New e-Health Services Design: User and Technical Requirements. Application in the Area of Telecardiology

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ABSTRACT

New telecommunication networks have allowed telemedical services to significantly advance and develop in the last years. In order to extract the maximum benefit from the new services, it is essential to accurately define not only the technical requirements and the network resources management, but also the scenarios where these services give response to main needs in medical assistance. Moreover, it is essential to carry out the evaluation of the mentioned services considering aspects like efficiency, acceptability, usability for the user, so that those services can be incorporated into health systems in the different medical environments (rural areas, home telemonitoring). This paper examines different e-Health services in the area of cardiology in which this technology can be carried out and proposes a methodology to define the best scenarios to implement these services in health organizations. This methodology also recollects the real users' requirements: patients, doctors and health-related professionals. Thus, the results obtained in specific scenarios of implementation for a telecardiology service allow new user-based designs that can be directly integrated in the medical practice in an efficient way.

Key words: e-health, user centered design, telecardiology scenarios, telemedicine

I. INTRODUCTION

Advanced Information and Communications Technologies (ICTs) have increasingly been used for clinical activities and research to improve health care delivery, providing new e-Health services and reaching the patient self-management and self-evaluation of the disease [1], [2]. These technologies have undergone many investigations to evaluate their effectiveness, efficiency, and feasibility [3]. These new e-Health services are usually based on multimedia technologies [4], [5] and they are expected to support diverse clinical applications over different network topologies [6]. Such heterogeneous environments require that different type of services (Real-Time (RT) vs. Store& Forward (SF) services) should be provided with different Quality of Service (QoS) technical requirements [7].

In the case of our research, the implementation of e-Health applications and telemedicine (TM) services is possible in a great variety of scenarios: hospital, home, rural, mobile environments, etc., where the specialist virtually "displaces" to the patient point-of-care through a communications network.

Moreover, the analysis of the implementation of an efficient TM device requires the integration of user and technological variables and the study of the health organizations, leading to a detailed description of their environments that are critical. In this paper, the main goal is to conciliate the user and technical requirements by generating an understanding, not only about technology but also focusing on health organizations and potential users of the new e-Health services. The need for a complete model to explore the different welfare levels in health systems looks forward to optimize the use of available sanitary resources and further to improve the patient Quality of Life (QoL).

The methodology of our research is presented in Section II. The results obtained in the specific case of a telecardiology service are given in Section III, where we present the technical characteristics of this telecardiology service, and its specific scenarios of implementation obtained from the methodology proposed. Discussion and conclusions are presented in Section IV.

II. METHODOLOGY

In order to conciliate technical requirements with organizational and user needs for a specific TM service, we designed a methodology to redefine potential scenarios (what technology can do) of these services from the user and health organizations point of view (what technology must do). This methodology can guaranty a major efficiency and acceptability in the implementation of TM services.

A high number of published experiences [8] relate the technological evolution of the traditional applications towards e-Health services: telemonitoring (reducing patient displacements to the health centre), teledermatology (remote evaluations of digital images), telesurgery (including a high quality videoconference and remotely-controlled robots), and teleelectrocardiology and teleechocardiology that are two of the most relevant TM services [9]. The methodology proposed in this paper is focused in these two services. Thus, we can implement advances in the transmission of biomedical signals (electrocardiography, ECG, and echocardiography, ECHO) in medical services in order to improve the welfare quality of patients and to facilitate doctors and health-related professionals work.

A. Exploration of welfare levels in health assistance.

This first phase uses qualitative methodologies based on the design of interviews and *focus groups* with relevant cardiologists in Spain. The *focus groups* [10] are collective sessions of discussion about a specific topic –in this case ideal scenarios, from a medical perspective, for the implementation of a telecardiology service. In these sessions, different points of view about the same topic can be confronted and discussed, at the same time, to collect the specific characteristics of the scenarios and ideal services to implement a telecardiology service. The design of interviews with expert cardiologists takes into account:

a. *Organizational variables*, needed to study specific scenarios in real medical healthcare.
b. *Cultural variables*, specific to the meanings that patients and doctors give to their daily routines, and to TM services and devices. The knowledge of these meanings serves to improve the design of Graphical User Interfaces (GUI) by minimizing, for example, the usual negative associations that the patients establish between the medical device and their illness.
c. *ICT use variables*. The observation of the use of ICTs from health-related professionals and patients, taking into account cognitive (the process of information with or without ICT devices), symbolic (cultural meanings of ICT) and practical aspects of this use (the ways of improve health-related professionals' tasks and quality of life of patients) that will be very useful in the design of TM device.

Scenario analysis [11] is a frequently used methodology within the discipline called Human Computer Interaction (HCI) to study the implementation of new technologies in specific contexts and applications actually not developed. The scenarios are descriptive narrations about the contexts in which determinate people do determinate actions. Scenario analysis have showed itself effective for managing interdisciplinary work between technology developers and user study experts, as it allows to explain in a simple and illustrated way: the contexts in which an application will be implemented, its functionalities, the characteristics of its users and their interactions.

After the interviews and the *focus group*, the next step is its content analysis, supported by the qualitative analysis software ATLAS-ti [12] that allows identifying the most relevant contents for the analysis and to establish relations between them (see Fig. 1). As result of this analysis, the different implementation scenarios of the service and its potential users are identified.

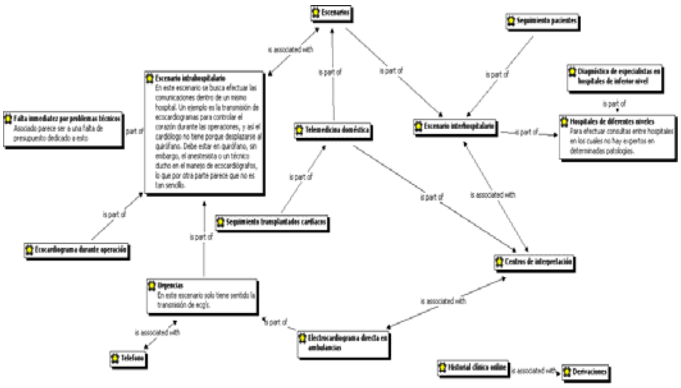

Fig.1. Relations network obtained with ATLAS-ti.

This knowledge allows selecting different but realistic proposals of environments where implementation of TM services and devices give responses to real problems: improvement of the quality of accessibility of medical services, the job of health-related professionals and the patient QoL.

On the other hand, the scenarios which can be selected as relevant from the previous analysis lead to varied technical situations. The different characteristics of each application or network technology may present very diverse QoS levels, which can have an important impact on the final application performance, mainly on multimedia real-time services. Thus, an accurate estimation of the network performance is critical for the success of any TM service. The most relevant parameters that influence QoS are Packet Loss Rate (PLR), End-to-End Delay (EED) and link capacity (C) which can be analyzed on the TM scenarios for the different applications.

Therefore, this paper proposes an integrated definition of an optimal scenario to implement a TM device taking into account organizational, user, and technical needs.

B. Implementation and evaluation.

This second phase study the implementation and evaluation of these technological requirements *in situ* (over the scenarios previously defined) by means of ethnographic methodology. In our ethnographical research, we adopt the sociological perspective of Actor Network Theory (ANT) [13]. ANT studies the relations established between human actors (people and organizations: physicians, doctors, patients) and artefacts (Electronic Patient Record (EPR), medical devices). From ANT, artefacts are understood as actors (like humans), because they have the ability to change relations in social organizations in a very meaningful way [14]. This perspective allows designing the possible scenarios and knowing the real user needs when the users interact with technology. From this knowledge, an efficient GUI can be designed collecting these cognitive, symbolic and practical characteristics of the use of ICT on daily tasks in the specific scenarios, as well as other cultural and organizational items that have been identified.

III. Results

A. Technical description

The main technical characteristics related to the considered telecardiology services are following described:

- *Teleelectrocardiology*. The use of the communication networks to transmit remotely the ECG (from a rural health centre or the patient home to the hospital) supposes an advantage in terms of time, money and QoL for doctors, patients and health service. The teleelectrocardiology [9] is based on the ECG signal, associated to electrical impulses that are generated by the heartbeat and acquired in a non-invasive way by several electrodes (between 3 and 12 channels). It uses sample frequency f_s=250Hz/channel, with resolution h=12-16bits; it implies mean ECG sizes S=10 MB. Usually these sizes are considerably reduced with compression methods in a factor 2:1 or 3:1 (lossless techniques), and 10:1, 15:1 or 20:1 (*lossy* techniques). The operation mode is usually SF: the ECG is pre-acquired and further digitally transmitted to the hospital. Moreover, other tests, such as emergencies, are based on RT mode.

- *Teleechocardiology*. The vital organs echography is usually used as the first diagnosis of the gravity of a patient. It is a non-invasive technique, based on the ultrasounds image [15], that does not produce ionized radiation and it is relatively cheap. The ECHO signal captures the ultrasounds obtained from video-images of the structures of the organism. The are several types of ECHO, but the most commonly used are based on images of 512x512, 640x480 or 1024x1024 pixels, with resolution h=8, 16 or 24bits/pixel, transmitting 24 images/s during several minutes. It is usually implemented in SF mode, but there are RT projects based on a portable echograph that allows the remote diagnosis.

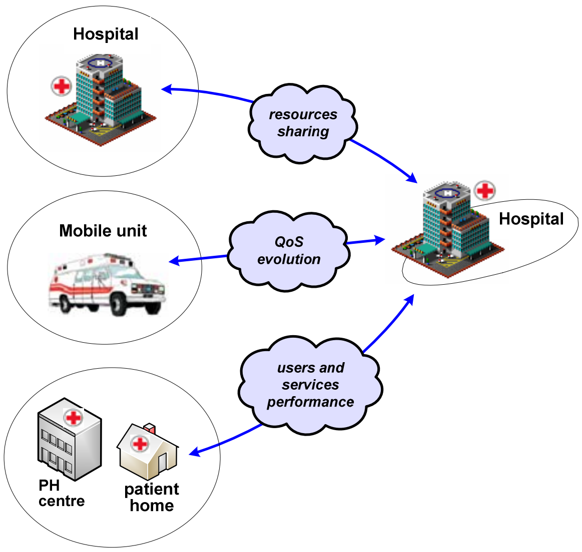

Fig. 2. E-Health scenarios considered in the study.

From these services considerations and a technological point of view, Fig. 2 shows a scheme of the main e-Health scenarios considered in this study. Thus, the technical description and analysis of these scenarios constitutes the previous step to select the most appropriate for assistance environments. This selection will permit to define the specific user requirements and to optimize the service design. These main generic scenarios are:

- *Hospital scenario*. Its basic characteristics are associated to the communication between doctors of different specialties (intra-hospital connections) or between doctors of the same specialty of different hospitals that share applications (inter-hospital connections). Since the intra-hospital connections do not usually suppose QoS or resources limitations, this scenario is focused in inter-hospital communications, based on switched broadband networks that share the available resources between different application types. Thus, the technological interest point is the evaluation of the resources sharing that permits to select the best parameters (compression rate, digital images resolution, etc.) in order to optimize the service and guarantee technical QoS.

- *Mobile scenario*. Its basic characteristics are associated to a high variability in the mobile link with network resources limitation and heterogeneous performance. In TM environments, it is focused in the interconnection between a non-specialist (from a mobile unit) and a specialist, during the run of the ambulance from the accident site to the closest hospital. Thus, the technological interest point is the QoS evolution regarding the network conditions.

- *Rural/home scenario*. Its basic characteristics are associated to the communication between a non-specialist (in the Primary Health (PH) centre) and the hospital in order to interchange medical tests and patient data. The PH can be located in a rural or metropolitan area but the difference is focused in the user profiles and the type of e-Health service. Thus, the technological interest point is the evaluation of the users and services performance, studying the optimum number of simultaneous e-Health services that permit to guarantee QoS from a technical point of view.

From this standpoint and regarding technological demands of biomedical signals RT transmission, a QoS may be good at rating what bandwidth is needed according to how many users are connected at the same time. An example of the QoS study on a rural TM scenario is presented now. In previous technical QoS studies [16] the recommended number of simultaneous users (m), regarding link capacity (C=k·64kb/s), has been evaluated. A simultaneity factor (m=m/k) has been defined as the addition of TM services (including videoconference, biomedical signal RT transmission and remote accesses to EPR) for each user access connection (with user rate transmission r≤64kb/s).

Fig. 3 shows the PLR/EED ratio for the most critical situations, closer to the specific QoS thresholds for TM services. Results obtained from the technical perspective in this scenario conclude, in generic terms, that for C=k·64kb/s, all the cases allow m=k simultaneous RT services and none case allows m=4k. This implies that the maximum number of TM services that the same PH centre can establish with the hospital varies between 2 and 3, for each 64kb/s. In those cases, the QoS is always guaranteed with m=2, and m=3 can be permitted depending on specific application parameters.

In summary, the results shown in this example indicate that these QoS studies permit to establish several good-performance areas and to determine the maximum number of simultaneous users, according to the available resources, in order to guarantee QoS. Thus, it could be interesting to monitor the number of simultaneous users and send a *feed-back* message (from the network to the user device) in order to manage the service parameters values. This adaptive control, recommended for the e-Health service design, is specific for every application. An example of the adaptive selection of parameters is shown in Fig. 4 in order to select the best value for the Maximum Burst Size (MBS), which defines how the information is generated by the multimedia applications and sent through the network, according to the monitored number of simultaneous users (N).

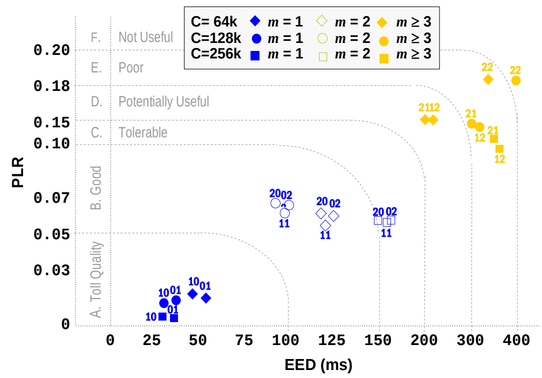

Fig. 3. PLR/EED ratio for the most critical situations of the multiplex factor (m) as a function of link capacity (C), in order to evaluate which combinations fulfill the recommended QoS thresholds in a rural TM scenario.

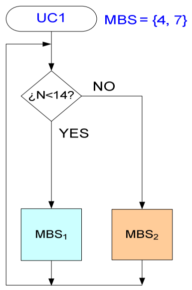

Fig. 4. Decision trees in order to select the best MBS values in the applications used for e-Health services in rural environments.

B. Optimal election of telecardiology scenarios and services.

The results of the first phase redefine the telecardiology scenarios: for example, home telecare only is really useful for patients with hearth transplant; but is also a privileged scenario for monitoring of chronic heart diseases –although it is only necessary to control basic parameters such as blood pressure and patient weight increases, which do not suppose challenges in network transmission. Thus, the results identify three relevant contexts in which the implementation of a TM system would be well valued by the cardiology experts:

I. Remote specialist consultation of ECGs and ECHOs, due to avoid patient and cardiologist displacements. It could be developed by means of an established protocol: for instance, a cardiologist from a rural hospital that consults periodically an expert from a third level hospital about its doubts with ECHO interpretations. Even it can have an occasional character, like in case of specific pathologies consultation in which the doctor that attends the patient is not as expert as another doctor located at a hospital in another city. And teleechocardiography can be very useful in rural or inter-hospital environment, because in this scenario the displacement of expert cardiologists for image diagnostic is often required. In this case, it is important to note that ECHO transmission requires the presence of a cardiologist or expert acquiring the test, in order to guarantee the quality of diagnostic images. On the other hand, the ECG transmission seems very useful in an inter-hospital scenario, specially when there are no experts in interpretation of ECG assisting patients.

II. Diagnosis interpretation outsourcing or cardiology test devices outsourcing. Tele-diagnosis services contraction, involves image transmission between professionals from different countries. And cardiology test devices outsourcing also involves image transmission, in this case between health organizations. In both cases it is necessary to transmit signs because there is no spatial and temporal coincidence between the people who administer the test and the people who interpret it.

III. ECG transmission is also interesting in a mobile scenario, where a fast diagnosis allows a fast treatment of some sharp heart diseases.

These results allow establishing the optimum scenarios to implement a specific design for the telecardiology systems that differs enormously: rural or urban contexts, home telecare or telediagnosis (sick sharp or chronic, punctual diagnoses, monitoring), extreme or well routine situations, etc. In every specific scenario, the telecardiology services can be optimized with a study of user requirements *in situ*, by means of ethnographic methodology [17]. The main objective of ethnographic methodology is to study real user needs in this specific scenario [18]. Ethnographic research allows integrating user needs and requirements with the previously described variables.

From all these considerations and after studying the user requirements in the chosen context, the second phase of the work would remain to be done. From the user-centred design perspective, in a further study these needs and requirements will be translated into recommendations for functionalities and design of a GUI device intuitive and easy to learn and use by patients or health-related professionals [19]. Thus, an evaluation of the demonstrator of the service will be performed not only from the technological point of view, but also from the user point of view in their specific context.

Finally and from these results obtained, we propose a listing of characteristics about health organizations, users and technical aspects in which the TM systems should be assigned to turn out to be more manageable. Evidently, these points are not axiomatic but they should be understood as luck of pragmatic norms to keep in mind:

- *Organizational aspects*: organizational culture (its important to explore the different meanings that health-related professionals give to their tasks and to the use of ICT), economic factors (the TM system must have a business plan economically sustainable), the adjustment to the scenario (a system can be very useful on a specific context and no sense in a different one), and the amount of information (in order to facilitate diagnosis, the system must take into account and be able to share important information about patients).

- *User aspects*: usability (the system must be easy to use and to learn), user profiles and requirements (take into account different levels of users in design), and the increase of volume of work (resistances from users can come from the increase of work in their tasks because of the implementation of ICTs).

- *Technical aspects:* low technology equipments in hospitals, technical problems, and security.

IV. DISCUSSION AND CONCLUSIONS

In order to answer the question about “not what technology can do but rather what must do”, it is remarkable the importance of an interdisciplinary work among health-related professionals, engineers, and social researchers, integrating organizational and user needs with technological requirements. Moreover, it is necessary to learn the user *know-how* in order to understand how people make sense of technology in their everyday life: frequently e-Health designs are without knowing about user specifications (e.g. patients do not want to wear something that stigmatizes them as “ill”). The results obtained demonstrate that each scenario (first diagnosis, emergencies, chronic illnesses monitoring) has its own set of rules that may be subsumed under the default encoding of a system already fixed on a laboratory-context if we do not pay attention to the user needs, attitudes, intentions, etc. Moreover, to get something to work (for years) is not only necessary that “it works out” but the device be accepted and appropriated [20] by real users.

In the case of the QoS there are questions that would be solved in further studies: decisions about resources availability as function of simultaneous users, plug-and-play and interoperability functionalities, decision making about priority among type of services, etc. Technologies do not only facilitate things, they also introduce more complexity in a context, heath, in which different positions about the management of these technologies coexist. The user and scenario centred design should emerge as an intermediate bridge between data processing and engineers on one side and health organizations on the other.

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