Wireless Sensor Network to Support Home Care in Telemedicine Applications

Silvia Jiménez-Fernández
Grupo de Bioingeniería y Telemedicina, Universidad Politécnica de Madrid, Spain

Antonio Cobo-Sánchez-de-Rojas
Grupo de Bioingeniería y Telemedicina, Universidad Politécnica de Madrid, Spain

Álvaro Araujo-Pinto
Laboratorio de Sistemas Integrados, Universidad Politécnica de Madrid, Spain

Pedro Malagón
Laboratorio de Sistemas Integrados, Universidad Politécnica de Madrid, Spain

Octavio Nieto-Taladriz
Laboratorio de Sistemas Integrados, Universidad Politécnica de Madrid, Spain

Paula de Toledo
Grupo de Bioingeniería y Telemedicina, Universidad Politécnica de Madrid, Spain

Francisco del Pozo
Grupo de Bioingeniería y Telemedicina, Universidad Politécnica de Madrid, Spain

INTRODUCTION

The care of patients suffering from chronic diseases is a growing source of expense for health care services around the world. The implementation of new models for patients' treatment and follow-up needs to be faced in order to increase patients' quality of life, and to reduce the costs associated. In this article, we propose a point-of-care for home care scenarios that is based on the remote monitoring of biomedical parameters.

BACKGROUND

Research experiences in the past have proved that home care can maintain or even improve old or chronically ill people's quality of life, as well as decrease health care costs associated. Home care delivery can still be improved through advances in human-machine interfaces that enable users (i.e., mostly old people) to deal easily and nonintrusively with technology (Ades, 2000; Hernandez, Casas, Escarrabill et al., 2003; Morlion, Knoop, Paiva, & Estenne, 2002). Many limitations brought on by aging are expected to be overcome by innovation in the area of Ambient Intelligence (AmI) (Cucchiara, Grana, Prati, & Vezzani, 2005; Trivedi, Huang, & Mikic, 2005), and focused on the design of devices easy to use and easy to learn that work transparently and pervasively to aid the user (Remagnino & Foresti, 2005).

Therefore, next generation home care and follow-up systems have important challenges to face, such as the development of nonintrusive systems that provide the right medical services on a highly-usable basis or systems that require minimum human-machine interaction to promote an augmented environment while making computers disappear in the background. Of course, it is important to make these necessities possible by means of developing affordable solutions for public and private health care institutions, only achievable with low cost structures easy to install and to maintain.

In order to achieve these requirements, we propose a Wireless Sensor Network, based on a Home Area Network (HAN), featuring a gateway, several biomedical sensors (pulse oximeter, electrocardiograph, and accelerometer to quantify daily activity) that the doctor recommends to the patient to control his/her health and a user interface, key element to inform the user of events registered (such as start of the exam, low battery supply, etc.). All network nodes are provided with wireless capabilities to allow full mobility (ISTAG, 2002).

THE BIOMEDICAL WIRELESS SENSOR NETWORK

Requirements

The requirements taken into account when designing the home care point-of-care have been mainly: self-management, context awareness, plug-and-play features, and security. Due to the need to achieve wearable and low cost sensors, limited resources in processing power have also been taken into account.

Regarding self-management and plug-and-play capabilities, the point-of-care has been designed to automatically route data packets. That is to say that the user does not have to consider nodes' breakup, or the addition of new nodes/sensors to the network, as they are transparently recognized and managed. For security reasons, data coming from new sensors is not sent to the telemedicine server until approved by it.

The nodes of the wireless network have to be context aware to adapt their behavior accordingly to environmental variables that govern the system, such as the actor of the system and the actor's preferences, the moment of the day when usage takes place, season, and so forth.

Once again, it is important to achieve these goals by means of low cost systems, as these points-of-care will not be deployed massively or used in clinical routine if they are not cost-efficient and provide benefits over traditional health care delivery. Of course, as costs are reduced, limitations arise, such as processing power, tight memory sizes, or low power consumption (batteries are required to last long enough to allow several measures to take place, as well as to support the wireless radio link power consumption).

Above all, there are security issues to be considered. For real scenario setups where sensitive and personal data will be in transit through the network, refusing intrusions, avoiding denial of service, driving the system into a safe state in case of failure, and so forth, are a must.

Functionality

Based on the requirements stated above, the wireless sensor network consists of three different elements: a gateway (center of the point-of-care), the sensors (used to monitor the patient's vital signs), and the user interface (to inform of upcoming exams, problems, etc.).

The functionality of the different elements follows. The gateway has twofold capability: (1) it is used to communicate with the sensors that the patient has, and (2) it is needed to send data to and from the health care institutions (i.e., hospital, primary care, etc.). The information regarding the doctor's prescription of medical exams is sent to the gateway where it is stored, processed, and routed to the specific sensor, stating the duration, sample rate, quality of the measure, amplification factor, or any precise parameter needed to collect the data.

The sensors have been developed as stand alone wireless devices and have been provided of automatic start of the measure, auto-discovery, and auto-configuration facilities. That is to say that the patient does not need to take care of configuring nor connecting them, for instance, to upload or download the data collected. It is important to note that the user does not need to ensure either that the sensors are powered on and off, as they are suspended and resume automatically after a given time. When resume is done every half minute, several tasks take place:

1. Checking the state of the sensor to become aware of the patient's willingness to start an exam. When the user wants to commence it, the user places the sensor on, so that the device is able to collect data. This situation takes place no matter whether the doctor programmed the test or the patient decided to take it (because of not feeling alright).
2. Connecting to the gateway. The radiofrequency module is powered on and a "keep alive" message is sent to the gateway. If there is information that needs to be transmitted to the node, as imminent exams that need to take place, it is sent at this moment. Afterwards, if data are still stored in the sensor, the data are forwarded to the gateway.
3. Checking battery level. When batteries are close to being used up, an alarm is sent to the gateway and the user is notified so that the user can recharge them. This check is performed every 10 minutes instead of every half minute.
4. Checking network failures.

Once all these tasks have been performed, the device is suspended again to save batteries. Using this method, battery consumption is decreased up to a maximum of 60%.