PATIENT TELMONITORING AT HOME

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Abstract- **One of the biggest problems in hospitals today is the increase of costs associated with the treatment of patients, especially in the case of the elderly. This trend makes it necessary to adopt new strategies in order to reduce such costs and, at the same time, maintain high levels of care that is provided to patients. One way to reduce such costs is by moving patients to non-specialised areas or, if possible, to his/her home as soon as possible.**

In this paper we present a remote monitoring system capable of monitoring the state of a patient 24 hours a day, 7 days a week through the analysis of parameters extracted from the electrocardiographic signal (ECG) and reporting any anomaly to the hospital. One important feature of the system is its flexibility for providing users with access to monitoring information. In order to do so, the system is equipped with two complementary interfaces, being capable of giving integral access to monitoring information at any time, any place and from any location in an optimal manner.

***Keywords* - Telemonitoring of patients, telemedicine, ECG monitoring.**

I. INTRODUCTION

According to Lin [1], the term *telemedicine* is applied to the use of the telecommunications technologies for the diagnosis, treatment and care of patients. Telemedicine enables the specialist physician to send diagnoses, supply medical care, propose treatments and communicate with medical and/or paramedical staff at a remote location. Therefore, the aim of telemedicine is to supply specialised medical treatment to remote areas through the use of information and telecommunications technologies.

Telemedicine is at present being applied in many fields, with radiology, pathology and cardiology currently being the most advanced. Nevertheless, other fields, such as for example, dermatology, neurology, ophthalmology o surgery, are also benefiting from these new technologies.

In terms of only the patient's home, when speaking of telemedicine, we can basically differentiate between:

a) *Tele-care,* which is the medical care delivered to a patient at his/her home by medical staff using telecommunication systems. This includes instructions to correct administering drugs, tele-assistance through urgency phone calls, etc.

b) *Tele-monitoring* of vital signs and other physiological signals: blood pressure, temperature, heart rate, etc.

This paper deals principally with the second task and, more specifically, with the remote monitoring of the ECG signal. Patients that may benefit from the use of ECG telemonitoring systems are, for example, those subjected to dialysis treatment, where the availability of a telemonitoring systems together with a portable dialysis system may drastically reduce the number of occasions that they have to attend the hospital, as well as patients that are convalescing after an acute myocardial infarct. In this regard, only a small number of monitoring systems designed for monitoring patients at home are described in the literature. Some examples are Telecardio [2] and the one described by Bai *et al.* [3]. Nevertheless, such systems usually present the following problems: firstly, they are designed over non-standard devices that make the replication of the system expensive and, secondly, they significantly restrict the mobility of patients, since the size and weight of the system means that it is not portable. On the other hand, in other solutions that attempt resolve both problems [4], the processing that is carried out on the acquired signals is either highly unsatisfactory or non-existent.

II. ARCHITECTURE OF OUR TELEMONITORING SYSTEM

The different elements that make up our monitoring environment are (Fig. 1):

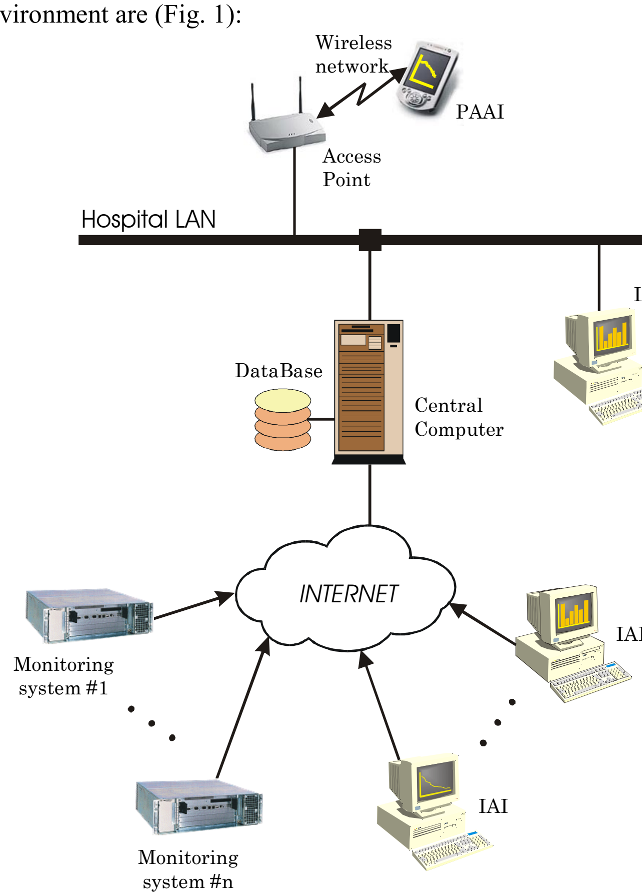

Fig. 1. Architecture of the telemonitoring system (user's viewpoint).

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1. A central computer located at the hospital. This system has the task of centralising all information received from the patients being monitored. It has a database (Oracle) in which all information of a permanent nature is deposited, and which will go on to form part of the clinical history of the patient. The system has also a web server, so all the monitoring information will be available using a web browser.
2. A monitoring system for each patient that will be installed on his/her house and will communicate with the central computer at the hospital. The system comprises three main blocks (Fig. 2): a commercial acquisition system based on the X-12 Digital Transmitter by Mortara Instruments[1], a CPU with the task of processing the information supplied by the aforementioned acquisition system and a PDA to communicate with the patient.

The commercial acquisition unit is physically attached to the patient and has the task of acquiring the ECG and any other physiological signals that may be of interest. This system makes it possible to acquire the 12 standard ECG leads up to a frequency of 500 Hz. All this information is transmitted by radio on the 2.4 GHz ISM band to a PCMCIA card that is equipped with a receiver that is installed in the monitoring system itself. All this information is processed in the CPU, and if any anomaly is found, this information is transmitted to the central computer at the hospital. In order to do this, the system is structured according to a flexible, modular software architecture that is based on a set of processing levels made up of tasks having similar activation frequencies. The following are some of the processing levels of which our monitoring system is made up of: firstly there is a set of tasks which are triggered with each new sample of signal that is acquired and which, amongst others, has the task of digitally filtering the detection of beats from the ECG signals; there are then those tasks that are carried out each time that a beat is detected, and which, amongst other things, are responsible for morphologically classifying the beat that has been detected or extracting from it a set of parameters, such as, for example, the height and width of some of the waves making up the cardiac cycle; on this set of parameters the tasks associated with the processing level charged with detecting clinically significant episodes (such as, for example, ischemic episodes) are executed.

In order to transmit all this information to the hospital, the CPU is connected to a PSTN, ISDN or ADSL network. The latter two options are generally recommended, due to their greater band-width and the possibility of being able to use a telephone line even when the system is connected to the network. Additionally, the patient is equipped with a PDA that communicates with the CPU through a wireless network and which serves as an interface between the monitoring system or the medical staff at the hospital and the patient.

3. A set of systems to facilitate the access to monitoring information to the medical staff at the hospital and the infrastructure to support them.

[1] http://www.mortara.com/oem.htm

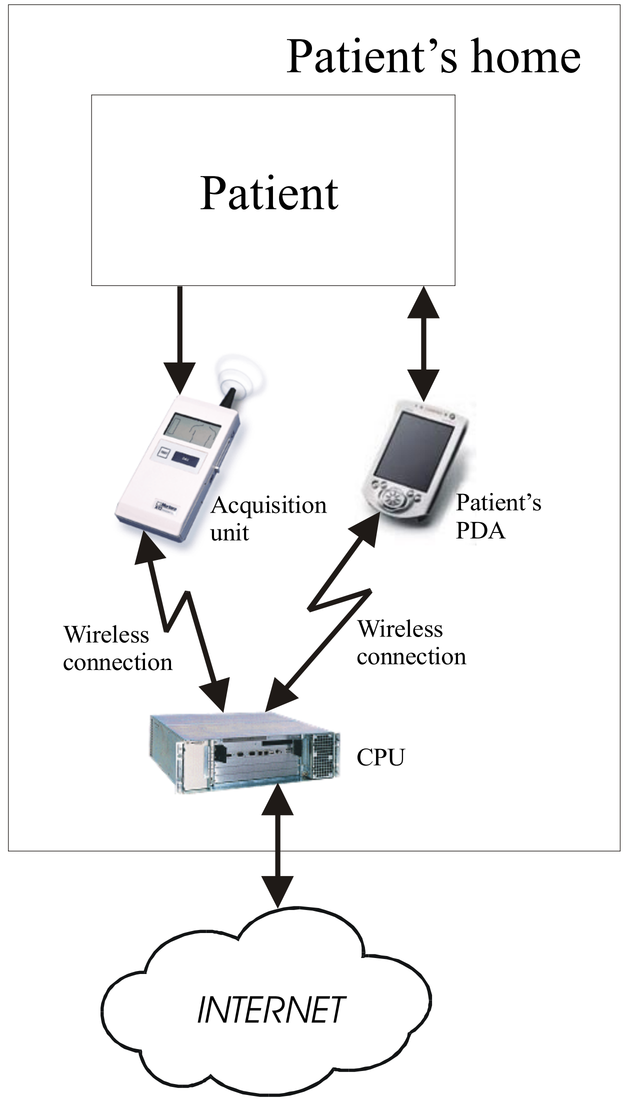

Fig. 2. Architecture of the telemonitoring system (patient's viewpoint).

III. Access to Monitoring Information

In order to facilitate access to monitoring information to the medical staff, we have developed two interfaces with different capabilities [5, 6]. These devices will receive information from the central computer at the hospital:

a) Integral Access Interface (IAI). This interface should be executed on a personal computer and has been developed taking into account independence with respect to the hardware being employed. In order to do so, we have developed this interface in Java. To execute this interface one only needs a personal computer loaded with a Java capable Web browser connected to Internet. The IAI fulfils the function of allowing remote access on the part of the specialist to information available on the patient, even when the physician is not physically in the CCU of the hospital itself (in this case, via Internet). Nevertheless, the need for suitable hardware, the size of which may be excessive (even when dealing with a laptop computer) could make this interface ineffective for the continuous monitoring of the patient. For this reason, we have developed another interface that is more appropriate in such situations.

b) Personal Access and Alert Interface (PAAI). The PAAI is a palm-top computer based user interface, the function of which is to alert the user each time that an alarm is received at the central computer. This is a nomadic device with a wireless communication card for connecting up to the central computer and for receiving information [7].

The PAAI is an event-driven interface. Each time that a significant event takes place the PAAI is notified. The system is provides the user with two time-dependent channels, which we classify as signals or parameters, depending on the frequency of acquisition. For the patient that has generated the alarm, the user will have a pre-established set of two default signals and two default parameters which he/she may wish to analyse, so that together with the notification of the alarm he/she also receives a 30-second sample of both signals (for example, the ECG at lead III and the arterial blood pressure) and a 30-minute sample of both parameters selected (for example, heart rate and ST deviation at lead III), always from a time zone close to the onset of the alarm (Fig. 3). At any moment in time the user can select a previous alarm and select another set of signals and parameters to visualise, so the system's limitation of showing only two signals or two parameters at any one time (due to the display resolution) does not constitute a significant problem.

Fig. 3. An example of interaction with the user by means of the PAAI.

IV. One possible scenario

We now go on to describe a possible scenario as to how our system could be used:

Patient X has recently suffered an acute myocardial infarct due to which he has had to be admitted to Casualty in the nearest hospital to his home. Once the nature of his ailment has been determined, he is admitted to the Intensive Coronary Care Unit, where he is subjected to a specific treatment, his temporal evolution being supervised with a bedside monitor.

After a reasonable period of time, and after having progressed satisfactorily, the medical staff decide to discharge him from the hospital. From the specialist in the Unit's point of view, the possibility of being able to carry on maintaining a certain degree of supervision over the patient is something which, is highly positive in these types of cases.

In order to use our system, hospital technicians will previously have to visit the patient's home to install the telemonitoring system, and to then teach him the basic instructions for its use. The equipment that is installed in the patient's home, as has already been mentioned, basically comprises three elements: a CPU connected to a telephone line, an acquisition system to which the patient is physically connected and a PDA.

The acquisition system wirelessly transmits the information acquired to the CPU, where it is processed. Due to the limitations imposed by the range of this transmitter, the patient will have to remain in close proximity to the CPU at all times; nevertheless, this is not such a severe limitation as the transmitting range is between 50 and 100 metres, depending on the obstacles that are present.

The signals received are processed in the CPU, and from these the set of parameters that describe the patient's physical state are extracted. This information is periodically transmitted by the CPU via telephone to be stored in a data base in the central computer at the hospital. Thus, each time that a clinically significant event occurs (e.g., ventricular tachicardia, ischemic episode, etc.) the system immediately contacts the central computer in order to inform on the said event. Once this information is stored in the central computer, it can be immediately accessed from both the IAI and the PAAI.

Regarding the patient's PDA, this serves as an interface with the monitoring system and its supporting infrastructure at the hospital. This device is connected to the CPU via a wireless communication network, it being supposed that the patient should carry it with him at all times, although it is not necessary to have it permanently upon his person, in the same manner as for the acquisition system. This PDA has three basic functions: to inform the patient of any sort of problem the may arise and the action that should be taken (e.g., if there is a tachycardia, rest is recommended), to serve as a pocket dairy to remind the patient when he should take a specific drug, and to act as a triggering mechanism at the patient's behest. Given that may be possible in the case of the patient wishing to trigger the alarm (e.g., in the event of palpitations) the PDA may not be at hand, it is also possible to trigger the alarm via a button on the acquisition system.

V. Discussion

The system herein described is currently at an advanced stage of its development, with the participation of the University Hospital of Alicante, Spain. It should be pointed out that the possible use of this system is by no means limited to patients who have actually been admitted to the ICCU, rather it is suitable for use with any type of patient requiring constant supervision over a period of time, fundamentally dealing with cardiovascular variables. This is the case, as we have already pointed out, of diabetic patients during periods of dialysis. Another possible field for its use could be the monitoring of the elderly. Nevertheless, the majority of experiments in the field of telemedicine have basically concentrated on tele-care and not on tele-monitoring, in spite of the promising results given by it economic and clinical benefits [8].

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References

[1] J.C. Lin. "Applying telecommunication technology to health-care delivery: the current status and challenges of telemedicine," *IEEE Eng. Med. & Biol. Mag.*, vol. 18, pp. 28-31, July/August 1999.

[2] J.P. Silva Cunha, M. Baptista, A. Ribeiro and A. Sousa Pereira. "Telecardio: especificação técnica e funcional do demonstrador de telecardiologia," Internal report INESC, INESCTEL and DID/CET, Portugal, 1998.

[3] J. Bai, Y. Zhang, D. Shen, L. Wen *et al*. "A portable ECG and blood pressure telemonitoring system," *IEEE Eng. Med. & Biol. Mag.*, vol. 18, pp. 63-70, July/August 1999.

[4] K.Y. Kong, C.Y. Ng and K. Ong. "Web-based monitoring of real-time ECG data," *Computers in Cardiology*, vol. 27, pp. 189-192, 2000.

[5] S. Barro, J. Presedo, D. Castro, M. Fernández-Delgado, S. Fraga, M. Lama and J. Vila. "Intelligent telemonitoring of critical care patients," *IEEE Eng. Med. & Biol. Mag.*, vol. 18, pp. 80-88, July/August 1999.

[6] J. Presedo, D. Castro, J. Vila, M. Fernández-Delgado, S. Fraga, M. Lama and S. Barro. "Wireless interface for monitored patients in Coronary Care Units," *World Congress on Medical Physics and Biomedical Engineering. Chicago 2000.*

[7] J. Zyren and A. Petrick "IEEE 802.11 Tutorial," *Wireless Ethernet Compatibility Alliance*. (http://www.wi-fi.net/downloads/IEEE_80211_Primer.pdf). 2001.

[8] A.J. Sixsmith. "An evaluation of an intelligent home monitoring system". *Journal of Telemedicine and Telecare*. vol. 6, n. 2, pp. 63-72, 2000.