A Pricing Model for Differentiated Service Billing

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Manuscript
Received:
2, Feb., 2012
Revised:
26,Feb.,2012
Accepted:
27,Mar.,2012
Published:
15, May,2012

Keywords
DS,
OPNET,
QoS,
Pricing,
IP.

***Abstract*— Wireless communication and Internet protocol (IP) network has evolved over the decade. Today multimedia applications now run on this network such as, voice over IP, streaming audio and video, etc, this has contributed immensely to the congestion on the broadband network. Quality of service (QoS), bandwidth management or IP service control are all general terms given to a broad range of techniques employed to control and shape traffic on this network. Pricing has become an essential tool for costumer care, operator's revenue and to affect QoS. In this work we present not only a new billing scheme termed Differentiated Service billing (DSB), which controlled congestion by checking user behavior with respect to type of application used on the network, we also introduced a mathematical description of the billing scheme. Our work improves the overall QoS perceived by users of 'relevant' applications. The DSB is an improved variant of usage billing. It effectively checks the usage of bandwidth-intensive applications, especially for a campus network. Our results clearly showed an improved network link performance when this billing scheme was compared with the traditional flat billing and usage billing schemes.**

1. Introduction

New generation of telecommunication technology have appeared about every ten years since the first move from analog (first generation, 1G) in 1981 to digital (second generation, 2G) transmission in 1992. This was followed, in 2001, by third generation (3G) multimedia support, spread spectrum transmission with speed of at least 200kbit/s [1]. However there exist an intermediate step between 2G and 3G networks named 2.5G technology. 2.5G enabled with the help of various technologies, such as High Speed Circuit-Switched Data (HSCSD), General Packet Radio Service (GPRS), supports data speed of up to around 100kbps compared to 9.6 kbps offered by 2G networks. 3G networks depend on emerging technologies like Enhanced Data Rates for Global Evolution (EDGE), Universal Mobile Telecommunications System (UMTS), with bandwidth rates of up to 2Mbps [2]. It was expected that in 2011, fourth generation (4G) networks would follow. The requirements for 4G networks include: peak speed of 100Mbits/s for high mobility communication and 1Gbit/s for low mobility communications [1].

This rapid development of wireless networks and terminals (laptop computers, modems, smart phones etc) supporting advance data technology and ultra-broadband has made it possible to develop more bandwidth consuming and sophisticated applications. Today services such as internet access, IP telephony, gaming services and streamed multimedia services can be rendered to users.

The advent of this multimedia services and the increase in the number of users who rely on peer to peer (P2P) protocol to allow the transfer of very large files and applications has lead to the congestion experienced by users of this IP network despite the considerable improvement on internet speed.

In the early days of 1G and 2G, billing was based just on voice minutes, as voice calls were the major product offered by telecommunication sector. Researchers focused their energy on technological development that would allow the availability of a wide variety of services. However, little effort was given towards developing an appropriate billing system. The existing billing schemes were just incapable of processing the large number of new variables. In recent years, the need to cover expansion costs and the possibility of using charging methods to influence user's behaviour in order to avoid congestion, has greatly increased interest on the topic of billing.

Today the need for a better QoS has brought about differentiated services on the IP network. These differentiated services include admission control, resource reservation setup protocol (RSVP), queuing management, and fair scheduling. This work implements differentiated service to billing on the IP network.

The rest of this work is organized as follows; Section 2 gives the problem background; Section 3 describes existing billing methods on the IP network; Section 4 describes some existing models or works on billing; Section 5 presents our model; Section 6 presents model validation and simulation results and Section 7 concludes the work.

2. Problem Background

The increase in broadband awareness and utilization has brought about congestion in the frequency spectrum most

This work was supported by the Department of Electrical and Electronics Engineering and the Department of Communication Engineering, Federal University of Technology Minna.

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especially for wireless network. This congestion is brought about mostly by abusive use of public connections. The effective delivery of information over the internet requires that bandwidth be managed. Managing bandwidth involves controlling and removing unnecessary traffic. It also levies traffic based on resource usage. Without a proactive management, network capacity gets saturated with inappropriate traffic so that connection becomes ineffective and user perceived QoS drops.

Many institutions are finding out that they still do not have reliable, usable Internet access for their students and staff despite considerable investment. A recent Bio Med Central survey of health journal access programme found that logging into some databases took so long that connections often timed out entirely due to network congestion [3]. A typical Internet connection involves huge investment on the part of the institution; two examples are the University of Ghana and Makerere University in Uganda, which spent roughly $10,200 and $27,045 per month for 1Mbps of bandwidth respectively in 2007 [4]. The Internet is one area a lot of institution is making considerable financial investments, there is, therefore, need to give them value for their money.

A survey project conducted by Aptivate to assess bandwidth management issues at the Kenya Education Network (KENET) and five of their member institutions revealed that one of the institutions limited student Internet access to five hours a week and another institution cut off students' use entirely [3]. This drastic decision is unfair and reduces the impact that online access of valuable information could have on students. Such desperate measures will not be necessary if an appropriate billing system, which also checks the behavior of users, is employed.

3. Some Billing Techniques

Billing on IP network refers to the ability of an Internet communications service provider to capture, measure, and charge communication events. These events include voice, data, and electronic contents such as Web browsing and e-mail, mobile commerce activities, and streaming video. Various billing methods exit today. Examples include:

- **Flat pricing [5]:** A flat pricing scheme is simply paying a fixed amount for unlimited data access, e.g. NGN 2, 000 (two thousand Nigerian Naira) per month. This pricing scheme is very popular with subscribers as it is easy to manage and is very cheap. However when the Internet becomes congested the traffic slows down, IP packets are delayed or even dropped. Those who really need the Internet for some productive reasons are not going to have any faster connection than some average surfers that visit the playboys' websites.
- **Usage-based billing:** This refers to any billing scheme where a customer's bill is scaled in some way to reflect actual use of network services [5]. Implementations of this scheme vary: some charge the customer based on actual number of packets transported; while others charge based on average billing cycle usage; and still others have sliding; flexible rates. All of these billing strategies are deviations from traditional flat rate billing structures. The usage based billing is also referred to as volume billing in this text.
- **Priority billing:** In priority billing scheme [6] users are offered different service priority and the financial cost for this priority. Under this billing scheme users are billed, say, NGN P for the lowest priority and say, additional NGN P for each level of higher priority. Once again this billing scheme only seeks for a guaranteed connection for users who can afford the higher priority connection but does not influence their behaviour on the link. Priority billing does not offer a congestion control pricing mechanism. Those with higher priority bids will pay more on the network.
- **Smart market billing:** In smart market billing [7] a user includes with the packets he sends over the IP network a 'bid', which means how much he is willing to pay for delivery of that packet. When congestion occurs, packets with lowest bids will be delayed or dropped if queues are full. Billing is made according to lowest bid transported. That is, the actual amount paid is that offered by the lowest bid transported. This billing scheme is also referred to as auction billing. In smart market billing what is eventually paid for is dependent on the other users of the network.
- **Edge pricing:** The edge pricing was introduced by Estrin, Shenker, Clark and Herzog in their work "Pricing in computer network [8]. The edge pricing methods focuses on the network architecture and structure and not on network optimality. In edge pricing all pricing decisions are made at the edge of the Internet service providers (ISP) locally.
- **Responsive pricing:** Responsive pricing was introduced by L. Murphy and J. Mackie in their work "Responsive pricing on the internet" [9]. Responsive pricing uses a feedback mechanism to determine price based on the level of congestion experienced on the network. Responsive pricing is anchored on the notion of adaptive user and on prices as feedback signal. Adaptive user will always respond to prices so that at peak period prices are raised and users reduce traffic on the network. Pricing in this billing method depends on other users on the network as prices are raised during congestion.

4. Existing Pricing Model

In literature several pricing models has been proposed and exploited in the analysis of IP networks for providing improved; quality of service, user's utility and to provide the ISPs with profit on their investments. Different authors considered different approaches; in this section we take a look at some existing pricing models.

Hailing Zhu et al.[10]-[11] in their work made a study on price competition among multiple WSPs and a pricing model was proposed using a two-stage non-cooperative game model, this model is aimed at maximizing users compensated utility by choosing a WSP offering the best QoS and price combination. In their work the choice of WSP is based on the client estimated satisfaction, which is a sum of both price paid and QoS enjoyed. Their work however interesting, focused on price competition among multiple WSPs (Oligopolies) and not on bandwidth resources management.

Benedeto F. et al in their work proposed a business model founded on Bayes decision test for video-call billing [12]. The work is based on the end to end QoS obtained by exploiting watermark tracing procedure. The rationale behind the approach is that the alterations suffered by the watermark are likely to be suffered by the data, since they follow the same communication link. Therefore the watermark degradation can be used to evaluate the alterations endured by the data. The aim of this is to realize a functionally intelligent and flexible billing model which is also able to optimize operator and service provider revenue while providing a fair policy towards end users.

Swarup M. et al [13]. In their work a revenue generation model was proposed for French auction and Dutch auction. Simulation results showed considerable improvement as regards the total revenue generated and call blocking probability when compared with flat pricing scheme. Performance of their revenue model was viewed from the service provider's point of view (more gain). On the other hand the work does not consider the need for putting normative control on network recourses usage.

Siris et al [14]. In their work, economic models for resource control in wireless network presented a model based on congestion pricing for resource control in wireless CDMA networks caring traffic streams that have fixed-rate requirements, but can adapt to signal quality. In their work they proposed and investigated an economic model that induces resource control based on actual network requirement of mobile users. Their economic model was compared with other economic models that have appeared in literature, identifying their similarities and differences. The model was based on the notion of utility function and congestion pricing in CDMA networks. Their proposed model was presented in the contest of CDMA network. However it does not extend the economic models to solving problems in wireless networks such as service differentiation.

5. Pricing Model for Differentiated Service Billing

Generally, differentiated service or diffserv is a computer networking architecture that specifies a simple, scalable and coarse-grained mechanism for classifying, managing network traffic, and providing QoS on modern IP network [15]. With the growing demand for sophisticated services like multimedia services, the allocation of different services levels in a network has gained importance. In this work we allocated different service level based on institutional relevance and link degradation caused by used services on network bandwidth resources. For a network transacting on different sophisticated applications let us consider n packet classifications. Cost of transacting on the network C by user j is determined from a dynamic billing process given by

$$C = \theta_k x_{ijk} \quad \text{(Equ. 1)}$$

Where θ is a time of the day coefficient and x_{ijk} is the total number of i packets class transacted by user j at time k of the day.

The network tariff for user j is given by

$$P_j = w_1 C + w_2 C \ldots + w_n C \quad \text{(Equ. 2)}$$

$$P_j = \sum_{i=1}^{n} C w_n \quad \text{(Equ. 3)}$$

$$P_j = \sum_{i,j,k=1} \theta_k x_{ijk} w_i \quad \text{(Equ. 4)}$$

Where w_n is a weighting factor for n service class. Weighting factor may be multiplied by a normalization price factor a set by the ISP providers. However in this work we simple take $a = 1\,NGN$ (Nigerian Naira)

$$W_i = a w_i \quad \text{(Equ. 5)}$$

In the proposed charging model, it is assumed that there are 3 service classes which are differentiated according to their bandwidth occupancy. Although there is no limit for the number of classes, we have employed three service classes i, which represent the various needs of customer j on campus. Fig. 1 shows the flow chat for our billing model.

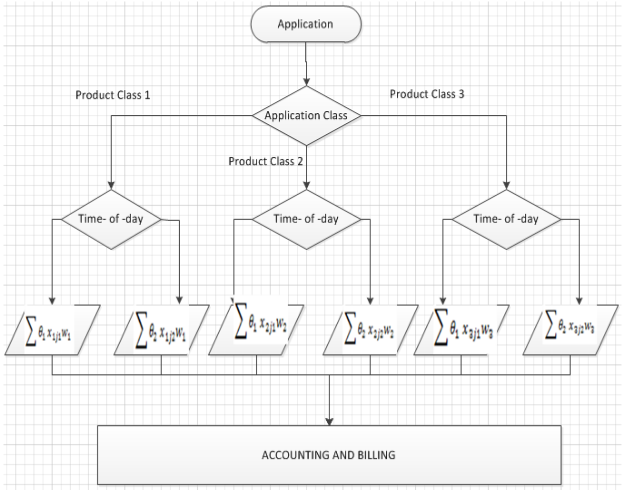


Fig. 1. Charging and Billing for j user

The time-of-day coefficient θ is a ratio for the price difference between peak and non-peak hours. θ was introduced just for encouraging users to prefer the non peak hours for their wireless applications.

The weighting factor coefficient is a combination of institutional relevance ρ and network degradation δ as a result of employing the service class i.

$$w_i = f(\rho, \delta) \quad \text{(Equ. 6)}$$

In this work we obtained the weighting factor coefficient from the packet inter arrival rate over time.

$$y = Z(1 - e^{-wt}) \quad \text{(Equ. 7)}$$

$w_2 > w_1 > w_3$ from the data rate we see that packets with a higher weighting factor and data rate congest the network more, so network performance will decay 6 exponentially with w_i

That is

$$6 = e^{-w_i t} \quad \text{(Equ. 8)}$$

Therefore

$$w_i = -\ln 6 / t \quad \text{(Equ. 9)}$$

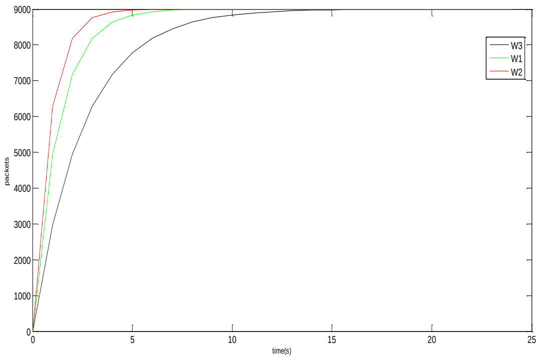


Fig. 2. Plot of Packet received over time y

We compute the weighting factors w_i from equation 9. In one second of simulation time bits received will equal data rate so that class 1, 2, 3 application will each receive packets equaling 30Kbits, 300Kbits and 13.2Kbits per seconds. We then obtain the weighting factors as w_1 =3.4, $w_{2=}$5.8, and w_3 *as* 2.5

6. Model Validation and Analysis

Our proposed billing model was designed and implemented on the OPNET network modeler. The design was implemented on two sub-networks namely, the network switching centre NSC, which hosts the servers and the local area network (LAN) which provides access to users and is implemented on a wired Ethernet technology. At the NSC we modeled the servers as sources of the three classes of applications. The Class 1 applications has a packet size of 1500 bytes and data rate of 30 Kbps, applications in this categories includes e-mail, remote long in, surfing the Internet using application protocol such as simple mail transfer protocol (SMTP), hypertext transfer protocol (HTTP), file transfer protocol (FTP) for research journals. Class 2 applications which modeled a video application has a packet size of 1500 bytes with data rate of 300 Kbps –typical of streaming voice and video applications, which demands high costant bandwidth and the Class 3 applications has a packet size of 40 bytes and data rate of 13.2 Kbps typical of VoIP packets, applications in this category have small packet sizes e.g. voice over IP (VoIP) and does not constitute much load on the link.

The various applications were identified and classified using the type of service field on the packet header. We investigated the network performance experienced by four users namely: Henry, Ohiani, Adeiza and Ohize under three different billing schemes namely the flat rate billing, volume billing, and our differentiated service billing.

The classification was guided by two criteria to control network congestion viz:

(i). The basic Internet needs of staff and students in a higher education institution
(ii). Resource (bandwidth) requirement of a given application.

At the start of the simulation all the four users paid NGN200 each into their network accounts and made requests for packets. The billing model was implemented on the LAN subnet. However θ was held constant. Henry, Ohiani Ohize and Adeiza each requested for applications of interest. Henry makes a request for Class I, Ohiani makes a request for Class II and Adeiza makes a request for Class III types of application. However, the fourth user Ohize entered the network and requested for three applications in three different classes.

Figs 3, 5 and 6 show the number of packets transacted by the four users under the differentiated service billing, flat rate billing, and volume billing respectively. Fig. 4 shows a magnified view of the packet count for the differentiated service billing.

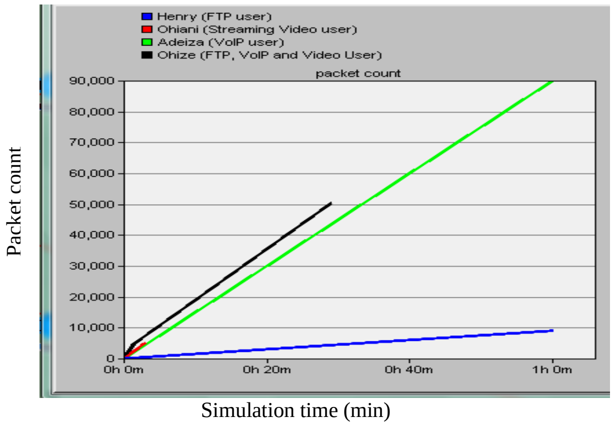


Fig. 3. Packet counts under the differentiated service billing

In the DSB the streaming video is billed highest since its weighting factor is highest so that Ohiani the video user only got 5000 packets before his money finished, as shown in Fig. 4. This billing scheme ensures that such a user does not stay long on the link because he consumes a lot of bandwidth just for fun. Adeiza the VoIP user sustained his session throughout the entire simulation time and he received a total number of 90,000 packets. He spent a total of NGN180 for the entire simulation time of one hour. The Class I user, Henry, only received about 9,000 packets throughout the simulation time. Ohize, who enjoyed the three classes of applications, quickly exhausted his money and was therefore disconnected. At about two minutes of his surfing the net, he realized video application was consuming his money so he sent a session termination request to the NSC. This explains the change in the slope of Fig. 4. Figure 3 shows that Ohize timed out early as he spent only 35 minutes on the link. The effect of Ohiani and Ohize timing out is clearly seen on the link performance as shown in Figs 7, 8, 9 and 10 for our DSB scheme. These Figs further show that this scheme reduces packet end to end (E2E) delay as Henry's packet E2E delay improved in the DSB as compared to the flat rate billing.

Fig. 5, shows the packet count for flat rate billing. In this scheme all the users had their fill to the detriment of network performance as made obvious in Figs 7, 8, 9, and 10. This billing scheme is ineffective for network optimization. It offers no congestion control and the effect is that users experience high network letency.

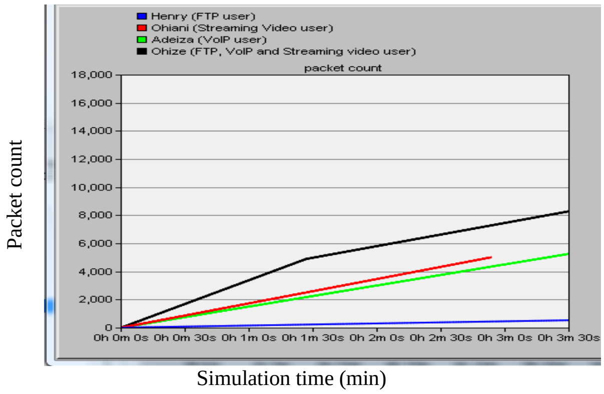


Fig. 4. A magnified view of Fig. 3.

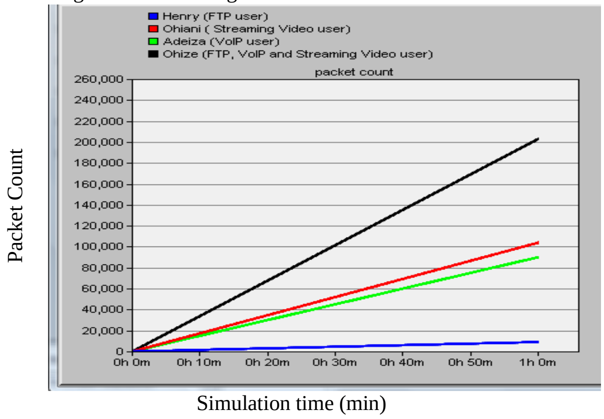


Fig. 5. Packet count on the flat rate billing

Figure 6 shows the packet count for Volume Billing. This scheme is a type of usage billing scheme that shows no regard to the type of application but only bills according to the actual number of packets transported in each application irrespective of the pressure it puts on the link and its relative relevance. The packets are billed at an average rate as a weighting factor is not introduced per packet so that users Adeiza, Ohiani, and Ohize received 10,000 packets each for NGN200, while user Henry received about 9,000 packets within the simulation time. In this billing scheme the Class II applications (streaming video) was billed the same with Class I (SMTP) (equivalent to small cars paying the same toll price with big trucks, while they do not put the same level of pressure on the road). Obviously, this scheme implemented some congestion control, thereby outperforming the flat rate billing scheme, by checking users' greedy behavior. It however exhibited unfairness in its method of control. In contrast, the DSB scheme showed a lot of fairness in its method of congestion control by ensuring that: for the same amount of money heavy application users got less data and spent shorter time on the link than light application users. There is also the subtle consideration for level of 'relevance' of an application that DSB introduced, which is very useful for bandwidth management in campus networks.. This consideration explains the curves of Figs 7, 8 and 9. Notice that the link utilization for the flat rate billing remained constant throughout the simulation time.

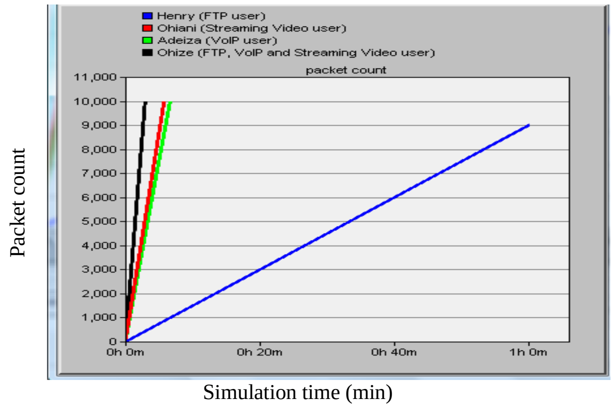


Fig. 6. Packets count on volume billing

This is because for the same amount of money, the users are allowed to be on the link for the same length of time transacting any type of traffic. There is no congestion control, as a result, the queuing delay and the E2E delay did not reduce. In the volume billing the link utilization dropped significantly because the users are allowed to consume as much traffic as they paid for. A user is forced to leave the link when his money finished. The link is thus decongested and the queuing and E2E delay reduced. It is however unfair in its billing. Notice also that the DSB scheme made a significant improvement over the volume billing: not only did the link utilization drop even further in this scheme, but the E2E delay also reduced considerably. This is because the heavier link users were forced to leave the link earlier thereby decongesting it.

Fig. 10 shows the effect of the various billing schemes on the packet E2E delay of a single user, Henry, who used Class I. This Figure tries to buttress the unfairness in the volume billing. Notice that his packet E2E delay improved considerably under our DSB and volume billing as compared to the flat rate billing. This is because other heavy link users were forced to leave the link earlier. The volume based billing seemed to have an improved E2E delay over DSB at about the 20th minute into the simulation. This is because the volume billing unfairly terminated the VoIP user (see figure 6 and 10), thereby enventually tending to have a lesser link utilization for Volume billing as shown in Fig.7.

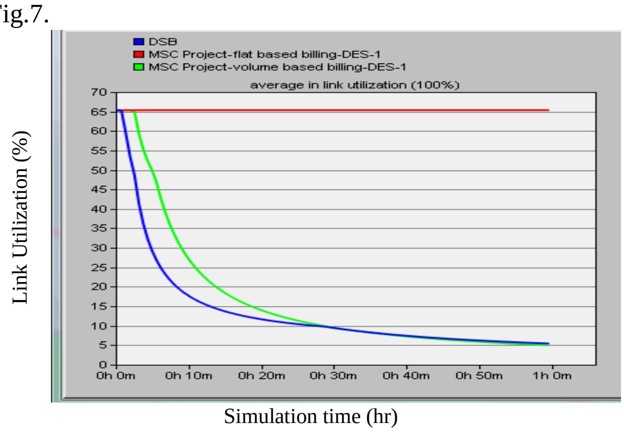
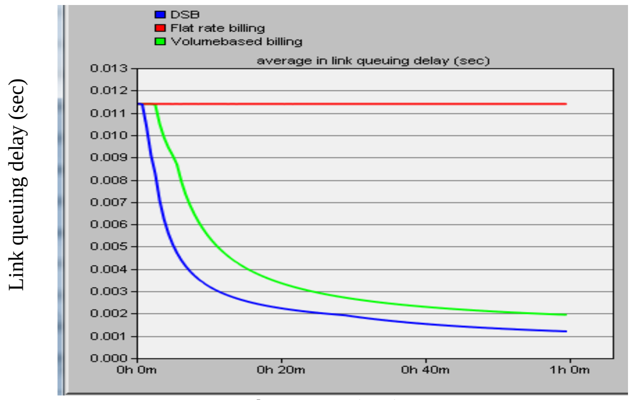
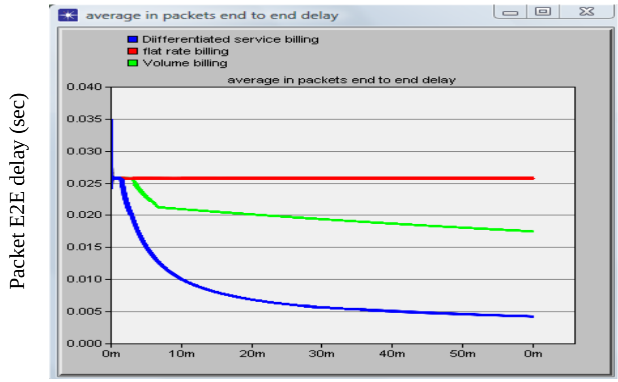


Fig. 7. Average link utilization between the NSC subnet and LAN subnet (in percentage).



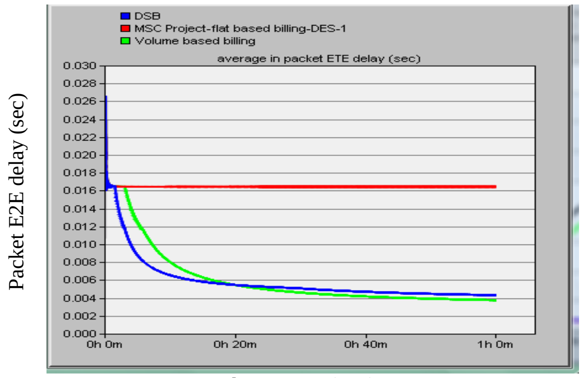
Simulation time (min)

Fig. 8. Average link queuing delay between the NSC the LAN subnet



Simulation time (min)

Fig. 9. Average packet end to end delay for all the users



Simulation time (min)

Fig. 10. Average packet end to end delay for user Henry

7. Conclusion

Solution to network congestion is not provided merely by increasing the available bandwidth, which is expensive especially for the African environment. Taking proactive measures, such as using billing schemes that not only offset cost of network implementation and management, but also control user behavior in such a manner that the QoS perceived by productive users is much better than the comfort enjoyed by Internet fun lovers. In this work we proposed the differentiated service billing (DSB) - a billing system that attempts to achieve this. Our scheme will find usefulness in a campus or corporate environment to check abusive network usage and help productive users have better value for their time and money. Our scheme does this by being able to discriminate between traffic flows on an IP network. It then bills a traffic type according to such set criteria that help to achieve the overall purpose of the network. The results obtained showed considerable improvement in overall congestion control in general and the QoS enjoyed by users of 'relevant' applications in particular. It is, therefore, a reasonable improvement over the ordinary usage billing schemes.

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