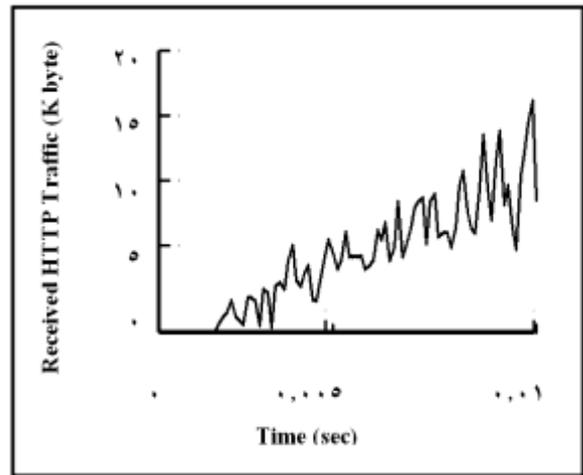


Figure 10: Received HTTP Traffic (Kbyte/ Sec)

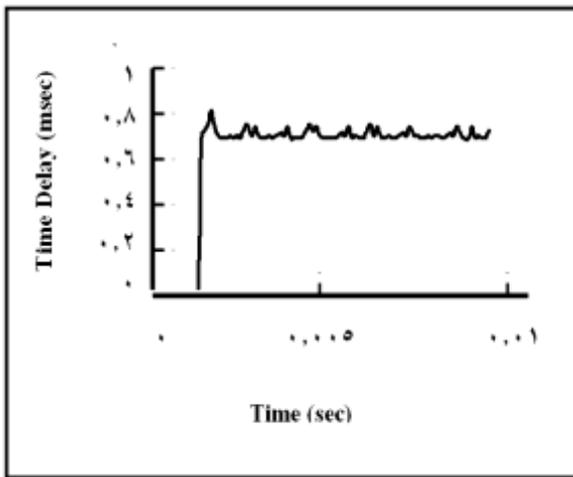


Figure (8): FTP Server Delay(msec)

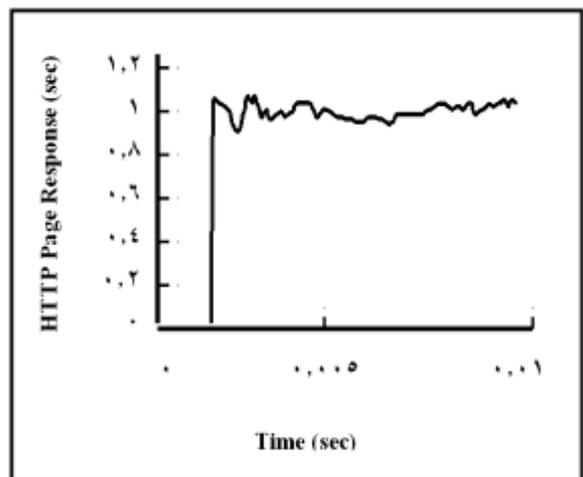


Figure (11): HTTP Page Response (sec)

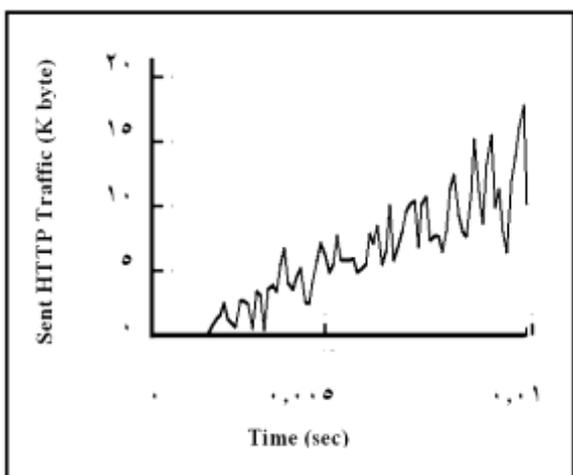


Figure (9): Sent HTTP Traffic (Kbyte/ sec)

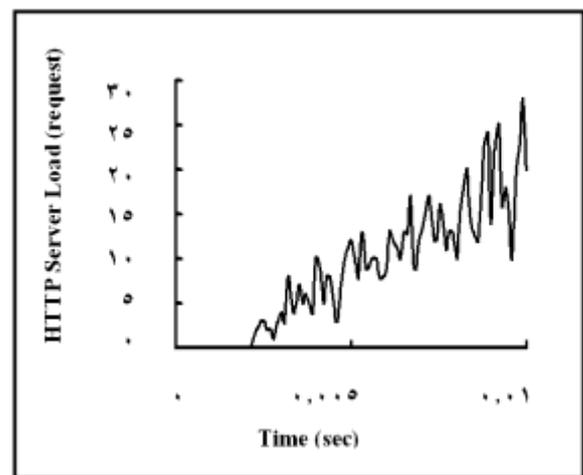


Figure (12): HTTP Server Load (request/sec)

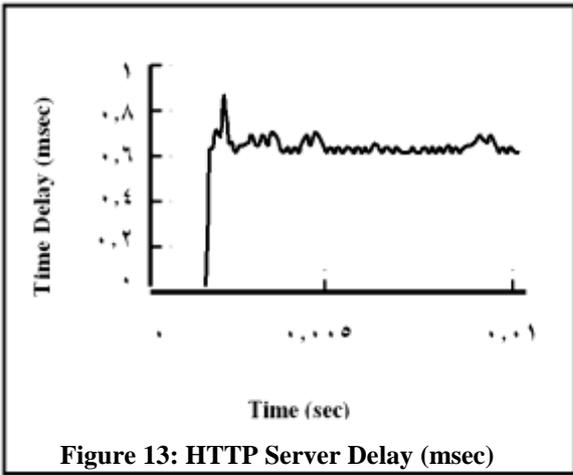


Figure 13: HTTP Server Delay (msec)

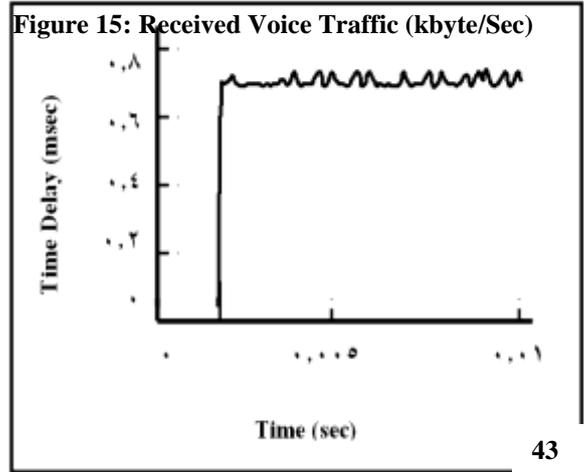


Figure 15: Received Voice Traffic (kbyte/Sec)

Figure 16: PCM End-to-End Delay (msec)

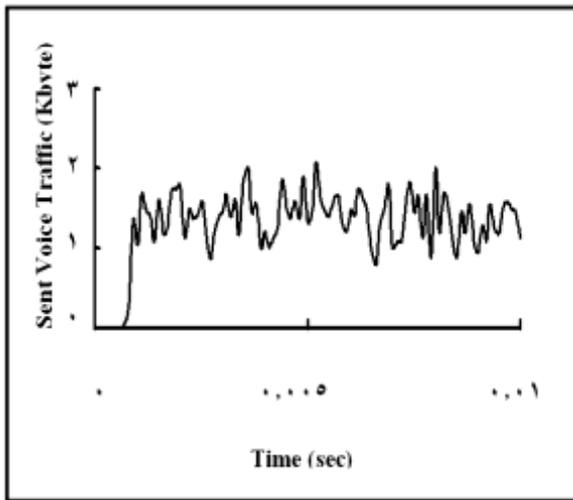


Figure 14: Sent Voice Traffic (Kbyte/Sec)

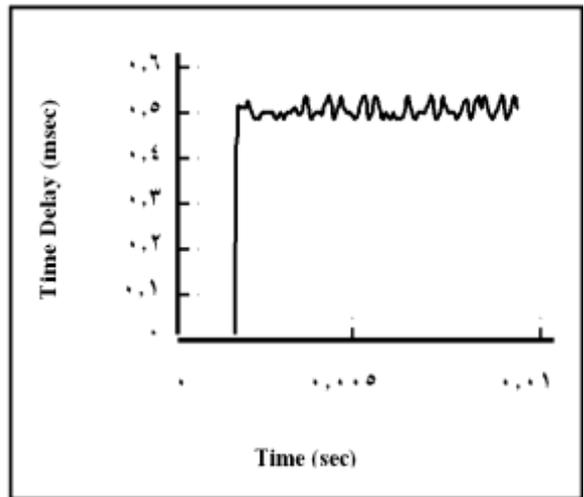


Figure 17: IP Telephony End-to-End Delay(msec)

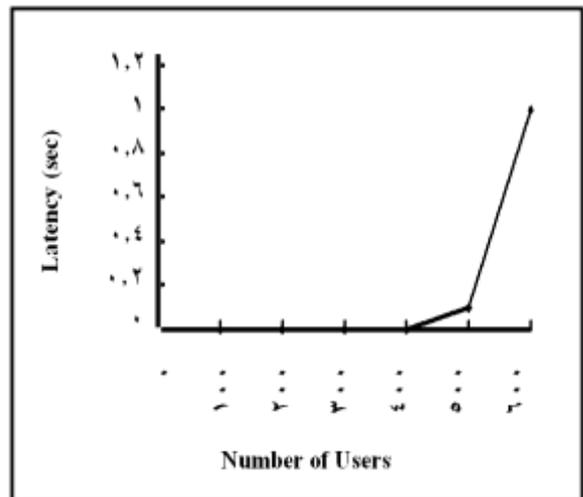
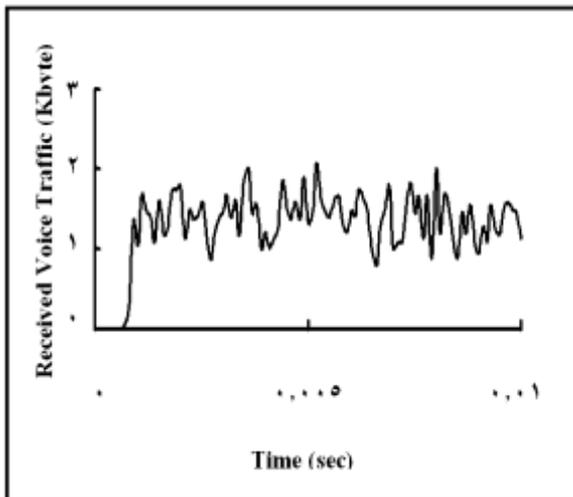


Figure18: PCM Latency (sec)

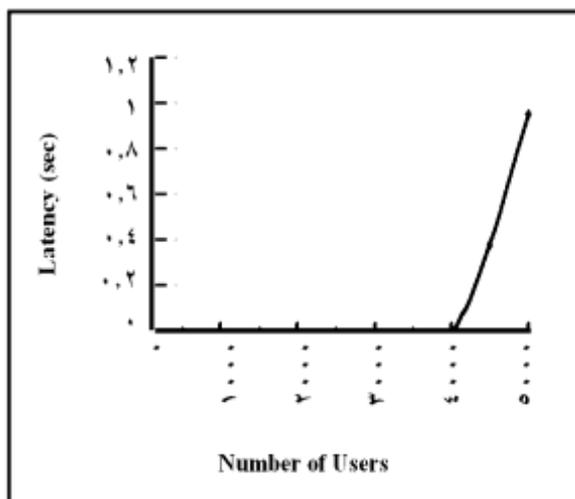


Figure 19: IP Telephony Latency (sec)