

DEVELOPMENT OF HEALTH CARE MONITORING SYSTEM BASED ON ZIGBEE

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DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled, "DEVELOPMENT OF HEALTH CARE MONITORING SYSTEM BASED ON ZIGBEE" in partial fulfilment of the requirements for the award of degree of masters of engineering in Electronics Instrumentation and Control Engineering submitted in Electronics Instrumentation and Control Engineering Department, Thapar university, Patiala, is an authentic record of my own work carried out under the supervision of **Mr. Nirbhow Jap Singh**, Assistant Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, Punjab.

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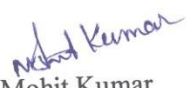
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ABSTRACT

A lot of research has been carried out in the field of health care monitoring. In the recent years, developing of wireless health care monitoring system has emerged as an area of research. The presented work deals with the development of health care monitoring system that can monitor the patient continuously and simultaneously transmit the physiological data to the doctors and other medical staff. The developed system is based on ZigBee protocol (IEEE standard 802.15.4). ZigBee is a dedicated communication protocol for sensor networks. The protocol is designed for low cost and low power consumption by the sensors network. The complete system consists of sensing node (transmitter) and the coordinator (receiver). The components used to develop the system are temperature sensor, microcontroller (PIC 16F886), LCD display and the transceiver (CC2520, based on the ZigBee protocol). The system developed has low cost, low power 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 parameters of human body. 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 result justifies the low power consumption of the system. 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.

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ABBREVIATIONS

ADC	Analog to Digital Converter
AES	Advanced Encryption Standard
APS	Application Support
BPSK	Binary Phase Shift Keying
BSS	Basic Service Set
CAP	Contention Access Period
CCA	Clear Channel Assessment
CCK	Complementary Code keying
CFP	Contention Free Period
CRC	Cyclic Redundancy Check
CSMA-CA	Carrier Sense Multiple Access with Collision Avoidance
DECT	Digital Enhanced Cordless Telecommunications
DIP	Dual in Line Package
DSSS	Direct Sequence Spread Spectrum
ED	Energy Detection
FFD	Full Function Device
FHSS	Frequency Hoping Spread Spectrum
GTSs	Guaranteed Time Slots
GFSK	Gaussian Frequency Shift Keying
IEEE	Institute of Electrical and Electronics Engineers
ICU	Intensive Care Unit
ISM	Industrial, Science and Medical
LCD	Liquid Crystal Display
LQI	Link Quality Indication
LR-WPAN	Low Rate Wireless Personal Area Network
MAC	Medium Access Control
MCPS	MAC Common Part Layer
MLME	MAC Layer Management Entity
MPDU	MAC Protocol Data Unit
MSDU	MAC Service Data Unit
OFDM	Orthogonal Frequency Division Multiplexing
PAN	Personal Area Network

PER	Packet Error Rate
PHR	PHY Header
PHY	Physical Layer
PLME	Physical Layer Management Entity
PPDU	PHY protocol Data Unit
PSDU	PHY Service Data Link
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RAM	Random Access Memory
RF	Radio Frequency
RFD	Reduced Function Device
RISC	Reduced Instruction Set Computing
SHR	Synchronization Header
SMD	Surface Mount Device
SPI	Serial Peripheral Interfacing
SSP	Security Service Provider
UWB	Ultra Wide Band
VMC	Virtual Medical Centre
WBSN	Wireless Body Sensor Network
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network
ZDO	ZigBee Device Object

CHAPTER-1

INTRODUCTION

In the health care domain, a major challenge is how to provide better health care services to an increasing number of people using limited financial and human resources. Wireless patient monitoring has the potential to support these multiple and conflicting requirements. It is based on wireless sensor networks. Wireless sensor network (WSN) is an emerging technology and has great potential to be employed in critical situations [20]. Wireless sensor networks have been deployed in various monitoring applications such as industrial, health, environmental, and security. The advantage of wireless sensor network is that it can be used easily in the environment where the wired system cannot be used or if used then caution should be taken for example in medical treatment. The wireless sensor nodes can also be implemented to monitor patients. The Wireless Sensor Networks comprise of relatively inexpensive sensor nodes capable of collecting, processing, storing and transferring information from one node to another. These nodes are able to autonomously form a network through which sensor readings can be propagated [20]. Therefore, a standard is required that is capable of establishing the network between these nodes as well as provide low cost and less power consumption. Fortunately, there is a standard called ZigBee that is capable of accomplishing all these requirements.

ZigBee standard is developed by the ZigBee Alliance that defines the communication protocols for low-data-rate and short-range wireless networking. ZigBee based wireless devices operate at 868 MHz, 915 MHz, and 2.4 GHz frequency bands. ZigBee is developed on the top of IEEE 802.15.4 standard [31]. The ZigBee protocol stack has a layered structure containing four distinct layers of which the two lower layers are defined by the IEEE 802.15.4 standard. IEEE 802.15.4 standard has defined medium access control (MAC) and physical layers (PHY) wireless standard. The ZigBee standard provides network, security and application support services. ZigBee supports various topologies such as star, clustered tree topology and mesh topology. It is designed for low-power consumption and allows batteries to last up to years using primary cells without any chargers (low cost and easy installation). ZigBee has a wide application area such as home networking, industrial networking, health care monitoring and many more having different profiles specified for each field. The upcoming of ZigBee will revolutionize the health care monitoring and rest of the wireless world.

The objective of the presented work is to develop a system for health care monitoring based on wireless networking. The developed system must have the following capabilities:

1. Low power consumption.
2. Low manufacturing cost.
3. Compact size.
4. Long distance of communication.
5. Reliable/secure communication
6. Expandable

Today's hospitals deploy numerous devices over wires for various medical applications such as monitoring, diagnosis, treatment, and alarms [26]. 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. So the complete process of development of the health care monitoring system is divided into two parts:

1. Hardware part
2. Software part

There are certain considerations that have to be kept in mind before implementing the system for health care monitoring in order to provide protection and safety against hazardous conditions. They are summarized as follows [40]:

1. User access to parts having hazardous voltages should be prevented as users are not trained to identify hazards.
2. Proper basic insulation should be provided, double or reinforced insulation can be used for better protection.
3. Selection of parts and components which are tolerant to high temperatures to avoid ignition.
4. Use of combustible substances should be avoided.

5. Use of enclosures or barriers should be done to limit the spread of fire within the instrument.
6. High temperature of accessible parts should be avoided, if unavoidable, then proper markings to warn the users should be there.
7. Rounding of sharp edges and corners should be done in order to prevent injury due to sharp edges.

The presented work is organized in the six chapters. The first chapter is an introduction to WSN and ZigBee technique. In this chapter the need of wireless networking for health care monitoring is discussed. Considerations that must be followed during the development of the system for health care monitoring are described. The second chapter presents a detailed literature review of existing work in the field of health care monitoring and wireless networking. Based on the literature review it is concluded that ZigBee technology is one of the most suitable wireless technique for the presented work. Then features and architecture of ZigBee technology are discussed. Finally ZigBee, Bluetooth and Wireless LAN protocols are compared. The third chapter presents the development procedure of the system for the health care monitoring. Two phases of the development of the system are discussed. The first phase presents the hardware part and the components that are used to develop the hardware, while second phase presents the development of the software. In the fourth chapter the analysis of the system is summarized in the different environment under various conditions. The fifth chapter concludes the presented work and suggests the identified future scope and the applications of the developed system.

The quality of the health care is improving day by day due to the advancement in medical science and technology [1]. The availability of new treatments together with improved life expectancy means that demand of the available resources is rapidly exceeding. To provide quality care and managing scarce medical resources is a major economic and ethical challenge of the present era. A lot of work has been carried out for developing the health care monitoring system. Most recent work is in the direction of developing wireless sensor networking for health care monitoring system [3, 4, 5, 6, 7, 8]. The existing work in the field of health care monitoring and wireless sensor networking is summarized below:

2.1 Literature Review of Existing Work

Liu Y [1] presented the design and implementation of a Virtual Medical Centre (VMC) for home care. The system is dedicated for providing telematic home monitoring of asthma and heart cared at their homes and community. The modular form of this design allows the system to be modified for other applications. The communication infrastructure of this system is based on the existing phone lines and PSTN. Interfacing is done via a personal instrument and DECT technology that offer a high degree of automation and mobility.

Howitt I *et al.* [2] presented a brief introduction of the IEEE 802.15.4 standard and analyzed the coexistence impact of an IEEE 802.15.4 network on the IEEE 802.11b devices. The IEEE 802.15.4 devices operate in the 2.4 GHz industrial, scientific and medical (ISM) band. The IEEE 802 wireless devices, such as IEEE 802.11b (WLAN) and IEEE 802.15.1 (Bluetooth) also used same operational band. Thus several devices coexist in the 2.4 GHz band. Therefore, it is an important issue in order to ensure that each wireless service maintains its desired performance requirements. The paper presented an analytical model to provide an approach for evaluating the coexistence between IEEE 802.15.4 and IEEE 802.11b.

Golmie N *et al.* [3] evaluated the use of the IEEE 802.15.4 standard specifications for medical applications in interference causing environments. The main objective of this work is to develop a universal and interoperable interface for medical equipment. The paper focuses on scalability issues and the need to support several communicating devices near a patient's

bedside. Different medical applications will use different wireless technologies depending on the nature and the diversity of the clinical environment. The paper quantifies the performance of IEEE 802.15.4 devices in the presence of IEEE 802.11b devices. Results show that WLAN interference is detrimental to a WPAN using 802.15.4. Choosing the optional sensing mechanism that detects any packet type for the 802.15.4 WPAN will improve its performance.

Townsend K.A *et al.* [4] presented state-of-the-art research on low power wireless systems for medical applications. Distinct design criteria and challenges in this area are addressed. Existing wireless technologies and their key applications are studied in this paper. A brief assessment of future trends in wireless medicine with a focus on emerging technologies is also presented. Revision of design criteria reveals that technical challenges as well as issues associated with the reliable and secure operation in medical applications must be considered. The paper describes several examples of current research-based devices and commercial products. Emerging techniques to realize low power systems have been presented. Finally, a number of different energy scavenging techniques for the future development of autonomous wireless nodes are reviewed.

Xijun C *et al.* [5] presented a WBSN node platform featuring an ultra-low power microcontroller, an IEEE 802.15.4 compatible transceiver, and a flexible expansion connector. The wireless sensor network is becoming a promising technology for various applications. If a miniature wireless intelligent module is integrated with some kind of biosensor then it is referred as WBSN node. The proposed WBSN provides a cost-effective, flexible platform that allows easy customization, energy-efficient computation and communication. As a case study, this paper presents an implementation of an ECG (Electrocardiogram) sensor.

Paksuniemi M *et al.* [6] studied usable wireless techniques for short-range data transmission as well as presented currently employed wireless applications in the hospital environment. The aim of the paper is to investigate theoretically the special requirements of utilizing wireless technologies in the hospital environment, particularly during anesthesia and in the ICU and to investigate which wireless technologies are suitable for this environment. Crucial parameters (blood pressures, electrocardiography, respiration rate, heart rate and temperature) of the patient are measured. There are no viable solutions for short range data transmission from patient sensors to patient monitors, but potentially usable techniques in the future are

based on the WPAN standards. These techniques include Bluetooth, ZigBee and UWB. The establishing of wireless techniques depends on ensuring the reliability of data transmission, eliminating disturbance by other wireless devices, ensuring patient data security and patient safety, and lowering the power consumption and price.

Lin B.S *et al.* [7] demonstrated the design and implementation of a real-time wireless physiological monitoring system for nursing system (RTWMPS). The described system collects data, such as body temperature, blood pressure, and heart rate, and then the data are stored in the computer of a network management center. Therefore, it is easy for the medical staff in a nursing center to monitor in real time or analyze in batch mode the physiological changes of the patients under observation. The system proposed in the paper has low power consumption, is cost effective. The proposed system has the capability of operating independently as well as capable of improving the service quality. The system has been tested on the spot at nursing centers and hospitals. The wireless communication distance can reach 50 m when the system is used indoors or 150 m when used outdoors. It provides the functions of real-time physiological monitoring, portability, bi-directional voice, and data transmission.

Varshney U *et al.* [8] presented ad hoc wireless networks for patient monitoring. However, the current quality and reliability of patient monitoring have not been very satisfactory due to the unpredictable and spotty coverage of infrastructure-oriented wireless networks. Ad hoc wireless networks can be implemented among mobile and wearable patient-monitoring devices for improving the coverage of patient monitoring when infrastructure-oriented networks are not accessible. The presented system provides support for reliable wireless patient monitoring by proposing several protocols for power management of devices, assisted power control, and sleep strategy. The system proposed a power management protocol, which can support a diversity of devices in order to provide a high reliability of message delivery at reasonable transmitted power. The performance results show that the protocols suggested in the paper can achieve high reliability under varying user densities, power levels, and numbers of hops.

Tsai H.M *et al.* [9] presented the application of wireless sensor networks in vehicles. Numbers of sensors deployed in the modern cars are increasing day by day. Therefore, elimination of the wires connecting sensors to the microprocessors in cars is the need of the present time. Implementation of an intra-car wireless sensor network can be achieved by using Sigsbee technology. The system presents the results of a Sigsbee-based case study

conducted in a vehicle. Results indicate that the change in link quality with respect to locations of nodes in the car is significant. Engine noise can increase the PRR/PER/good put received sensitivity threshold by 2–4 db. The results of the experiments and measurements show that Sigsbee is a feasible and promising technology for implementing an intra-car wireless sensor network.

Shin D.I *et al.* [10] investigated several wireless technologies of biological sensor networking for u-healthcare. For wireless networking, there are some standards such as Bluetooth, Wireless LAN and Sigsbee etc. This paper investigated these standards for biological sensor networking and made a comparison. The results show that for biological sensor networking Sigsbee is a suitable standard. As a result a patient monitoring system based on Sigsbee is developed which has several biological parameters.

Li Y.Z *et al.* [11] created a wireless health care monitoring platform and an experimental study is done that shows Sigsbee devices are interfered by Wi-Fi devices. Results comprised by the authors show that Sigsbee communication could be potentially blocked by Wi-Fi device. Experimental results suggested that these interferences can be minimized by choosing a suitable Sigsbee communication channel and frame length. Results also show that localization accuracy could be partially corrected by adding more reference nodes as well as more reference node did not necessarily contribute to higher localization accuracy. The authors suggest finding out the best possible combinations on the reference nodes and the various communication tests should be undertaken with different reference nodes.

Key Z *et al.* [12] presented the advantages of Wireless Sensor Network and a WSN project based on Sigsbee technology to be used in the petrochemical industry. Free scale Semiconductor's product C13192-SARD DSK board is used to implement the WSN project. Theoretical analysis and the experiments confirm that the design of the project is reasonable, hardware system works normal, the software procedure compiled for WSN is correct. It has the very good practical value. The application prospect of this design is very useful in the petrochemical industry.

Bandyopadhyay L.K *et al.* [13] presented a wireless information and safety system for mines. Underground mines are prone to disaster and it is very difficult for mine management to identify where the person is trapped and location of the trapped person, in case of disaster. Therefore, identification and coding of miners is essential for underground mine management

in disaster as well as normal operating conditions. The system consists of hardware devices and application software. Hardware module consists of radio frequency transceivers which is compatible with ZigBee protocol. A mesh network is established to locate the mobile assets, people and monitor the environmental conditions using sensors. Application software is developed to track the miners vehicles, environmental monitoring and prevent vehicle collisions. The proposed system will also useful to keep records of attendance and working hours of the workers.

Kyriacou E.C *et al.* [14] provided an overview and the current status of mobile health care systems as well as their applications for Emergency health care. Due to the advancement in mobile communications and medical technologies, the development of emerging mobile systems and applications for healthcare is becoming easier. The paper reports on journal papers that use wireless, emergency telemedicine systems that appeared since 2000. Most of the applications are focused on the transmission of critical biosignals for the support of heart-related healthcare. A few numbers of new studies were focused on supporting emergency health care for trauma by facilitating both 2D image and video transmission. Rather, new studies have focused on integrated systems for specialized emergency scenario such as stroke.

Veerasingam S *et al.* [15] presented a portable wireless data logging system for temperature monitoring in real time process dynamics. Process variables (like temperature, pressure, flow, level) vary with time in certain applications and these variations should be recorded so that a control action can take place at a defined set point. The authors proposed an 8-bit embedded platform for a temperature sensor node having a network interface using the 802.15.4 ZigBee protocol, that is a wireless technology developed as open global standard to address the low-cost, low-power wireless sensor networks. The wireless temperature sensor node senses and transmits the variations in the local temperature to the central computing unit placed within the range. The central base station receives the data and stores it in the file and plotting the variations simultaneously.

Li J *et al.* [16] presented an embedded system to monitor the miner lamp with the help of ZigBee technology. Miner lamp is essential to underground coal miners to keep them safe. The system consists of a central control station and a number of the miner's lamp charging node for monitoring purpose. The system monitors and controls the state of charge on the miner's lamp. Monitoring and controlling of the miner's lamp are realized through the data

collected of a battery voltage, current and temperature. In the paper analysis of circuit design, bottom drives design, operating system transplant and user program design are done. The system effectively improved the reliability of the miner's lamp charging system.

Burns A *et al.* [17] presented a report on the motivation and scope of the capabilities of the SHIMMER platform. The use of wireless sensors for biomedical research applications has been widely reported in the literature. These applications utilize wireless sensing capabilities in the form of either body worn or ambient sensing devices. Researchers applying new approaches to noninvasive patient monitoring and diagnostics are assisted by the features of Sensing Health with Intelligence, Modularity, Mobility and Experimental Reusability (SHIMMER™), a flexible sensing platform. Integrated peripherals, open software, modular expansion, specific power management hardware, and a library of applications supported with platform validation provide SHIMMER with advantages over many other medical research platforms. SHIMMER is an extremely flexible sensor platform. SHIMMER has the ability to monitor for low-voltage conditions via the Supply Voltage Supervisor feature or ADC method.

López M *et al.* [18] implemented the wireless sensor network to sense the pH and temperature for a fish farm. The application requires two different kinds of modules: the sensor to collect the data and the wireless module to transmit the data. Collected information is transmitted to the central unit, which manages the network and stores all the received data. The sensor module includes a pH sensor based on a specially designed ISFET and a commercial temperature sensor. The wireless node collects the sensed data by means of an asynchronous wired serial polling communication. The use of this kind of protocol allows connecting a single master with multiple slaves. In the system one master is connected with four slaves using a transmission rate of 9600 b/s. Implementation of this system is based on the ZigBee standard. The number of nodes distributed in the fish farm has been limited to 30 while the maximum number of hops to 6. An energy management layer is included between the MAC and the routing layer to reduce the power consumption of the wireless network using an RF activity duty cycle for the reception stage at the final end device of around 0.02%.

Du Y.C *et al.* [19] presented a telecare system to monitor blood pressure of patients with Hemodialysis. Hemodialysis has been a common medical treatment for the people with renal insufficiency. Blood pressure is measured in every 30 min to 1 h during about 4 h

hemodialysis processes. Therefore, an assisted measurement on blood pressure is required in dialysis care centers. In the paper ZigBee wireless standard is utilized to establish a mesh network to monitor blood pressure automatically and data storage in medical record system for display and further analysis. When the blood pressure exceeds the normal range then this system is able to send a warning signal to inform the relatives and the clinicians in health care center immediately. The proposed system provides more useful information for improving the quality of caring patients with hemodialysis and save the medical manpower.

Padmavathi G *et al.* [20] presented a wireless network system for vehicle detection and tracking. The system estimates the target based on the spatial differences of the target signal strength. The paper focuses on magnetic and acoustic sensors and the signals captured by these sensors. The system has three components for detecting and tracking the moving objects. The first one consists of inexpensive off-the shelf wireless sensor devices, which is able to measure acoustic and magnetic signals generated by vehicles. The second one is responsible for the data aggregation. The third one is responsible for data fusion algorithms. This work focuses the overview of each algorithm for detection and tracking and compares them based on evaluation parameters.

Pengfei L *et al.* [21] discussed the technical characteristics, network topology structures and application prospects of ZigBee and proposed a scheme on a wireless temperature monitoring system based on ZigBee. The system adopted star topology structure CC2430 chip of Chipcon Company and 18B20 temperature sensor of MAXIM Company. The results show that the performance of the temperature monitoring system is stable and the accuracy of wireless signal transmission is very good. The results show the correctness and feasibility of the system and verify that ZigBee is an ideal solution to implement the wireless monitoring network.

Xue Y *et al.* [22] described implementation and deployment details of a two-tier real-time environmental monitoring network in Nebraska. The sensor network infrastructure suggested in the paper, used typical Wireless Sensor Network (WSN) structure at a tier-two to conduct dynamic sensing tasks with high resolution and flexibility. The real-time groundwater level data collected from the current network deployment shows that the tier-one satellite network can provide the reliable communication between the rural monitoring sites and the base station, while enabling easy failure detection and isolation in large-scale environmental

monitoring networks. The power system designed for the on-site installation are proven to be feasible and reliable.

Kalaivani T *et al.* [23] provided an overview of ZigBee based wireless sensor network (WSN) and presented the application of ZigBee in agriculture for intelligent farming. In this paper, a survey on wireless sensor networks has been carried out. Based on the analysis and survey this paper suggests the necessity for intelligent farming especially in developing countries like India. In this paper different surveys have been carried out on the applications of ZigBee based wireless sensor network in agriculture such as monitoring of environmental conditions like weather, soil moisture content, soil temperature, soil fertility, weed-disease detection, monitoring leaf temperature/moisture content as well as monitoring growth of the crop, precision agriculture, automated irrigation facility, storage of agricultural products etc. The paper also provides the possible research issues existing in Physical layer of ZigBee.

Cheong P *et al.* [24] presented a ZigBee based wireless sensor network node for the ultraviolet (UV) detection of flame. Fire is a serious threat in our daily life. Its spreading rate is very fast and soon it becomes a disaster. Therefore, low cost, reliable, and wide coverage fire alarm systems are essential in the industry to protect the equipment and other valuable things. The system has the sensor node, which is composed of a ZnSSe UV photodetector, a current- sensitive front end including a high gain current to voltage amplifier with 120 dB and a logarithm converter, and a transceiver operated at a 2.4-GHz industrial, scientific, and medical band. A passive photo detector is designed to have a cutoff at 360 nm and convert the UV emission of flame into pico amperes. The performance of a prototype sensor node was verified when the luminous flame was imaged onto the sensor node with different angles ranging from -30° to 30° and distances of 0.1, 0.2, and 0.3 m enabling effective fire safety applications.

Shin Y.S *et al.* [25] presented a multi-priority queue system to improve quality of service that differentiates between various types of frames. The effect of the proposed system on the average delay and throughput is explored herein. This multi-queue system prioritizes frames on the basis of priority classes. The system achieves this by employing different contention window parameters based on IEEE 802.11 e. A novel analytical model is used to evaluate the performance under both saturated and unsaturated traffic conditions. This model comprehensively integrates two legacy models for 802.15.4 and 802.11e. To improve the accuracy, this model also incorporates the transmission retries and deferment algorithms that

significantly affect the performance of IEEE 802.15.4. The multi-queue scheme is predicted to separate the average delay and throughput of two different classes by up to 48.4% and 46%, respectively, without wasting bandwidth. The outcomes indicate that the multi-queue system should be implemented in health care systems for the prompt allocation of synchronous channels and faster delivery of urgent information. The simulation results validate predictions of the model with a maximum deviation of 7.6%.

Lee H *et al.* [26] suggested how to design a medical-grade wireless local area network (WLAN) for healthcare facilities. Unlike the IEEE 802.11e MAC, which categorizes traffic primarily by their delay constraints, this paper prioritizes medical applications according to their medical urgency. The paper also suggests a mechanism that can guarantee absolute priority to each traffic category, while the conventional 802.11e MAC only provides relative priority to each traffic category. The paper is focused on the performance of real-time patient monitoring applications, which based on absolute priority as well as derive the optimal contention window size that can significantly improve the throughput performance. Finally, for proper performance evaluation from a medical viewpoint, the paper suggests the weighted diagnostic distortion (WDD) as a medical QoS metric to effectively measure the medical diagnosability by extracting the main diagnostic features of medical signal. Simulation result shows that the proposed mechanism can significantly improve the medical-grade QoS performance over the conventional IEEE 802.11e MAC.

Singh R *et al.* [27] presented a pressure monitoring system based ZigBee technology and used CC2520 to design sensor nodes and the master. The sensor node will acquire and internally store data periodically. As soon as a mobile network is detected in its proximity the node will automatically transfer data. This system is based on an AVR microcontroller coupled to an RF transceiver. The system is interfaced to a piezoresistive pressure sensor, typically used to determine water levels in closed tanks or open aquaculture systems. The system is small, less power consuming, provides reliable data transmission and has low cost.

Jeong S *et al.* [28] presented an integrated health care system for personalized chronic disease care in home and hospital environments. A health care system for chronic diseases is classified as an at-hospital and at-home service according to a targeted environment. The aim of these services is to provide patients with accurate diagnoses of disease by monitoring a variety of physical states with a number of monitoring methods. There is a lot of difference between home and hospital environments. Therefore, the different characteristics should be

considered in order to provide more accurate diagnoses for patients, especially, patients having chronic diseases. This paper proposes a patient status classification method for effectively identifying and classifying chronic diseases and shows the validity of the proposed method.

Kalidas U *et al.* [29] deals with the rapid growth in biomedical sensors and power consumption of ZigBee module in different modes of operation. This paper presents the body area networks based on ZigBee wireless networking. Body area networks are composed of tiny, cheap and low power biomedical nodes. These networks are dedicated for health care monitoring applications. In the paper author suggests a network model to ensure a continuous monitoring of vital parameters of plant operators in bio-power plants. The author also suggests an external energy model which produces energy from human body motion to meet the requirement of the energy of the sensor nodes.

Abdullah A *et al.* [30] presented a wireless sensor monitoring system for environmental applications. The system is based on wireless ZigBee standard and uses 32-Bit Arduino Uno microcontroller for monitoring of environmental parameters measurements online. This system is tested at a height of two meters on a tree at School of Biology, Universiti Sains Malaysia. The system uses five modes (idle mode, transmit mode, receive mode, sleep mode, and command mode) for data gathering and is able to monitor carbon dioxide and oxygen. Data collected by the system can be applied at all levels of the organization to create the awareness and to perform scientific warming. The results show that the system is able to monitor and analyze the CO₂ and O₂ in the deployed environment.

Finally, from the literature survey it is concluded that wireless sensor networking for health care monitoring is the need of an hour. From the available technologies one of the most suitable wireless networking technique for this application is ZigBee technology. The features of ZigBee technology that makes it one of the most suitable technique for the proposed work are summarized as below:

The ZigBee standard defines the protocol and compatible interconnection for data communication devices using low power, low data rate and low complexity. The standard is defined for short-range radio frequency (RF) transmissions in a low rate wireless personal area network (LR-WPAN) [31].

2.2 General Characteristics of ZigBee

The objectives of the standard are to provide easy installation, reliable data transfer, good battery life, short range operation and extremely low cost [31, 32].

1. Data rates of 250 kbps (at 2.4 GHz), 40 kbps (at 915 MHz), and 20 kbps (at 868 MHz).
2. Optimized for low duty-cycle applications (<0.1%).
3. Multiple topologies: star, peer-to-peer, mesh.
4. Carrier sense multiple access with collision avoidance (CSMA-CA) channel access.
5. Allocation of guaranteed time slots (GTSs)
6. Fully acknowledged protocol for transfer reliability
7. Low power consumption.
8. 1 channel in the 868 MHz band, 10 channels in the 915 MHz band and 16 channels in the 2450 MHz band.

2.3 Device Types in ZigBee

There are two different device types in LR-WPAN; a full function device (FFD) and a reduced function device (RFD). The Full function device can operate in three modes. The FFD can be used as a personal area network (PAN) coordinator, a coordinator, or a device while the reduced function device cannot operate as a coordinator or a PAN coordinator. An FFD can talk to other FFDs or RFDs, while an RFD can talk only to an FFD. An RFD is intended for extremely simple applications, such as a light switch or a passive infrared sensor. The RFD can be implemented using minimal resources and memory capacity [31, 32]. An IEEE 802.15.4/ZigBee network requires at least one full function device as a network coordinator, but endpoint devices may be reduced functionality devices to reduce the system cost.

2.4 Network Topologies

The standard defines two types of network topologies; the star topology and peer to peer topologies. All devices operating on a network of either topology have a unique 64 bit extended addresses or a short address allocated by the PAN coordinator [31]. The topologies are explained below:

2.4.1 Star Topology

In the star topology a single central controller, called the PAN coordinator, communicates with the devices as shown in Fig.2.1. A device typically has some associated applications and is either the initiation point or the termination point for network communications. A PAN coordinator can be used to initiate, terminate, or route communication around the network [31].

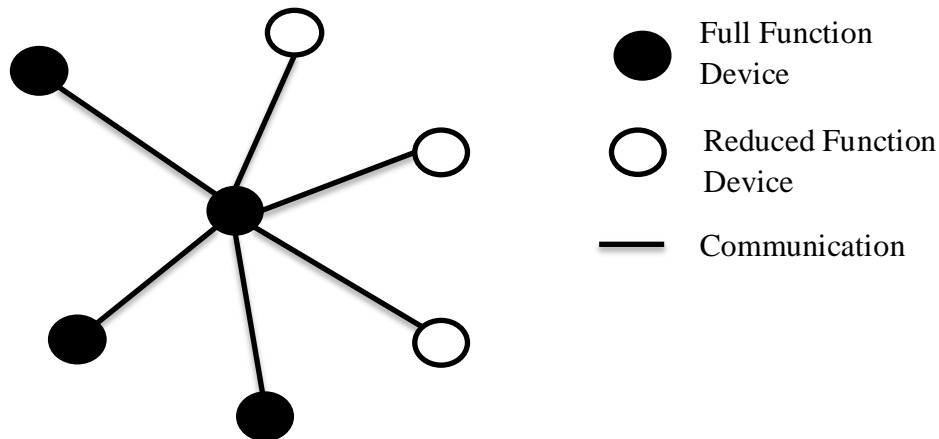


Fig.2.1: Star topology

2.4.2. Peer to Peer Topology

In peer-to-peer topology any device can communicate with any other device as long as they are in range of one another. This topology also has the PAN coordinator. Complex networks can be easily implemented in Peer to Peer topology, such as mesh networking topology [31].

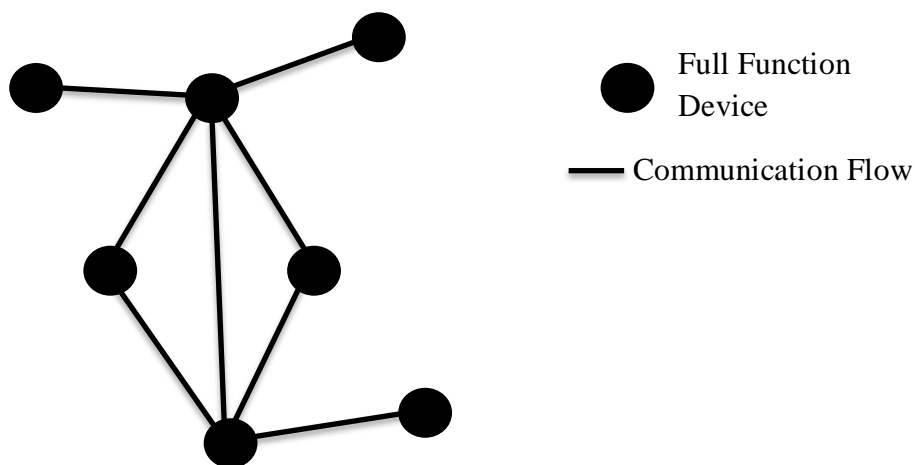


Fig.2.2: Peer to peer topology

2.5 Architecture of ZigBee

To simplify the standard the architecture of ZigBee is categorized in terms of number of layers. Each layer responsible for its operation and provides services to the higher layer. The architecture is based upon the open systems interconnection (OSI) seven layer model. The architecture of ZigBee is shown in Fig.2.3. The layers which form the ZigBee networking are explained below:

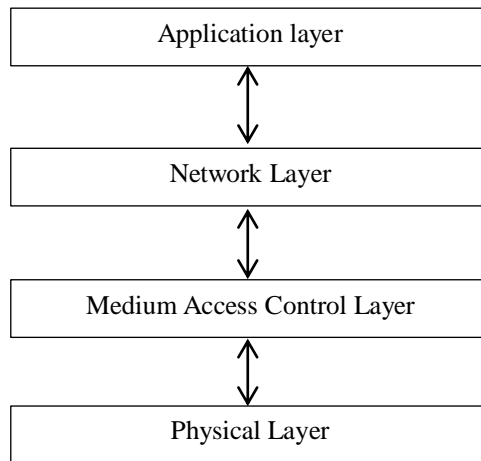


Fig.2.3: ZigBee architecture

2.5.1 Physical Layer

The Physical layer provides two services: the PHY data service and the PHY management service interfacing to the physical layer management entity (PLME). The PHY data service enables the transmission and reception of PHY protocol data units (PPDUs) across the physical radio channel. The features of the PHY are activation and deactivation of the radio transceiver, ED, LQI, channel selection, clear channel assessment (CCA), and transmitting as well as receiving packets across the physical medium [31, 32].

2.5.2 MAC Layer

The MAC layer provides an interface between the application layer and the PHY layer. The MAC layer provides services to the application layer through two groups: the MAC Management Service (called the MAC Layer Management Entity or MLME) and the MAC Data Service (called the MAC Common Part Layer or MCPS). The features of the MAC

layer are channel access, GTS management, frame validation, beacon management, acknowledged frame delivery, association, and disassociation [31, 32].

2.5.3 Network Layer

The responsibilities of the ZigBee network layer are summarized below [33, 34]:

1. To successfully establish a network.
2. To configure the stack for operation as required.
3. To assign addresses to devices joining the network.
4. To achieve synchronization with another device either through tracking beacons or by polling.
5. Applying security to outgoing frames and removing security to terminating frames.
6. Routing frames to their intended destinations.

2.5.4 Application Layer

The ZigBee application layer consists of the APS sub-layer, the ZigBee device object (ZDO) and the manufacturer-defined application objects [33].

a. Application Support Layer

The responsibilities of the APS sub-layer include maintaining tables for binding, which is the ability to match two devices together based on their services and their needs, and forwarding messages between bound devices. Another responsibility of the APS sub-layer is discovery, which is the ability to determine which other devices are operating in the personal operating space of a device [33, 34].

b. ZigBee Device Object

The responsibilities of the ZDO include defining the role of the device within the network, initiating and/or responding to binding requests. ZDO is also responsible to establish a secure relationship between network devices selecting one of ZigBee's security methods such as public key, symmetric key, etc. [33, 34].

2.6 Frame Structure

The frame structures have been designed to keep the complexity to a minimum while at the same time making them sufficiently robust for transmission on a noisy channel. Each successive protocol layer adds to the structure with layer-specific headers and footers [31].

The IEEE 802.15.4 MAC [31, 32] defines four frame structures:

1. A beacon frame, used by a coordinator to transmit beacons.
2. A data frame, used for all transfers of data.
3. An acknowledgment frame, used for confirming successful frame reception.
4. A MAC command frame, used for handling all MAC peer entity control transfers.

The data frame format is shown in Fig.2.4. The Physical Protocol Data Unit (PPDU) is the total information that is transmitted over the air. The Physical layer adds the following overhead:

Preamble Sequence	4 Octets
Start of Frame Delimiter	1 Octet
Frame Length	1 Octet

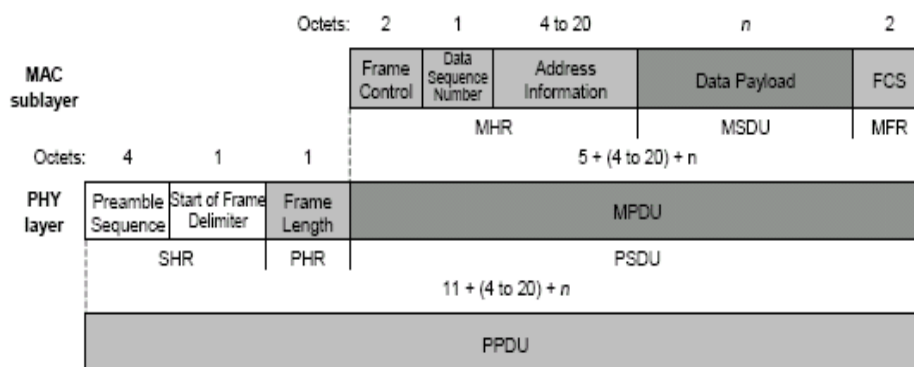


Fig.2.4: IEEE 802.15.4 data frame format [31]

The MAC adds the following overhead:

Frame Control	2 Octets
Data Sequence Number	1 Octet
Address Information	4 – 20 Octets

Frame Check Sequence 2 Octets

In summary the total overhead for a single packet is therefore 15 -31 octets (120 bits); depending upon the addressing scheme used (short or 64 bit addresses).

2.7 Superframe Structure

The superframe is bounded by network beacons and is sent by the coordinator. Superframe is divided into 16 equally sized slots. The beacon frame is transmitted in the first slot of each superframe. To synchronize the attached devices and to identify the PAN beacon frames are used. Beacon frames also describe the structure of the superframes. If any device wants to communicate during the contention access period (CAP) between two beacons, it will compete with other devices using a slotted CSMA-CA mechanism. All transactions shall be completed by the time of the next network beacon. For low latency applications PAN coordinator may dedicate portions of the active superframe called guaranteed time slots (GTSs) to that application. The guaranteed time slots comprise the contention free period (CFP), which always appears at the end of the active superframe [31, 32].

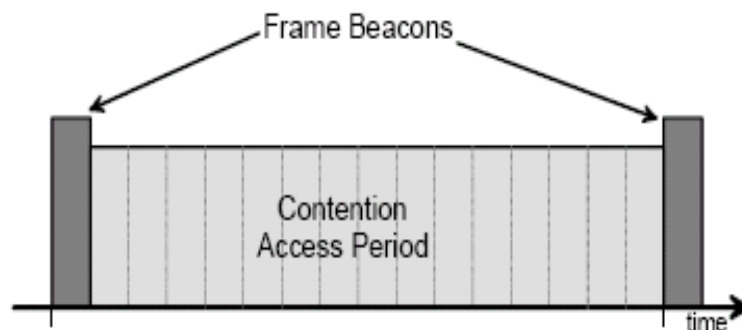


Fig.2.5: Beacons frame followed by CAP

All contention based transactions shall be completed before the CFP begins. Also each device transmitting in a GTS shall ensure that its transaction is complete before the time of the next GTS or the end of the CFP [31, 32].

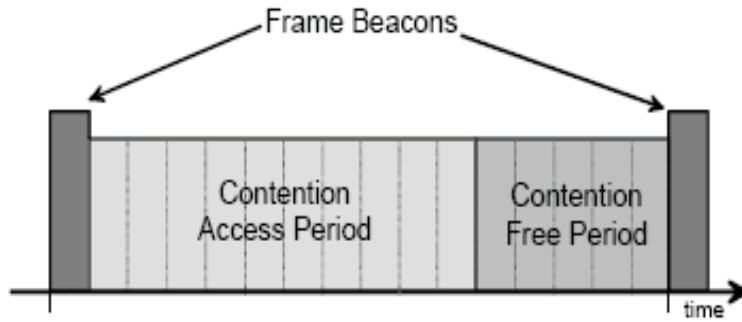


Fig.2.6: Beacons frame followed by CAP & CFP

2.8 Beacon and non-Beacon Communication in ZigBee

In beacon communication, first the devices listen for the beacon network. When the beacon is found the device synchronizes to the superframe structure [31]. The device transmits the data to the coordinator at the appropriate time. In beacon communication, devices use the slotted CSMA-CA mechanism. When the coordinator receives the data, it sends the acknowledgement frame to the device. Sending the acknowledgement frame is optional. When the device receives the acknowledgement frame, communication is over. Flow of data sequence in beacon communication is shown in Fig.2.7.

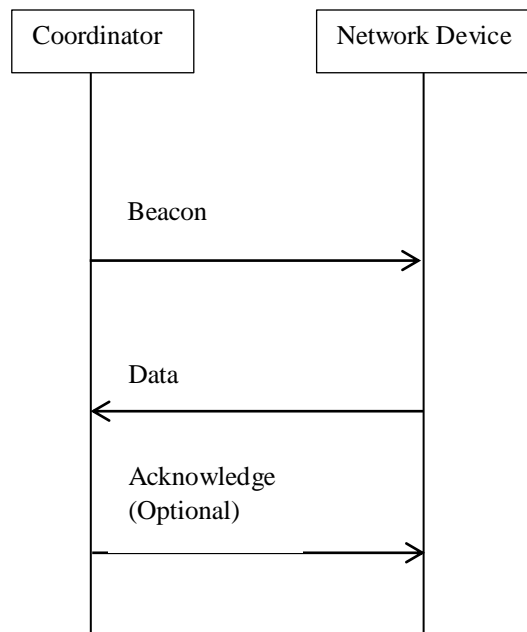


Fig.2 7: Communication in a beacon-enabled network

In non-beacon communication, the devices simply transmit the data to the coordinator [31]. In non-beacon communication, devices use the unslotted CSMA-CA mechanism. The coordinator sends the optional acknowledgement frame, when it receives the data from any device in the network. Communication is over, when the device receives the acknowledgement frame. Flow of data sequence in non-beacon communication is shown in Fig.2.8.

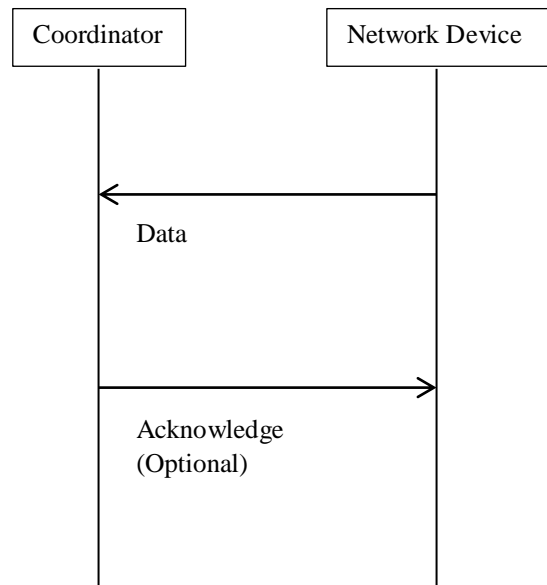


Fig.2 8: Communication in a non-beacon network

2.9 Addressing in ZigBee Technology

IEEE 802.15.4 uses two methods of addressing [31]:

1. 16-bit short addressing
2. 64-bit extended addressing

A network can choose to use either 16-bit or 64-bit addressing. Using the short addressing mechanism reduces the packet length and thereafter the space to store the addresses. This mechanism allows addressing within a single network; however, the combination of a unique PAN ID (personal area network identifier) and 16-bit addressing can be used to address independent networks. Alternatively, 64-bit addressing in IEEE 802.15.4 has not limitation on the number of devices in a single network [32].

2.10 Security

The Security Services Specification is a complete chapter in the ZigBee Specification [33] which specifies the security services available within the ZigBee stack. These services include methods for key establishment, key transport, frame protection and device management.

ZigBee provides security mechanisms for the NWK and APS layers. Each layer is responsible for securing their frames. In addition, the APS sublayer provides services for the security relationship establishment and maintenance whereas ZDO manages the security policies and the configuration of ZigBee devices.

2.11 Comparison of ZigBee, Bluetooth and WLAN

ZigBee standard is a set of protocol for data communication devices using low power, low data rate and low complexity. The standard is defined for short-range radio frequency (RF) transmissions. It is defined at the 2.4 GHz Industrial, Science and Medical (ISM) frequency band. It is based on the IEEE 802.15.4 standard [31].

Bluetooth is a wireless standard for short range communication. It is designed for small and low cost devices. Bluetooth works at 2.4 GHz ISM frequency band. Bluetooth is defined by the IEEE 802.15.1 standard [38].

Wireless LAN (WLAN) is a set of protocol for data communication. It is defined at the 2.4 GHz and 5 GHz ISM frequency bands. Wireless LAN is specified by the IEEE 802.11 standard [39].

Comparison between ZigBee, Bluetooth and WLAN is summarized in the Table 2.1

Table-2.1: Comparison of ZigBee with Bluetooth and WLAN

Characteristic	ZigBee [31]	Bluetooth [38]	WLAN [39]
IEEE Std.	802.15.4	802.15.1	802.11
Nominal Range	10-100 m	10 m	100 m
Data Rate	20-250 Kbps	1 Mbps	54 Mbps
Power Consumption	Very low	Medium	High
Security	AES block chiper	AES block chiper	AES block chipper
Operating Frequency	868/915 MHz, 2.4 GHz	2.4 GHz	2.4 GHz
Network Topology	Star, mesh, peer to peer	Piconet	BSS
Modulation type	BPSK, O-QPSK	GFSK	BPSK, QPSK, M-QAM
Spreading	DSSS	FHSS	CCK, OFDM
Error checking and correcting code	16 bit CRC	16 bit CRC	32 bit CRC

CHAPTER-3

SOLUTION METHODOLOGY

In the health care domain, demand of the quality services is increasing day by day. To provide better health care services is a challenging task of the present era. Most of the health caring systems of the present time are based on wired networks. In health care domain number of parameters such as monitoring, diagnosis, treatment, and alarms are increasing day by day due to the advancement of the medical facilities. Therefore, wired system is becoming more and more complex. The complexity of the wired system makes the patient uncomfortable. Therefore, the replacement of the wired network with the wireless network is the need of an hour. This replacement is also capable of reducing the deployment cost and time. The replacement of wired networking with wireless networking depends upon the networking modules. These modules are programmable and most of them consist of microcontroller as a device manager.

Therefore, the presented work has been completed in two phases. The two phases of the development of the wireless network for health care monitoring are described below:

1. Hardware Development
2. Software Development

While implementing the system for health care monitoring, some safety regulations must be considered to provide protection against hazardous conditions. These safety regulations have already been discussed in the first chapter.

3.1 Hardware Development

Hardware part consists of two modules: 1. Sensing node. 2. Coordinator. The detailed discussion of their implementation is as follows:

3.1.1 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 the following components:

1. Microcontroller.
2. Radio transceiver.
3. Sensors.
4. Power supply.

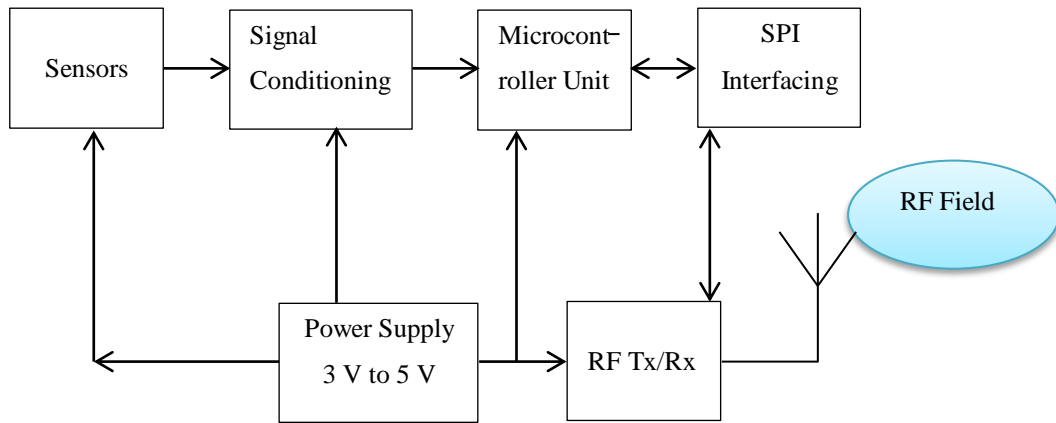


Fig.3.1: Block diagram of sensing node

3.1.2 Coordinator

The function of the coordinator is to gather data and then display the data as per the requirements. Coordinator consists of the following components:

1. Microcontroller.
2. Radio transceiver.
3. Display device.
4. Power supply.

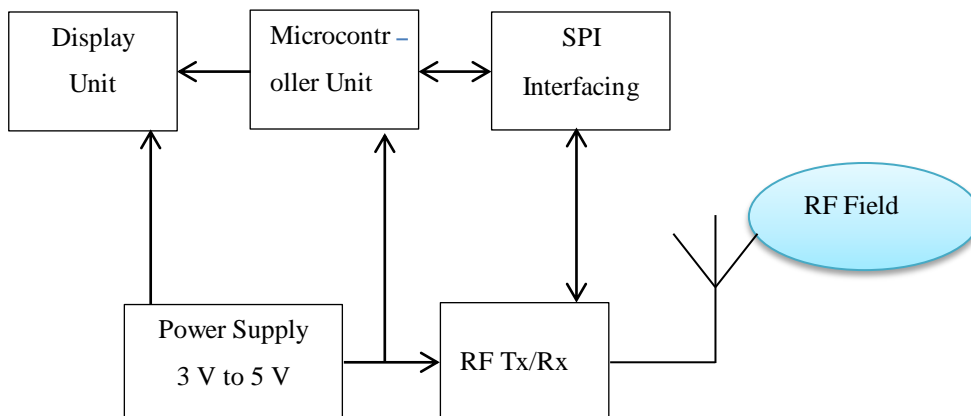


Fig.3.2: Block diagram of coordinator

3.2 Component Description

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

3.2.1 Sensor and Signal Conditioning

Sensor is the essential part of any instrumentation system. Sensing is the first stage of any process in the instrumentation system. Sensors are required to sense the variations in the physical quantities. According to the variations in the physical quantities sensors give the output, which is electrical in nature. Without the sensors it is not possible to convert the physical quantities into the electrical form. The unique capability of conversion of the physical quantity into the electrical form makes the sensors most essential part of the presented work.

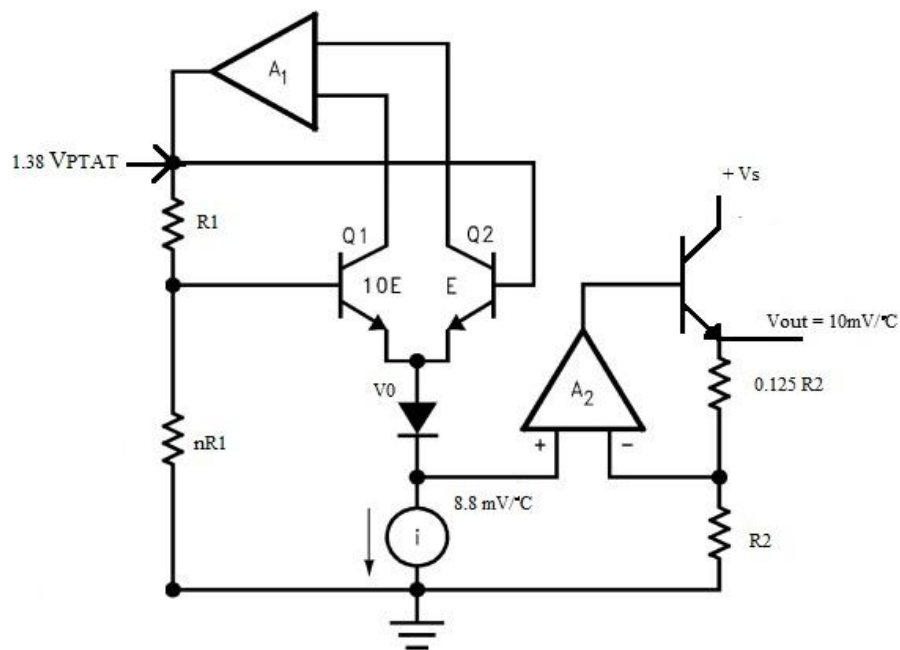


Fig.3.3: Circuit diagram of LM35

In the presented application a temperature sensor is used to monitor the temperature of the human body. LM35 is used as a temperature sensor. The LM35 series are precision integrated-circuit temperature sensors. The output voltage of LM35 is linearly proportional to the Celsius (Centigrade) temperature. The LM35 does not require any external calibration. It can provide accuracies of $\pm 1/4^\circ\text{C}$ at room temperature and $\pm 3/4^\circ\text{C}$, over a full -55 to $+150^\circ\text{C}$ temperature range. The LM35 has low output impedance, linear output, and precise inherent

write/ erase cycles. PIC 16F886 consists flash program memory up to 8K x 14 words and data memory up to 368 x 8 bytes. Features of PIC 16F886 are listed below:

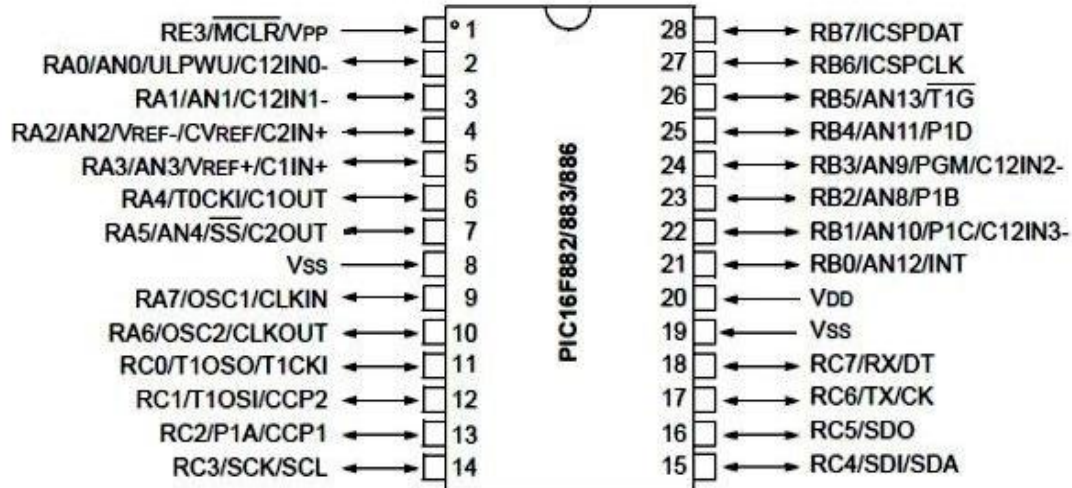


Fig.3.5: Pin diagram of PIC 16F886

3.2.3 Features of PIC 16 F886

Features of PIC 16F886 microcontroller are summarized below [35]:

1. 20 MHz oscillator/clock input.
2. Interrupt Capability.
3. Direct, Indirect and Relative Addressing modes.
4. Power-Saving Sleep mode.
5. Power-on Reset.
6. Standby Current consumption: 50nA at 2.0V, typical.
7. Operating Current consumption: 11 micro-amps at 32 kHz, 2.0V and 220 micro-amps at 4 MHz, 2.0V.
8. 24 I/O Pins with Individual Direction Control with High current source/sink.
9. Analog Comparator Module with two analog comparators.
10. A/D Converter with 10-bit resolution and 11 channels.
11. Timer0: 8-bit Timer/Counter with 8-bit programmable prescaler.
12. Enhanced Timer1: 16-bit timer/counter with prescaler.
13. Timer2: 8-bit Timer/Counter with 8-bit period register, prescaler and postscaler.

14. Enhanced Capture, Compare, PWM+ Module with 16-bit Capture, maximum resolution 12.5 ns.
15. Enhanced USART Module.
16. In-Circuit Serial Programming via Two Pins.
17. Master Synchronous Serial Port (MSSP) Module supporting 3-wire SPI (all 4 modes) and I2C Master and Slave Modes with I2C Address Mask.

3.2.4 Interfacing of LM 35 with PIC 16F886

LM 35 is interfaced with PIC 16F886 in a simple way. Pin 1 of LM 35 is connected to 5 V regulated power supply. Pin 2 (output) of LM 35 is connected to pin 3 of the microcontroller. Pin 3 of LM 35 is connected to the ground. Pin diagram of LM 35 is shown in Fig.3.8.

The output of LM 35 is analog in nature. So analog to digital conversion is required. Most of the microcontrollers, which are available in these days, have on chip analog to digital converter (ADC). Therefore, any external ADC is not required. PIC 16F886 also has on chip ADC. It has 11 channels of ADC and has 10 bit resolution of ADC. In the presented work the channel second of ADC is used for the temperature sensor and channel third is used to monitor the level of the voltage of the battery. ANSEL, ANSELH, ADCON 0, ADCON 1, ADRESH and ADRESL registers are dedicated for the ADC. ANSEL and ANSELH are used to make the I/O pins as an analog input pin. ADCON0 are initialized to select the channel of ADC and to start the analog to digital conversion and also show the status of the conversion. ADCON 1 is used to select the reference voltage and how the result is stored either in the left justification or in the right justification mode. ADRESH and ADRESL registers are used to store the result of the conversion.

3.2.5 Transceiver

The presented application is based on wireless networking. Therefore, an RF transceiver is must for this application. At least two RF transceiver are required, one for the sensing node and one for the coordinator. In this application CC2520 is used as RF transceiver, which is based on Zigbee technology. Pin diagram of the CC2520 is shown in Fig.3.6.

The CC2520 is TI's second generation RF transceiver that works at the 2.4 GHz unlicensed ISM band. This chip enables industrial grade applications by offering state-of-the-art

selectivity/co-existence (Adjacent channel rejection: 49 dB and Alternate channel rejection: 54 dB), excellent link budget. In addition, 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. These features reduce the load on the host controller. Power consumption of CC2520 is very low. In receiving mode (receiving frame, -50 dBm) it consumes 18.5 mA current and in transmitting mode it consumes 33.6 mA current at +5 dBm and 25.8 mA at 0 dBm [36]. Some other features of CC2520 are listed below, which makes it suitable for the presented application.

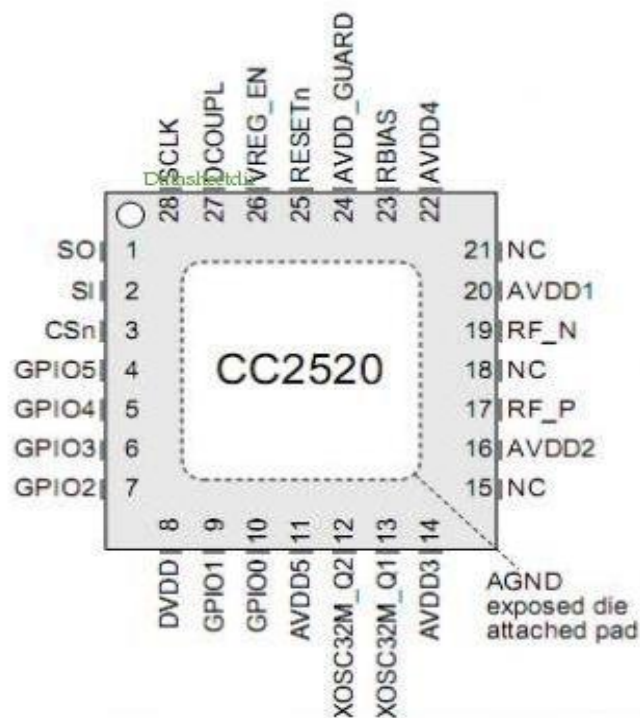


Fig.3.6: Pin diagram of CC2520

3.2.6 Features of CC2520

Features of CC2520 are summarized below [36]:

1. Extended temp range (-40 to +125°C).
2. Wide supply range: 1.8 V to 3.8 V.
3. Extensive IEEE 802.15.4 MAC hardware support to offload the microcontroller.
4. AES-128 security module.
5. IEEE 802.15.4 compliant DSSS baseband modem with 250 kbps data rate.

6. Excellent receiver sensitivity (-98 dBm).
7. Programmable output power up to +5 dBm.
8. RF frequency range 2394-2507 MHz.
9. Digital RSSI/LQI support.
10. Automatic clear channel assessment for CSMA/CA and Automatic CRC.
11. 768 bytes RAM for flexible buffering and security processing.
12. Fully supported MAC security.
13. 4 wire SPI.
14. 6 configurable IO pins.
15. Interrupt generator.
16. Frame filtering and processing engine.
17. Random number generator.

3.2.7 Impedance Matching of CC2520 with Antenna

The antenna used with CC2520 has 50 ohm resistance. Therefore, a proper impedance matching network is required to match the 50 ohm load. An impedance matching network is suggested in the datasheet of CC2520 [36], which consist of transmission lines with capacitors. In place of transmission lines discrete inductors can also be used. One other solution is to use a chip balun in place of the inductor and transmission lines. The simplified impedance matching network for CC2520 is shown in Fig.3.7.

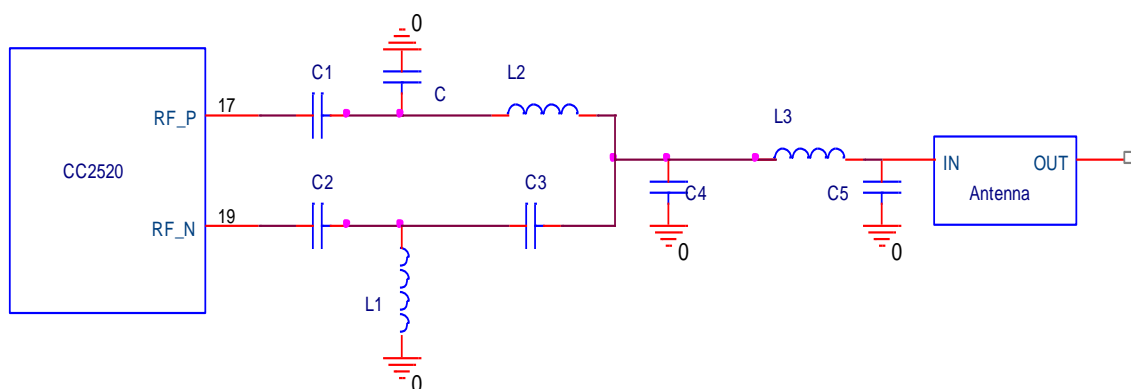


Fig.3.7: Impedance matching network for CC2520

3.2.8 Interfacing of CC2520 with PIC 16F886

Interfacing of CC2520 with PIC 16 F886 microcontroller is done by using serial peripheral interfacing (SPI) protocol. PIC 16F886 has dedicated SPI module. CSn, SCLK, SI and SO pin of CC2520 are connected to the microcontroller to enable the SPI interfacing. RESETn pin could be connected to the microcontroller or to the 3.3 V power supply. It is recommended in the datasheet [36] of CC2520 that CC2520 is reset for instance after powering up. VREG_EN is connected to the microcontroller, so that power saving mode can be used. If power saving is not important then it may also be connected to the VDD and leave the regulator on permanently [36]. GPIO pins are also connected to the microcontroller to provide more flexibility and less SPI traffic because it reduces the need to keep reconfiguring the GPIOs for different uses. The interfacing of PIC 16F886 with CC2520 is given in Table 3.1.

The 6 GPIO pins of CC2520 can be configured individually as inputs, outputs and active pull up resistors. Each GPIO pin has an associated register, GPIOCTRLn. By setting or resetting the MSB of the GPIOCTRLn, GPIO pin can be configured as input or output.

Table-3.1: Interfacing of CC2520 PIC 16F886

CC2520 Pin	PIC 16F886 Pin
VREG_EN	7
RESETn	3.3 V Supply
SCLK	14
CSn	13
SO	15
SI	16
GPIO0	12
GPIO1	18
GPIO2	11
GPIO3	17
GPIO4	5
GPIO5	3.3 V Supply

A simplified drawing of the interconnection of CC2520 with PIC 16F886 is shown in Fig.3.8.

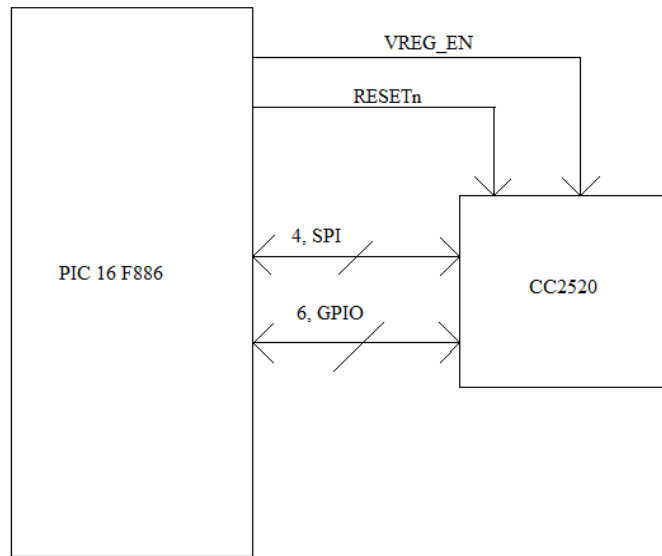


Fig.3.8: Interfacing of CC2520 with PIC 16F886

3.2.9 Display Unit

Display device is required only at the coordinator end. To know what is going on the sensing node, the data must be shown on the display. This data can also be recorded and kept safe for the analysis. Health status of the human can only be known by observing the data. That's why the display is must for the presented application.

For the presented work, LCD is used as a display device. LCD is the short form of the liquid crystal display. LCD displays utilize two sheets of polarizing material with a liquid crystal

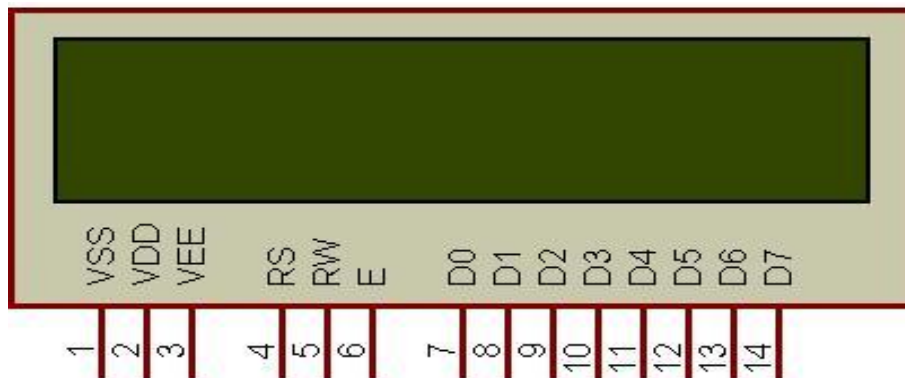


Fig.3.9: Pin diagram of LCD

solution between them. An electric current passed through the liquid causes the crystals to align so that light cannot pass through them. Each crystal, therefore, is like a shutter, either allowing light to pass through or blocking the light. Pin diagram of the LCD display is shown in Fig.3.9.

3.2.10 Interfacing of LCD with PIC 16F886

The display used for the application is a 14 Pin LCD display. Interfacing of LCD with PIC 16F886 is summarized in Table 3.2.

Table-3.2: Interfacing of LCD with PIC 16F886

LCD Pin	PIC 16F886 Pin
VSS	GND
VDD	+5 V
VEE	GND
RS	26
RW	GND
E	25
D0-D4	GND
D4	21
D5	22
D6	23
D7	24

3.2.11 Power Supply

There are several components used at the sensing node and coordinator end. These components have different operating voltage such as PIC 16F886 microcontroller operates at 3 V to 5 V, ZigBee transceiver operates at 1.8 V to 3.8 V, LM 35 and LCD display operates at 5 V. To meet these requirements of different operating voltage ranges a proper arrangement of power supply is required. The 7805 voltage regular is used to provide 5 V regulated power supply and AMS 1117 is used to provide 3.3 V regulated power supply.

At sensing node a 9 V battery is used to provide power to the system. The block diagram of power supply at the sensing node is shown in Fig.3.10.

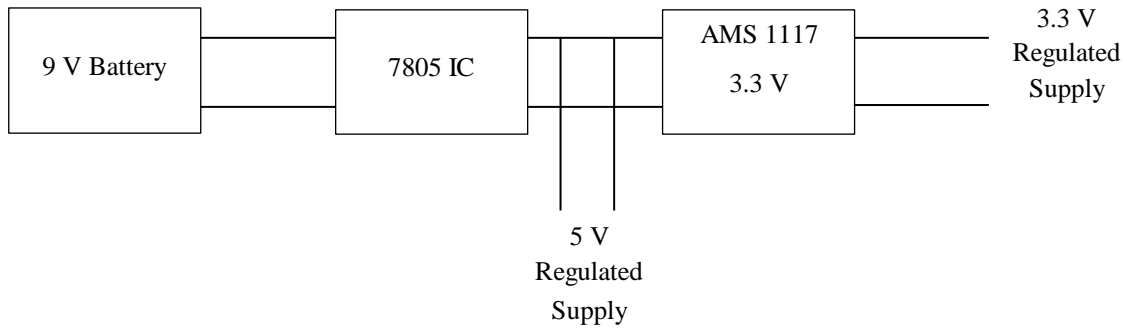


Fig.3.10: Power supply at sensing node

At coordinator side an AC source is used to provide power to the system. The block diagram of power supply at coordinator side is shown in Fig.3.11.

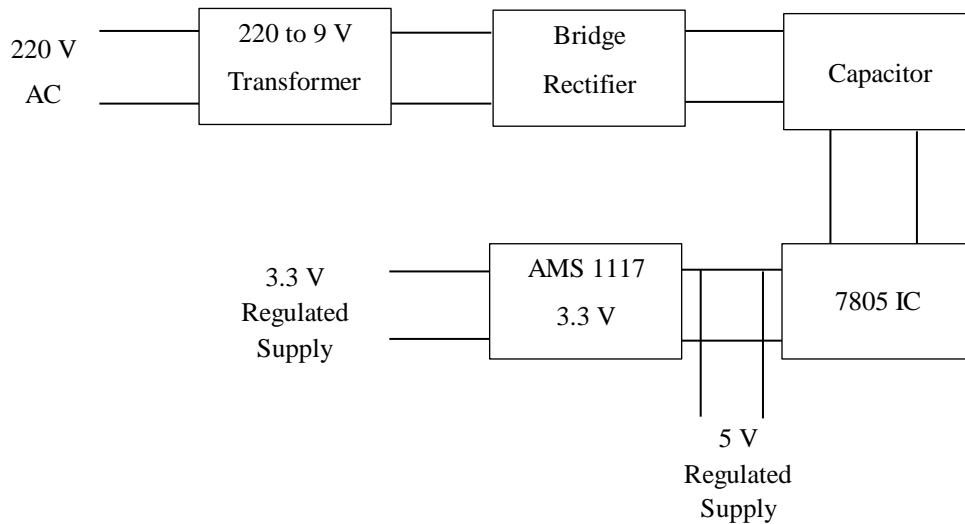


Fig.3.11: Power supply at the coordinator end

3.2 Software Development

PIC 16F886 has been programmed to test the hardware as well as to achieve the goal of the application. The steps involved to develop the software for the application are shown in the flow chart given below:

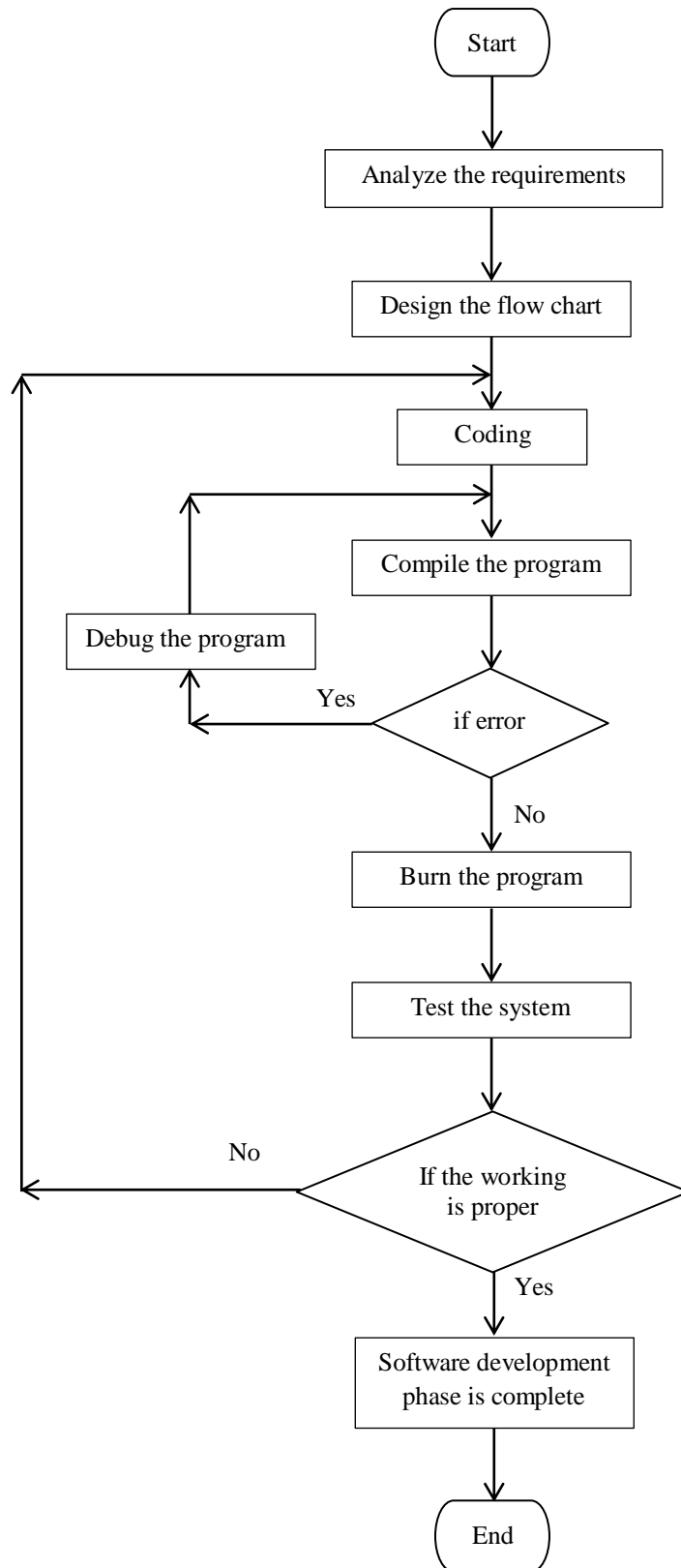


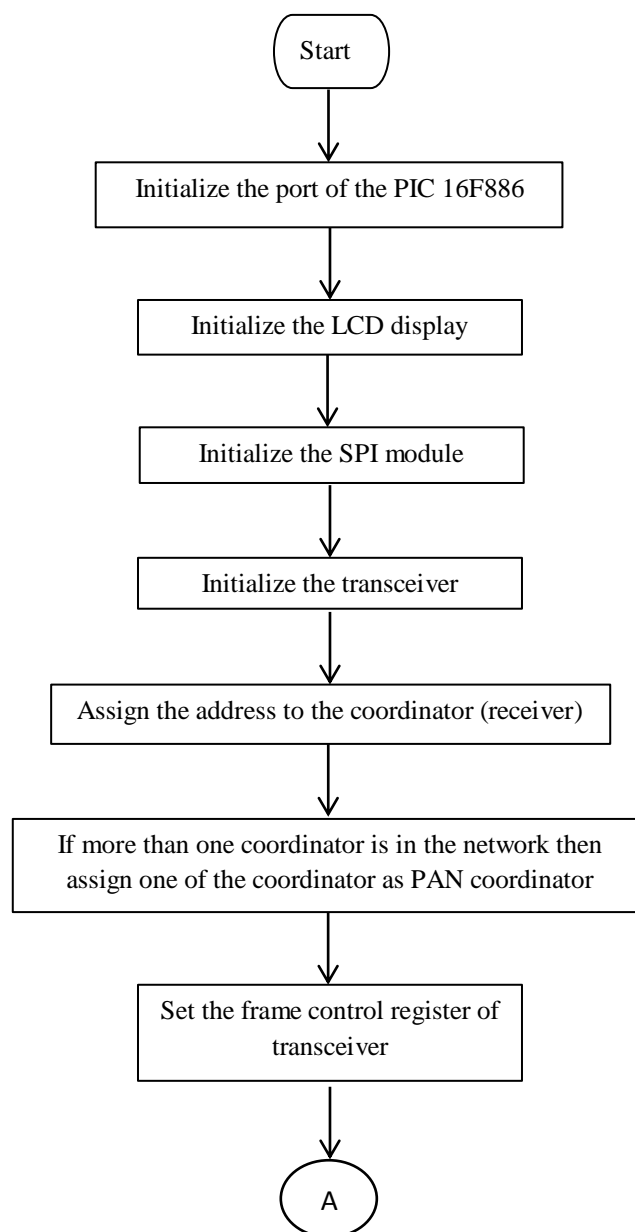
Fig.3.12: Flow chart of software development phase

3.2.1 Analyze the requirements

Before writing the code all the requirements for the system to achieve the desired task should be considered.

3.2.2 Design the flow chart

After analyzing the requirements flow chart is designed. There are different requirements at the sensing node and at the coordinator end. Therefore, the flow chart is designed separately for sensing node and coordinator end. The flow chart at the coordinator end is shown below:



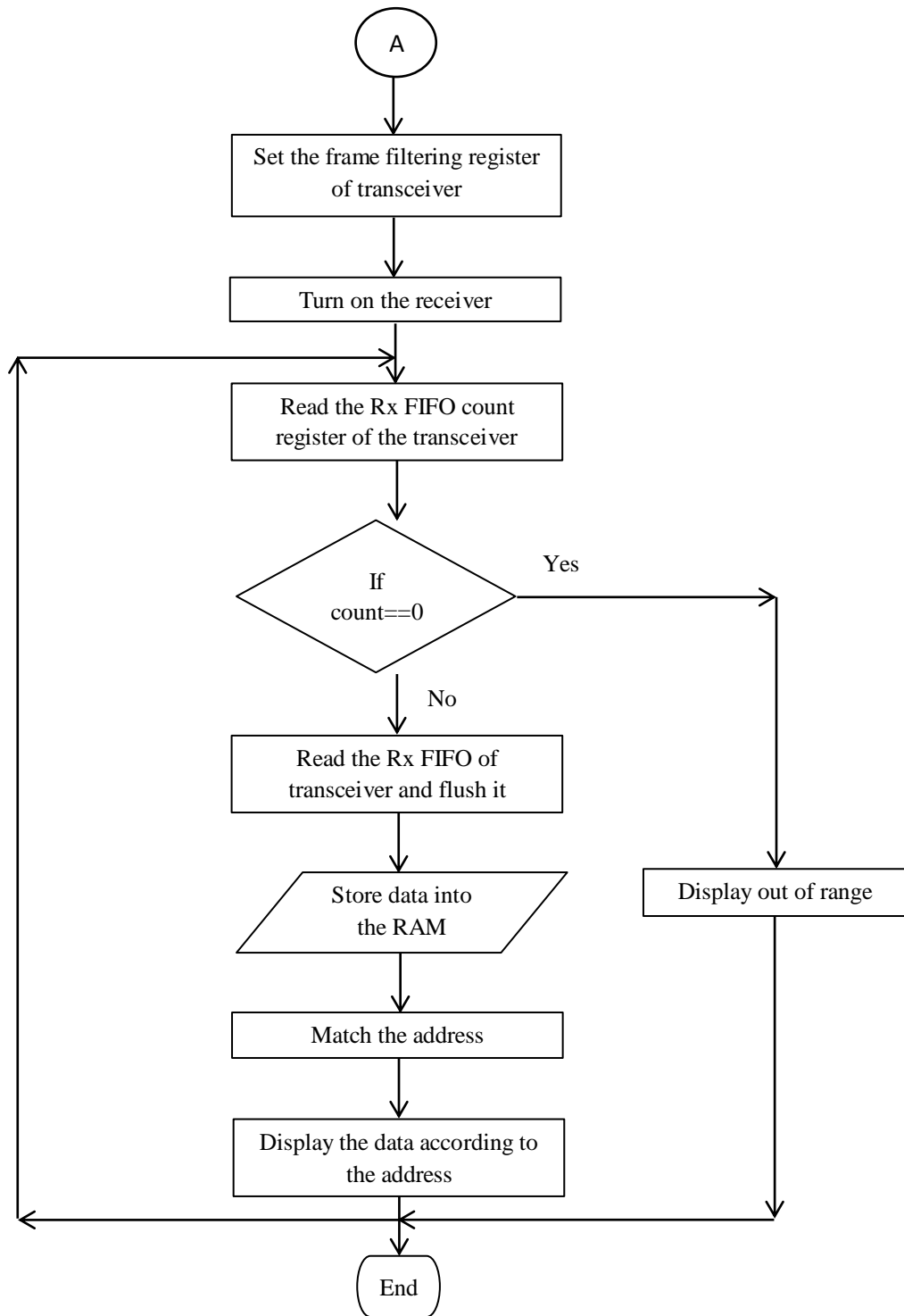
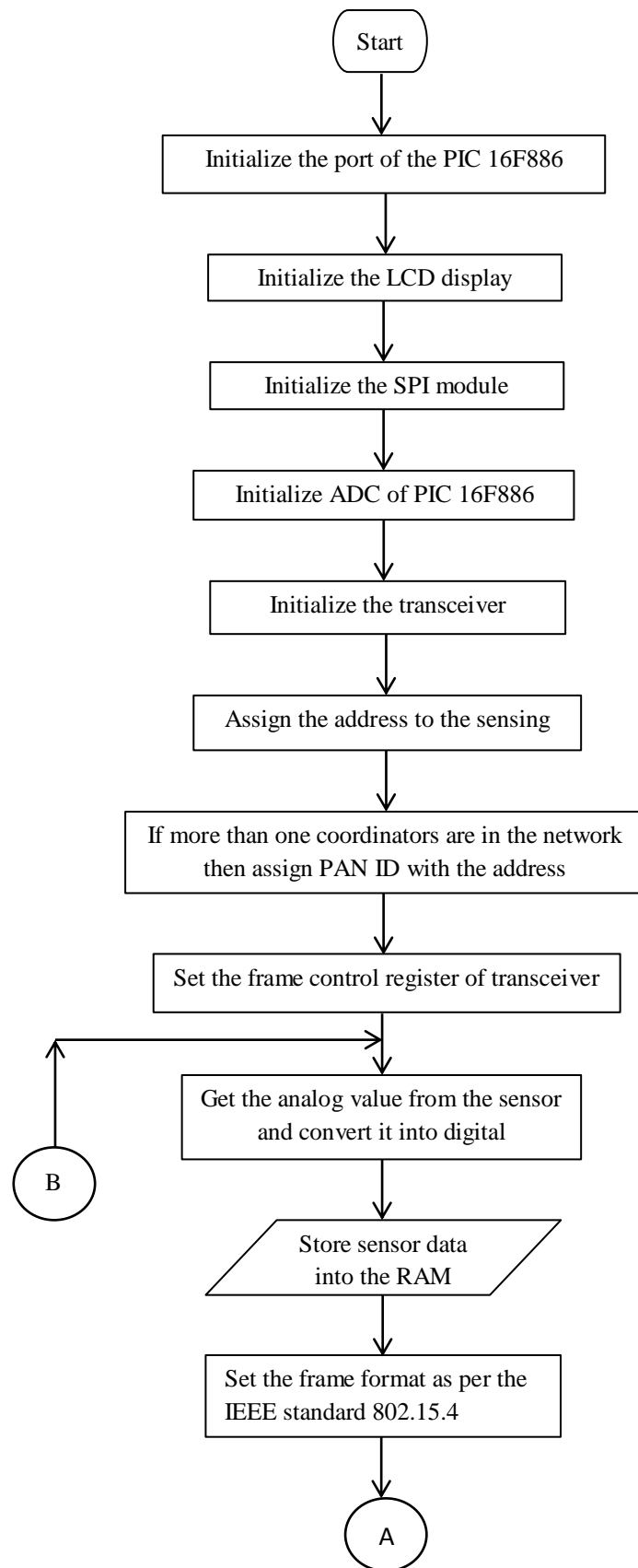


Fig.3.13: Flow chart at the coordinator end

The flow chart at the sensing node is given below:



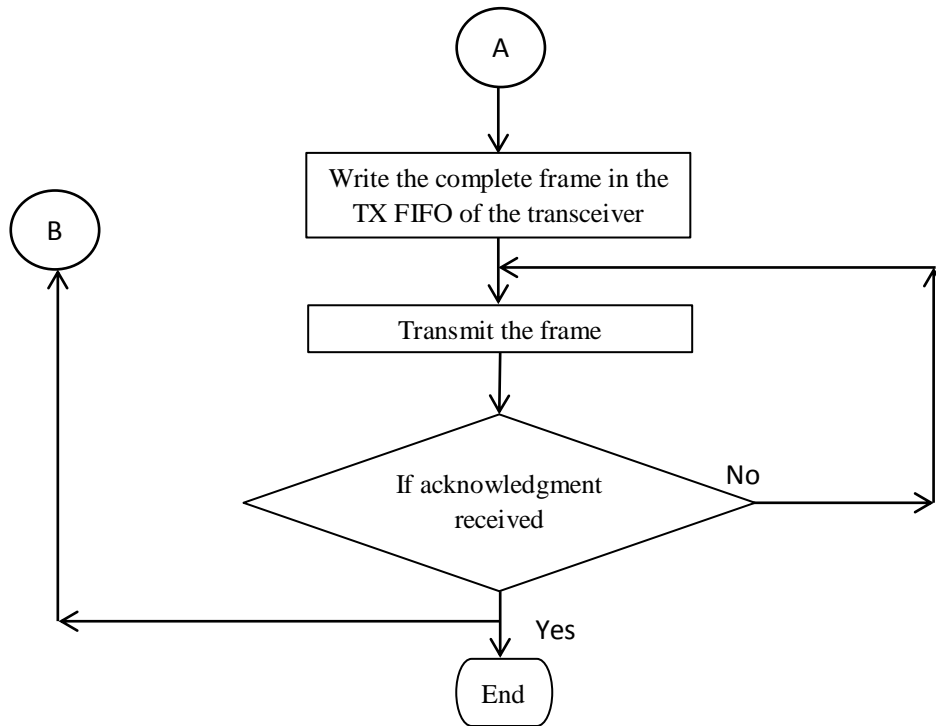


Fig.3.14: Flow chart at the sensing node

The flow chart of the initialization of the transceiver is given below

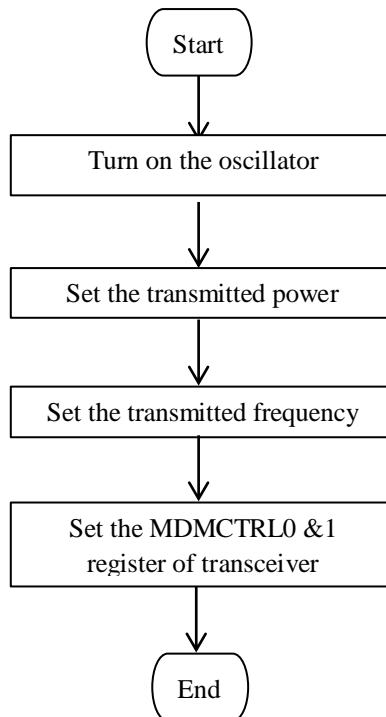


Fig.3.15: Flow chart of the initialization of the transceiver

The flow chart to display the data on the LCD is given below

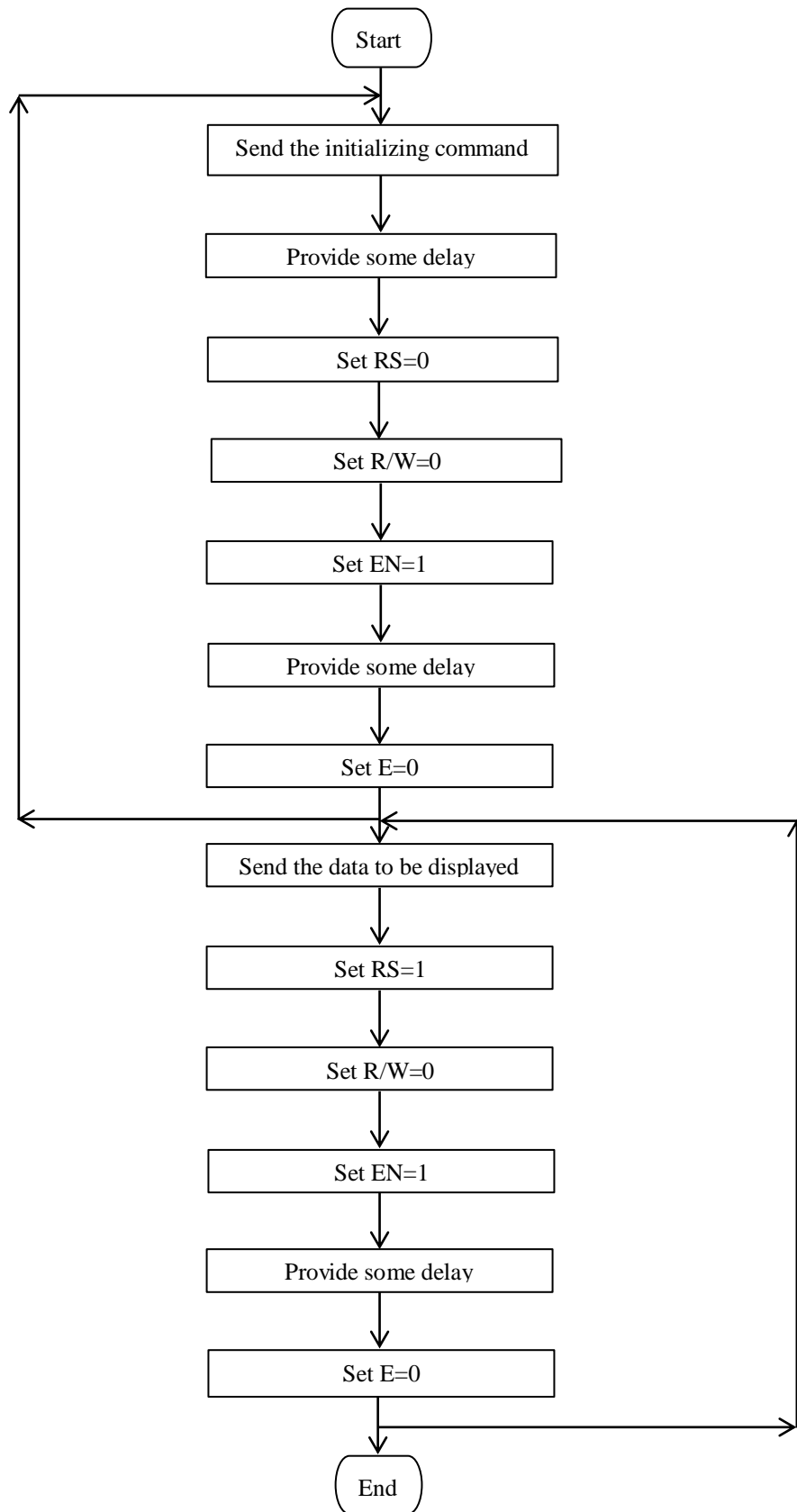


Fig.3.16: Flow chart to display the data on the LCD

3.2.3 Coding

The coding of the algorithm is implemented in MIKROC Pro complier. Source code has been written in the embedded C language. Two separate codes have been written for sensing node and the coordinator.

3.2.4 Compiling and Debugging

The compilation of the C program converts it into machine language file (.hex). This is the only language the microcontroller will understand. If any error occurred during the compilation then debugging is done. If compilation is completed without any error then go to the burning step.

3.2.5 Burning

Burning the machine language file into the microcontroller's program memory is achieved with a dedicated programmer. In the presented work the Mikro prog suite for PIC has been used to burn the machine language file into the microcontroller's program code memory.

3.2.6 Testing

If the system performs all the required tasks and behaves as expected the software development phase is over. If system behavior is not as per the expectation, the whole procedure will have to be repeated again. This procedure will continue until the expected behavior of the system is achieved.

The pictures of the implemented hardware are shown in Fig.3.17 and in Fig.3.18.

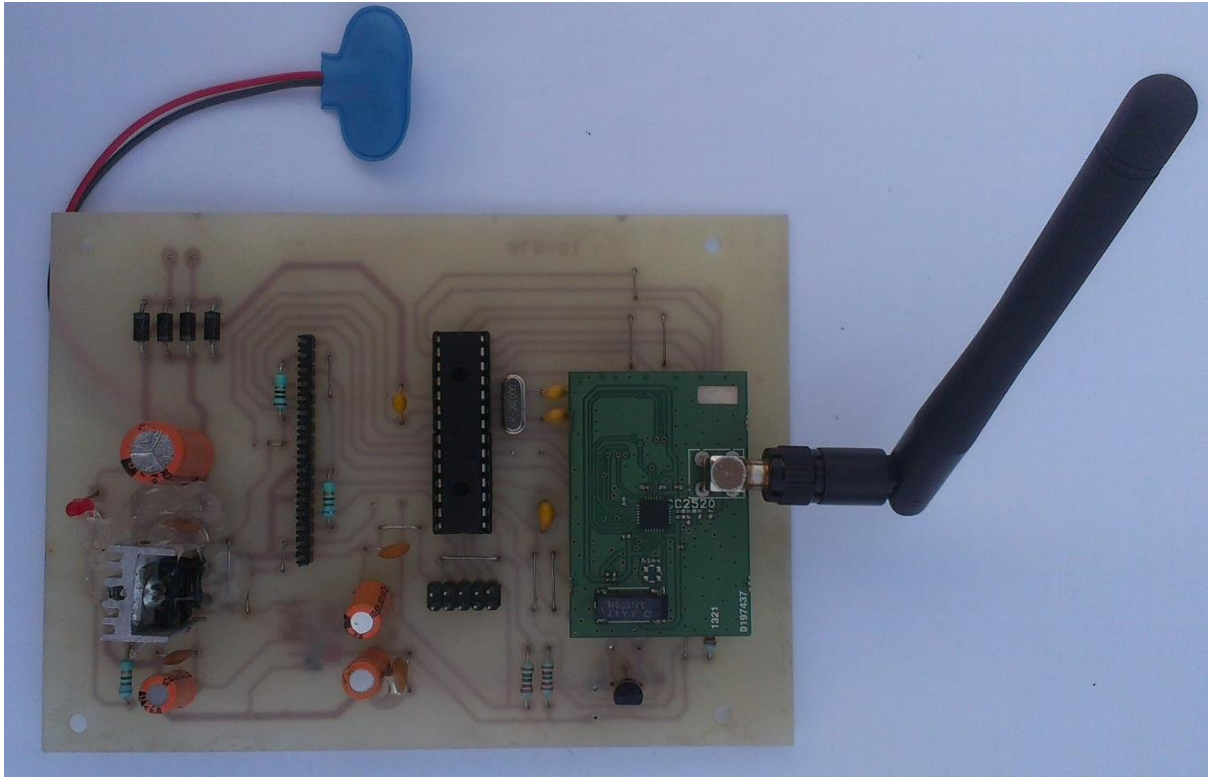


Fig.3.17: Sensing node

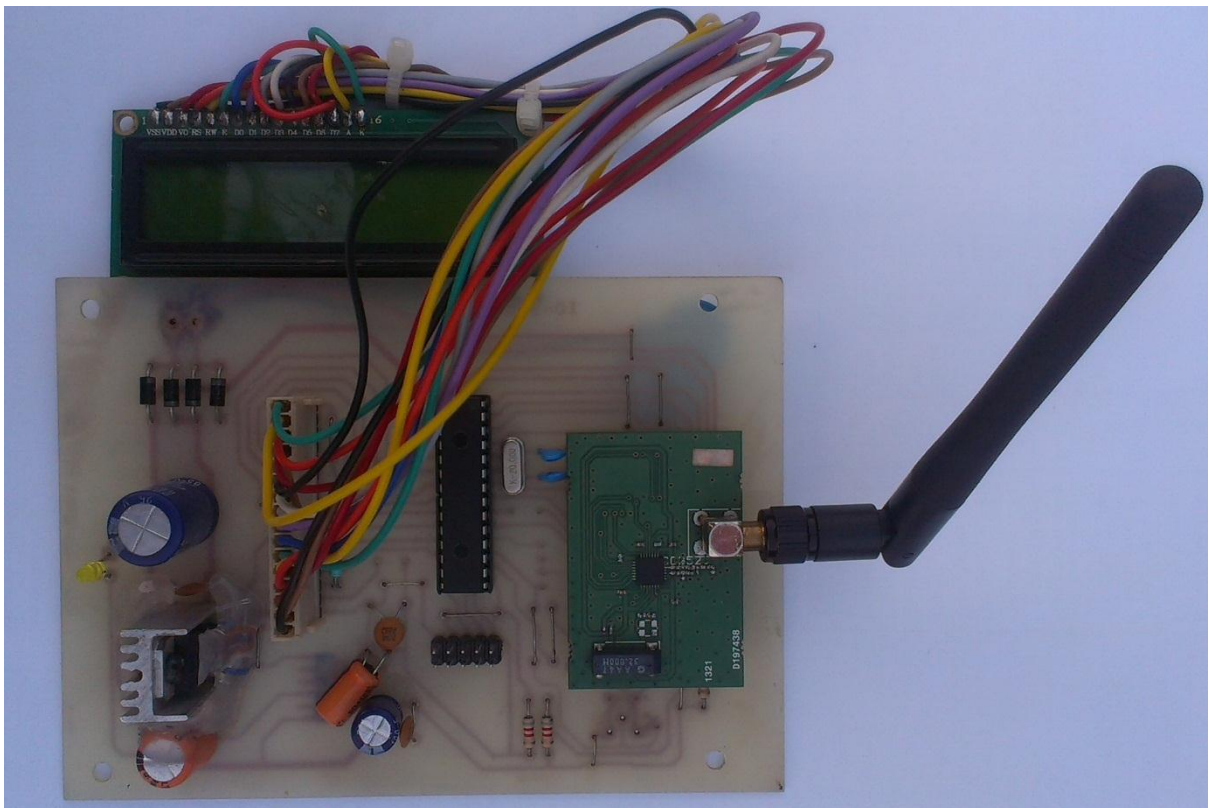


Fig.3.18: Coordinator

CHAPTER-4

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. The system is tested with 3dBi antenna. 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 4.1.

Table -4.1: 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 4.2.

Table-4.2: 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. It is the requirement of the developed system to consume lesser power at the sensing node because a 9 V battery is used at the sensing node. A battery is used at the sensing node, so that the weight of the system can be minimized. Consumption of power at sensing node can be minimized by setting minimum transmitted power. The power supply is not a problem for

routers and coordinator because the AC power source can be used with the routers and coordinators. Therefore, higher transmitted power can be set at routers and coordinator.

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 4.3 and in the outdoor environment are summarized in Table 4.4. 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-4.3: 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-4.4: 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 Bluetooth 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 simultaneously 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 if a 9V standard battery with a current capacity of 550mAh is used, the sensing node can be supplied with power for about 8 hours, while the transmitted power is set at -18 dBm.

CHAPTER-5

CONCLUSION AND FUTURE SCOPE

The developed system in the presented work 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).

The developed system is expandable in terms of networking, instrumentation and design consideration. In this work a star network is developed for communication. In future a mesh network can be developed to cover a larger area. This system is designed for monitoring only one parameter that is the temperature of the human body. In future a system can be so designed that it is capable of monitoring more than one parameter. The developed system has small size and light weight. Two different PCBs are designed for the system: 1.RF part. 2. Microcontroller part. The PCB designed for RF part is smaller than the PCB designed for microcontroller part. The PCB of RF section is designed with the SMD components and PCB of microcontroller is designed with DIP components. In future the whole system can be designed at the single PCB with the SMD components. Hence, the size and the weight of the system can be further reduced. The system developed in the presented work is not limited to the health care monitoring. It also can be used for other applications such as: Home automation, Remote control application, Environmental parameter monitoring, Retail services, Water level monitoring.

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