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Soil Monitoring System using Zigbee for Smart Agriculture

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Abstract

The soil moisture level is one of the critical parameters, that controls the quality of the crops grown in farms. Monitoring agricultural environment for various factors such as soil moisture, temperature and humidity along with other factors can be of great significance. A traditional approach to measure these factors in an agricultural environment meant individuals manually taking measurements at various times. The main objective of this research is to investigate the development of a low cost remote soil moisture monitoring system by deploying sensors, which can be used in a Zigbee mesh network. These nodes send data wirelessly to a central server, which collects the data, stores it and will allow it to be analyzed. This data can then be displayed as needed and can also be sent to the client mobile. A routing algorithm is used for the network consisting of smart devices, thereby allowing the Internet of Things and its enabling technologies to provide high reliability while the transmitting the data.

Keywords: Arduino Microcontroller, Zigbee, Wireless Sensor Network, Remote Monitoring

I. INTRODUCTION

Soil moisture along with climatic conditions are the two most important factors, which decide the agriculture productivity. As India consumes 80 percent of total available water resources for irrigation purpose, there is an urgent need to reduce water consumption using advanced scientific techniques. The water is scarce nowadays. We need to use it with utter care. During irrigation, water wastage should be avoided. The plants or crop should be irrigated only when they need to be. When plants transpire more amount of water, the relative humidity of atmosphere increases. This presence of large amount of relative humidity increases the chances of disease attack. So, soil moisture levels in the field requires periodic inspection, from where one can determine, when the next irrigation should be done and how much amount of water should be applied. Current developments in the miniaturization of electronic devices and wireless communication technology have resulted in the emergence of an energy efficient Wireless Sensor Networks (WSN). This makes it possible to acquire the field information more timely, accurately and conveniently. Monitoring parameters of temperature and humidity is an important means for obtaining high-quality environment. Remote monitoring is an effective method in order to avoid interference environment and improve efficiency. Today, Ethernet network and ZigBee wireless networks are used to transmit data in remote monitoring System. The Internet of Things (IoT) is a system which integrates the computing devices, possessing the ability of transferring the data over the network via the better route. [2] This paper gives a review of remote control and monitoring systems based on existing technologies and a ZigBee based IoT network to allow efficient routing in the network.

II. PROPOSED SYSTEM ARCHITECTURE

This paper would take the opportunity to design a device that monitors soil moisture, temperature and humidity of field atmosphere, and transmit the information to the remote receiver at the farmhouse or outside the field. The remote receiver is a laptop connected to the Zigbee transceiver. [5] The proposed system as shown in fig 1 consists of Arduino as processing unit and WSN base station. A soil moisture and temperature humidity sensor is connected to the WSN data collection node. The sensor node also consists of a LCD module, where the sensor output is displayed in real time. The sensor node is building block of the WSN. The task of sensor node is to achieve the perception, collection, processing and wireless transmission. The sensor node converts the physical quantity to the voltage signal and Arduino UNO board controls the processing, and manages the communication protocol. The sensor node communicates with the base station using transceiver. The base station collects all the data send by sensor node.

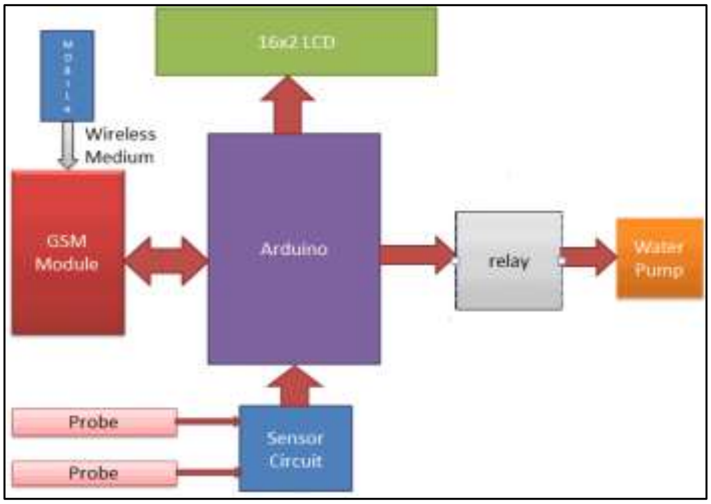

Fig. 1: System Architecture Design

III. COMPONENT DESCRIPTION

The whole system is made with the collaboration of hardware and software components. The hardware components include Arduino UNO board, soil moisture sensor, DHT11 temperature humidity sensor, LCD module and Zigbee transceivers. The software includes Arduino IDE and X-CTU.

A. *Arduino*

The Arduino UNO is a microcontroller board based on the ATmega 328. It has 6 MHz ceramic resonator, a USB connector, reset button and a power jack. It is the most robust board. It has 14 digital I/O pins and ICSP header. Arduino doesnt require any extra hardware for boot loading. It is pre planned with boot loader that makes it simpler to upload programs to on board flash memory. The advantages of Arduino are that it provides inexpensive and simpler method for novices and professionals to create their own devices using sensors. It provides platform that easily runs on windows and Linux operating system.

Fig. 2: Arduino UNO Micro-controller Board

B. *Zigbee*

Zigbee is developed by Zigbee alliance. It is based on IEEE 802.15.4 standards. Zigbee is well known wireless communication protocol. It has very less power consumption and is reliable for wireless personal area network. There are three types of device in Zigbee network. A network may consist of a coordinator node and multiple router and end devices. The configuration of Zigbee modules is done through X- CTU software.[6] Zigbee operates in the industrial, scientific and medical (ISM) radio bands: 915 MHz in the USA and Australia, 868 MHz in Europe, and 2.4 GHz in worldwide. Apart from the agriculture and food industry, Zigbee is widely used in home building control, automation, security, consumer electronics, personal computer peripherals medical monitoring and toys.[3] Zigbee has following advantages in these applications such as, it offers long battery life, reliability, automatic or semiautomatic installation, the ability to easily add or remove network nodes, signals that can pass through walls and ceilings and a low system cost.

C. *Arduino IDE Tool*

Arduino IDE is Arduino integrated development environment or we can say it is Arduino software. It consists of a text editor, where the code is written. A message area is given, which shows message or any error message. The tool bar contains buttons for common features. The programs are uploaded to Arduino board by USB connection. This process is called code-uploading or code-burning. The coding for soil moisture monitoring system is done using Arduino IDE.

D. *X-CTU Software*

It is a simple graphical user interface designed for the multi-platform applications to interact with digital RF modules. X-CTU is specially targeted towards systems using Zigbee (XBee) specification. It contains tools that are used to setup, configure and test Zigbee modules. It can be used to configure multiple modules. It receives the data using Zigbee transceiver and displays the results of sensors on the console.

E. *Sensors*

Sensors are commonly used for detection of parameters and respond to any of electronic controller to acquire and collect information. The information gathered by sensor is usually a data signal and is converted to human readable format and represented on a display. The following types of sensors are used in this system.

1) Soil Moisture Sensor

This sensor is used to evaluate the content of soil water level in volume unit. Due to the plant uptake and evaporation which leads to the loss of moisture, this sensor is capable in measuring its value. Also it can analyze the desired soil moisture contents for various species of crops. It can enhance the soil moisture content by monitoring and controlling the irrigation in greenhouses.[1] The soil moisture sensor will be used by the proponents. This is the specific sensor that will detect the water level within the soil. It gives an accurate information of soil water content along with being cost-effective. This sensor can observe the moisture of the soil up to 10 meters above the ground.

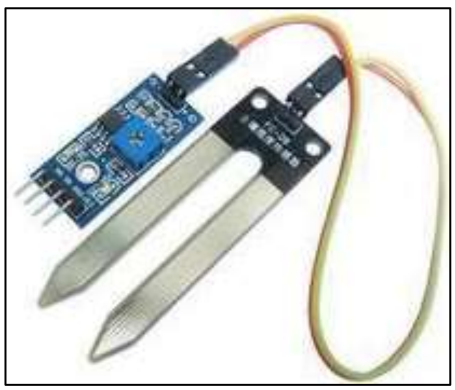

Fig. 3: Soil Moisture Sensor

2) Humidity and Temperature Sensor DHT11

Humidity is the amount of water vapor present in the air. Humidity sensors detect the relative humidity of the surrounding environment. DHT11 measures both the humidity and temperature of the air. It expresses relative humidity as a percentage of the ratio of moisture in the air to the maximum amount that can be held in the air at the current temperature. Humidity sensors use capacitive method to find out the amount of moisture present in the air. [1] The temperature measurement is done using the principle of thermistor. This sensor provides a long term stability and high reliability. Also, it provides the advantages of high cost performances, quick result and a satisfaction of quality. This sensor can also monitor the humidity because it highlights an accurate calibration of humidity calibration chamber.

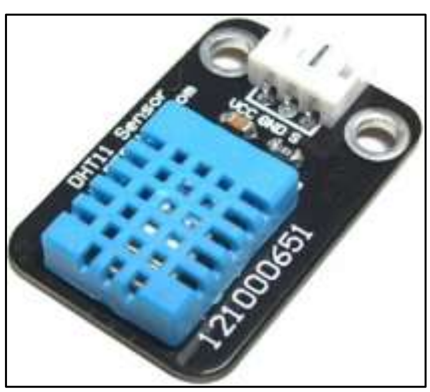

Fig. 4: DHT11 Temperature and Humidity Sensor

3) pH Sensor

pH Sensor measures the acidity levels of soil. The pH sensor is ideal in this system because it has a specifications that fits the standard of the proponents to monitor acidity of the soil. This sensor will provide reliable and precise information. It can be use in a long term basis. Also, it has high quality because of its specification which is a compatible with Arduino and can be used for long term solidity. This sensor has been verified to determine the accuracy and range of its specifications.

Fig. 5: pH Sensor

F. LCD (Liquid Crystal Display)

The LCD is commonly used in the panel and laptop monitors because of its features that is super thin. It is formed by inserting between two electrodes to provide images in electronically based. The color of this substance can be transformed by increasing or decreasing the electrical current. They use up much less power because LCD are based on the source of blocking light.[5] The LCD will be used by the proponents because it is ideal in displaying the information gathered and is suitable for easily monitoring the transmitted data values of parameters in a set period of time.

G. Data Loggers

Data logging and recording is a very common measurement application. In its most basic form, data logging is the measurement and recording of physical or electrical parameters over a period of time. Here we are using these data loggers for acquiring data from the different sensors we used in the field (temperature, soil moisture, humidity). The data logger we use is a simple equipment built up by a precision analog to digital converter with 8051 micro-controller and flash memory (MSC1210). Different sensors we use are connected to the analog input ports of MSC1210. ZigBee is used to transmit the data from data loggers to the base station.

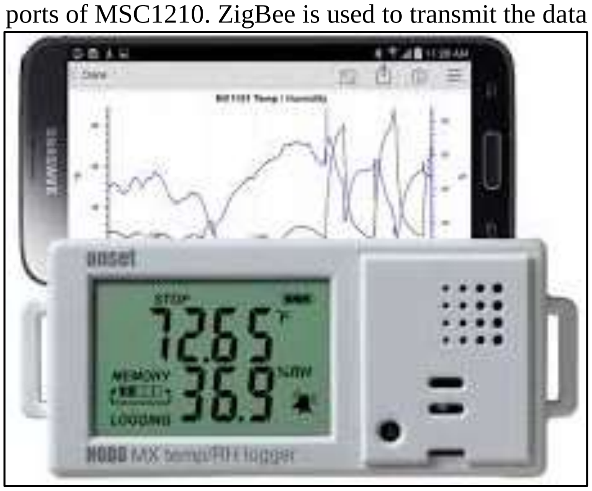

Fig. 6: Data Loggers

IV. WORKING OF THE SYSTEM

At the Transmitter end, initially power is on. After this, system is reset. Signals are read by different sensors and its output is given to microcontroller. Output to microcontroller from sensor is taken and given to Zigbee. At receiver side ZigBee come into picture. Signal is send to microcontroller and parameters like temperature, soil moisture and humidity are monitored. These parameters are monitored on computer using RS-232 port. This data can be used for precision farming the actuators can be controlled using microcontroller data. This is how total working takes place of automation irrigation system. [6]

So, to sum up, the working of this system can be given as follows:

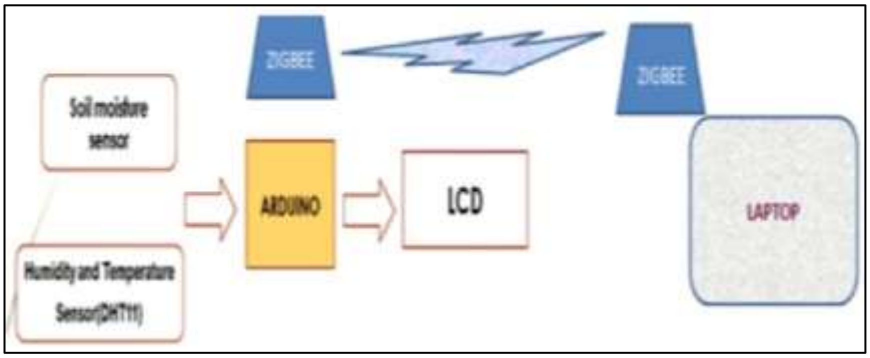

Fig. 7: Proposed System Connections

- A ZigBee wireless sensor network is designed for the purpose of monitoring the crop field area. This can be done by deploying moisture sensors in the land to detect the places where the water level is low. From those results we can irrigate to that particular segment in the field. Thus, we can conserve water and minimize the problem of water logging in the land.
- Humidity sensor is used to sense the weather. Using this the farmer gets an idea about the climate. In case of any probability of rainfall, the farmer need not irrigate the crop field, thereby conserving water and power also, since no water sprinklers and pumping motors will be turned on.
- Nowadays in the fields, the fertilizer levels are increasing, which negatively affects the crops as well as the people working around them. By using pH sensors we get the information about the soil and analyze the acidity level of the soil, after which we can apply fertilizer to the place where it needs. By this we can avoid over fertilization of the crops. Temperature is a randomly varying quantity in the environment. Temperature reading gives information to the farmer. By using temperature sensors, we can detect the temperature values.

V. WSN BASED IOT MODEL

The IoT network includes wireless sensor network (WSN) and other countless devices which are connected wirelessly to the Internet. Figure 8 shows the architecture of wireless sensor network based IoT. [7] The WSN based IoT network contains one base station or sink node DB, cluster heads HC and also h number of IoT nodes which is represented in Figure 8. The wireless links between the IoT nodes represent the direct communication within the radio range. Each IoT node has its maximum communication radio range that is uniformly distributed within the dimension of Ut and Vt meters. Every IoT node has a unique ID and these nodes are grouped to form clusters in the network. The optimal location of sink node in IoT network model is defined as 5Ut; 0:5V. Sink node DB, used to receive all the data symbols from all the IoT nodes in the network. The coordinate value of Ui and Vi represents the location of every IoT nodes. Thus, the IoT node transfers the data packets to the base station or sink node using the cluster head mechanism. Here, the cluster head node in every cluster is denoted by HC which contains the number of IoT nodes. HhC is a set of IoT nodes under the cluster group, HC. Thus, the IoT network is divided into HC number of clusters, where, the number of normal nodes is equal to (h.HC).

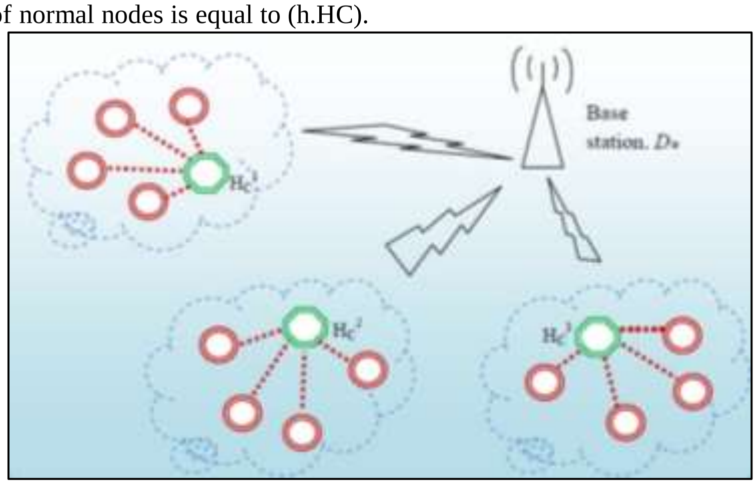

Fig. 8: WSN based IoT Model

In IoT network, once the cluster groups are formed, then the data packets are transmitted from every normal node DN to their corresponding cluster head DC. Thus, the cluster head collects all the data packets from every IoT node and send it to the base station, DB. All the IoT nodes are located at the fixed location in the network and the distance between the mth normal nodes to the nth cluster head is denoted as dm,n. sn is the distance between the nth cluster head to the sink node, DB.

VI. CAMRA ROUTING PROTOCOL

Context awareness multipath routing algorithm (CAMRA) protocol is a reactive protocol which is suitable for energy con- strained, static and delay tolerant IoT networks.[4] The devices using CAMRA will sense the information in timely manner. Minimizing the use of average energy is the ultimate aim of CAMRA, for that delay is sacrificed sometimes. The routing protocol is based on two mechanisms: Rank computation and data routing. CAMRA is a context aware routing protocol. Left over energy of the nodes is considered as prime context.
CAMRA Has Following Features

A. *Simplicity*

This algorithm is a simple algorithm. The major thrust to drive this protocol is obtained through local interaction between the neighbouring nodes.

B. *Less Memory Requirement*

Every node stores routing information about its neighbors only. It reduces the overall memory requirement automatically.

C. *Load balancing*

Algorithm balances the load at local level. It sends the traffic based on nodes left over energy value. While forwarding the traffic to sink, always care is taken to forward the traffic through most energy efficient node which reduces energy holes creation.

D. *Multipath routing*

The sensed information is send to the sink by various paths. Routing decisions are taken dynamically based on the context information available at the local node. [4]

VII. SETUP OF ROUTING NETWORK

The routing algorithm will work in two major steps

A. *Network Setup Phase*

Network setup phase starts immediately after the deployment of the network. It contains two major phases

1) Rank calculation of the IoT devices

This mechanism involves calculating a Rank of every device which will be used while routing the data to sink node as well as while balancing the network load. While calculating Ranks of the devices, parallelly routing table formation is also done. Expected outcome of this algorithm is assigning the Rank to every node of the graph. Rank will give more information about the distance of current node from the Sink node. Rank in this case may not exactly provide the hop count information of the current node from sink in actual routing scenario, but it will definitely provide some number which can be used for comparative analysis. [4]

2) Creation of routing tables

The topology of IoT net- works is not always firm. It gets changed time to time due to various reasons. So it is always essential to update the routing tables for maintaining the validity of the routing entries inside it. Every node in CAMRA algorithm maintains two types of routing table, named Superior routing tables (SRT) and Colleague routing table (CRT). These routing tables will hold the values of Superior ID (in SRT) or Colleague ID (in CRT) and left over energy of the corresponding superior or colleague node. Both the tables have almost identical data structure and the table items are listed in ascending order of superior ID or colleague ID.

B. *Data transfer phase and route maintenance phase*

These are two separate phases but these will go hand in hand with one another due to that we have considered them as a single phase. [4] Data transfer phase is complex in nature as it has to take the routing decision while transferring the data to sink by selecting a suitable node from the set of superiors of a current node by considering their left over energy. Route maintenance phase is event based. The event occurs in two situations:

1) Sink will send Prank messages in timely manner for updating the routing tables of all the network nodes, and
2) When the left over energy of the superior as well as colleague node set of a specific node drops below the specified network energy threshold (NEth) value.

VIII. RESULTS

The implementation of soil moisture monitoring system involving soil moisture, temperature and humidity sensors for monitoring various agriculture parameters of agriculture has been successful. When soil sensor is embedded into soil, it gives percentage of water present in the soil on LCD, laptop screen or mobile application. The data received from the sensors is displayed on IDE serial monitor, which gives the value of soil moisture in percentage.

IX. FUTURE PLANS AND IMPROVEMENTS

A. *System Improvements*

The system can be improved by introducing a frost management system and excess heating control. The existing system and farm sprinkler system can be integrated to protect the crops from frosts and extreme heat conditions and at same time can be used to optimize the irrigation requirements.

B. *Hardware and Software Improvements*

A modular architecture minimizes the software upgrade down time and enables hardware re-usability. Such a design allows greater flexibility for the end product. The same node can be utilized for different applications when equipped with the required sensor modules. This is highly desirable when each sensor node collecting micro climate, atmospheric and plant data in different agriculture farms requires a different sets of sensors.

X. CONCLUSION

Zigbee-based agriculture monitoring system serves as a reliable and efficient system for monitoring agricultural parameters. Wireless monitoring of field will not only allow user to reduce the manual labour, but also to see accurate changes in it. It is cheaper in cost and consumes less power. Such a system can be easily installed and maintained. The scope for future work in this study will include fabrication, experimental investigation, and data analysis for predicting crop yield, control solution and complex networks setups.

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