Proceedings of the 26th Annual International Conference of the IEEE EMBS
San Francisco, CA, USA • September 1-5, 2004

Mobile Telemedicine System for Home Care and Patient Monitoring

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Abstract— **Home care services are growing up in the past years. Contemplating the patient/family pair, it represents a solution to the medical problems of the modern life. With the social trends, the senior population has been increasing in the last years. However, as living is more stressful than ever, there are more cases of chronic diseases. The difficulties of transport in the big cities and the scarcity of hospital streambeds turn the home care an attractive solution. However, its routines can be switched by telemedicine. This paper describes the implementation of a telemedicine system for patient monitoring using mobile telephony. The major aspect about this application is its generality, which allows the use of any patient monitor with a RS-232 interface. The system proved to be quick and reliable. Therefore, it represents an applicable solution to telehomecare.**

Keywords— **Home care, mobile telephony, telemedicine, vital signals retrieval, XML export format**

I. Introduction

Once there are more senior citizens and chronic diseases than ever, the number of people who need constant assistance increased a lot. Also, patients are being discharged from hospitals early and often require additional health care services and monitoring of their health status [1]. Nevertheless, the current scenery reflects in long patient and operation waiting lists, shortages in hospital beds, community care and inadequate medical facilities in intensive care and emergency units [2]. Additionally, the high costs involving the conventional internment and the frequent problems in patient transporting do necessary a different way of providing good medical care. Thus, home care services are becoming rather important in the last few years.

Conventional home care basically involves a fixed and limited number of visits by a trained nurse to a patient's home. All activities during these visits are controlled by the nurse: they may include vital signals recording, general assessment of the patient's therapy progress, medication and patient's instruction on particular needs observed during the visit [3].

Many parties had already proven that these procedures could be switched by telemedicine applications. The term telemedicine refers to the utilization of telecommunication technology for medical diagnosis, treatment and patient care [4]. It also can be described as the transfer of electronic medical data from one location to another [5]. This second definition is mainly relevant once it retrieves to the vital signals recording and monitoring, which are necessary for the implementation of a telehomecare system.

Recent breakthroughs in communication technologies have stimulated the development and demonstration projects in telemedicine [6]. There have been many studies to provide a solution to telehomecare. They include GSM, satellite communication etc. Particularly, mobile telemedicine is a new research area that exploits recent advances in cellular telecommunications networks, which provide the potential for highly flexible medical services that are not possible with standard telephony [7].

Actually, the mobile phone has been recognized as a possible tool for telemedicine since it became commercially available [8]. In fact, the mobile telephony has evolved a lot and offers new devices with some useful resources, such as serial ports and Internet connections. Therefore, the phones can interact with electromedic devices (EMDs) – like patient monitors, for example – and transmit vital signals through Internet protocols, such as TCP/IP and UDP.

Indeed, the use of the Internet by health care providers, and certainly their patients, has seen dramatic increases in the past few years [9]. The Internet protocols represent highly tested tools for transmitting general data. Medical data – such as heart rate, ECG, temperature and other vital signals – can also be grouped in packets and transported through TCP/IP and UDP. Finally, employing standards usually represents a good plan when developing systems that may interact with other applications.

This paper describes a mobile telemedicine system for home care and patient monitoring. The system takes advantage of the serial port available in new mobile phones to implement a generic interface for patient monitors. The vital signals are acquired from the EMD using the RS232 interface and transmitted through Internet.

II. Methodology

Telehomecare services are based in client-server architecture. There is a server application (normally, sited in a hospital) which storages and makes available the incoming vital signals came from the clients. The client, in its turn, is responsible for acquiring data from patient monitors and transmitting them through Internet. Fig. 1 shows the system schematic.

At his home, the patient is connected to the patient monitor. So, the EMD acquires the usual vital signals, such as ECG, heart rate, blood pressure, SPO_2, respiration rate and temperature. Next, the mobile phone connected to the monitor receives the information through the RS232 interface.

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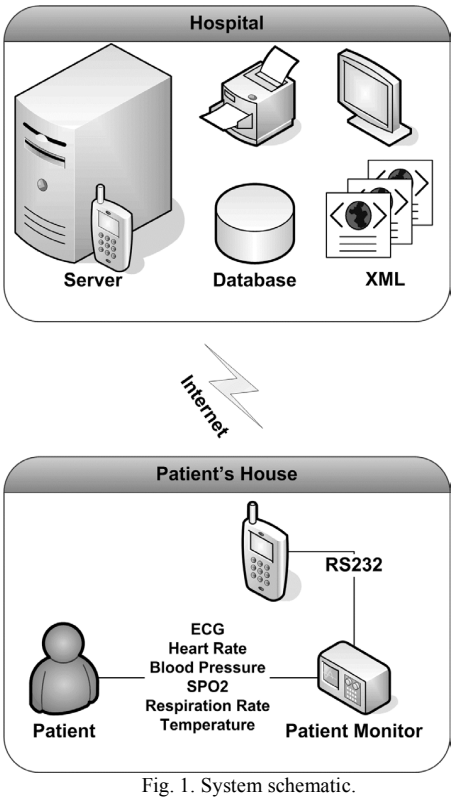

Fig. 1. System schematic.

The signals are converted in packets and transmitted to the server using TCP/IP and/or UDP protocols. The server settled in hospital stores data in a relational database. Then, health care providers (HCPs) monitor their patients using the server application. Also, signals can be exported to XML files or printed.

A. Client Side

Most of the existing patient monitors present traditional and reliable signals acquisition capabilities. Nevertheless, this kind of equipment usually is not developed aiming the connectivity. Most of these monitors and alarms are historically serial-port (RS232 standard) based [10]. Additionally, each vendor is used to develop its proprietary communication protocols. Thus, it becomes necessary to implement drivers for the different equipments. As developing them presents a hard task by itself and it is not inside the system's scope, a generic driver was modeled. It can be specialized for all protocols. In the current project, the driver was implemented and tested to communicate with an Agilent A3 patient monitor [11].

The client application, including the communication protocol, runs over the mobile phone. It is implemented using the Java MIDP. MIDP stands for Mobile Information Device Profile. It provides the core application functionality required by mobile applications - including the user interface, network connectivity, local data storage, and application lifecycle management - packaged as a standardized Java runtime environment and set of Java technology APIs [12].

Once the client application is supposed to be utilized by patients, its interface should be simple. Therefore, the MIDP program was specified to have few commands and simple options, making easier to the user. Since the platform is a mobile phone, all the software was designed to not be different from the usual programs in this kind of device. Actually, the client side was projected with just four screens: main, setup, equipment and connect. The screens allow the choice of patient monitor, the patient's ID and the connection with the server.

B. Server Side

In the application of telemedicine, the medical information usually needs to be distributed among medical doctors and display, archival, and analysis devices [6]. Therefore, the server side was developed with the purpose of receiving, storing and distributing the vital sign data from patients. It was developed under Java technology too. So, many classes were reutilized.

Basically, the server is composed of a Java application and a relational database. The application offers the follow features: a) list of patients; b) personal information about patients; c) visualization of vital signals; and d) data export. The doctor controlling the server has several tools to work with ECGs. It is possible to list, visualize (with a zoom option) and export to PNG format. The ECG can be also printed. Because XML [13] has becoming an important standard in computer science, it was utilized as an export format. The codification scheme implemented in XML is described elsewhere [14].

III. Results

The system was implemented as previously described. As mentioned, both client and server side utilized Java programming language. Fig. 2 shows the four screens of the client application. A XML exported file is presented in Fig. 3. The server application is shown in Fig. 4.

The system guaranteed the transmission of a packet per 600 milliseconds, e.g. the measured baud rate was 3400 bps. So, an ECG signal sample with 5000 bytes approximately takes 30 seconds to be transmitted. Other signals, such as heart rate and temperature, need 2 seconds. Furthermore, lost packets are tracked, once it is implemented cyclic redundancy code (CRC).

IV. Discussion

As the transmission is digital, there is no noise in the signals. It represents an important feature because noise effects commonly hardly affect telemedicine systems. The

baud rate allows the transmission of vital signals without problems. The discrete signals (heart rate, blood pressure and temperature, for example) are quickly transmitted. Nevertheless, spending 30 seconds to transmit an ECG signal sample does not represent a big problem.

The system can interact with other applications through the XML exported files. Using standards represents an important step for integrating telemedicine systems.

Fig. 2. Interface on mobile phone.

```
<vital>
 <patient id='1234' name='Anonymous'
      birthday='20/04/1981' gender='M'>
  <historic>
   <evaluation date='02/12/2003' time='12:03:29'
      id_responsible='123' id_equipment='12'>
    <signal type='heart_rate' value='65'
      unit='/min' />
    <signal type='spo2' value='98' unit='%' />
    <signal type='mean_arterial_pressure'
      value='100' unit='mmHg' />
    <signal type='temperature' value='36.5'
      unit='C' />
   </evaluation>
  </historic>
 </patient>
</vital>
```

Fig. 3. Exported file.

V. CONCLUSION

Home care represents a growing field in the health assistance [15]. It reduces costs and increases the quality of life of patients. As the modern life becomes more stressful and acute diseases appear, prolonged treatments become more necessary. The same occurs for the elderly or handicapped patients. Home care offers the possibility of treatment in the patient's house, with the assistance of the family. It reduces the need of transporting patients between house and hospital.

Fig. 4. Server application.

As previously explained, the home care routines can be switched by telemedicine applications. Actually, this switch is also called telehomecare, which can be defined as the use of information and communication technologies to enable effective delivery and management of health services at a patient's residence [1].

This paper presented a telehomecare system using mobile telephony. The application was designed for remote patient monitoring. Its capability of utilize standard patient monitors allows the use of telehomecare without deprecating the current EMDs. This feature makes it an important platform for future studies and products.

Recent studies conclude that early and specialized pre-hospital management contributes to emergency case survival. The system can also be applied in emergency telemedicine applications in reason of its mobility. Such application was done in Greece [16].

The relevancy of standards and codification schemes has been highly debated. The proposed system utilized XML and EDF+ for storing acquired data. The implementation of such features is described elsewhere [14], as mentioned before. Furthermore, the exportation to XML allows the possibility of integration with other projects. As an example, artificial intelligence systems could also monitor patients.

ACKNOWLEDGMENT

The authors thank to Rafael E. R. Christ, Guilherme N. Nogueira-Neto, Peter Marik and Robert C. Burnett for their assistance.

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