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ZIGBEE BASED PHYSIOLOGICAL STATUS MONITORING SYSTEM

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Abstract
A lot of research has been carried out in the field of health care monitoring. In the recent years, development of wireless health care monitoring system has emerged as an area of research. The presented work falls under the health care monitoring system. Here the system monitors the patient continuously while simultaneously transmitting the physiological data to the doctors and other medical staff. The presented system is based on a dedicated communication protocol for sensor networks, ZigBee. The system has low cost, low power requirements and compact. The performance of the system is analysed for indoor and outdoor environment, under various conditions. It is observed that the system provides reliable monitoring and secure wireless transmission of the monitored data. Further it is observed that the current consumption of the system is 64.1 mA and 71.2 mA at the sensing node and coordinator respectively, when transmitted power is set at -18 dBm. The range of the system varies from 10m (indoor environment) to 30m (line of sight range in outdoor environment) at -18 dBm transmitted power, which is suitable for hospital environment.

Keywords
ZigBee, Microcontroller, sensor, Health monitoring

1 Introduction

Modern times have seen a lot of development in health care domain. With the advances in medicine the cost of health care has rose many folds on one hand and a rapid increase of the aged population due to the newer and better medicines on the other. The key to saving lives and improving the overall safety of a patient's care still remains in providing timely access to complete patient information, ofcourse need not to mention the medical supervision. As the number of patients increase the need to monitor and record for use by experts later becomes more and more important. Several works have already been done to improve the recording and reporting systems have been developed to provide a wealth of healthcare data [1], still the information remains fragmented and largely inaccessible. With the recent developments in wireless systems [2]-[10] there has been renewed interest for medical applications [11]-[19]. Significant inputs are being directed towards development of novel low power circuits and systems. Wireless systems hold a number of advantages over wired alternatives, including: ease of use, reduced risk of infection, reduced risk of failure, reduced patient discomfort, enhanced mobility, quick & easy setup of the wireless sensor networks make them the only choice in case of disaster response to setup immediate temporary health care center, and lower cost of care delivery [20],[21]. Applications demand expertise in multiple disciplines, suggesting opportunity for System-on-Chip (SoC) or System-in-Package (SiP) integration. The demand for wireless connections increases with as more and more biomedical sensors emerging.

The medicare centers like hospital, nursing homes, clinics etc. impose their own specific requirements for wireless data transmission, for example the selected technology has to be extremely reliable, to make a more humane environment for the physical and physiological heath care more feasible for patients especially the aged ones, frequent monitoring and recording of their physiological status becomes very important [22],[23],[24], the stringent regulations relating to patient treatment and monitoring set strict specifications for possible solutions. In addition, and the sensors' power consumption must be low etc. To prevent accidents from happening and prevent sudden situations that cause accidents, the role of the wireless sensor networks comes in very handy, specially for ICU (Intensive Care Unit), ICCU (Intensive Cardiac Care Unit), Burn Wards or Gynae wards where the admission is very restricted due to the reasons of getting further infections from the visiting human personals that would include the hospital staff. It has been often observed that during surgical operations and during their stay in these wards patients monitoring is done by attaching to them monitoring equipment by cables. Cabling, however, offer many hindrances in many ways to the treatment process; for instance, cables obstruct nursing procedures and complicate patient transfers, as they have to be attached and detached. Detaching the sensor would mean loss of monitoring information which could be vital in some cases. Ideally, sensors should be attached to patients on their arrival at the hospital, and detached upon their discharge. In countries like ours were the mass population is still thriving for one square meal the increasing cost of medicine becomes difficult, also the hospitals and nursing centers are overloaded by patients due to lack of widely available services. It is mandatory to reduce not only the cost of treatment but also the load on the institutions offering such facilities. A wireless sensor is best suited for such situations. Many a measurements can be performed.

The purpose of present work is to develop a system that is low power consuming, low manufacturing cost, compact size, long distance of communication, reliable and secure communication, expandable and meets the governing regulations concerning wireless patient monitoring. For the current work in the first place we designed a physiological status examination device for collection of the physiological status information from patients in real time. Once this information has been collected, the monitoring device transmits this acquired information to the nursing staff via wireless network using the zigbee protocol [25],[26],[27]. The system has the advantage that it is microcontroller based and thus can be programmed to display various quantities, such as average, maximum and minimum rates over a period of time for different physiological parameters and so on. The design may be expanded and connected to a recording device or a PC for data collection and analysis. The total cost of the system is around INR 1000 per node and could come down on mass production. Similar devices cost around US$ 20 – 100 for monitoring single physiological parameter and / or with no or limited extension capabilities.

2 Solution Methodology

Today's hospitals deploy numerous devices over wires for various medical applications such as monitoring, diagnosis, treatment, and alarms. In order to plug in more and more devices in hospitals, it is essential to replace wires with wireless technologies. This replacement not only reduces the deployment cost and time, but also gives patients an increased mobility and comfort by reducing the complexity of the network.

The process of replacing wired network with wireless network depends upon the availability of networking modules. The wireless networking module available these days are usually programmable by the microcontroller/microprocessor. Therefore, the complete process of development of the health care monitoring system is divided into two parts:

1. Hardware part
2. Software part

2.1 Hardware Implementation

Hardware part consists of two modules: 1. Sensing node. 2. Coordinator.

Sensing Node. The main objective of the sensing node is to collect the data from the sensors, perform signal conditioning operation and then transmits the data to the coordinator. Sensing node consists of Microcontroller, Radio transceiver, Sensors and Power supply.

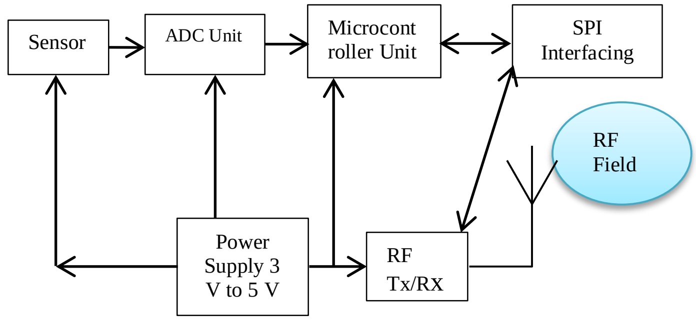

Fig.1. Block diagram of sensing node

Coordinator. The function of the coordinator is to gather data and then display the data as per the requirements. Coordinator consists of Microcontroller, Radio transceiver, Display device and Power supply.

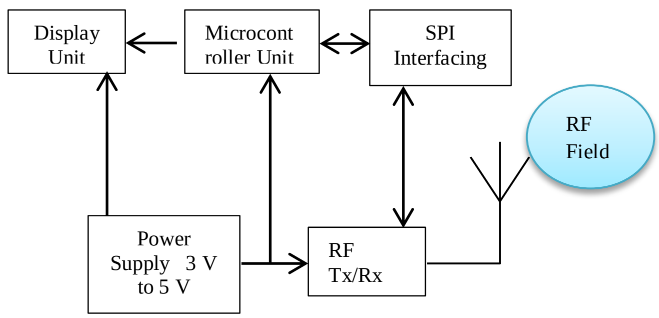

Fig.2. Block diagram of coordinator

2.2 Component Descriptions

Components that are used to develop the system are described below:

Sensor. In the presented application temperature of human body is measured. To measure the temperature various sensors are available such as: thermocouple, thermistor, RTD and IC temperature sensors. For the presented work, system must be compact and light weight. Therefore, IC temperature sensors are most suitable here. LM35 is used as a temperature sensor. It can provide accuracies of ± 1⁄4˚C at room temperature and ±3⁄4˚C, over a full −55 to +150˚C temperature range. The LM35 has low output impedance, linear output, and precise inherent calibration [28]. These features make it easily controllable and suitable for the presented work.

ADC and Microcontroller. For the application any microcontroller which has dedicated SPI module and inbuilt analog to digital converter (ADC), is suitable. PIC 16F886 is chosen for this work. Any better version of the available microcontroller can also be taken. PIC 16F886 has 11 channels of ADC and resolution upto 10 bits [29].

Transceiver. In this application CC2520 is used as RF transceiver, which is based on Zigbee technology. The CC2520 is TI's second generation RF transceiver that works at the 2.4 GHz unlicensed ISM band. The CC2520 provides extensive hardware support for frame handling, data buffering, burst transmissions, data encryption, data authentication, clear channel assessment, link quality indication and frame timing information. Power consumption of CC2520 is very low. In receiving mode (receiving frame, -50 dBm) it consumes18.5 mA current and in transmitting mode it consumes 33.6 mA current at +5 dBm and 25.8 mA at 0 dBm [30].

Power supply and Display Unit. To meet the power requirements a suitable arrangement is accomplished with the help of 7805 and AMS 1117 voltage regular. For displaying the valuable information a 14 pin LCD display is used.

2.3 Software Development

PIC 16F886 has been programmed to test the hardware as well as to achieve the goal of the application. The coding of the software is implemented in MIKROC Pro complier. Source code has been written in the embedded C language. Flow charts of the software implementation are as follows:

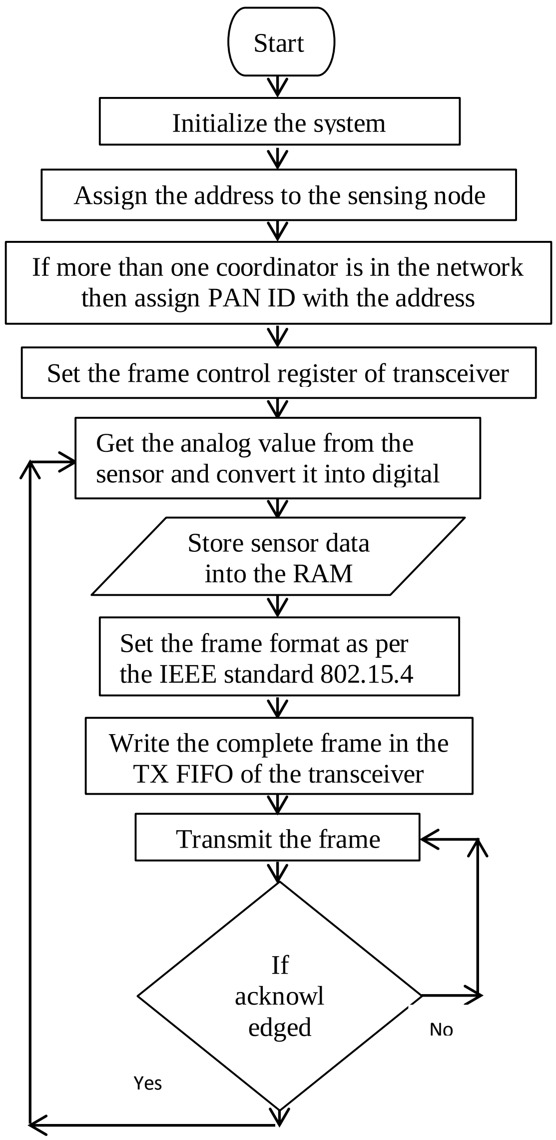

Fig.3. Flow chart at the sensing node

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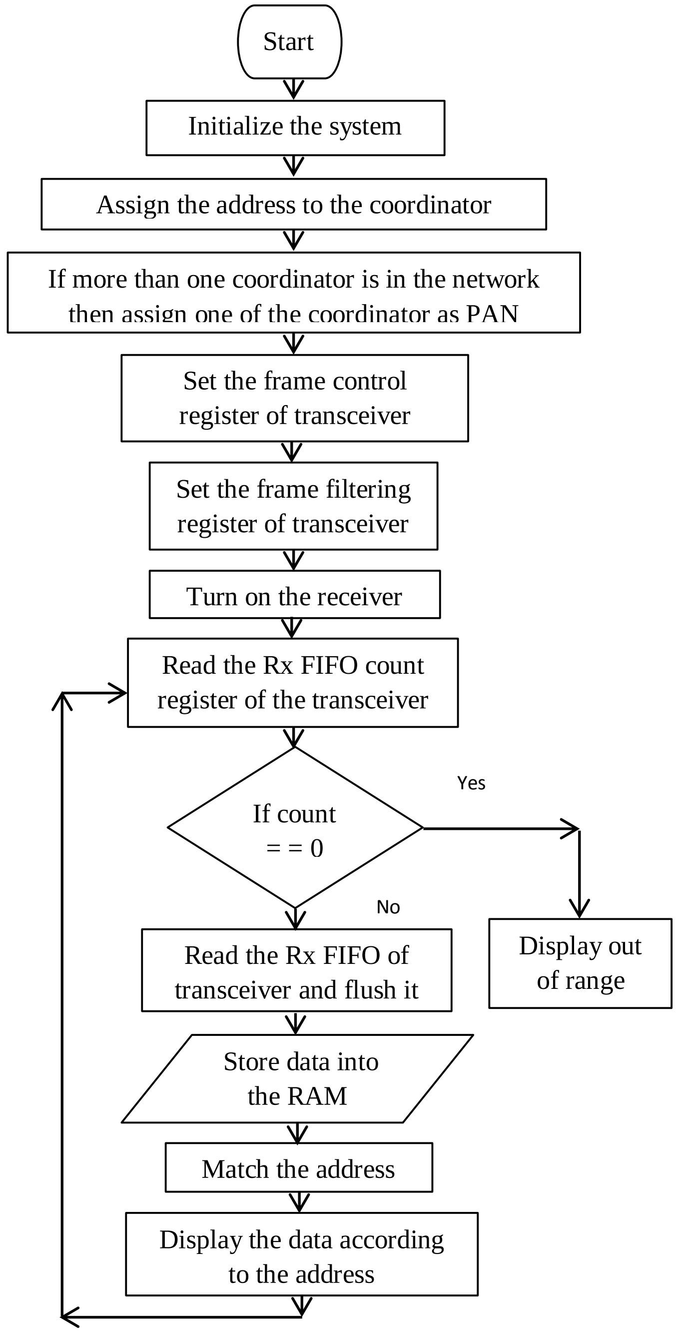

Fig.4. Flow chart at the coordinator

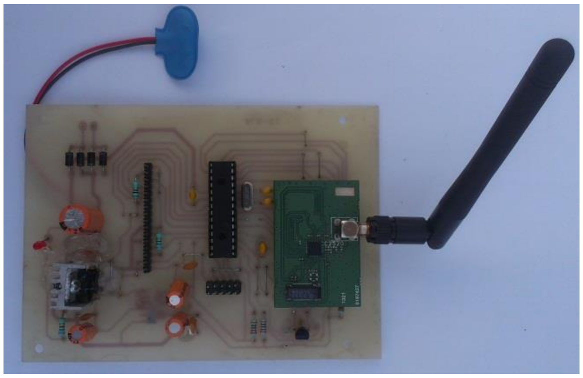

Fig.5. Sensing node

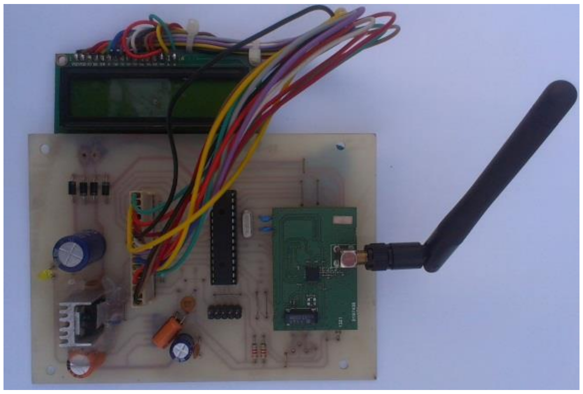

Fig.6. Coordinator

3 Result And Discussion

The system has been tested for different environments and under different conditions such as indoor environment where various obstacles are present and outdoor environment in Thapar University, Patiala. This system performed well in both the environment. All the tests are performed with an antenna of 3dBi gain. To determine the power consumption of the developed system, current consumption is checked at different transmitted power. Current consumption at the sensing node at different transmitted power is summerized in Table 1.

Table 1. Current consumption at the sensing node

Transmitted Power in dBm	**Current consumption in mA**
5	80.3
2	75.5
0	70.2
-7	66.5
-18	64.1

Current consumption at coordinator at different transmitted power is summerized in Table 2.

Table 2. Current consumption at the coordinator

Transmitted Power in dBm	Current consumption in mA
5	87.5
2	80.6
0	77.5
-7	73.3
-18	71.2

It is observed that the current consumption of the whole system is very nominal. A 9 V battery is used at the sensing node, to make the system portable(for providing comfort to the patient). In effect of this, power is limited at the sensing node. Therefore, low power consumption is the prime requirement at the sensing node. Result shows that the system is capable of fulfiling the requirement of low power consumption.To achieve this transmitted power must be at minimum level. However, the power supply is not limited for routers and coordinator due to the use of AC power source. Therefore, higher transmitted power can be set at routers and coordinator to achieve higher range of transmission.

The range of the communication of the system varies in the indoor and the outdoor environment. The ranges of the system at different transmitted power in the indoor environment are summarized in Table 3 and in the outdoor environment are summarized in Table 4. For indoor environment the trials are performed in the labs of Thapar University, Patiala and for outdoor environment the trials are performed at the campus of Thapar University, Patiala.

Table 3. Ranges of the system in indoor environment

Transmitted Power in dBm	Range in indoor environment in Meters
5	50
2	40
0	30
-7	20
-18	10

Table 4. Ranges of the system in outdoor environment

Transmitted Power in dBm	Line of sight range in outdoor environment in Meters
5	360
2	270
0	200
-7	80
-18	30

It is observed that in line of sight communication the system achieved a very good range of communication. The range of the system is highly affected in the indoor environment in the presence of the obstacles. It is further observed that the transmitted signal is highly attenuated in the presence of the obstacles. The work presented here is for health care monitoring. Therefore, the work is more focused for the indoor environment. Attenuation of the signal in the indoor environment might be a serious problem. The problem could be easily removed by using the routers. The power supply is not limited for routers and coordinator. Therefore, the higher communication range can be achieved by setting maximum transmitted power for routers and coordinator, while keeping the transmitted power at the minimum level for sensing node.

The system is also tested in the presence of other wireless networks such as Bluetooth and WLAN because these two also have the same range of the working frequency. The system performed well in the presence of Blutooth and WLAN. It is seen, there is no disturbance in communication in the presence of Bluetooth and WLAN.

In the presented work, a star network is developed for health care monitoring. The body temperature of three different subjects is monitored simultaneouly and continuously by providing separate sensing node to each subject. The system successfully transmitted the data and displayed it at the coordinator end.

It is further seen that with a 9V standard battery (current capacity of 550mAh), the power can be supplied to the sensing node upto 8 hours, while the transmitted power is set at -18 dBm.

4 Conclusion

The developed system is low cost, autonomous, and light weight. It consists of sensing nodes. These nodes can be strategically placed on the human body and capable of creating a wireless body area network (WBAN) to monitor various physiological parameters. These parameters can be monitored for a long period of time and provide real-time feedback to the user and medical staff. The system is also capable of providing reliable and secure communication. The system further promises to revolutionize the health care monitoring. In this work temperature sensors are used to collect physiological data from patients. The data is then transmitted to the coordinator using ZigBee standard, where it can be observed by the doctors and other medical staff. The developed system is also capable of improving the battery life by reducing power consumption during the transmission. Minimum transmitted power of the system is -18 dBm. The current consumption of the sensing node is 64.1 mA and coordinator is 71.2 mA, when transmitted power is fixed at -18 dBm. At -18 dBm power the communicating range of the system varies from 10m (indoor environment when obstacles are present) to 30 m (line of sight range).

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