Implementation of a Wireless Body Area Network for Healthcare Monitoring

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Abstract: The rapid growth of wireless technologies and personal area networks has enabled the continuous healthcare monitoring of mobile patients using compact sensors that collect and evaluate body parameters and movements. These sensors constitute a body area network (BAN) where patients' vital signs are collected and reported wirelessly to a base station. Once the data is received, it is displayed or stored in a database for future use. The use of BANs is to provide the users with logging of patients' critical vital signs, and also to provide primary healthcare providers a snapshot of the wearer's health. The goal of this project was to investigate the feasibility of the inexpensive construction, and use of a BAN. A BAN, consisting of two nodes and a base station was successfully built and tested using open source and inexpensive hardware to measure pulse rate, body temperature, and patient's location. Each node consisted of a pulse sensor, a temperature sensor, a GPS module and a ZigBee wireless modem packaged together. The nodes were designed to incorporate other sensors, such as an accelerometer, in the future. The base station consisted of a receiving ZigBee modem and a Wi-Fi module. The captured data was inserted into a MySQL database where a webpage with a graphing application programming interface (API) was used to display the data. The system has been successfully tested in real time where data was successfully obtained and displayed. Future enhancements to safeguard the data, including the encryption of the patient data is under investigation.

Keywords: Body Area Networks, Sensor Networks, Wireless Communications.

I. Introduction

Pressing medical issues such as the aging population in developed countries and the skyrocketing cost of healthcare have prompted the emergence of technology-driven improvements of current healthcare practices. For instance, recent advances in electronics have enabled the development of bio-medical sensors that can be worn or implanted in the human body. These sensors have the capability to collect important data about the body's health condition and thus facilitating the introduction of new types of networks among which are Wireless Body Area Networks (WBANs) [1]-[11]. WBANs are networks of nodes with the capability of real time monitoring of patient's vital signs such as pulse rate, body temperature, blood pressure, and more. The information collected is wirelessly relayed to the physician or caregiver in a timely fashion. Essentially, the data collected by the sensors is sent to an external server for analysis and storage. As it turns out, using a wired connection for this purpose will be cumbersome and will involve high deployment and maintenance cost. While the use of a wireless interface allows an easier application and is more cost efficient [1]. With the current traditional medical care system, there are limitations in diseases diagnosis in addition to difficulties experienced in early detection of diseases and long term patients monitoring. WBANs constitute an effective and efficient solution to the formerly mentioned issues [2]. WBAN can monitor single or multiple vital signs at the same time and can include implantable or wearable bio-sensors. The data transmission in WBANs can include ZigBee, Bluetooth, and Wi-Fi. Data access points in a WBAN where the data is collected, stored or displayed can include laptop computers, smart phones and personal digital assistants.

In this paper, we present the implementation of a real time patients monitoring system based on wireless body area networks. The system consists of two nodes where vital signs are collected and transmitted wirelessly to a base station where the data can be stored and displayed on a continuous basis. Each node comprises a pulse sensor, a temperature sensor, a GPS module, and a ZigBee wireless module. The base station consists of a receiving ZigBee module and a Wi-Fi module. These wireless modules are easy to configure and good for point-to-point, multipoint and convertible to a mesh network point [13].

The rest of the paper is organized as follow. In Section II, the network architecture is described. In Section III experiments and results are discussed and finally in Section IV, we conclude the paper.

II. Network Architecture

The Wireless Body Area Network (WBAN) was implemented using a single hop star topology in beacon mode (data being sent continuously without interruption) where sensors collect data and send it to the base station which is the task manager of the network. The proposed WBAN architecture is shown in Figure 1. Two individual body sensor nodes serving as transmitters have been designed to collect, process, and transmit the pulse rate, body temperature, and the patient's location signals in real time. The system operates within a range of 30m from the base station.

A. Sensor Nodes

To achieve a power efficient network, open source and low power consumption hardware were used to implement the sensor node. Figure 2 shows the schematics of the sensor node and the actual node after construction. Each sensor node consists of one off-the shelf ZigBee wireless module for wireless transmission, one pulse sensor, one temperature sensor, and one GPS module. The ZigBee wireless module operates on the 802.15.4 protocol at a frequency of 2.4GHz with a power output of 1mW and a data transmission rate of 250kbps. The sensor node consists of the following elements:

- One pulse sensor wearable on the ear or on a finger with a current consumption of 4mA at 5V , 16mm of diameter, 3mm of thickness, and a cable length of 609mm.
- One TMP36 analog temperature sensor with a voltage output of 1.75V to measure the body temperature.
- One GTPA013 ultimate GPS module with a -165dBm sensitivity and only 20mA current draw; This module was used to determine the location of the subject at all times.
- A 9V battery.
- A ZigBee wireless module to wirelessly transmit the collected to the base station for processing, display, and storage.
- An Arduino Uno microcontroller for data processing.

B. Base Station

The base station which is the network coordinator manages the activities of individual nodes by periodically requesting data. In addition to data integration and analysis, the base station also relays processed data to display devices and PDAs. The base station is equipped with an Arduino Uno Microcontroller for system coordination, a receiving ZigBee module and a Wi-Fi module for wireless communication and data transmission over the 802.11b/g wireless networks which make it possible to access the collected data via the internet.

The tasks of the base station are given below:

- To coordinate the two transmitting nodes by sending periodic data requests.
- To receive patient's physiological data from all transmitting nodes in real time.
- To relay the received data to display devices for a remote visualization.

C. User's Interface

The user interface which is a display website was designed using php and html codes. The software intended to be easy for medical personnel to use and provides enough details on patient pulse rate, temperature and location on a continuous basis. The sensor device on the patient transmits raw data to the receiver which in turn sends the data wirelessly to the MySQL database using a WiFi shield. When the database gets new data from the device, it refreshes the page and displays the new data in the format that the user can understand. The data can be also saved on the server so it can be used for future references.

III. Experiments and Results

To check the functionality of the body area network and the operation of the sensor nodes a set of experiments were performed. First to compare the performance of the pulse sensor data was collected both using the pulse sensor and an industrial sensor. Figure 3 shows the comparison between an industrial pulse sensor and the experimental pulse sensor that was used in the construction of the body area network. As it can be seen from Figure 3, it is clear that the data obtained from the experimental pulse sensor is very similar to the data obtained from an industrial pulse sensor, which indicates the reliability of the data obtained by the experimental pulse sensor. Figure 4 shows the data received from the temperature sensor during different physical activities. As expected the body temperature rises when there is high physical activity. In Figures 5 and 6, the pulse variation, due to different activities, for the industrial sensor and the experimental sensor are shown, respectively. Comparison of Figures 5 and 6 indicate that the pulse sensor used in the construction of BAN can produce reliable data.

IV. Conclusion and Future Research

A low cost Wireless BAN, using off-the-shelf hardware was built and successfully tested in real time where data was successfully captured and displayed on a website. The BAN collected the pulse rate, the temperature and the location of the patients. The captured data was made available through a graphing application programming interface, where data can be continuously monitored on a website. Future enhancements to safeguard the data, including the encryption of the patient data is under investigation. Currently the BAN is powered using a 9V battery. In the future we plan to investigate the use of body temperature or the physical movement of the patient as means to produce power for the BAN.

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Figure 1. Network architecture

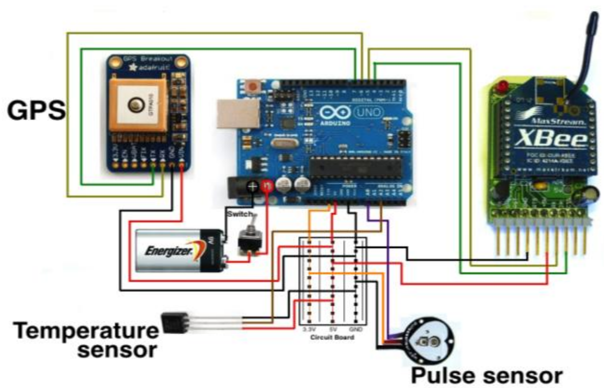

Figure 2a. The sensor node circuit circuit schematics. The sensor node consists of a temperature sensor, a pulse sensor, an ZigBee module, a GPS module and Arduino Uno microcontroller for data processing.

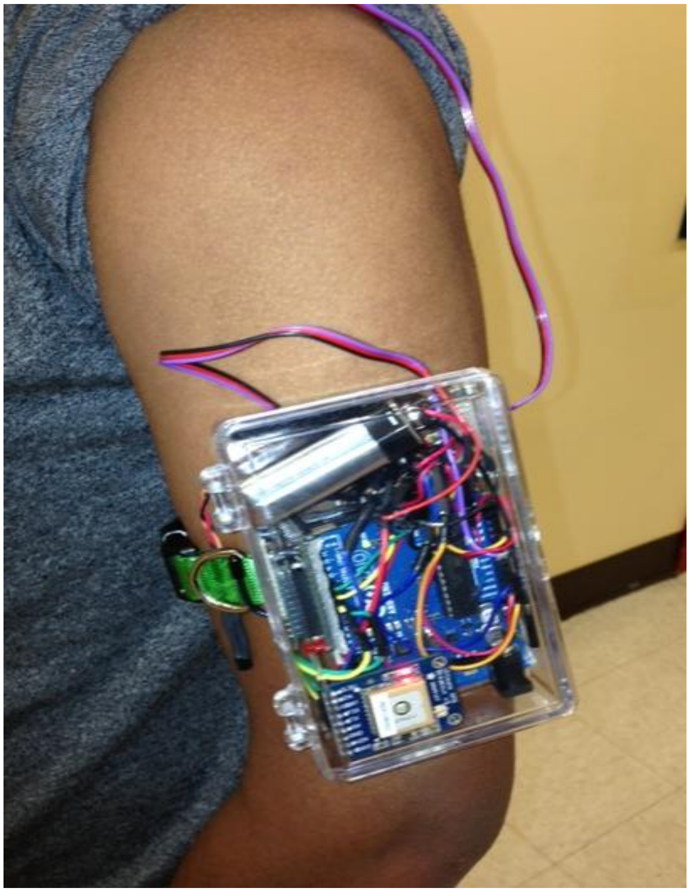

Figure 2b. The sensor node.

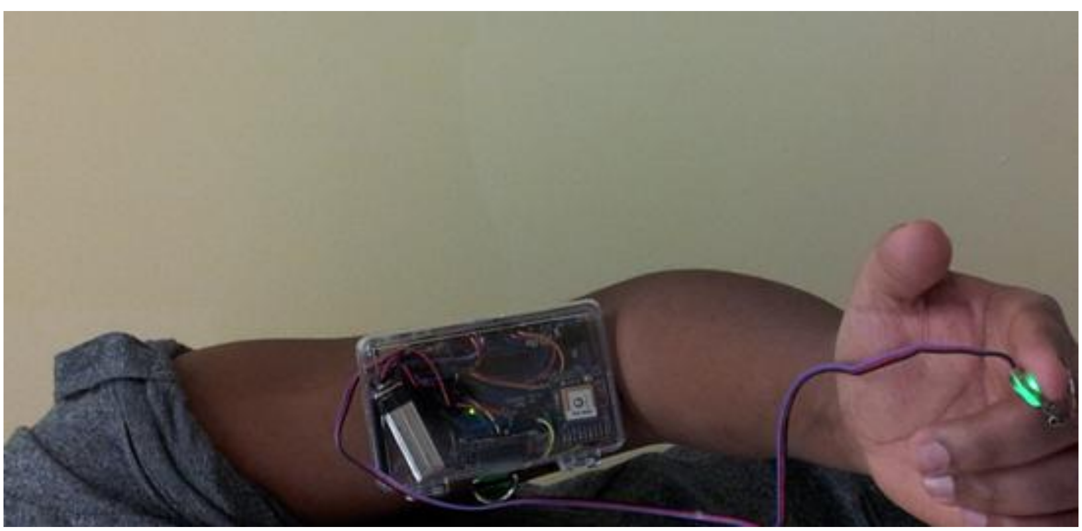

Figure 2c. The sensor node.

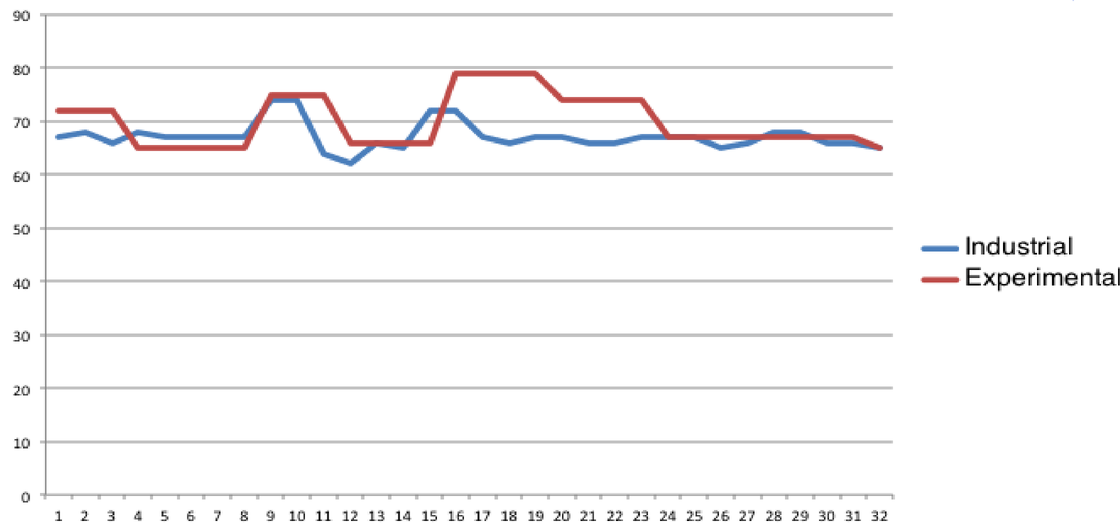

Figure 3. Pulse data comparison between an industrial sensor and the experimental sensor used in the construction of the BAN.

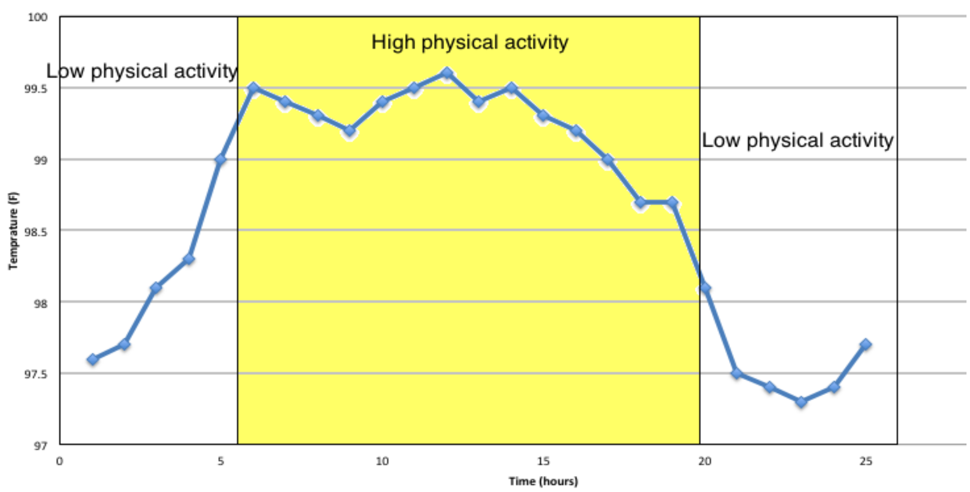

Figure 4. Body Temperature data during different physical activities.

Figure 5. Pulse Variation with Different Activities (industrial sensor).

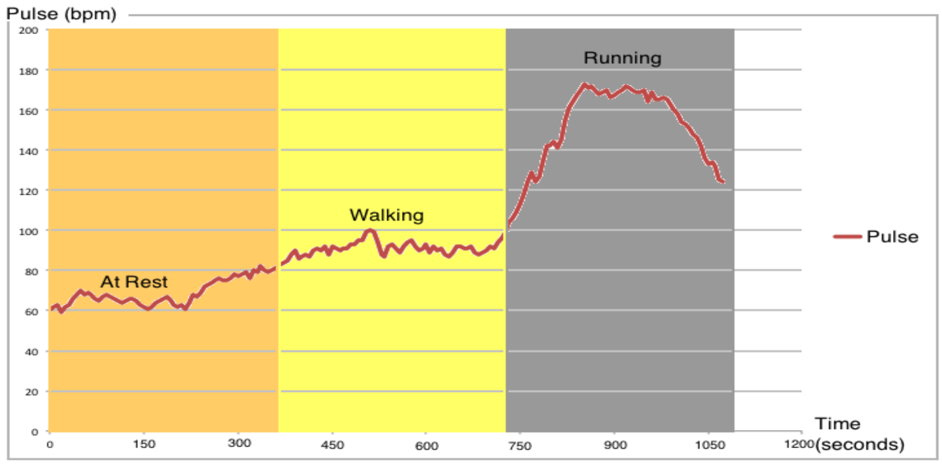

Figure 6. Pulse Variation with Different Activities (WBAN sensor)