Analysis of QoS Requirements in Developing Countries

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Abstract:
The world's dependency on information technologies is at its highest with Internet providing access to information from different parts of the world. While the developed world is capitalising on this, developing countries are still struggling with poor or no technological infrastructure. This has led to lack of access to the Internet in many areas of these countries leading to the exclusion from the online communities. Few areas that get access to the Internet are still struggling with lack of Quality of Service (QoS) assurance. This paper presents the QoS required for developing countries using Tanzania as a case study. It discusses issues surrounding QoS requirements for the modern world and compares this with the situation in developing countries. It presents the results from a study conducted in Tanzania on QoS requirement around the country. It examines the present, perceived and required QoS and compares this with the standard QoS recommendation from key studies. The results show that most Internet connections are well below the recommended quality. The Internet penetration is still low. While many Internet users engage in basic Internet use such as e-mail and web browsing, they are also keen to have reliable connections. The findings are also useful for other countries sharing general characteristics with Tanzania.

Categories and Subject Descriptors: H1.2 [**Models and Principles**]: User/Machine Systems - *Human factors*; *Human information processing;* K3.0 [**Computers and Education**]: General; K4.0[**Computers and Society**]: General

Additional key words and phrases: internet-assisted research, Nigeria, tertiary institutions, internet usage, students, strategies

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1. INTRODUCTION

QoS, which are the parameters that contribute towards the overall performance of the service, has become one of the issues that affect all parts of the industry. From technical specification to customer satisfaction, QoS has been and is now one of the important factors in any Internet service [Buccafurri, F. et al., 2008]. The quality of Internet services has been challenged by a new shape which the Internet is changing into. In developing countries however, the need for basic Internet application is

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yet to be fulfilled. To tackle the problem, a number of initiatives are underway to increase Internet penetrations and reduce or remove barriers that hinder people from accessing the Internet. Most of these initiatives tend to solve problems facing a certain society addressing issues faced by it. There is a need to study perceived and required QoS and factors that affect QoS in these countries. The QoS required can be used as a quality guide for any project in the future in developing countries.

The Internet infrastructural challenges come a long way with since the birth of telephones. The Internet was created after traditional telephone technologies and many countries are still using these networks i.e. public switched telephone network (PSTN), to connect people to the Internet. This has been the case mostly in the developing world where PSTN still serve to provide backbone connections using copper cables. Although a number of modern and digital technologies like ADSL have been created to improve PSTN, this system still has difficulties due to the fact that it was designed for analog telephone services [White, 2008]. In developed countries however, many operators are now using fibre technologies to provide backbone at least to connect major towns. The inherited challenges that come with PSTN together with its poor condition in developing countries make these infrastructures highly unreliable [Sedoyeka 2008].

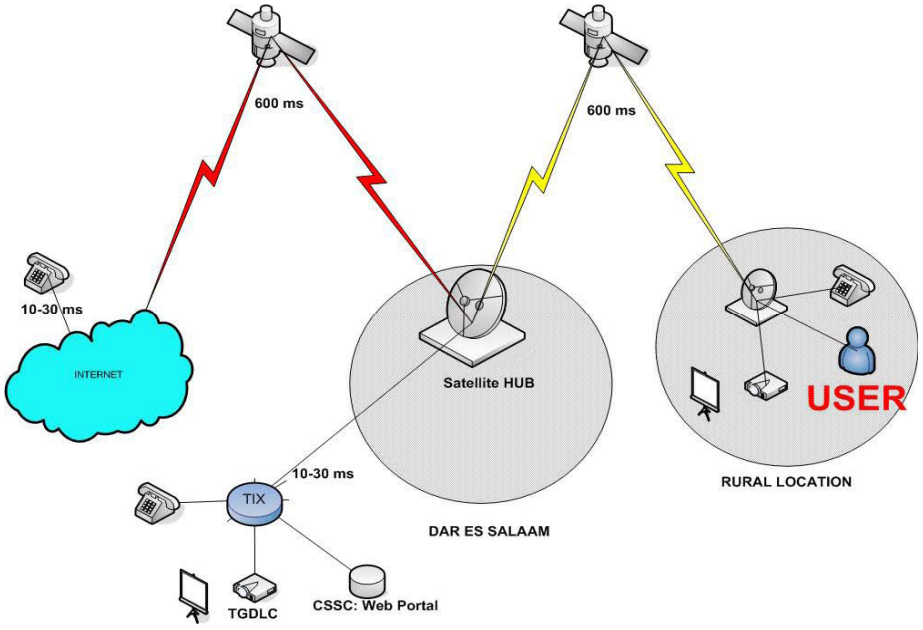

Fig 1. A topology for the ISP with the local hub (Source: SWOPnet/IICD)

Web demands pose a new dimension [Buccafurri, F. et al., 2008]. Connecting to the World Wide Web (www) is still a challenge with a number of developing countries especially in Africa still use satellite to connect countries to the world. This has a major implication in QoS offered to Internet subscribers and adds challenges on top of PSTN ones, affecting the choices operators can make when offering services. These challenges also have a number of implications in QoS metrics mainly throughput, link stability, minimum delay and error rate [Salonen et al, 2002]. Currently there are two major types of satellite connections in Tanzania, those with a hub in Dar es Salaam having local traffics routed to Tanzania Internet Exchange (TIX) (fig 1) and those which connect directly to the international hub (fig 2).

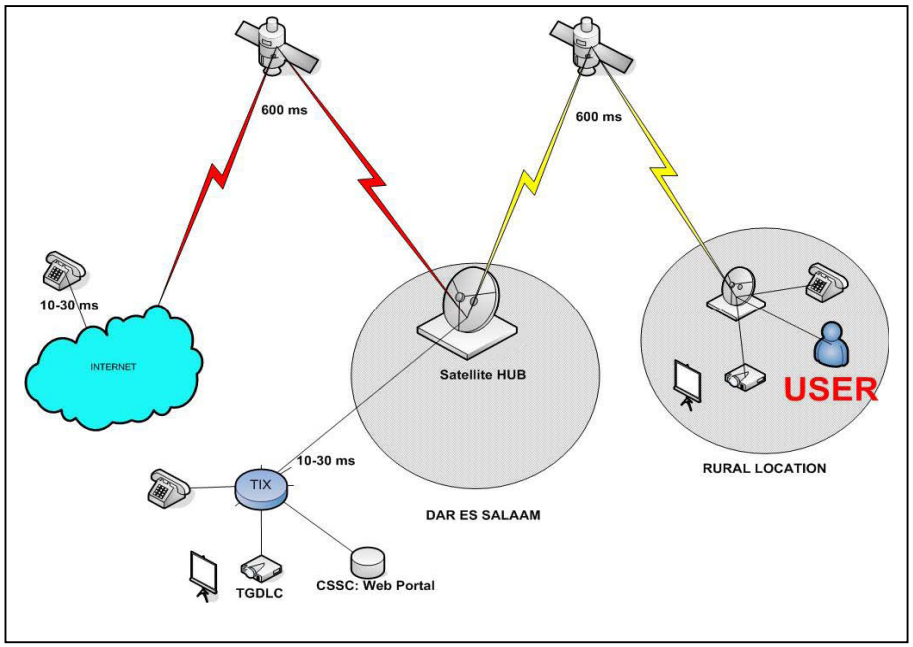

Fig 2. A topology for the ISP with the local hub (Source: SWOPnet/IICD)

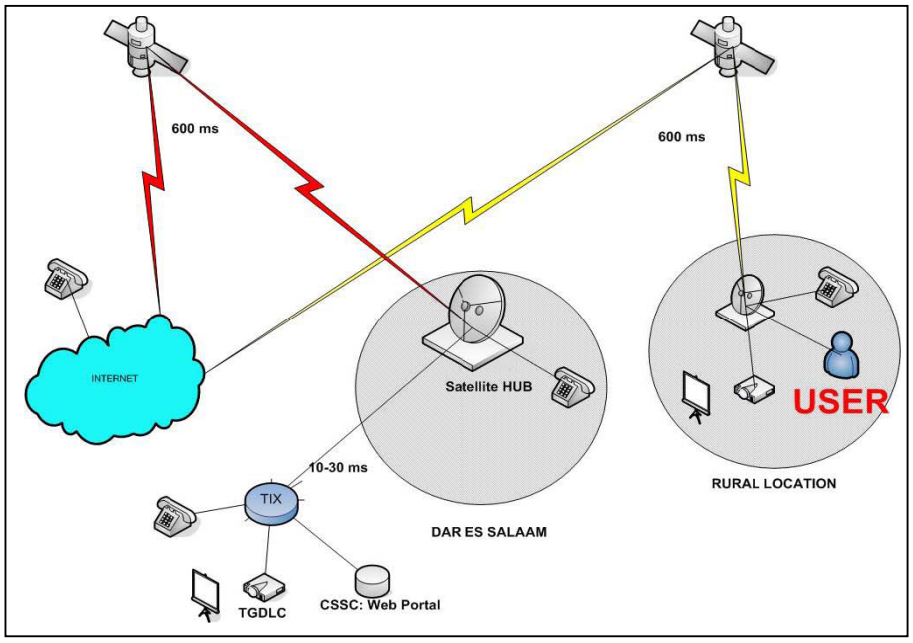

Fig 2. A topology for the ISP with an international hub (Source: SWOPnet/IICD)

The dilemma of what is the required QoS or what is enough bandwidth is still faced by many. This study intended to address these issues in order to understand the demands, project the future and estimate the required QoS. This study was conducted in Tanzania, which shares similar economical and technological features with many of the developing countries.

Tanzania is one of the biggest countries in Africa with an area of four times the size of England and population of above 35 million people. This tropical East African country's economy grew at a rate of 6.7% in 2006, with a 6.0% growing rate in the agricultural sector, which employs the majority of the population. The communication sector grew at a rate of 6.2%, which was highly contributed by mobile phone companies [Tanzania Economical Report, 2006]. The country is looking forward to be connected to the under see fibre optic cable for super fast Internet services [Sedoyeka 2008].

This paper consists of six sections. QoS is defined and explained in section II. Section III will layout the methodology used to conduct a study in Tanzania while section IV will present the findings. Section V will discuss the required QoS and finally the conclusion in section VI will present the summary of the paper.

2. QOS DEFINED

According to Oodan et al. [1997], QoS is viewed from two main perspectives. From a customer perspective, QoS is defined by *"attributes or criteria that are considered to be essential in the use of service"*. From a service provider perspective, QoS is defined by *"parameters that contribute towards the end-to-end performance of the service, reflecting the customer's requirements"*. The primary goal of QoS, from a network operator perspective, is to provide different priority to different applications including dedicated bandwidth, controlled jitter and latency (required by some real-time and interactive traffic) and improved loss characteristics. It also makes sure that providing priority for one or more flows does not make other flows fail [Cisco, 2007]. In computer networks, QoS refers to resource reservation control mechanisms rather than the achieved service quality. It has a number of technical parameters associated with it, for example, bandwidth, delay, delay variations, and packet loss which are all important in determining QoS requirement of a certain application. Different network/Internet applications require different bandwidth and they behave differently when there is delay, jitter or packet loss. Due to this fact, these applications require different treatment within a network, as some will need preference over the others [Cisco, 2007].

The Internet was predominantly used by conventional TCP-oriented services and applications such as web ftp and email, but for the last few years the Internet has been used to transport streaming audio-visual contents of average quality [Miras, 2002].

According to Crovella and Krishnamurthy [2006], peer-to-peer (P2P) applications constitute the largest share of Internet traffic. They categorized Internet applications as DNS, Web and Peer-to-Peer. The Web has more number of users, but P2P applications like Kazaa and BitTorrent are dominating the traffic. In USA alone, P2P users downloaded over 4 billion songs in 2003.

Before the required QoS is determined, the user needs to provide an accurate description of its traffic to the network so that proper network resources can be allocated. A bit rate of an application is one of the important factors for network resource allocation and they are categorized as Constant Bit Rate (CBR) and Variable Bit Rate (VBR). CBR applications send traffic at a constant rate while VBR do not. MPEG coded video is VBR and changes its bit rate when there is a change in scenario. There are a number of issues that contribute to the formulation or allocation of QoS strategy for different applications. The growth of different bandwidth hungry applications and the variability of bit rates of some of the VBR applications are a few of the issues [Jha, 2002].

3. METHODOLOGY

The study was conducted in two phases. Phase one involved public lectures, which were followed by group discussions. The lecturers introduced the subject (QoS issues) to the participants and engaged them into a question and answer session afterwards. The participants were then asked to voluntarily fill in the questionnaires, which gathered data about their experience on using the Internet. The questions were designed to extract information about the type of activities and tasks they perform on the Internet.

Phase two of the study used site visiting as a technique of fact gathering where a number of public and private organisations including Internet cafés were visited. This involved visiting remote areas to witness the state of Internet facilities. Staff and customers (who were willing to participate) in the Internet cafes were interviewed to share their experience on the issue. Tests were run to measure basic QoS metrics in these areas and comparisons were made with those from urban areas. The technology that gives connections to there remote areas was also examined. This phase also involved interviews with ICT professionals about their experience, views and requirements of QoS. The aim of these interviews was to get specific, quantitative QoS requirements from the participants. Ordan [1997] suggests that, although questionnaires are the main method when it comes to collecting user's views or requirements, interviews are much more effective for QoS issues. Many of the interviewed participants held technical positions in their organisations, which gave them more knowledge about their organisational requirements. The questionnaires used in phase one were also made public and distributed via online email groups and other social networks to everyone who wished to participate. In total, more than 800 participants were involved from different locations (fig 3).

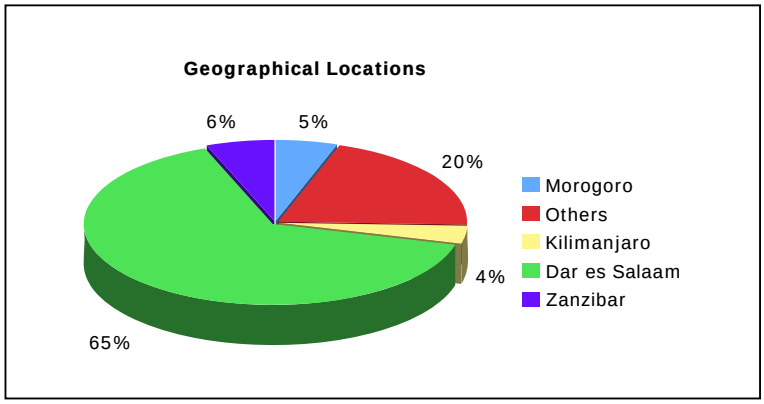

Fig 3: Distribution of the study participants, majority coming from Dar es Salaam.

4. THE FINDINGS

4.1 The infrastructure

The core of all the QoS challenges has been found to be linked directly with the infrastructure. The available telephone network (Tanzania Telecommunication Company Limited TTCL) that is supposed to provide backbone connectivity around the country is patchily and in a poor condition. This network, which is responsible to link the country to the world, has not reached all parts of the country, leaving many communities unconnected. As a result of the non-existence of under-sea fibre cables, Tanzania relies on satellite links to get connected since TTCL connects to the world via satellites. Many organisations own 0.5 – 2 Mb private satellite links, which is also the case for most of the remote areas. This introduces another problem since local traffics destined for local destinations are unnecessarily being sent via international locations and brought back. This study found a big increase in the number of wireless subscribers where 80% of those who have the Internet connection at home use wireless links (fig 5). This adds more problems to QoS and cost since wireless connections can easily be affected by external factors like rain and fog [Chakravorty, 2002].

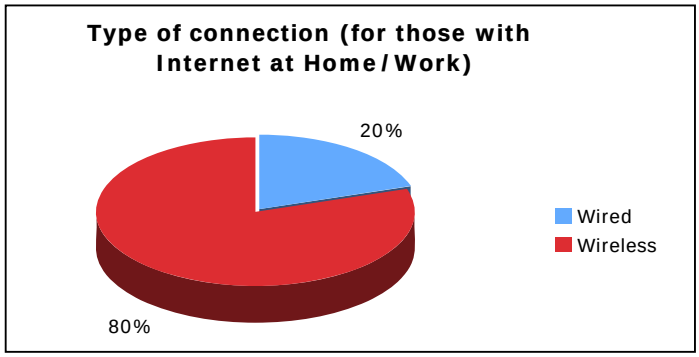

Fig 4. A chart showing the growing number of wireless broadband users

The test conducted on different sites showed that the quality of the services is regardless of the locations. The one conducted in Karatu, a small town at the gate of Ngorongoro, 1,200 km from Dar es Salaam, showed equal and almost better quality than some sites in the capital city, Dar es Salaam (fig 5). Sites in Karatu returned negligible packet loss while sites in Dar es Salaam returned 4 – 6 % packet loss. Although pings from Karatu returned higher RTT than pings from Dar es Salaam, the Karatu link showed more stability than the Dar es Salaam one. With delay ranging from above 600ms to more than 1000ms, it is clear that the connections are very slow. Given the very poor link stability, measuring throughput was next to impossible. The method used to measure the time taken to download or upload a file (10MB file) was challenging because of the interruption of losing the connection which was caused by timing out for taking too long.

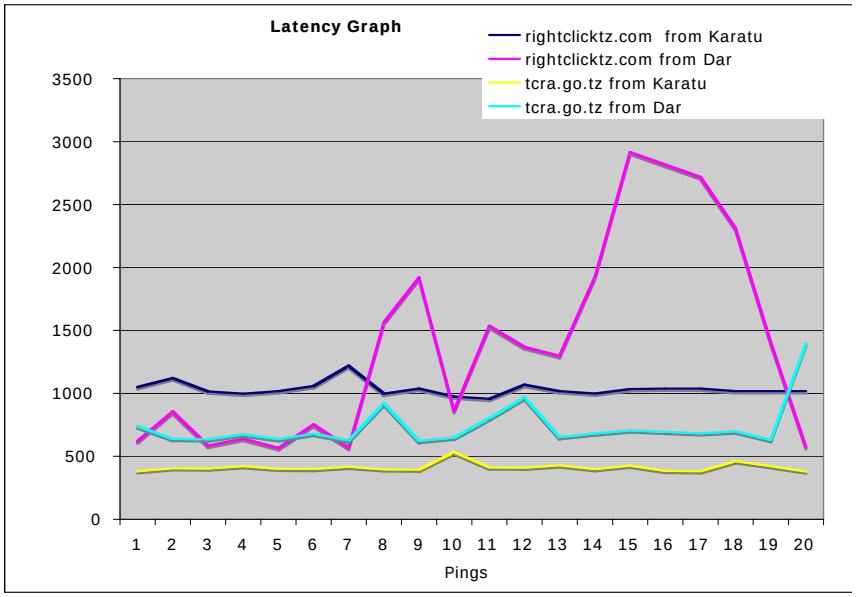

Fig 5: Latency graph showing pings from a remote area (Karatu) and urban area Dar to USA (rightclicktz.com) and to a local destination (tcra.go.tz)

4.2 Requirements

The attempt to get quantitative QoS requirements through interviews was also a challenging one. Although not all participants could specifically say what the levels of service required are in terms of major QoS metrics, many were able to point out main activities performed by their organisations and their users. The number of users in organisations was the key factor used to express resource requirements. Some organizations own corporate intranet connecting their branches. Most of the banks use Virtual Private Networks (VPN) to connect to Automated Teller Machines (ATM). Although Internet services are not used throughout the day, most foreign banks connect to their headquarters to upload daily records after office hours. To perform this, a reliable link is a mandatory requirement. For universities and colleges, the main problem is the high number of users. Although most of them use basic Internet applications, their number increases the demand for bigger bandwidth.

Although most of the participants (75%) access the Internet at least once a week, only 19% access the Internet daily (fig 6). This number can be viewed as small considering the fact that most of the participants are either ICT professionals or ICT higher learning students. The results also show that more than 80% access the Internet from Internet cafes while the number of those who access from their mobiles is twice that of those who access from home or work places (fig 7). It also should be noted that there are participants who access from both locations.

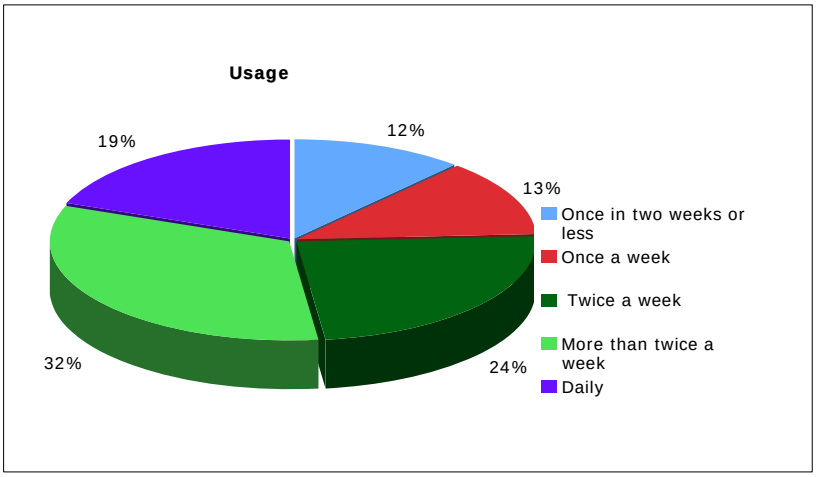

Fig 6. Frequency of accessing the Internet

During the interviews most participants expressed their demand for easy access to the Internet rather than quality. Most of them, as mentioned earlier, use the Internet to perform basic tasks like e-mailing (more than 90%), chatting (more than 60%) and education and research (more than 85%). Less than 15% perform online businesses, Less than 5% conduct video conferencing while less than 5% use the Internet to access corporate intranet (fig 8). This gives a picture of a society where a majority do not access quality sensitive applications. Most of them have to travel long distances just to read their emails. There is no clear difference on the type of activities performed by ICT processionals compared to normal users. On one hand, professionals have a little edge on surfing the Internet, reading online news, online forums and Internet calls. On the other hand, normal users have an edge on listening to online music and watching video clips.

Most professionals pointed out that they are keen on low levels or error tolerance for their personal and organisational use (fig 9). Although most showed the demand for minimum amount of errors, most participants access applications that can tolerate errors like e-mails and Internet surfing. Tests conducted also found the packet loss percentage to be ranging from 4 – 8 % depending on location and periods.

In response to the importance of the factors participants would consider when choosing the Internet connection; mainly speed (throughput), packet loss, link stability and latency (delay), a majority of the participants (81%) responded that it is **very important** that services should always be available while 14% said it is **important** to the same question (fig 10). This indicates that service availability, as expected, is considered as one of the major concerns. When asked in the interviews about this issue, many pointed out that it is important that the services be available when needed and that the connection does not go off when they use the Internet. Packet loss is closely watched as well. Although most of the participants do not use error sensitive applications on the Internet, many (74%) still pointed out that low percentage packet loss is **very important**, 16% saying it is **important.**

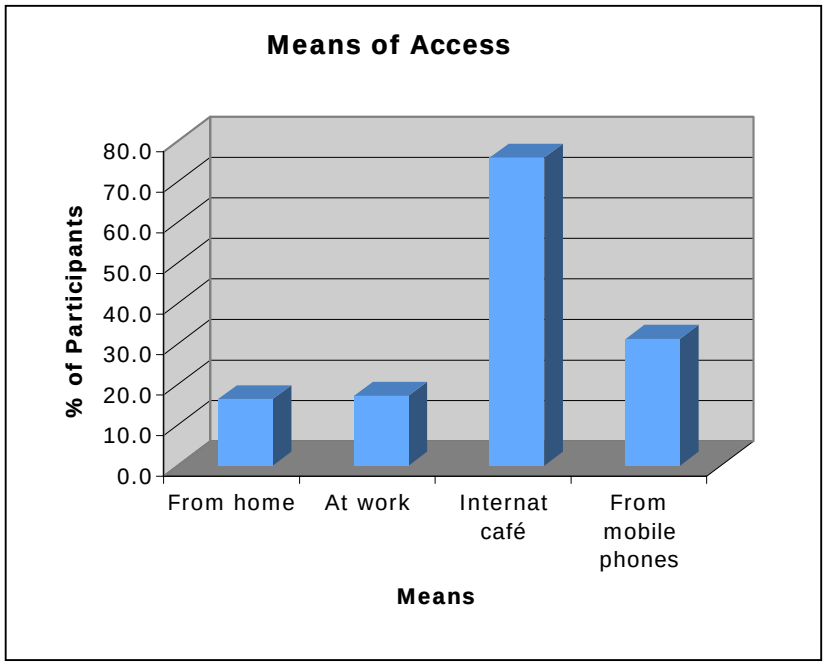

Fig 7: different means of accessing the Internet showing the increase of mobile access to the Internet.

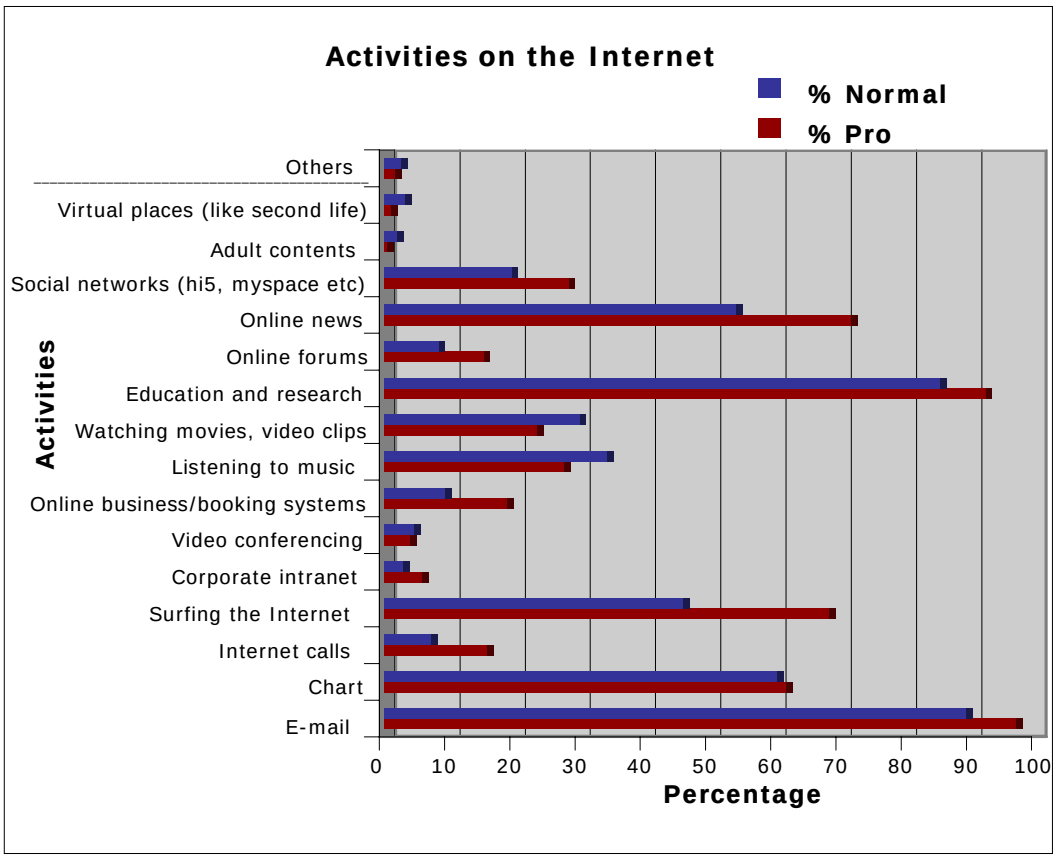

Fig 8: participants showing which activities they mostly do on the Internet

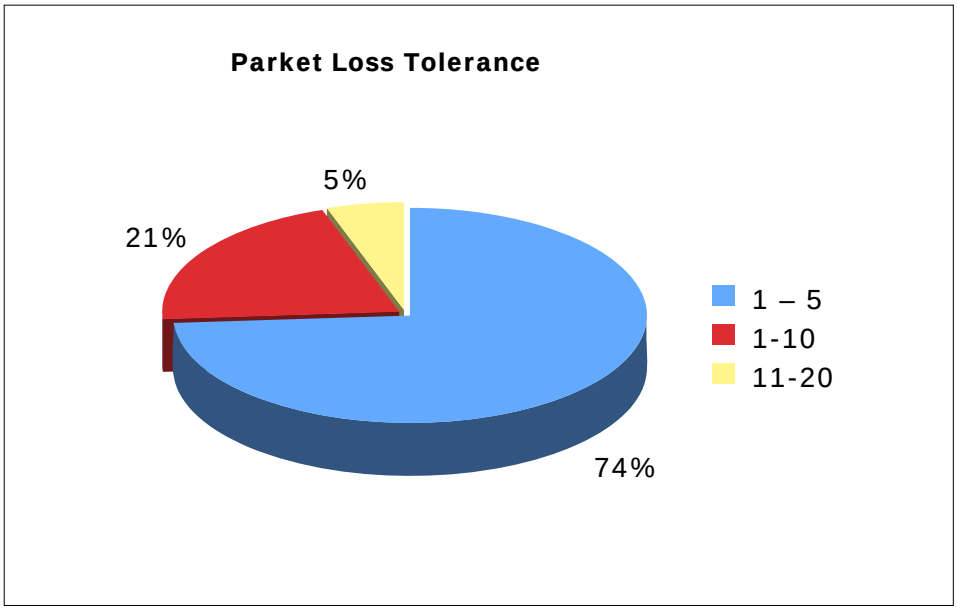

Fig 9: Packet loss responds

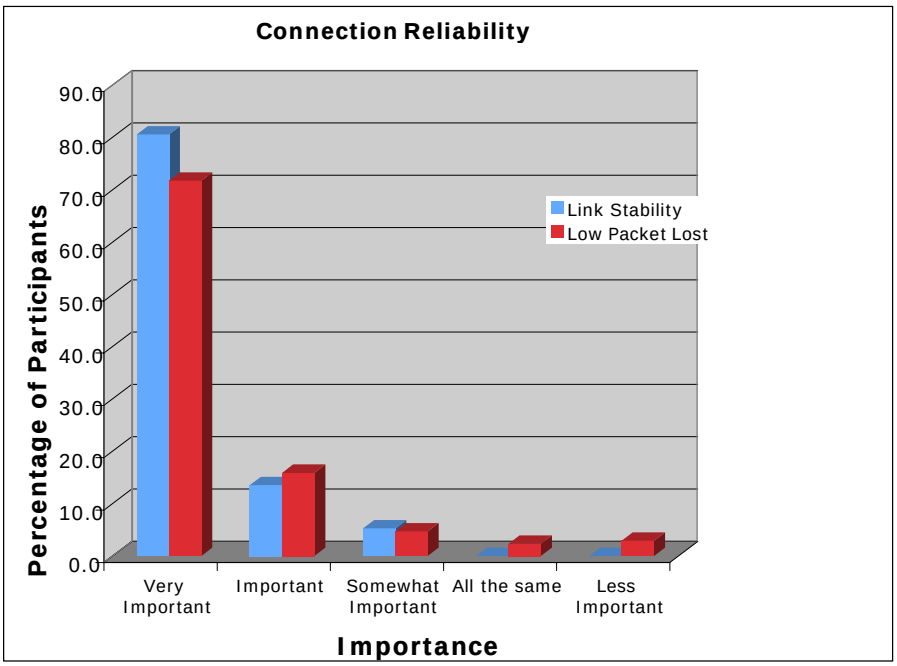

Fig 10: The importance of service reliability

Speed was also one of the main issues. Given the poor infrastructure in place and the rapid use of wireless connections, speed becomes the key measuring factor of a link quality (fig 11). 83% said speed is **very important** while 13% said it is **important**. The need for fast connections is supported by the need for low delays, of which 82% of the participants pointed out the importance of a network with lowest possible latency.

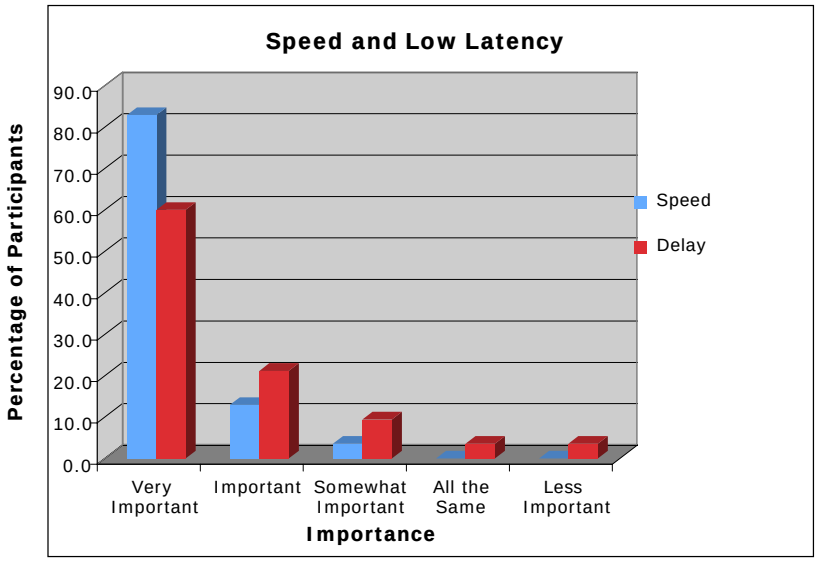

Fig 11: The importance of speed in Internet connections

The use of high bandwidth demand applications is still in the early stages. Only a small number of the participants (less than 10%) use voice over IP (VoIP) applications. The same applies to video applications, like video chatting. It is understandable why many would not try video applications due to the level of quality experienced. Figure 12 shows that video chats, Internet calls and live video conferencing are not considered as important as the speed and reliability in figures 10 and 11. This can also be linked to the influence of perceived QoS into required QoS. There are few video conferencing

facilities in the country and only a small number of people have ever witnessed a live video conferencing session underway such as a remote seminar. Only a few utilise video chatting capabilities in messenger applications. Although many pointed out their demands for speed and reliability, their demands can easily be met since majority access basic Internet applications.

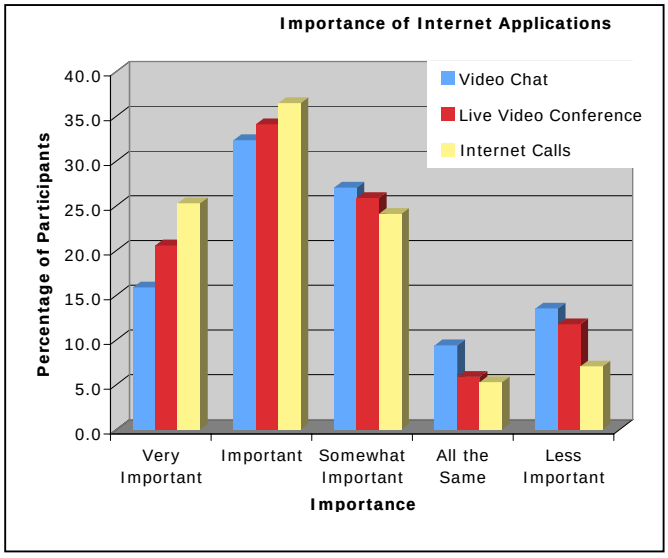

Fig 12: The importance of video chat, video conferencing and VoIP applications

5. DISCUSSIONS AND THE REQUIRED QOS

Studies show that it is not a simple task to pinpoint the exact QoS requirements especially where there are a number of user groups who access different applications. Oodan et al. [1997] point out that conducting QoS requirement studies gives one the best chance to estimate the optimum quality requirements. The results of the study presented here have shown a varying range of requirements by Tanzanian Internet users. Szigeti and Hattingh [2004] have categorised Internet traffic into three major groups, audio, video and data. This paper presents and recommends the required QoS using their approach.

5.1 Audio

When using Internet to talk, clarity is an important factor. Voice quality is directly affected by all QoS quality factors, speed, link stability, loss, latency and jitter. VoIP deployment requires reliable bandwidth service for call-signalling traffic and priority servicing for VoIP traffic. According to Szigeti and Hattingh (2004), some of the QoS requirements and recommendation for voice are:

- Loss should be no more than 1 percent.
- One-way latency (mouth to ear) should be no more than 150 ms.
- Average one-way jitter should be targeted at less than 30 ms.
- A range of 21 to 320 kbps of guaranteed priority bandwidth is required per call depending on the sampling rate, the VoIP codec, and Layer 2 media overhead.
- Miras [2002] also provides guidelines for VoIP that concur in some way with Szigeti and Hattingh [2004].

One-way delay	**Effect on perceived quality**
< 100–150 ms	Delay not detectable
150–250 ms	Still acceptable quality, but a slight delay or hesitation is noticeable
Over 250–300 ms	Unacceptable delay; normal conversation impossible

Table 1 - Delay guidelines for VoIP (Miras, 2002)

Delay variation (jitter)	Effect on perceived quality
< 40 ms	Jitter not detectable
40–75 ms	Good quality, but occasional delay or jumble noticeable
Over 75 ms	Unacceptable; too much jumble in the conversation

Table 2 - Jitter guidelines for VoIP [Miras, 2002]

However, it has been found not to be the case for the quality in Tanzania networks. Delays to yahoo.com, which is what many use for voice chat, averaged over 1000 ms. With this kind of networks, voice conversation becomes difficult and at most times impossible. Since the country is connected via satellite link, it is not possible to achieve delays below 250ms. This can only be achieved if the talking parts are within the country connected with the same network (excluding satellite links) and using a local domain for their voice applications. However, for future plans, to technically satisfy the majority of Tanzanian Internet users, a delay ranging from 300ms - 500ms (RTT), 64Kbps speed and less than 2% packet loss is recommended for live audio application.

5.2 Video

There are two types of video traffic, Interactive-Video (video conferencing) and streaming-video (both unicast and multicast). Video streaming refers to the real-time transport (live) or stored video [Miras, 2002].

Recommended guidelines for Interactive-Video (video conferencing) traffic [Szigeti, Hattingh 2004]

- Loss should be no more than 1 percent.
- One-way latency should be no more than 150 ms.
- Jitter should be no more than 30 ms.

It is recommended to overprovision the bandwidth required for videoconferencing session by 20%. For example, a 384-Kbps videoconferencing session requires 460 Kbps of guaranteed priority bandwidth.

Recommended guidelines for Streaming-Video traffic [Szigeti and Hattingh 2004]

- Loss should be no more than 5 percent.
- Latency should be no more than 4 to 5 seconds (depending on the video application's buffering capabilities).
- There are no significant jitter requirements.
- Guaranteed bandwidth (CBWFQ) requirements depend on the encoding format and rate of the video stream.

Streaming-Video is typically unidirectional; therefore, remote branch routers might not require provisioning for Streaming-Video traffic on their WAN or VPN. Streaming-Video applications have more lenient QoS requirements because they are not delay sensitive (the video can take several seconds to cue up) and are largely not jitter sensitive because of application buffering. However, Streaming-Video might contain valuable content, such as e-learning applications or multicast company meetings, in which case it requires service guarantees [Szigeti and Hattingh 2004].

Video format	Typical bandwidth requirement
Uncompressed HDTV (High Definition TV)	1.5 Gbits/sec
HDTV, Interim format	360 Mbits/sec
Standard Definition TV (SDTV), SMPTE	270 Mbits/sec
Compressed MPEG-2 4:2:2	25–60 Mbits/sec
Broadcast quality HDTV (MPEG-2)	19.4 Mbits/sec
MPEG-2 Standard Definition TV (SDTV)	6 Mbits/sec
MPEG-1	1.5 Mbits/sec
MPEG-4	5 Kbits/sec–4 Mbits/sec
H.323 (H.263)	28 Kbits/sec–1 Mbits/sec

Table 3: Typical bandwidth requirements for some commonly used video formats [Miras, 2002]

It is clear that a good quality link is a mandatory requirement for video applications. In Tanzania currently, the study shows that packet loss ranges from 4 – 6 %. It also shows that less than 5% of participants use the Internet to access video applications. This shows a low demand for this level of quality, at least for now. Few organisations, which own video conferencing facilities use private satellite links and guaranteed bandwidths. As the world is moving towards digital television by 2012, better links are a major requirement for the country. This study recommends the maximum delay of 300ms (RTT) and 460Kbps for live video streaming while keeping the delay bellow 1ms. It also recommends at least 10Kbps for other video applications with less than 800ms delay and packet loss kept under 5%.

5.3 Data

Classes of data traffic were created according to general networking characteristics requirements and these classes are Best-Effort, Bulk Data, Transactional Data/Interactive Data and Mission-Critical Data. These classes cover all data traffic including the one that use TCP and UDP [Szigeti and Hattingh, 2004].

Application Class	**Example Applications**	**Application/Traffic Properties**	**Packet/Message Sizes**
Interactive	Telnet, Citrix, Instant Messenger, Netmeeting Whiteboard.	Highly interactive applications with tight user-feedback requirements.	Average message size < 100 bytes. Max message size < 1 KB.
Transactional	SAP, PeopleSoft—Vantive, Oracle—Financials, Internet Procurement, B2B, Supply Chain Management, Application Server, Microsoft SQL, BEA Systems, DLSw+.	Use of client/server protocol model. User-initiated, client-based queries are followed by server response. The query response may consist of TCP and FTP sessions running simultaneously	Depends on application; could be anywhere from 1 KB to 50 MB.
Bulk	Database syncs, network backups, Outlook, e-mail download (SMTP, POP3, IMAP, Exchange), large FTP file transfers.	Long file transfers. Always invokes TCP congestion management.	Average message size 64 KB or greater.
Best-Effort	All non-critical traffic, HTTP web browsing, other miscellaneous traffic.		

Table 4: Summary of different types of application classes and their packet/message size [Szigeti and Hattingh 2004]

This is one the most important group of Internet traffic. For Tanzanians in particular, more than 90% of the participants access applications whose traffic are of best-effort nature. The requirements for this group of data seem to be achievable for most of the network operators in Tanzania. Given the rise of the Internet users and rapid growth of bandwidth hungry applications; the need for better quality services is clear. The advantage of this group is its resilience to low QoS, especially for developing countries. This group can connect with low levels of QoS as it has been found in the study. It could be argued however, that the activities performed by users might have been dictated by what could be performed, due to low quality offered.

Requirement varies depending on type of data traffics:

Interactive and best effort - Interactive applications like instant messenger are delay and error tolerant. We recommend the speed of above 5kbps.

Transactional and bulk – Depending and the nature of the organisation, the importance of the data and amount of data involved in daily basis, we recommend 10Kbps for speed.

Some of the metrics of all of the recommended QoS requirements can vary depending on the level of quality of other metrics. For example, for voice applications, if one has a connection with a speed of

2Mbps, the requirements for delay can be irrelevant since this link will provide a good service anyway. It should be noted that, these recommendations are suitable for end-to-end QoS. This means, it is possible for a connection to give good results while connecting to destination A, but not similar results will be found when connected to destination B. This could be caused by the state of QoS in the destination side. .

6. CONCLUSION

In this paper QoS requirements for developing countries is analysed and presented. The analysis is the results of a study conducted in Tanzania, a country that shares similar features with many developing countries. The infrastructure problems in the country are historical, economical and technological. The country is connected to the Internet via satellite links. With the number of Internet users increasing and the rise of wireless subscribers, QoS offered is constantly deteriorating. However, a majority of Internet users access the Internet to perform basic tasks like reading e-mails. Participants of the study pointed out the main concerns on QoS as being the speed and reliability while indicating low interest on high bandwidth Internet applications like video conferencing.

It has been challenging to point our specific QoS requirements due to the state of the infrastructure and the nature of the Internet users in the country. It has been learnt that the poor infrastructure and current QoS level have been preventing Tanzanian citizens from access applications with high QoS requirements. Based on the literature reviewed and the findings found from the study, this paper has made several recommendations. Delay ranging from 300ms to 500ms, packet loss less than 2% and 64Kbps speed is recommended for audio applications. It has also recommended maximum delay of 300ms, speed of 460Kbps and packet loss below 1% for live video streaming. For other video streaming, 10Kbs speed, 800ms delay and packet loss below 5% are recommended. For data traffics, we have recommended the speed of 5kbps for interactive and best effort applications while the speed of 10kbps has been recommended for transactional and bulk applications. It should be noted that these recommended speeds are the minimal requirements taking into consideration all the difficulties the developing countries are facing.

7. RECOMENDATION

As the Internet becomes an integral part of the modern world, developing countries need to put more emphasis on more Internet penetration countrywide. More work needs to be done to improve the quality of Internet offered in the country. Academicians, researchers and governments' participations with funding and better policies would remarkably boost the state of the Internet in these countries. Efforts should also be directed to community owned network projects which will create small not-for-profit networks aiming at providing connectivity to these communities. The role of the government should be ensuring QoS issues are considered users' satisfactions.

There should also be specialised government departments which ensure that the current telecom companies provide a certain level of quality quantitatively. QoS recommendations provided by this paper could be used as initial guide to what is expected from these companies.

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