Dedicated real-time monitoring system for health care using ZigBee

Omar S. Alwan, K. Prahald Rao ✉

Electrical and Computer Engineering Department, Faculty of Engineering, King Abdulaziz University, Jeddah-21589, Saudi Arabia
✉ *E-mail: prahladk@gmail.com*

Published in Healthcare Technology Letters; Received on 29th April 2017; Revised on 30th May 2017; Accepted on 31st May 2017

Real-time monitoring systems (RTMSs) have drawn considerable attentions in the last decade. Several commercial versions of RTMS for patient monitoring are available which are used by health care professionals. Though they are working satisfactorily on various communication protocols, their range, power consumption, data rate and cost are really bothered. In this study, the authors present an efficient embedded system based wireless health care monitoring system using ZigBee. Their system has a capability to transmit the data between two embedded systems through two transceivers over a long range. In this, wireless transmission has been applied through two categories. The first part which contains Arduino with ZigBee will send the signals to the second device, which contains Raspberry with ZigBee. The second device will measure the patient data and send it to the first device through ZigBee transceiver. The designed system is demonstrated on volunteers to measure the body temperature which is clinically important to monitor and diagnose for fever in the patients.

1. Introduction: We all agree that health life is our fundamental right which is the main objective of World Health Organization as well [1]. Therefore, it becomes essential for individual to make use of modern health care system to keep themselves healthy and fit [2].

Wireless transmission data technology in the medical field is the most important application that any organisation in the health sector needs it. As well as this technology is often characterised by the speed, safety and easy installation of hardware at lower costs. Patient monitor systems which are used in hospitals are used for continuous monitoring of patient's physiological values. The limitation of these systems is that the sensors are 'hardwired' to the monitors or PCs nearby the patient. In spite of wired connectivity with the monitoring devices, nursing staff should keep track of all vital values by making note the records either manually or entering into the computers which would sometime tend to make human errors that may lead to serious consequences on the patient [3].

In this work, we have demonstrated the body temperature measurement data transmission wirelessly using two transceivers based on ZigBee. One of them is connected to a small but low-cost Raspberry Pi and the other is connected to a simple microcontroller board Arduino which works as a simulator for a medical equipment that in turn senses the temperature.

The main objective is to design a real-time monitoring system (RTMS) for a patient by measuring the temperature. The system recommended to be an integrated, small, with low cost and low power consumption. This will facilitate the physician who may be roaming or from his office to monitor the patient hospitalised for illness. In addition, the system (RMTS) includes saving of time and effort of the medical staff (physician and nurses), quality improvement of patient care and reducing error rate of human mistakes. The system measures the vital physiological values (e.g. temperature) and sends alarms making alert for medical staff to attend the patient for emergency. Also the system makes it possible to transmit the data and save automatically on repeated measurements for the same connectivity [4].

2. Related works: Real-time monitoring of only electrocardiogram (ECG) for the patients using Zigbee and Session Initiation Protocol has been reported in [5] and for several biomedical signals from different patients can be found in [6] which are to be accessible easily by health care professionals.

Recently, Google Android [7] has released a health care gadget called 'BluetoothHealth' [8] that supports the ISO/IEEE Standards. Another system for ECG monitoring based on ZigBee technology can be found in [9]. However, their system needs a PC with graphical user interface interface. Since the Bluetooth operates on low energy, so for monitoring the ECG signal from the patient, another system on mobile technology has been implemented by Yu *et al.* [10]. Besides the ECG signals, a system has been developed [11] for monitoring of obstructive sleep apnea syndrome, a sleeping disorder in patients. It is also reported by researchers for the rehabilitation of aged people to monitor and assist while they are walking [12]. The recorded real-time data could be helpful for the corrective treatment by health care professionals.

However, an integrated simple system (RTMS) for patient monitoring is required that should be characterised by its size, time, cost, communication protocol, range and the speed of data transmission.

3. Methodology and procedures: The proposed RTMS consists of the following stages: (i) system design, (ii) system installation and (iii) programming codes. The integrated system having these important stages is shown in Fig. 1.

3.1. System design: The system design is the most important stage to build any system. The system design must be integrated in order to increase the system efficiency and limit the future problems and errors as much as possible. This system design is based on the following characteristics: parameters, technologies, circuits, approximate cost, components and software. Among various physiological parameters, primary parameter to be observed from the patients is the body temperature. So the main components are the temperature sensors for measuring the temperature, the embedded system that connected with the sensors and processing of signals, the transmission modules that transmit and receive the signals, and the embedded controller which process and display the received signals.

Generally, there are many wireless technologies that can be used for the transmission of medical data such as Wi-Fi, Bluetooth, ZigBee, Bluetooth Low Energy, LoRaWAN and so on. A particular application can be decided by examining several characteristics which include power consumption, data rate and the range. These three characteristics have been considered in designing this

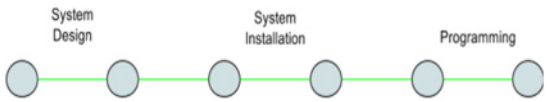

Fig. 1 *Main stages of the system*

system and the overall cost of the system. In comparison, ZigBee is more suitable due to the following features:

- Power consumption of ZigBee is very low.
- The range of ZigBee is very large (300 ft–40 miles) [13] which is an essential feature to monitor the patient within health care facilities (hospitals and clinics) or from outside the buildings like ambulance services.
- The data rate in ZigBee (250 kbit/s) is low which is suitable for measuring and sensing the vital signs.
- The cost is low.

3.2. System installation: Fig. 2 is the diagram of the RTMS.

The proposed system of our work is based on wireless transmission of medical data through two transceivers. The first embedded device consists of a Raspberry Pi and Zigbee module. Raspberry Pi is connected to liquid crystal display (LCD) monitor, LCD 16 × 2, light-emitting diode (LED), buzzer, keyboard and a mouse while the second device consists of Arduino (Mega 2560) and another Zigbee transceiver module that fixed in Arduino through the ZigBee shield.

Arduino has an outlet power with 5 V DC. LED is connected to the controller through port A0 for the positive pin and ground for negative pin. A temperature sensor (LM335z) is connected to 2 kΩ resistor which is used to improve the sensitivity and protect the sensor from high power surges. The resistor is connected to 5 V power supply port in the right pin of the sensor. The middle pin of the sensor is connected to ground point.

Specific code is written in Arduino software and then uploaded to Mega2560 that has a microcontroller. The software code enable the sensor to sense the temperature of the skin surface in contact and then will transfer the temperature signal from the first transceiver module to the second which is connected to the Raspberry Pi. Finally, the temperature value will be displayed on LCD screen or LCD 16 × 2. Raspberry Pi is programmed through Python language code. In addition to monitor the temperature by visual display on LCD or TV screen, the Raspberry Pi produces sound alarm through a buzzer. The positive terminal of the buzzer is connected to pin 2 of the Raspberry Pi and the negative is connected to GPIO pin 7. The positive leg of the LED is connected with Raspberry through pin 1 (3.3 V) and the negative to the GND. Table 1 shows the pin connection details between the Raspberry Pi and LCD.

The sensor which is calibrated with a digital thermometer will measure the temperature and transmit it through ZigBee module.

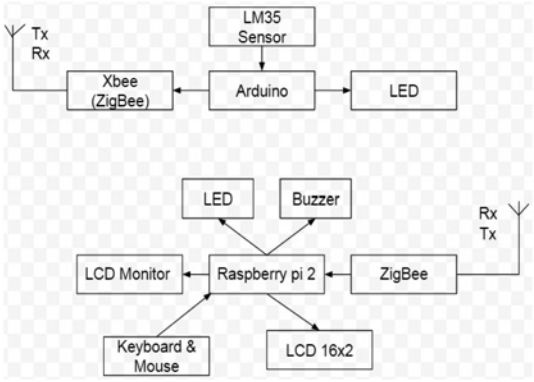

Fig. 2 *RTMS block diagram*

Table 1 Pin connection between Raspberry Pi 2 and LCD 16 × 2

Raspberry pin no.	Raspberry Pi 2 indicator	LCD 16 × 2 display indicator	LCD 16 × 2 pin no.
2	5 V	Vcc	2
23	GPIO 11	LCD D7	14
29	GPIO 5	LCD D6	13
31	GPIO 6	LCD D5	12
33	GPIO 13	LCD D4	11
35	GPIO 19	enable	6
37	GPIO 26	RS	4

Another ZigBee will receive the sensed data while LCD screen or LCD 16 × 2 monitoring the temperature. When the temperature exceeds 38°, the buzzer and LED alarms turns on. By pressing the keyboard which is connected with Raspberry Pi, the alarm stops but the display on TV or LCD 16 × 2 continue to indicate the temperature readings.

The flowchart shown in Fig. 3 gives the details of instructions followed in the RTMS.

3.3. Programming and codes: Two software languages have been programmed in this system. Raspberry Pi is programmed by Python language and Arduino is programmed by C/C++ languages.

3.3.1. Code for Arduino microcontroller: The following code is used to sense the temperature of the sensor, connected to the Arduino and send it through the ZigBee module.

```
int outputPin = 0; //initialises/defines the output pin of the sensor
void setup()
{
Serial.begin(9600);
}
void loop()       //main loop
{
int rawvoltage = analogRead(outputPin);       //pin A0 for the sensor
float millivolts = (rawvoltage/1024.0) * 5000;
float kelvin = (millivolts/10);
//Serial.print(kelvin);
//Serial.println('degrees Kelvin');
int celsius = kelvin – 273.15;
Serial.print(celsius);
Serial.println('degrees Celsius');
delay(3000);
}
```

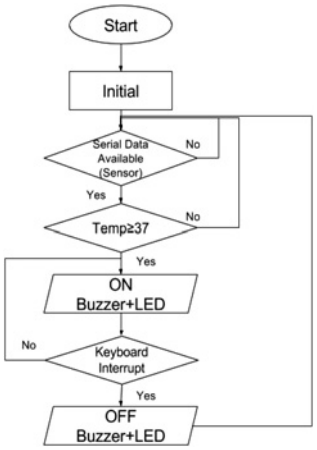

Fig. 3 *Flowchart of the system after sensing the temperature (Raspberry Pi system)*

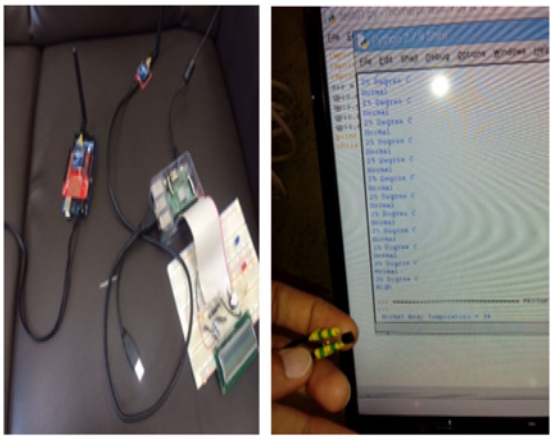

Fig. 4 *Snapshots of an integrated system and the temperature measured from a volunteer*

3.3.2. Python code for Raspberry Pi: The following code is used to monitor the sensed temperature which displayed on LCD screen as well as to send the alarms for both buzzer and LED. It is also set in the code to make alert the attendee when the temperature exceeds the preset value of 37°C by automatically activating the buzzer sound and LED blinking. The alarms will work continuously until the physician/staff interrupt them by pressing the keyboard button (Fig. 4).

```
import time
import RPi.GPIO as gpio
import serial
ser = serial.Serial('/dev/ttyUSB0', 9600, timeout = 0.5)
gpio.setwarnings(False)
gpio.setmode(gpio.BOARD)
gpio.setup(7, gpio.OUT)    'Pin 7 for LED'
gpio.setup(18, gpio.OUT)    'Pin 18 for Buzzer'
print 'Normal Body Temperature = 36'
while True:
f = ser.readline()
print f + 'Degree C'
if f! = '':
time.sleep(0.01)
if int(f ) > 37:
print 'High'
try:
while True:
gpio.output(7, True)
gpio.output(18, True)
time.sleep(0.5)
gpio.output(7, False)
gpio.output(18, False)
time.sleep(0.5)
except KeyboardInterrupt:
gpio.output(7, False)
gpio.output(18, False)
ser.flushInput()
else:
print 'Normal'
```

4. Conclusions: Arduino is a popular open-source electronic hardware circuit board that can read as well as write the code simultaneously. In our system, it is used to read the instructions for turning LED on or off, and at the same time to write the sensed temperature values for sending it to the Raspberry Pi that displays on the screen. This process takes place wirelessly which is considered as an important feature of the device in terms of the speed thus saving the time and effort. By using the Raspberry Pi which is an affordable single board computer programmed for alarming abnormal values and continuously display on the screen. By using these two specialised electronic hardware circuits the speed enhances at lower power consumption compared with other versions of RTMS technologies.

It can be extended for the desired physiological parameters cascading with appropriate patient monitoring devices such as blood pressure, heart rate, SPO_2 pulse oximeter and so on, based on the type of illness of the patient. The physician can monitor the patients remotely and can plan for further course of treatment. The doctor can save the valuable time by instructing the paramedics to apply prescribed medication on the patients.

As the technology is dramatically progressing, the electronic hardware component's quality is improving but the costs are decreasing. The components used in our proposed system for health care application are affordable which make the dedicated system cost effective.

5. Funding and declaration of interests: Conflict of interest: None declared.

6 References

[1] A Right to Health. Available at http://www.who.int/mediacentre/factsheets

[2] Abdullah A., Ismael A., Rashid A., *ET AL.*: 'Real time wireless health monitoring application using mobile devices', *Int. J. Comput. Netw. Commun.*, 2015, **7**, (3), pp. 13–30

[3] Sirisha B., Shraddha T., Vijayanand K.: 'Real-time multi-patient monitoring system using ARM and wireless sensor network', *Int. J. Commun. Netw. Secur.*, 2013, **2**, (2), pp. 41–47, ISSN: 2231–1882

[4] Lin Y.-F., Shie H.-H., Yang Y.-C., *ET AL.*: 'Design of a real-time and continua-based framework for care guideline recommendations', *Int. J. Environ. Res. Public Health*, 2014, **11**, pp. 4262–4279

[5] Kim B., Kim Y., Lee I., *ET AL.*: 'Design and implementation of a ubiquitous ECG monitoring system using SIP and the ZigBee networks'. Proc. of the Future Generation Communication and Networking (FGCN 2007), Jeju, Korea, 6–8 December 2007, pp. 599–604

[6] Fariborz H., Moghawemi M., Mehrkanoon S.: 'The design of an intelligent wireless sensor network for ubiquitous healthcare'. Proc. of the Int. Conf. on Intelligent and Advanced System, Kualalumpur, Malaysia, 25–28 November 2007, pp. 414–417

[7] Google Inc. Android Developers. Available at http://www.android.com/, accessed on 9 February 2017

[8] BluetoothHealth. Available at https://developer.android.com/reference/android/bluetooth/BluetoothHealth.html, accessed on 9 February 2017

[9] Sia H.-Y.H., Wang L.-H., Lin F.-C., *ET AL.*: 'Design and implementation of a wireless ECG acquisition and communication system with health care services'. Proc. of the Int. Symp. on Bioelectronics and Bioinformatics, Suzhou, 3–5 November 2011, pp. 25–28

[10] Yu B., Xu L., Li Y.: 'Bluetooth low energy (BLE) based mobile electrocardiogram monitoring system'. Proc. of the IEEE Int. Conf. on Information and Automation Shenyang, China, June 2012, pp. 763–767

[11] Gao R., Yang L., Wu X., *ET AL.*: 'A phone-based e-health system for OSAS and its energy issue'. Proc. of the Int. Symp. on Information Technology in Medicine and Education, Hokodate, Hokkaido, 3–5 August 2012, pp. 682–696

[12] Lan T., Li X.: 'Gait Analysis via a high resolution triaxial accelartion sensor based on ZigBee technology'. Proc. of the Int. Conf. on Complex Medical Technology, Beijing, 25–28 May 2013, pp. 697–702

[13] https://www.sparkfun.com/pages/xbee_guide