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Analysis of Environmental Sensors in ZigBee Based Green House Control and Monitoring System

Jaypal Baviskar[1], Afshan Mulla[2], Amol Baviskar[3], Neha Baviskar[4]
[1, 2, 3, 4] *Department Of EXTC Engineering, Vishwatmak Om Gurudev College Of Engineering, Aghai-Thane*

Abstract: Appropriate environmental condition sare necessary for optimum growth of the plant, improved crop yields and efficient use of sparse sources like water along with other resources. Environmental diversity affects the growth of plants; moreoversome plants require certainstringent environmental conditions. Such plants need to be cultivatedsynthetically. Hence an automated system which fulfillsthese requirements as well as to eliminate the deterioration of plantation due to such conditions which is caused by selfish human acts needs to be developed. This paper proposes a WSN (Wireless Sensor Network) based embedded system anddeals with implementation of ZigBee technology (over IEEE 802.15.4) for remote control and monitoring of Green house parameters. Further it demonstrates the analysis of various sensors implemented in system viz.temperature, humidity, light etc.
Keywords: Diversity, WSN, Embedded system, ZigBee, Green House, sensors.

I. INTRODUCTION

Automation is facilitated due to research and advancement in various fields including wireless communication. It incorporates different modern disciplines including communication, information, computer, control systems and wireless sensors in an integrated way leading to new solutions, better performance and an absolute system [1]. Automation along with the use of Wireless Sensor Networks (WSNs) has superseded the traditional manual control systems hence gaining popularity in industrial, domestic as well as in agricultural sector. In the field of automation WSNs have revolutionized the design of emerging embedded systems in terms of various factors *viz.* scalability, mobility, power consumption etc.

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. As stated by

A. Palanisamy et al. in [2] the unique characteristics of WSNs are:

1) Can store and harvest limited power
2) Ability to withstand harsh environmental conditions
3) Ability to cope with node failures
4) Mobility of nodes is possible
5) Dynamic network topology
6) Heterogeneity of nodes
7) Large scale deployment
8) Unattended operation and self governing ability
9) Node capacity is scalable, only limited by bandwidth of gateway node.

WSN can be established to extract data from an environment such as green house parameters from remote location and route it to the user side. Thus, a wireless sensor network consisting of small-size wireless sensor nodes equipped with radio and one or several sensors is an attractive and cost-efficient option to build the required measurement system Growth of the plants depends on the ecological conditions and efficient use of the resources like water. Environmental diversity arises due to the drastic change in natural conditions from region to region which creates the variety in the cultivation of crops and plantation. The main objective of the green house is to cultivate any plant in any particular region independent of its existing environmental conditions.

WSN can be established for auto mating the data acquisition process of the soil conditions and various climatic parameters that govern plant growth. It allows user to collectinformationathighfrequencywithlesslaborrequirement.Theexistingsystems are either PC based [4]which updates the user about the conditions inside the green house; but most of them are unaffordable, bulky, difficult tomaintain and less accepted by the technologically unskilled workers. Hence an automatic embedded system is required to facilitate the smooth maneuver by eliminating these tribulations.

The detailed comparative study [3,5,21,22] of the different short-range wireless protocols viz. Bluetooth (over IEEE 802.15.1), UWB (over IEEE 802.15.3), ZigBee (over IEEE 802.15.4) and Wi-Fi (over IEEE 802.11a/b/g) shows the unique features of ZigBee such as ultra low power consumption, scalability and apposite data rate makes it suitable in field of automation.
Being an automatic, controlled and monitoring system our proposed model [19,20] is implemented with ZigBee protocol. It consists of two modules i.e. one is user side module in which the transceiver is connected to the user PC to control the various green house appliances remotely and the other is green house side module to which sensors are interfaced. It monitors all the parameters, fetches the real time sensed value and depicts the same on LCD display.
This paper is organized as follows; Section II deals with the brief study of existing systems. Section III provides the details regarding the ZigBee protocol and its network topologies whereas our proposed model is discussed in Section IV. Section V describes the analysis of various sensors used and the final Section presents the conclusion of our paper.

II. ZIGBEE PROTOCOL

ZigBee is designed as anultra low power, low-data rate and low cost wireless mesh technology. Being an efficient protocol it is gaining popularity in various applications such as building automation networks, home security systems, patient monitoring, remote metering, industrial control networks etc.

A. Introduction to ZigBee

ZigBee standard (IEEE 802.15.4) is formed by the ZigBee Alliance Companyin 2002. It is a low data rate WPAN(LR-WPAN) standard which provides data rate up to 250 Kbps in the global 2.4-GHz Industrial, Scientific, Medical (ISM) band. Ultra low power consumption and scalability are the main features of ZigBee. It also provides self-organized, multi-hop, and reliable mesh networking with long battery lifetime [5] [6
Since our proposed model is mainly concerned with the controlling and monitoring purpose, the data rates provided by ZigBee are suitable for our application. Also thepower consumption of ZigBee as depicted in Fig. 1 is much less than Wi-Fi. Though power consumption of Bluetooth and ZigBee protocol is comparable but the unique features of ZigBee such as scalability, range of deployment, low latency[10] [11] have added advantage.

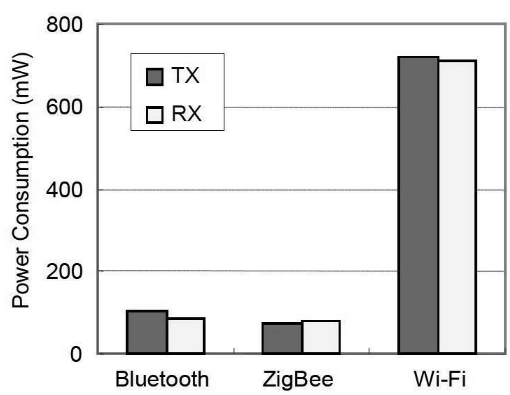

Fig2. Comparison of the power consumption for each protocol.

B. ZigBee devices

Devices [23] used in ZigBee protocol are categorized on the basis of their functionality as follow:

1) Full-function Device (FFD): The FFD has full functionality and it can communicate with other FFDs and RFDs. It can act as a PAN coordinator, a coordinator and router or even as a RFD.
2) Reduced-function Device (RFD):The RFD can communicate only with the FFD *viz.*network coordinator or router. Hence communication between two RFDs cannot be esablished.

Among all the devices in a PAN, only the PAN coordinator has greater computational resources. It is the only network element which is able to communicate with other networks.

C. ZigBee Protocol stack

Though the ZigBee standard is formed in 2002 but the complete ZigBee protocol specifications were ratified in December 2004 [3]. ZigBee uses the IEEE 802.15.4 PHY and MAC layers to provide standard-based, reliable wireless data transfer (ReferFig. 3). The ZigBee Alliance specifies the Logical Network,Security and Application Software to complete the communication suite. Further the interoperability and inter compatibility between similar products from different manufacturers are provided by ZigBee profiles defined in application layer [12].

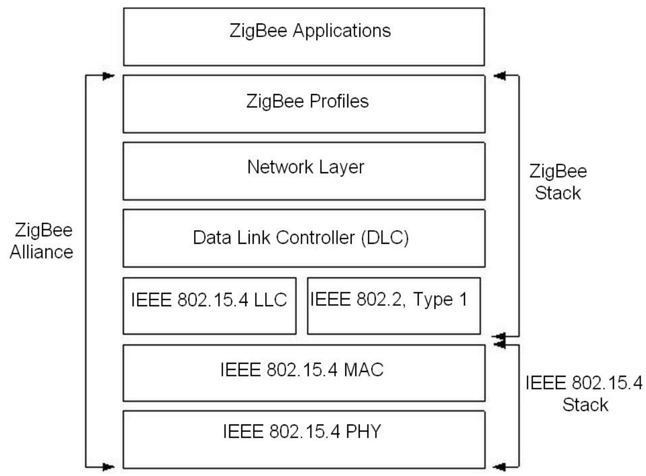

Fig. 3. ZigBee Protocol Stack

The IEEE 802.15.4 provides three frequency bands for communications. ZigBee uses a Direct Sequence Spread Spectrum (DSSS) radio signal in the 868 MHz band (Europe), 915 MHz band (North America) and the 2.4 GHz ISM band (available worldwide). In the 2.4-GHz ISM band sixteen channels are defined; each channel occupies 3 MHz and channels are centered 5 MHz from each other, giving a 2-MHz gap between pairs of channels. ZigBee uses an 11-chip PN code, with 4 information bits encoded into each symbol giving it a maximum data rate of 128 kbps. Currently, ZigBee modules are available with advanced coding and Modulation technique which can provide data rates upto 250 kbps.

D. Network Topology for ZigBee

The network layer of ZigBee supports star, tree and meshtopologies. The ZigBee Alliance’s core specification definesZigBee as an innovative, self-configuring, self-healing systemof redundant, and a very low-power nodes [13]. In meshnetworks each wireless node communicates with the oneadjacent to it as shown in Fig. 4 below. If any one of the nodefails, the information is automatically rerouted to allowdev-icesto go on communicating without the failure of com-munication.Because of their rerouting capability, nodes on a ZigBee canwalk through walls and even communicate with each otherthrough building floors thereby making it suitable to beemployed in office premises, campuses or factory units.

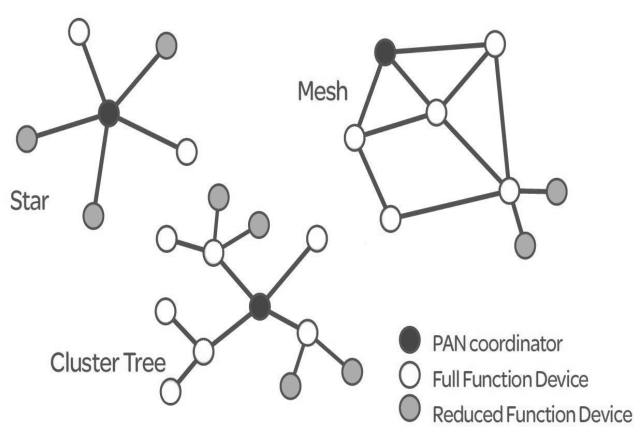

Fig. 4. Network Topology for ZigBee

The star topology being the most common network configuration is useful when endpoints are closely clustered and communicate with a single router node. This helps in reduction of the battery consumption at client nodes. Similarly the tree topology brings together several star networks with the data and control messages being transferred using hierarchical routing strategy.

III. SYSTEM DESIGN

Our designed system is implemented with ZigBee protocol. Its mainly consists of three units viz. User End Control Unit (UECU), Green House Control Unit (GHCU) and Relay Control Unit (RCU). Theblock diagram is as shown in Fig. 5 below:

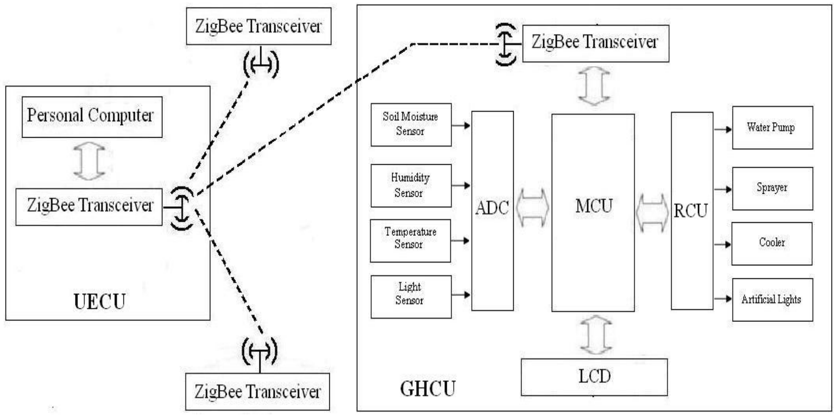

Fig. 5. Block diagram of proposed system

A. User End Control Unit (UECU)

UECUmainly consists of two parts: PC and ZigBee moduleinterfaced with PC via UART (Universal AsynchronousReceiver/Transmitter) port. Module of XBEE Series2 of DigiInc. [8] is used as a part of ZigBee stack. The Xbee radiosare programmed using X-CTU software in Application ProgrammingInterface (API) mode with the desired baud rate[14]. Unlike the Transparent mode (AT mode), the APImode unleashes the full power of the Xbees and allows toconstruct a real wireless network consisting of two or moredevices in the network. The module connected to PC is configured as ZigBeeCoordinator API. A Java based GUI application is developedon PC which enables the user to control the appliances remotely according the status of sensed parameters. Fig.6 shows the GUI windows. This applicationcarries out operations such as switching ON/OFF the appliances andindicating their status.

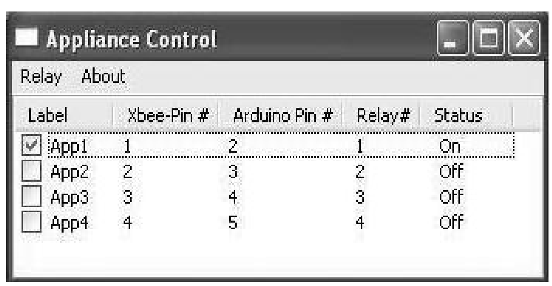

Fig. 6.GUI for Appliance Control.

B. Green House Control Unit (GHCU)

Both UECU and GHCU are wirelessly linked by ZigBee withSTAR topology. At GHCU, the ZigBee transceiver module isinterfaced with the Controller Board and is configured as ZigBee Router in API mode. There are five basic stages for any control process of GHCU:

1) It receives control commands in form of packets from UECU via ZigBee transceivers.
2) Commands are processed by MCU.
3) MCU check the present status, threshold value and compares them to take an appropriate action.
4) Then MCU performs the switching operation of appliances if it'snecessary.
5) Present appliances status is retransmitted towards UECU and GUI window is updated automatically.
6) *Microcontroller Unit (MCU):* Arduino controller board with ATmega328microcontroller serves as MCU which is used to drive theRCU (Relay Control Unit) to turn the appliances ON/OFF. The purpose ofusing Arduino board is because it is an open-

source electronicsprototyping platform based on flexible, easy-to-use hardwareand software [15]. Also the microcontroller on the board(Atmel ATmega328) can be programmed using the Arduinoprogramming language which is similar to the C programminglanguage. The GHCU transceiver Module receives the controlcommands from the UECU in the form of packages and forwardsthose to the controller board. The controller manages thedifferent relays and the XBee radio reads its status andtransmits it back to the UECU.

7) Threshold Set Unit (TSU):TSU is designed by using four push to on switch, interfacing with MCU is ss depicted in fig . Hence it's a customized system; various parameters values can be set by user as per the requirement of particular plant or crop. The functions of various switches are given in table I.

8) Sensing Unit (SU):Sensing Unit consists of an ADC along with the various sensors *viz.* temperature, light, moisture, humidity, PH sensor etc. which sense their relevant phenomenon. ADC converts any input analog sensed value into its equivalent digital output and provides it to the MCU for further processing. MCU keep on updating these values on LCD and whenever it receives command from UECU itfirst checks the present status then provides appropriate control signals to RCU for switching operation of the corresponding appliances. Fig. 7 depicts the LCD display indicating the sensor values.

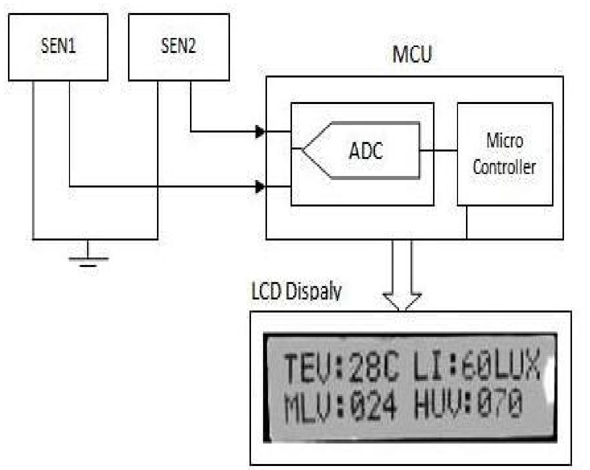

Fig. 7 LCD displaying Sensor values

C. Relay Control Unit (RCU)

The RCU mainly consists of relays and thedriving circuitry used for its operation. As our proposed system controls four appliances, we have designed four relay RCU.These relays serve two purposes:

1) To perform the switching operation of appliances

2) To provide isolation between the controland the loadcircuit.

In the circuit, the transistor is controlled by thecontrol output pin of the MCU[16,17,18] and it drives the relay accordingly.

IV. ESTABLISHMENT OF ZIGBEE NETWORK

In our system communication between UECU and GHCU is established by ZigBee network. UECU side Transceiver is connected to user PC via BAFO cable and it is configured as the network PAN Coordinator. It is unique and has capacity of structuring the network, establishing an addressing scheme, keeping the addresstables. It exchanges the required commands with GHCU side Router. As explained by ZiangQian et. all in star topology Star topology is implemented for our system which is efficient for controlling one greenhouse. Range of the system is limited by the XBee-S2 modules [7,8,9].

A. Mesh Architecture Implementation

The range can be extended using ZigBee's self-forming and self-healing mesh network architecture as depicted in Fig. no 8. In mesh topology control commands and data can be passed from one to another node using multiple paths. Our system is limited to GHCU1 where star network is used but mesh network can extend it to many Greenhouse Units and can monitor the data simultaneously. PAN coordinator communicates with all routers and updates each one. The multiple paths ensure the reliability of communication.

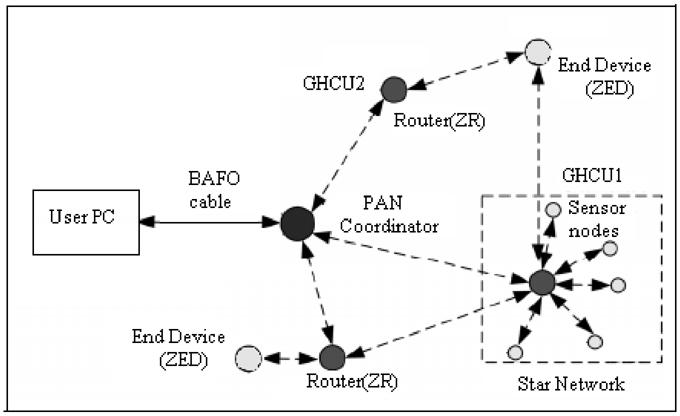

Fig. 8 Implementation of ZigBee Star and Mesh network for GHCU

B. Configuration of XBee modules

We have used XBee-S2 modules have two modes of operation; Transparent (AT mode) and API mode. API mode is enabled in which modules can be configure as PAN coordinator, Router or End Device by using X-CTU software [8].Configuration of XBee transceiver as PAN coordinator is as depicted in fig. no.9

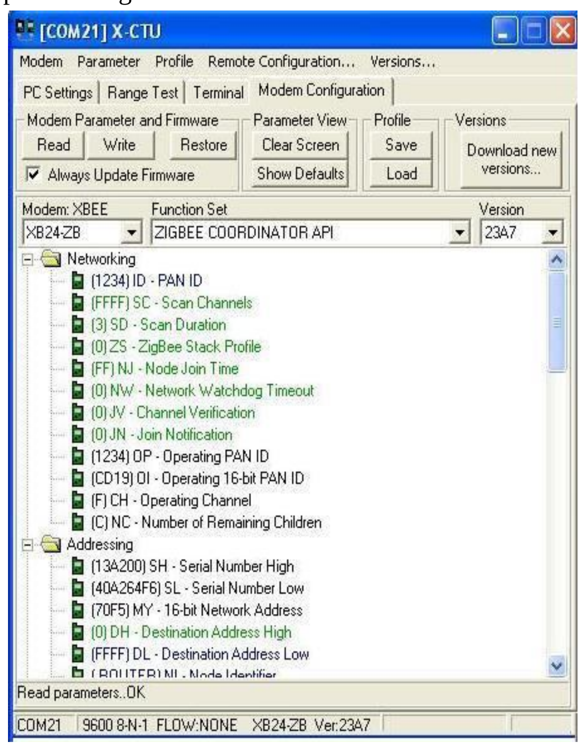

Fig. 9 Configuration of XBee transceiver as PAN coordinator

While establishing the ZigBee network the PAN ID must be same for all the XBee radios, in our case its 1234. Also the Baud rate has to be same for all, Default baud rate is 9600 which can be modified as 115200 using X-CTU API mode.

For operating Coordinator in ‘Broadcasting mode’ its DL - Destination Address Low has to be FFFF as depicted in Fig. For Router DL address is set to 0 which is the default DL Address for Coordinator.

V. IMPLEMENTATION OF VARIOUS SENSORS

Suitableecological conditions required for plantationis influenced by various parameters. These parameters viz. atmospheric temperature, humidity, soil moisture level, Light intensity andpH value of the soil not onlyinfluence thegrowth rateof the p l a n t s but also affectthe photosynthetic and transpiration processes. Sinceallthese parameters are interlinked, a closed loop (feedback) control system is employed inside the green housealong with the various sensors. Thevarious sensorsusedinoursystemare as follow:

A. *Temperature Sensor*

National Semiconductor's LM35 IChas been used for sensing the temperatureinside the green house.The comparison of different temperature sensors is carried out as shown in Table 1. After comparing different parameters of the sensors, LM35 is finalized for the implementation. It is a low cost precision integrated-circuit temperaturesensor and its output voltage is linearly proportional to the input Celsius temperature. Thus the linear output and precise inherentcalibration in terms of Celsius makes it superior than linear temperature sensors which are calibrated in terms of Kelvin scale.

TABLE**1**

Parameters	LM35	S8110C	S813A	MP9700	TMP35
Current drain (mA)	60	4.5	4	6	50
Sensitivity (mV/°C)	10	8.2	11.04	10	10
o/p voltage(V)	1-6	2.4-10	2.4-10	2.3-5.5	2.7-5.5
Range (°C)	-65-150	-40-120	-40-120	-40-150	-40-125

1) *The features of LM35 are as follow are given below*

a) Low current requirement, 60 µA from the supply

b) Very low selfheating, typicallyless than 0.1°C in still air making

c) Wide temperature range [22] from -55 to +150 degreeCelsius

d) Good sensitivity of 10mV / °C

Good sensitivity, linearity and operation over a wide temperature make it suitable for our system.Output of the sensor is amplified using operational amplifier circuitry to convert it into significant output. LM378 is used as operational amplifier with gain of 10. Output is obtained over wide range of temperature. Output is evaluated using following formula:

$$Vout = (Sensitivity)*Tin*Gain$$

The graph of the same is as depicted in Fig. No 10

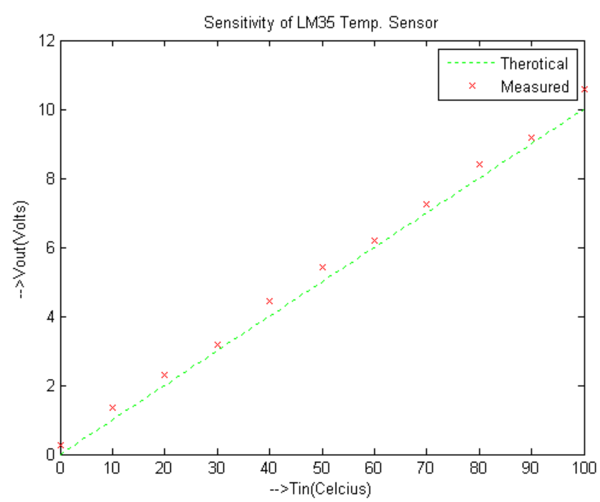

Fig. 10 Sensitivity of Temperature Sensor

B. *Humidity Sensor*

Humidity normally expressed in terms of RH (Relative Humidity) which is the ratio of actual moisture in the air to the highest amount of moisture that can be held by air at the same temperature. Variation in humidity directly affects the transpiration rate from the leaf.

HIH4000 is used as humidity sensor which is ideally suited for low drain, battery operated systems. It just draws 200uA current and its multilayer construction prevents it from various hazards such as wetting, dust, dirt, oils and common environmental chemicals. Along with this it has the following features:

1) Output voltage is linearly proportional to input %RH

2) Chemically resistant and highly accurate

3) High resolution up to 0.5%

4) Extended exposure to >90% RH causes a reversible shift of3% RH

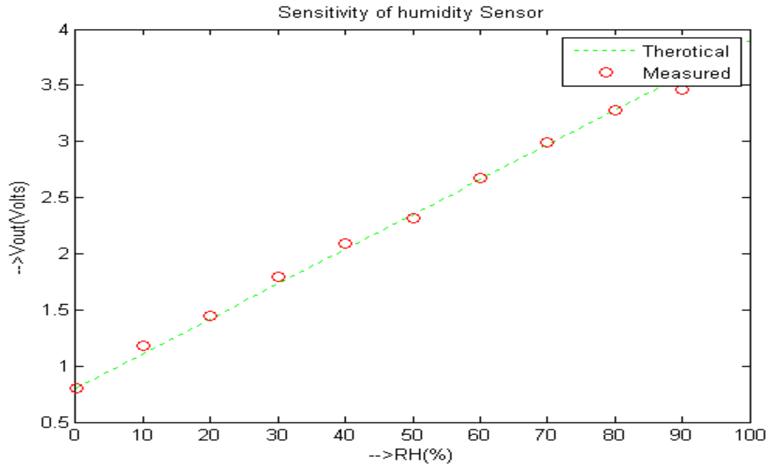

Fig. 11 Sensitivity of Humidity Sensor

According to the change in % of RH, output Voltage is measured and sensitivity slope is evaluated which is almost same as the theoretical one i.e. 31.483mV/% RH. The graph is depicted as in Fig. 11 It is having the zero offset of 0.8V. Output is characterized by the following formulae at temperature of 25%:

$$V_{out}= (V_{supply})(0.0062*(Sensor\ RH)+0.16)$$

C. Soil Moisture Sensor

The content of water held within the soil pores is called soil moisture.Soil water is the major constituent of the soil in relation toplant growth. Absence of water in a sowed land results in arid and barren terrain causing drought like conditions. In order to avoid such circumstances the moisture level of the soil should be maintained. If the moisture content of the soil is optimum above the wilting point, plants can readily absorb soil water which serves as a solvent and carrier of food nutrients for the plant growth [10] [11].

In our system the copper probes are used as moisture sensors which are interfaced to the MCU via ADC. According to the present status of Moisture Level Value(MLV) and threshold value of moisture level which is set by user MCU takes appropriate control action.Present status of MLV is updated continuously in MCU and displayed. Hence the system is able to keep a constant check over the moisture content, thereby automating irrigation whenever necessary. This facilitates an efficient use of water.

MLV is characterized by dryness of the soil. 100% MLV corresponds to very high resistance between the probes which indicates it's a dry soil. It follows the basic principle, as moisture level increases resistivity decreases.

Table{} 100 70t100 30 t0 70 1 t0 30

D. Light ntensity measurement Sensor (LDR)

Light Dependent Resistor (LDR) made up ofCadmiumSulphide (CdS) is used.Two CdS photoconductive cells spectral response is almost similar to that of human eye.It works on the principle of negative co-efficient property. The cell resistance falls withincrease in light intensity. Some LDRs can even work on positive co- efficient property. But our system uses a LDR with a negative resistance property.

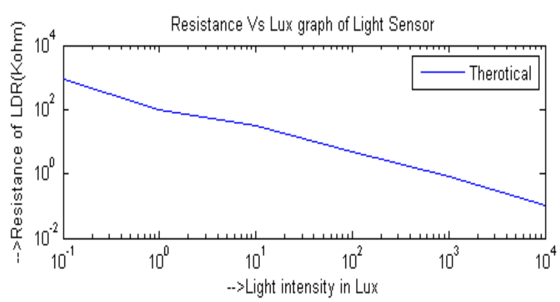

Fig. 12. Resistance as a function of illumination

The LDR sensor is implemented as shown in fig. 13 It uses a 10 kΩ fixed resistor which is supplied by to5VV_{cc}. This topology causes decrease in output voltage with increase in light intensity.Vout of the LDR can be characterized by the following equation:

*Vout = 5*RL / (RL+10)*

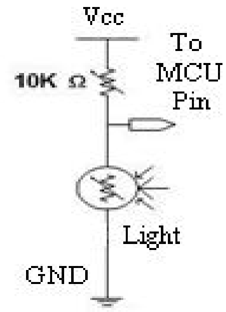

Fig. 13 LDR

Sensitivity of the photoconductive cell establishes relation between the light falling on the device and the resulting output signal. For practical measurement purpose LDR is illuminated under various conditions such as overcast day, bright sunlight, twilight, incandescent bulb, Laboratory light.The analysis of sensitivity of the LDR is as depicted in fig. 14

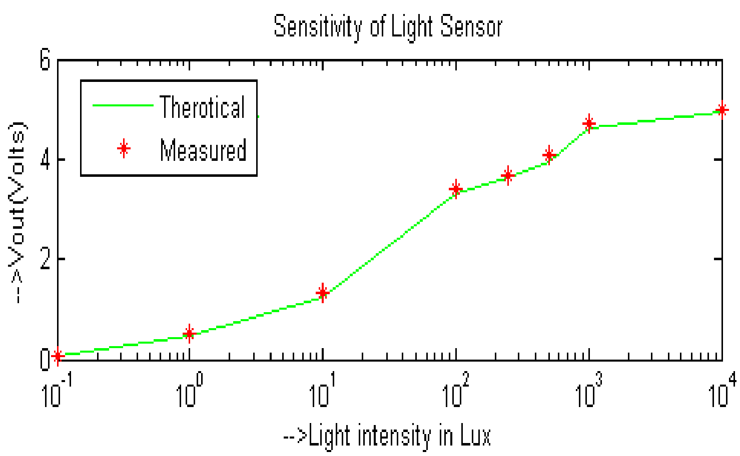

Fig.14. Sensitivity of LDR

Sensitivity of the sensor can be increased by reducing the value of the fixed resistor in series with the LDR.

E. pH sensor

The mixture of mineral nutrients assimilated in the soil that are required to help the plants nourish healthily should be absorbed by the roots efficiently. But depending upon the crop planted the requirement varies which gives rise to dissimilar pH level of the soil. In order to determine this pH level, sensors are implemented deep down the soil. As wired communication to transmit the measured pH value to the remote PC in this case will cause huge inconvenience, hence our proposed system utilizes Zirkon pH sensors shown in Fig.15. It has an inbuilt mechanism which gives us the output in the form of an electrical signal. Zirkon pH sensors are highly sophisticated ones, provides the following features:

1) Provide conductivity less than 150 µS/cm
2) Wide operating temperature range from -5°C to +70°C
3) Have in built temperature sensors embedded in it ; usually PT100 or PT1000.

The sensor which is inserted in the soil transfers the data to the to the central MCU. Here the received pH value is compared with the database present. Accordingly the nutrients which are below the required level are added to the soil from the nutrient deposit, by actuating the relay circuitry. This acts as one of the very important parameters for maintaining the required conditions within the green house for improved crop cultivation.

Fig.15 Soil pH level sensor (Zirkon Series)

VI. CONCLUSION

The ZigBeeis an efficient wireless protocol in terms of powerconsumption, scalability and it also provides a suitable datarate for controlling and monitoring purpose. Hence theemergence of ZigBee revolutionized the automation industry. This paper describesan embedded wireless system built using the ZigBeetechnology. A GUI application developed on the java platformfacilitates controlling of various appliances remotely. Also the MCU continuously monitors thevarious green house parameters and displays on LCD. Our proposed system can be easily implemented and it can open new arenas for the development of the age-old technology used in the field of agriculture all over the world. With the help of this system artificial conditions can be created and crops can be cultivated anywhere on the earth, be it in the arid climate of deserts or cold weather of the Arctic pole.

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