A USER-CENTRIC MODEL FOR EVALUATING & VALIDATING USER-PERCEIVED QUALITY OF SERVICE (QOS) IN WIRELESS NETWORK

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ABSTRACT
A wireless network allows computers to share printers, files or an internet connection without any wires between them. Quality as a generic performance measure can have many meanings. Quality of Service (QoS) represents the set of those quantitative and qualitative characteristics of distributed multimedia system necessary to achieve the required functionality of an application. Until recently QoS from a network perspective has dominated research in Wireless Network. While the network approach is not the recommended one to evaluate and improve the user experience, the user-perceived approach remains attractive as it affords tangible values (reliability, satisfaction, efficiency) that can be accurately measured, quantified and tested continually given the latest robot technology available. This research proposed a user-centric model for evaluating and validating the quality of service of wireless network from users' perspective using satisfaction, efficiency and reliability as measurement parameters. Analysis of research findings using the proposed model based on questionnaire responses shows that users measure of QoS is directly proportional to bandwidth size. The higher the size of the bandwidth, the higher the user's satisfaction while using the network. Satisfaction is inversely proportional to rate of loss, that is, the higher the loss, the lower the satisfaction of the user. Interestingly, the results show that there were no significant within-subject differences in the perception of network performance as a function of physical environment (indoors versus outdoors). However, significant differences between subjects on this variable highlight that users bring with them their own subjective perceptions and attitudes that affect their user-experience.

Keywords: Wireless Network, Service, QoS, Users, Satisfaction, reliability and Efficiency

1. INTRODUCTION

A wireless network allows computers to share printers, files or an internet connection without any wires between them. Wireless networking hardware uses radio frequencies to transmit information between the individual computers; each computer requires a wireless network adapter [1]. It is also the connection with internet without needing to attach cables to one's computer. It uses low power microwave radio to link one or more groups of users together. The popularity of wireless network has risen primarily to their convenience, cost efficiency, and ease of integration with other networks and network components. The majority of computers sold today come pre-equipped with all necessary wireless network technology [16].

The benefits of wireless network include:

a) **Convenience**: The wireless nature of such networks allows users to access network resources from nearly any convenient location within their primary networking environment (a home or office). With the increasing saturation of laptop-style computers, this is particularly relevant [2].
b) **Mobility**: With the emergence of public wireless networks, users can access the internet even outside their normal work environment. Most GSM operator, for example, offers their customers a wireless connection to the internet at little or no cost [4].
c) **Productivity**: Users connected to a wireless network can maintain a nearly constant affiliation with their desired network as they move from place to place. For a business, this implies that an employee can potentially be more productive as his or her work can be accomplished from any convenient location [4].

d) **Deployment**: Initial setup of an infrastructure-based wireless network requires little more than a single access point. Wired networks, on the other hand, have the additional cost and complexity of actual physical cables being run to numerous locations (which can even be impossible for hard-to-reach locations within a building). [5]

e) **Expandability**: Wireless networks can serve a suddenly-increased number of clients with the existing equipment. In a wired network, additional clients would require additional wiring [16].
f) **Cost**: Wireless networking hardware is at worst a modest increase from wired counterparts. This potentially increased cost is almost always more than outweighed by the savings in cost and labor associated to running physical cables [16].

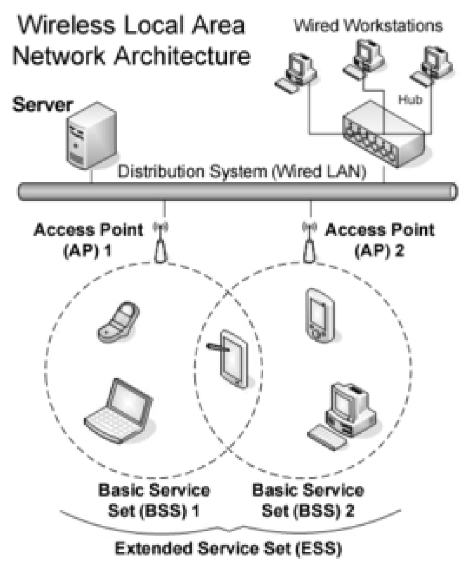

Fig 1. Wireless Architecture Using an Infrastructure BSS [17]

1.1 Wireless Network Quality of Service Assessment

Quality as a generic performance measure can have many meanings. Quality of Service (QoS) has no formally agreed definition. QoS represents the set of those quantitative and qualitative characteristics of distributed multimedia system necessary to achieve the required functionality of an application. It is often defined in terms of network performance or network characteristics, with little consideration to QoS requirements from a user perspective [18]. It is also the service performed to a level that satisfies the user of that service. The user is not concerned about how a service is provided, but only the resulting quality they receive [19].

QoS vary on multiple network parameters such as [18]:

- Packet loss,
- Jitter
- Delay (latency) and
- Bandwidth.

When attempting to validate an existing web appropriate QoS scale, three valid, reliable subscales are considered which are labeled [20]:

- Information
- Site and
- User.

A controlled environment is paramount for the accurate reconstruction of the same experience for all user's perspective, is a multi-dimensional and variable concept [18]. Therefore, a controlled environment and specific target group of participants are essential in being able to control for external factors such as:

- Motivation
- Patience
- User experience and context.

A user's behavior is most accurately predicted by analyzing their:

- Mental constructs,
- Context of interaction,
- Motivations and
- Tacks they perform while using the network services.

A behavior research was consulted to establish an understanding of the factors that sway users in their evaluation of service quality. Across these researches, four main factors are believed to have direct linkages to the user perception of network QoS [21]:

- **Reliability**: This examines how important and useful it is to know in advance the level of network performance.
- **Efficiency:** This represents a measure of how quickly the system responds to requests, or the perceived speed of network performance
- **Predictability:** This is concerned with the degree to which the user experience followed the expectations of the user.
- **Satisfaction:** Probed to what degree the user was satisfied with each experience.

Assessments of these factors afford service providers with valuable insight into user perceived network performance requirements. As illustrated in fig.1 , understanding these factors helps to identify the user satisfaction threshold, which indicates the minimum network performance necessary for a satisfying user experience and the knee of satisfaction (the inflection point where further improvement in the underlying network performance cease to translate into a significantly improved user experience).

2. RELATED WORKS

QoS (Quality of Service) refers to a broad collection of networking technologies and techniques. The goal of QoS is to provide guarantees on the ability of a network to deliver predictable results [22]. QoS has been a widely explored area of research in recent years. A remaining problem in this area is to create a model which is easy to use for application programmers or service users. This is an important problem since an overly complex service model with too many QoS parameters to configure is likely not accepted by a user or deployed by a service provider [23].

In wireless mobile networks, this problem becomes even more complex since, for example, the occurrence of handoffs renders the deployment of QoS more difficult. There are no agreed quantifiable measures that define unambiguously QoS, as perceived by a user. Thus, terms such as “better”, “worse”, “high”, “medium”, “low”, “good”, “fair”, “poor”, are typically employed, however, these are subjective and cannot be translated precisely into network level parameters that can subsequently be designed by network planners. The end effect at the terminal is also heavily dependent upon issues such as compression algorithms, coding schemes, the presence of higher layer protocols for security, data recovery, re-transmission, etc., and the ability of applications to adapt to network congestion, or their requirement for synchronization [23]. However, network providers need performance metrics that they can agree with their peers (when exchanging traffic), and with service providers buying resources from them with certain performance guarantees. The following five system performance metrics are considered the most important in terms of their impact on the end-to-end QoS, as perceived by a user:

- Availability: Ideally, a network is available 100% of the time. Even a high-sounding figure as 99.8% translates into about an hour and a half of down time per month, which may be unacceptable to a large enterprise. Serious carriers strive for 99.9999% availability, which is referred to as "Six nines," and which translates into a downtime of 2.6 seconds per month [23].
- Throughput: This is the effective data transfer rate measured in bits per second. It is emphatically not the same as the maximum capacity, or wire speed, of the network, often erroneously called the network's bandwidth [23]. Sharing a network lowers the throughput that can be realized by any one user, as does the overhead imposed by the extra bits included in every packet for identification and other purposes. A minimum rate of throughput is usually guaranteed by a service provider (who needs to have a similar guarantee from the network provider).
- Packet loss: Network devices, such as switches and routers, sometimes have to hold data packets in buffered queues when a link gets congested. If the link remains congested for too long, the buffered queues will overflow and data will be lost. The lost packets must be retransmitted, adding, of course, to the total transmission time. In a well-managed network, packet loss will typically be less than 1% averaged over, say, a month for the network operations to be considered worthwhile [24].
- Delay: The time taken by data to travel from the source to the destination is known as delay. Unless satellites are involved, the latency of a 5000 kms voice call carried by a circuit-switched telephone network is about 25 ms. For the public Internet, a voice call may easily exceed 150 ms of delay because of: signal processing (digitizing and compressing the analogue voice input) and congestion (queuing) [6].
- Jitter (delay variation): This has many causes, including: variations in queue length; variations in the processing time needed to reorder packets that arrived out of order because they traveled over different paths; and variations in the processing time needed to reassemble packets that were segmented by the source before being transmitted [7].

Network planning is the tool for ensuring that the availability, throughput, packet loss, delay, and jitter values are within the limits needed to provide acceptable end-to-end QoS. This calculation has to take account of the nature of the underlying network (physical capacity and the protocols used at the layers) and the knowledge of whether (and if so, how and where) network resources are shared [25].

2.1 Mechanisms for measuring network performance

Network planning aims at designing a network that will have the performance to support a given mix of services to a certain number of users with an acceptable QoS. The more sophisticated that the services become, and the more choice in QoS selection is given to the user (and the frequency at which this can be changed), the more complicated becomes the network planning [8]. There are currently 3 main mechanisms to achieve a network performance that is better than "Best Effort":

- Overprovision of capacity
- Pre-reservation of resources
- Prioritization of certain services/users

Quality of Service in the past is generally view from the networking perspective. Other areas where QoS has been majored are: networking QoS, IP QoS, Application QoS, and Physical QoS etc.

The CMP Media (2006) [8] brought out a research on how to tune network QoS to match user expectations. In the research, The Universal Mobile Telecommunications System (UMTS) is being deployed at a time when access to data services through the Internet is taken for granted. Current GSM and GPRS systems serve voice and messaging—typically SMS. Even with a perfect terminal, whether a service is used or not depends on whether the service is acceptable to the consumer [31]. The measure of acceptability may be referred to as the End-User Quality of Service (QoS), or Quality of Experience (QoE). Although more subjective than network QoS, it is nonetheless a useful metric; get it wrong and the consumer does not use the service. For audio and video based services the perceived quality is dependent on how tolerant the consumer is to imperfections in the received content. The parameters that can be tested to tune network QoS to user expectation include both the Network QoS parameters selected by the application and the parameters within the RNC (Regional Node Centers) that affect the performance of the radio resource management algorithms.

The parameters used include the radio bearer size, whether shared or dedicated channels are to be used, the coding type and gain to be used, power control targets and soft handover criteria and the packet size related parameters that are set in the RLC layer. The laboratory environment is designed to emulate real-world scenarios, the scenario data being captured from live networks at different locations during typical busy hours. The scenario data is used to generate a traffic load, replicating the exact service mix that was observed during the busy hour [9]. With such scenario data forming the baseline the effect on the parameter changes on network performance metrics can be assessed systematically. The S-curve correlations can then be used to derive a score for the end user QoS and hence the revenue impact can be easily assessed.

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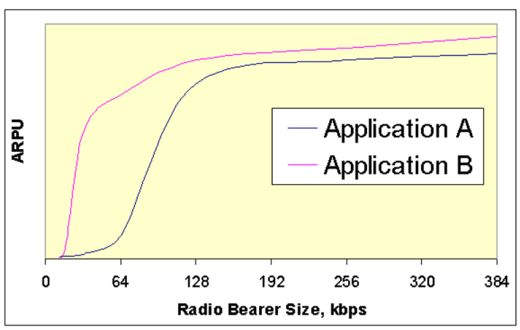


Fig 2. S Curve [75]

One advantage of a laboratory based network is that the scenarios are repeatable. If the testing is carried out on a live network then a measurement of the change in the end user QoS may simply be due to a more benign or more demanding traffic load and not due to the change in network parameters under test. Another advantage is that parameters may be tested across their full range; on live networks there is always a tendency to only tune close to the initial set-up point thus potentially only finding local maxima and missing more significant improvements further along the range of values for the parameter being adjusted. Testing on live networks carries risks that the changes could adversely affect performance more than expected, or the incorrect input of a parameter could result in the drastic reduction of network performance.

The conclusion of the research is that a laboratory-based solution allows new data services to be tested prior to deployment; if the end user QoS is inappropriate, a potentially attractive application can fall at the first hurdle. Testing a new application in the laboratory environment allows the impact of a new service deployment on existing services to be assessed. This would avoid the situation where the introduction of a new service that in itself is successful, but generates a disproportionate additional load which adversely affects other services and the net result is that there is an overall decrease in ARPU (Average Revenue per User). Anthony J. et. Al (2005) proposed a user-perceived QoS. The study investigated the user-perceived, application and IP QoS. The results were presented as separate application specific quantitative user satisfaction models, showing the relationship between the user QoS and various network parameters.

The user QoS variables used were satisfaction, efficiency and reliability. Wireless data networks are layered structures, with each layer's performance having a distinct role and the potential to impact upon the performance of the layers above it. Figure 2.2 shows the proposed wireless QoS hierarchy as it fits into the open systems interconnection (OSI) layered framework. Hence, it is possible to obtain an in-depth understanding of each layer's performance and the relationship between layers in the hierarchy.

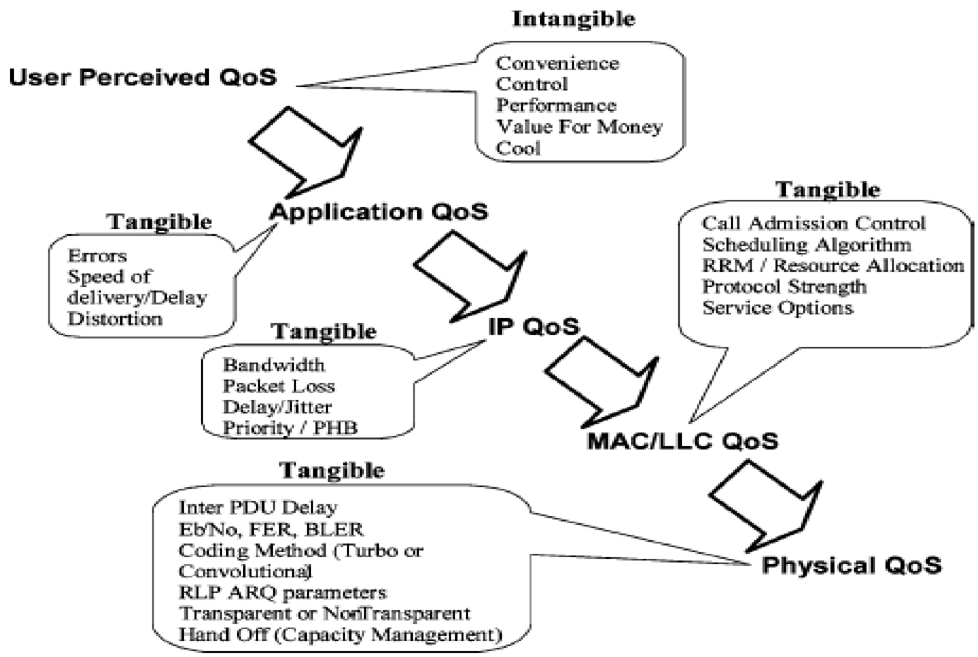


Fig.3: Hierarchical framework of wireless network. [64]

The above fig is hereby explained thus:

Distortion: This is the change in an audio signal that results in the presence of frequencies in the output signal that was not present in the original signal [10]. It is the alteration of the original shape (or other characteristic) of an object, image, sound, waveform or other form of information or representation. Distortion is usually unwanted.

Bandwidth: A measure of the capacity of a communications channel. The higher a channel's bandwidth, the more information it can carry. Bandwidth is usually stated in bits per second (bps), kilobits per second (kbps), or megabits per second (mps). It also refers to how fast data flows through the path that it travels to your computer [11].

Packet Loss: This as the fraction of packets sent from a measurement agent to a test point for which the measurement agent does not receive an acknowledgment from the test point. This includes packets that are not received by the test point as well as acknowledgments that are lost before returning to the measurement agent. Acknowledgments that do not arrive within a predefined time at the measurement agent are also considered lost [12]. Packet loss can be caused by a number of factors, including signal degradation over the network medium, oversaturated network links, corrupted packets rejected in-transit, faulty networking hardware, or normal routing routines.

3. RESEARCH OBJECTIVE

In the past, Quality of Service of network was generally viewed from the network capabilities perspective. This usually creates problem of no interaction between the network QoS and the users' view of QoS. What is tangible and important to the network provider is not important to most users. This due to the fact that the user only wants to be satisfied with the network performance and does not want to know how the provider achieve his/her satisfaction. This research therefore viewed QoS of wireless network from users' perspective. Wireless applications must be carefully designed to ensure that user expectations and the wireless operator's capabilities are in synchronization. This two element should be in line with the characteristics of all relevant applications. Until recently QoS from a network perspective has dominated research in Wireless Network.

While the network approach is not the recommended one to evaluate and improve the user experience, the user-perceived approach remains attractive as it affords tangible values (reliability, satisfaction, efficiency) that can be accurately measured, quantified and tested continually given the latest robot technology available. Additionally, wireless data networks are layered structures, with each layer's performance having a distinct role and the potential to impact upon the performance of the layers above it. The main objective of this research is to evaluate quality of service of wireless network from users' perspective.

4. RESEARCH METHODOLOGY

The research investigate the top three layers (user-perceived, application and IP QoS) in the Fig. 2.3 framework. This is to present a separate application-specific quantitative user satisfaction models, showing the mapping of user perception of service quality as a function of varying levels of network performance. The user-perceived variables to be investigated are 'satisfaction', 'efficiency', and 'reliability'. We simplify the process by doing the following:

a. Relating the user-perceived and IP QoS layers (bandwidth, packet loss, and jitter).
b. Taking into account the impact of the application QoS layer by separately studying the mapping between user-perceived and IP QoS layers for different applications (speed of delivery, distortion).
c. Reducing the number of IP layer parameters to a core subset, deemed to have the most impact on the ultimate (user-perceived) QoS result. The core subset of the network parameters will be made up of a range of values for available IP-layer bandwidth and IP packet loss percentage.

4.1 Model Analysis and Design

Usually in the past, QoS is measured from the network parameters without considering the user of the service. However, we argued that QoS should also be measured from user's perspective because without the user for a particular network, the operation will be useless. We therefore define User-Perceived QoS as the service performed to a level that satisfies the user of the service (Network operation in this regards).

4.2 Parameters for Measuring User-Perceived QoS in Wireless Networking

The term parameter, which originates in mathematics, has a number of specific meanings in fields such as astronomy, electricity, crystallography, and statistics. Perhaps because of its ring of technical authority, it has been used more generally in recent years to refer to any factor that determines a range of variations and especially to a factor that restricts what can result from a process or policy. In this use it often comes close to meaning "a limit or boundary" [13]. Parameter can also be any factor that defines a system and determines (or limits) its performance [14]. Parameters are constant quantities in networking but varies in some cases [15]. Parameter in this case is a user-adjustable quantity that governs some aspect of a network's performance.

Quality of Service (QoS) parameters characterizes the quality level of a certain aspect of a service being offered, and ultimately the customer satisfaction. QoS parameters represent subjective and abstract user-perceived "quality" in terms of numeric (quantified) values. These parameters can be used by service providers to manage and improve their service provision, as well as by the customers (end users or partner providers) to ensure that they are getting the level of quality that they are paying for.

4.3 Proposed QoS Parameters Model from Objective and Subjective Measurements

As earlier mentioned, QoS parameters can be obtained from objective or subjective measurement methods. Objectives QoS parameters are obtained from measurement of physical attributes of circuits, networks and signals. They are normally used as internal indicators for service quality characterization and improvement. The subjective QoS parameters are obtained by actually conducting well-designed customer opinion surveys. They are normally used as an external indicator, e.g. used for customer relationship management. This research employs the QoS parameters to determine the level of satisfaction, reliability, efficiency, predictability and security level as all affect the service provision on the part of the users.

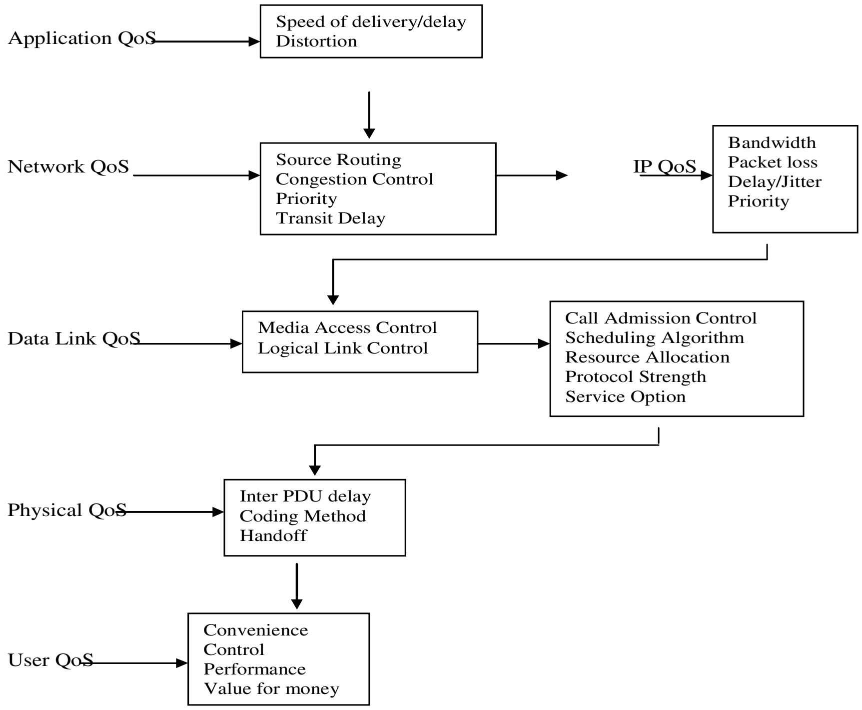


Fig 4: Propose QoS model for measuring user-perceived QoS

4.4 Statistical Analysis

The importance of a network achieving a reasonable level of reliability and validity cannot be overemphasized. A score of 80%, say, may be no different than a score of 70% or 90% in terms of what a student knows, as measured by the test. If a network is not reliable, it is not valid. This project employs, SPSS (Statistical Package for the Social Sciences) was used to evaluate and validate the reliability and satisfaction of a wireless network. A total of 130 questionnaires was administered to different network users/operators, interviews was also conducted in some areas to facilitate proper understanding of the terrain, and subsequent analysis for proper advice.

Statistical Package for the Social Sciences

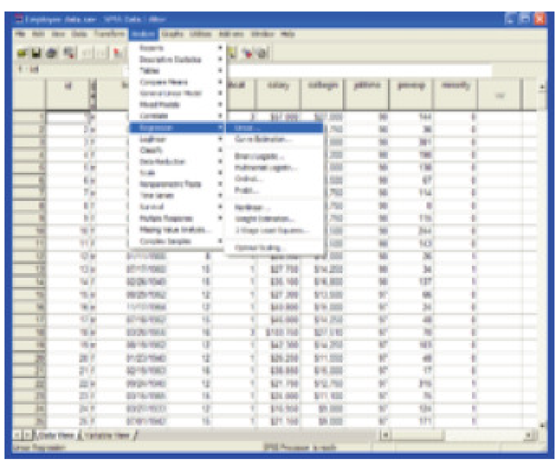


Fig 5. Typical SPSS project page

SPSS is a program which allows you to analyse and describe data. It provides statistical analysis and data management system in a graphical environment. SPSS was released in its first version in 1968, and is among the most widely used programs for statistical analysis in social science. It is used by market researchers, health researchers, survey companies, government, education researchers, and others. In addition to statistical analysis, data management (case selection, file reshaping, creating derived data) and data documentation (a metadata dictionary is stored with the data) are features of the base software.

SPSS for Windows provides you with a broad range of capabilities for the entire analytical process. With SPSS, you can generate decision-making information quickly using powerful statistics, understand and effectively present your results with high-quality tabular and graphical output, and share your results with others using a variety of reporting methods, including secure Web publishing. Results from your data analysis enable you to make smarter decisions more quickly by uncovering key facts, patterns, and trends.

It is more user friendly in making complex tables and graphs.
SPSS can take data from almost any type of file and use them to generate tabulated reports, charts, and plots of distributions and trends, descriptive statistics, and conduct complex statistical analyses. SPSS is available from several platforms; Windows, Macintosh, and the UNIX systems [27].

5. RESULT AND ANALYSIS

In this section, the focus on the result obtained from the questionnaire that was given out to people using wireless networking for home use, office use, use in school, and business centers. The result obtained is as follows:

Table 1: Representation of Report
Questionnaire Analysis

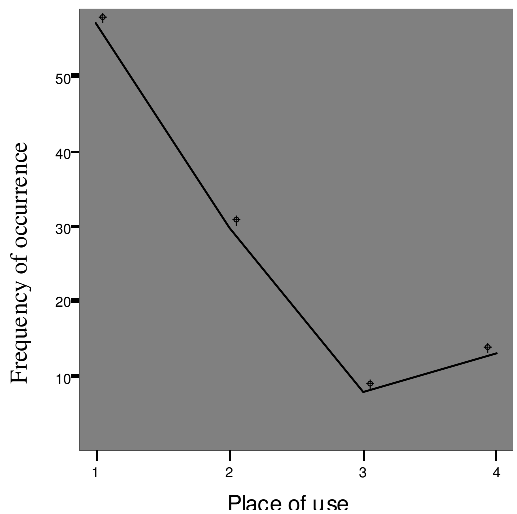
Variable	Number of valid entry
Place of use	108
Type of Connection	108
How often do you use the wireless network?	108
Do you agree that wireless the network is important?	108
How important is the network to you?	108
Why is the network important?	108
Do you get your money worth?	108
What do you use the network for?	108
How reliable is the network?	108
How satisfied are you with the service?	108
How efficient is the network?	108
What is the level of performance of the network	108
Have you changed your service provider before?	108

The above table represents the overall input from the questionnaire that was given out to users. Each column consist of variables e.g. the column for place of use of wireless network, type of connection, why wireless network is important, how efficient is the network, level of performance of network etc. The row labeled valid contains the amount of users that answered each questions and the row labeled missing consist of number of times users did not give answer to a particular question in that column. In the table above all question were answered expect for column seven (7), where 8 users did not answer the question. Considering the variable “place of use” that is used to derive Table 2. The table shows the four categories of places/environment where users make use of wireless network. Wireless network is often use in offices, homes, schools and business centers.

Table 2: Place of use

		Frequency	Percent
Valid	Office use	57	52.8
	Home use	30	27.8
	Business Center	8	7.4
	School	13	12.0
	Total	108	100.0

Column 1 represent the environment of use of wireless network, column 2 represent the frequency of times a particular place of use occur, column 3 represent the percentage of use. Each row shows the number of times a particular variable occurs.



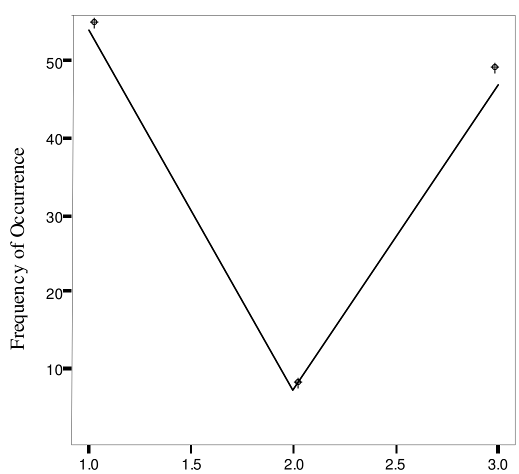
KEY:
Place of use:
1:.Office Use
2. Home Use
3. School Use
4. Business Center

Figure 4.1 Graphical representation of Place of use.

Table 3 Level of efficiency of service

How efficient is the network?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very efficient	54	50.0	50.0	50.0
	Not efficient	7	6.5	6.5	56.5
	Fairly efficient	47	43.5	43.5	100.0
	Total	108	100.0	100.0	



Key:
Count: Frequency
1.0: Very Efficient
2.0 Not Efficient
3.0 Fairly Efficient

Fig 2: How efficient is the network?

Table 3 and Figure 2 show the level of efficiency of wireless network. The table rows are labeled very efficiency, fairly efficiency and not efficient. From the table, very efficient has the highest percent of 50% which indicate that just half of the users believe that wireless network is efficient. 43.5% users believe that it is fairly efficient while 6.5 believe that is not efficient. The X-Axis of the graph represents count i.e. the number of time a particular variable occurs and the Y-Axis represents the level of efficiency. Value 1.0 for “very efficient”, 2.0 for “not efficient” and 3.0 for “fairly efficient”.

Reliability

This answers the question "how reliable is wireless network?" Reliability can vary from places to places depending on the service provided. The table and graph below shows how well users believe wireless network to be reliable.

Table 4. Level of Reliability

(III) How reliable is the network?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very reliable	40	37.0	37.0	37.0
	Not reliable	6	5.6	5.6	42.6
	Fairly reliable	62	57.4	57.4	100.0
	Total	108	100.0	100.0	

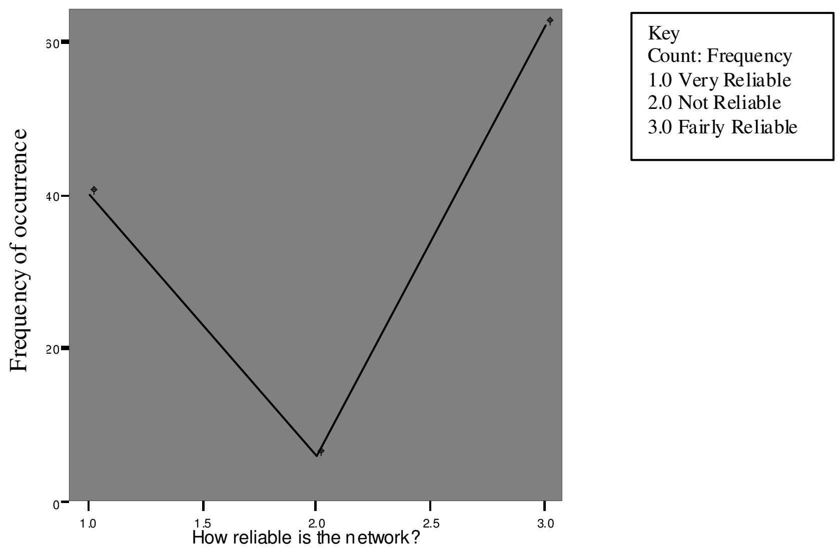


Figure 3 Level of Reliability

Table 4 and Figure 3 show the level of Reliability of wireless network. The table rows are labeled very reliable, not reliable and fairly reliable. From the table, very reliable has the count of 40 which is 37%, not reliable 6% and fairly reliable has count of 62 which is 57.4% which indicate that not up to half of users have the believe that wireless network is reliable. The X-Axis of the graph represents count i.e. the number of time a particular variable occurs and the Y-Axis represents the level of reliability. Value 1.0 for "very reliable", 2.0 for "not reliable" and 3.0 for "fairly reliable".

Satisfaction

This illustrate how well the user as been satisfied with the performance of the network. The table 4.5 shows the level of satisfaction of users with wireless network. The rows represent "Very good", "Good", "Fair", "Poor". From this research, users are not very satisfied with wireless network; they just feel it is good/ok. Very good has count of 9 which is just 8.3%. Good has the count of 73 which is 67.3% the highest count. Fair has the count of 21 which is 19.4% and Poor satisfaction has the count of 5 which is 4.6%.

Table 5 Level of satisfaction

IV) How satisfied are you with the service?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very good	9	8.3	8.3	8.3
	Good	73	67.6	67.6	75.9
	Fair	21	19.4	19.4	95.4
	Poor	5	4.6	4.6	100.0
	Total	108	100.0	100.0	

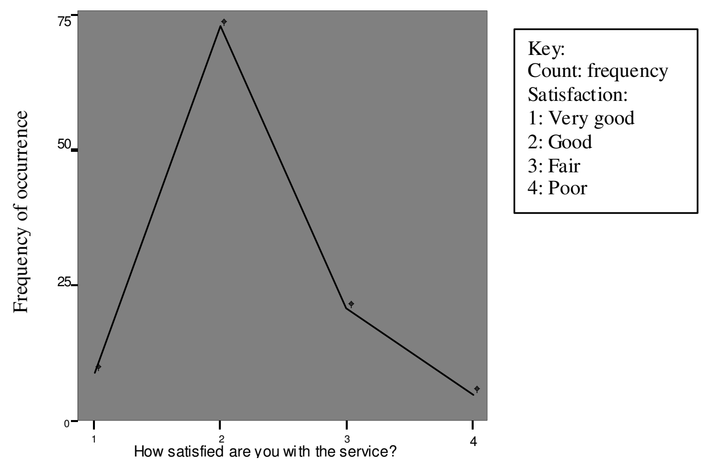


Figure 4: Level of Satisfaction

The figure above shows the graphical representation of level of satisfaction of users of wireless network. Value 1 represents very good, value 2 represents good, value 3 represent fair and value 4 represents poor satisfaction respectively.

Predictability
This represents performance of the service in users view.

Table 6: Level of Performance

V) Level of performance

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Too Slow	12	11.1	11.1	11.1
	Slower than expected	1	.9	.9	12.0
	Fairly ok	22	20.4	20.4	32.4
	ok	66	61.1	61.1	93.5
	Faster than expected	7	6.5	6.5	100.0
	Total	108	100.0	100.0	

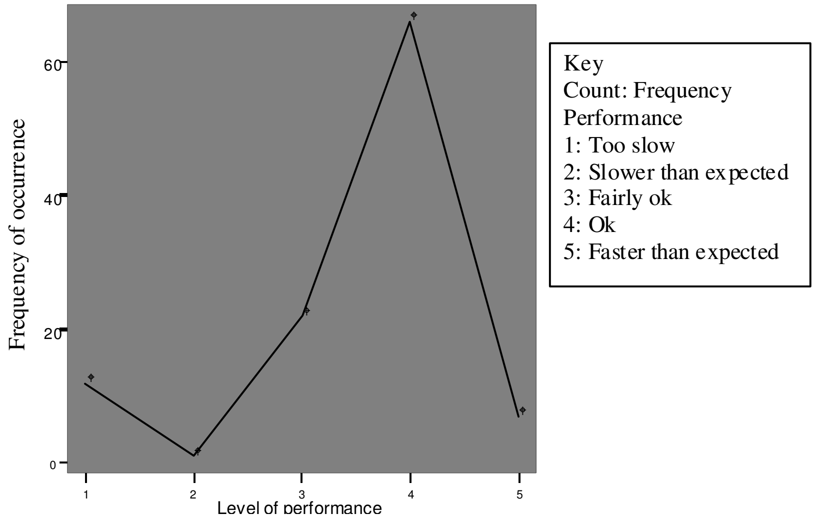


Figure 5 level of performance.

Value 1 represents Too Slow, value 2 represents slower than expected, value 3 represent fairly Ok and value 4 represents Ok and value 5 represents faster than expected level of performance respectively. Too slow has 11.1%, slower than expected has 0.9%, fairly ok has 24.4%, ok has 641%., and faster than expected has 6.5%

Relationship between Variables
This dealt with mapping of variable "Satisfaction" with variable "Reliability". X-Axis represents level of satisfaction of user and Y-Axis represents Reliability of service. Thus, the higher the reliability the higher the satisfaction and vice-versa. If the reliability is low then satisfaction will also be low. Using table 4.4 and table 4.5, the figure 4.6 below shows the graphical representation of satisfaction against reliability.

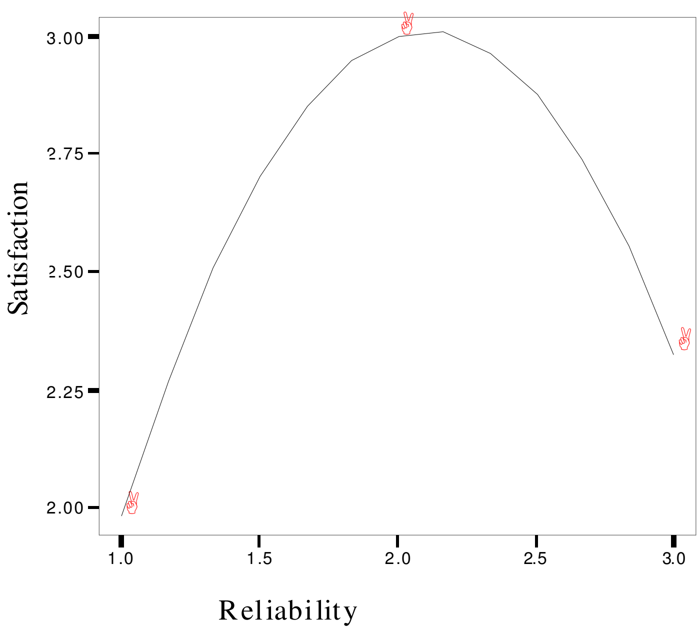


Figure 6 Satisfactions against Reliability.

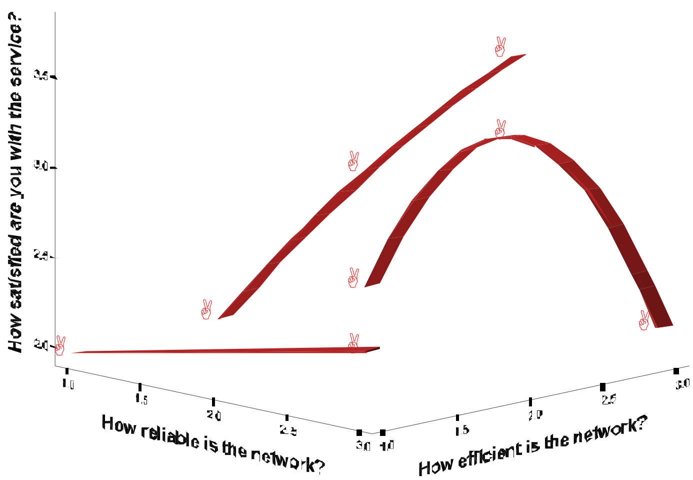


Figure 4.7 Comparative analyses amongst satisfaction, reliability and efficiency.

Figure 6 shows the relationship between satisfaction, reliability and efficiency. The higher the networks' efficiency and reliability the higher the user's satisfaction. And the lower the reliability and efficiency the lower the satisfaction. User-perceived and IP QoS layers (bandwidth, packet loss). This section is focused on IP QoS layer (bandwidth, packet loss and jitter). The IP QoS is usually the determinant of satisfaction of service provided by wireless network. in other for the service to be satisfaction then the bandwidth must be high enough and there must be low rate of packet loss. The figure below is used to show the relationship of User-Perceived QoS (satisfaction) against bandwidth.

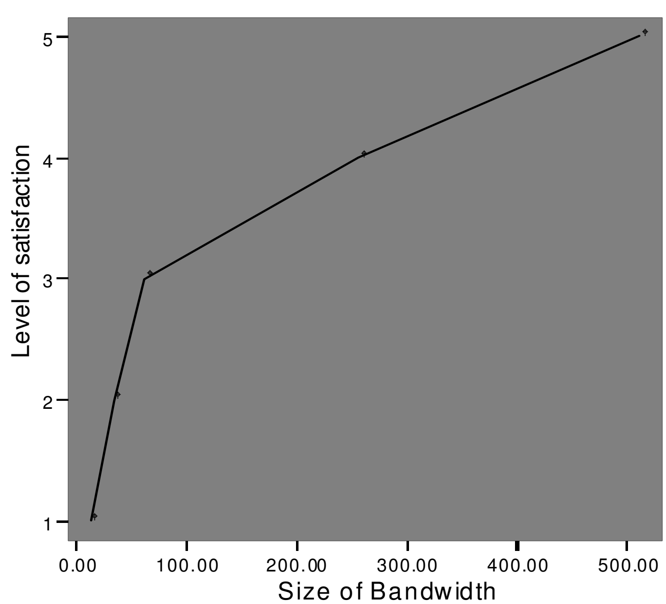


Figure 7 Satisfaction/Size of bandwidth

This shows that the higher the size of the size of bandwidth the higher the level of satisfaction. And if the bandwidth size is small then the user's satisfaction will be small. Satisfaction is proportional to size of bandwidth. Figure 4.8 shows the relationship between user-perceived QoS (satisfaction) and packet loss. If the rate at which data is lost is high, users satisfaction will be very low. Satisfaction is inversely proportional to packet loss.

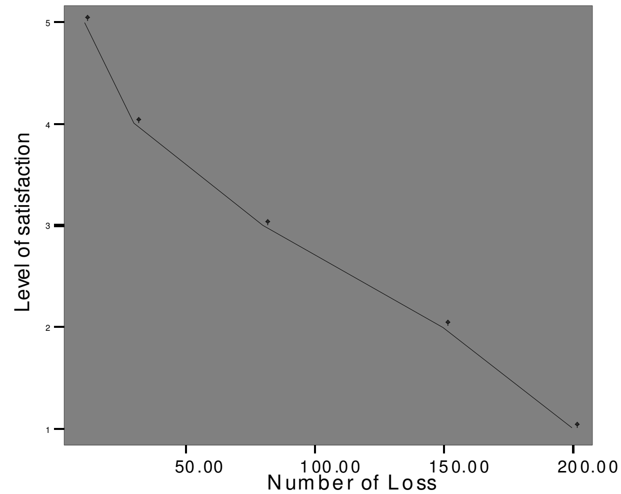


Figure 8 Satisfaction/ Number of loss.

The higher the loss the lower the level of satisfaction and the lower the loss the higher the satisfaction becomes.

6. RELATING USER-PERCEIVED AND IP QOS DIRECTLY

This involves the relationship between the users QoS and IP QoS. The figure below shows how the size of the bandwidth can affect satisfaction and the rate of loss. The higher the size of the bandwidth the higher the satisfaction and lower the rate of packet loss. The size of the bandwidth is measured in megabits per second (mps). The rate of packet loss does not have a specific measurement, it is based on the rate at which users can define the rate at which data loss occur while using the network. the level of satisfaction represents rate at which users are satisfied.

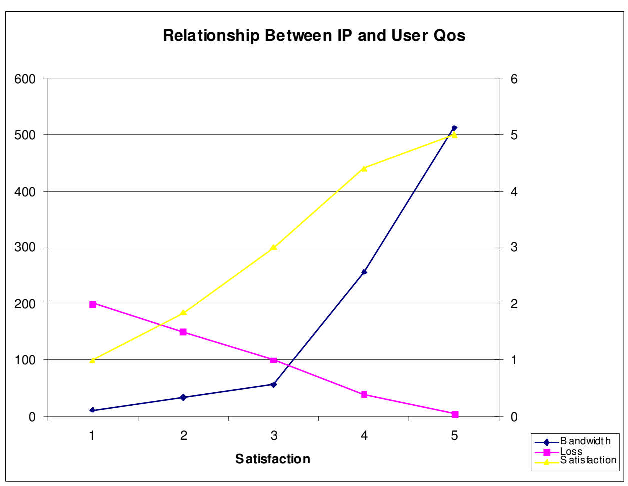


Figure 9 Relationships between IP and User QoS

Taking into account the impact of the application QoS layer by separately studying the mapping between user-perceived and IP QoS layers for different applications (speed of delivery, distortion).

Distortion is the change in an audio signal that results in the presence of frequencies in the output signal that was not present in the original signal. The factors that can cause or contribute to distortion include attenuation, crosstalk, interference, and delay. Speed of delivery is time taken for data to reach it destination. Figure 4.10 show the relationship between Application QoS (Distortion and Speed of Delivery) and User-Perceived QoS (Satisfaction). The higher the speed at which data is delivered the higher the satisfaction and the lower the distortion rate. If the distortion rate is high then satisfaction will be low.

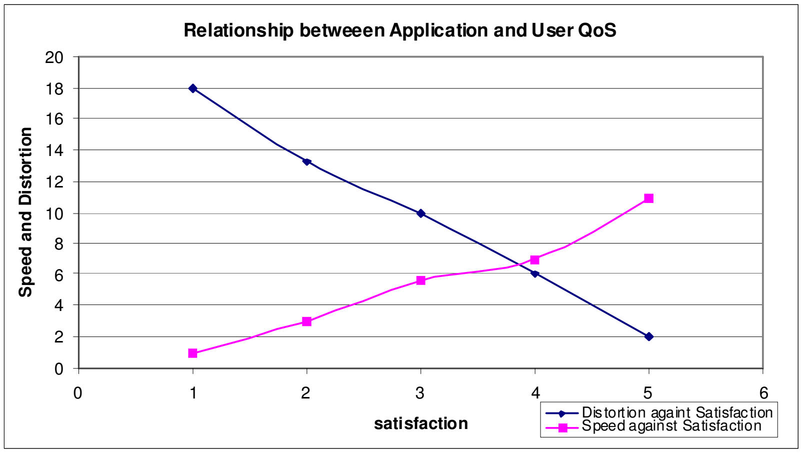


Figure 4.10 Relationship between distortion, speed of delivery and satisfaction.

From the above tables and graphs, it can be deduced that user-perceived QoS is dependent of quality of service of networking layer. The study has contributed to our understanding of QoS by drawing attention to this relationship between actual network performance and user-perceived QoS. These findings suggest that taking a bottom-up approach to ensuring QoS can be unnecessarily costly to ISPs if they continually

7. SUMMARY OF FINDINGS & CONCLUSION

From the analysis in chapter four, we conclude that satisfaction (users QoS) is directly proportional to bandwidth size. The higher the size of the bandwidth, the higher the user's satisfaction while using the network. Satisfaction is inversely proportional to rate of loss, that is, the higher the loss, the lower the satisfaction of the user. Hence, the relationship can be expressed as Satisfaction = 1 / Loss. In summary, network efficiency can be improved by increasing the bandwidth size. As has been demonstrated, ISPs would benefit from identifying the network parameters necessary to provide users with a satisfying QoS and dimensioning their networks accordingly. Interestingly, the results show that there were no significant within-subject differences in the perception of network performance as a function of physical environment (indoors versus outdoors). However, significant differences between subjects on this variable highlight that users bring with them their own subjective perceptions and attitudes that affect their user-experience.

This paper has demonstrated the importance of defining the concept of user-perceived QoS and linked this to specific wireless data network parameters for a range of anticipated valuable applications. It has been shown that a quantitative rating can be obtained for a variety of important factors in the assessment of service quality for wireless applications and related to the values of multiple network parameters. This study is the first step to understanding what levels of network parameters are required to provide users of wireless data services with a repeatable satisfactory experience, and how networks can be dimensioned to perform at optimum levels to provide these experiences. Most relevant, it indicates that QoS is application-specific and that various applications require different levels of network performance to satisfy users.

7.1 Concluding Remarks

Service providers should observe quality of service from user's perspective. Users should also help providers by updating themselves in areas of use of technology wherever necessary. The quality of service model gives providers upper hand in satisfying the users. Providers should also make a documentation of any technology they feel the users will not be able to use in other to guide them in the use of any such new technologies. Further comparison could be done to help in understanding the relationship between user defined and operator defined quality of service.

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