SMS-Based Platform for Cardiovascular Tele-Monitoring

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Abstract

The focus of this paper is to describe a fully automatic platform to transmit, using the SMS service, medical data collected at home. The overall platform has two main components: a central server for SMS receiving (Central Receiving Unit, CRU) and the remote sending data collection and transmitting units (Home Transmitting Unit, HTU). HTU is connected to commercial meters of arterial pressure and blood glucose, and to a step-counter. The CRU is located in a clinical center and acts also as a server for the database housing and for the users applications (data display, trend visualizations, alarms). Five platforms (CRU+5HTU) have been realized and given to patients. During a cumulative monitoring period of 251 days, there were 175 data transfer sessions, a mean of 35±20 per patient. The stability of the telemonitoring system and the mean percentage of successful encoding of the transmitted data were 100%.

1. Introduction

Utilization of mobile information and communication technologies in home monitoring applications is becoming more and more common. In the cardiologic sector, telemedicine projects include the establishment of monitoring of several parameters (heart rate, arterial pressure, glycaemia), for which the technology of the medical devices provides self-measurement methods. Several telemedicine solutions proposed so far, rely on Internet Connection and dedicated Web Server Applications. However, if the data to be transmitted do not require particular bandwidth or transfer rate, the Short Message Service (SMS) of the GSM mobile cell network can be a convenient, reliable, affordable, and secure mean of telemedicine. Many telemedicine projects involve the use of SMS service only as a support for manual data entry or teleconsulting and emergencies [1-3]. The focus of this paper is to describe the development of a fully automatic prototype application, based on this technology embedded in a home monitoring system, to transmit medical data collected at home from automatic devices using the SMS service. The feasibility and usability of this approach are evaluated and compared with concepts used in previous approaches.

2. Methods

The overall platform has two main components: a central server for SMS receiving (Central Receiving Unit, CRU) and the remote sending data collection and transmitting units (Home Transmitting Unit, HTU). A general scheme of the platform is depicted in figure 1. The data collected remotely are transmitted by the HTU using a single SMS message, each day, to the CRU where are stored. The CRU, which is located in a clinical center, acts also as a server for the database housing and for the users applications (data display, trend visualizations, alarms). The platform is fully automated: no specific action is required to the patient for transmitting the data, nor from the clinicians for receiving and using them. To increase the robustness of the system, in this project, in case of lacked or uncorrected reception of the measures, the clinical center may interact, directly or through the support of volunteers involved in the plan, with the patients in order to implement opportune corrective actions. In the following the CRU and HTU are described in details. Daily, the patient is asked to wear the step counter in the morning, to perform one or more blood glucose testing (according to the medical indications) and at least one blood pressure measurement. Because of the different firmwares of the meters, the downloads of the measures to the HTU occur with different modalities. Blood pressure meters and step counters are interrogated during the night, while blood glucose levels are downloaded once the meter is reconnected to the HTU. The CRU consists of a laptop PC connected to a GSM modem (TC65, Siemens, Germany). The PC routinely interrogates the modem to look for new SMS messages sent from the HTUs. SMS messages are then downloaded, decoded and then cancelled from the

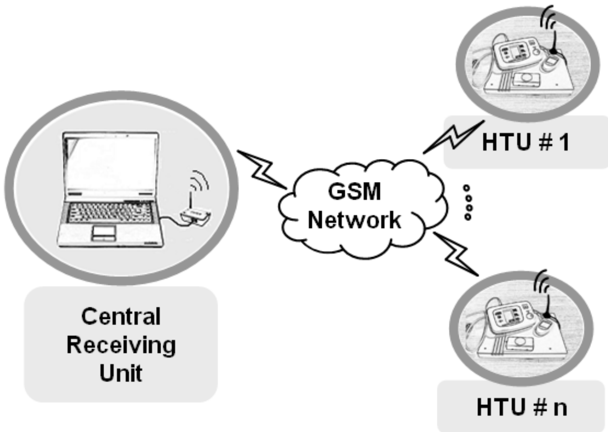

Figure 1. Model of the proposed platform for SMS data transmission.

modem memory. The communication between the PC and the GSM modem is implemented using the AT commands. A Java Sun Study 1.4.1 application decodes the messages and store the data on the specific database, in a Microsoft Access database. The database consists of two tables: the first one concerns the personal and medical data of the patient, and it is filled by the doctors during the registration procedure; in the second table the measures received through the messages are stored. The application also sends alerts and alarms in case of missing SMS or corrupted SMS content. The HTU, is an embedded system able to retrieve data using the serial RS232 connection from up to 4 medical devices. In the actual configuration it is connected to commercial meters of arterial pressure (UA767PC, A&D, Japan) and blood glucose (GLUCOCARD G+, Menarini Diagnostic, Italy), and to a step-counter, GEMU. The GEMU is a new wearable system for the step counting for telemonitoring applications. This step counter is based on a wearable device with a force sensing resistor and a belt; it is affixed at the calf gastrocnemius level for the monitoring of the muscular expansion correlated to the gait [4]. The GSM modem provides the wireless transmission of the data; it is also used as real time clock for the embedded system. The core of the embedded system is a microcontroller (18F8722, Microchips, USA) which manages the communication with the GSM modem, and retrieves the data from the meters of pressure, glycaemia and physical activity. A conditioning circuit is also necessary to multiplex and transceive the serial data (figure 2). Attention has been paid to the safety of the overall HTU. The power supply of the GSM modem and of the conditioning electronics has been obtained using a medical wall transformer compliant with the EN60601 harmonized standard; the blood pressure meter, the blood glucose meter and the physical activity monitor

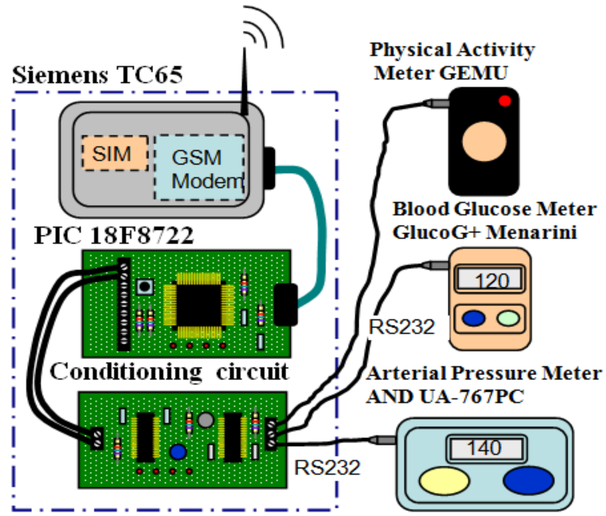

Figure 2. HTU: interconnection of different modules

are battery operated. The microcontroller firm was developed using the MPLAB IDE, in C. At the start-up (HTU connected to the mains), the system performs an initial check for the GSM signal quality as well as the local GSM service availability. A feedback led indicates that a valid connection to the operator has been established. The patients are instructed to place the HTU following this led indication. Then the HTU waits for either a connection to the blood glucose meter or to interrogate the GEMU and the blood pressure meter. Such interrogation is scheduled at night (02.00 am) not to interfere with the use of the meters by the patients. After the nocturnal interrogation, measures are codified in a text string. This string can contain up to three measures of blood pressure and heart rate, six of blood glucose and one of physical activity, given the maximum allowed size for a single SMS (160 chars). When interrogation is completed and the message assembled, the microcontroller sends, via AT commands through the serial port, the assembled string to the TC65 for the SMS transmission (figure 3).

3. Results

Five platforms (CRU+5 HTU) have been realized and given to patients (figure 4). Each participant received an HTU equipped with an automatic blood pressure device and a digital blood glucose meter. The physical activity monitoring was not required for these patients. In total, 5 patients were monitored for 50 days each. They were asked to measure their blood pressure, pulse and blood glucose depending on the their history/pathology.

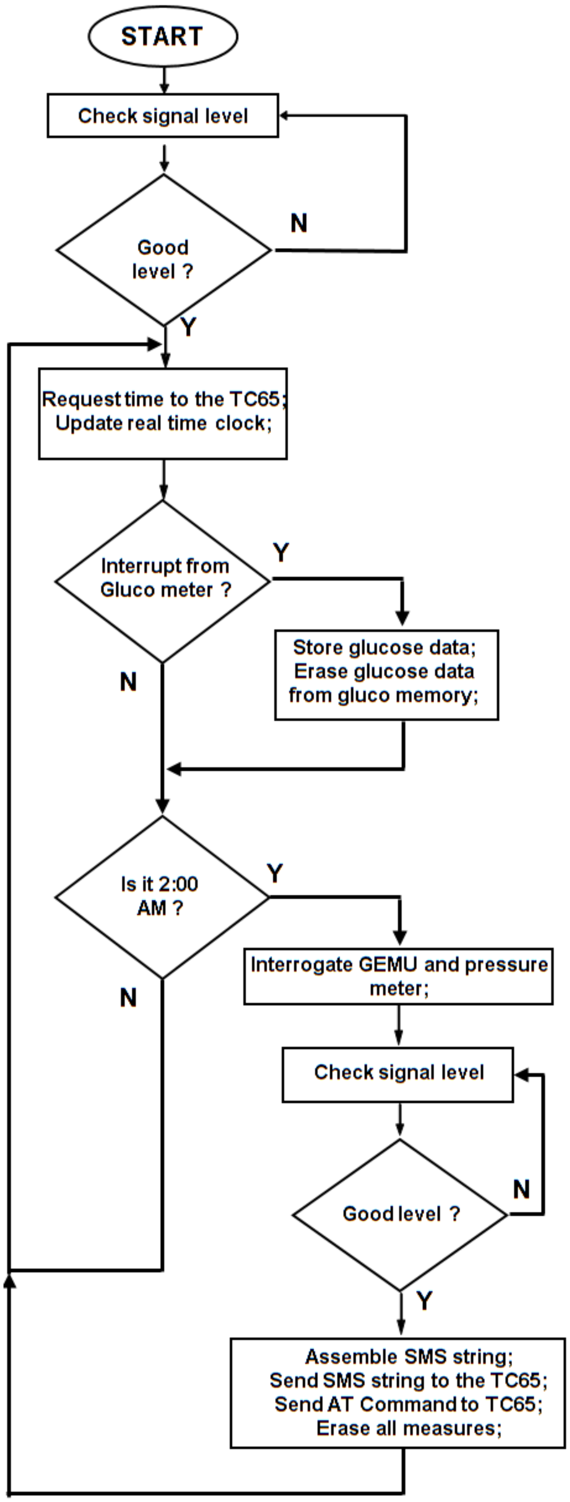

Figure 3. Flow chart of the microcontroller operations.

During a cumulative monitoring period of 251 days, there were 175 data transfer sessions, a mean of 35±20 per patient.

Figure 4. The Home Transmitting Unit, with the commercial blood pressure and blood glucose meters.

On average, the arterial pressure and blood glucose measures received were respectively 1.51 and 0.42 per day. In particular, figure 5 shows the daily average blood pressure and glucose measures for each patient (blood glucose measure was not required for patient Id 4).

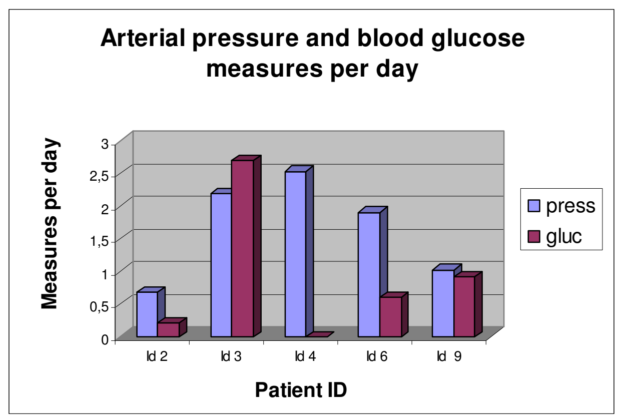

Figure 5. Average number of blood pressure and glucose measure per day, for each patient.

The percentage of successful encoding of the data transferred was 100%. The stability of the telemonitoring system was 100%, meaning that patient data transfer was always possible.
On conclusion of the trial each subject completed a questionnaire detailing their satisfaction with the portable unit and any recommendations for improvements. The patients' compliance with the system was high.
The web-based home-monitoring system was reliable and easy handle for health care professionals. It may be a useful tool for patients with heart failure as well as hypertensive patients.

4. Discussion and conclusions

Post acute cardiovascular event patient, discharged by a health structure, has to follow a long and complex therapeutic/rehabilitation path, which involves either medical doctors and his own family. Indeed, recent data enhance the importance to get therapeutic targets within short periods to reduce the probability of novel acute events. The technology of the medical devices provides self-measurement methods for some parameters of cardiovascular interest (heart rate, arterial pressure, glycaemia) helpful to delineate the patient health state and to assess the risk of acute events. However, multiple factors can limit the usability of these instruments for some patients who, for economic or cultural reasons, may not follow the therapeutic path. Medical device manufacturers have done much work to make self-measuring devices easy of use and reliable. Several studies investigated the reliability of the self measurement of blood pressure and glucose blood. New guidelines and thresholds for self-measured parameters have been also defined [5]. On the other side, several telemedicine applications still rely on manual data entry on Web server application or using cell phones [6]. Such data entry approaches require certain skills and it may result impracticable for some groups of patients. In these cases a further technological effort is important to provide fully automated data transmission to the clinical centres. In this paper a platform for the follow-up of post acute event patients is described. This platform is based on the self-measurement and on the automatic transmission of blood glucose, blood pressure and physical activity, using the GSM network. The main peculiarity of the proposed platform relies on the choice of the SMS service to automatically transmit the medical data, without any action required to the patient. The choice of the SMS service through the GSM technology well fits the transmission of blood pressure, blood glucose and a daily activity parameter, since no particular bandwidth, transfer rate or memory amount are required. Some authors have proposed solution based on the use of commercial cell-phones or Palm PC instead of embedded systems and wireless modems [7], also in view of the significant progress in the recent years of such devices. In spite of such a progress, we found that, at the moment, these solutions are both more expensive and less robust. Many medical device manufacturer have put on the market meters with Bluetooth connectivity. At the moment, compared to the RS232 connection, this interface nearly double the costs of the meters and thus was not considered in this project. In conclusion, the main characteristics of the proposed platform are: the low costs associated to the home instrumentation (lower than 350 EUR); the facility of use from patients, eventually with the aid of staff without specific formation (relatives, volunteers); the possibility, with affordable costs, to follow the patient also for long periods (months). Such characteristics allow its integration in the plans of in-home attendance, developed in various national sanitary systems. In particular, it represents a tool for therapeutic target control in hypertensive/diabetic patients and may works as monitor of the physical activity during rehabilitation assessments. This work has been carried out within a project on the continuity of care funded by the Italian Ministry of Health (grant of this publication). At the moment, the proposed solution has been adopted as the technological platform for a pilot study on post-stroke patients (CASE project, Continuità Assistenziale post StrokE).

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