SMART CONTROL OF ENVIRONMENTAL PARAMETERS FOR RURAL DEVELOPMENT USING WEARABLE COMPUTING

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In recent years with the advent of WSN and wearable technologies, considerable interest has been gestated in studying the application of wearable devices for gathering information. The present thesis is merely based on investigation carried out by the author during last four years in this subject. Though considerable care has been taken in preparing the thesis, there may remain error along with the incomplete bibliography for which the author may kindly be excused.

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SUSHABHAN CHOUDHURY

CERTIFICATE

This is to certify that the dissertation on "**SMART CONTROL OF ENVIRONMENTAL PARAMETERS FOR RURAL DEVELOPMENT USING WEARABLE COMPUTING"** by **SUSHABHAN CHOUDHURY** in Partial completion of the requirements for the award of the Degree of Doctor of Philosophy (Engineering) is an original work carried out by him under our joint supervision and guidance.

It is certified that the work has not been submitted anywhere else for the award of any other diploma or degree of this or any other University.

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AUTHOR'S DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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LIST OF ABBEREVATION

WSN	wireless sensor network
IEEE	Institute of Electrical and Electronics Engineers
PSO	Particle swarm optimization
PVIDSS	Precise vine irrigation decision support system
GSM	Global system for mobile communication
Wi-Fi	Wireless Fidelity
SACAD	Supervisory control and data acquisition
GPRS	General Packet Radio Service
RFID	Radio frequency Identification
USB	Universal Serial Bus
PC	Personal computer
RF	Radio frequency
LCD	Liquid crystal display
ADC	Analog to digital converter
USART	Universal synchronous and asynchronous receiver and transmitter
AVR	Advance virtual reduced instruction set control
SEI	Serial interrupt enable
ISR	Interrupt service routine
SM	Soil moisture
TEMP	Temperature
H	Humidity
T	Temperature
MCU	Microcontroller unit
ACO	Ant colony optimization
GA	Genetic algorithm

ABSTRACT

In this era of modernization, lots of systems have been introduced by which the human effort has been limited to a certain level. In this work a data acquisition system has been developed for agricultural environment monitoring, which will measure the certain parameters like temperature, humidity, water level and the level of gases present in atmosphere. The data is collected from sensor nodes which are deployed in the field and transmitted to the control room node using ZigBee network and then retransmit the desired data to handheld device of concerned person. The LCD is used to display the sensor parameters. The RF modem is used to transmit the values to the control room node using mesh network topology. The control room node contains ZigBee transceiver module to receive the information. The ZigBee network is working at 9600 baud rate and 2.4GHz frequency in ISM band. The ZigBee nodes are capable to transmit the information up to 100meteres and for long distance communication; multi-hopping can be used.

Since the sensors is to be deployed in the field to cover all area without any dark zone, the sensors position need to be placed in a way to ensures high quality of service. This is achieved by placing optimal number of sensors covering maximum area in the network without any communication failure. In order to achieve the same network optimization algorithm is used for efficient routing. There are various optimization algorithms available. However, after comparative study of algorithms particle swarm optimization algorithm is selected and used to find the optimal positions of the sensors because of better scalability. The proposed work is demonstrated by implementation of hardware. Data from various field sensor nodes is collected by central server. The handheld device is designed to display all required information through the server node, which is connected to network by means of zigbee.

Wireless sensor networks are concluded as helpful to a great extent to reduce the physical effort involved in performing the strenuous agricultural

practices. The nodes are economical and can be installed in harsh environmental conditions. Circuit simulation is done before actual hardware implementation of the system. Programming for microcontroller is done with the help of AVR studio4 using embedded ‘C’. USB to serial programmer is being used to program the system.

The major outcome of the research is an innovative method, an apparatus and an algorithm for wireless sensor network for development of a system for smart control of environment parameters for rural development particularly useful for farmers. The innovation in the present work is the development of handheld device for farmers, optimized algorithm for individual sensors nodes and optimization of placement of the nodes.

CHAPTER-1

INTRODUCTION

1.1 Role of wireless sensor network in agriculture

Agriculture plays a very important role in the economy of any country. However, agriculture is totally dependent on the climatic conditions. The detection of the effect of climate changes on food production is very difficult. As level of carbon dioxide increases, the temperature of the environment also gets increased. Some crops needs high temperature condition while some needs low temperature condition. Besides this; water availability, level of nutrient, soil moisture level are some factors which also affect the productivity of the crops.

There is an impact of the environmental situations on crops. For instance, U.S exports supply of corn, rice and wheat all over the world is more than 30 % according to U.S. Census Bureau (2011). Warmer temperature may enhance or reduce the growth of the crops. Hence, there is an effect on the production of crops[1]. If warming increases above certain level, then yield in crops will be affected. There are different kinds of weeds, pests and fungi which grow along with crops when the temperature gets warmer and wetter climate. According to reports revealed by United States Global Change Research Program, farmers have spent more than $11 billion per year in order to prevent the growth of weeds in the United States. To fight against the weeds farmers have to increase the use of fungicides and pesticides that indirectly affects the health of human being very badly.

The Government of India also take some important steps by setting up Ministry of Food Processing Industries, function of which is to observe and stimulate the agriculture sector to make it more beneficial. The agriculture sector of India extremely depends upon the monsoon season as light rainfall during the summer time decreases the level of harvesting. However the agriculture sector cannot be governed by only one season and also the environmental conditions are not same throughout India. In order to increase the growth rate and irrigation area, there is effective need in the improvement of certain segments such as water management ,soil quality and flower/fruit/herbs bifurcation, which are also important points on which the Green Revolution relies.

At international level, there is also a deep impact of climate modification on agriculture and food supply. Moreover, some factors such as growth in population may also increase the effects on crops productivity. For instance, in developing countries changes in crop-management and improvements in irrigation are more limited than in the United States and other developed countries. In this thesis, an effort has been made to design and implement a WSN based system for monitoring the environmental parameters affecting the agriculture.

1.2 Recent developments in wireless sensor network based precision agriculture

Currently, wireless technology is a developing technology in various divisions and is having a prospective application in areas such as security, disaster management, monitoring of environment and also in healthcare. All technical challenges of wireless sensor network are being removed in the present system. Important features of wireless network are low power consumption, good data rate, mobility and flexibility of wireless system with the extension of network.

Application of wireless sensor network in the area of precision agriculture is one of the most challenging tasks. In terms of precision agriculture, there are several forms of elements which should be kept under consideration. These elements are basically soil type, pH value and temperature of soil, and many more.

To monitor all these elements, there is a need of such system which will be low cost and efficient. Wireless sensor network is a proven effective technology to improve production and quality of crops.

It is very easy and optimum to determine the requirements of fertilizer usage with the help of precision agriculture with respect to timing of harvesting, phase of ripening and growth of product. For this purpose, various wireless technologies are being utilized. These technologies include Zigbee (70 m), Bluetooth (10 m) and wireless local area network (100 m); in terms of communication distance between adjacent nodes. A simulated application of wireless sensor technology is implemented, which is adept to provide all the parameters of elements in precision agriculture to the end users.

However by using satellite imaging; grouping and observing different kinds of crops was done by investigating the interaction of electromagnetic waves with the crops. Different types of hardware and software was established by Pierce and Elliot for actual time farming on field by utilizing the technology of wireless sensor networks in Washington State (USA). Self-organized, autonomous ad hock network which is composed of different amount of wireless nodes and powered with the help of battery are applied [2]. This type of network has all the features which are very useful in terms of precision agriculture. These features are as follows:

- There is no need to change topology of the network. Nodes are placed in such a way that they are able to adapt to any change in the network. Any node can be added or removed from the network without reconfiguring the network.
- This type of network is more resistant to errors than other kind of networks because failure of any node is compensated by the another node in the network, also termed as dynamic network reconfiguration.
- All nodes in the network are optimized from power consumption point of view as individual node has its own power supply, either renewable or battery powered[3]. With this, nodes are able to work at least for one agricultural cycle.
- Sensor network which is to be used in precision agriculture should be in sync with environmental conditions, with high resolution and having great level of accuracy. Cost is also reduced by embedding the sensors in the motes.

The main components of motes are processor, power supply and radio module for communication and sensor for determining the environmental conditions. The communication standard used by these motes is basically based on IEEE 802.15.4 (IEEE, 2006) and also on Zigbee[4]. Main advantage of these standards is that the system do not consume more power and hence suitable for working up to a week or month. Function of power supply is to provide proper voltage for establishing communication among the motes. In this thesis a low powered, low cost motes for precision agriculture is designed and implemented.

1.3 History of wearable devices

In the year of 1961 two mathematicians, Edward O. Throp and Claude Shannon developed miniature computerized timing device which can be worn on modified platform of shoes, in order to predict the result of casino roulette games.

In present day wearable devices are fully merged and have immense use in our daily lives. Fruit harvesting is totally a labour work that depends on efficiency of the labour and the cost of labour is almost 50% of the total production cost[5]. Various efforts were made to improve the process of data collection in production of crops in past years. Most of the processes focused on paper procedure which was time consuming[3, 4].

By the development of these techniques for automated field data acquisition, there is an improvement in the quality of crop production and also reduction in the production cost. Any new system must be robust and adaptable to any changes in order to increase real time decision making capability and should provide the needful information to the end user [6]. In some technologies, GPS data is not reliable for gathering the information about the crops. For this, radio frequency identification (RFID) and barcode registration technology can be used in terms of refining farm management. In this thesis a small handheld device as wearable device has been designed and implemented for data acquisition.

1.4 Algorithms used for optimization of sensor nodes in precision agriculture

There are different kinds of algorithms that are being used in wireless network out of which most important and adaptable algorithm is PSO (particle swarm optimization). PSO algorithm is a multidimensional optimization technique which is very easy to use by the end users. Huge computational efforts are the necessity of the traditional analytic optimization and due to this the size of system increases, which is important concern.

For precision agriculture, different kinds of model based on theory have been developed and deployed successfully in real time. Out of these theoretical model, some are based on radiative transfer equations, method for solving this equation is to solve iteratively second order matrix. Other methods are founded on the Foldy–Lax multiple-scattering equations. Effects which are composed of mainly Multiple-scattering and coherence are more concerned in terms of using Foldy–Lax equations. Authors have done a successful experiment showing that modelling of paddy canopy by utilizing the iterative solutions for radiative transfer equations with the application of dense medium model for the corps by taking into account effects such as coherence and volume scattering [7].

PSO algorithm was discussed where a number of discrete PSO algorithms have been proposed [8]. Using the discrete PSO algorithm, the traveling salesman problem and for the permutation flow shop sequencing problem with make span criteria were discussed. In this proposed structure a discrete PSO is considered to achieve the perfect optimization of the elements or nodes. However, the problem which is found while utilizing this algorithm is of complex nonlinear constrained optimization. Because of robustness of the discrete PSO algorithm, there is no requirement of rigorous representation of particles.

Redundancy of the search space can only be reduced by good representation and this also improves the efficiency of the system and thus performance of algorithm improves. In general, while selecting the particle for representation, three main principles should be taken in account: soundness, non- redundancy and completeness. Soundness is understood as each and every element in the encoding space should resemble to a probable solution in the represented space. Non-redundancy is basically defined as on sight bond between elements in the encoding space. Completeness is simply well-defined as each element in the problem space having a feasible solution becomes the phenotype of elements in given encoding space. All three principles mentioned above are difficult to include in any present encoding scheme, but Wenzhong Guo have implemented all the three principles in single encoding scheme. In this thesis PSO algorithm has been used for optimum placement of sensor nodes in the agricultural field.

1.5 Existing technology used in wireless sensor network based precision agriculture

Another application of wireless sensor network was successfully completed in the project named as "Zebranet" by the research students of Princeton University [9].

The main aim of the project was to develop a miniaturized device which has the computational capabilities in order to determine long range migration of zebras in the urban region of Africa.

A platform named as Body sensor network was developed due to some limitations of WSN such as monitoring of internal environment of human body. BSN architecture is mainly developed in order to make wearable device which can be fixed on human body. Each element in the body sensor network was made up of a microprocessor, transmitter and power supply for proper establishment of the network. BSN network is capable of integrating with home, hospital and office environment. Accurate data capturing is ensured by the sensors presented in the network and then transmitted wirelessly to the local processing unit [10].

By the application of wearable technology, sophistication is also increased and this is clearly illustrated by the use of stethoscope, which is developed from simple tube. In terms of personal healthcare, wearable devices also find very important application.

For monitoring the temperature, heartbeat, pulse rate and blood pressure of the patient wearable devices are very useful and have wide range of application in different kinds of field. In order to monitor crops situation such as time for ripening, harvesting, ph value of soil and temperature of soil, wearable handheld device can play an important role. Because of small size and easy handling of the devices which are the part of handheld wearable architecture, it is very easy to monitor the crops. An attempt has been made in this thesis for design and development of the same.

1.6 Wearable devices based precision agriculture using wireless sensor network

Wearable devices, which can record position of labour in the farm and can identify the diseases in corps such as grapes, guava were also developed. This delivered promising outcome to the end users. The technologies used in precision agriculture are already discussed and analysis have been done for the application of wireless system such as RFID, Global positioning system and Zigbee[11]. But all these technologies were focused on the traceability of the crops and precision management, very few efforts has been put to develop such automated system that will record the efficiency of worker doing harvesting in the farm.

A prototype system has been developed and tested in order to study the harvesting efficiency of the picking crew in the orchard that record the weight of the standard bucket, it measures average harvest rate but not that of particular individuals and thus cannot measure the accurate labour efficiency[12].

A fully integrated, real time and user responsive system was developed in order to gather the information related to efficiency of individual picker and the process of fruit harvesting[13]. An effective system not only requires trustworthy observation but also a predefined detection and recording of the information or data related to crops production. For getting improved system for farm management ,use of communication and information technology is implied successfully.

Paper [14,15] presents one of the main problems while implementing the traceability and digital documentation is the acquisition of the data related to first stage of production chain. For general crop cultivation and harvesting the application of data acquisition is lacking[16]. Basic fundamental behind the development of automated and wearable technology is to track particular labour and to gather information which plant is cultivated or harvested by particular labour. Authors have developed a wearable device or module that is implemented in order to trace labour position in farm or in protected environment[13]. This device consists of a pedometer and barcode reader, the function of barcode reader is to read the tags that are attached on the tree and pedometer is used to calculate the relative displacement with respect to the initial position. Barcode simultaneously provides the position at regular interval of time in order to minimize the level of error.

With the development of wearable devices utilizing the wireless technology, it is very easy to optimize the position of the tree and time for the cultivation of it. Moreover with this it becomes easy to calculate the working hours of individual labour and thus working efficiency is also measurable. By having such type of smart motion tracking system various kinds of improvements are observed in the productivity of specialized crops.

The proper management of farming is dealing with many problems such as exact time of harvesting, amount of water, ph value of soil, temperature of environment amount of pesticides. There is a need for such system that can automatically and precisely detect all these parameters so as to achieve the good productivity of crops in reduced time and minimize the production of cost. A low cost wearable device based environmental monitoring system for measuring and detecting above mentioned parameters has been designed and implemented in this thesis.

1.7 Objective of the current thesis

- To identify the environmental parameters which are useful for agricultural fields.
- To Design a system to collect the data from environment.
- To implement optimization algorithm to optimize the value of continuous collected data.
- To design a handheld device for farmers on which optimized data will be displayed.

- Performance analysis of the system.
- To Design a graphical user interface for data logger.
- Hardware Implementation of the proposed system.

1.8 Proposed system in the current thesis

From the above discussion following can be inferred:

- WSN has been used for collecting environmental information but it required technical know-how for accessing. Ordinary farmer had limited access to this data.
- Easy interpretation through low cost wearable device showing the environmental data suitable for agricultural field for ordinary and precision farming affordable to farmers are not available.
- Sensor node placement algorithms and its practical implementation for agricultural fields with and without vegetation were not available.

In this thesis the system is developed in order to address these issues and is explained as below:

The system is configured with three units. The aim of the design is to provide the optimized field parameters for agriculture use. Different sensor nodes placed in the field to collect the data from the environment like temperature, humidity, gas, water level and soil moisture, sensors will continuously monitor the environmental changes and communicate the whole data to data logger by RF module and then data will be collected to data logger and will be optimized by using optimizing algorithm and an this optimized value will be communicated to the fabricated small hand held wearable devices and the whole information will be displayed on display unit provided on the device.

The placement of these sensor nodes are to be done in such a way that the full agricultural field is covered with optimum placement of sensor nodes for which optimization algorithm (PSO) is used. Wireless communication in agricultural field is faded because of the presence of vegetation of various kinds.

Hence the numbers of nodes that are to be placed are optimized accordingly. In this thesis this aspect is investigated in details for finding the scattering effect of different vegetation and optimum placement of sensor nodes thereof .This System provides a low cost and low power consumption solution for a better optimized data technique which will be useful for farmers.

In this proposed system an integrated system is developed which consists of nodes with one as master node. All these nodes are equipped with sensors, RF module, and display unit and efficient power supply. The function of sensors is to determine the parameters such as humidity, temperature, ph value, water level and soil moisture. RF module is for providing proper communication between the nodes. Zigbee (CC 2500) working at frequency of 2.4 GHz. LCD (2*16) module is attached with each and every node so that it can show the data to the end users. A power supply of five volt and one miliampere current is used to provide power to the nodes. Whole data is collected by the data logger from which any one can read the data at any time.

Fig.1.1 Proposed System

Papers on systems used for monitoring the environmental parameters for different purposes like disaster management, green house monitoring, animal monitoring etc. are studied and it is concluded that ZigBee based monitoring systems are low cost, low power reliable systems and can be used for data collecting and monitoring. Further optimizing techniques are studied to find out the algorithm for data optimization. The wearable computing devices are the latest technology used for monitoring purposes in order to cater for the rural peasants who as end user need not be aware of the complexity of the computing devices.

1.9 Motivation of Research

The agricultural sector in rural India suffers from lack of information regarding environment as a result of which there is large scale damage of crops every year. So a low cost WSN whose parameters can be displayed on a wearable device will be of great help to the cultivators.

Wearable technology is related to both the field of ubiquitous computing and the history and development of wearable computers. With ubiquitous computing, wearable technologies share the vision of interweaving technology into the everyday life, of making technology pervasive and interaction friction less.

1.10 Thesis Organization

The whole document is divided into seven chapters.

Chapter 1 is about introducing the research background of developed system including role of wireless network for precision agriculture. On the bases of motivation for research, objectives are formulated.

Chapter 2 is Literature review, which discusses the already existing art by referring various research papers published in reputed journals. It includes the conclusion from existing art and research gap and their limitations.

Chapter 3 describes the system development with the help of block diagrams and circuit diagrams for all sensor nodes, handheld device and server.

Chapter 4 describes the circuit diagram and simulation for development of the system.

Chapter 5 explains the stepwise process for software development, which includes the algorithm for each node, handheld device and server.

Chapter 6 concludes all the results from sensor nodes, with detail description of each sensor.

Chapter-7 is describing the research publications to support the thesis during 2014-15

1.11 Chapter Summary

This chapter gives brief introduction to the methods for precision agriculture. Role of wireless sensor network is discussed for parameter monitoring. On the basis of background, Zigbee protocol is selected for communication between sensor nodes, handheld device and server.

CHAPTER-2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

ZHANG Xiaoshuan et. al suggests a system for precision irrigation for vine's growth by developing a PVIDSS system and provides an efficient way to improve the irrigation efficiency [17].

Limitation- Paper suggests improving the irrigation efficiency, but doesn't discuss any procedure to monitor the values of parameters required to make it more efficient.

Aggarwal, Rajan, et al. discusses about one of the major problems for irrigation in an agriculture field is the shortage of water. WSN based weather forecast information using GSM is developed, which is on the bases of data collected from sensors [18].

Limitation- Paper discusses the GSM based WSN system which is licensed network and hence user needs to pay for using the network. Present requirement is license free network where end user need not pay for the use of network.

Kuang-Yow Lian et al. proposes a system which monitors the environmental parameters like temperatures, humidity , quality of air and the electric load. The system is implemented using smart phones. The developed system will also be able to measure the vibrations of operating machinery.

For intelligent monitoring, ZigBee and Wi-Fi protocols are used. The integrated system is fabricated by 32 bit ARM core Arduino Duo module. The measurement results were displayed using the Android and web based system. TCP/IP protocol has been used to transmit the data to a cloud device [19].

Limitation- Zigbee, Wi-Fi and ARM based factory monitoring system is discussed, but the issue of cost and code size has not been tackled in this paper. It is not a cost effective solution.

Mohamed Hefeeda et al. in this paper a sensor network has been designed for observing early symptoms of fire in the forest. Fire weather index system is analyzed for this purpose. With the help of wireless sensor network efficient fire detection system has been developed. [20].

Limitation- Paper discusses the use of fire sensor in forest, but doesn't include other components for wild life security.

Garcia-Sanchez et al. demonstrates an Irrigation Management System by using wireless sensor network. Paper talks about an advanced irrigation scheduling based on IMS for Manja Township, City of Blantyre. The system is based on a remote monitoring mechanism using GPRS modem [21].

Limitation- The system is based on GPRS, which is not a cost effective solution.

Wang, Ning et al. proposes a routing method for efficient Irrigation Management System using Bluetooth sensor. Paper describes a multi hop Bluetooth ad-hoc network model. The model collects data from sensor through Bluetooth sensor and alerting the farmer with mobile phone [22].

Limitation- The proposed system is based on Bluetooth network and alerts the farmer by sending message on mobile phone, which is not a cost effective solution.

Wenyan, Li. proposes a solar energy based water-saving irrigation system using the ZigBee wireless sensor network. Zigbee nodes collect the data from soil temperature and moisture sensors and transmit the data by the GPRS network [23].

Limitation- Paper describes only the irrigation system but doesn't include other important parameters like fire sensor, gas sensor etc.

Fried Ewald et al. describes the several challenges to be addressed in implementation of ubiquitous computing. The next generation technological innovation will be through this technology. In this paper the author suggest methods to implement ubiquitous computing by considering the criteria of economic sustainability and social computability [24].

Limitation- The paper describes the technical and legal challenges of ubiquitous computing, but implementation strategies are not discussed.

Venayagamoorthy describes the Wireless sensor networks (WSNs), its challenges, failures, and computational constraints. Further importance of computational intelligence for WSN is discussed. This paper shows that computational intelligence conveys additional features in the WSN like flexibility, autonomous behavior and robustness. It also takes care of communication failures and scenario changes. A comparison of computational intelligence algorithms with WSN solutions is described [25].

Limitation- Importance of computational intelligence in WSN is discussed but its role in agricultural field is not included. The implementation strategies are also not discussed.

Mrugala et al. in this paper a management application of an automobile warehouse has been proposed for dynamic locating the automobile using handheld device. This device will be worn by the end user for monitoring the warehouse and to compute the parking space dynamically [26].

Limitation- A computing system is proposed for warehousing of automobiles, but its application in other related field like environmental monitoring is not discussed.

Velázquez et al. proposes a handheld assistive device for the blinds to improve the quality of life. [27].

Limitation- The paper describes the RF communication but doesn’t include its application in the other related fields.

V.Vanitha et al. discusses an extended service oriented architecture for designing customizable sensor network and also discusses the solution to overcome the limitation of sensing systems like robustness, complexity etc. The system is basically improvement in service oriented architecture of embedded systems [28].

Limitation- Paper describes the architecture for wireless sensor networks but doesn't discuss about application of WSN in related fields like precision agriculture etc.

Goel et al. suggests a solution for measuring and controlling **the environmental parameters like temperature, pressure and humidity remotely by using** an integrated wireless SCADA system. It consists of GPRS based mobile network and The SCADA system is integrated with GPRS mobile network . **D**ata collection or data logging can be done in faster and cheaper way in this system by using the personnel free inspection. [29].

Limitation- This paper proposes GPRS based monitoring system which has wide coverage range but needs large infrastructure for implementation.

Chengbo Yu et al. propose an environment monitoring system and discuss the reason of choosing ZigBee technology as communication module in Wireless Sensor Networks. The system uses CC2430 board and verifies the correctness and feasibility [30].

Limitation- Wireless sensor network based monitoring system is discussed using Zigbee, but its application in agricultural field is not included.

Jiang, Peng, et al. describes a wireless sensor network based measurement and control of water environmental system. The system has been implemented by three nodes. They are base station node, remote control node and data monitoring node. The system developed has accomplished the task of online measurement of ph value and the temperature of the water [31].

Limitation- Paper only discusses about water monitoring system using only one type of sensors. The problem of implementing multiple sensor nodes using WSN are not discussed.

Dr.S.S.Riaz Ahamed in this paper the IEEE ZigBee slandered has been discussed. The paper suggests that network security is provided by Zigbee which can be implemented for small power consumption and minor cost [32].

Limitation- Paper is all about the features of ZigBee technology, but its applications in wireless sensor networks are not included.

Luis Ruiz-Garcia et al. in this paper the application of latest technical and scientific innovation in wireless sensor networks for the agriculture and food sector. The main focus of the paper is on WSN, RFID and ZigBee. The future applications of wireless sensor network in agricultural and food industry have been illustrated [33].

Limitation- The system that uses technologies related to RFID and Zigbee is developed for agri-food industry but the effects of various environmental parameters on the agri culture field are not discussed.

Mitsugu Terada in this paper a sensor network based on ZigBee module has been proposed for acquiring and monitoring data. In this implemented sensor network PC acts as a base station. ZigBee module communicates to PC via USB interface. The sensors collect the data and communicate to the base station. The format used for data recording in the display device is by means of hexadecimal number system [34].

Limitation- However the latest technology is aiming at development of small handheld / wearable devices for recording of data.

E.S. Nadimi a,b et al. in this paper a system has been developed for monitoring online the presence or absence of cows in a grassy area by using wireless sensor network. Wireless sensor nodes are attached to the cows which can communicate with central station or server via gateway [35].

Limitation- Zigbee based animal monitoring network is developed but its application for a monitoring environmental parameters were not discussed.

Cho, Min Je, et al. discusses the role of ubiquitous sensor networks in disaster preventing system. The system proposes a platform to prevent man-made disasters in case of a gas leak explosion by monitoring and controlling relevant facilities [36].

Limitation- The paper describes the role of sensor networks for monitoring environmental parameters but only limited to gas sensor.

V. G. Sangam et al. in this paper a data acquisition system has been interfaced with AT89C51 microcontroller for development of bio analyzer for monitoring concentration of glucose**.** The optimization of different parameters has been done for performance enhancement [37].

Limitation- System is developed using AT89C51 microcontroller. More cost effective and high performance solutions could be used.

Liu, Chong describes the importance of wireless sensor networks for collecting and monitoring environmental variables such as meteorological parameters or pollutants.

The system can efficiently monitor and detect anomalies, a context for the monitoring and near-real-time assessment of environmental data is proposed that offers reduced data representation utilizing fuzzy clustering for the shrinkage of spatial data combined with an LZW scheme for the compression of temporal data [38].

Limitation- The paper describes the implementation of system based on fuzzy logic. The other less complex algorithm can be used for the same purpose.

Kamarul Ariffin Noordin suggests an implementation scheme for remotely measuring environmental parameters like temperature, atmospheric pressure and relative humidity by using the sensors. The sensors output are analog in nature and hence converted to digital signal by means of a Analog to digital converter interfaced with a microcontroller.

A data logger is interfaced through an USB port to PC. The measured signal is displayed in a LCD. Data analysis is done by the PC with a graphical user interface . [39].

Limitation- A data logger is implemented through the USB link with PC, which is neither portable nor a user friendly solution. The display used in this paper is a LCD display. More cost effective solutions like by displaying in LED's or wearable devices are feasible.

Zhang, Qian, et al. presents a low power ZigBee sensor network with bidirectional communication and control of inter-node data pack reception designed for use in agricultural fields. The network consists of sensors, routers to propagate over larger distances, and a computer to controls the complete system. The end devices provide data from the sensors to the personal computer at variable time points determined by the central node. The central node controls the water flow to the plants in a greenhouse [40].

Limitation- Paper describes the neural network based irrigation control system only more parameters could be monitored and controlled which is not discussed.

Frigioni, Daniele et al. discusses Demetreseu and italiano's algorithm for routing for maintaining shortest path for all pairs of nodes [43].

Limitation- The paper discusses only one type of algorithm without comparing it with other related algorithms.

T. Starner explores the possibility of harnessing the energy during the user's everyday actions to generate power for his or her computer. Power generation by leg motion is analysed [44].

Limitation- Power generation by leg motion is described but its applications and result analysis are not included.

Marinetti, Luca, et al. discusses about a neural network based intelligent water-saving system. In this paper soil moisture sensor, air temperature sensors are used as precise irrigation equipment for best water utilization [45].

Limitation- This paper does not discuss other methods for implementing intelligent systems. The paper only describes few limited sensors.

Rasin, Zulhani et al. elaborates the use of wireless sensor network (WSN) for a water irrigation control monitoring. In this paper, the authors shows a system where water flow is controlled through a control room by giving command to motors, based on data collected from sensor nodes [46].

Limitation- WSN based water irrigation system is discussed but real hardware is not developed, implemented and tested.

Catarinucci, Luca shows simulation based results for irrigation applications based on Wireless sensor networks using Zigbee. Simulation results show the robustness of the proposed multipath links using dynamic multi paths [47].

Limitation- Only simulation based results are discussed. However no hardware system is implemented.

Gagnon, Romain presents, a pumping station measurement and control system by using ZigBee and 3G network. The experimental results show that the system overcomes the defects of control system [48].

Limitation- The paper describes the Zigbee and 3G based networks. But it doesn't discuss the comparison of other technologies related to wireless communication.

Dursun, Mahir et al. in this paper author has designed a method for precision irrigation by implementing fuzzy logic. The paper infers that the system will be having high reliability in terms of communication and high accuracy in terms of control [49].

Limitation- The test results are based on simulation only, no hardware implementation is discussed.

Kim, Yunseop et al. has developed and implemented an automated sprinkler irrigation system which would be site-specific and by utilizing it amount of water can be saved. Authors have also incorporated the technical specifications of ZigBee network [50].

Limitation- This system is focused only one parameter. The other relevant parameters have not been discussed.

Gutierrez, Jessica, et al. in this paper authors have implemented an interfacing of temperature and soil moisture sensors with microcontroller in order to control the actuators [51].

Limitation- Information on the environmental parameters are not displayed for easy monitoring by the end user.

Ganesan, Deepak, et al. describes the importance of wireless sensor networks for collecting and monitoring environmental variables such as meteorological parameters or pollutants. The system can efficiently monitor and detect anomalies. A context for monitoring and near-real-time assessment of environmental data is proposed which offers reduced data representation utilizing fuzzy clustering for the shrinkage of spatial data [52].

Limitation- The paper discussed the development of fuzzy logic based wireless sensor network for monitoring the environment parameters, which is complex system. Other simple solutions are not discussed.

Zhang, Yang et al. The paper discusses about measurement of parameters which is situated away from the main body of the wireless sensor network. Errors , noise, security are examples of this type. This paper compares the existing techniques and provides a guideline for selecting a technique for a particular solution. [53].

Limitation- this paper discusses guidelines but actual implementation scheme for the measurements are not shown

Ganesan, Deepak et al. in this paper the author explores the feasibility of a system for networking many numbers of wireless devices whose size can be small and consumes less power. This paper also proposed a system that tries to implement uniformity in sensor network for handling of the observed data [54].

Limitation- The paper discussed the data handling in sensor networks with pattern mining. The real hardware development and implementation is not discussed.

Alippi, Cesare, et al. in this paper the author presents a detailed analysis of the major problems in the wireless sensor networks in terms of energy. The author also discusses that lifetime of a battery is limited and it is the only source of power for sensor nodes. Hence it infers that the major requirement for sustenance of the wireless sensor network will depend upon how efficiently energy is managed in the network [55].

Limitation- Paper focuses on the management of energy in the sensor network. It discusses the policies to use energy efficiently. No hardware complexities are discussed.

Lee et al. the author has implemented wearable device based electrocardiogram measurement system for monitoring of health in real time. The wearable device can be fixed on shirt for transmitting signals from the body continuously. The sensors worn in the shirt consumes small power and is very compact in size. The noises are eliminated by using adapted filter [56].

Limitation- Wearable technology for health monitoring is explored in form of a shirt. However displaying a communication of other types of signal is not included in this paper.

Varkey et al. proposes a novel wireless sensor based system for recognition of daily work done by the workers in specific company. Furthermore a new algorithm is designed and implemented in order to observe the amount of work done and the payment is done on that basis [57].

Limitation- The paper describes the algorithm to control the on fly range movements and same algorithm is used for controlling the motor movement, but the performance is not compared with other algorithms.

Milenković et al. in this paper the author has implemented a prototype for monitoring of health using sensor network. In this paper the author has developed the overall architecture and has discussed about the organization of hardware and software. The synchronization of time, management of power and signal processing on the chip has also been implemented [58].

Limitation- The paper discussed the use of sensor network for health monitoring by observing the motion and heart activities of the person. The other applications for the same type of network are not discussed.

Pandian et al. in this paper the author has discussed about the implementation of wearable device based physiological monitoring and its applications. Wearable sensors which are fixed to the fabric of the clothes collect information from the human system and send the physiological data to a data acquisition system. The system after acquiring data processes it and then transmits it to remote location for monitoring [59].

Limitation- Wearable technology for physiological monitoring is discussed. The applications of this technology for other applications need to be explored.

Darwish et al. In this paper the author has shown the importance of body area network and WSN for monitoring of health of the patients. The author has also shown how this technology can be utilized for monitoring of health old and disabled and also discusses ways and means by which these disadvantaged people can live a normal life by using this technology. It also presents the drawbacks and problems faced by present day technology. [60].

Limitation- The paper describes about the application of WSN in monitoring health parameters but application for other parameters are not described.

Tsow, Francis, et al. the author has implemented a bluetooth interfaced based toxic sensors. By means of experiments the authors have shown that the system can detect the desired toxicity. The other applications of the system like detecting various gases are also demonstrated [61].

Limitation- The paper describes the development of device which can detect toxic volatile organic compound and results show the device is useful in environmental health monitoring. Bluetooth has been used for communication which has a very limited range. Sensors nodes for other types of sensors are not discussed.

Alemdar et al. In this paper author reviews the existing health care system of elderly persons and children. The paper also demonstrates the use of wireless sensor network for day care and active life of the citizens. It also analysis the challenges and benefits faced by the existing system [62].

Limitation- Paper includes the review for already existing health care system based on wireless sensor networks for health care, but doesn't discuss on implementation strategies.

Römer et al. the paper describes a multidisciplinary research area for collaboration between various stack holders in wireless sensor network and infers that a close collaboration is required in order to design an efficient system [63].

Limitation- Paper describes the multidisciplinary research area in the wireless sensor networks but its real hardware complexities are not discussed.

Ndzi, David Lorater, et al. In this paper the authors have calculated the attenuation of signal due to different types of vegetation like mango and palm oil The paper also suggests the best model for deployment of sensor nodes in agricultural fields. The paper also suggests the best position of placement of nodes in different types of plantation.[64].

Limitation- The vegetation attenuation model shows only the attenuation of signals at different frequencies for different plants but algorithm for optimum placement of nodes are not discussed. Simulation of optimum placement of nodes were also not done.

Yahide et al. elucidate how web based intelligent drip irrigation system is solution to water management and precision agriculture. In web based system water supply can be controlled by using solenoid valve. The whole system is micro control based and can be operated from remote location. Smart sensor based decision making by end user like farmer is implemented in this paper is used to take sensor reading of soil like soil moisture, temperature, air moisture and light micro controller take decision control by user (farmer). Web based intelligent irrigation system helps a farmer to take decision on water management in farm and there is no need to maintain irrigation time table [65].

Limitation- The paper elaborates the web base precision agriculture for water management system. But this is not a cost effective solution for farmer.

Kulkarni et al. the author discusses about networks of autonomous sensor nodes for environmental monitoring. It also discusses various challenges of the WSN. The paper goes on to discuss the use of particle swarm optimization for solving the optimization issues for deployment and localization of sensor nodes [66].

Limitation- The paper describes the PSO as optimization algorithm for optimal deployment of nodes in field for WSN. But hardware implementation of the deployment is not discussed.

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Wenqi, G. U. O. et al. proposes a variety of mathematical models to serve as analytical tools in quantifying battery discharge characteristics. However, batteries, as the primary power supply, still fail to last their projected working time. To further analyze the factors that affect battery discharge, and understand the characteristics of WSN power supply, this paper surveys both physical and network communication parameters that can affect battery lifetime and cause the difference between the simulation and application results. Furthermore, it introduces new energy harvesting techniques such as photovoltaics or piezoelectric generators [67]

Limitation- The paper focusses on the energy efficiency of WSN. It discusses different techniques for energy harvesting, but it is only survey based data and no experiment has been performed for data collection.

Park, Gyoutae, et al. has developed a system for improving the management of gas safety with the help of WSN and smart appliances. The system includes the subsystems for automatic extinguishing , detection of gases. It also includes the gas meter controlled by a microcomputer for monitoring gas flow and pressure. The whole procedure of early warning in case of a gas flow to the detection of any hazardous gases is controlled by the network[68].

Limitation- The develop system has only one type of sensor. However the effect and measurement of other environmental parameters are not discussed.

Kulkarni et al. this paper describes the implementation strategies for UAV assisted deployment of sensor nodes. The image processing techniques are used for identifying the exact place of deployment and PSO and BFA are also used for deploying the WSN nodes. The paper infers that PSO based localization is faster than BFA but less accurate [69].

Limitation- The UAV is used for disaster monitoring in the given paper. PSO and BFA are used for image segmentation and deployment of sensor nodes. But only simulation results are discussed, real hardware complexities are not discussed or considered.

Jose, Deepa V et al. Mobile sink assisted algorithm for efficient energy management in WSN has been simulated in this paper[70].

Limitation- Only simulation has been done but no hardware implementation of the same has been discussed.

Bai Q et al. the author has presented algorithm for implmentation of PSO. The same can be used for rapid development and it is easy to use. The author also has shown various applications of PSO in different technological fields[71].

Limitation- PSO has not been implemented for the specific instance of autonomous deployment of sensor nodes.

Gupta B.K et al. this paper describes how to use PSO for placement of nodes. It adresses the issues related to optimal deployment of sensor node. It also gives comparisoin between various optimization algorithm and infers that PSO gives a better solution[72].

Limitation- the implementation of the algorithm using standard simulation software is not done.

B.S.Paul et al. describes how wireless communication in an agricultural field is adversely affected by vegetation in the surrounding. In this paper the author also proposes model for optimum placement of these nodes when agricultural field is surrounded by vegetation. [73]

Limitation: Only one type of vegetation was considered. The scattering effect for different vegetation will be different.

Nikitha et al. describes deployment of sensor nodes using PSO. The author also tries to maximize the coverage by placing the nodes optimally. [74]

Limitation: It only considers the placement of nodes in the barren field without vegetation.

2.2 Chapter Summary

From the literature review, it can be inferred that the wireless sensor network has very important role in precision agriculture. There are sensors available to monitor the field parameters which need to be interfaced with advance controllers for proper monitoring and measurement of environmental parameters relevant to agriculture field. Although interfacing of such devices for limited number of sensors have been reported in the literature but an integrated system for measuring and controlling a major section of environmental parameters need to be implemented. Also the display of such data on a user friendly /handheld device for ready interpretation by a non-technical person like farmer also needs to be implemented. The optimum placement of sensor nodes have been reported but the effect of various types of surrounding vegetation on placement of these nodes and its software solution using optimization technique needs to be implemented.

CHAPTER-3

SYSTEM DEVELOPMENT

The Chapter describes the working of the system with the help of block diagrams of the different parts of system.

Wireless sensor network basically involves a large number of compact sensors having the ability to communicate and measure parameters. These compact sensors are termed as node. The basic problem in any wireless communication system are the range of communication channel, consumption of energy, availability of proper energy source and the ability of sensing.

In order to overcome these problems, fabrication of small node can be done in wireless sensor network for efficient working [41].

The main objective of any wireless sensor network is to gather the needed information in any environment. Design of sensor node is possible due to availability of low power source, embedded microprocessor and communication kits at micro level.

The system which is being proposed in this thesis consists of sensor nodes. These nodes are equipped with a proper communication medium, a proper and efficient power source and combination of sensors. Thus each node provides the computed data which is the combination of data collected by sensors deployed at different positions in the field [42].

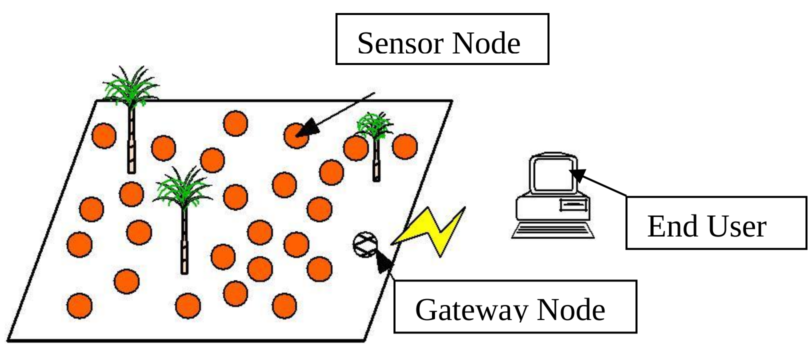

Fig 3.1 Architecture of Wireless Sensor Network

In order to design a node there are basically three main sections, processing unit, power unit and sensor unit. The function of sensor unit is to sense and measure the parameters in the existing system. Use of sensor is depending on the application i.e. for measuring moisture of soil, there should be moisture sensor. Power unit provides the proper voltage and current to the sensor node for maximum time and to increase the efficiency. Most important role is played by the processing unit in the sensor node in the wireless network system. Processing unit may consist of either microcontroller or microprocessor based on the application.

This unit does efficient computation on the data collected by the sensor attached with the node. After computation in specific format data is sent to the Gateway node through a proper communication channel by different sensor nodes. Gateway node collects data from different sensor node and transmits to the end user or base station.

3.1 SYSTEM DESCRIPTION

The aim of this system design is to provide the optimized field parameters for agriculture use. Different sensor nodes will be placed in the field which will collect the data from the environment like temperature, humidity, gas, water level and soil moisture.

The sensors will continuously monitor the environmental changes and send the whole data to data collecting unit by RF module. After that the data will be collected by data logger and the value will be sent to fabricate small handheld device and the whole information will be displayed on the display unit provided on the device. This system provides a low cost and low power consumption solution for a better optimized data technique which will be useful for farmers.

3.2 SENSOR NODES

NODE1

Node1 comprises of microcontroller, power supply, display unit, RF module, temperature sensor and soil moisture sensor.

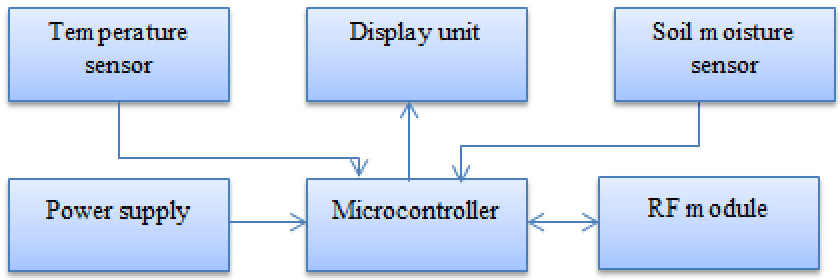

Fig3.2 Block Diagram for Sensor Node1

NODE2

Node2 comprises of microcontroller, power supply, display unit, RF module, temperature sensor and soil moisture sensor.

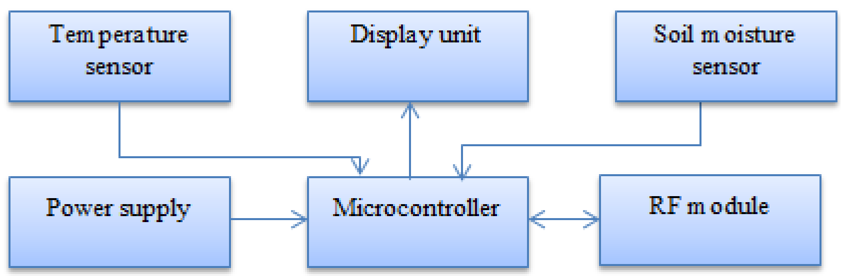

Fig3.3 Block Diagram for Sensor Node2

NODE3

Node3 comprises of microcontroller, power supply, display unit, RF module, temperature sensor and Gas sensor.

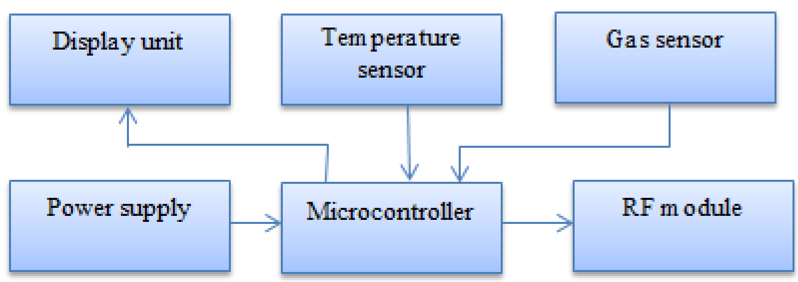

Fig3.4 Block Diagram for Sensor Node3

NODE4

Node4 comprises of microcontroller, power supply, display unit, RF module, temperature/humidity sensor.

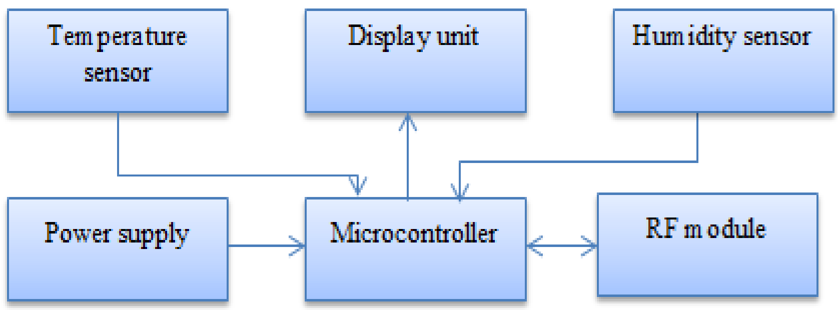

Fig3.5 Block Diagram for Sensor Node4

NODE5

Node5 comprises of microcontroller, power supply, display unit, RF module, temperature sensor and ultrasonic sensor.

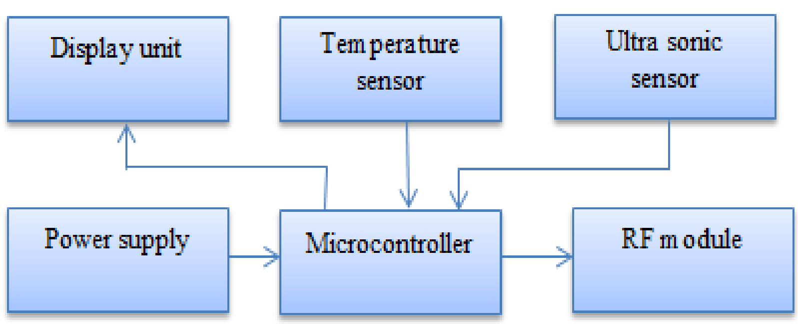

Fig3.6 Block Diagram for Sensor Node5

SERVER

Server node comprises of microcontroller, power supply, display unit, RF module, Bluetooth modem, max, DB9 and PC

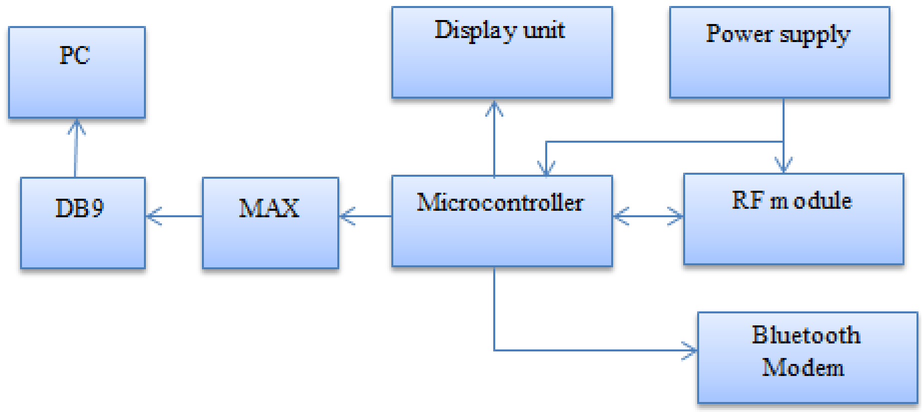

Fig3.7 Block Diagram for Server Node

HANDHELD DEVICE

Node comprises of microcontroller, power supply, display unit, RF module.

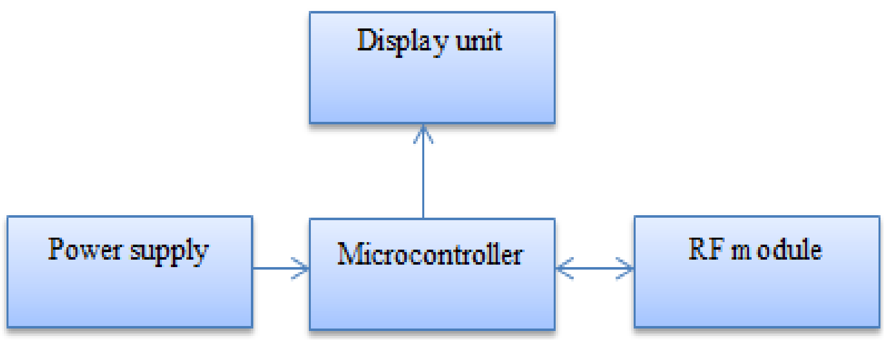

Fig3.8 Block Diagram for Handheld device

MOBILE AS DATA LOGGER

Blue Term is used to capture the real time data in smart phone via bluetooth. Blue Term is a free app for android and it can be found in the Google Play market. It is a terminal emulator for communicating with any serial device using a bluetooth serial adapter.

3.3 CHAPTER SUMMARY

This Chapter describes the different parts of the developed system such as sensor nodes, server and data logger with their brief description. The detailed block diagrammatic description of the each part of the system is discussed.

CHAPTER-4

CIRCUIT DIAGRAM AND SIMULATION

The Chapter describes the working of the system with the help of circuit diagrams and simulation models for the system and brief components description is also included.

4.1 CIRCUIT DIAGRAM

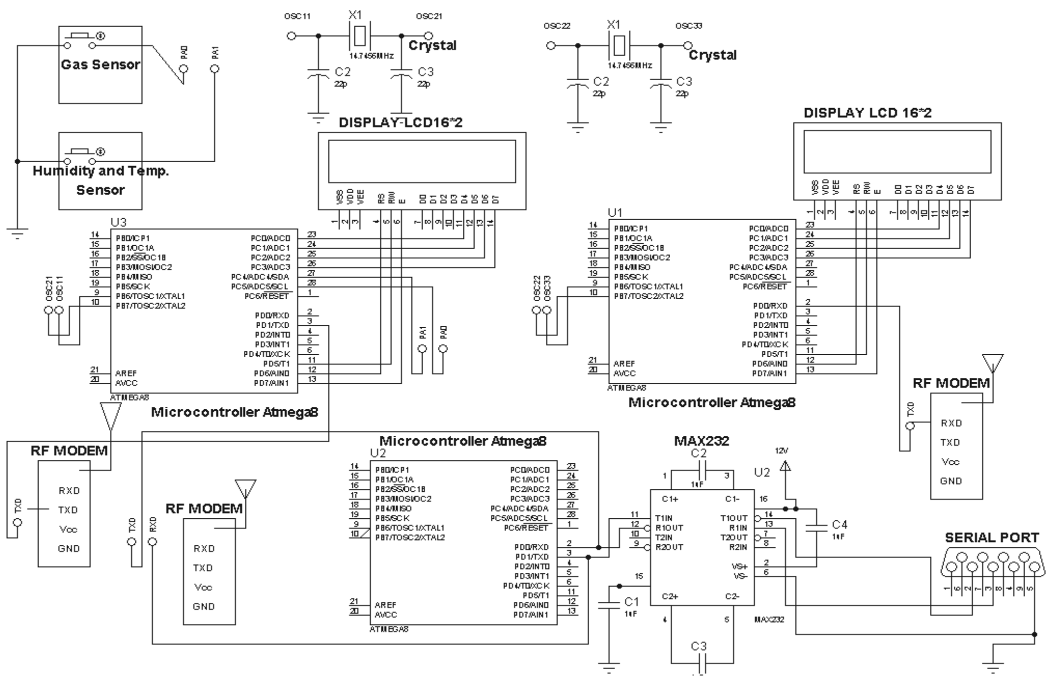

Fig.4.1 Circuit Diagram for the sensor node and handheld device

Fig. 4.1 elucidates the connection of different electronic components in the node. Every node is composed of RF modem that works in full duplex mode in order to transmit the data from one node to another connected in the network. Principally two sensors (gas sensor and humidity sensor) are connected to the node which is placed in the field. Function of the gas sensor is to measure the concentration of the gas (such as LPG, Butane) in the present environment. Humidity of environment is detected with the help of humidity sensor. Humidity sensor gives serial data at the 9600 baud rate to the microcontroller. The output of these sensors is in analog form. Analog signal from the sensor is fed on to the analog to digital pin of microcontroller (ATMEGA 8). The function of this pin is to convert analog signal in to digital signal. After fetching the signal from sensor attached, microcontroller do logical operation and controls the overall operation. A display (16*2 LCD) is attached to each node. Function of this is to display the measured parameters. MAX 232 IC is also used to provide communication between the node and PC. With the help of this, end user can easily observe the parameters and can do needful action. Whole circuit is working on the 5V power supply. RF module is attached to the transmitter and receiver pin of microcontroller. A ZigBee module (CC2500) is used in the system to provide wireless communication in the network. This module works in full duplex mode and also can communicate with many devices at the same time. The topology of each node in the presented network is based on mesh topology.

4.1.1 CIRCUIT DIAGRAM OF INDIVIDUAL NODES

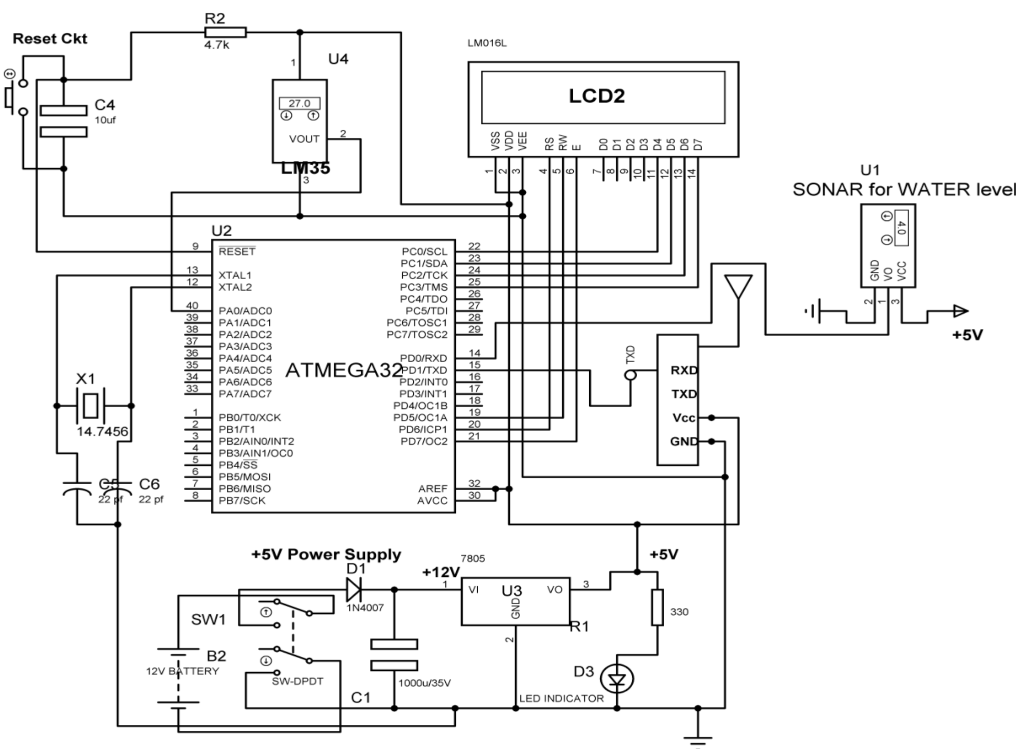

Fig.4.2. Circuit Diagram of node 1

Fig. 4.2 shows the circuit diagram of node 1 which consists of a water level sensor and temperature sensor. A 16*2 LCD is also used for displaying the readings of the sensors. A 5 V power supply is used to provide proper voltage in whole circuit. The outputs of both sensors are fed to the ADC port of the microcontroller. A zigbee modem is used for providing the communication between other nodes.

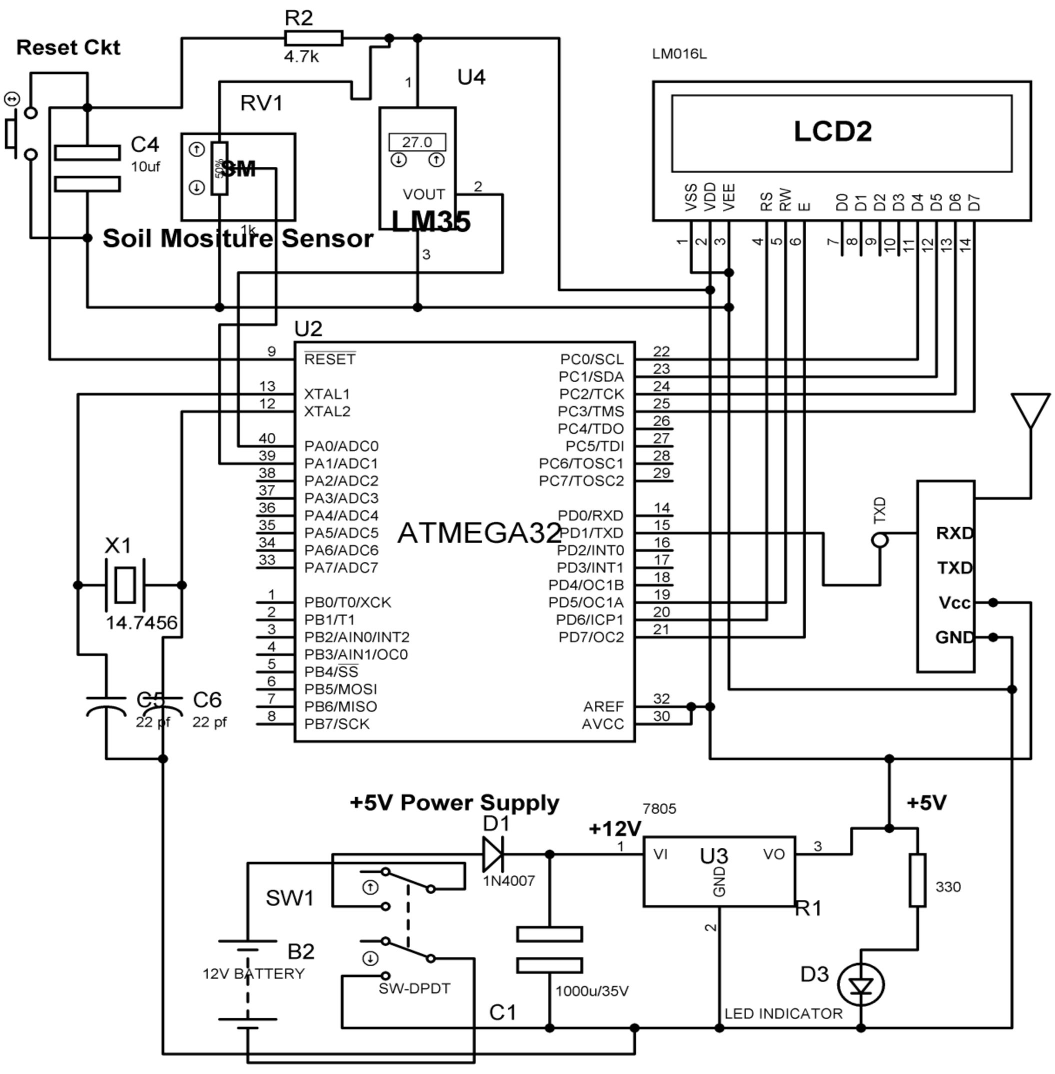

Fig.4.3 Circuit Diagram of node 2 &3

Fig. 4.3 shows the circuit diagram of node 2 & 3 which consists of a soil moisture sensor and temperature sensor. Soil moisture is used for measurement of moisture of soil. A 5 V power supply is used to maintain proper voltage in whole circuit. The outputs of both sensors are fed to the ADC port of the microcontroller. A zigbee modem is used for providing the communication between other nodes. A 16*2 LCD is also used for displaying the readings of the sensors.

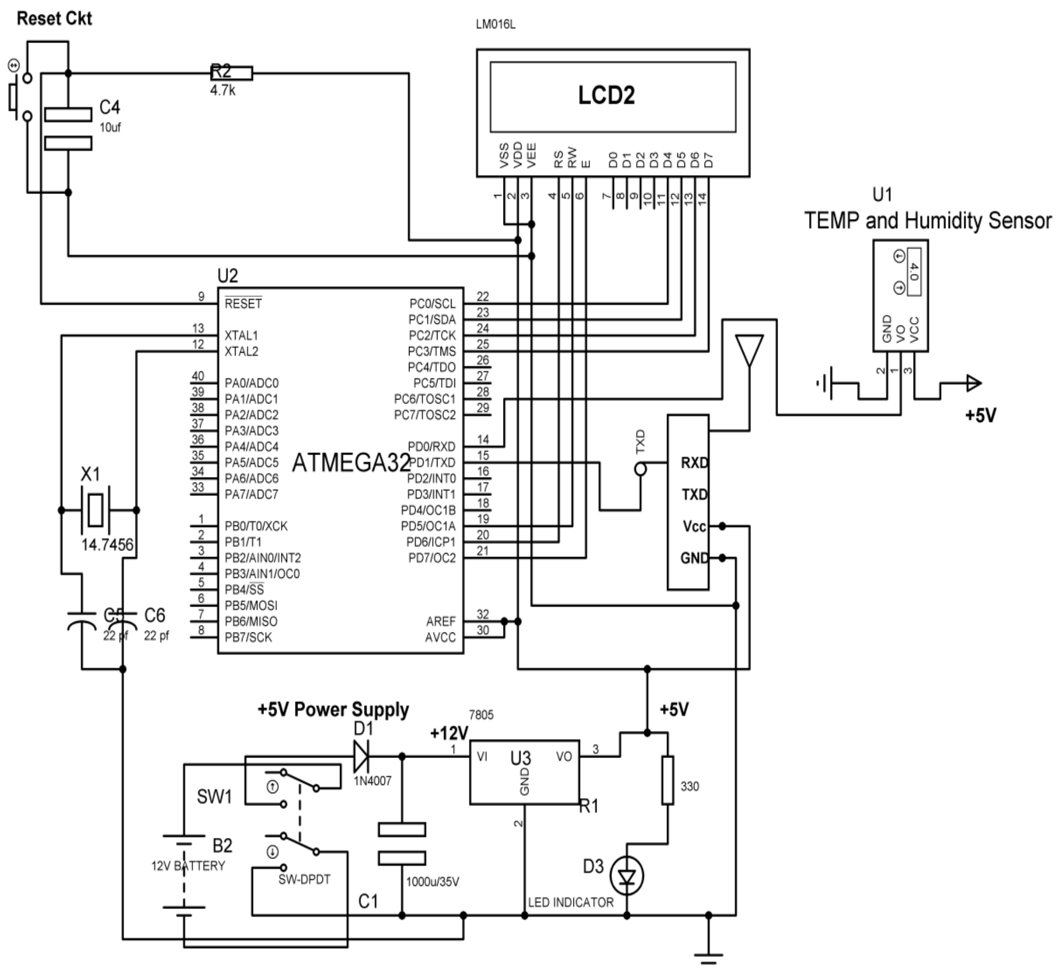

Fig.4.4. Circuit Diagram of node 4

Fig. 4.4 shows the circuit diagram of node 4 which consists of a humidity sensor and temperature sensor. Humidity sensor is used for measurement of humidity of soil. A 5 V power supply is used to deliver proper voltage in whole circuit. The outputs of both sensors are fed to the USART port of the microcontroller. A zigbee modem is used for providing the communication between other nodes. A 16*2 LCD is also used for displaying the readings of the sensors.

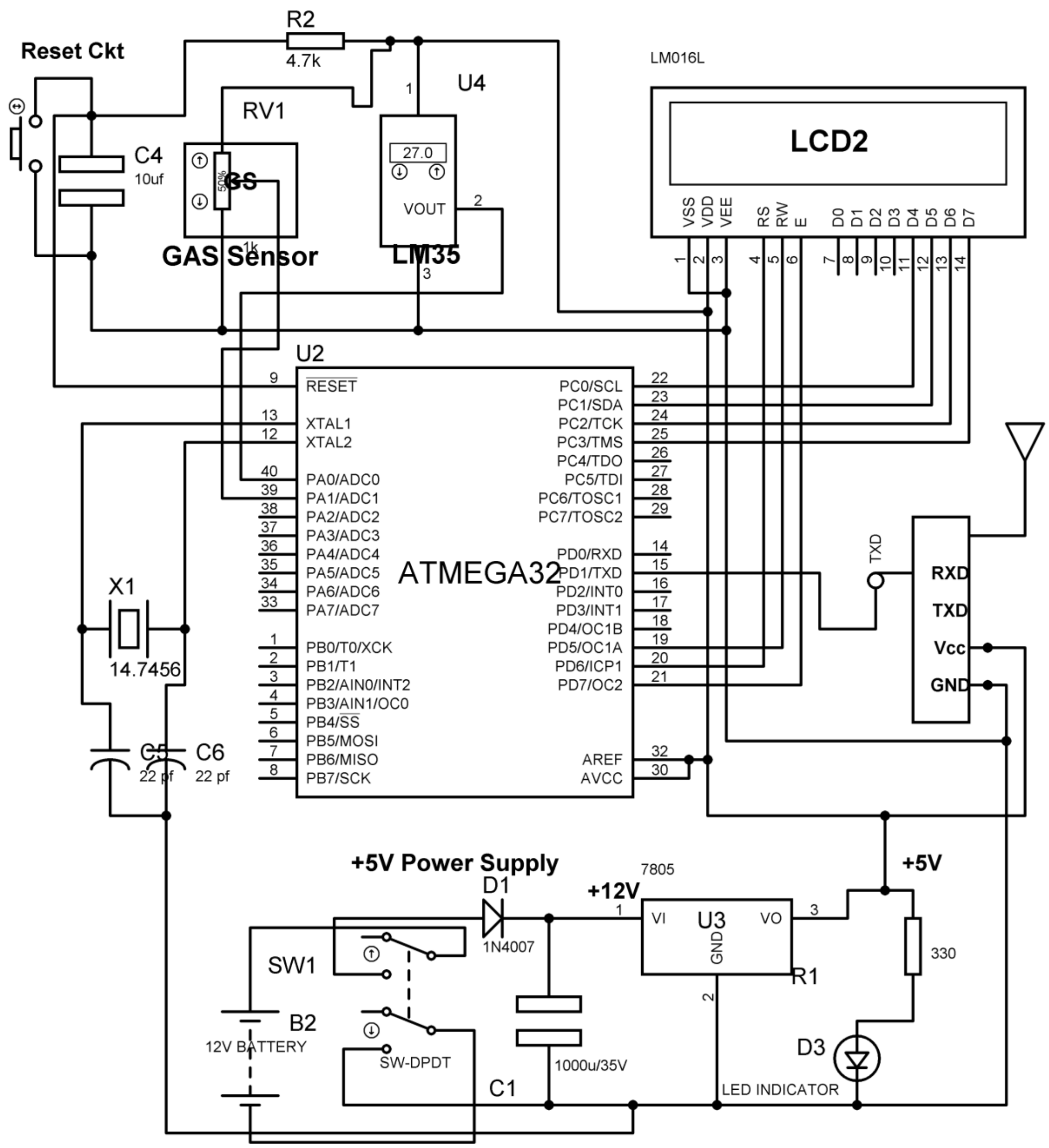

Fig.4.5. Circuit Diagram of node

Fig. 4.5 shows the circuit diagram of node 5 which consists of a gas sensor and temperature sensor. Gas sensor is used for measurement of hazardous gas in environment. A 5 V power supply is used to provide proper voltage in whole circuit.

The outputs of both sensors are fed to the ADC port of the microcontroller. A zigbee modem is used for providing the communication between other nodes. A 16*2 LCD is also used for displaying the readings of the sensors.

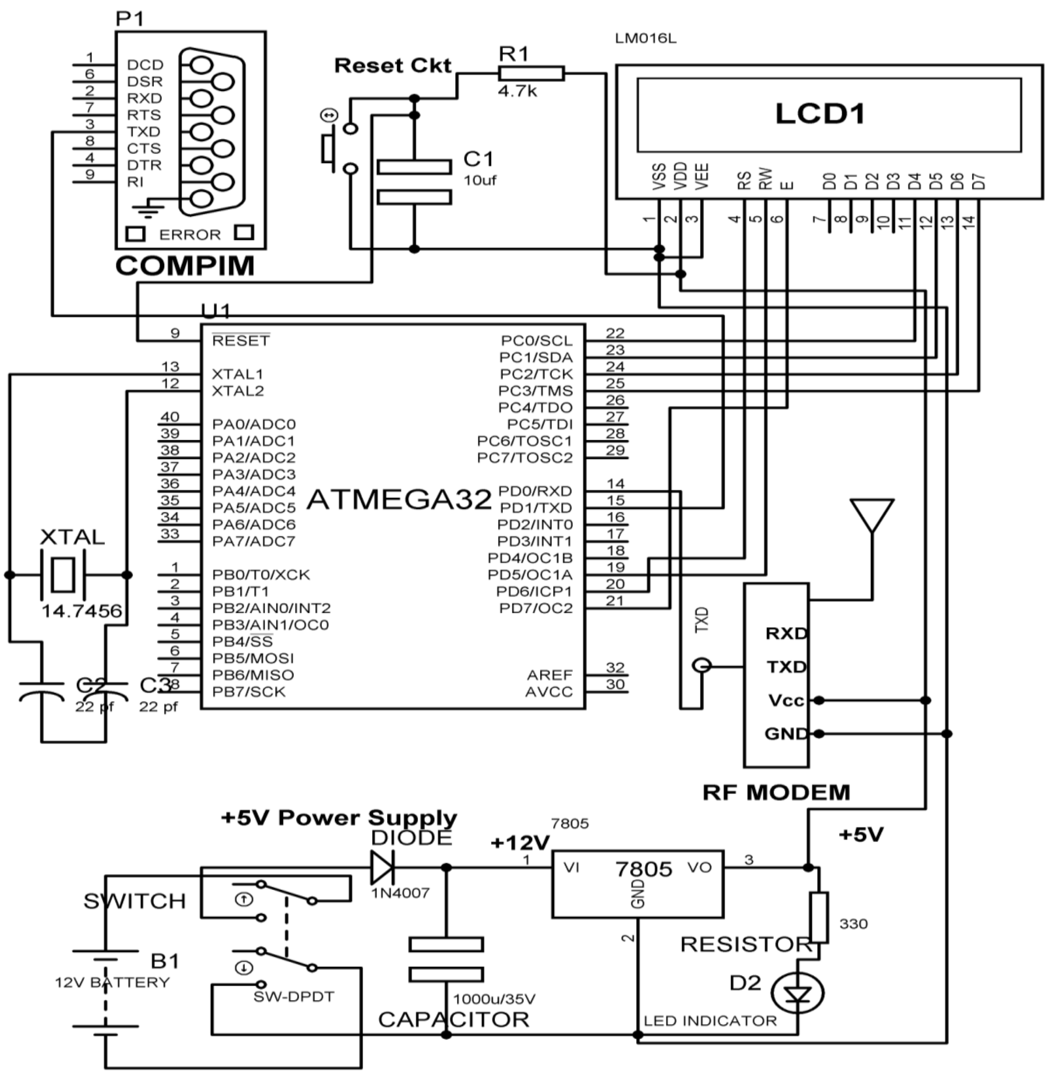

Fig.4.6. Circuit Diagram of data logger

Fig. 4.6 shows the circuit diagram of data logger. Data from this node is fed to the personal computer and from there it is transferred to the handheld device. The main function of this node is to collect data from other five individual nodes. Besides this a 16*2 LCD is used for displaying the collected data.

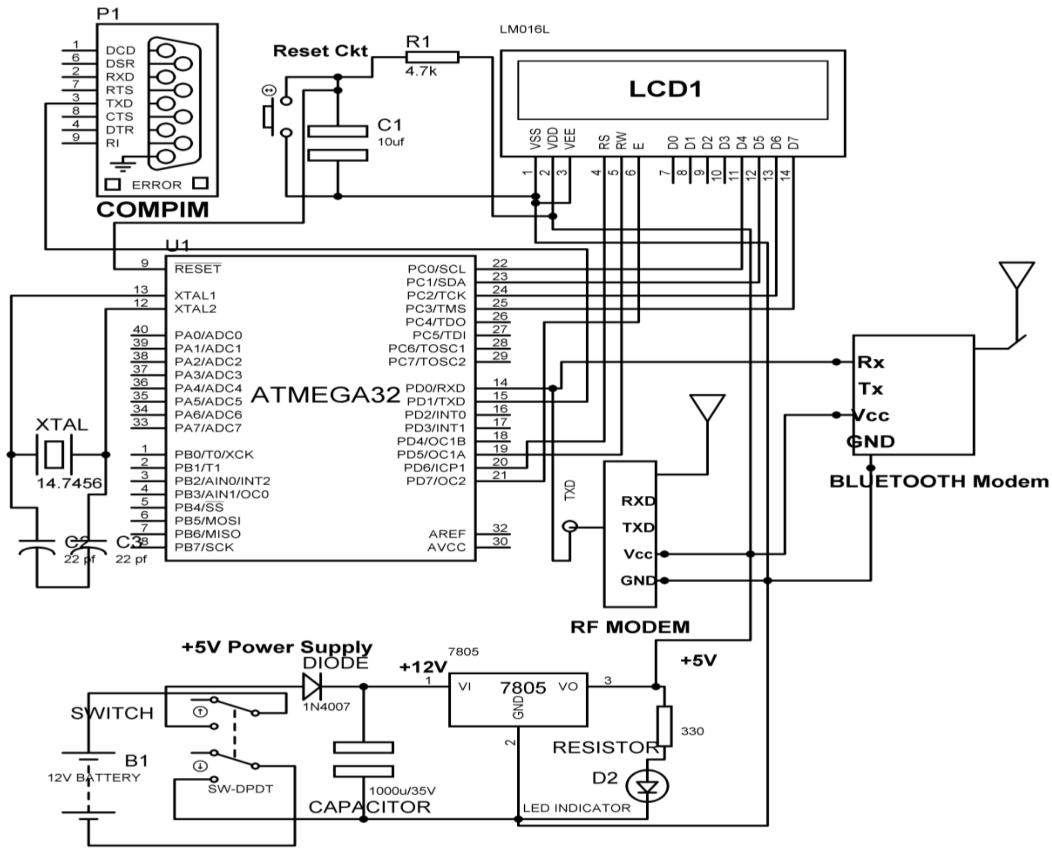

Fig.4.7. Circuit Diagram of handheld device

Fig. 4.7 shows the circuit diagram of handheld device which consists of a Bluetooth modem. The main function of this modem is to receive the data transferred from the data logger node. This node is at end user and easily provides the collected data to the end user. This node is connected with other nodes in mesh topology. A display is used for showing the measured data. On the basis of this data end user can easily take the decision.

4.2 PROTEUS SIMULATION MODEL

Simulation of the system has been done as shown in Fig.4.2 for each working part of the system, before its hardware implementation and real time deployment. Simulation is done by using Proteus software version 7.8 from lab center and feasibility is checked. It is easy to simulate each and every node in the proteus software before implementing in the real time. Basically the function of proteus software is to create virtual environment for any system consisting of electronic circuits. In order to do simulation and to determine the feasibility of the proposed system in real time, generated hex file is loaded in to the microcontroller virtually.

All the components such as LCD, gas sensor, humidity sensor, resistor and capacitor are picked from the component library included in the software itself. A virtual terminal is also used to provide communication between PC and the simulating software. A play and stop button is also given in the simulation environment so that at any desired time, simulation can be stopped or started. Robustness of the proposed system is also determined before implementing in real time environment so that it is easy to set the control parameters of the PSO algorithm.

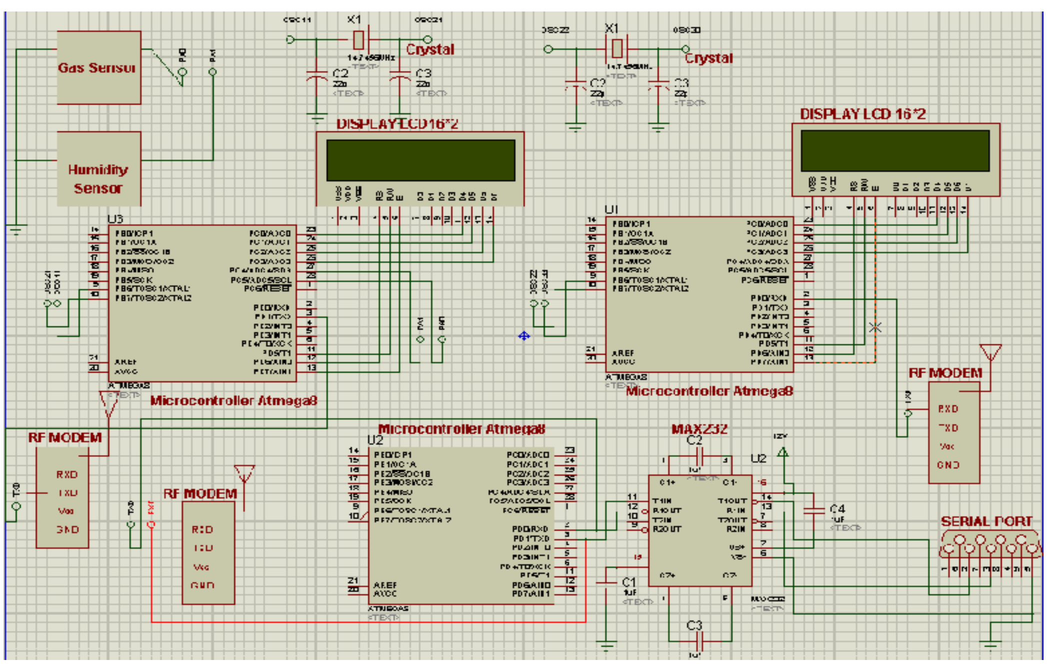

Fig.4.8 Proteus Simulation model for sensor nodes

4.3 COMPONENT DESCRIPTION

Table 4.1 gives brief description of the modules which are used to develop hardware for the system.

Table-4.1 Brief description of components used

S. N.	Device/Module	Make/ Model no.	Specifications and working
1.	Soil Moisture Sensor	Sunrom model no. 1282	It detects moisture value present in the soil.
2.	Gas Sensor	**S**unrom model no. 1105	Used in gas leakage detecting equipment for detecting of LPG, iso-butane, propane, LNG combustible gases.
3.	Temperature sensor	Sunrom model no.3001	LM35, Calibrated directly in Celsius (Centigrade), Linear + 10.0 mV/ C scale factor
4.	ZigBee	Sunroom model no. 1124	RF data modem working at 2.4 Ghz frequency. Receives and Transmits serial data of adjustable baud rate of 9600/4800/2400/19200 bps at 5V
5.	Bluetooth modem	Sunrom model no.1179	This module enables the wireless transmit & receive serial data. Bluetooth works on protocol-2.0, Range 10 meters, Frequency- 2.4 Ghz, ISM, Modulation-GFSK
6.	Power supply		This module is basically designed to achieve 5V/500mA
7.	Temperature/ humidity Sensor	Sunrom model no. 1211	Serial data output at 9600 baud rate. Relative Humidity from 1%-100% Temperature from +2 deg C to +60 deg C

4.4 CHAPTER SUMMARY

This Chapter accomplishes the setting up of basic component used and working circuit diagrams for the system.

CHAPTER-5

SOFTWARE DEVELOPMENT

In this thesis the placement of sensors is tackled keeping in mind both barren field and field with vegetation. The distance between each vegetation and types of vegetation are also considered. The agricultural management concept based on responding to inter and intra field variability in vegetation is called precision. To collect data from sensors, multiple wireless sensor nodes are deployed within the application area to create a multi-hop wireless sensor network (WSN).

The architecture of a wireless sensor node comprises of one or more transducers or sensor, a processing unit a communication unit and power source. WSN operates with low data rates.

In Wireless Sensor Networks (WSN), for maximizing the coverage area sensor node deployment is very important. But different optimization solution suffers from limited energy storage. So to solve this issue, a multi-objective PSO sensor node deployment is proposed. The objectives considered include maximizing network coverage, connectivity and network lifetime.

On the basis of simulation deployment of nodes is done. Each sensor node comprises of one or more sensors, a radio transceiver, a microcontroller and an energy source. The most effective approach of sensor deployment is to place sensors in such a manner that the maximal network coverage is achieved. The deployment process is done according to following constraints:

- number of sensors
- event detection probability
- Size of area

5.1 SOFTWARE DEVELOPMENT

Programming is done in Embedded ‘C’ language. The microcontroller has been programmed to test the hardware as well to achieve the goal of WSN application, which involved the following steps-coding/debugging, compiling, burning and evaluation.

This work is about the development of a handheld device for displaying optimized field data with network optimized wireless sensor network.

An embedded system had been developed for this purpose. The system is developed using AVR Atmega16. Therefore, AVR studio is employed as the IDE and firmware is developed in embedded C environment.

Along with the main programme the firmware comprises of various modules developed for specific tasks.

Following are the modules developed and used in the programme with proper sequence.

a) ReadADC(uint8_t ch) is used to read the Analog signal.

b) ADCcalibration(uint8_t) is used to calibrate the Humidity sensor

c) InitLCD is used to Initialize the LCD

d) LCDWChar is used to write characcter on LCD

e)USARTReadChar(uint16_t ubrr_value) and USARTWriteChar (uint16_t ubrr_value) for serial communication

f) Serial communication [ser_trans_zigbee(ubrr_value)]

g) dealy(_ms) is used for Delay Function

5.2 FLOW CHART FOR SYSTEM

The sensors attached to the system gives measured parameters to the main processing unit. Particle Swarm optimization algorithm is used to find the best position of the node with respect to other nodes and also optimize the position of nodes in the network.

Data is collected from each node and sent to the master node with the help of wireless communication. After that the information collected by master node is sent to the handheld device at end user. There is a display unit on the side of end user that clearly depicts the real time value of data measured by the sensors.

Fig. 5.1 shows the algorithm of the whole system.

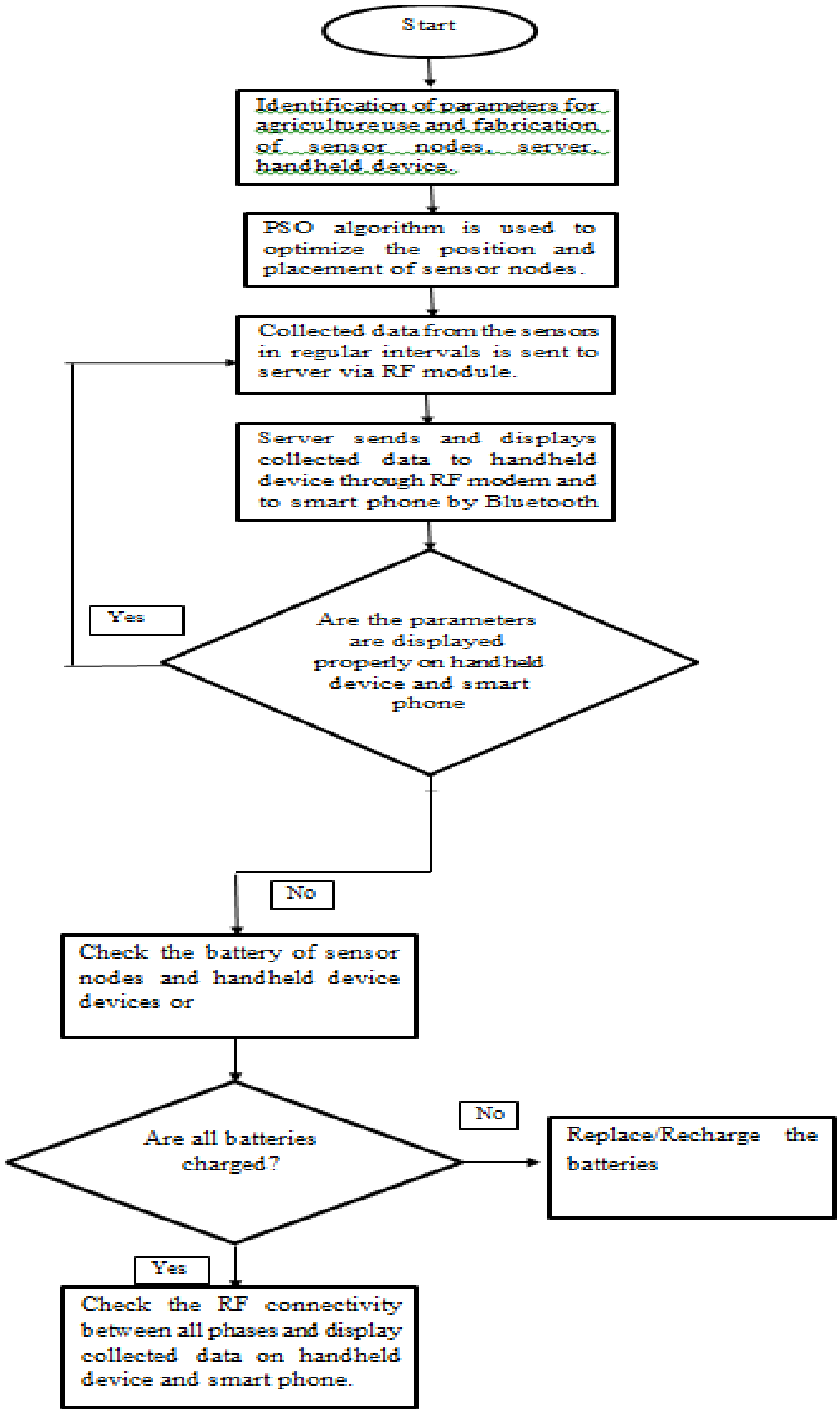

Fig.5.1 Flow chart for system

5.3 PROGRAMMING FLOW CHART FOR NODE1

Algorithm used in first node is being elucidated with the help of Fig. 5.2. In the first node temperature sensor is attached. This temperature sensor gives analog data to the controller existing in the node and microcontroller converts this analog value to digital form. An interrupt service routine is written. The function of which is to interrupt the current execution of process. It automatically sends the recorded data to the master node in short duration of time by determining the shortest path. PSO technique is utilized to optimize the communication path between the nodes and master node.

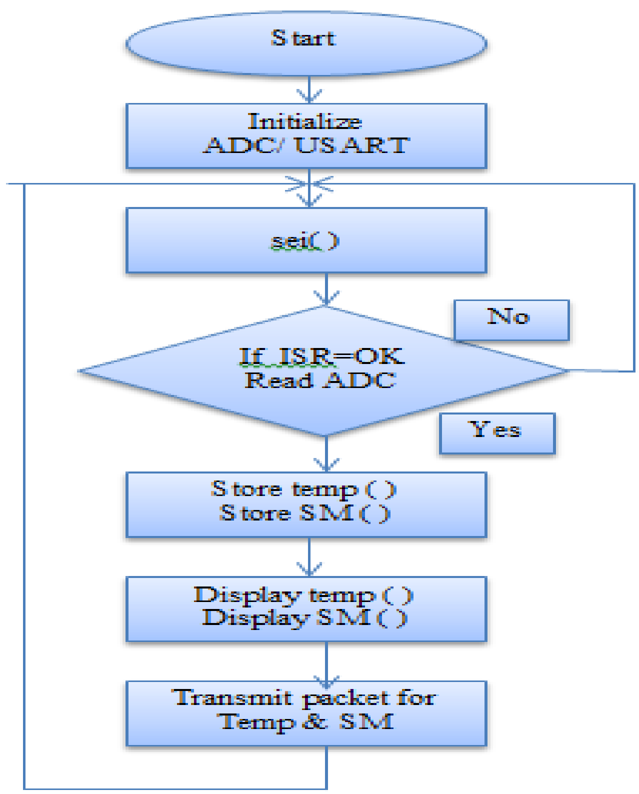

Fig.5.2 Programming Flow Chart for node1

5.4 PROGRAMMING FLOW CHART FOR NODE2

The algorithm used in node 2 is depicted in the Fig. 5.3. This node is a homogenous node. It is also composed of temperature sensor to measure the temperature of the surroundings. The data is read by the controller with the ADC pin. Interrupt service routine compare the data given by sensor and if it is above the threshold value then the process is executed as described in the subroutine. Data is displayed on the LCD screen at each individual node. After processing, this data is sent to the master node serially in small data packets through the ZigBee module wirelessly.

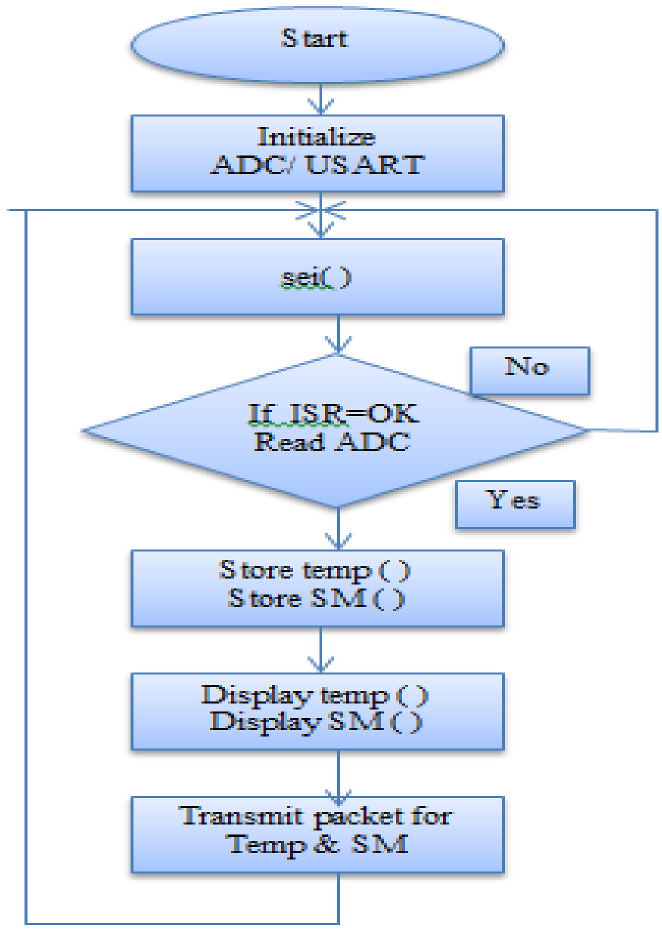

Fig.5.3 Programming Flow Chart for node2

5.5 PROGRAMMING FLOW CHART FOR NODE3

Node 3 is basically composed of temperature and gas sensor. Function of node 3 is shown with the help of Fig. 5.4. Here both analog to digital pins and USART pins are initialized. This initialization is done with the help of code written in the microcontroller. Data is depicted on the LCD screen attached and sent serially and wirelessly through the Zigbee module.

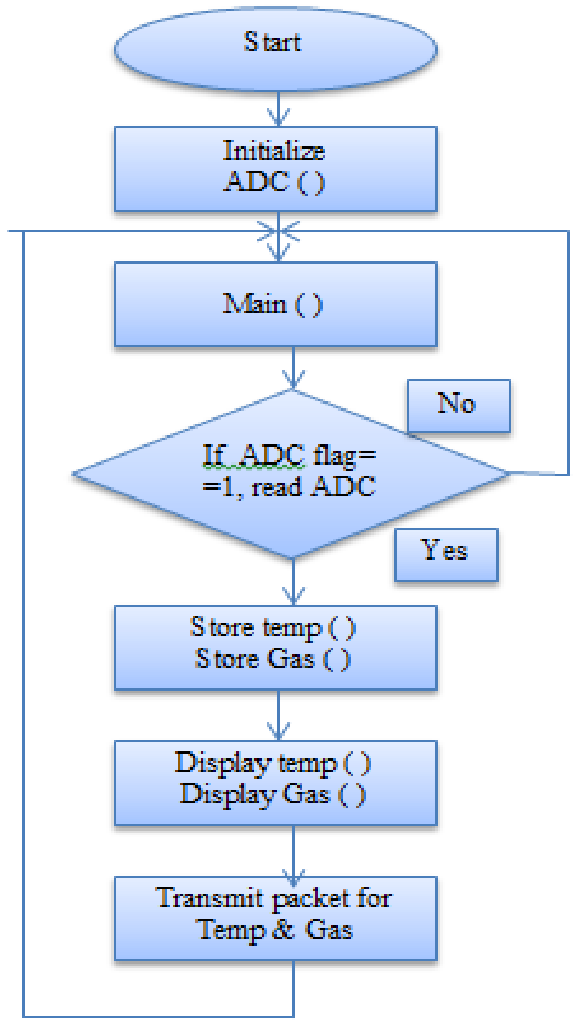

Fig.5.4 Programming Flow Chart for node3

5.6 PROGRAMMING FLOW CHART FOR NODE4

Node 4 is not equipped with any sensor. It is only equipped with wireless Zigbee module. Only function of this node is to provide the wireless communication channel between the other nodes. This node receives and sends data only. This node can be termed as communication node for convenience.

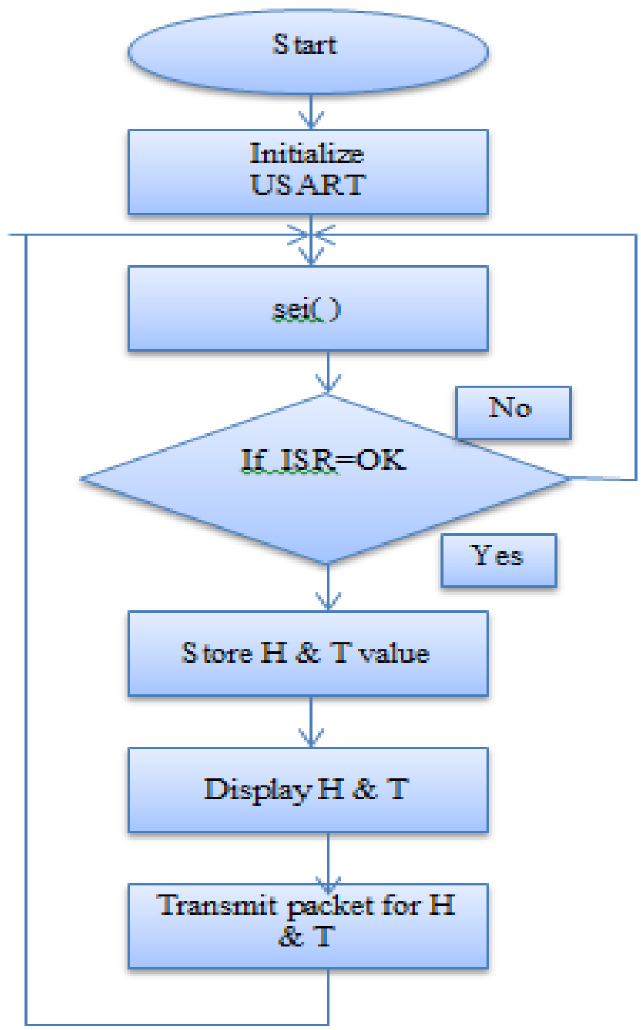

Fig.5.5 Programming Flow Chart for node4

5.7 PROGRAMMING FLOW CHART FOR NODE5

Node 5 is basically composed of distance and temperature sensor. Function of node 5 is being clearly depicted with the help of Fig. 5.6. In this node firstly the initialization of analog to digital pin and USART pin is done. The initialization process is done with the help of some instructions which is written in the microcontroller in hex code. Distance sensor is used to determine the distance between the consecutive nodes and value provided by it is optimized with the help of PSO technique.

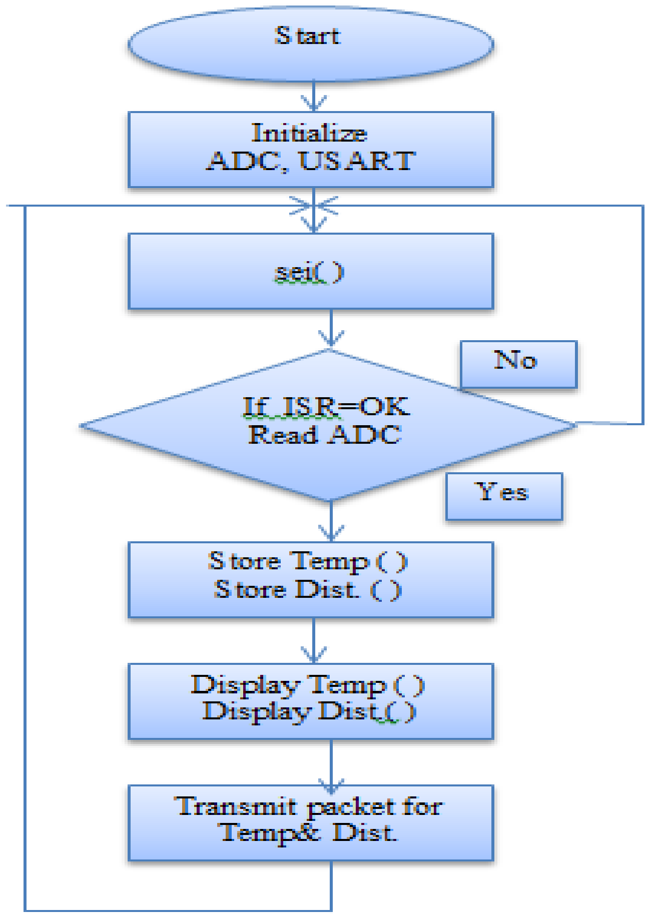

Fig.5.6 Programming Flow Chart for node5

5.8 INTERRUPT SUBROUTINE FOR SENSOR NODES

An interrupt service routine (ISR) is basically a software routine that hardware executes in response to an interrupt. ISR work in such a way that it examines an interrupt and governs how to handle it. ISRs handle the interrupt, and then yield a logical interrupt value. The working of interrupt service routine is being explained in Fig 5.7.

If the size of data packet received and size of prestored data packet is same then the corresponding interrupt will be executed which is written in the service routine. After that there is increment in data packet. This increment will give some new value in return which is used in coding by the user. After that to repeat this process while loop is used.

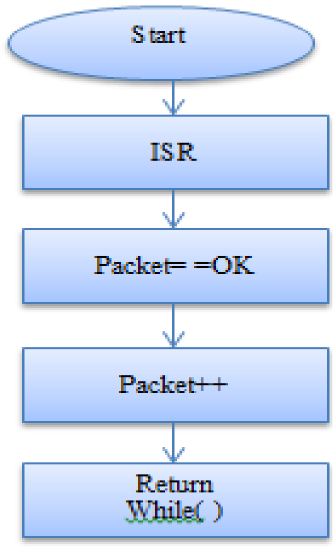

Fig.5.7 Programming Flow Chart for ISR for sensor nodes

5.9 PROGRAMMING FLOW CHART FOR HANDHELD DEVICE

Fig. 5.8 describes the architecture of the handheld device at the side of end user. Handheld device is also composed of wireless module and receives the collected data from all the nodes existing in the system. First step is to initialize the USART communication and after that interrupt service routine checks the interrupt and executes the interrupt according to priority. Here address of each node is different since the data is being transmitted serially. The bifurcation of address is done on the basis of the type of byte that is assigned to the individual nodes. Each individual node has its own priority of interrupt. Interrupt Service Routine starts as soon as the signal is received from the individual nodes. After that it will check the buffer of each and every interrupt. If the value of buffer obtained and prestored value in the system is matched then that buffer will be incremented and controller will keep the track of received data. The whole communication is done serially.

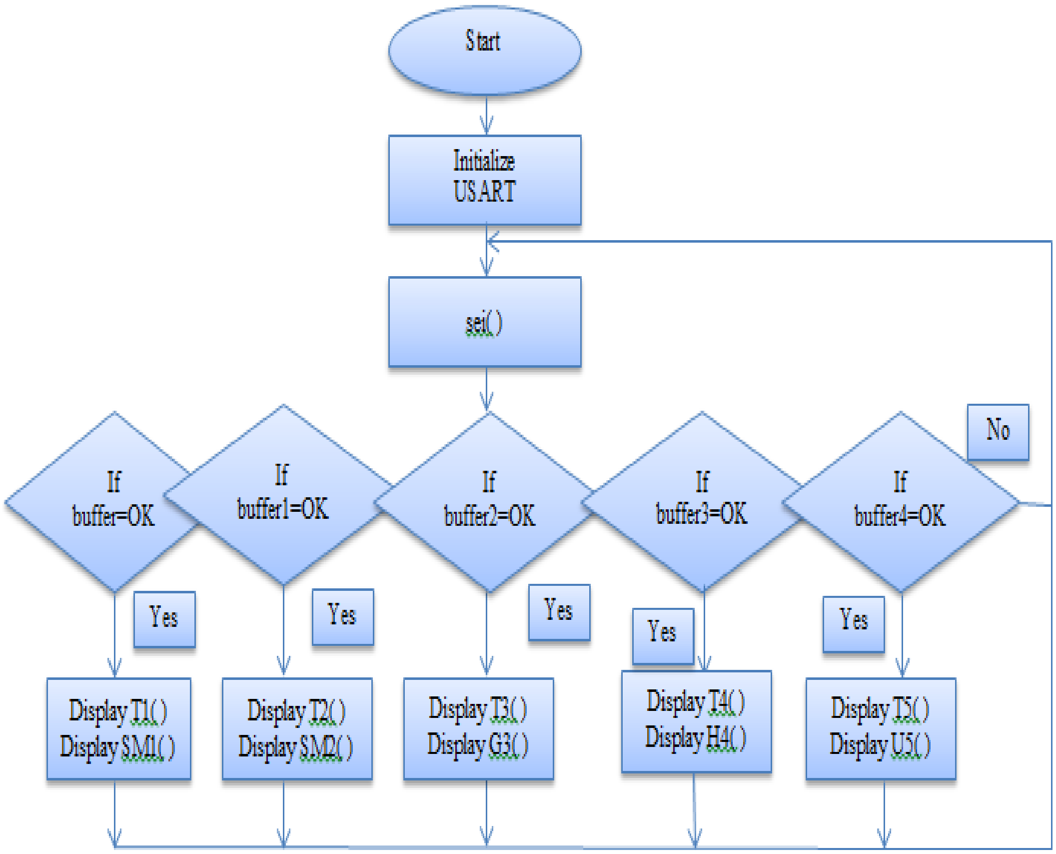

Fig.5.8 Programming Flow Chart for Handheld device

5.10 PROGRAMMING FLOW CHART FOR SERVER

A communication server is a dedicated system that provides communication services for users on a network who need to transfer files or access information on systems or networks at remote locations over telecommunication links. The communication server provides communication channels for one or more users simultaneously, depending on the software and the hardware capabilities.

The architecture of the server is shown in the Fig.5.9. Basically server assists the purpose of gateway and modem function simultaneously. Gateway function is used to provide users with connections to host computers by translating between data formats, communication protocols, and cable signals. Modem is used to provide the internal users access for dial-out sessions or remote users access for dial-in sessions. The main function of server is to keep the record of all the data collected by individual nodes. It also keeps the track of the communication and data fetched by the node. Each discrete node has its own identity and this identity is defined at the convenience of the node. So there is no chance for the interferance of data from neighbouring nodes.

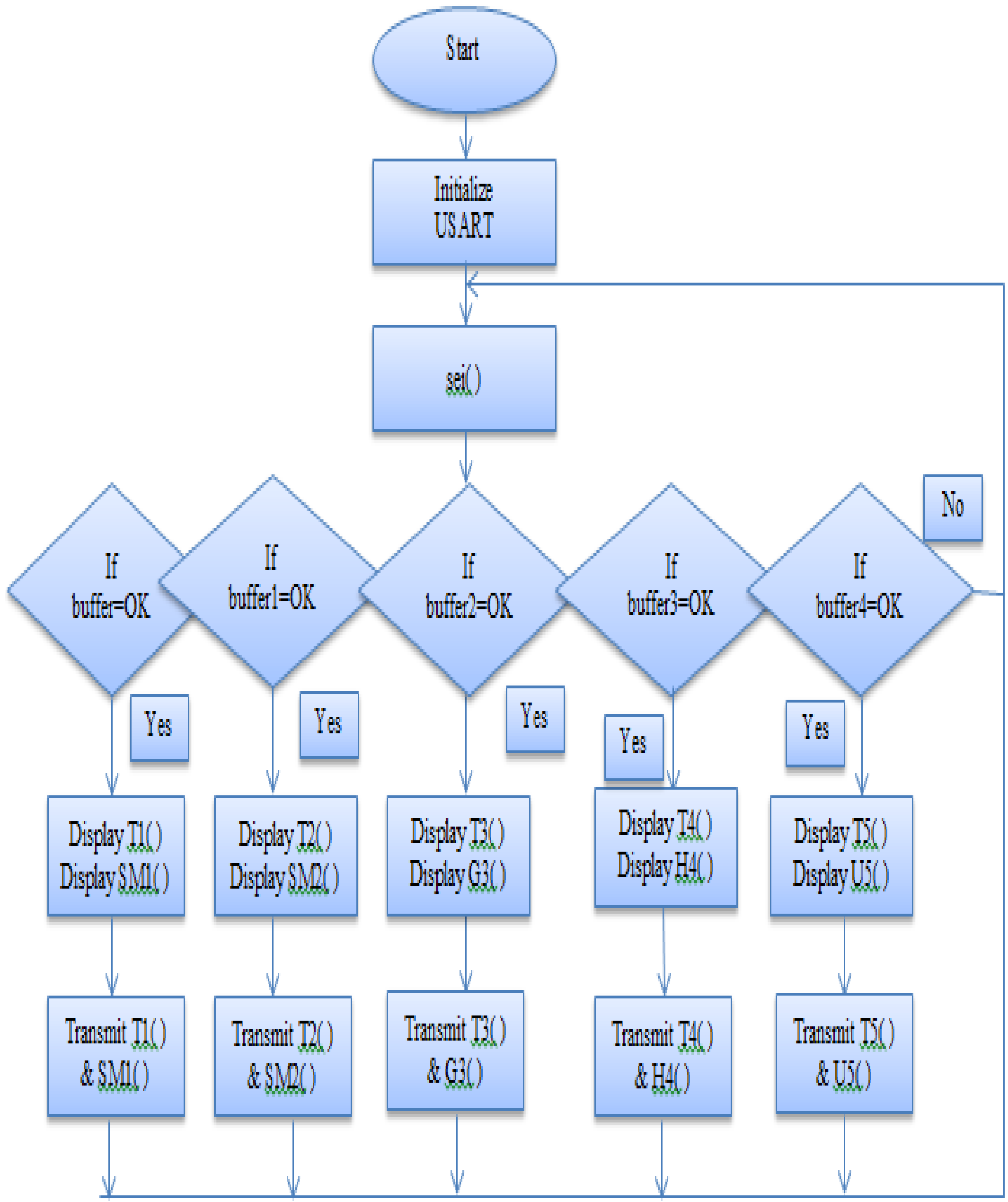

Fig.5.9 Programming Flow Chart for Server

On server side the differentiation of identity of each node is done with the help of Zigbee module. Here service interrupt routine checks the identity of the individual nodes and according to the routine and priority , it communicates with the node.

Data gathered by each wireless sensor node is diplayed on a display unit attached with the server. Each and every individual node communicates its data first to the server and then the server provide this data to the handheld device at the end user. Once the microcontroller of base station gets the receiving nodes information from the ZigBee module through UART interface, The MCU processes the information received from receiving nodes and sends that information to the LCD module. The LCD will display the received sensor readings. The MCU also uploads the processed sensor information of each end node to the Ethernet controller which sends this data to the host computer as a UDP packet

5.11 INTERRUPT SUBROUTINE FOR SERVER AND HANDHELD DEVICE

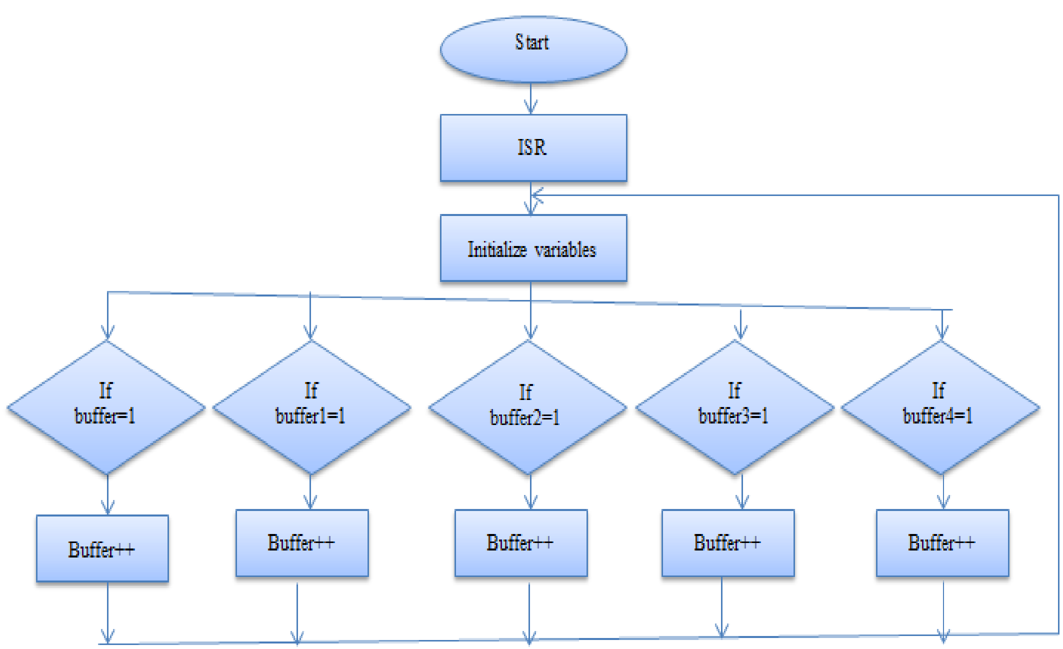

Fig.5.10 Programming Flow Chart for ISR for server and handheld device

Interrupt Service Routine (ISR) is used for interrupt handling. Interrupt latency is defined as the time delay between the occurrence of an interrupt and the running of the corresponding Interrupt Service Routine (ISR). The execution of interrupt on the priority basis is being depicted clearly in Fig. 5.10.

Each individual node has its own priority of interrupt. Interrupt Service Routine starts as soon as the signal is recievd form the individual nodes. After that it will check the buffer of each and every interrupt. If the value of buffer and pre stored value in the system are matched then that buffer will be incremented and the system will keep track of recived data. The whole communication is done serially.

5.12 PACKET FORMAT

NODE1

0x0A (1byte)	NODE ID (1byte)	Data bytes (3bytes)	0x0a (1byte)

NODE2

0x0B (1byte)	NODE ID (1byte)	Data bytes (3bytes)	0x0b (1byte)

NODE3

0x0C (1byte)	NODE ID (1byte)	Data bytes (3bytes)	0x0c (1byte)

NODE4

0x0D (1byte)	NODE ID (1byte)	Data bytes (3bytes)	0x0d (1byte)

NODE5

0x0E (1byte)	NODE ID (1byte)	Data bytes (3bytes)	0x0e (1byte)

5.13 DEPLOYMENT OF SENSORS IN THE FIELD WITH PSO ALGORITHM

Deployment of sensor nodes in the field can be done with the help of several optimization algorithms like PSO, ACO, GA etc. however PSO has been selected for the following advantages [72].

1. PSO is useful equally either in scientific research or engineering use.
2. In PSO search is carried out with the help of speed of the particle.
3. In PSO calculation is very simple and it inhabits the better optimization capability and it can be accomplished simply.
4. PSO accepts the real amount code, and it is decided straight by the result.

Particle Swarm Optimization Algorithm is used to find out the location to deploy the sensor node. The PSO algorithm is as follows [74]-

1. For parameters initialization the every particle is given a random position and velocity.
2. Initialize the number of the sensor node particles, maximum number of iterations
3. Set the position of the initial sensor node
4. Allocating the dynamic value for calculating gbest
5. Define the objective function
6. Set the position of the particles
7. Set initial velocity for particles
8. Evaluate the function using the position of the particle
9. Compare the function values to find the best ones
10. Update best position with the velocity
11. Get the updated position
12. Update the best value so far for network as global best value

13. update the velocity of the particles

For The optimization of parameters the following equation has been used .

n = 60;   % Size of the swarm " no of birds "

B_setp=60;   % Maximum number of "birds steps"

dimension= 2;   % Dimension of the problem

inertia=1.0

correction factor=2

fitness=0*ones(n, bird_setp);

Using the developed model, the Wireless Sensor Node is designed and implemented. The PSO algorithm has achieved the optimal solution for the field being covered by the sensors in the WSN.

5.13.1 DEPLOYMENT OF SENSOR NODES WITHOUT CONSIDERING VEGETATION IN FIELD

Objective Function- = @(x)(x(:,1)).^2 + (x(:,2)).^2;[74]

Fig.5.11 depicts the command window for writing the command in order to get desired output. In this some instruction are used for defining the velocity of particle, bird step and dimension of the swarm.

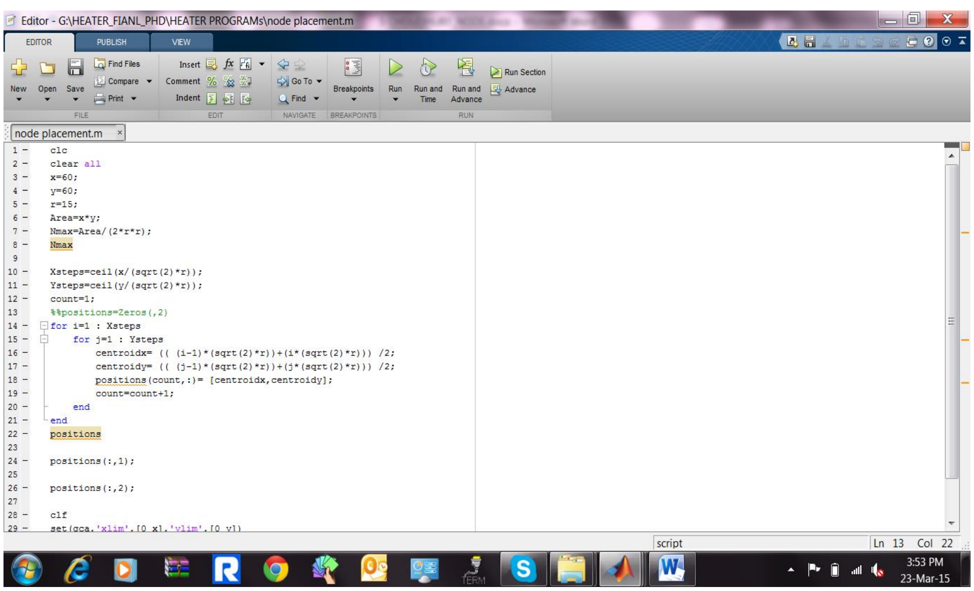

Fig.5.11 Programming window for MATLAB

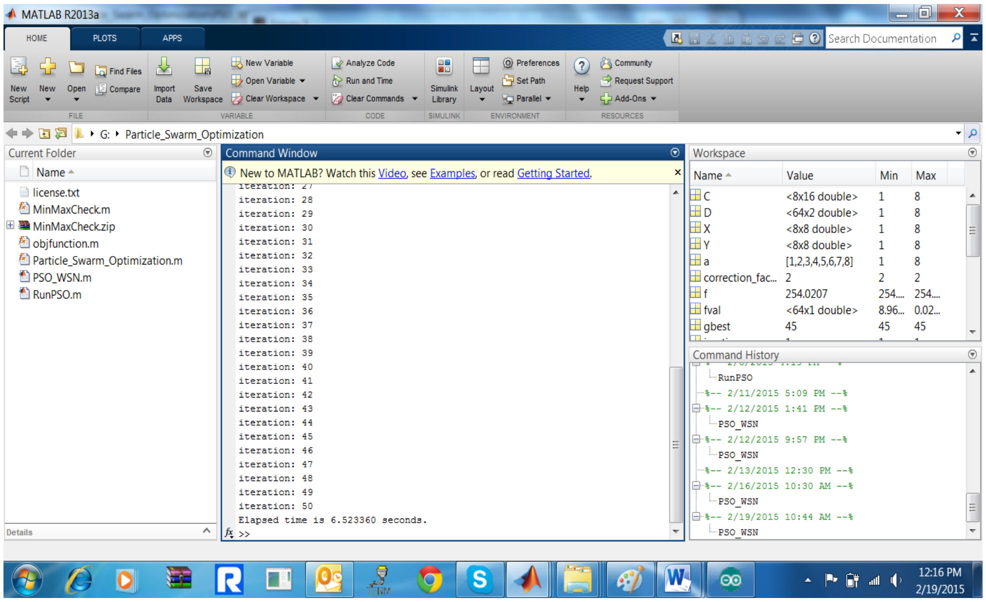

Fig.5.12- Elapsed time for 50 iterations

Fig. 5.12 shows the time taken by whole swarm in order to get minimum optimum solution. Here the elapsed time is 6.523360 seconds between each iteration. Total 50 iterations were done for determining the best position of the nodes.

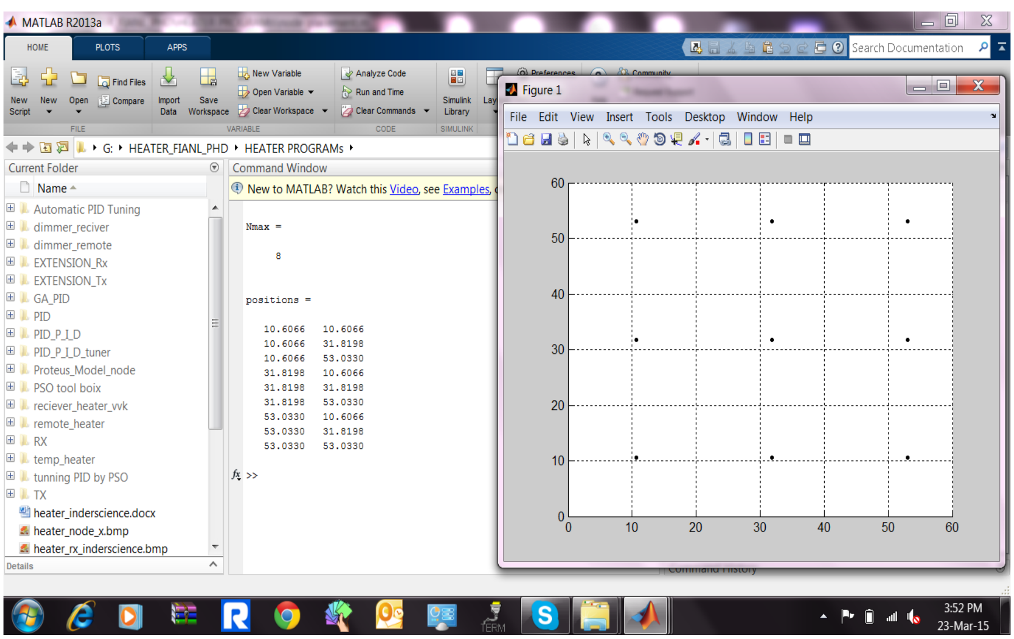

Fig. 5.13 Deployment of sensor nodes in the defined area

Optimal placement of nodes is described in Fig. 5.13. Area for the placement of nodes is divided in the form of grid at the interval of 10. After executing the code optimized placement of node is easily obtained.

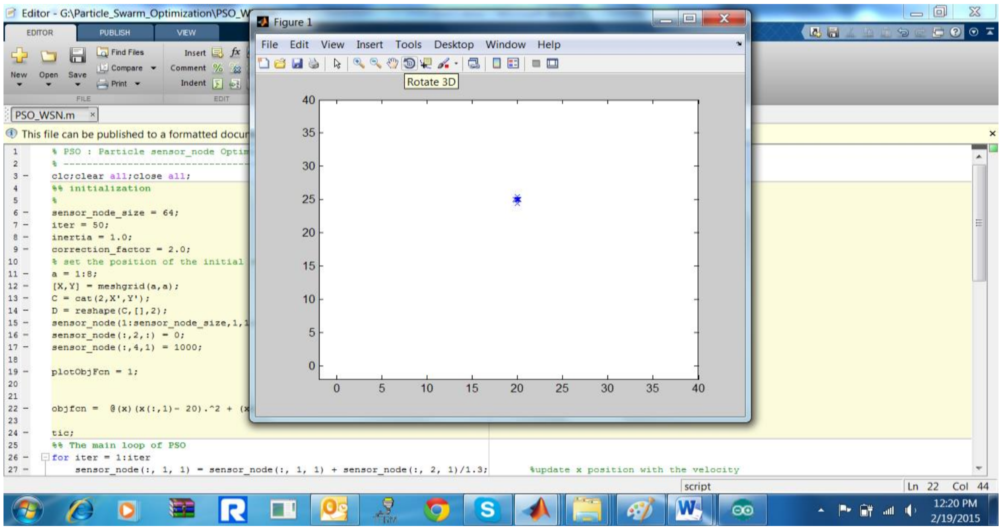

Fig.5.14 Centroid node position for model

Placement of single node is initially shown in Fig.5.14. This initial position is calculated with the help of reference of value obtained from ultrasonic sensor, initial position is decided. This centroid will help to determine better positon for the placement of node.

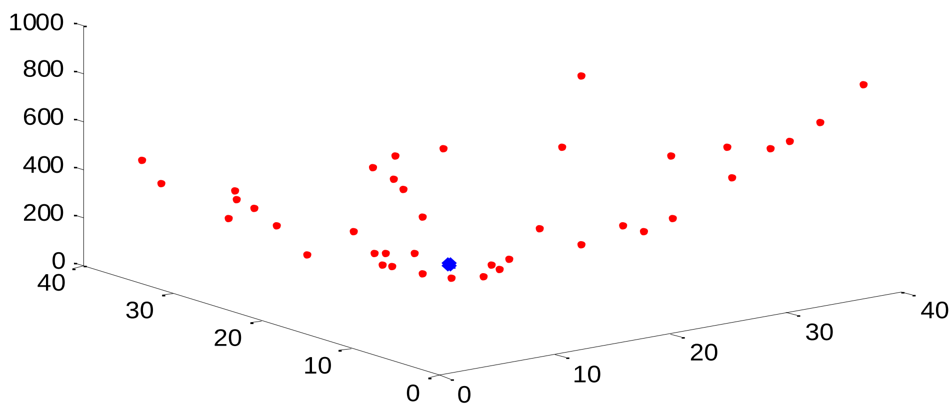

Fig.5.15- Deployment of forty sensor nodes in the defined area without vegetation

In order to determine the optimum node position within a 110m by 110m area MATLAB simulation is used as shown in Fig.5.15. It also shows the placement of node in terms of without vegetation. Without vegetation scattering of signal is very less. Due to less scattering of signals the communication gap between the nodes is very less.

5.13.2 DEPLOYMENT OF SENSOR NODES WITH VEGETATION IN FIELD

Objective Function- = @(x)(x(:,1)- 20).^2 + (x(:,2) -25).^2;

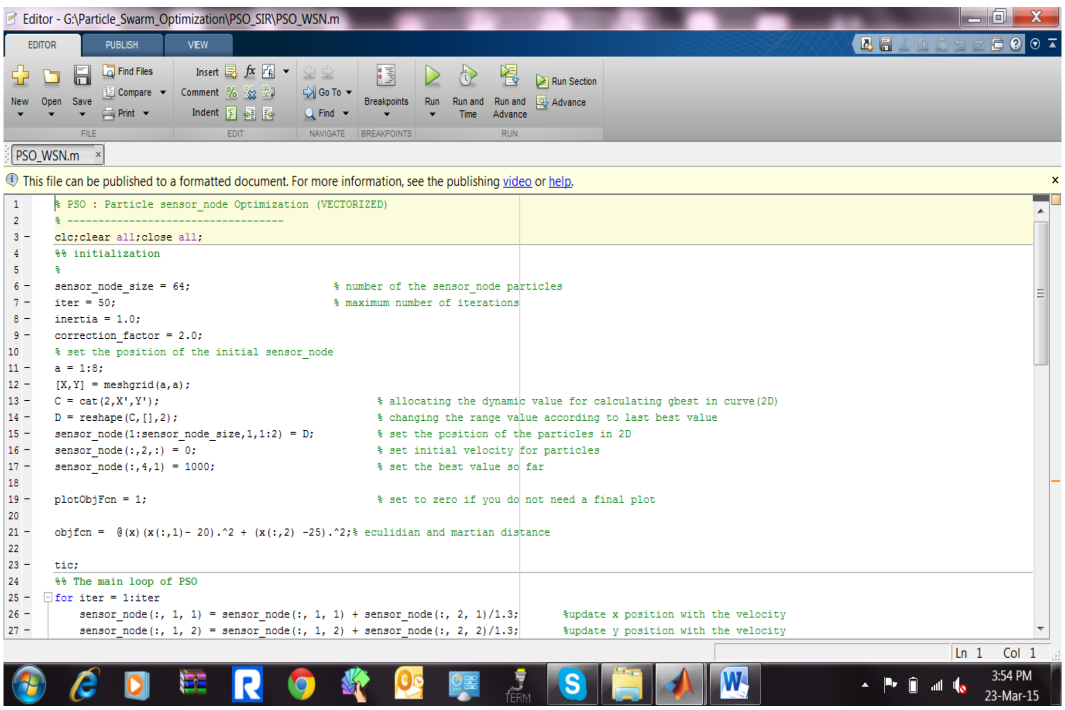

Fig.5.16 Objective function defined for deployment of sensor nodes with vegetation in field

Fig. 5.16 depicts the editor window of MATLAB. In this window a code is written in which particle swarm optimization technique is used for the optimization of placement of nodes. Control factors are used to decide the optimization.

Dynamic values are also allocated for calculating gbest and pbest. Position of each particle is also fixed in this code. After optimization new values are allocated to the particle. And thus various iterations are performed to determine the best position for the placement of node in the specified area. Initially position of sensor node is also being fixed in this editor window and after iterations on the basis of value of gbest and pbest, placement of nodes existing in the network is done very accurately and precisely.

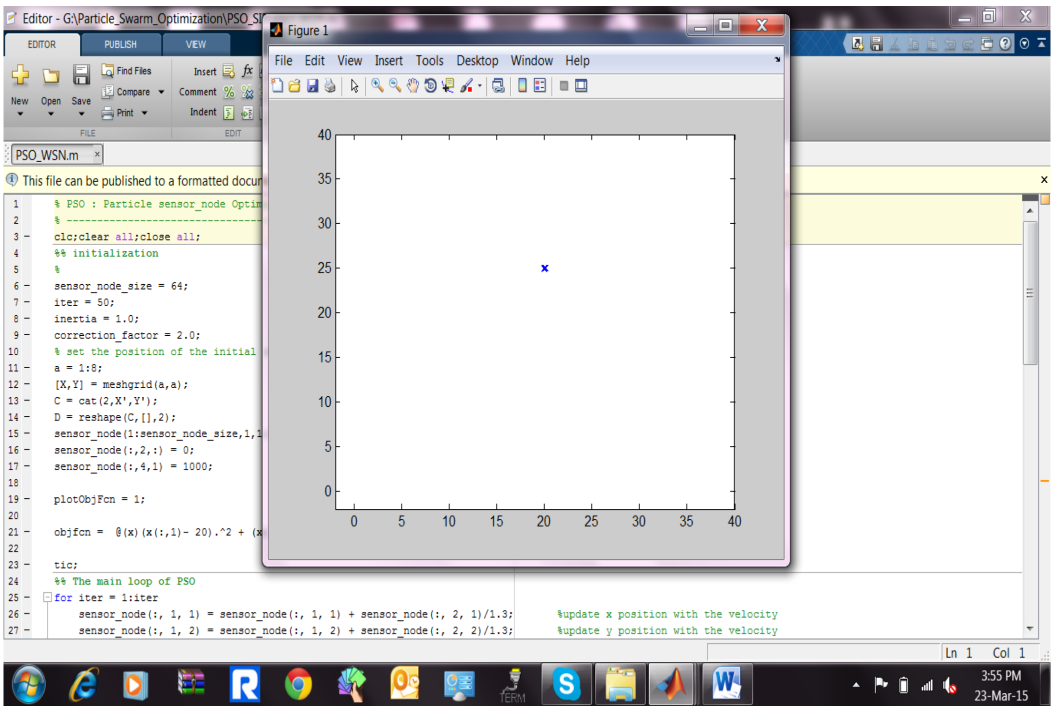

Fig.5.17 Centroid node position for model

Initial placement of single node is shown in Fig.5.17. By taking the reference of value obtained from ultrasonic sensor, initial position is decided . In specified area, first step is to fix the centroid of the node. This centroid will help to determine better positon for the placement of node. Other nodes will be centered on this node and with the help of ultrasonic sensor attached with each individual node, distance between two adjacent nodes will be determined very accurately. The value obtained will be optimized by utilizing the PSO technique.

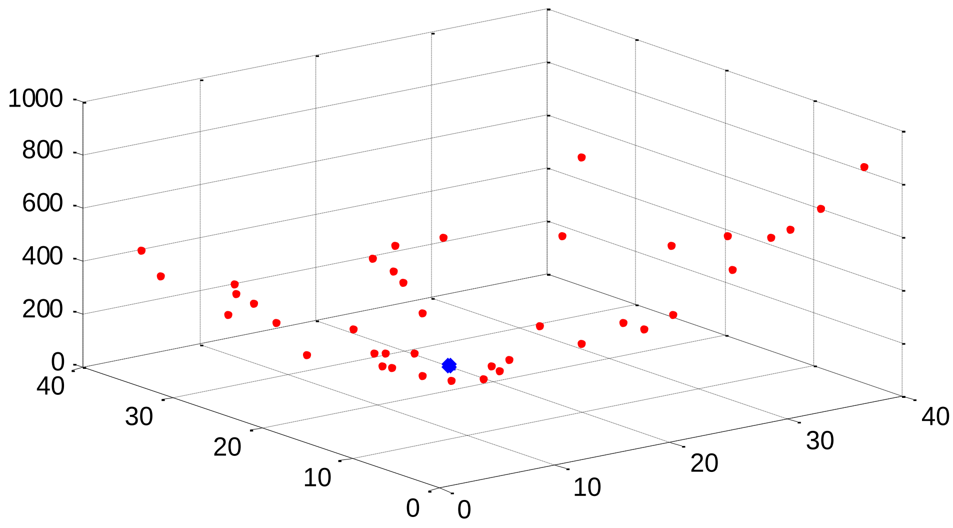

Fig.5.18- Deployment of forty sensor nodes in the defined area with vegetation

A MATLAB simulation is done to determine the optimum node position within a 110m by 110m area in Fig.5.18. It also shows the placement of nodes considering the general vegetation in to account. During vegetation the length of crops increases and due to this, scattering of signal increases. Scattering of signals will lead to the communication gap between the nodes and thus there will be no accuracy in the data transmitted between the nodes. For the proper placement of wireless sensor nodes few experiments were conducted for depicting a uniform placement of sensor nodes around area [73].

Experiment-1

In Fig.5.19, Deployment of sensor nodes in the defined area with vegetation 1 is shown[64][73] . The Nodes positions are such as to ensure maximum coverage. The plant 1 is placed 15m apart. Result shows that there are ten scatterers presented in green color around each individual plant. These are Gaussianly distributed around each plant. Blue squares represent the initial position of sensor node at an approximate distance of 5 m from the plant position. For the maximum coverage area the initial position of next node is kept along the y-axis. By this method the strength of power received by each node due to scatterers with respect to the initial node is determined [64][73]. Calculation of the distance of the next node is done on the basis of strength of power signal. If the obtained value is greater than threshold value then the position of node is correct and if it is smaller than threshold value then the node position should be recalculated or must be shifted closer to initial node at a distance of 1m. This process is kept on repeating until maximum coverage is obtained within the area of application. The following graph will illustrate the above .

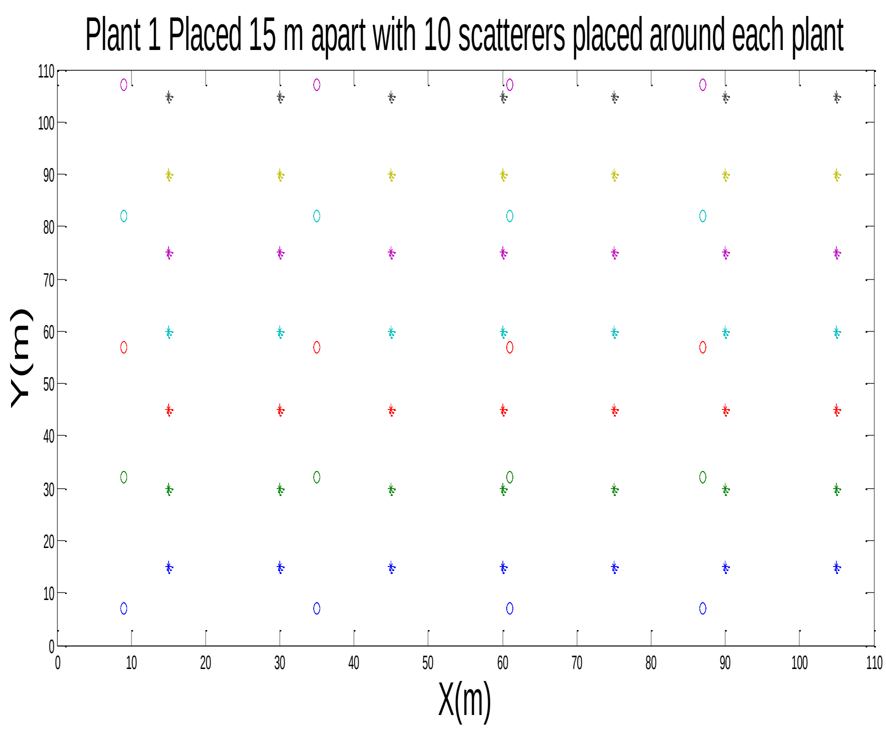

Fig.5.19- Deployment of sensor nodes in the defined area with vegetation 1

Experiment-2

In Fig.5.20, Deployment of sensor nodes in the defined area with vegetation 2 is shown [64]. The nodes positions are such that to ensure maximum coverage same as in experiment 1. The plant 1 is placed 15m apart. Blue Square represents the position of initial node as in experiment 1. For the maximum coverage area the initial position of the next node is kept along the y-axis.

Calculation of the distance of the next node is done on the basis of the strength of the power signal. If the obtained value is greater than threshold value then the position of node is correct and if it is smaller than threshold value then the node position should be recalculated or must be shifted closer to initial node. If there is problem in receiving proper power signal then an extra node is placed at the distance of maximum range from the transmitter node. The main function of this extra node is only to provide the communication between the next sensor nodes as per the specifications given by the algorithm. The scattering effect produced by foliage also results in a different placement of sensor nodes as compared with the placement of sensor under free space conditions.

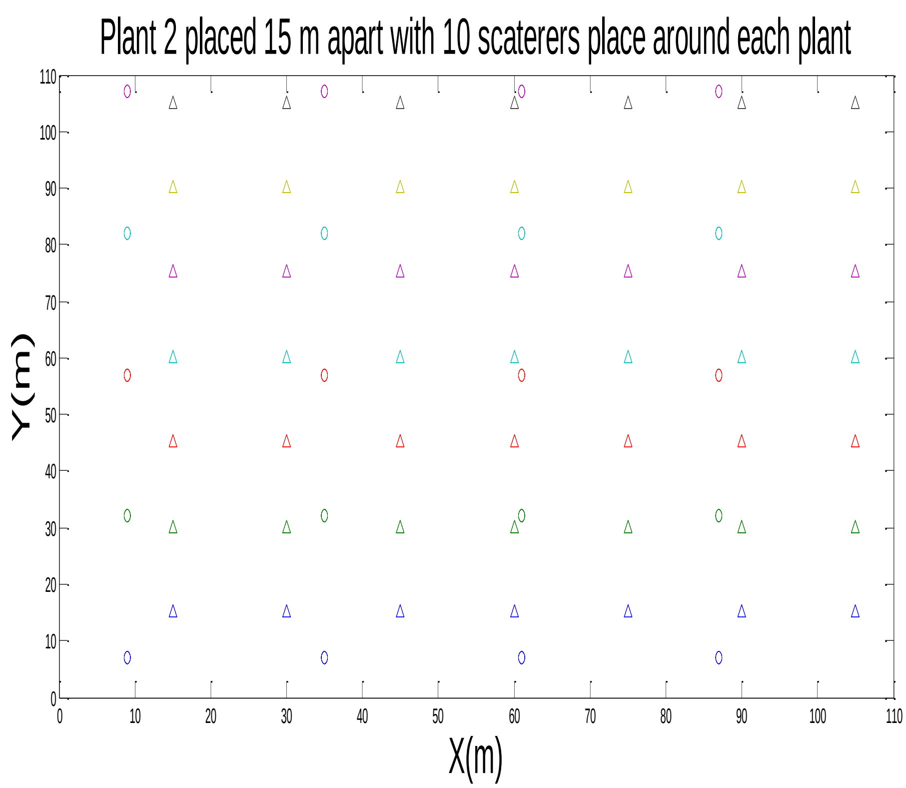

Fig.5.20- Deployment of sensor nodes in the defined area with vegetation 2

Experiment-3

In Fig.5.20, Deployment of sensor nodes in the defined area with vegetation 2 is shown [64]. The node position are such that to ensure maximum coverage.

The plant 1 is placed 18m apart. Blue Square represents the position of initial node as in experiment 1 and 2. For the maximum coverage area the initial position of next node is kept along the y-axis. The Calculation of the distance of the next node is done on the basis of the strength of power signal.

If the obtained value is greater than threshold value then the position of node is correct and if it is smaller than threshold value then the node position should be recalculated or must be shifted closer to initial node. If there is problem in receiving proper power signal then an extra node is placed at the distance of maximum range from the transmitter node.

The main function of this extra node is only to provide the communication between the next sensor nodes as per the specifications given by the algorithm. The scattering effect produced by foliage also results in a different placement of sensor nodes as compared with the placement of sensor under free space conditions.

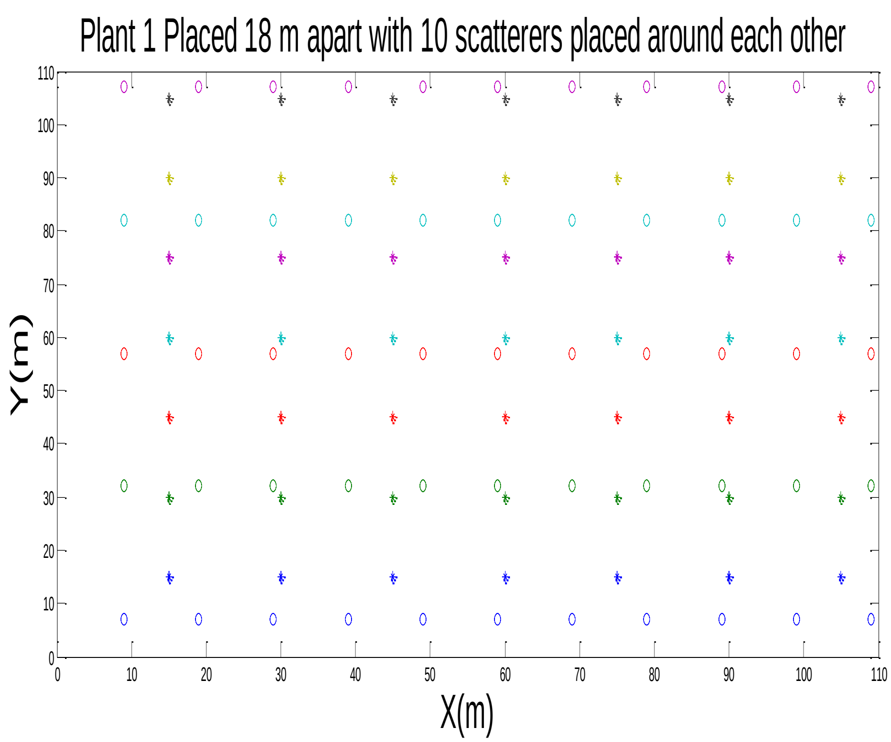

Fig.5.21- Deployment of sensor nodes in the defined area with vegetation 1 with different distance

5.14 CHAPTER SUMMARY

This chapter describes the software development for all the sensor nodes used in the thesis. Detailed block diagram & flow chart are used to explain the development of various nodes server and handheld device.

Chapter also describes the software development for optimum placement of sensor node in an agriculture field without vegetation & with vegetation was considered & optimum placement was done. Different types vegetables were considered for analysis & subsequent optimum placement of nodes in those conditions were found.

CHAPTER-6

RESULTS AND DISCUSSION

Sensor calibration is an important step, before actual implementation of sensor in the system. For the developed system each sensor is first calibrated with standard instruments and after checking its accuracy, sensors are used in the system.

For calibrating soil moisture sensor, oven method is used. For temperature/humidity sensor calibration, Psychrometric is used. Ultrasonic sensor is calibrated with standard measurement ruler.

6.1.1 SOIL MOISTURE SENSOR

Soil moisture sensor is taken from Sunrom model no. 1282. The sensor gives reading in terms of numeric values. This measures moisture on the basis of volumetric water content present in the soil. On the other hand standard oven method to find out the soil moisture gives readings in terms of percentage. First of all the readings of sensor with standard method is mapped. Then different samples are taken for experiment and results are shown in terms of tables and graph charts. Results show that the sensors are calibrated accurately.

Table-6.1 Calibration of soil moisture sensor with standard method

Soil Moisture reading	Standard value (%) (Oven method)
0	0.39
10	3.9
20	7.8
30	11.7
40	15.6
50	19.5
60	23.4
70	27.3
80	31.2
90	35.1
100	39

120	46.8
150	58.5
200	78
250	97.5
255	100

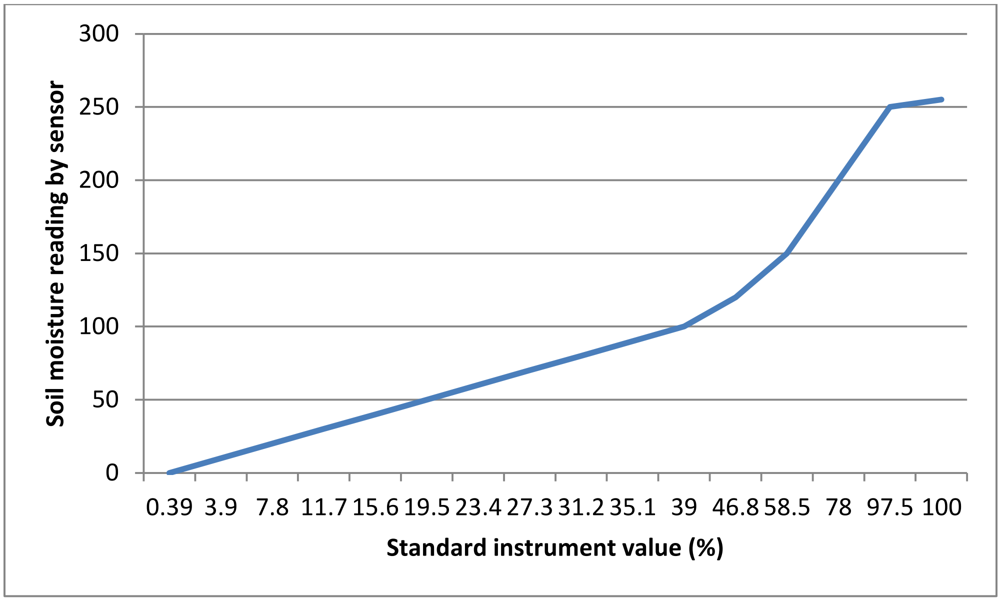

Fig.6.1 Calibration of soil moisture sensor w.r.t standard instrument

Fig.6.1 shows the relation between soil moisture content shown by sensor and by standard instrument. It gives calibration values of sensor with respect to percentage value of oven method. To validate the calibration repeated experiments were conducted by taking soil sample from five different places with valid water content and calibrated with the standard instruments. The table below lists the sensor reading versus actual soil moisture content for these samples.

Table 6.2 shows the Sample readings by soil moisture content (%) with sensor values. The sensor readings are converted into % values. It is observed that sensor is calibrated accurately and gives exact same reading, as given by standard instrument.

soil moisture (%) = (Wet soil(g) – dry soil (g)) * 100 / dry soil(g)

Table-6.2 Data collection from soil moisture sensor and reading by standard method for different samples

Samples	**Sample 1**			**Sample 2**		
	wet soil (g)	dry soil (g)	soil moisture	wet soil (g)	dry soil (g)	soil moisture
Standard instrument reading	114	98	16%	62	52	19.23 %
Sensor reading			42			49

Sample 3			**Sample 4**			**Sample 5**		
wet soil (g)	dry soil (g)	soil moisture	wet soil (g)	dry soil (g)	soil moisture	wet soil (g)	dry soil (g)	soil moisture
68	50	36 %	72	52	38.46 %	78	53	47.16 %
		93			95			123

Fig.6.2 shows the sensor values from soil samples and its value in % by standard method i.e oven method. Sensor shows the accurate readings with respect to its calibration readings.

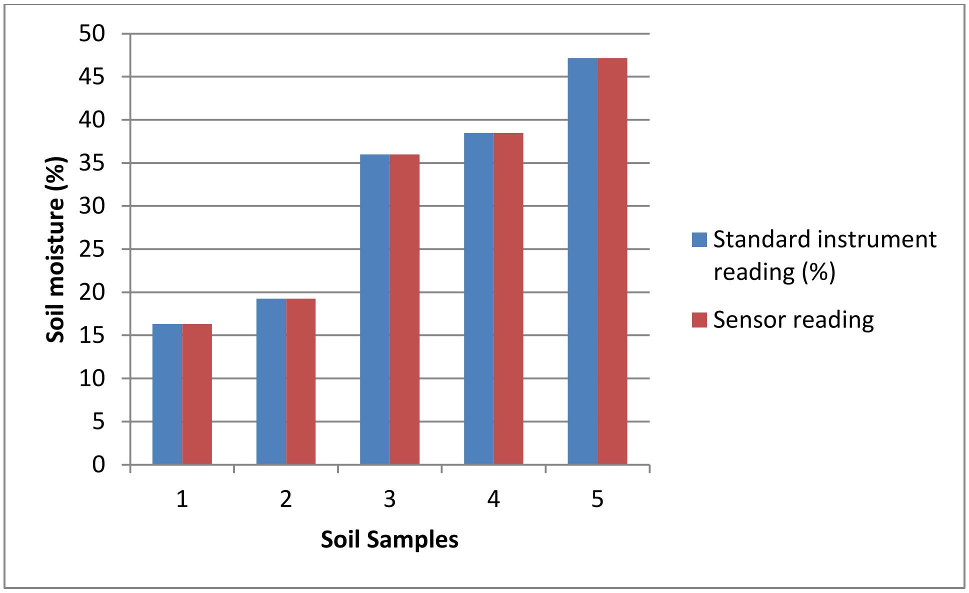

Fig.-6.2 Soil moisture value in (%) by standard instrument and sensor

6.1.2 ULTRASONIC SENSOR

Ultrasonic sensor is calibrated with standard scale. Table-6.3 clearly shows the bias value between sensor value and scale is 3 c.m in each case. So this biasing is managed by programming the microcontroller accordingly.

Table-6.3 Calibration of ultrasonic sensor with standard instrument

Distance by standard scale (c.m)	Distance by ultrasonic sensor (c.m)	Bias (c.m)
10	13	3
15	18	3
20	23	3
25	28	3
30	33	3
35	38	3
40	43	3
45	48	3
50	53	3

55	58	3
60	63	3
65	68	3
70	73	3
75	78	3

Fig.6.3 shows the calibration of ultrasonic sensor with standard instrument (scale). It shows a constant bias value by the sensor, which is eliminated with the help of the program in microcontroller. After calibration, sensor shows accurate readings.

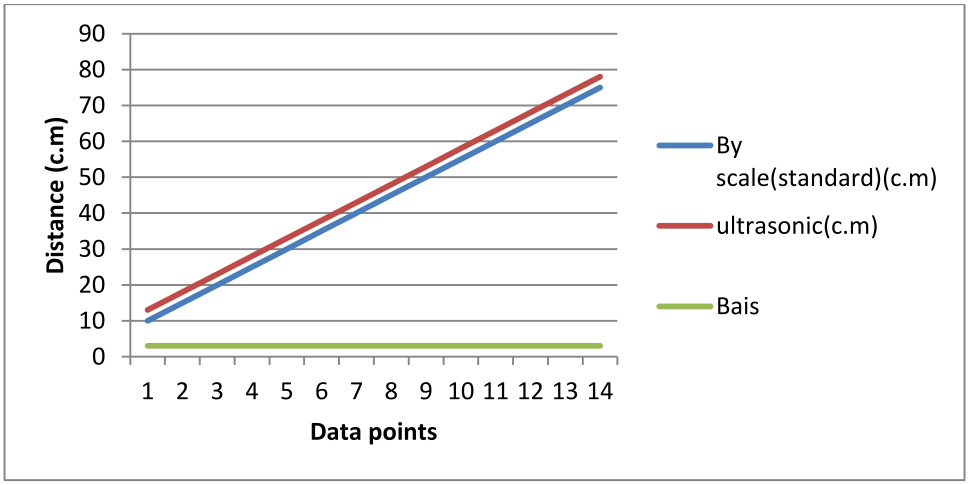

Fig.6.3 Calibration of ultrasonic sensor w.r t standard instrument

6.1.3 TEMPERATURE/HUMIDITY SENSOR

Temperature/humidity is calibrated with standard instrument (Psychrometer). It is achieved by mapping the values of sensor with that of standard instrument, The values are adjusted by means of programming the controller. Fig.-6.5 accurate calibration of sensor with zero percent error. The readings are taken for every half an hour in the month of March 2015. As shown in table-6.4 readings are taken and sensor is calibrated accordingly. For calibration of sensor Phycrometer is used as per the calculation given on [http://www.4wx.com/wxcalc/formulas/rhTdFromWetBulb.php]

Table-6.4 Calibration of temperature/humidity sensor with standard instrument

Dry temperature by standard instrument	wet temperature by standard instrument	Relative humidity by standard instrument in %	Temp. sensor (Sunrom 1211)	humidity by sensor in % (Sunrom 1211)
18	10.8	47.3	18	47
19	11.5	46.1	19	46
20	12.1	45	20	45
21	12.7	44	21	44
22	13.4	42	22	43
23	13.8	41	23	41
24	14.1	42	24	42
25	15.1	40	25	40
26	16.1	41	26	41
27	17.1	39	27	39

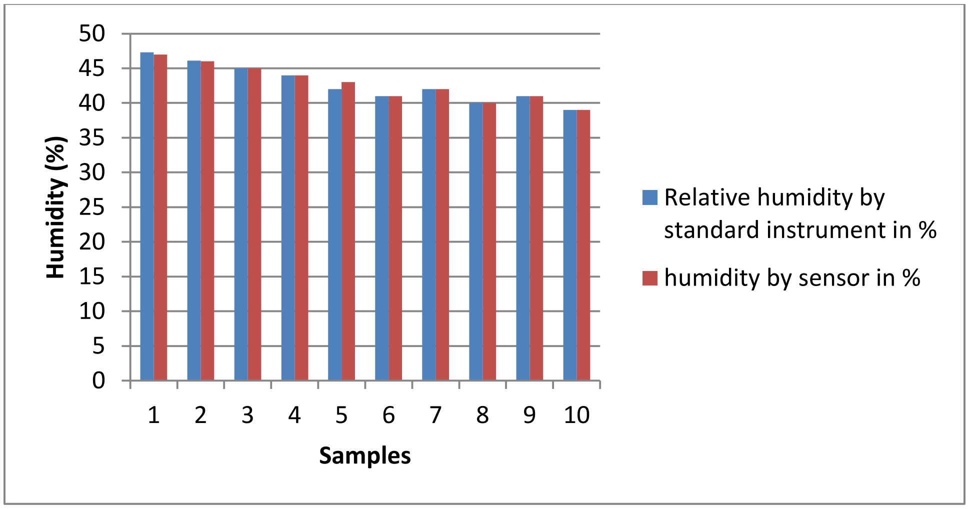

Fig.6.4 relative humidity calculated by standard instrument and sensor

Fig.6.4 shows the relative humidity with respect to dry and wet temperature calculated by the standard instrument, which is same as measured from the sensor as discussed in table-6.4. The same reading shows the accurate calibration of sensor.

Fig.6.5 shows that the error between the temperature readings by standard instrument and sensor is zero%.

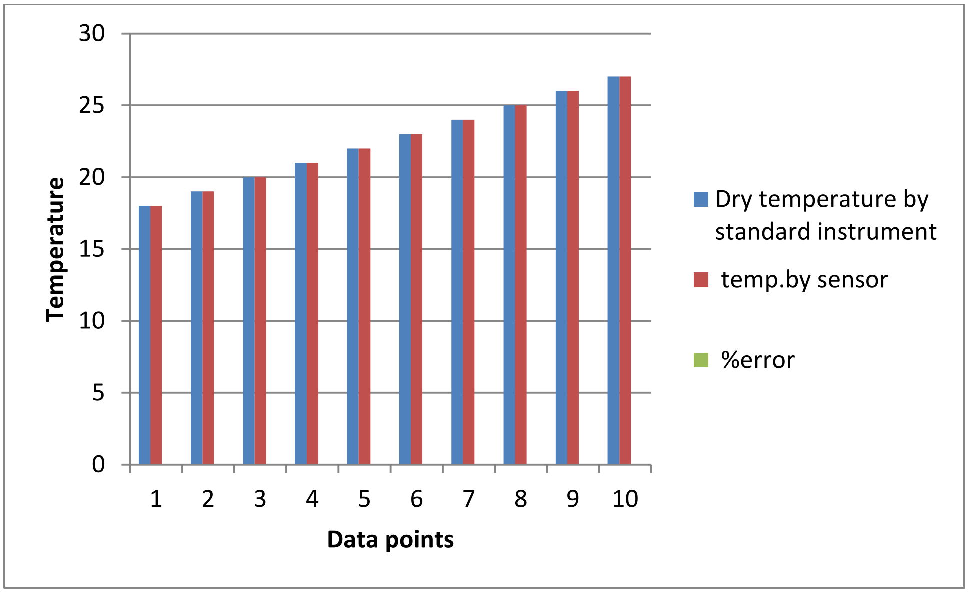

Fig.6.5 Relation between temperature calculated by standard instrument and sensor

6.1.4 GAS SENSOR

For gas sensor 10 min. warm up time is required. After that it starts giving accurate readings, as shown in Table-6.5. The sensor is calibrated against LPG by using gas lighters. The sensor is also calibrated against fire smoke by using the spark from the matchstick. Whenever there is a fire the smoke can be detected by gas sensor.

Table-6.5 Gas sensor readings

Open air (10 min. warm up time is required)

Time duration	Gas sensor value (PPM)
10:00 A.M (ON)	154
10:05 A.M	144
10.10 A.M	134
10.15 A.M	134
10.20 A.M	134

6.2 CODE SIZE ANALYSIS

Mica2 sensor mote [http://www.eol.ucar.edu] and MicaZ [http://www.memsic.com], which uses the TinyOS over the AVR platform, has been compared in terms of code size with the present work. The code size of the Mica Mote for radio application is 9.5 KB but for the present work it comes out approximately 1400 Byte for sensor nodes. It is found that code size of the developed system is very less when compared to Mica Mote.

NODES CODE SIZE-

NODE1

Program size- 1308 Bytes

Data- 32 Byte

NODE2

Program size- 1308 Bytes

Data- 32 Byte

NODE3

Program size- 1184 Bytes

Data- 36 Byte

NODE4

Program size- 1490 Bytes

Data- 43 Byte

NODE5

Program size- 1506 Bytes

Data- 49 Byte

SERVER

Program size- 2300 Bytes

Data- 263 Byte

HANDHELD DEVICE

Program size- 1224 Bytes

Data- 43 Byte

6.3 COST ANALYSIS

The sensor nodes, server and handheld device are designed with components as discussed in tables-6.6, 6.7 and 6.8. It can be seen, the cost of the nodes are less when compared to mica2 and mica Z nodes .

NODE COST

Table-6.6 Cost Analysis for developed sensor nodes

Components	Cost Node1 (Rs.)	Cost Node2 (Rs.)	Cost Node3 (Rs.)	Cost Node4 (Rs.)	Cost Node5 (Rs.)
Microcontroller	160	160	160	160	160
RF modem	600	600	600	600	600
Sensor1	(LM 35) 25	(LM 35) 25	(LM 35) 25	(LM 35) 25	(LM 35) 25
Sensor2	(Soil moisture) 1500	(Soil moisture) 1500	(Gas sensor) 400	(Humidity sensor) 675	(Ultrasonic sensor) 900

LCD(16x2)	110	110	110	110	110
Miscellaneous	100	100	100	100	100
Total (Rs.)	2495	2495	1395	1670	1895

SERVER COST

Table-6.7 Cost Analysis for developed server node

Component	Cost (Rs.)
Microcontroller	160
RF modem	600
Serial interface	100
LCD (16x4)	270
Bluetooth	950
Miscellaneous	100
Total	2180

HANDHELD DEVICE COST

Table-6.8 Cost Analysis for developed handheld device

Component	Cost (Rs.)
Microcontroller	160
RF modem	600
LCD (16x4)	270
Miscellaneous	100
Total	1130

6.4 CURRENT CONSUMPTION ANALYSIS

Current consumption analysis is performed on the basis of the current required by each component used to develop the system. The power consumption by RF modem is maximum for each node, followed by consumption by microcontroller.

Even though power was not a design issue for the system, it is evident that designed system requires less power than standard available devices like mica2 and micaz nodes.

Table-6.9 Current consumption Analysis for developed sensor nodes

Components	Node1 (mA)	Node2 (mA)	Node3 (mA)	Node4 (mA)	Node5 (mA)
Microcontroller	17	17	17	17	17
RF modem	58	58	58	58	58
Sensor1	1	1	1	1	1
Sensor2	5	5	180	20	3
LCD(16x2)	4	4	4	4	4
Total (mA)	85	85	264	104	83

Table-6.10 Current consumption Analysis for server

Component	Current (mA)
Microcontroller	17
RF modem	58
LCD (16x4)	4
Bluetooth	20
Total	99

Table-6.11 Current consumption Analysis for handheld device

Component	Current (mA)
Microcontroller	17

RF modem	58
LCD (16x4)	4
Total	79

6.5 DEVELOPED NODES

Fig.6.6 Snapshots for Developed nodes

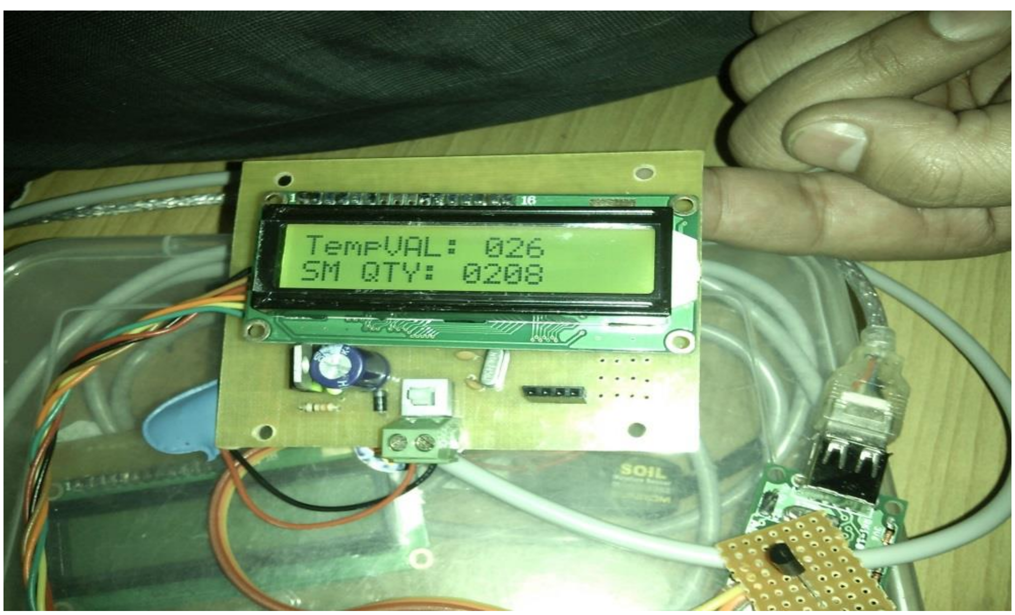

Fig.6.7Sensor node with temperature sensor and soil moisture sensor

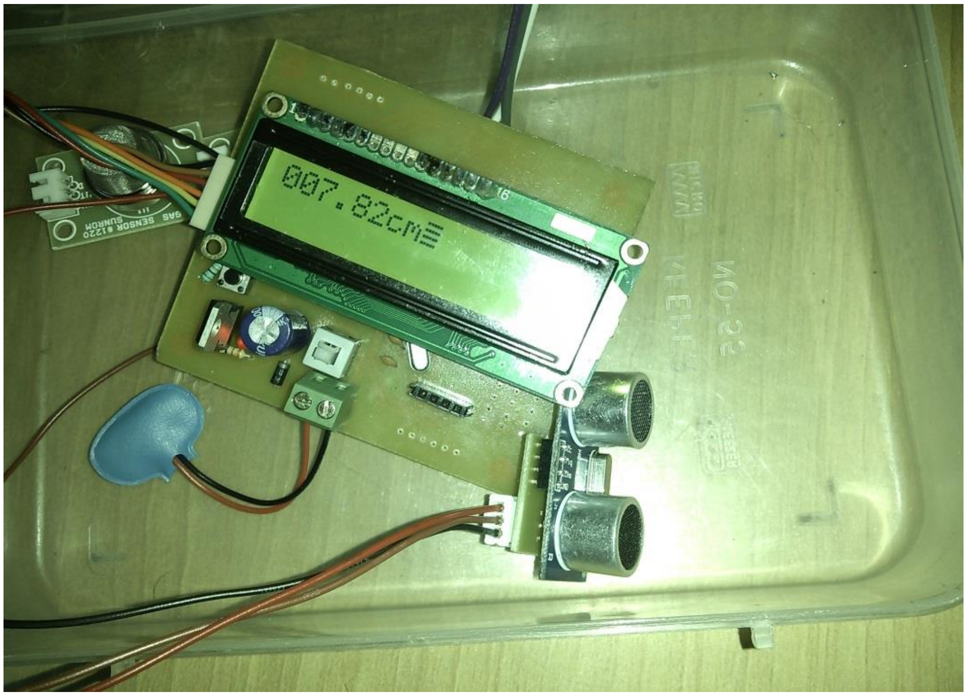

Fig.6.8 Sensor node with ultrasonic sensor

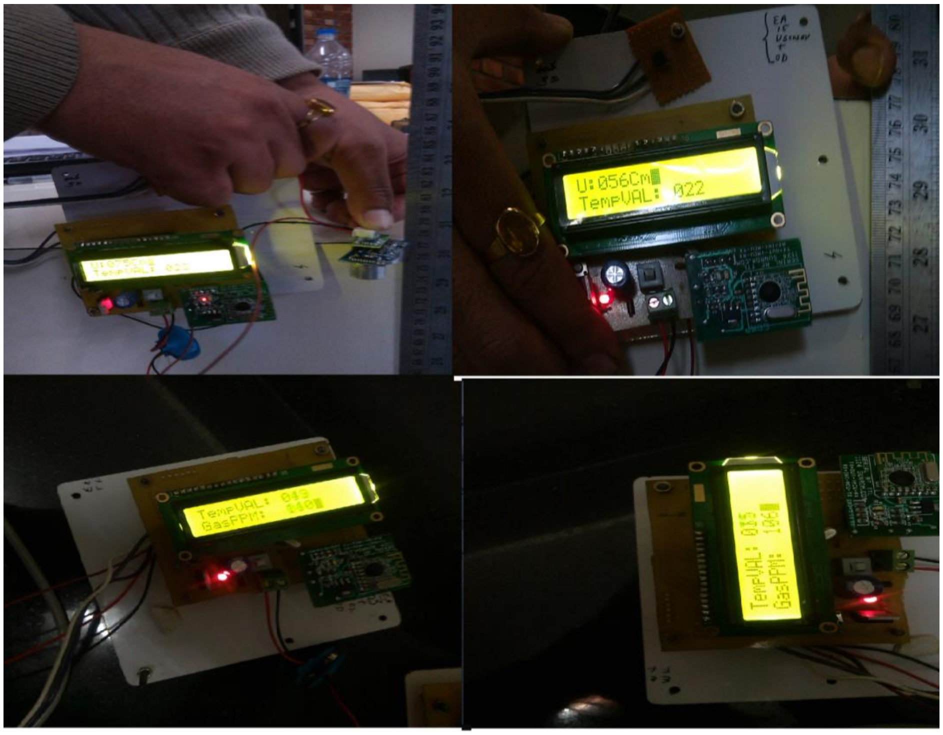

Fig.6.9 Snapshots for ultrasonic and temperature sensor nodes

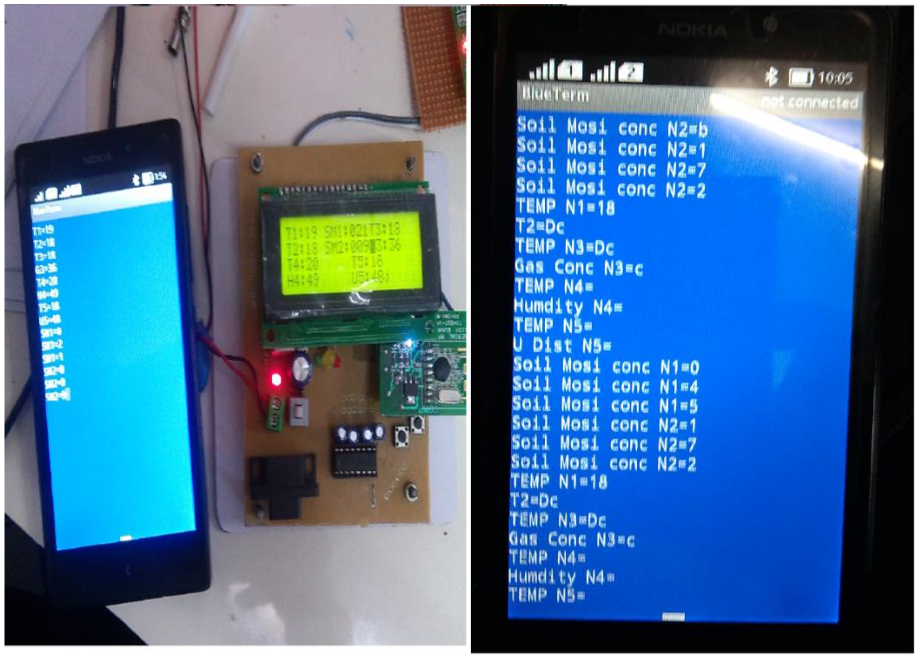

Fig. 6.10 Data from server to mobile phone

6.6 Chapter Summary

The chapter describes the calibration of the sensors (Temperature/humidity, soil moisture, ultrasonic and gas sensors), used to develop the system. The testing is performed for each sensor and compared with standard instruments. It is observed that the sensors are calibrated accurately. The cost analysis and current consumption analysis of the system shows, it is an energy efficient and low cost solution for the environmental parameter monitoring.

CHAPTER7

CONCLUSION AND FUTURE SCOPE

7.1 Conclusion and Future scope

The primary goal of this thesis is to develop a wearable/handheld device for early warning in the restricted area, displaying various physical parameters like temperature, hazardous gases, sound and metal and soil moisture in the agricultural field useful for agricultural farmer by wirelessly measuring them. It will also be useful for farmers for getting all information about the environment in a single piece of device which is easily operable by anyone. This system is a reliable communication system without breakdown because of the use of Personal Area Network.

All the data can be read by the smart device without interruption and delay because of the efficient use of communication algorithm in the control node. Employing embedded technology, based on Arduino, the Wireless Sensor Nodes are designed and implemented.

The results show that the temperature and gas sensor data given by the sensor node are accurate. The data received from humidity sensors, soil moisture sensors and water level sensors are calibrated against standard instruments and found to be accurate. The RF module Zigbee operated at 2.4GHz ISM band really help for secure data transmission.

The temperature in degree centigrade and gas data in ppm, soil moisture in percentage is continuously observed on the monitor of the base station. Thus, the control room could get the temperature of different places and the presence/absence of hazardous gases in a particular area and soil moisture content which could be useful to the farmer for having prior information about the environment thereby increasing the yield. The system works with great reliability.

The smart phone will receive data from the field through the central node. The smart phone will be available to the farmers for monitoring various environmental parameters

The system developed will also be useful for wireless monitoring and management systems for dams. The device fabricated can also be used for monitoring the water level, discharge of water and rain network for the purpose of agriculture and disaster monitoring and management. Rice being one of the staple foods, has to be produced in large quantities. Because of labour shortage many farmers are giving up their interest in paddy cultivation. Reducing the manual effort through mechanization is a solution to the problem of labour shortage.

Technology developed for this thesis can play a better role in modernization and automation of paddy cultivation. In this thesis, a method has been shown for the application of Wireless Sensor Networks in water level regulation in the paddy fields. This helps to reduce the manual effort required to observe the water level and to pump in or out of the field. The system has the capability to manage the power optimally which makes it economically viable.

In this thesis, optimization algorithm has been implemented in order to place these sensor nodes in the agricultural field. The exact placement of these nodes in order to cover the entire given agricultural field area has been carried out. The placement of these sensor nodes becomes very challenging in the agricultural fields when surrounded by different types of vegetation, because of scattering effect of the wireless signal. In this thesis, this problem is considered and placements of sensor nodes are discussed with different vegetation. The objective of the thesis was not to examine the safety and reliability of the sensor nodes employed in the field.

In future the system can be included with more number of sensors like metal and sound sensors in order to make the agricultural field intrusion free. In future the same system can also be developed to sense the amount of nutrients required and to supply the same in correct quantities. A detailed study of effect of foliage surrounding plants on scattering of the wireless signals can be carried out so as to decrease the number of extra nodes.

7.2 MAJOR OUTCOMES

- A new method, an apparatus and a computer program product for wireless sensor network are provided for displaying environmental parameters useful for agriculture in rural area

- Optimization of the input parameters results in more efficient realization.
- A new device is developed, to assist the persons even with zero knowledge about the technology.

CHAPTER-8

PUBLICATIONS

8.1 PUBLICATIONS (2014-15)

Papers published-

- Sushabhan Choudhury, Piyush Kuchhal, Rajesh Singh, Anita, "Development of PSO based Handheld Device to Monitor the Environmental Parameters for Coal mines and Rigs" , International Journal of Applied Engineering Research (IJAER), March 2014 **(Scopus Indexed)**
- Sushabhan Choudhury, Piyush Kuchhal, Rajesh Singh, Anita, "ZigBee and Bluetooth Network based Sensory Data Acquisition System", ELSEVIER on "Procedia Computer Science", May 2014 **(Scopus Indexed).**
- Sushabhan Choudhury, Rajesh Singh, Anita, Bhupendra Singh, "Wireless Disaster Monitoring and Management System for Dams", ELSEVIER on Procedia Computer Science, May 2014 **(Scopus Indexed)**

Patents –

- Sushabhan Choudhury, Piyush Kuchhal, Rajesh Singh, Anita, "Wireless Data Acquisition for Agricultural Field through A Wearable Device", Ref. No. /Application No 2605/DEL/2014.
- Sushabhan Choudhury, Rajesh Singh, Anita, Arpit jain, C.Meera, Sai Ram, Sunil Sunny, "Method and Device for Smart Projector Screen", Application no.- 3790/DEL/2014.
- Sushabhan Choudhury, Rajesh Singh, Anita, Amit lamba, Apoorva Patel, Alka Jha, Anirudh, "An electronic system for fan cum exhaust fan", Application No.- 3199/DEL/2014.

8.2 Research Contribution

- Sushabhan Choudhury, Piyush Kuchhal, Rajesh Singh, Anita, "Development of PSO based Handheld Device to Monitor the Environmental Parameters for Coal mines and Rigs" , International Journal of Applied Engineering Research (IJAER), March 2014 (Scopus Indexed)

In this paper a data acquisition system has been implemented for coal mines and rigs which will measure the certain parameters like temperature, humidity, the level of gases present in atmosphere and transmit these parameters to the control room wirelessly as well as to the concerned person of the area by the latest smart handheld device. Since these sensors will be deployed randomly, the coverage of these sensors on the field has been investigated. The sensors position need to be placed in such a way that the network covers the full field area for high quality of service. This can be achieved by placing optimal number of sensors covering a maximum area in the network without any communication failure or dark zone. In order to achieve the same, in this paper, network optimization algorithm was used for efficient routing. There are various optimization algorithms available and studied. However, particle swarm optimization algorithm was selected and used to find the optimal positions of the sensors because of better scalability.

- Sushabhan Choudhury, Piyush Kuchhal, Rajesh Singh, Anita, "ZigBee and Bluetooth Network based Sensory Data Acquisition System", ELSEVIER on "Procedia Computer Science", May 2014 (Scopus Indexed)

In this era of modernization, lot of systems has been introduced by which the human effort has been limited to a certain level. In this paper a data acquisition system has been implemented for factories and industries or environment monitoring, which will measure the certain parameters like temperature, humidity, the level of gases present in atmosphere, motion of any person near the restricted areas at a time and transmit these parameters to the control room wirelessly as well as to the concerned person of the area on the latest smartphone/ tablets. Through the smartphone, the person can give command to the control room if any parameter crosses a certain level. The data is collected from sensor nodes to the control room node using ZigBee network and then the desired data is retransmitted to smart phones, tabs and PCs using Bluetooth network.

- Sushabhan Choudhury, Rajesh Singh, Anita, Bhupendra Singh, "Wireless Disaster Monitoring and Management System for Dams", ELSEVIER on Procedia Computer Science, May 2014 (Scopus Indexed)

A drastic change in environmental conditions and geographical conditions causes big disasters. To save lives, monitoring of these changes is a big challenge. Along with monitoring, corresponding action to be taken within time limit is also important. To achieve this objective timely information about it is required. In this paper a Zigbee based system is implemented for disaster monitoring and management. In this paper a system is implemented for wireless monitoring of water levels of a group of dams. Corresponding to the any drastic change in water level in any river or lake the gate of the dam will be opened or closed depending on the preset danger level. This control action is controlled with the help of sensory data collected from different nodes, placed over an area. A WSN based solution is implemented, for monitoring the water level, discharge of water and Rain network for the purpose of disaster monitoring and management.

- Sushabhan Choudhury, Piyush Kuchhal, Rajesh Singh and Anita, "Zigbee and PSO based Monitoring and Control of Water Level in Paddy Fields", International Journal of Applied Environmental Sciences, Volume 10 Number 4, pp. 1465-1473, 2015. (Scopus Indexed)

In this paper a system is developed and deployed by utilizing the sensor nodes composed of various types of sensors for observing the important parameters such that water level, soil moisture, temperature, humidity, pH level in the paddy. Particle swarm optimization algorithm is applied for the optimized placement sensor nodes with vegetation or without vegetation. On comparison in both conditions it was found that during vegetation the problem related to level of water was removed with the help of wireless communication. A hand held wearable device is designed and implemented for monitoring the parameters discussed above.

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