CHARGING FOR COMPUTER NETWORKS AT HIGHER EDUCATIONAL INSTITUTIONS IN DEVELOPING COUNTRIES

F. O. Kumolalo, E. A. Olajubu and G. A. Aderounmu
Department of Computer Science and Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria

ABSTRACT: The advantage of the Internet to academia and research cannot be underestimated; nevertheless in developing countries the ability to support this important resource, as a viable tool for teaching and research, is undermined by lack of funding. This makes it necessary to apply a charging mechanism that will make it possible to render this facility available to the higher education system, while encouraging its use primarily for teaching and research. In this paper we present a proposal for a charging system that can be applied to achieve this aim. Our proposal discourages the use of the Academic Network for purposes other than teaching and research.
KEYWORDS: Higher Educational Networks, National Research and Education Networks, charging schemes

Introduction

Global connectivity has greatly enhanced communication, collaboration and the exchange of ideas and information. The Internet, which came into existence as a tool for research collaboration among academics and research institutions, has now become an important tool in the commercial arena, with little impact on academics in the developing world. The impact/importance of Internet cannot be underestimated for citadels of learning, especially in the tertiary academic environment. According to the African Association of Universities, (2000), such use includes:

- Support of Higher Educational Institutions' (HEI) core process of teaching and learning through a provision of contents that form a tool to enhance learning and prepare students for the labour market. The advantage is further demonstrated in that it supports teaching methodology, management and monitoring of the teaching and learning process.
- Support of HEI's core process of research which includes collection, exchange and dissemination of academic information in support of research and management of research projects.
- Support of HEI's core process of academic information services. Transformation of the library from the traditional book-oriented approach to an outward-looking one, with emphasis on information handling (not only cataloguing information) but in fact collecting, processing, compiling and disseminating it in support of students and researchers inside and outside the institution.
- Support of administration and operational management.
- Support of tactical and strategic management of Information and Communication Technology (ICT) technical organisational infrastructure.

Therefore, that institutions of higher education such as the universities and polytechnics should have a networking facility such as Local Area Networks and connection to the Internet must be expected. In this spirit, academic institutions in developing countries of Africa are getting connected to the Internet for teaching and research purposes. Among the first to acquire the facility was the South African Rhodes University (RUITD, 2002). Thereafter other institutions on the continent received the facility mainly through collaboration with external organisations such as the International Centre for Theoretical Physics (ICTP) Italy, which assisted with the setting up of the Obafemi Awolowo University Network (OAUNET); Ile-Ife, Nigeria (Onime *et al*, 1999); US Agency for International Development (USAID); Leyland Initiative for University of Ghana, Accra, Ghana (AAU, 2000 and Missen, 1999); as well as many others throughout Africa. The common problem of these ICT networks in Africa is the problem of funding and maintenance of the infrastructure, due mainly to low or non-existing budgetary allocation for ICT in these universities. Each institution has had to devise ways of meeting the running and maintenance costs of their network (Missen, 1999). In Table 1 the average cost of bandwidth provision in the HEI network in some of the developing world's universities, especially in Africa, is clearly reflected. It is important to note that bandwidth is very expensive in this part of the world (INASP, 2003).

TABLE 1: COST OF BANDWIDTH PROVISION.

S/N	University	Bandwidth Available		Cost ($)
		Down	Up	/Month
1	Makerere University, Uganda	1.5MB	768Kbps	22 000
2	Eduardo University, Mandlane	1MB	384Kbps	10 000
3	University of Ghana, Ghana	1MB	512Kbps	10 000
4	Obafemi Awolowo University, Nigeria	768MB	256Kbps	12 288

Moreover, the financial implication goes beyond bandwidth provisioning. It also includes the following costs: hardware purchase/replacement, software purchase/upgrade, antivirus licensing, payment of personnel, electricity and provision of alternative power supply (power failure is a common phenomenon in developing nations), cooling system (for tropical regions) and light/radiation preventive systems.

Also, the provision of logical and physical security is very important. The financial implication of these items varies from one nation to another. Some accounting is also needed for the sake of record keeping so that the university is able to calculate the pattern and actual consumption of bandwidth (Morris, 2003).

HEIs in developing nations need to generate funds to meet network maintenance and expansion expenses. They can do this through in-house management teams or by outsourcing management expertise. The in-house team may charge different tariffs for user categories for cost recovery only, while outsourced managers will charge commercial, profit-oriented rates. The HEIs may also sublet some of their bandwidth.

In this paper, we examine the various charging schemes and propose a model which will

- relate fund generation by the network proportionally to the service rendered by the HEI network;
- help modify the traffic usage pattern on HEI networks to encourage academic use as well as maximisation of resources, while at the same time maintaining fairness to all users.

The rest of this paper is arranged as follows: the next section briefly takes a look at existing schemes and their shortcomings, while Section Three discusses the architecture and charging parameters of the proposed scheme. The last section summarises our proposal in this paper.

Existing Charging Schemes:

Charging and billing of Internet services is one of the major determining factors in the development of Internet usage (Farrera *et al*, 2002), and as such it is important to have a scheme that will encourage the usage and development of the Internet and networking in the higher educational institutions in Developing Economies (DE). There are presently various schemes in use in various HEIs to address atypical situations in such places. Therefore the following scheme, which some of the HEIs in Africa have employed, is examined; each of the schemes has a varying degree of success and obvious shortcomings as evidenced below:

national research and education networks (nrens)

NRENs are specialised Internet service providers that are keen to supply the needs of research and educational communities within a country with a high-speed backbone network. According to Galagan and Looijen (1999), in NRENs, while there are many components to network cost, bandwidth cost is the major factor that determines a user's bill. The two pricing models in NRENs are flat rate and usage-based pricing. Furthermore, the authors claim that although most NRENs use a flat rate model, some NRENs like JANET, REUNA, KAREN utilise usage-based charging models so that variable quality of service (QoS) can be implemented and network resources can be used optimally.

flat rate charging schemes:

The traditional scheme of charging service usage on the Internet, the flat rate, is commonly adopted by many of the HEIs (Farrera *et al*, 2002; Aaito, 2003 and Koutsopoulou *et al*, 2004). The advantage of this scheme is the simplicity and zero-cost of obtaining charging information. All that is needed is the list of subscribers to the institution's network; a flat rate is then allocated to each subscriber.

According to Koutsopoulou (2004), this scheme can be subdivided into two:

- Non-subsidised flat rate: Here, the total running cost of the network is divided equally among the users.
- Subsidised flat rate: Part of the running cost is borne by the institution's management and the remainder is equally divided among the users.

However, the following shortcomings are identified in the flat rate scheme:

- it encourages waste of bandwidth and increases cost;
- it forces light users with lower use of resources to subsidise heavy users;
- it can introduce differentiated service quality only by inefficient segmentation in quality tiers (Farrera, 2002).

This leads us to the second scheme.

institution internet service provider scheme:

This scheme is one in which the institution provides facilities for connection to ISPs which provide service to the members of the community at their commercial rate. This means that even though the ISP is working on campus, clients from the institution are charged and billed as other clients using their service outside the academic environment. This scheme removes every cost from the institution, but it does not encourage the use of ICT and the Internet for teaching and research purposes. This fact makes a commercial rate a disincentive to academic work.

Differential rate charging scheme:

HEIs have also been known to implement a scheme of differential rates in which users are grouped into different categories and each category then pays a specified, fixed period charge. Such grouping may be influenced by cadres such as senior/junior staff or academic/non-academic staff. The drawback is that, like the flat rate, it does not reflect the actual bandwidth consumption by the user, hence it has the inherent deficiencies of flat rate in addition to the fact that segregation that is not determined by bandwidth usage leads to misappropriation of network resource, which makes cost inefficiency too high in the network (Aalto, 2000).

Quota-based charging scheme:

A quota–managed charging scheme has also been implemented in HEIs in developed and developing countries (Farrera *et al*, 2002). This scheme set a usage quota for the users either in categories or by a flat usage quota for all users within the network. This has the advantage of reducing unnecessary consumption of bandwidth, but becomes a disadvantage when there are users who have legitimate needs, such as an on-going research project, who may be denied the service because of the quota limit set. There are also other schemes, for example the duration-of-use charging scheme proposed by Mobilein Minute, (2001) and IUPUI, (2000), whose charges are based on amount of time connected but not on actual user throughput or effective bandwidth consumption.

Problem definition:

The above charging schemes have being noted to have one or more of the following deficiencies:

- inability to reflect actual usage of the network resources and therefore inability to provide insight into planning and performance measurement;
- unfairness in charging, making light users subsidise heavy users, which has led to abuse of the network, such as users giving their access rights to others; and
- inability to control usage patterns in an economic way so that resource provision and usage are balanced with cost.

Proposed Architecture

Due to some of the deficiencies of the abovementioned schemes we propose a scheme that will be fair to users and also encourage optimum use for research and teaching purposes. The proposed scheme takes the following into consideration: consumption pattern of bandwidth; the type of service used; content/volume; duration of usage and the relative source-destination of traffic.

Bandwidth usage pattern:

The widely observed phenomenon in communication networks is that the period of usage is usually divided into peak and off-peak periods. Peak periods are the time of maximum usage, mostly during the day, especially during working hours, while off-peak periods are in the early hours of the day and late hours in the evenings. These patterns characterise Internet usage and are also observed in research and academic networks of the HEI. The empirical study carried out within the OAUNET in Obafemi Awolowo University showed that the pattern of aggregate traffic levels fluctuates following the Extreme Value Type I distribution function. The bandwidth consumption pattern within OAUNET is illustrated in Figure 1.

Figure 1: Daily bandwidth aggregate usage pattern for OAUNET

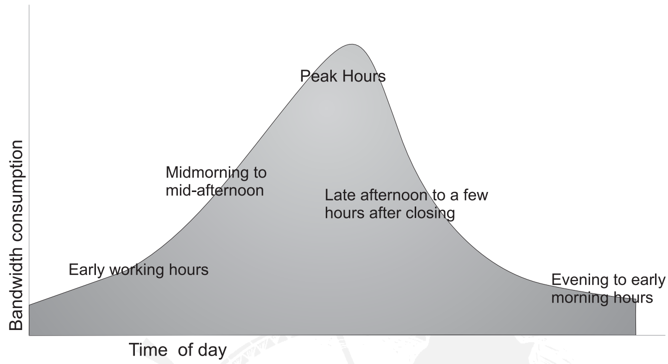


Figure 1 shows the three noticeable periods in the pattern of bandwidth usage. The figure reflects the total aggregate traffic level (both local traffic to the servers through the LAN and external traffic to the Internet).

The traffic is very low early in the day, in which most traffic is from a few people night browsing. It remains low but starts to pick up as people start arriving at their offices. A steep rise is noticed as workers resume work by 9:00 GMT. Between the hours of 14:00 GMT and 17:00 GMT the traffic volume seems fairly constant and then begins to decline. Towards closing hours another sharp reduction in the traffic volume is experienced, leaving behind a few academic staff and research students who may want to continue their research work late into the night.

The above represents the aggregate bandwidth usage pattern, which is often not taken into consideration in the design of a charging mechanism but which has a serious impact on the value attached to the service at a particular time of the day. This information will now be embedded in the development of a new charging scheme for academic and research environments. This charging scheme may be useful to other types of communication networks outside academic networks.

parameters for charging

According to Alexander (1996) "pricing schemes for different incarnations of usage-based bandwidth are all over the map. Some charge by the bit, per event, per broadcast or per audio stream using a fixed period of time for a certain rate of transmission. Some charge by the amount of port bandwidth, or the clock speed at the entry port going to the Internet". However, in this paper we propose the utilisation of a multi-parameter scheme that will be able to redress the shortcomings mentioned in section 2.5. These parameters are: time, traffic volume, type of service consumed and source-destination value. Farrera (2002) opined that time should be taken into consideration in schemes that use effective throughput as a basis for billing. Since it is possible for a client to be on a network with an open connection although not seriously downloading or uploading, this still ties up network resources, although volume downloaded is nil. Time therefore becomes an important parameter in determining clients' utilisation of the HEI network. It is also taken into account because a client that is connected for a length of time t has a port or a tunnel to the local server dedicated to it and this puts load on the performance of the server as there is a limit on the efficiency/load ratio for the server ((Alonistioti *et al*, 2001 and Cardellini *et al*, 1999). Traffic volume is another parameter specified for the proposed scheme, as it is a factor that affects available bandwidth. This is very important, considering the fact that bandwidth is a limiting factor and occupies a huge place in the monthly cost of running the network.

The third parameter specified for the scheme is the destination based on Veciana *et al*, (2002). This parameter is aimed at creating incentive to users to concentrate on using the facility of the network for the primary purpose of research and teaching. Using the above parameters as variables in the algorithms that will be developed, effective usage of the network resources and attendant opportunity cost to other users have been considered. This is because other factors like peak and off-peak periods reflecting usage will be considered in applying weight to each of the variables in the algorithm.

Arising from these parameters we propose the following algorithm to serve as a charging scheme for research and academic networks in developing countries:

$$Bill = R_1 \, x \, T_w \, x \, P_t \, x \, t + (R_2 \, x \, V_w \, x \, P_v + R_3 \, x \, D_w) \, x \, V \qquad (1)$$

$$\sum_{i=1}^{3} R_i = 1.0 \qquad (2)$$

For all *I* that is a real number such $\forall i \;\; \exists R_i \;\; \Pi \;\; 0.0 < R_i < 1.0$

R_i = Proportion of the cost/bill that will be assigned to each parameter.

T_w = Time weight

P_t = Price per second

t = duration of connection (in seconds)

V_w = Volume weight

P_v = Price per volume

v = Volume transferred from/to client (in bytes)

D_w = Destination weight

T_w is the time weight that is defined by the pattern of daily usage. This will cause peak hours to be charged at a premium rate higher than off-peak hours. The average pattern of daily usage has been found to have an approximated pattern of the Extreme Value Type I Distribution. According to Evans *et al*, (2000), the Extreme Value Type I (minimum) distribution is given by the equation 3.0

$$f(x) = \frac{1}{\beta} \quad {}^{\frac{x-\mu}{\beta}} \; - \; {}^{\frac{x-\mu}{\beta}} \qquad (3)$$

The Extreme Value Type I (maximum) distribution given by the equation 4.0

$$f(x) = \frac{1}{\beta} \quad {}^{\frac{x-\mu}{\beta}} \; - \; {}^{\frac{x-\mu}{\beta}} \qquad (4)$$

Figure 2, which is the aggregate of the daily consumption of bandwidth on the OAUNET, has a similar pattern to the Extreme Value Type I distribution. The average pattern was generated from the analysis of the network traffic data on a daily basis. Thus the Extreme Value Distribution can be used with some modification to set the value of T_w for the network.

The modification is done by combining a portion of Extreme Value Type I minimum and maximum in such a way that the Type I maximum reflects the last 41.67% of the daily consumption while the Type I minimum reflects the first 68.33% of daily usage.

Figure 2: Aggregate Daily Bandwidth usage of OAUNET

In equations 3.0 and 4.0, the U is the location parameter which determines the point on the time axis at which the distribution will reach its peak and hence its shape, while B is the scale parameter which determines peak value of the probability distribution. x is the variable on the horizontal axis. Using the combination of the equation 3.0 and 4.0 U will be used to define the peak period while B will be used to describe the average peak pattern for each day of the week. X will represent the time variable. This will generally provide incentive to do volume-intensive and time-consuming activities on the network at off-peak hours and hence there will be no need for limitation through administrative restrictions. Thus value of T_w, which varies throughout the day using the new equation derived from equations 3.0 and 4.0, will ensure that there is enough traffic during the off-peak period. This leads to maximisation of available bandwidth with increase in performance during the peak period.

P_t is the price that is charged per second connection to the network whether there is active download of content or otherwise. This will encourage users to effectively close down their connection when not in use, as open connection is always used by adware and spyware, which also consume network connections. Also, aimless browsing will be drastically reduced to the minimum, and also minimises the hijacking of such connection for malicious purposes. This has the resultant effect of reducing the use of an academic network for entertainment and encourages purposeful academic pursuit.

V_w is defined by such combinations as the transport protocol (that is TCP, UDP, SMTP) (Arunm, 2005 and Koutsopoulou *et al*, 2001), whether the traffic demand is real-time or non-real-time, connectivity, and the application type (eg HTTP, FTP and RTP). Some usages are linked to particular application types and the purpose of the Volume weight is to give priority to the applications that are not often used for entertainment purposes. This will make browsing for research cheaper without preventing others from accessing what they may also consider important to them.

Pv is the price to be charged per volume, which is price that is attached to each unit of information transferred. This parameter is used to make sure that the user is charged per byte of what is transferred, so that light users are not made to subsidise the heavy users. This parameter will interact with V_w to make sure that traffic generated for research purposes is still cheaper and at the same time, payment is proportional to usage.

D_w is the weight to the traffic as per the destination type. The destination weight is used to differentiate values attached to traffic from/to different sources/destinations. The determination of the value of the destination weight is done by grouping sites into three (3) broad groupings such that a particular page (or site) could be classified as generating internal traffic if the destination is within the local area network (LAN). Requests that are served from a proxy server will also be classified as internal. Using content-filtering packages, external traffic to the internet will be classified as premium or non-premium. Premium traffic will be to the sites that are set in the network filtering package. An additional proposal is the development of a continually updated database of major journals and sites hosting research articles and academic works. The aim of the content-filtering package in this case is not to block any site which might be considered as anti-freedom of expression but rather to place premium on usage of network for academic purposes. It is noted in INASP (2003) that it should be possible to unblock a site that was blocked in error. The combination of the content filtering package and the research database will go a long way in helping to determine sites that are resourceful to the academic and research. The traffic has been group thus:

D_w = LanD, pID, oID

LanD = within the local area network (LAN). The request made for traffic to the Internet which was, however, served from the proxy server cache will also be classified as traffic within the LAN;

pID = traffic to the Internet that could be classified by simple heuristics as academic-oriented traffic content;

oID = Traffic to the Internet for other purposes outside academic usage.

Traffic within the LAN will attract the lowest cost, followed by premium Internet usage, and the highest cost goes to connection for non-premium sites. According to INASP (2003), this proposal should be made policy for academic networks that will be administered by an ICT implementation committee that would consider different research content of academics and researchers within the institution.

HYPOTHETICAL ILLUSTRATION

We considered a hypothetical case of six users: Clients A and B both worked within the morning off-peak period of 7.00 am to 9.00 am. Client A's network activities are classified by the network filter as premium usage while client B's activities comprise both premium and non-premium usage. Even though the average network activities measured by file download and bandwidth consumption are the same for the two, using equation 1.0 A will have a lower bill than that of B because his D_w value is lower.

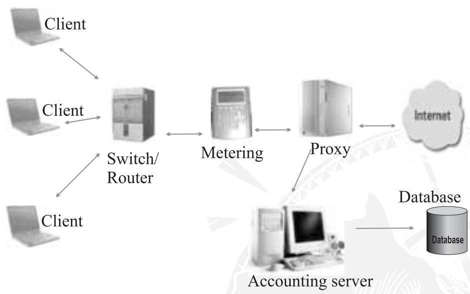
Clients C and D respectively worked at the peak period of 10.00 am to 1.00 pm and 6.00 pm to 9.00 pm on the same day. Both of them worked using the same amount of bandwidth and both worked on premium-classified sites, downloading about 20MB of journal papers and articles. Unlike the destination parameter D_w that has only two possible discrete values, the Time Weight Parameter T_w has a value determined by the continuous function derived from Extreme value Type I distribution functions. Hence C will have a higher cost profile than D.

Similarly, while client A worked on the network using TCP to download an audio file of 50MB, another client, F, used UDP to stream the same audio file from another server. Although the same audio file (a non-premium service) was accessed, the cost profile of client A is less than that of F because the Volume weight parameter V_w is lesser for TCP non-real-time connections than for UDP near real-time connections.

ARCHITECTURAL FRAMEWORK

The charging scheme is proposed to work within the framework of the architecture shown in Figure 3.0.

FIGURE 3.0 HYPOTHETICAL SYSTEM ARCHITECTURE



Users connect through the switch/router to the Internet having been allocated an address by the DHCP server. The metering device MD is positioned before the proxy server so that it can collect individual user's traffic data sent to the different addresses, recognisable to the proxy server. User/IP address association is sent from the DHCP to the MD after user log-on to the network. The MD associates packets with users within the network. The MD generates the usage log that is downloaded to the charging and accounting server database in preconfigured format and at regular intervals and finally at user's logoff time. This client data will be used to determine the charging values of the parameters specified in the charging equation. Once these values are determined, the bill is generated.

CONCLUSION

If Internet usage is going to be as valuable to academics in the developing economies as it is in developed economies, the charging schemes used in commercial setup will need to be modified to allow Internet usage to support teaching and research works in HEIs. To make this possible, we proposed an algorithm that encourages the use of academic networks for teaching and research purposes rather than for entertainment and commercial usage. This charging scheme is flexible enough to differentiate between Internet usage for academic and research on the one hand and for other purposes on the other. This discrimination will allow academic networks to be wholly dedicated to research and teaching purposes in the developing economies. The algorithm does not prohibit the use of this network for other purposes outside teaching and research, but the user will have to pay more for this facility. As a matter of policy, an academic network is to support academic and research activities. In addition, it is expected that it will afford every member of the academic community access to the network irrespective of their financial status. ❑

REFERENCES

Aalto, S. (2000). "Implementing Prepaid Internet Access at University of Zululand." Retrieved 10 November, 2004. http://www.upe.ac.za/citte2000/docs/soraalto.htm

Alexander, P. (1996). "If You Can't Bill, Forget It. ATM service providers faces new billing challenges" *Telephony*. September 16, 1996 Retrieved 04 December, 2003. http://telephonyonline.com/ar/telecom_cant_bill_forget/index.htm.

Alonistioti, A., Houssos N., Panagiotakis S. (2001)."A Framework for Reconfigurable Provisioning of Services in Mobile Networks" in Proceedings of ISCTA 2001 Ambleside, UK July 2001.

Arunm, E. (2005) "Billing for Telecommunication Services : How accurate , Intelligent Billing can help to Build Brand Loyalty" Retrieved 22 February, 2005. http://www.anglefire.com/ny5/earnum/news/silicon.htm

Cardellini, Colajanni, M. and Yu, P. (1999)."Dynamic Load Balancing on Web-Server Systems." *IEEE Internet Computing*, pages 28—39, May/June 1999.

Evans, M., Hastings, N. and Peacock, B. (2000). *Statistical Distribution*, 3rd Ed, John Wiley & Sons.

Farrera, M.P., Lucio, G.F. and Ghanhari, M. (2002). "A Proposal for Billing Internet Services Based on User Throughput and Service Categorization" Retrieved 10 November, 2004 http://www.essex.ac.uk/~mpared/publications/icese_billing.pdf

Galagan, D. and Looijen, M. (1999). National Research and Education Network: Analysis of Management Issues. Proceedings of INET99 Retrieved 08 January, 2009 http://www.isoc.org/inet99/proceedings/3h/3h_1.htm

IUPUI FY00-01 "University Information Technology Services. Rate for Direct-Bill Services" Retrieved 22 February, 2005. http://www.indiana.edu/~uits/bussiness/ratesin00.html

Koutsopoulou, M., Gazis, E. and Kaloxylos, A.(2001). "A Novel Billing Scheme for UMTS Networks" in International Symposium on 3rd Generation Infrastructure and Services. Athens, Greece July 2001.

Koutsopoulou, M., Kaloxylos, A., Alonistioti, A. and Merakos, L.(2004). "Charging, Accounting and Billing Management Schemes in Mobile Telecommunication Networks and the Internet": in *IEEE Communication Survey*, First Quarter 2004, Vol 6 No 1. Retrieved 02 February, 2005. http://www.comsoc.org/pubs/survey/billing.pdf

Missen, C. (2004). "Universities as Internet Service Providers" USIA/GTC Assessment of Internet Connectivity Needs of Nigerian Universities. http://www.widernet.org/NigeriaConsult/index.htm Retrieved 10 November, 2004.

Mobile in Minute. Billing. Retrieved 5 August, 2003. http://www.mobilein.com/billing.htm

Morris, S. (2003) Network Management, MIBs and MPLS. Prentice Hall PTR. June 2003.

Onime, C., Bello, M., Ola, A. and Oluwaranti, A. (1999). "Evolution of OAUNET: Lessons from Sub-Saharan African" Retrieved 10 November, 2004 http://www.isoc.org/inet99/proceedings/3f/3f_1.htm

Rhodes University Information Technology Division "Internet Quota System"Retrieved 22 February, 2005 http://www.ru.ac.za/administrative/it/policies/quota.htm

The African Association of Universities (2000). Summary Of On-Line Discussion On Ict In Higher Education Institution In Africa (April 21 to May 8, 2000) Retrieved 10 November, 2004. http://www.aau.org/english/documents/aau-ictreport-p4.htm

The International Network for the Availability of Scientific Publications (INASP "Optimising Internet Bandwidth in Developing Country Higher Education" A study presented at the Regional Training Conference on *Improving Tertiary Education in Sub-Saharan Africa: Things That Work!* Accra, September 23-25, 2003 Retrieved 15 March, 2005 http://www.inasp.info/pubs/bandwidth/

Veciana, C., Sole-Pareta, J., Domingo-Pascual, J and Gay, J. (2002)."Cost Sharing and Billing in Research Networks: MIRA Approach" in Proceedings of TERENA Networking Conference , University Limerick, Ireland July 2002.