BAN-Based Health Telemonitoring System for In-Home Care

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Abstract

The aim of the research is to build a prototype of the BAN-based monitoring system for in-home care. The system consists of body central unit with Bluetooth module and selected both wearable and stationary sensors that monitor human physiological and movement parameters. Body central unit acquires data from wearable sensors and transmit it wirelessly to the home base station for analysis and storage. The home base station sends data to the remote medical server where they are available via web based graphical interface. The system was tested by six volunteers in home environment. The maximum measured packet loss rate was 2%. Experimental results showed that proposed system was feasible and can provide with information about selected health parameters to physicians or family what can improve the patient quality of life.

1. Introduction

The proportion of the world's population over 60 years will double from about 11% to 22% between 2000 and 2050. The number of people aged 60 years and over is expected to increase from 605 million to 2 billion over the same period according to the World Health Organisation (WHO) statistics.

The continued growth in the number of elderly will cause an increase in the number of people who are most affected by chronic conditions and need constant health monitoring. Furthermore, there will be not enough physicians. At present, about 44% of WHO Member States report to have less than 1 physician per 1000 population. One of the solutions to the problem of providing healthcare services to the growing number of people is telemedicine. Telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve a patient's clinical health status. The most common telemedical services are medical education, telemonitoring and teleconsultations.

During the last few years there have been advances in medical sensors technology in terms of device miniaturisation, mobility, wireless transmission and communication. However, the main drawbacks of currently deployed monitoring systems are closed architecture, high cost and designed for in-hospital use. Previous studies have focused on human monitoring using mostly accelerometers [1, 2] and heart rate monitors [3,4]. It was demonstrated in [5] that video monitoring can be used in eldercare to assist the independent living of elders and to improve the efficiency of eldercare practice.

There is growing research interest in multiparameter monitoring systems [6,7]. In [8] the prototype of Wireless Multiparameter Patient Monitoring System is described which performs acquisition of three types of physiological measurements: ECG, finger PPG, and blood pressure plethysmography. The waveforms are sent to a remote backend server using a Wi-Fi internet connection. In [9] an innovative wearable and minimaly invasive system named WEALTHY is presented. It is fully integrated garnent system that is able to acquire simultaneously a set of physiological parameters. The acquired signals can be transmitted to a remote monitoring system.

This work presents the prototype of BAN-based health telemonitoring system, which monitors patient at home. The proposed system differs from the existing solutions in the following way - it acquires data from both wearable sensors and stationary sensor. Acquired information can be integrated with patient electronic health data what can help in monitoring patient habits and potential health hazards. System monitors selected health and movement parameters.

The rest of the paper is organized as follows. In Section 2, the hardware and system architectures are presented. In Sections 3, results of different test scenarios are included. The concluding remarks and system limitations are given in Section 4.

2. System architecture and hardware

The main goal is to develop a method for remotely acquire data from sensors located on the patient body and selected stationary sensors located at home.

The system developed in this work consists of Body Sensor Unit (BSU), Body Sensor Boards (BSB) and Home Sensor Board (HSB).

The Body Sensor Unit (BSU) is based on Atmel microcontroller, a Bluetooth radio and accelerometer. There are two Body Sensor Boards: ECG Sensor Board (ECG-SB) and Temperature Sensor Board (T-SB).

The ECG-SB is built using dedicated low noise specification and low energy consumption integrated circuit for acquisition of electrophysiological signals. ECG-SB captures ECG signals from 3 electrodes.

The T-SB is based on DS18B20 digital thermometer, which provides 12-bit Celsius temperature measurements and has an alarm function with non-volatile user programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. It has an operating temperature range of -55°C to +125°C and is accurate to ± 0.5°C. In addition, the DS18B20 can derive power directly from the data line, eliminating the need for an external power supply of T-SB.

The S-SB is an electronic wireless electronic scale for measuring subject weight using piezoelectric sensor. It tracks body weight and body mass index (BMI) of one patient. It transmits wirelessly data to the Home Base Station (HBS). S-SB is an example of using data from external sensor, which is located at home to extend the amount of information about patient health and make more health information available electronically.

The BSU acquires data from sensor boards and encapsulate it into packet. Data from BSU passes through a Home Base Station (HBS) to a remote server (RS). The data processed by the Home Base Station (HBS) is sent through the Internet to the remote server (RS) every five minutes. In a prototype implementation a home base station is a PC computer equipped with Bluetooth wireless interface, which is connected to the Internet. System architecture was shown in the Figure 1.

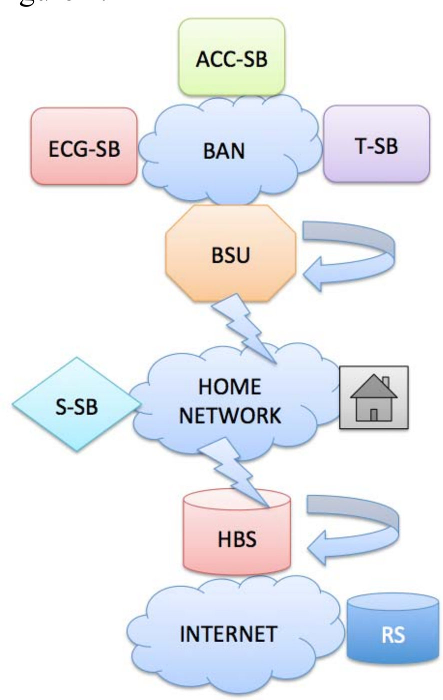

Figure 1. System architecture.

The software in the system was designed in three phases, as described below.

The BSU software was implemented in C language, and it consists of several processes, as follows: (a) initializing sensor boards; (b) establishing wireless connection with HBS; (c) receiving the data from sensor boards; (d) encapsulating the data packet; (e) sending the data packet to HBS.

The HBS software was implemented in C#. There are two main software tasks. The first one is to process and analyse incoming data. The second one is to encapsulate data into electronic record and send it to the remote server, where it can be available to selected users using web-based graphical user interface.

The server software was implemented in PHP language and it controls the following aspects: (a) the information reception; (b) the management of patient recording database; (c) sharing data with authorised users.

3. Testing and results

The System was deployed in a home environment to test and evaluate the proposed algorithms and methods. There were three testing scenarios.

In the first scenario sensors accuracy was measured. The accuracy of the following signals was investigated: acceleration, heart rate, body temperature and body weight. Experimental results for six volunteers showed maximum 6% absolute error in comparison with certified medical devices (heart rate monitor, medical accelerometer, body temperature sensor, medical scale).

In the second testing scenario one a volunteer was asked to put on the following elements of the System: the BSU, the T-SB and the ECG-SB. The volunteer with the sensors worn on the body was shown in the Figure 2.

Figure 2. Location of the System elements on the volunteer body.

Next, he was asked to stand on the wireless scale. After 30 seconds he was asked to sit on a chair and watch a movie for 4 minutes and 30 seconds. After completing this task the experiment was finished.

During the experiment sensor data was collected. Example of the ECG signal collected by the System was shown in Figure 3, while example three dimensions acceleration signal was shown in the Figure 4.

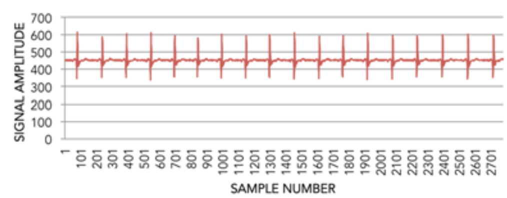

Figure 3. ECG signal.

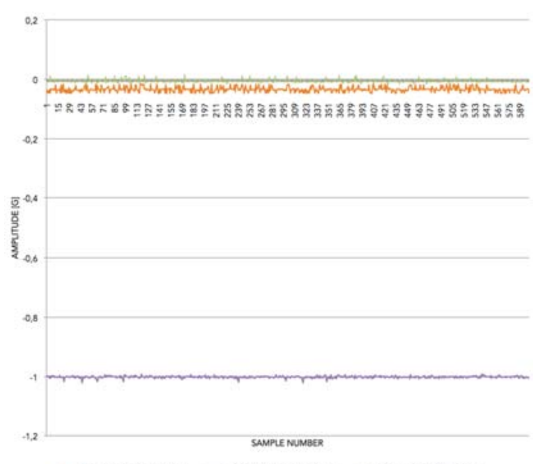

Figure 4. Three dimensions acceleration signal.

Algorithms were implemented to calculate the following parameters: activity, body temperature, heart rate, and weight. Activity parameter is binary (values LOW/HIGH) is calculated based as an absolute sum of acceleration data in a time window. The threshold is set individually. Example data vector was shown in the Table 2.

Table 2. Experimental data vector

Parameter	Value
Activity	LOW
Temp. [°C]	32.80
Hear rate [BPM]	72
Weight [kg]	79.8

In the third scenario we collected 20 minutes of monitoring data to investigate the packet loss rate (PLR). The maximum measured packet loss rate was 2%.

4. Discussion and conclusion

This study shows that BAN-based health monitoring system can be used for monitoring human at home. It can collect healthcare data at home and share it with authorized users. The study found that the telemonitoring based on wearable and stationary sensors was feasible. Further validation is necessary to evaluate system performance. Author identified several areas of research and development that need to be undertaken. This includes, but is not limited to: security, privacy and hardware miniaturization. Home-based health monitoring systems can improve the quality of care provided to the older people and reduce the cost of healthcare services.

Acknowledgements

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