EMERGENCY TELEMEDICINE VIA WIRELESS HANDHELD DEVICES

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Abstract: Minimising the time required for a patient to receive primary care has always been the concern of the Accidents and Emergency units. Ambulances are usually the first to arrive on the scene and to administer first aid. However, as the time that it takes to transfer the patient to the hospital increases, so does the fatality rate. On the other hand, the evolution of telecommunications technologies, in connection with the robustness and the fidelity these new systems provide, have opened up many new horizons as regards the provision of healthcare and the quality of service towards the patients. The purpose of this paper is to present a mobile teleconsultation system which can permit biosignal transmission from the side of the patient to a doctor/consultant within a base station (usually a hospital). In addition to biosignals, voice and high quality still images of the patients and screenshots from medical equipment can also be sent. The system was tested and validated by both engineers and doctors. The results show that the system can perform satisfactory in most conditions and can effectively increase the patient's quality of service, while having a modest cost.

Introduction

The term tele-consultation, in its wider sense, refers to the application of synchronous telecommunication and information technologies, mainly towards the bidirectional communication between patients and medical experts, by means of audio-visual transmission, targeting the provision of medical care to remote patients. Studies conclude that a constantly increasing number of patients are monitored at home, aiming at the reduction of cost as well as the upgrade of the provided healthcare services [1]. Congestive heart failure, diabetes, asthma as well as high risk pregnancy are only a few of the patient conditions currently included in home telemedicine projects or programs.

One of the most important factors when trying to improve the healthcare delivery in emergency situations is the minimisation of time required to provide primary care (and most importantly consultation) to the patient. In most cases an ambulance has to respond to an emergency call, administer first aid and in many cases carry the patient to an Accident and Emergency ward in a close by hospital. Patients transferred that are in critical condition, would benefit by a faster access to medical expertise (that cannot be provided by staff operating the ambulance) and more specifically, direct interaction with either a doctor or a consultant.

According to the Annual Report of the National Centre of Immediate Assistance of Greece, for the year 1998, in 9 out of the 12 evolved precincts, a total of 461,341 ambulance calls took place . In the precinct of Attica (including the island of Evia), a total of 267,076 calls took place, i.e. 57.89% of the total. Emergency incidents summed up to a total of 371,281 calls, while chronic incidents summed up to a total of 90,060 calls, that translates to 4.12 emergency calls for 1 chronic patient. Out of the total 327,945 imports, 58,887 patients (17.96%) were imported via ambulances of the N.C.I.A., which equals a daily average of 161 imports [2].

Research Activities

One of the first innovative attempts that tried to improve the above situation and provide a wireless channel of information between the moving ambulance and a base station, was a project developed by the National Technical University of Athens in 1998; Emergency 112 [3]. The objective was to reduce treatment times, improve medical diagnosis, and minimise costs by developing an integrated portable medical device for Emergency Telemedicine. The device enabled physicians to provide pre-hospital care more effectively, as critical biosignals (ECG, BP, HR, SpO2, Temperature) and still images of the patients would be sent from the portable device to a base station situated either in a hospital or a medical centre.

Posterior attempts, involved transmission of larger image files (the increase in size was due to the increase in clarity and bit-depth of the images) as well as real-time video-conferencing between the patient and the consultant [4], [5]. The increase in bandwidth demand was made up for by the 3G networks recently deployed, that supported data transfer rates up to 384 Kbps. After all, when conceived, 3G telecommunications networks aspired to provide bit rates up to 2 Mbps to low mobility users and up to 144 Kbps to high mobility users, while being compatible with the 2G GSM system [6].

The most recent attempts to improve the overall teleconsultation scheme involved the utilization of wireless handheld devices. Approaching in dimensions a deck of playing cards, these hand-held devices are surprisingly powerful computers that can store data, share files with computers, display graphs and images, and rapidly exchange information. With new wireless technologies, some smart phones even have the capability to access email or the Internet anytime, anywhere.

Originally designed to organize the fast-paced schedules of businesspeople, smart phones are beginning to make inroads into some unexpected places. For example, at Consolidated High School District 230 located in Orland Park, IL, high school students are using PDAs and attachable sensors to monitor pH levels, temperature, dissolved oxygen, heat, and other qualities of a nearby pond. Immediately, the information collected by the sensors is recorded on student PDAs and data can be graphed immediately. In addition, GLOBE (Global Learning and Observation to Benefit the Environment) students are using hand-held computers in the field to document precise measurements and GPS (Global Positioning System) readings.

PDAs have also been used as physiological monitoring systems by other researchers [7], while mobile phones have also had their share in telemedicine systems design [8]. Nevertheless, the majority of the research efforts does not provide evidence-based information about the use of handheld devices in medicine [9].

The objective of this paper is to present the readers with an innovative wireless teleconsultation system, that can easily be installed inside an ambulance and be used for emergency situations, or even be used for home care, and thus effectively increase the patient's quality of service, while having a modest cost.

Methodology

The mobile teleconsultation system proposed in this paper consists essentially of 3 hardware components: a CE certified medical monitor , a commercial RS232 to Bluetooth Converter and a commercial 3G, Bluetooth enabled smart phone, running on Windows OS.

The medical monitor is responsible for the collection of the critical biosignals (ElectroCardioGraph, Blood Pressure, Oxygen Saturation and Temperature) from the patient, via corresponding sensors, as well as for the extraction of the aforementioned biosignals through its integrated serial port.

The extracted data in turn go to the RS232 to Bluetooth Converter. The available bandwidth (coming up to a maximum of approximately 100 Kbps actual data transfer rate) allows for real-time transmission of the data. Afterwards, Bluetooth technology takes over in order for the smart phone and the converter to establish a connection for the transmission of the data. The smart phone becomes the master and the converter becomes the slave in a typical Bluetooth topology. This converter intervenes between the medical monitor and the smart phone, allowing for wireless straightforward connection between these devices, thus establishing a true wireless replacement solution.

The smart phone, after having received the biosignals, is in turn responsible for the transmission of the medical data, as well as for the still images taken via the device's camera, from the patient or the medical equipment, to the consultant. The consultant might either be inside a hospital using fixed or wireless networks (xDSL or WLAN respectively) or even be on the move. For the transmission of the data the smartphone utilises any of the telecommunications networks available, namely GSM, GPRS, or even the 3G network that was only recently deployed in Greece covering a significant geographical area.

The procedure followed is illustrated in the folloing figure:

Figure 1. Proposed teleconsultation system

A series of tests were conducted in the city of Athens in order to evaluate the system. The system was not tested on actual patients, yet they were simulated with healthy volunteers. The transmission started when the paramedics reached the accident site and ended on the arrival at the hospital. Thus transportation times and factors regarding the mobility of the vehicle were taken into account.

Approximately 10 hours of biosignals were transmitted to be evaluated by the consultants and 60 images were transmitted in order to evaluate the acceptability of the delay and the network throughput. The images transmitted were medical images of different resolution and thus byte size. The results are summarised in brief in Tables 1 and 2.

Results

This paragraph presents the results of the tests conducted, regarding the efficiency of the proposed scheme. The transmission of the biosignals did not pose any significant and worth-analysing strain as regards the bandwidth required, since real-time transmission of both arithmetic data and waveforms were merely in the order of a few KB.

What was worth measuring, was the transfer time of the medical images of variable format, resolution and bit-depth, after having established connection with a 3G network cell. The time required for the cell phone to

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register to a cell is not calculated. The results are presented in table 1.

Table 1: Engineering Evaluation

Resolution	Size (KB)	Total Transfer Time (sec)	Network Throughput (Kbps)
Lowest	81	16	40.5
Low	289	59	39.2
Medium	423	83	40.8
High	514	101	40.7
Highest	1025	204	40.2

Of equal importance is the fact that as the system handed over from one 3G cell to another, the transaction was very smooth and literally undetectable to the user, as the mobile terminal was connected to both cells during the HO period. CDMA systems can provide the means for active connection maintenance between the mobile terminal and the network, over several radio links, which can also be activated through different radio base stations. In the channel changing stage, typical of the hand-over process, connection continuity is guaranteed through the multiple paths set up between the mobile terminal and the "controlling point" in the network [10].

Nevertheles, when the system handed-over from a 3G cell into a 2.5G or 2G cell, there were some inevitable delays as the terminal had to reregister to another cell. At those times, the transition from one cell to another was perceivable by the users. Impermanent losses of signals may not be crucial in many real time applications, yet is crucial in cases where healthcare delivery is concerned and human lives are at risk. Delays varied from 5 to 15 sec. One such 3G to 2.5G handover procedure is depicted in Figure 5.

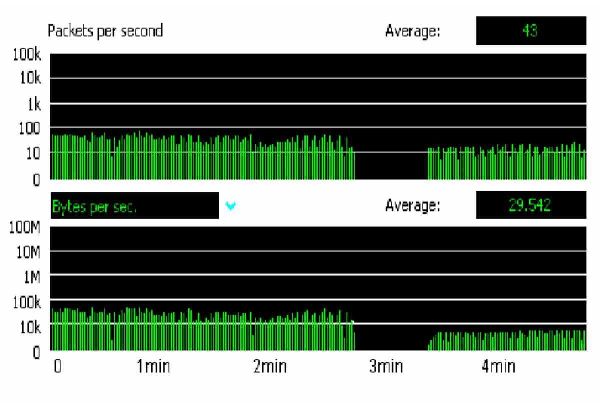

Figure 2. 3G to GPRS handover procedure

Apart from the engineering evaluation, the system was also evaluated by medical consultants. The following table illustrates the general impression of the consultants who used the teleconsultation system and were situated in a base station (which is usually a hospital) monitoring the patient's condition. The consultants' evaluation regarded mainly three parameters: the clarity of the images sent, the total delay of the data transmission, and the added value of the proposed scheme.

Table 2: Medical Evaluation

Factor	Poor	Acceptable	Good
Image Clarity	10 %	65 %	25 %
Total Delay	5%	50%	45 %
Added Value		25 %	75 %

The overall system performance has met or even exceeded the expectations of the personnel involved, and showed that the system can be effectively deployed on a larger scale.

Benefits and Limitations

The telemedicine system proposed here made use of wireless handheld devices, namely an RS232 to Bluetooth converter and a smart phone. Smart phones as stated earlier grand the user with a load of features, while remaining fully functional despite being small in size.

One of the most attractive features of handheld technology is that the devices, depending on their features, are reasonably affordable when compared to desktop computers. In addition, compared to laptop computers, handheld devices are much more compact and lighter, and thus can be carried everywhere. On top of that, these devices disengage the user of cords, granting great freedom as regards the user's mobility. Furthermore, Internet enabled handheld devices can provide quick, convenient and discreet Internet access.

Handheld devices are designed to communicate with personal computers and thus information exchange between such devices is rather uncomplicated and straightforward, while smaller volumes of data such as memos and contact info can be exchanged via the widely supported infrared feature.

Last but not least, handheld devices offer great performance while providing more efficient use of memory and processing power, which also contributes in the reduction of size and weight of such devices.

On the other hand, being small in size causes a great limitation to the size of the screen, making it impractical and difficult to view detailed images. Further, due to their small size, smart phones are not particularly useful for inputting or editing large quantities of text.

Discussion

As stated earlier, the proposed scheme can be used in both emergency situations as well chronic incidents. The usage scenario follows: As illustrated in Figure 3, either the patient is at home, on the move or involved in a car accident, the user of the proposed scheme can register to any available network via his smart phone and establish a conferencing session with a consultant, who can either be at a hospital using a fixed line (e.g.

xDSL) or on the move as well. The user can also send static images of the patient or of medical equipment that might be monitoring the patient (e.g. during transportation of patients inside a moving ambulance).

Transmission of medical images is vital since a significant percentage of accidents lead to incorrigible mistakes. For example, in many cases of multi-injured persons, the victims should only be moved by experts and in a specialized manner. The optical perception of the patients from the experts can increase the viability of such accidents. Yet, what is even more helpful and facilitated nowadays via telecommunications networks of greater bandwidths is the transmission of real time video, in which case the doctors have a substantial apprehension of the patient, and the patient feels more secure just by having a visual contact of the remote doctor.

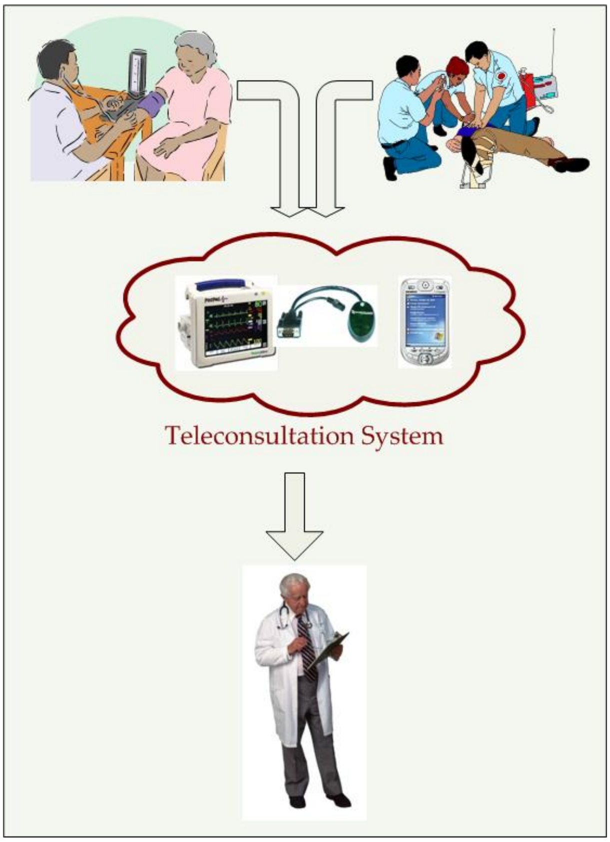

Figure 3. Usage Scenario

The capabilities of the proposed infrastructure expand to a wide range of applications of healthcare delivery. Thus, it can be applied to chronic patients, for example diabetic patients, whose glucose levels can be monitored either at home or while on the move and be transmitted to their healthcare providers, as well as benefit the provision of healthcare in rural centers. Young doctors don't want to take full responsibility of the patients. The contact with specialized doctors would significantly uplift these young doctors and reduce patient transportation rates, thus reducing costs.

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