HEALTHCARE ICT NETWORK EVALUATION USING ANALYTIC HIERARCHY PROCESS

Astrid Oddershede*
Industrial Engineering Department,
University of Santiago of Chile
Santiago, Chile
E-mail: astrid.oddershede@usach.cl

Rolando Carrasco,
School of IEEE
Newcastle University/
Newcastle Upon Tyne , UK
E-mail: r.carrasco@ncl.ac.uk

ABSTRACT

This paper presents a framework to assist the evaluation process to improve the quality of service (QoS) of an Information and Communication Technology (ICT) network system in health care service. The multiple competing goals and conflicting objectives existing in the Health sector needs a special treatment thus the Analytic Hierarchical Process (AHP) is suitable to identify ICT network QoS requirements and implications. Integrating AHP with modeling and simulation through Optimization Network Engineering Tool (OPNET) platform permit to characterize main ICT user and identify applications priority to examine network behavior and evaluation. The stakeholder interface perception and resources for ICT network support are investigated through a case study for Chilean hospitals.
Keywords: AHP, Multi-criteria evaluation, ICT Healthcare

1 Introduction

A demanding task of current innovation in healthcare processes is to reduce the time before treatment. Appropriate medical intervention immediately following an emergency or urgency situation significantly increases the chance of recovery for the patient. The need for quality medical services is vital in private and public policies of any country. Many actions oriented to improve the operation and the quality of healthcare service depends, to a great extent, on the level of information available and the communications system. ICT appears as an emerging concept in health care accomplishing an essential role for healthcare-related activities (Bourret, 2004). An information technology system provides stakeholders with several applications to support their duties in clinic care, medical research and administrative issues. It can also provide mechanisms of management of information that reduce paper work and support administrative transactions, public health supervision, professional education, and medical research as mentioned by the National research council, (2000).

However, the provision of these applications depends on the communications network infrastructure, the devices and communications links and its performance. Then, the challenge of providing QoS in a health environment is rather complex since QoS needs of individual health organizations vary over time. Moreover, as the world's elderly population grows, there is more aged patient to serve and additional services to provide. ICT system should be a facilitator for health care users since they need to access all types of data existing on all types of systems. A poor ICT network system implementation may generate a negative effect on the service, patients and health care providers. Some authors, (Ammenwertha, et al., 2003) have drawn attention to the importance on relying on evaluation mechanisms for decision makers and users.

* Corresponding author

The purpose is to develop a prototype assessment model based on data collected from the main users of the health network system. What are in question are the *implied* needs of classes of users, which must be worked out through user profiling and requirements analysis. So far, it has not been possible to do much work on defining appropriate techniques for characterizing health ICT users and their needs, but their importance has become increasingly obvious. The model will be of assistance to find out client perception of quality of the service related to the communications system in a healthcare institution, to identify critical areas for QoS, to provide a decision making tool as a guidance to analyze and evaluate a networked system for health related activities, to compare the different requirements and to enable tradeoffs in accordance to the institution necessity.

The results obtained through the multi-criteria approach using AHP (Saaty, T.L., 2001) model lead to determine the properties or characteristics of the system concerning the stakeholders that could subsequently affect their degree of satisfaction with the ICT system in unanimity with their activities. This data allows generating user profiles and applications profiles to support the design of models for appraising ICT healthcare network QoS through the Optimization Network Engineering Tool (OPNET) simulation platform to examine the network behavior and performance. Section 2 introduces the conceptual method description. Section 3 describes the case study. Section 4 the AHP application is presented and its results. The simulation outcome given in section 5 generates information that is not currently available. In section 6, the conclusions are provided.

2. Healthcare ICT network system evaluation

The evaluation methodology could be described in two main parts: On the first stage, the efforts are oriented to identify the type of user, the activities they are involved in, the ICT network system requirements, applications and its attributes. AHP modeling is used for ICT system provision, parameters identification and prioritization.

The second stage is concerned with modeling and simulation to examine the network and check the performance on an application. The QoS technical metrics related to each attribute has to be defined together with the applications profile. QoS offered by a particular network could be established by technical parameters that can be measured objectively. However, the user perception depends upon their needs, their precise applications and their expectations. It is a difficult task to find a set of universal parameters for every type of service because there are many and dissimilar parameters involved in the performance evaluation.

We suggest modeling and simulation using Optimization Network Engineering Tool (OPNET) (Opnet: User Manual 2004), (Xinjie Chang, 1999) simulation platform to examine the network behavior to ensure consistency and reliability for thousands of staff across the hospital network. Moreover, the introduction of new service and technology deployments could be analyzed using predictive planning. (Heath A., Carrasco R. 2001). It is possible to study protocol behavior under different network conditions and application performance. The results will reveal key QoS parameters that generate user and activities profiles to support the assessment of communications resources of Local Area Networks (LAN) in a hospital. Then, it is useful to analyze which of the parameters would be relevant when considering the user perception for a determined service. The organization must then define a service level agreement (SLA) for their main applications.

3. The Case Study

The stakeholder interface perception and resources for ICT network support are investigated through a case study for Chilean hospitals. A pilot study has been carried out collecting data from health Institutions in Chile (private, public, regional) to examine ICT infrastructure, ICT network provision and stakeholders perception related to ICT network system. Through the AHP it was possible to identify applications priority and to characterize main ICT system users for configuring profiles and by simulation to examine network behavior and evaluation. The relative importance of ICT network support for each activity to deliver a better service is obtained. The essential QoS attributes to meet

the ICT support requirement for each defined activity and ranking has to be established then. It follows the process to determine the QoS attribute relative importance for applications according to user type expectation. This refers to the ICT support user perceives, to capture service satisfaction. For example: success in the connection, accessibility, velocity, etc. ICT system users expect that the network will help to deliver a service on time with the required functionality and within the budget.

In previous work, (Oddershede, 2007) stakeholders are classified into four groups. A group constituted by the patients who demand a health care service; other conformed by the clinic care staff (Physician, nurses, paramedics, etc) who would make use of ICT to deliver a health care service, a third group represented by those users who develop medical research, collecting disease statistic and/or investigate new drugs and new devices. The fourth group is integrated by users who perform the administrative activities, billing, products distribution, and inventory control or other connected. Initial data was collected from 480 participants; following an expert team of 36 is grouped comprising representatives from each category from all of the three types of hospitals considered.

An AHP model is developed and processed. The pairwise results from stakeholders' perspective indicated the relative *importance* of ICT system alternatives for performing their activities. It revealed that ICT support has a greater impact on supplying clinical care service. This service is concerned about the activities developed by the physician, nurses, and paramedics. So far, it has little impact on the patients. Therefore, we assume for the study, that the main ICT network system users are those who develop activities in clinic care, medical research and administrative area.

4. The AHP application

Once the most important activities developed by each group, the research is centered in finding out the relevant ICT application that would support to perform a better service. For the case in study, the AHP application revealed the applications to be supported by a server as: Email, Web Browsing (Http 1.1), File transfer, Database Access, File Print, Video Conferencing, and Voice. The relative importance results, stakeholder declarations and the actual usage collected from data are depicted in Figure 1 showing discrepancy.

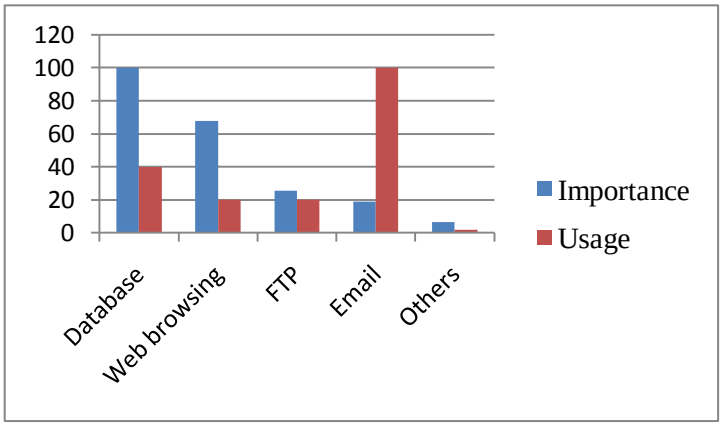

Figure 1.*Relative importance ICT applications and usage in healthcare institution*

Moreover, analysis of the results suggests that the expectations of health ICT network users are that the network will help to deliver a service with the required functionality on time and within the budget, but also to help to satisfy various quality criteria.

Consequently a new AHP model is developed, to bring about information with respect to user perception related to the most important attributes to develop the necessary applications related to the service they perform. Then the hierarchy structure should consider the attribute that would improve/ensure a better performance. The attributes considered are based on standard ISO quality software model (ISO/IBC, 1997): Functionality, Efficiency, Reliability, Availability, and

Serviceability. Figure 2 shows the overall relative importance for attributes that the panel of experts indicated. And the relative importance of ICT support for each type of user in Health service.

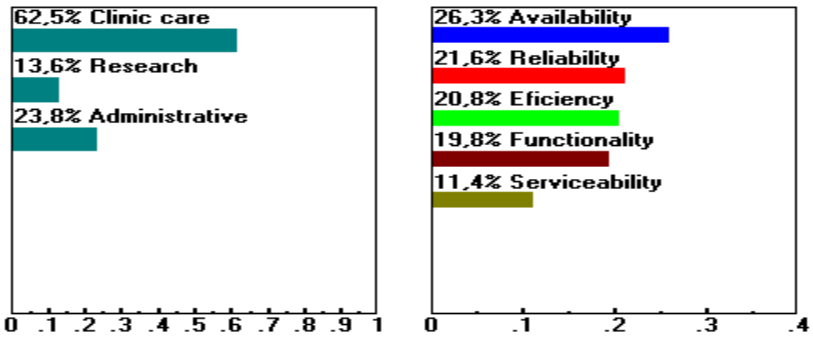

Figure 2. *User relative importance for attributes*

Even though, the five attributes are very important, it was possible to detect some differences in relation to the type of user. The two overall most important QoS attributes concomitant to the ICT applications in performing their health related activities system are *availability* and *reliability.* The *reliability,* however seems to be immediately followed by *efficiency* and *functionality*. Figure 3 shows a comparison between these two attributes and relevancy for the user groups..

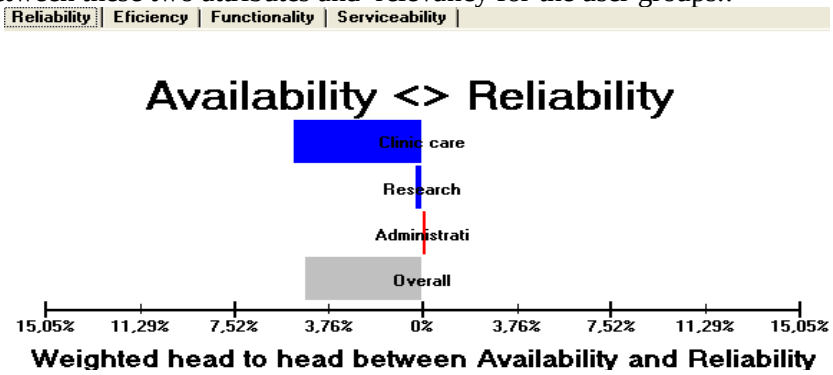

Figure 3. The importance of Availability vs Reliability attribute for each type of user

It can be seen that the attribute ***availability*** is most important for the group who develop task in Clinic care. In effect, clinic care professionals require having information on their patients including those elaborated by others, such as, complementary tests results, at the moment and the place of attendance. *Availability* of ICT support is critical, when dealing with an emergency situation. A patient admitted to a hospital for observation could shorten his/her stay, if the hospital has an information system to make able to retrieve previous tests results implying lowering treatment cost, as well.

At this point, the QoS technical metrics that would guarantee a service (i.e. end to end delay, packet loss,) related to each attribute are defined together with the applications profile.

5. Simulation and Modeling Network Architecture for Hospital

With the purpose of emphasizing National Health Service communications network in Chile, level of network utilization, and substantiating the treatment in real world conditions; basic Hospital ICT network system are modeled via simulation.

In the telecommunications domain there is an increasing concentration in having a network simulator with powerful tools, with the objective to design models, simulate topologies and network performance analysis. Data is obtained by author's research and extensive collaboration with the IT network and management teams from a range of hospitals which differ in size and category, like, public, university, private in order to have a picture related to ICT network technical aspects and

analyzed by simulation using OPNET methodology. (Opnet: User Manual, 2004). According to the methodology, the first step is to select a topology, then a typical public hospital zone is considered as an initial pilot study to analyze technology infrastructure and network performance.

The next step is to set up profile applications according to each user type which is based on the AHP results obtained previously. Every workstation will have a profile application consistent with the users' main role.

Table 1: User Applications Profile

Profile name	Applications Profile	Profile name	Applications Profile
Secretary	• Email (Heavy) • Database Access (Heavy) • File transfer (Heavy) • Web Browsing (Light Http 1.1) • File print (Light)	Researcher	• Web Browsing (Heavy Http1.1) • Database Access (Light) • File transfer (Light) • Email (Light) • File print (Light)
Clinic care	• Database Access (Heavy) • Web Browsing (Light Http1.1) • Email (Light) • File Print (Light) • Video Conferencing (Light)	Management	• Database Access (Heavy) • Email (Heavy) • Web Browsing (Light Http1.1) • File Print (Light) • Video Conferencing (Light)
		Training	• Video Conferencing • Voice

Once applications and profiles are defined, it is possible to characterize different scenarios for each study case intended for visualizing how sensible is a networks performance with respect to changes.

For the zone study, simulations are ran increasing the number of ICT network user, formulating scenarios ,varying the number of users and/or varying the links (Ethernet connections) between workstations and switches, to obtain the point to point throughput in bits/secs. and utilization (link usage%).

The Utilization percentage of link usage is expressed as:

$$\frac{\textit{Point-to-point. Throughput (bits/sec)} * 100}{\textit{Ethernet connection (Mbps)}} \qquad (1)$$

For this case the maximum percentage of link usage showed to be very low channel utilization. The network is prepared then to support more applications and a greater number of users without generating problems.

6. Conclusions

The proposed methodology for assessing QoS of ICT network in Healthcare service shows the interface of user perception and technical aspects.

AHP permits to identify the main users, to elaborate a profile and characterization of the ICT support requirements in healthcare service. This analysis helps decision makers' network planners and operations engineers to manage complex and constantly changing networks, using predictive planning for reacting to critical network issues using real-time network visualization and troubleshooting. These issues are critical to effects of a healthcare institution operation.

The use of AHP modeling and empirical evaluation permits to capture human perspective. It could be detected that there is a gap between the actual usage and what a user finds important about a service. The attribute for measuring quality in Clinic healthcare system, availability and the need for ubiquitous access to integrated information are considered most important.

The technical aspects indicated that even though the technical aspects indicated low delay and high throughput, stakeholders are discontent about the access and ubiquity. Users complain about the straightforward access, new applications and number of computers. Consequently, one of the reasons could be caused of unbalanced resources distribution, some resource policy distribution, or other.

REFERENCES

Ammenwerth, E.. Gräber, S .. Herrmann, G, Bürkle, T. and König, J. (2003) "*Evaluation of health information systems problems and challenges*", International Journal of Medical Informatics 71, pp.125-135.

Bourret, Christian**,** (2004) "Data Concerns and Challenges in Health: Networks, Information Systems and Electronic Records," *Data Science Journal,* Volume 3, 17 September .

Feng GAO, Xinfeng YE, "A Hierarchical Trade-off Assessment Model and the Systematic Evaluation of Networked Systems", Fast Abstract ISSRE ,Copyright 2002 Chillarege Press .

Heath A., Carrasco R.(2001),"Access techniques for 3G multimedia wireless packet switched networks: simulation using OPNET™," *IEE/IEEE/BCS 6th International Symposium on Communication Theory and Applications (ISCTA01) Lancaster University (15-20 Jul 2001.*

ISO/IEC: "ISO/IEC 9126–1(1997**):** *Information Technology – Software quality characteristics and metrics* –Part 1: Quality characteristics and sub–characteristics .

National Research Council. (2000).*Networking Health: Prescriptions for the Internet.* National Academic Press ISBN–10: 0–309–06843–6,

Oddershede, A. (2009) "Methodology to Evaluate QoS of ICT Networks for the Chilean National Health Service" A thesis submitted to Newcastle University for the degree of Doctor of Philosophy, 2009.

Oddershede,A.M, Carrasco, R.A (2007). *"Perception of Mobile Technology Provision in Health Service" Chapter book in* Global Mobile Commerce: Strategies, Implementation and Case Studies, A book edited by Dr. Wayne Huang, Dr. Y.L. Wang and Dr. John Day, Ohio University, USA, 2007 ISBN Nº 1599045583, 9781599045580.

Opnet: User Manual (2004). http://www.opnet.com/university_program/teaching_with_opnet/ textbooks_and_materials/materials/OPNET_Modeler_Manual.pdf

Xinjie Chang, "Network Simulations With Opnet". (1999). Proceedings of the 1999 Winter Simulation Conference P. A. Farrington, H. B. Nembhard, D. T. Sturrock, and G. W. Evans, eds., Network Technology Research Centre School of EEENanyang Technological University, Singapore 639798.1999

Saaty, Thomas L. (2001) *Decision Making for Leaders.* Vol. II, AHP Series 315 pp., RWS Publ., (new ed.). ISBN 0–9620317.