

Simulation Study on Internet Applications over DSL Access

Network: KFUPM Campus as an Example

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Abstract

Internet application services are the most successful services offered over Digital Subscriber Line (DSL). King Fahd University of petroleum and Minerals (KFUPM) is in the final stages of deploying the DSL technology within its campus. The current traffic statistics show that the available bandwidth is almost fully consumed. Therefore, intuitively, it is expected that the deployment of DSL technology as an access network should make the network load worse. This paper addresses the consequences of DSL technology addition through simulation. OPNET Simulator is used to simulate the whole KFUPM campus with and without DSL access network. Several scenarios for Internet connectivity and applications are studied and evaluated.

1. Introduction

The recent years have shown a tremendous growth in the number of DSL subscribers (residential and businesses) overall the world. The total number of DSL subscriber has reached over 64 million at the end of December 2003, according to figures presented by the international DSL Forum. In fact the DSL Forum is expecting that by the end of 2005 the number of DSL subscribes would reach 200 million which means a 20% penetration of all phone lines [1]. Compared to other Broadband technologies, DSL technology has the advantage of using the existing telephone lines. DSL users can obtain speeds of up to 100 times faster than 56 Kbps modes, which is of special interest for low cost and high rate [3]. Hence, Internet application services are the most successful services offered over Digital Subscriber Line (DSL) [4].

The purpose of this paper is to evaluate the ADSL (stands for Asymmetric Digital Subscriber Line) technology that will be deployed nearly at KFUPM faculty housing. We investigate on how the ADSL technology would provide the services to faculty

housing and its effects on the overall academic campus and students' dorms. The rest of paper is organized as follows. Section 2 introduces briefly different DSL technologies. Then, the current network traffic of faculty housing dial-up network and over all KFUPM network will be described in section 3. After that, Section 4 presents OPNET simulation of KFUPM Campus network. Simulation results are presented and discussed in section 5. Finally, conclusions and recommendations are discussed in section 6.

2. Digital Subscriber Line Technology

The xDSL indicates a growing family of standards and technologies, all are designed to provide high-speed data communication over long distances of twisted pair wire [3]. xDSL technology can be classify as two types:

- *Symmetric DSL* (SDSL, HDSL, etc.) is design for short haul connections that require high speed in both directions.
- *Asymmetric DSL* (ADSL) is for internet access, where fast downstream is required, but slow upstream is acceptable.[3]

ADSL technology has a 1.5-8 Mbps data rate for the down stream and a 16-640 Kbps for the up stream [2].

ADSL has three transmissions methods [3]:

- Quadrature Amplitude Modulation (QAM)
- Discrete Multi-tone Modulation (DMT)
- Carrier-less Amplitude/phase Modulation (CAP)

2.1 Quadrature Amplitude Modulation (QAM)

QAM is a way of fitting information onto a limited frequency line, in the case of ADSL, it is a copper wire. QAM can create 16 different signals by using both phase and amplitude modulation. QAM uses a combination of sine and cosine waves at different phases to each other to produce these signals. Instead of using amplitudes of 1, QAM uses four different amplitudes for each of the two waves [3].

2.2 Discrete Multi-tone Modulation (DMT)

DMT is the official standard line code for ADSL. The basic idea of DMT is to split the available bandwidth into a large number of sub- channels (sub-carriers or tones). If some sub-channel cannot carry any data, it will turn off and the use of available bandwidth is optimized. In DMT, there are 256 tones for downstream and 32 tones for upstream. Each tone is implementing QAM with a bandwidth of 4.3125 KHz. Each tone carries 2 to 15 bits (Rate adaptive). Because it is rate adaptive, users can choose bandwidth requirements in 32Kbps steps (64Kbps to 8.192Mbps DS. and 16Kbps to 768Kbps US.). DMT is Built-in error correction [3].

2.3 Carrierless Phase/Amplitude Modulation (CAP)

CAP is a close relative of a coding technique known as Quadrature Amplitude Modulation (QAM). These techniques are almost mathematically identical except that

CAP does not transmit a carrier and instead reconstructs it electronically at the destination. CAP is also known as carrier-suppressed QAM [2].

2.4 ADSL Network Components

ADSL network has a number of components as follows:

- **Central Office (CO)**

It is a circuit switch that terminates all the access lines in a particular area; a physical building where the local switching equipment is found. xDSL lines running from a subscriber's home connect at their local central office. (At KFUPM CO is Telephone Exchange Building) [2].

- **Customer Premise Equipment (CPE)**

It is a wide range of customer-premises terminating equipment which is connected to the local telecommunications network. This includes telephones, modems, terminals, routers, set-top boxes, etc [3].

- **Digital Subscriber Line Access Multiplexer (DSLAM)**

It is the device placed in the CO that accepts all the ADSL lines [3].

- **Splitter**

It is a small device that captures the first 14 kHz of frequency and splits them off for phone use, the rest of the data is passed onto the ADSL equipment [3].

- **Main Distribution Frame (MDF)**

It is a big distribution connector, where all telephone lines are connecting to it [2].

3. KFUPM Campus Area Network Traffic Analysis

The KFUPM campus area Network is composed of three major parts, namely, Academic, Faculty and Students' dorms as illustrated in Fig. 1. Currently, the faculty housing area is connected to the internet/intranet through a dial-up network that can serve up to 240 users simultaneously. The Information Technology Center (ITC) provides a bandwidth pipe up to 100 Mbps for all RAS users. Each user is limited by the modem speed that is between 36Kbps and 56Kbps. The applications used in the faculty housing are basically HTTP, SMTP, POP3, SNMP, and FTP.

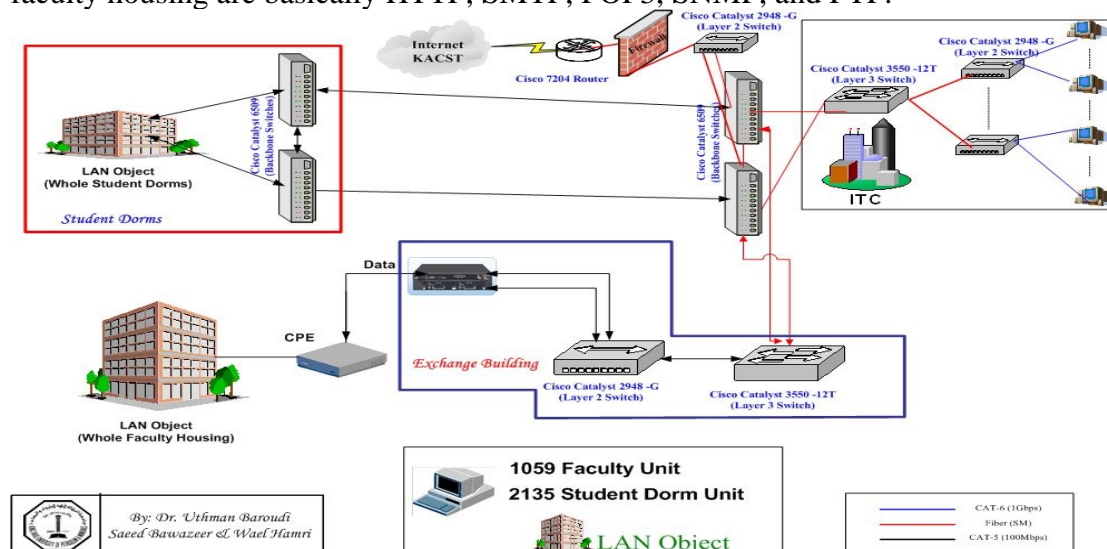


Figure 1: KFUPM Campus Area Network Diagram

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The uplink/downlink traffic of the whole faculty housing dial-up network was monitored daily for one week using MRTG software. Distinct Network Monitor was also used to monitor the applications protocols and the bandwidth. Figure 2 shows the uplink/downlink traffic where the **downlink (Green Color)** represents the traffic (e.g. downloading a web page) that is coming towards the end users. Therefore, **UPLINK (Blue Color)** traffic (e.g. sending HTTP requests) is going towards RAS users from ITC. On other hand, **UPLINK (Blue Color)** means the traffic that is coming toward ITC. The **Orange Color** is the percentage of ((Incoming Traffic in Bits per Second) / (Outgoing Traffic in Bits per Second))*100. The following graph is the downloading/uploading speeds averaged for every 5 minutes for one day.

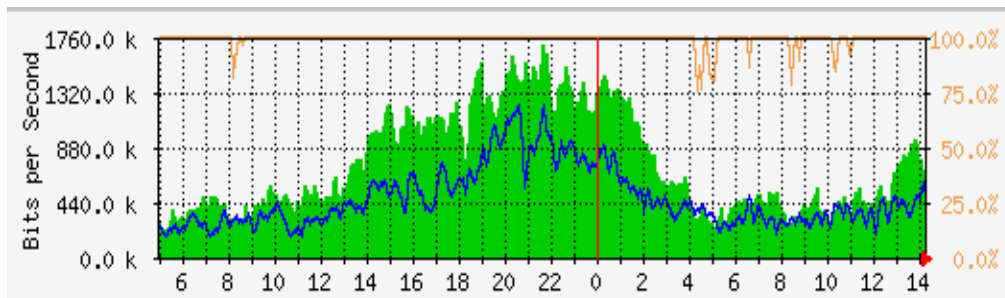


Figure 2: Faculty Housing uplink/downlink bits per second (Tuesday, 21 October 2003)

Now, we turn to the overall traffic for the whole KFUPM network. ISU (Internet Service Unit) was used to monitor traffic from ITC to observe the uplink/downlink traffic over the whole KFUPM. Using this monitor daily, weekly, monthly and yearly traffics were obtained. Moreover, the Distinct Network Monitor was used to monitor the applications protocols and the bandwidth. Both tools provide a graphical user interface results. Out of these tools we emphasize on the type of applications, protocols, number of users and the throughput. Figure 3 illustrates our findings.

From Figure 3 , it can easily be observed that the Internet bandwidth is fully utilized from 6am to 1am every day. These traffics are only the traffic generated from the academic area and dial-up faculty connection. For the weekly and monthly and yearly traffics, overall KFUPM traffics are almost same as the daily traffic except for vacations. Consequently, many questions would be raised. Just to name a few, how would the KFUPM Network cope when the DSL network in faculty housing and the student dorms network are deployed?! What then are the solutions to alleviate the expected problems? This study tries to answer these questions and provide viable solutions for the foreseen problems.

Table 1: Summary of broad types of existing networks at KFUPM

Network Area	Access Network Type	Expected number of users
Academic	Gigabit Ethernet	3604
Faculty	Dial-up	1059
Students	-----	2135

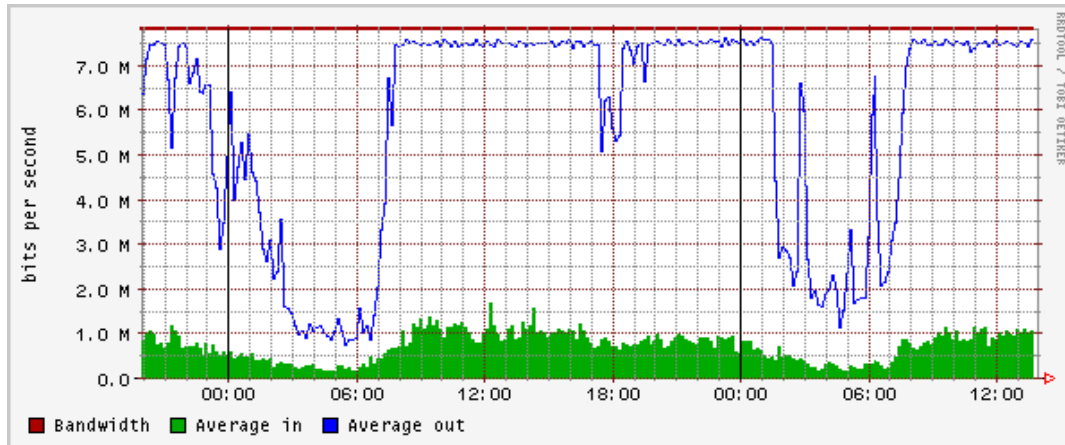


Figure 3: Overall daily KFUPM (Uplink/Downlink) traffic (bps)

4. OPNET Simulation of KFUPM Campus Area Network

As was mentioned above that the focus of this study is to investigate the consequences of replacing the dial-up connectivity of faculty housing area by a DSL access network. Using OPNET, the three main areas (faculty, academic and students) were simulated. Firstly, the academic area network was modeled as an Ethernet LAN-Object where its traffic parameters were calibrated such that it will generate a similar traffic load as it was monitored on the real network. Similarly, the faculty area network was simulated as an Ethernet LAN-Object connected through a DSL link to ITC. More, as the farthest housing unit in faculty housing campus is 3km far from the DSLAM, it is assumed that the distance has no effect on the supported ADSL data rate.

4.1. Internet applications parameters

This simulation study assumes three Internet applications, namely, Web Browsing including Image Browsing, FTP, and Email. OPNET allows choosing different load intensity for each application type (i.e. heavy, light, etc.). The following table summarizes these applications:

The load intensity for each application is configured according to several parameters. One common parameter used is the service time. The service time for an incoming request is a function of the following factors [5]:

- *Request or response size.* For certain applications (FTP get, Email receive, DB query, HTTP), the service time calculation uses response size. For all other applications, the calculation uses request size.
- *Processing speed, Processing overhead, and Processing speed multiplier.* These are configurable attributes for each application.
- *Processor load.* This is the number of active requests currently serviced by the server.

Service time is calculated as follows [5]:

$$Service\ Time\ (sec) = f \frac{(Request\ or\ Response\ size / Processing\ speed + Processing\ overhead) * Processor\ load}{Processing\ speed\ multiplier}$$

Each application has specific attributes that also affect the load intensity. The attributes were used are summarized in the following table according to each application:

Table 2: Summary of Internet Applications Attributes

No.	Application	Attribute	Description
1	HTTP	HTTP Version	The name of the supported HTTP version.
		Page Interval Time (seconds)	Time between subsequent pages that a user browses.
		Object Size (bytes/object)	Average size of an object.
2	FTP	Inter-Request Time (seconds)	Time between subsequent file requests.
		File Size (bytes)	Size of a file being transferred.
3	Email	Receive Interval Time (seconds)	Time between e-mails received from the server at the client.
		Email Size (bytes)	Average size of an e-mail message.

A trial was run assuming heavy type of applications over the faculty housing area. Figure 4 shows the download traffic. It clearly illustrates that the faculty housing traffic would be doubled (at least twice the dial-up, 1.7Mbps).

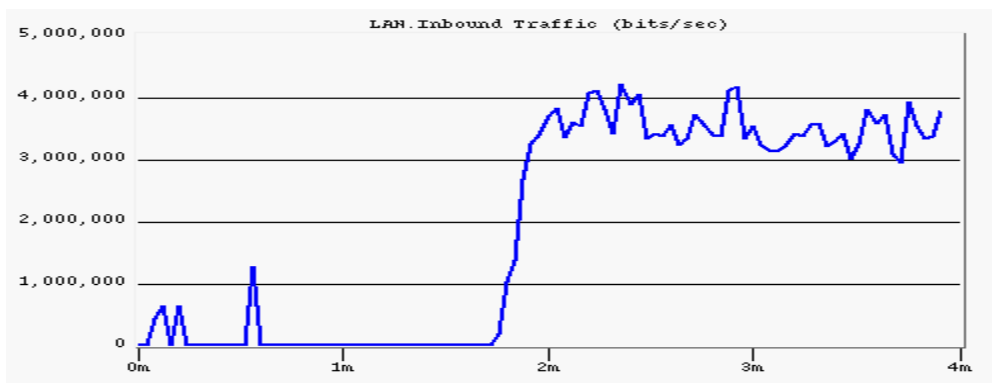


Figure 4: Faculty Housing Inbound Traffic (downloaded traffic in bps)

5. OPNET Simulation Results

In this section, two major scenarios will be simulated and studied. The first scenario is where the KFUPM Campus Area Network with DSL is tested under fixed 8Mbps Internet connectivity. The second scenario shall test the KFUPM Campus Area Network with DSL under several proposals for upgrading the Internet Connectivity.

5.1. KFUPM Campus Area Network Performance under 8Mbps Link

The simulation setup assumes that academic area network is granted higher priority than the other network areas. This criterion is imposed by granting the academic area a link of at least 6Mbps. More, the student dorms is assumed generating a traffic load

of 3 Mbps. In regard to the Faculty housing area, it is assumed generating 4 Mbps. The main type of applications in all KFUPM is HTTP besides some HTTP with medium images.

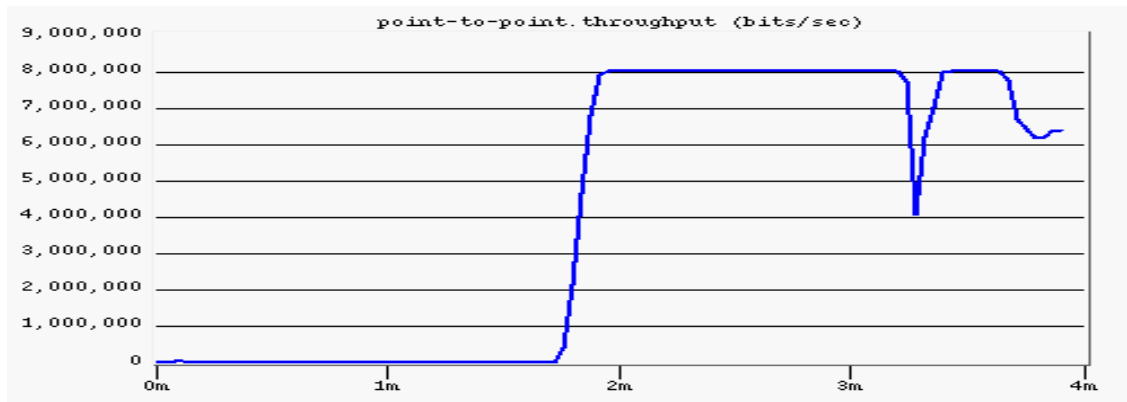


Figure 5: Overall KFUPM Internet bandwidth in bps

Figure 5 shows the throughput performance over the Internet Link to overall KFUPM from KACST. This result illustrates the Internet connectivity is fully utilized which may eventually cause a significant drop in the link as shown Figure 5. This indicates that the network is highly congested because of very high number of requests from KFUPM users over the limited Internet bandwidth of 8Mbps. Furthermore,

Figure 6 shows the response time for HTTP requests.

Figure 7 and Figure 8 show the effect of this limited 8Mbps Internet connectivity on each KFUPM networks. The term 'IN Traffic' means the amount of traffic (bits/sec) that is received by that area. The following observations can be made. First, the academic area users, even though high priority status is granted, they are affected by adding ADSL network and student dorms network. In fact, they only got 4.2Mbps (see Fig. 7) that instead of 6Mbps as ITC statistics shows. Second, Faculty housing network did not take the full advantages of DSL technology. They only receive 2.25Mbps download traffic from Internet as shown in Fig. 8. Consequently, the client HTTP average response time can reach up to 20.4 seconds. Thirdly, there is a drop in the IN traffic in each KFUPM network because of the congestion caused by large number of users trying to have service. This in sequence causes the number of client HTTP average request pages in faculty housing to be 16.9.

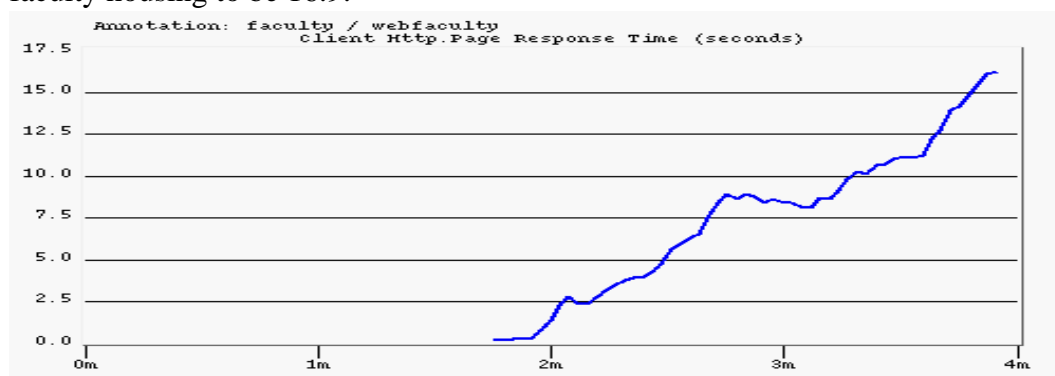


Figure 6: Client HTTP page response time

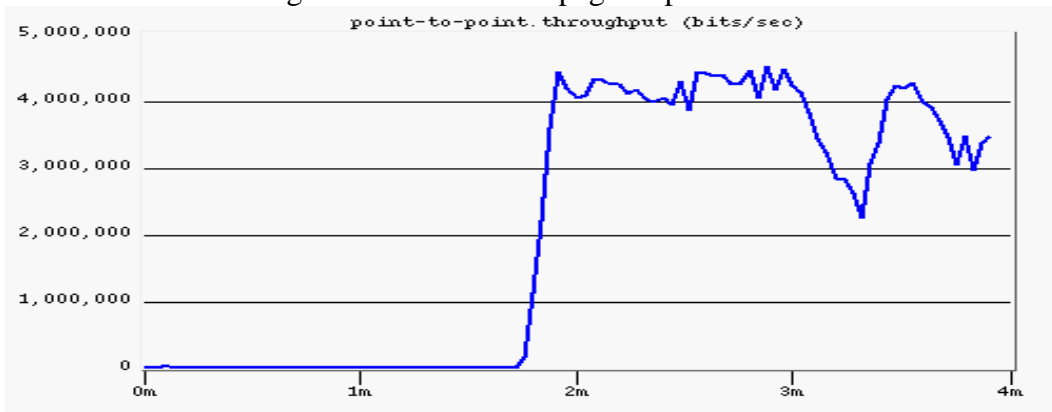


Figure 7: Academic Area IN Traffic in bps



Figure 8: Faculty Housing IN Traffic in bps

5.2. KFUPM Campus Area Network Performance under Upgraded Link

In this section, the KFUPM campus area network shall be evaluated under different Internet Connectivity speeds. This would help in finding the appropriate Internet connectivity solution for this new campus network. Several scenarios shall be studied assuming Internet connectivity speeds to be; 8Mbps, 10Mbps, 12Mbps, 14Mbps, 16Mbps and 155Mbps. More, the main type of application is HTTP as well as HTTP that would include medium images. Figure 9 illustrates the overall network throughput assuming the Internet connectivity to be 14Mbps.

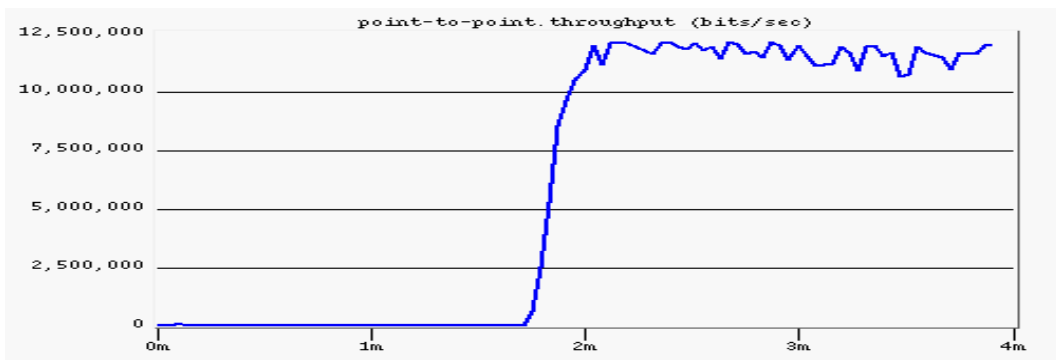


Figure 9: Throughput of the whole KFUPM Network

Table 3 summarizes the KFUPM campus Area network performance over several scenarios of Internet connectivity speeds. Considering these findings, several conclusions can be observed. Given the same traffic characteristics, increasing the data rate higher than 8Mbps causes the client HTTP response time to drop sharply in the ADSL network, 0.155 with 14Mbps. Moreover, the average number of supported requests by client in the faculty housing increased dramatically when the Internet link increased up to 66 with 16Mbps. More, it can easily be noticed that both the client HTTP downloaded pages and the response time haven't shown proportional improvement when the connectivity speed is increased beyond 16Mbps. This finding is very interesting in the sense that the cost/performance ratio for each scenario should be the merit that has to be considered in choosing among these proposed scenarios.

Table 3: Summary of HTTP Application performance over KFUPM Network

No.	Data Rate (Mbps)	Client HTTP Downloaded Pages (Avg.)	Client HTTP Response Time (sec) (Avg.)	Cost* (SR)/Year
1	8	16.9	20.4	200,000
2	10	42.3	6.66	250,000
3	12	66	0.281	300,000
4	14	66	0.155	350,000
5	16	66	0.154	400,000
6	155	68	0.159	387,5000

* Prices are listed according to Saudi Telecom offers in May 2004.

6. Conclusion and Recommendations

In this study, KFUPM Campus Area Network was simulated using OPNET simulator. The focus was to investigate the consequences of the deployment of DSL technology for the faculty housing area network. Faculty housing network along with academic area and student dorms networks were simulated and analyzed. Several Internet connectivity speeds were considered. As expected, the current Internet connectivity (i.e. 8Mbps) can't cope with this addition of DSL. The simulation results have shown a significant drop in throughput and a prohibitive increase in the response time.

Therefore, in order for KFUPM to make a smooth transition from dial-up connectivity to DSL connectivity and at the same time keep the Academic Area network leveraging its current 6Mbps connectivity to Internet, we propose the following solution.

Based on the data collected from ITC, the main application carried over KFUPM network is HTTP. Although, the 14Mbps Internet connectivity speed seems to be sufficient, but it is not recommended for the following reasons. First, many new applications would be accessible to users such as video conferencing and voice over IP. Second, upgrading to 16Mbps, KFUPM would pay just SR50,000 additional to the 14Mbps cost.

Therefore, for future applications and for scalability and expected growth in the number of users, it is recommended upgrading the Internet bandwidth to 16Mbps. With 16Mbps, a client in the faculty housing would have a response time of 0.154 seconds, which is more than 100 times faster than the current network. Moreover, with the recommended bandwidth each client in the faculty housing would have an average of 66 requests. So, each user would have an additional 49 requests in average.

Acknowledgment

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