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Methodology to measure the quality of service in healthcare information and telecommunications infrastructures

Eduard Babulak

Abstract—The telecommunications industry in last decade went through the dramatic changes motivated by mobility, wireless technologies and miniaturization. The continuous increase in the complexity and the heterogeneity of healthcare telecommunications infrastructures requires reliable methodology to assess the quality of service provision. This article presents a cost effective methodology to assess the user's perception of quality of service provision utilizing the existing Staffordshire University network by adding a component of measurement to the existing model presented by Walker. This paper offers a cost effective approach to assess the QoS provision within the University campus network, which could be easily adapted to any campus network or healthcare organization in the world.

***Keywords*— user's perception of quality of service, assessment methodology, electronic health record, health care telecommunications infrastructures, Staffordshire University network communications infrastructure.**

1. Introduction

The world today is driven by the information exchange providing support for the national and global cooperation. The supporting telecommunications infrastructures are becoming more complex providing the platform for the user driven real-time applications over the large geographical distances. The essential decisions made concerning the state welfare, heath systems, education, business, national security and defense, depend on quality of service (QoS) provision of telecommunications and data networks. Regardless of the technology supporting the information flows, the final verdict on the quality of service is made by the end user. The users' perception of telecommunications' network infrastructure QoS provision is critical to the successful business management operation of any organization. As a result, it is essential to assess the quality of service provision in the light of user's perception. The quality of service is one of the most elusive, confounding, and confusing topics in data networking today [1]. While research papers on QoS hardly ever questioning raison d'etre it is frequently the topic of heated debates. Why are so many publications and even workshops on a topic which is questioned vehemently while at the same time has so little impact on current products or services [2]? The term *service quality* may have a different meaning to different people [3]. This is perhaps more accurately called QoS, as opposed to service quality, which could be taken to mean the entirety of outcome and experience [4]. The great majority of users are not interested in the engineering of telecommunications networks or its QoS specifications; instead they expect fast, reliable, and easy access to online resources, applications and Internet (i.e., online databases, banking services, e-commerce, e-mails, web servers, etc.) [5]. Most doctors and medical staff today (i.e., clients) expect to have immediate access to various communications technologies (i.e., wireless, mobile, fibre optics, Ethernet, etc.) using almost any software application, following the banking principle of anywhere, anytime, and anyhow [6].

2. Staffordshire University network

2.1. SUN's overview

The SUN has three major sites including stoke-on-trent, Stafford and Litchfield and a number of buildings distributed around each site interconnected via leased communications lines shown in Fig. 1.

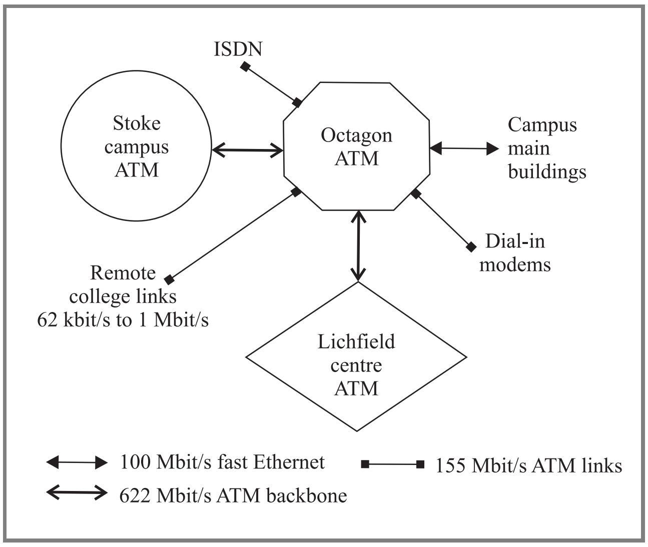

Fig. 1. Staffordshire University network diagram.

The SUN was installed by the Digital Equipment Corporation (DEC) more than ten years ago using CAT4 cables (up to 16 Mbit/s transmission rates), which are currently being upgraded to CAT5 (up to 100 Mbit/s transmission rate). The Catalysts 1900 series switches replaced the DEC 90T hubs. Each building has a router connected to an Ethernet, with concentration of switching in the wiring closets. Specialized networks for graphic arts and computer science are also connected behind firewalls, and these are based on 100 Mbyte connections. To provide support for users who do not have computers, all student mail and files are stored on shared network drives accessible from terminals in the various campus computer labs. Students with their own computers run e-mail clients that map to the remote e-mail

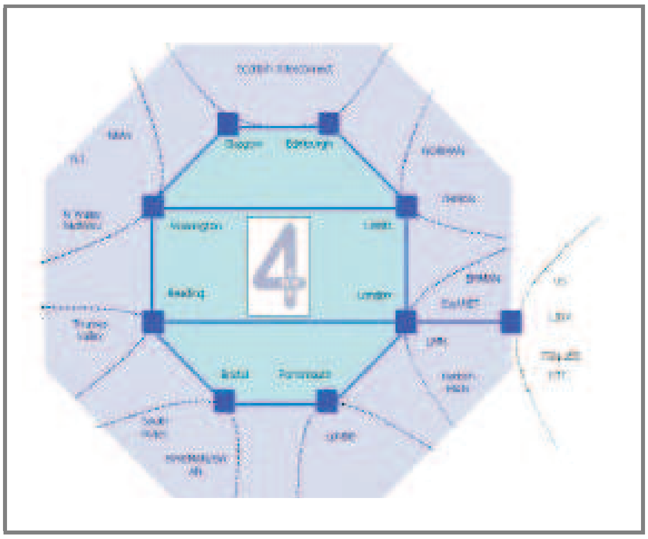

Fig. 2. SuperJanet4.

server when connected. A network administrator accesses each student's computer at the beginning of the semester to set up the appropriate drive mappings and permissions. Every time the SU users send or receive anything over the Internet it travels through Staffordshire University and connects to the Net North West network, which is the gateway to the Janet network show in Fig. 2.

2.2. Quality of service

2.2.1. Information technology QoS framework

The ISO has produced a draft international standard ISO/IEC DIS 13236 [7], "is to provide a common basis for the coordinated development and enhancement of wide range of standards that specify or reference quality of service requirements or mechanisms". The framework is a structured collection of concepts and their relationships, which describes QoS and enables partitioning of, and relationships between, the topics relevant to QoS to be expressed by a common description. It is intended to assist developers of new and revised standards, which define and use QoS mechanisms, and users expressing requirements for QoS [8]. The typical QoS characteristics represent some aspect of the QoS of a system, service or resource, which can be identified and quantified. User requirements drive the QoS-management activities and originate with an application process that wishes to use a service. The requirements may be retained in an entity which may also analyze them in order to generate further requirements that are conveyed to other entities as QoS parameters, and so on. Examples of such parameters are given from network measurements:

- a measured value, used to convey historical information;
- a threshold level (i.e., the threshold for the users' perception of network QoS provision).

2.2.2. Enhanced disconfirmation model

The existing information technology (IT) definition of QoS lacks the clarity required to express separately the service provider's and customer's viewpoints. Disconfirmation model applied to assess the SUNCI QoS provision is illustrated in Fig. 3, which illustrates the enhanced disconfirmation model of customer satisfaction based on the original model [8]. The advancement of current measurement technologies and the results of this paper introduce a new model by comparing the performance measurements (M) with the expected (E) and perceived (P) performance. Empirical evidence suggests [8] that there are a number of key characteristics or attributes which customers will generally evaluate to determine the quality of any particular product or service. The disconfirmation model shows that

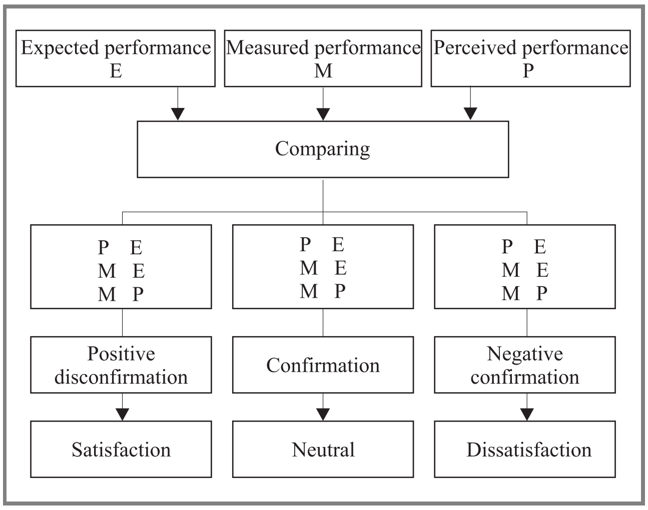

Fig. 3. The enhanced disconfirmation model of customer satisfaction.

customer's satisfaction will be dependent on both the size and direction of disconfirmation, with only three possible outcomes. When "perceived" is greater than "expected", customers will be very satisfied; when "perceived" is equal to "expected ", customers will be satisfied (i.e., the product is performing exactly as expected); when "perceived" is less than "expected", customers will be dissatisfied. The QoS required by the customer is a statement of the level of quality of a particular service required or preferred by the customer [9]. A typical customer is not concerned with how a particular service is provided or with any of the aspects of the network's internal design, but only with the resulting end-to-end service quality [8]. It must be recognized that the customer's QoS requirements are useful, although subjective.

A customer may judge the service based on his or her location, connectivity and means of access, as well as the computational processing power on his or her workstation. It is up to the service provider to translate this into something of objective use [9].

Quality as perceived by customers from a comparison of what they feel the product should offer (i.e., drawn from their expectations) with their perception of the actual performance of the product. When customers register with the campus network, they already have expectations of how network should perform and this will cover a whole host of criteria [8] including:

– conformance to specification (user accounts and privileges, accessibility);
– performance (primary network characteristics, such as utilization and error rate);
– reliability (probability of the network malfunction-free performance);
– availability (probability of the network being available);
– simplicity (ease of use);
– serviceability (speed, courtesy and competence of repair).

The network expectations may be considered as predictions, sometimes subconscious ones, which customers make about what is likely to happen during the use of it. In practice, this may differ significantly from the views of IT services, whose views of quality will be based on their perspectives of the network services offered. However, the most important evaluation of quality is that carried out by the customer and network real-time measurements. This evaluation draws on expectations and expectations introduced by Gronroos [10] in defining quality within the service environment as:

quality = customer's expectations – customer's perceptions.

This may be further analyzed and subdivided using the disconfirmation model, if quality is "conformance to requirements" and the real judge of quality is the customer, and then they must evaluate quality in relation to their satisfaction. For the purpose of clarity author defines the level of expectations being always greater that the level of perception. For example, the users' expectations of the services are very high equal to ten on ten, but their perception is only four on ten, which correspond to less than good.

However, if the user's perception reaches level of 10 on 10 then this considered to be an exceptionally good service. Given the SUN current technological and SU financial status it is quite unlikely that the level of user's perception of SUNCI QoS provision would exceed the level of their expectations. In other words, if the SU marketing strategy to attract the overseas students is based on offering them the best services, then the ultimate judgment will be carried out by the student once he or she had actually used the particular services. This may be further analyzed and subdivided using the disconfirmation model, if quality is "conformance to requirements" [11]. The real judge of quality is the customer, then they must evaluate quality in relation to their satisfaction. The "enhanced disconfirmation model" of customer satisfaction was based on the original model [11]. The advancement of current measurement technologies and the results of this work introduce a new model by comparing the measurements performance (M) with the expected (E) and perceived (P) performance. According to the IT service norms the SUN average utilization for half-duplex communications1 is 70%. Figure 4 illustrates the system utilizations measurements and the daily top talkers access to the IT network. The network utilization bounces from under utilized (i.e., from 10:00 until 14:00) to over utilized (i.e., from 14:00 until 19:00 with utilization decrease between 17:00 until 18:00). From the graphs captured, it is evident that the utilization increases in the late afternoon hours, due to the students' assignments submission deadlines. Results of SUNCI measurements show in Fig. 4, illustrate that system utilization reflects the users' utilization pattern and the error rate is equal to null, which constitute a good correlation with the survey questionnaire results.

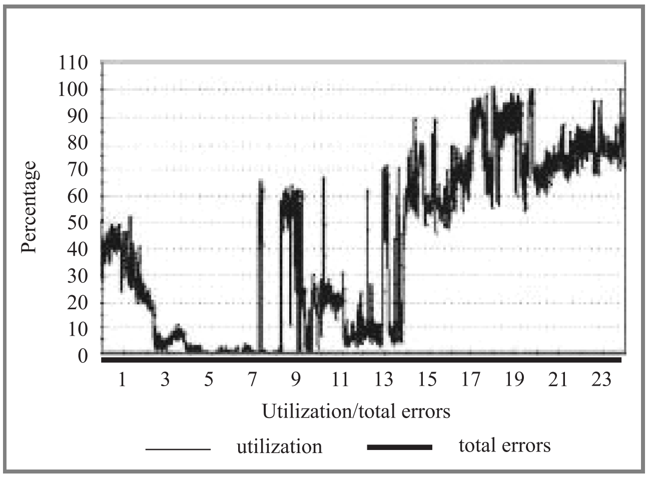

Fig. 4. The system utilization/total errors on Tuesday April 3rd 2002 at residency network.

Half-duplex communications systems are those systems where information is transferred on two directions, but only in one direction at the time.

Empirical evidence suggests [10] that there are a number of key characteristics or attributes which customers will generally evaluate to determine the quality of any particular product or service. The disconfirmation model shows that customer's satisfaction will be dependent on both the size and direction of disconfirmation, with only three possible outcomes. When "perceived" is greater than "expected", customers will be satisfied; when "perceived" is equal to "expected", customers will be neutral, neither satisfied nor dissatisfied (i.e., the product is performing exactly as expected); when "perceived" is less than "expected", customers will be dissatisfied.

2.2.3. Four quality cycles

There are two principal parties in the QoS cycle, the customers and the service providers as shown in Fig. 5. For the service provider, such a division leads to planned and achieved quality. For the customers this division leads to their QoS requirements or expectations and their perception of the performance experience.

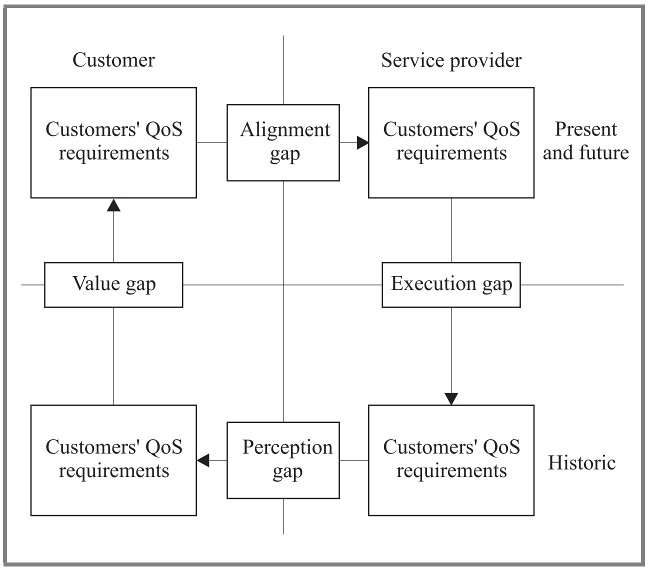

Fig. 5. Quality cycle [8].

The scale of customer satisfaction or dissatisfaction will be dependent on the difference between "expected" and "perceived" performance of these key characteristics or attributes. QoS offered by the service provider is a statement of the level of quality that is offered to the customer. This is the level of service that the service provider can achieve with the design of the network. The level of quality is expressed by values assigned to network performance parameters, which cover the network and network support [12]. The QoS achieved by the service provider is a statement of the level of quality achieved by the service provider. It is a record of the levels of quality that have been achieved. These are expressed by values assigned to the parameters specified for the offered QoS. These performance values are summarized for specified periods, for example, for the previous three months and/or on an annual basis. The QoS perceived by the customer is a statement expressing the level of quality experienced by the customer. The perceived QoS is usually expressed in terms of the degree of satisfaction and is assessed by the information technology survey questionnaire.

3. Users' perception surveys

This section presents results of the IT survey questionnaire used to assess the QoS. In order to assess SU users' perception of SUNCI QOS provision and their level of satisfaction, two IT surveys were conducted over a period of two consecutive semesters. The results of both surveys provided the IT management team with useful information about the users' perception. Generally there are two types of questionnaire: one to assess customer opinion of a particular service, the other to assess the overall opinion of a service provider [8]. The IT survey questionnaire was designed to address all major groups of SU users, their relation to the SU, access point location; means of access connectivity, the end workstation type the application access priorities and the critical time of network utilization for a specific type of application.

3.1. Survey results

Respondents were asked for their perceptions on response times on a scale from excellent down to very poor. If the response was scored such that: excellent = 10, very good = 8, good = 6, reasonable = 4, poor = 2, very poor = 0. The results illustrate clearly that the majority of average scores lie between 4 and 6, indicating that respondents typically see response time lying between reasonable and good, on average. The total number of respondents to both surveys was 1116, which represents more than 10 percent of SU users' community. The results show the evidence that most users tend to use their computer for a significant period of time, once they are online. Respondents were asked about the time of day they tended to use the University facilities. The only exceptions appear to be the use of ftp transactions, which are often seen as less than reasonable, particularly at a student residence or at home. Clearly there is the perception that there is better support on-campus compared with off-campus. Table 1 illustrates the users' perception of application performance

Table 1
User's perception of the application performance

Applications	Campus	Student residence	Home
Last use	5.5	4.3	4.9
FTP	4.7	4.0	4.7
Web	5.6	4.3	5.0
E-mail	5.9	4.4	4.9
Admin	5.3	–	4.9

while accessing the network from home, residencies and main campus.

The results demonstrate that the respondents' perception of IT support is that it is quite good on campus, better than reasonable at residences, but worse than reasonable off-campus (see Table 2). The majority of respondents' primary applications tend to be e-mail and the second most significant use is web browsing. The IT services are currently focusing on application performance management.

Table 2
The average scores

Places	Score
Off-campus	4.5
Student residence	4.6
On-campus	5.7

According to survey results the 56 K modem was the main type of remote access connection for the majority of users. In addition there was a variety of makes and models of computers, although the majority appeared to have a Pentium processor and be less than three years old.

4. Conclusions

The current technological evolution in the electronic health record presents new challenges and research problems to community of experts working in the field of medicine and information technology. However, despite of technological and medical research advancements it is essential that the computerized electronic health record systems will be available to all community of doctors, medical staff and patients worldwide as a tool that ultimately contributes towards the process of humanization of all aspect related to medicine. In the current climate of business-driven education with a focus on the user's satisfaction it is essential that the university campus networks provide support for a large number of software applications running reliably over very complex interconnection hardware with fast system response and high security. This requires a great deal of interoperability and dynamic resource allocation within the networks. The concept of assessing QoS provision is often represented in many different ways by various specialists groups including; computer scientists, network engineers, network administrators, Internet services providers, and university business managers. This paper discusses the theoretical background on QoS, SUNCI current network monitoring practices, and an IT survey questionnaire. In this paper the author presents a new cost effective methodology for assessing the QoS provision with a minimum effect on network performance and its functionality, while discussing the users' perceptions of SUNCI QoS provision. The results suggest that the level of users' satisfaction of SUNCI QoS provision is reasonable and that there is a good correlation between the users' perceptions and the traffic measurement of SUNCI QoS provision. This research further promotes future research in merging the engineering methods and business perspectives on the QoS provision. Speed and accessibility to any information at any time from anywhere will create global communications infrastructures with great performance bottlenecks that may put in danger human lives, power supplies, national economy and security. It is essential to measure all engineering and social issues with much faster speeds. The future of telecommunications industry will be driven by four major drives for prosperity starting with the differentiated networks, health informatics, advanced television and sensor networks. The continuous increase in complexity and the heterogeneity of university campus networks will require assessment methods that are capable of addressing all engineering and social issues with much faster speeds. Speed and accessibility to any information at any time from anywhere will create global communications infrastructures with great performance bottlenecks. To find the solutions to deal with network congestion and information overflow will remain an engineering, social and mathematical problem.

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Eduard Babulak – Professor, Eur.Ing., Ph.D., P.Eng., C.Eng., CITP, SMIEEE – worked as a University Professor, Senior Lecturer and Researcher in mathematics, electrical, computer engineering and computing science in Canada, USA and United Kingdom. He speaks 14 languages and was nominated to a Fellow of British Computer Society (BCS) and a Fellow of the Association of Computer Machinery (ACM). He is a Senior Member of IEEE, a Corporate Member of IEE, a Professional Member of BCS, a Professional Member of ACM, a Member of American Society for Engineering Education (ASEE), American Mathematical Association (AMA) and a Member of the Mathematical Society of America (AMS). He is an international scholar, researcher, consultant, educator, professional engineer and polyglot with more than twenty two years of teaching experience and industrial experience as a professional engineer in USA, Canada, UK, Germany, Austria, and Czech Republic and Slovakia. Professor Babulak's biography was selected for citation in the Cambridge Blue Book 2005, the Cambridge Index of Biographies 2004 and 2005, the Dictionary of International Biography 2004, published by the Cambridge Center of International Biographies, Who is Who in the Science and Engineering 2003, 2004 and 2005, Who is Who in the Industry and Finance 2004 and 2005 and in the Who is Who in the World 2003 and 2004. Professor Babulak's academic and engineering work was recognized internationally by the Engineering Council in UK and European Federation of Engineers. His academic qualifications have been recognized and credited by the Association of Professional Engineers of Canada in Toronto. His current research interest include ubiquitous computing, e-manufacturing, QoS provision for computer and telecommunications communications infrastructures, differentiated networks, health informatics, electronic health record, sensor networks, automation and applied mathematics.

e-mail: e.babulak@staffs.ac.uk
Faculty of Computing and Engineering Technology
Staffordshire University
Beaconside, Stafford, ST18 0DG, United Kingdom

e-mail: eduard_babulak@uqar.qc.ca
Départment of Mathématique, Informatique et Génie
Université of Québec in Rimouski
300 rue des ursulines
Rimouski, Québec
G5L 3A1 Canada