Patient Health Monitoring Using Wireless Body Area Network

Hsu Myat Thwe, Hla Myo Tun

Abstract: Nowadays, remote patient health monitoring using wireless technology plays very vigorous role in a society. Wireless technology helps monitoring of physiological parameters like body temperature, heart rate, respiration, blood pressure and ECG. The main aim of this paper is to propose a wireless sensor network system in which both heart rate and body temperature ofmultiplepatients can monitor on PC at the same time via RF network. The proposed prototype system includes two sensor nodes and receiver node (base station). The sensor nodes are able to transmit data to receiver using wireless nRF transceiver module.The nRF transceiver module is used to transfer the data from microcontroller to PC and a graphical user interface (GUI) is developed to display the measured data and save to database. This system can provide very cheaper, easier, and quick respondent history of patient.

Keyword: Heart rate, body temperature, WSN, nRF24L01, ATmega, Arduino.

I. INTRODUCTION

One of the many applications of Wireless Body Area Network is in medial environment where conditions of patients are continuously monitored in real time. In order to deploy a complete wireless senor network in healthcare systems, wireless monitoring of physiological data from a large number of patients is one of the current needs. A wireless network containing small interdependent sensor nodes is called WSN (wireless sensor network). Such a wireless sensor network system is very suitable to be used in hospital environments to reduce human errors, to reduce health care cost, to provide more time to health professionals to deal with other important issues.Physiological data are to be measured and monitored with the help of this proposed system. The data that is measured by these sensor nodes is sent to a base station using RF (radio frequency) communication. The communication between the nodes and the base station can be a single hop communication or it can be a multi hop communication depending on the remoteness of the sensor node. The base station also controls the whole network. On each sensor node there are various hardware components. Some of those are Microcontroller, Sensor or Transducer, Radio Frequency Transceiver, Battery or some other power source. Several other components are used for signal processing purpose to bring the sensor output signal in proper form and for proper power supply required for main components. The components required for this purpose are voltage regulators, Amplifiers, resistors and capacitors. The main purpose of this system is to achieve the communication between different sensor nodes and a single receiver simultaneously.

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The receiver that is base station should be able to display the information received from the sensor nodes. Three similar nRF24L01+ nodes were designed and tested to monitor patient's data. An ATmega328 microcontroller is used to design both the sensor nodes and at the base station. These microcontrollers are programmed in C with Arduino 1.0.5-r2. The signal received from the sensors is converted from analog to digital by the microcontroller and delivered it to nRF24L01 where it is sent by the radio. The communication between base station and PC is established by a USB connection. PC is used as a display device. The rest of the paper is organized as follows: Section II discusses the theoretical background.Section III explainsthe operation of the system. Section IV shows hardware configurations. Section V is the program flowcharts of the system. Section VI describes experimental setup. The discussions and conclusion are presented in Section VII.

II. THEORETICAL BACKGROUND

Heart rate is the number of heartbeats per unit of time and is usually expressed in beats per minute (bpm). In adults, a normal heart beats about 60 to 100 times a minute during resting condition. The resting heart rate is directly related to the health and fitness of a person and hence is important to know. This system has incorporated a microcontroller based heart rate and body temperature measurement system that uses optical sensors to measure the alteration in blood volume at fingertip with each heartbeat and LM35 sensor for body temperature.The heart beat sensor consists of an infrared light-emitting-diode (IR LED) and a photodiode. The IR diode transmits an infrared light into the fingertip (placed over the sensor unit), and the photodiode senses the portion of the light that is reflected back. The intensity of reflected light depends upon the blood volume inside the fingertip. So, each heart beat slightly alters the amount of reflected infrared light that can be detected by the photodiode. The changing blood volume with heartbeat results in a train of pulses at the output of the photodiode, the magnitude of which is too small to be detected directly by a microcontroller. Therefore, atwo-stage high gain, active low pass filter is designed using two Operational Amplifiers (Op-Amps) to filter and amplify the signal to appropriate voltage level so that the number of pulses within a certain interval (say 15 sec) can be counted by a microcontroller and easily determined the heart rate in bpm. Fig 1 is given below indicateblock diagram of patient health

monitoring via wireless body area network. This might be the wireless monitoring system caretaker of a medical doctor to multi-patients.

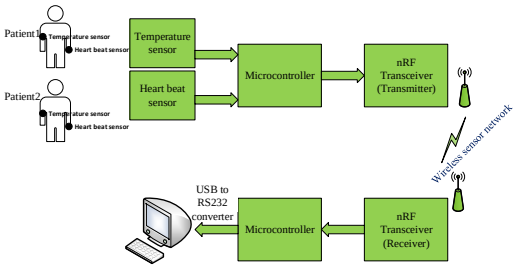

Fig.1 *Block diagram of patienthealth monitoring via wireless body area network*

III. Operation Of The System

A detail description of the proposed monitoring system is provided as following: The system is mainly constructed two sensor nodes and receiver node (base station). The sensor nodes contains sensors and microcontroller (in this case ATmega328). Sensors acquire the data and send it to microcontroller. All these sensor (LM35 temperature sensor, and pulse rate sensor) send the analog data to micro-controller. To make the data understandable to microcontroller it needs to be converted into digital form. It is done with the help of an ADC convertor which is integrated in the microcontroller.

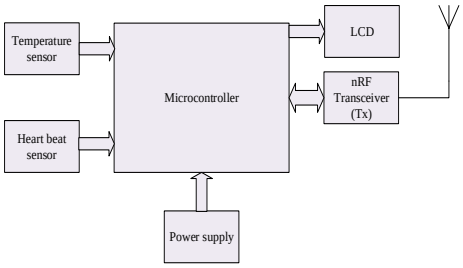

Fig.2 *Block diagram of transmission section (node 1)*

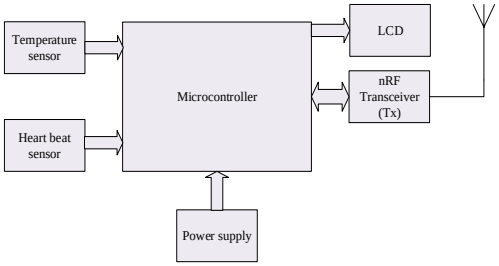

Fig.3 *Block diagram of transmission section (node 2)*

Fig 2 and 3 are shown that block diagram of transmission section(node 1 and 2). It contained two sensors (heart beat sensing and body temperature sensing), microcontroller, nRF transceiver, LCD and power supply for each node. Heat beat sensor is sent pulse signal to microcontroller (Arduino promini), then converted it to machine language, and then counted the heart rate. A microcontroller is used to interface sensors and nRF transceiver. Microcontroller receives data from sensors and then nRF transceiver sends these data by the radio.

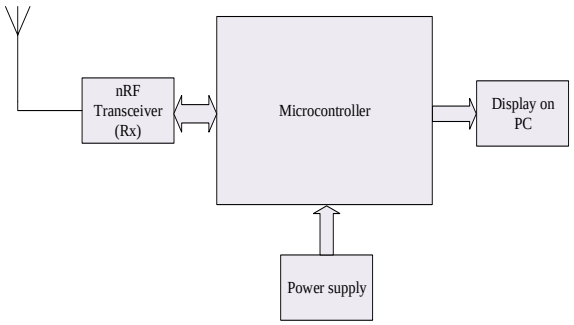

Fig. 4 *Block diagram of receivernode (base station)*

Fig 4 describes block diagram of the receiver node.The base station receives the transmitted digitized signal, and sends it to MCU to establish a connection to PC to displayheart rate and the body temperature.PC is used as a display device by using Visual studio.

IV. Hardware Configurations

A. Sensor nodes design

Sensor node are designed to collect raw signals from human body. A sensor node undertakes three tasks: detecting signal via a front-end, digitizing/coding/controlling for a multi access communication and finally wireless transmission via a radio transceiver technology. The signal from a human body is usually weak and coupled with noise. Thus, the signal should go through an amplification process to increase the signal strength. It then passes through a filtering stage to remove unwanted signals and noise. After which, it will go through an analog to digital conversion (ADC) stage to be converted into digital for digital processing. The digitized signal is then processed and stored in the microcontroller. It will then pack those data and transmit over the air via a transmitter.

B. Temperature sensor node design

The temperature sensor is chosen LM35. It has a good accuracy which is ±0.4°C and draws very low-power only 60µW. Temperature sensor produces analog voltage with respect to the Celsius temperature. The ADC in the microcontroller samples the voltage and converts to a digital data for the RF transmission. The transmitter adds some overhead and package the data for transmission.

C. Pulse rate sensor node design

The pulse rate sensor node comprises of the pulse detector, operation amplifier (LM358), ADC, signal processing by the microcontroller and the transmitter. The microcontroller ATmega328 and nRF transceiver are selected in the project because of the following reasons: overall cost saving, low power consumption, size and the suitability operating at 2.4GHz (ISM band) and for physiological data processing.

D. Arduino

At receiver (base station) side an Arduino promini is being taken into use. This will also work as the programmer device for Atmelmega328 micro-controllers. ISP connectors and SPI interface will help in the programing of microcontrollers.It transfer 8-bit data and have digital I/O

pins 14(of which 6 provide PWM output).ATmega328 microcontroller is used for both sensor nodes and receiver (base station).

E. Nrf24L01 module

These Nrf24 modules performing at 2.4GHz frequency are radio frequency transceivers.This transceiver module has 8 pins: GND,V_{cc}, CE, CSN, SCK, MOSI, MISO, IRQ. This module is designed by Nordic Semiconductor. This module is very much applicable for applications that needs ultra-low power for wireless data communication. Its interface to the microcontroller is done via SPI interface. These modules sends the data to the microcontroller after receiving. Also microcontroller sends those commands as well as data which is processed and ready to be transmitted. Microcontroller is responsible to put these modules in different modes of operation. NRF24s use GFSK modulation scheme to modulate the baseband data. They are operated with the power supply of 1.9 - 3.3 volts. Very less power is consumed in standby mode. Comparison of the types of transceiver is shown in below table.

Table I. *Comparison of the types of transceiver*

	Bluetooth	**nRF Transceiver**	Zigbee
Band	2.4 GHz ISM band	**2.4 GHz ISM band**	2.4 GHz ISM band
Standard	IEEE.802.15.1	**IEEE.802.15**	IEEE.802.15
Distance	Short distance (1~10m)	**Long distance (>1000m)**	Long distance (10~100m)
Data transfer rate	1Mbps	**250k/1M/2Mbps**	250kbps
cost	Fairly expensive	**Low cost**	Expensive

F. SPI Interface

The serial peripheral interface (SPI) is a synchronous data link. It is invented by Motorola. SPI is often called as a 4 wire serial bus. Its operation is in fully duplex mode. Single master and short distance communication link uses this interface. In this link the device communicates in master-slave configuration. The master always initialize the data frame.

G. Display

In this work, LCD and PC are used as the output devices for displaying devices. Information transferred from nRF24L01 can be sent to PC via USB to RS232 converter.

H. USB to RS232 converter

The MAX232 is used parallel-in-serial-out shift registers to convert the digital data in the serial form for wireless communication. UART IC in microcontroller allows the digital data transmission in the form of bits per second in asynchronous manner. RS232 standards are commonly used in computer serial ports for serial communication transmission of data, which are not Transistor Transistor Logic (TTL) compatible.

I. Power Supply

The transformer 230Volts will be stepped down to 12-0-12 one side of the 12V is given to the Atmega328 and sensors. In this work, the microcontroller requires +5V power supply. The voltage from transformer is step down to 5V by using L7805, linear voltage regulator, for the supply of the entire project. The voltage of 5V is given to the microcontroller, pulse rate sensor and temperature sensor, 3.3V for the nRF transceiver.

V. PROGRAM FLOWCHART

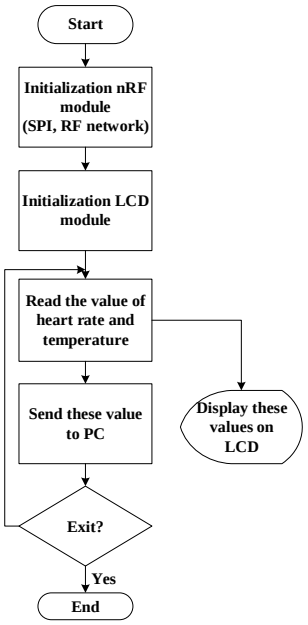

Fig. 5 *Program flowchart for transmission section (node 1 and node 2)*

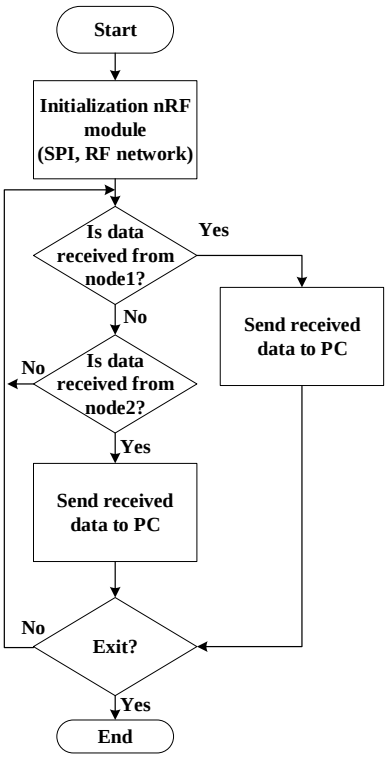

Fig. 6 *Program flowchart for receiving section (base station)*

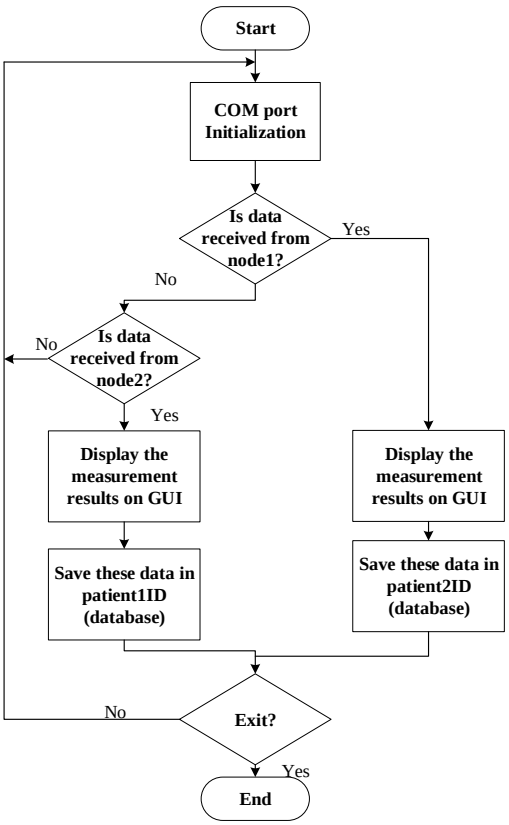

Fig. 7 *Program flowchart for C# GUI*

VI. EXPERIMENTAL SETUP

This following figure (8) showsthe transmitter prototype system of the temperature and pulse sensing circuit. The microcontroller is programmed to convert analog to digital from sensors, to count the heart rate and to transfer the sensed data using nRF24L01.ATmega 328, SPI bus uses pins 10(SS), 11(MOSI), 12(MISO) and 13(SCK). The supply voltage of nRF24L01 is 3.3V. The supply voltage of sensors and Arduino is 5V.

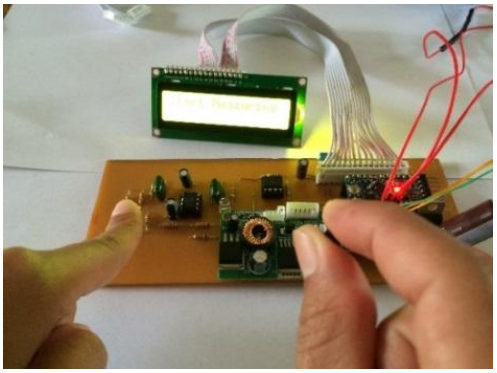

Fig. 8 *Measurement of heat beat body temperature (patient 1)*

Fig. 9 *LCD screen for display result(Patient 1)*

This figure (9) shows thatby the use of respective sensors the body temperature and heart rate of the patient 1 (node 1) and the data is transferred to microcontroller. The transmitted digital data after conversation from analog data by ADC, the data is displayed on LCD.The measured data is also delivered to nRF24L01.

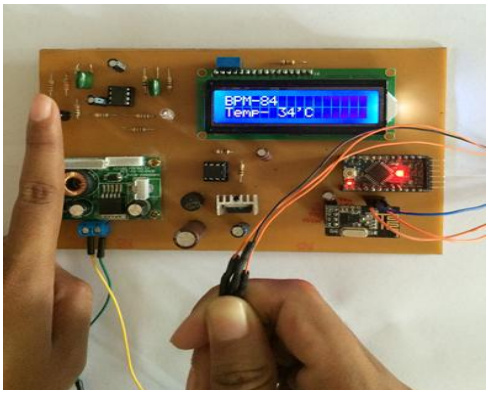

Fig. 10 *LCD screen for display result(Patient 2)*

This figure (10) also shows thatthe body temperature and heart rate measurement of the patient 2 (node 2) and the data is transferred to microcontroller. The transmitted digital data after conversation from analog data by ADC, the data is displayed on LCD. Next, the measured data is delivered to nRF24L01.

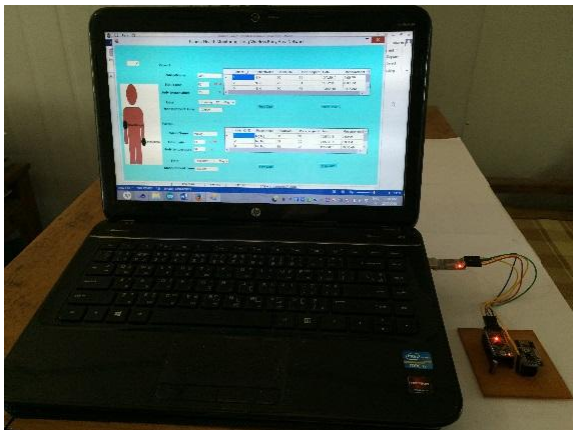

Fig.11 *Receiver node (base station)*

In order to monitor data and save data, the C# program is written in Microsoft Visual Studio 2010. Fig 11 is the receiving part of patient health monitoring in wireless body area network. The received data is converted by microcontroller to the language that can know from the computer, and then the data is sent to the computer by the use of RS232 serial communication.

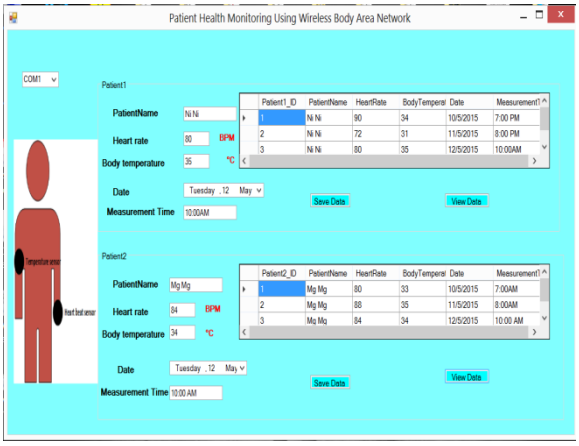

Fig. 12 *A GUI screen: Physiological data measurements for two patients, archiving*

A graphical user interface (GUI) at the local PC is also designed to display medical data and record the patients' data. Both the data received from sensor nodes and PC can be displayed by GUI in a text formats. The physiological signals of patients can be accessed by medical staff as long as their computer are connected to the RF wireless network in the building. An example of live monitoring from two patients scenario is shown in Fig(12). It display heart rate information (BPM) and temperature (°C) of two patients at the same time.

Table. II *Measurement of heart rate and body temperature.*

Person	Heart rate (BPM)	Body temperature (ºC)
Child (male)	104	35
Child(female)	100	34
Adult(male)	84	34
Adult(female)	80	35

This table (II) shows the measurement of heart rate and body temperature for different ages.

VII. Discussions And Conclusion

This paper presented a Wireless Body Area Network (WBAN) system with the help of RF (Radio Frequency) technology that can be used in medical environment for patient monitoring.This system was mainly designed and implemented with three nRF transceiver modules: two for transmitter and one for receiver. Microcontroller is used to read measured values from heart rate and body temperature sensing circuits. After obtaining data from sensing circuits, the data can be transferred to a remote PC through nRF transceiver module. Therefore, vital signs such as heart rate and body temperature can be acquired from multi-patients at the same time. A major limitation in this System is transmission and reception range. The range of nRF24L01 is about 70 feet. Due to its range, this system is not suitable for large hospital. In order to cover the whole area of large hospital range, the nRF24L01p+PA+LNA(available >1000m) should be used. As the result that the cost for this nRF24L01+ would be more expensive compared with the proposed system using nRF24L01 transceiver module. Therefore, this low cost wireless network system can provide to reduce the workload, to improve the efficiency of hospital staff as well as to increase the comfort of the patients.

Acknowledgment

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