A WI-FI BASED PERSONAL WIRELESS HUB FOR MEDICAL DATA ACQUISITION APPLICATION

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ABSTRACT

In this paper, a design of a Wi-Fi based Personal Wireless Hub (PWH) for medical application is proposed. Using the PWH, data from wired and wireless biosensors are collected and sent to data acquisition unit. The proposed PWH is light weight, power efficient and multipurpose device which is used with different biosensors to collect physiological data from human body. An android based mobile application is developed to store, analyze and display the medical data collected from the Wi-Fi based PWH. The collected data can be sent to remote server using an android based smartphone or stored in local storage. This enables remote and local access of medical data for diagnosis purpose. The Wi-Fi based personal wireless hub is prototyped in laboratory and tested with android application and computer software.

INTRODUCTION

Recent advancement of miniature sensors led to the development of wearable devices that are able to collect vital parameters from human body. There are existing pulse sensors that have Bluetooth capability [1]. The work presented in [2] discusses about design and development of wireless non-contact EEG/ECG electrodes. It claims that the total power consumption is only 300mW where a low frequency band is used for signal transmission. The work presented in [3] uses android smartphone for real time heart monitoring system which has Bluetooth connectivity with ECG sensor. There are existing commercial products designed for wireless data transmission of medical signals. The work in [4] presents a wireless system for ECG monitoring. It has patient transceiver station as well as monitoring station. The ECG data collected by patient transceiver is transmitted to monitoring station using Bluetooth technology. The design in [5] has patient monitoring system which includes bio patches that are attached to patient body to collect data using traditional disposable ECG electrode.

MOTIVATION

There have been several studies on wireless sensor network to increase its data transport capability, to reduce the sensor node size and power consumption. The work presented in [6] uses tablet computer for biomedical signal processing. It proposes a Bluetooth module for sensing and transmitting biomedical signals. The Android mobile app processes, visualizes and stores the collected data. The work in [7] proposes a hardware and software system that is used to collect EEG data from patient and sends it to android smartphone using Bluetooth technology. Current works are focused on the use of Bluetooth technology for data transmission from bio sensor node to data logging unit. Most of the work proposes single tier system architecture. In our work, we propose a two-tier system architecture. In the first tier, biosensors communicate with intermediate device using wired and wireless medium. In the second tier, the intermediate device communicates with data logging unit. Since most of the bio sensors have their proprietary communication protocol, it is difficult to incorporate them into single platform. The proposed hardware/software co-design communicates with different bio sensors and collects data and converts them into generic packet format. This enables generic socket enabled application to get data using transmission control protocol /internet protocol (TCP/IP). The proposed system architecture is shown in Figure 1.

Figure 1: Proposed system architecture

DESIGN CONSIDERATION

A. Wireless Protocol

The system is designed to support up to 6 wireless bio sensors operating on 2.4GHz frequency which is compatible with nRF24L01 [8]. For wireless communication with data logger, Bluetooth is a good candidate because of its lower power consumption, smaller size of module and low cost characteristics. According to the specification of Bluetooth low energy (BLE), the maximum data rate attainable is 1Mpbs but it is not optimized for streaming data [9]. It is optimized for burst transmission which is not suitable for continuous transmission of real time data from bio sensors. BLE is capable of transmitting ECG, heart rate, and EEG data, but not sufficient for real time transmission of images from wireless capsule endoscopy [10]. As a result, we have used Wi-Fi in our design as it supports maximum data rate of 10Mbps for 802.11 g standard. This data rate can go up to 300Mbps and depends upon the Wi-Fi 802.11 a/b/g/n standards on use.

B. Hardware configuration

The proposed PWH hardware contains minimal components needed for data collection, transmission and minimal user interaction. The architecture of the proposed Wi-Fi based PWH hardware is shown in Figure 2.

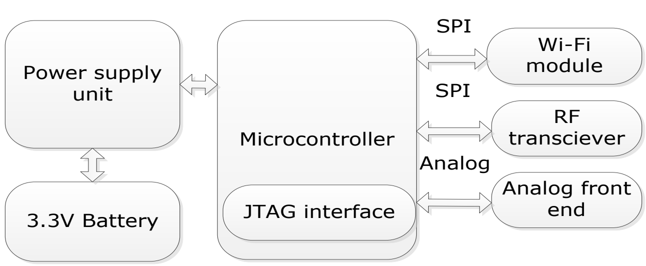

Figure 2: Hardware architecture of PWH

1. Microcontroller

The microcontroller controls all activities related to PHW operation. It is responsible for collecting, buffering, sequencing, packetizing and transferring data from bio sensor interface into TCP/IP network. The microcontroller has operational and supervisory role. It supervises its interfaces for errors in data, abnormal operations and fault conditions, and reports those conditions to remote data logger unit. A microcontroller from Texas instrument LM4F120 ARM cortex M4 is used in our design. It has 12-bit ADC and SPI interfaces to communicate with Wi-Fi and RF modules. It also has deep sleep capability which reduces power consumption significantly during idle conditions.

2. Wi-Fi module

The proposed PWH is based on Wi-Fi connectivity. Wi-Fi is common on hospital and personal home network and easily accessible to the users with proper configuration. The proposed PWH acts as Wi-Fi client and connects to the access point either in hospital network or patient's home network. CC3000 Wi-Fi module is selected since it has low power and small size [11]. It consumes 207mA at 3.3V during transmission and 103 mA at 3.3V supply during reception on 802.11 g mode. It has low profile so that it can be fit into a small area [11]. It is easily configured by smartphone application called *smart config* which eventually reduces additional cost and space of using user interactive displays and interfaces [12].

3. RF Transceiver

Nordic RF transceiver nRF24L01 module is selected in our design due to its lower power consumption, small size and high bandwidth. It operates on 2.4 GHz ISM band and can attain maximum 2Mbps of data rate. It uses SPI interface to connect with microcontroller at speed of 8 MHz. It has cyclic redundancy check (CRC) with automatic repeat request (ARQ) so that the data transmitted is guaranteed to be received by the receiver, which is essential on medical data transmission. The overall power consumption of RF transceiver operating at 2Mbps is 14mA at 3.3V power supply.

4. Power supply

The proposed design uses 3.3V 2200mAh lithium-ion rechargeable battery. The battery is charged using universal serial bus (USB) port. It takes 5 hours on average to fully recharge the battery.

C. Firmware

The firmware of the proposed PWH is developed on the base of application protocol interfaces (API) provided by Texas Instruments for LM4F120 microcontroller and CC3000 Wi-Fi module. The Firmware consists of three layers - device drivers, system operation and system monitor subsystems. It uses simple interrupt based scheduling scheme for scheduling the tasks.

1. Device drivers

The proposed design uses low level device drivers provided by TI as the part of LM4F120 microcontroller and CC3000 Wi-Fi module. Current device driver of CC3000 supports two simultaneous socket connections. It enables two data logging devices to can connect with the PWH at the same time; as a result, more users can connect the PWH with their smartphone and other online servers simultaneously.

2. System operation

Figure 3 shows the internal operation of system. The device driver layer is responsible for collection of data from bio sensor. It places collected data into shared memory pool. The operating system collects data from the memory pool according to the priority assigned to the sensor node. This helps to avoid the loss of data packet from the bio sensor which needs more bandwidth compared with other bio sensor's data. For example, real time image transmission in capsule endoscopy requires higher priority compared with temperature data. The data selected for further transmission is now packetized on standard format shown in the Figure 4. Each data packet is formatted into variable length data packet with header and payload data. The current data packet supports individual sensor node identification, date and time stamp payload data length and payload data.

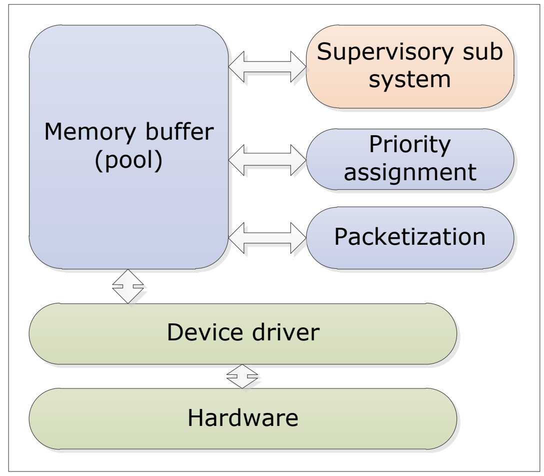

Figure 3. Internal operation of PWH

Sensor ID (4 bit)	Date/ Time Stamp (64 bits)	Payload length (8 bit)	Variable length payload

Figure 4. Data packet format for PWH and data logging application

3. System monitor

The proposed PWH has capability to monitor its health internally. It measures memory buffer overrun, data congestion, data packet loss and connection drop counts and reports back to connected data logging device. This data helps to configure device properly. The data packet containing four 0's in the "sensor ID" field indicates that the payload is system monitor data.

RESULTS AND DISCUSSIONS

The proposed PWH is tested with two sensors - pulse sensor [13] and temperature sensor. The Android smartphone acts as Wi-Fi access point (AP) where the PWH connects with smartphone without the need of Wi-Fi router. Optionally it can work in infrastructure mode, where smartphone and PWH can connect to Wi-Fi router directly. A computer application is also developed to connect with PWH, extract pulse sensor and temperature data, plot and save the logged data. The size of the prototype is 5cm x 6 cm x 3 cm; its weight with battery is 78g. The experimental setup with the proposed PWH and smartphone is shown in Figure 5 and Figure 6 below.

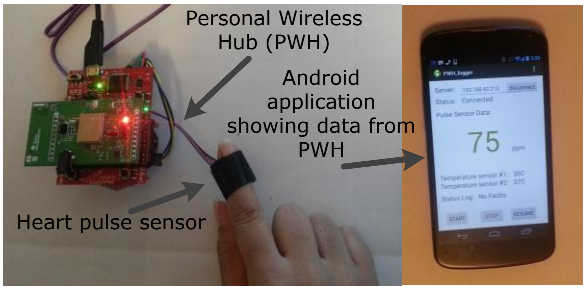

Figure 5: PWH with heart pulse sensor and Android application

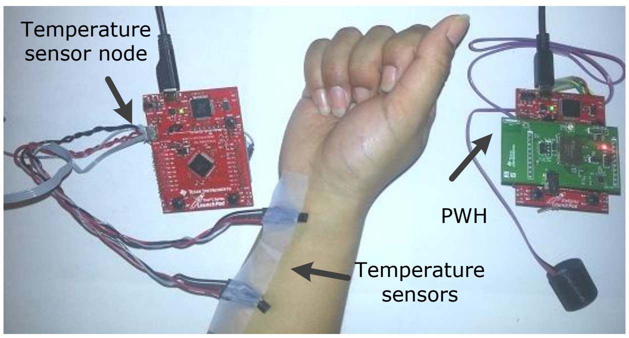

Figure 6: PWH with wireless temperature sensor node with two temperature sensors

The heart pulse sensor is connected to the analog to digital converter (ADC) pin configured to 12bit and 125Ksps sampling rate. The body temperature sensors are connected to wireless sensor node with LM4F120 microcontroller and Nordic nRF24L01 RF transceiver. The two temperature sensor nodes are connected to the PWH using the same RF transceiver. It can be extended for up to six wireless transmitters using individual pipes for data transmission. The PWH was able to transmit temperature and heart pulse rate data using Wi-Fi successfully. The Android data logging software displays the logged data visually and saves it into SD card in the form of comma separated value (CSV) format for future processing.

The average current consumption of the PWH is 150mA. It can run for 13 hours with a 2000mAh battery which is sufficient for medical data logging purpose. The Wi-Fi module consumes 120mA current on average. The microcontroller and Nordic RF transceiver consume 30mA current. The power consumption can be reduced by using more power efficient and miniature Wi-Fi modules.

CONCLUSION

In this paper, the design of a Wi-Fi based personal wireless hub (PWH) for medical data acquisition is proposed. It reduces the complexity of using different types of bio sensors from different vendors and makes simple communication between medical data collection nodes and data logging unit. The proposed PWH has IP connectivity so that the data can be directly sent to cloud, remote server or centralized data collection center. The proposed device is prototyped and tested in laboratory and its advantages have been demonstrated using pulse sensor and temperature sensor.

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