Wireless Wearable Body Area Network (WWBAN) for Elderly People Long-Term Health-Monitoring

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Abstract

This project proposes and implements a prototype for a wireless system for elderly people long-term health-monitoring. The system is composed of two main components namely, a wireless wearable body area network (WWBAN) and a smart-phone based on Andoid-platform. The WWBAN sensors and smart-phone are connected wirelessly via Bluetooth connection based on the IEEE 802.15.1 standard. The project provides a platform for day-to-day long-term health-monitoring of elderly people, and consequently minimizes risks that can threat their lives.

I. Introduction

Wireless Wearable Body area networks (WWBANs) are the systems of sensors that operate in close proximity to a person's body to provide a benefit to the user. There are a wide variety of applications of WWBANs, particularly in the field of biomedical engineering. These applications typically use biomedical sensors to monitor the physiological signals and vital signs of patients, such as electrocardiogram (ECG), blood oxygen level, blood pressures, blood glucose, body weight, heart-rate, oxygen saturation, etc [1,2].

Long-term health-monitoring requires intensive and repetitive assessment that could last for months or even years to regain the lost functions, such as in the case of rehabilitation and elderly people health-monitoring [3]. Typically, WWBANs provide a promising solution for such situations, however, currently WWBAN technology is evolving, and there are many challenges to address. One of these challenges is the integration and coordination of multiple sensors with different applications.

II. Overview of Project

The objective of this project is to design and implement a wireless system for elderly people long-term health-monitoring that is composed if a WWBAN and a smart-phone. The proposed WWBAN uses two non-invasive wireless wearable sensors. Theses sensors communicate wirelessly, and transmit real-time measurement data via means of Bluetooth connections to a smart-phone. Each sensor has a Bluetooth circuit that is used for real-time data transmission. A key advantage of this project is providing a life-risk alert system via means of specialized mobile based application design.

III. System Architecture

The proposed system is designed to monitor the elderly health status, and is based on two main components. The first component is an on body wireless wearable body area network (WWBAN). The second component is a smart-phone that will work as a gateway for the transmission of data to medical specialists and family members via means of internet connection.

The proposed wireless WWBAN consists of two non-invasive sensors namely, heart-rate and blood oxygen sensors. The two sensors are placed on the body of patient, where they measure the appropriate data. The sensors transmit the measured data to the second component of the proposed system namely, the smart-phone via Bluetooth communication protocol. A block diagram of the proposed WWBAN for elderly people health-monitoring is shown in Figure 1.

The proposed WWBAN is based on the star-topology, which implies a centralized architecture where the intelligence (IOIO board) of the system is concentrated on a central-node which is superior to the peripheral sensors in terms of resources such as processing. A schematic diagram of the on-body WWBAN sensor connection is depicted in Figure 2. As was previously mentioned, the proposed WWBAN consists of two types of sensors, heart-rate and blood oxygen sensor. Description of the employed sensors is as follows.

A. Heart-rate Sensor

Heart-rate is defined as the number of heart beats recorded per minute, and is measured in Beats per minute (Bpm). In particular, we selected the heart-rate sensor for our proposed WWBAN, as the measurement of heart-rate reflects both activity and heart performance of the elderly test subject. In addition, it is a very important metric in long-term health-monitoring of elder people.

B. Blood Oxygen Sensor

Oxygen present in the blood is found attached to hemoglobin molecules. The amount of oxygen in the blood is measured in the form of oxygen saturation. Oxygen saturation is a measure of the maximum percentage of oxygen carried in the blood. Typically, one hemoglobin molecule can carry up to four molecules of Oxygen. Then, if a hemoglobin molecule carries three molecules of oxygen, then it is said to carry 3/4 or 75% of the maximum amount of oxygen it can carry. Sometimes, Oxygen saturation is referred to as SpO_2 [4].

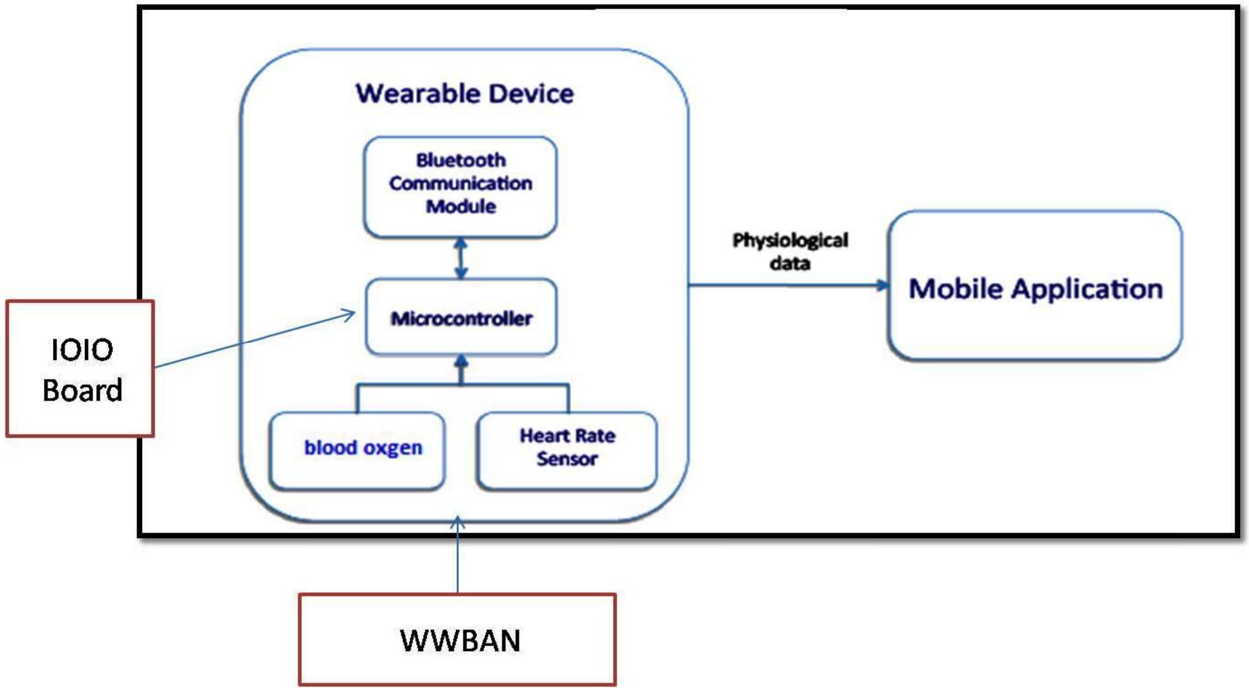


Fig. 1 Proposed WWBAN architecture.

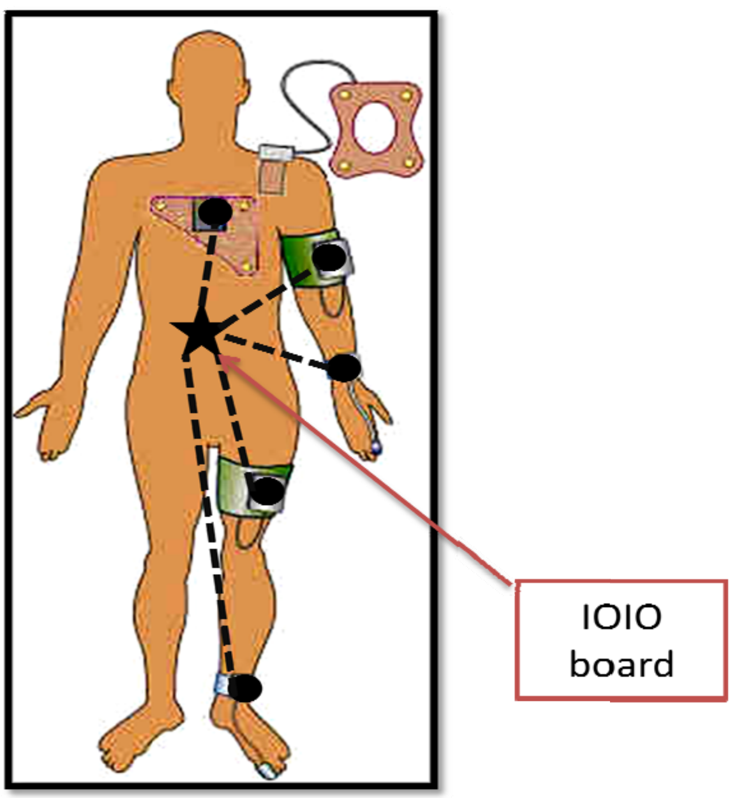


Fig. 2 Proposed WWBAN connection diagram

IV. Selection of IEEE Standard

Generally, medical WWBANs are supposed to support a low-complexity, low-cost, ultra-lower power, and highly-reliable wireless communication connection. Common IEEE standards used in WWBANs include Bluetooth (IEEE 802.15.1) and Zigbee (IEEE 802.15.4) standards. IEEE 802.15.1 standard supports data-rates up to 250 Kbps, and cover ranges 1-10 m. On the other hand, IEEE 802.15.4 standard supports data-rates up to 2.1 Mbps, and cover ranges 1-100 m [6]. For our project, we select the IEEE 802.15.1standard for two main reasons. The first reason is that our proposed WWBAN is supposed to communicate with a smart-phone, and currently almost all modern smart-phones are equipped with Bluetooth connections. The second reason is the low data-rate requirements of the employed sensors in our WWBAN. Typical data-rate requirements of heat-rate and blood oxygen sensors are 128 bps and 80 bps, respectively [7].

V. Practical Implementation

The main hardware components of our WWBAN are as follows. We use IOIO board for Bluetooth connection from sensors to Android-based smart-phone. For heart-rate sensing, we use a polar heart-rate transmitter and receiver. For blood oxygen saturation sensing, we use pulse oximeter sensor. The details of the hardware components are as follows.

A. IOIO Board

The IOIO is a Bluetooth board that works with Android-based smart-phones. The IOIO board provides robust connectivity to any Android-based device via means of USB or Bluetooth connection. In our case, we consider the Bluetooth connection. Figures 3 (a) and (b) show the IOIO board and a schematic diagram of the internal board hardware.

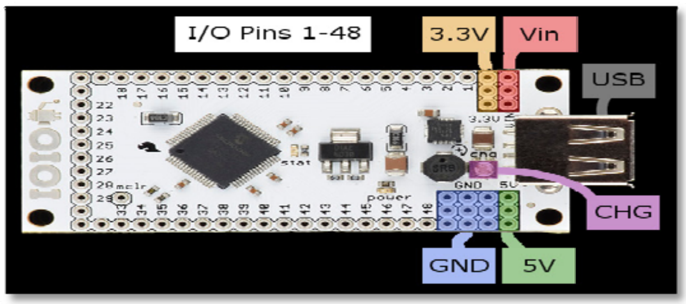
B. Polar Heart-Rate Transmitter

Polar is a commercial heart-rate transmitter that transmits heart-rate data wirelessly to a corresponding heart-rate receiver. One of the advantages of polar heart-rate transmitter is that it does not require conductive gel, as shown in Figure 4.

C. Polar Heart-Rate Receiver

Heart-rate receiver receives heart-beat signals from a compatible transmitter. It indicates a received heart-beat signal using a low/high output-signal. The wireless interface between the receiver and compatible transmitter can cover a range of up to four feets. Figure 5 shows the polar heart-rate receiver board. Figure 6 shows a diagram of the heart-rate sensor connection to an IOIO board and a smart-phone.

(a)



(b)

Fig. 3 (a) Commercial IOIO board. (b) Hardware of IOIO board

Fig. 4 Polar heart-rate transmitter

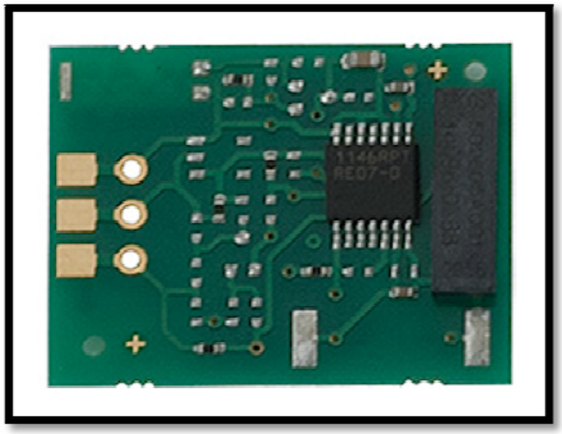


Fig. 5 Polar heart-rate receiver

D. Blood Oxygen (Pulse-Oximeter) Sensor

We consider a pulse oximeter for blood saturation measurement. The sensor is integrated with an e-health sensor platform for Arduino and Raspberry Pi boards. It is specially designed for medical applications. The pulse oximeter and e-health platform board are associated with specially designed phone application that works on Android-platform. The board, pulse oximeter and snap-shot of phone application are shown in Figure 7.

VI. Test Results

The proposed WWBAN prototype has been implemented and integrated with a smart-phone. In addition, a specially designed smart-phone application based on Android-platform has been designed to display the measured heart-rate on the smart-phone. Figure 8 shows the hardware implementation of the proposed system; the WWBAN is connected wirelessly to a smart-phone. The figure also shows a comparison of the measured heart-rate by the employed sensor to a commercial device, and both give approaching values.

VII. Summary

This project proposed and implemented a prototype of a system consisting of a WWBAN integrated with a smart-phone for elderly people long-term health-monitoring. The proposed WWBAN consists of two wearable non-invasive sensors namely, heart-rate and blood oxygen sensors. The measured data via the proposed WWBAN is transmitted in real-time to a smart-phone based on Android-platform. Also, a smart-phone application based on Android-platform has been developed to record the measured data in real-time. The wireless connection is based on the IEEE 802.15.1 standard. The implemented WWBAN was tested against a commercial device, and both gave approaching results.

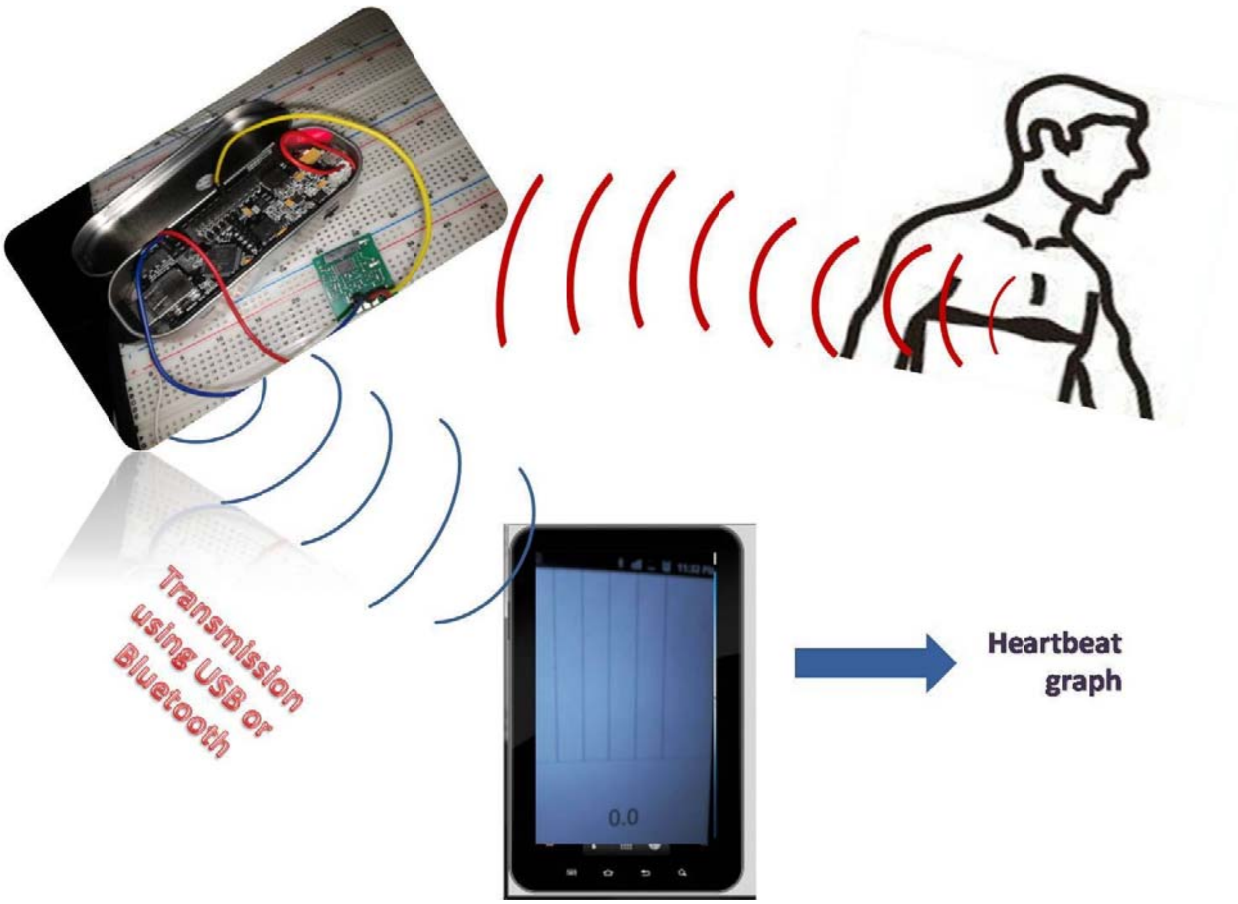


Fig. 6 Schematic diagram of heart-rate transceiver sensor connection to smart-phone

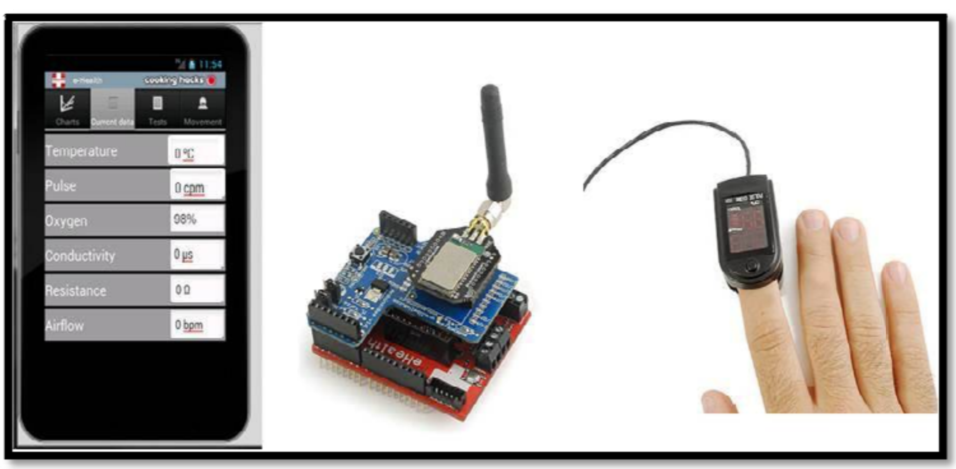


Fig. 7 Pulse oximeter sensor

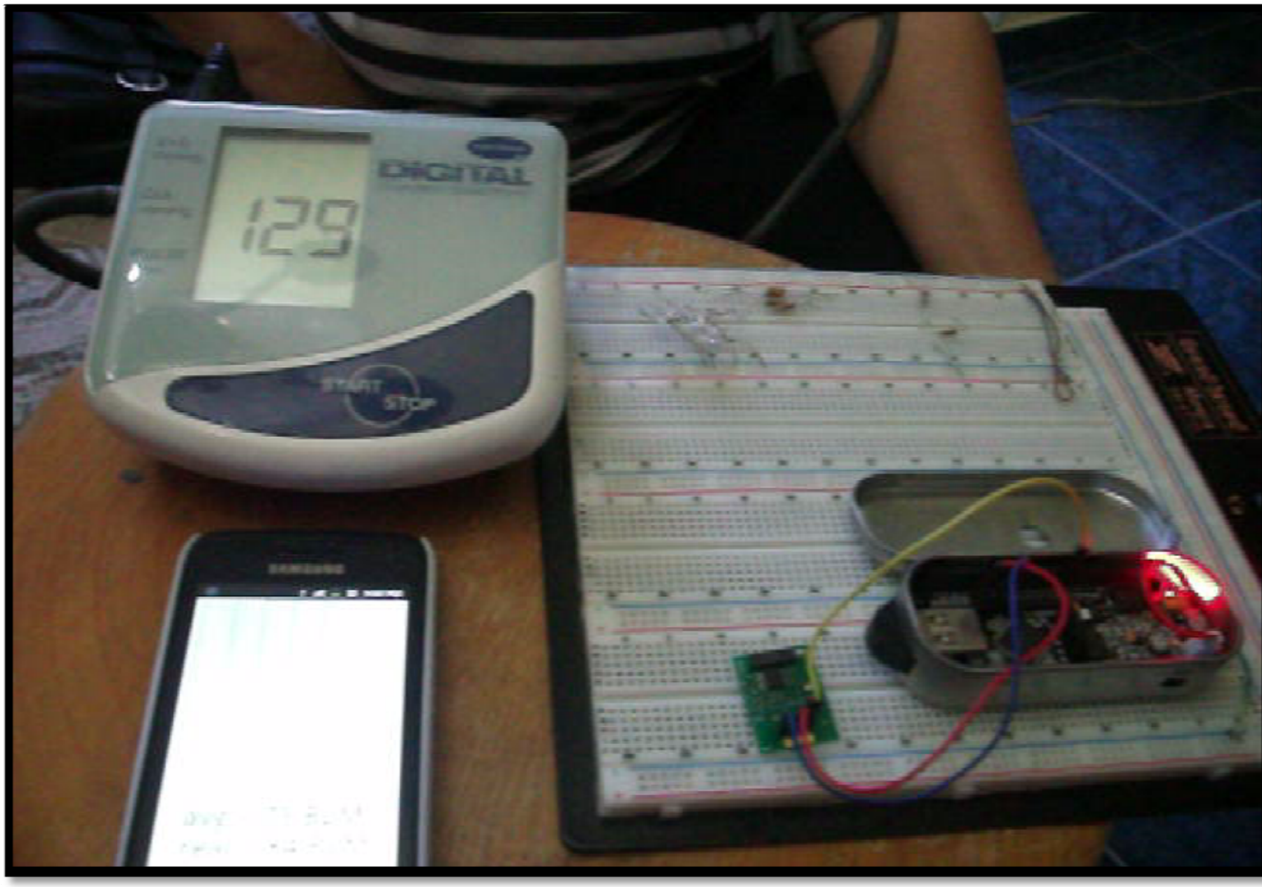


Fig. 8 Actual hardware implementation

Acknowledgement

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