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Development Of An Automatic Monitoring System Of A Greenhouse Environment Using Zigbee

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Abstract- A Greenhouse is a closed transparent environment used for growing plants. Manual system of monitoring the microclimate of greenhouse involves the use of individuals to manually take measurement and regulate the Greenhouse environment at regular intervals. This can affect the crop yield as individuals may be unavoidably absent at a particular time. Wireless sensor network using zigbee technology can be utilized to automatically acquire the microclimate and regulate the greenhouse environment remotely. This work includes identification of parameters affecting plant growth, selection of sensors for the measurement of the identified parameters and the configuration of a wireless sensor and actuator network using SENSEnuts motes to remotely monitor the greenhouse environment. Automatic monitoring using wireless technology will make the greenhouse cheaper, less complex, and easy to manage as the use of wires are greatly reduced in the measurement and control system

Indexed Terms- automatic monitoring Greenhouse, SENSEnuts, and sensors.

I. INTRODUCTION

Agriculture has played a significant role in human development. A lot of efforts have been put in place by different individuals in order to increase food production so as to meet up with demand[1]. Greenhouse farming is considered as one of the ways of increasing crop yield as in enables the regulation of the crop's environment for optimum growth[2]. Continuous monitoring of environmental parameters that have direct influence on quality and productivity of plant grown is required before the environmental regulation. Wireless sensor network is being utilised as a tool in the monitoring and control of greenhouse environment [3]

This paper is aimed at utilising a commercial off the shelf sensors and actuator nodes to develop automatic data acquisition system of a greenhouse environment. This involves the identification of parameters affecting plant growth, configuration of the sensor network using the SENSEnuts platform and data acquisition from the configured Network.

II. RELATED WORK

[4] Developed a remote monitoring system using zigbee protocol that eliminates the use of individuals to manually check the microclimate at regular intervals. The system uses sensor nodes to acquire and send the environment parameters to a central server. The data is saved in Microsoft excel format and is later sent to a farmer for quick response using the drop box technique.

[5] Developed wireless monitoring and control system for greenhouse based on Zigbee that solves the problems of poor real time data acquisition, excessive manpower requirement and the complexity of the wired system of data acquisition. This system uses nodes developed using an ARM processor that transmits signals using Zigbee technology to the VB based web server and android mobile phone via a Wi-Fi or internet connection. The benefits of this system include labour saving and improved quality of produce.

[2] developed a wireless sensor network for greenhouse monitoring by utilising the sensor platform provided by Sensinode Ltd with temperature, humidity, carbon dioxide and light intensity sensors. The network is deployed in a greenhouse where tomatoes are grown with nodes are connected in star topology. The tomato yield has been shown to improve at the end of the season.

III. IDENTIFICATION OF PARAMETERS INFLUENCING PLANT GROWTH

Plant growth has direct relationship with temperature of the air/soil, humidity, amount of sun light and the soil moisture.[6]. It is important to understand how these environmental factors affect plant growth and development.

- Temperature effect on plant growth

The effect of temperature on plant growth is dependent upon the particular plant grown in the greenhouse. Each kind of crop has a range called optimum air temperature range in which it grows and develop rapidly[7]. For most crops the optimum functional efficiency occurs mostly between 55 and 75^0F (12 and 24^0C). Soil temperature has a dramatic effect on seed germination, root development and nutrient absorption by root. When the temperature rises too high, heat destruction of the chloroplast result in cell death. Soil and air temperature of the greenhouse must be monitored in order to provide a favorable atmosphere for proper growth of the plant.

- Light effect on plant growth

Light in plant is used for producing food through photosynthesis. Light intensity is the major factor governing the rate of photosynthesis. The amount of light received by plants in particular region is function of the amount of incident (incoming) light and the length of the day. Crops such as corn, cucurbits, legumes, potato, and sweet potato require a relatively high level of light for proper plant growth while onions, asparagus, carrot, celery, lettuce and spinach can grow satisfactorily with lower light intensity. Understanding of the light requirement of the particular plant grown in the greenhouse will enable the user to monitor and regulate the light for a better yield.

- Humidity effect on plant growth

Plants require a higher humidity when the temperature is high and a lower humidity when it is low. This helps to moderate the transpiration rate of the plant i.e. when it is hot the plant will tend to transpire heavily so by making the RH high this will tend to reduce transpiration and delay the point at which the plant starts to wilt. The converse is also true i.e. when temperatures are low then RH should be reduced. At low temperatures the plant will tend to reduce transpiration (with consequently reduced growth) but by reducing the RH this will tend to raise transpiration back up again. The ideal level for humidity depends on the type of crop to be grown. Plants from tropical climates will need a higher humidity than those native to arid regions. Most greenhouse crops favor relative humidity between 60% and 80% RH.

- Effect of soil moisture on plant growth

Water is required by all living organism. Plants can be stressed by lack of moisture as well as excess of moisture. Water deficit is developed in plants when the rate of transpiration exceeded that of water absorption.

IV. SENSORS SELECTION FOR THE MEASUREMENT OF THE IDENTIFIED PARAMETER INFLUENCING PLANT GROWTH

The parameters influencing the growth of plants are identified and the next challenge is to select the sensors that could allow us to monitor these parameters for the purpose of making the greenhouse environment favorable.

- Temperature and light measurements sensor selected

Careful attention is giving in selecting the sensor that can withstand the high and low temperature of the greenhouse as well as having a high sensitivity and reliability in a suitable range for crop cultivation. Sensor TL module which is a part of SENSEnuts development platform which comprises of a temperature and light sensor is selected for the measurement of the temperature and light of the greenhouse. Both the temperature and light sensors are accessed from I2C port of the radio module. The temperature sensor on the module is a 12-bit resolution digital sensor, which can detect a temperature change of as low as 0.0625^0C. The operating range of temperature sensor is from -25 to 80^0 C. the sensor is capable of working at an extremely low power. The ambient light sensor on the SENSEnuts TL module has a 16-bit resolution with an excellent UV/IR rejection capability. The operating range of light sensor is from 0 to 64k Lux. The sensor is capable of working at an extremely low power. The two sensors in the module are capable of generating software independent interrupt to update the microcontroller about a critical

- Soil moisture sensor selected

Soil moisture sensor-digital output from SUNROM electronics with model number 1282 is used to measure the moisture content of the soil. It obtains volumetric water content by measuring the dielectric constant of the media through the utilization of frequency domain technology. Since the dielectric constant of water is much higher than that of air or soil minerals, the dielectric constant of the soil is a sensitive measure of volumetric water content.

The sensor has a low power requirement and very high resolution. This gives the ability to make many measurements (i.e. hourly) over a long period of time with minimal battery usage. In addition, the sensors incorporate a high frequency oscillation, which allows the sensor to accurately measure soil moisture in any soil with minimal salinity and textural effects.

- Humidity sensor selected

For measurement of humidity SHT75 is selected. Fast response time, low power consumption and tolerance against moisture climate made SHT75 relative humidity and temperature sensor a perfect solution for greenhouse humidity measurement. A capacitive sensor element is used for measuring relative humidity while temperature is measured using band-gap.

V. WIRELESS SENSOR NETWORK ARCHITECTURE AND DEVICES

- wireless sensor network

The wireless sensor network consists of spatially distributed embedded devices called sensor nodes that form multi–hop adhoc network. The sensor nodes will measure the phenomenon of interest within the greenhouse environment and communicate it to a sink node also called data collector/gateway. The gateway node will collect the raw data packets from each node and interface it via a USB to a host personal computer. A single zone-based network deployment is employed where by a node-based addressing scheme with 16-bit node ID is used to identify each node. Fig 1.0 shows the WSAN architecture. A simple star topology was applied where four nodes with temperature, luminosity and humidity sensors measured climate variables and communicated directly with the gateway node. The gateway node acted as a coordinator and received the measured data from the sensor nodes. It was located in the greenhouse entrance hall because the humidity there was 20-30% lower than inside the greenhouse. A laptop computer was connected to the gateway node by USB-cable.

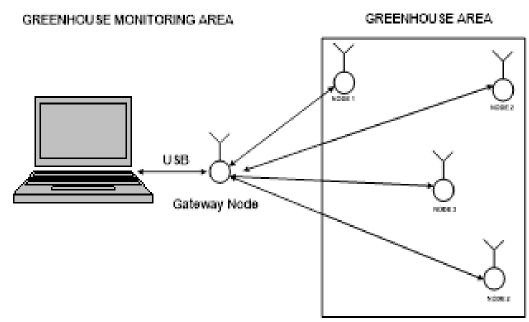

Fig. 1 WSN ARCHITECTURE

- Network devices

According to IEEE 802.15.4, there are three configurations of a device possible. They are PAN coordinator, Coordinator and a Reduced Function Device (RFD). It must be noticed that in SENSEnuts, any mote can be configured in any of the three mentioned devices.

- PAN coordinator

PAN Coordinator initiates the network. It performs an energy scan and selects the quietest of the available channels (11-26 channels) and starts a PAN over the same. It selects a PAN ID and allocate to the personal area network. It also allocates a node ID to the nodes in the network.

- Coordinator

The coordinator will start an active scan and check all the channels (11-26) to determine the channel on which the PAN is set based on the link quality. Getting to the channel on which the PAN is set the PAN coordinator will respond saying that a PAN is set here and this is the PAN ID you can now associate with me. The coordinator will now send associate request to the PAN coordinator and the PAN coordinator will respond by giving a node ID to the coordinator.

- Reduced function device (RFD)

Reduced function device cannot act as a router and they can send the data only to the coordinator they are associated with.

VI. SENSENUTS PLATFORM

SENSE-nut platform developed by Eigen-technologies includes wireless sensor node and the GUI used for configuring the node and the display of the data collected from the nodes[8]. SENSEnuts is widely suited for greenhouse application. Wide range of sensors can be connected with the motes depending upon the requirement of the application. Environment monitoring, home automation, agriculture monitoring, industrial control, location tracing are few other applications that can be achieved using SENSEnuts platform.

- SENSEnuts hardware modules

The hardware of the SENSEnuts devices used in developing the wireless sensor network are modular and easy to use. They include:

1. Radio module
2. Gateway module
3. Sensor module
4. Battery pack module
5. Extender module

- Radio module

The radio module is powered by Jennic JN5168 wireless microcontroller which is powerful and specifically designed for IEEE 802.15.4 based applications. With an extremely low power consumption and low form factor. The processor is suitable for battery and portable devices. It has UART, I2C, SPI and ADC communication ports. It has the following features:

a. IEEE 802.15.4 transceiver with integrated antenna
b. 32-bit RISC processor with a dynamically adjustable clock frequency
c. Dynamically controllable power
d. 128-bit AES security processor

Figure 2.0 Radio module

- Gateway module

USB gateway module is the bridge between SENSEnuts IEEE 802.15.4 network and the user interface. It enables the programming of the radio module and displays the data that is coming from the network on a personal computer. The gateway module is connected to computer by a USB mini cable. Some of the features of the gateway module are:

a. USB to asynchronous serial data transfer interface
b. 128 byte receive and 256 byte transmit buffer for faster transmission
c. Data transfer rate at 115200 baud
d. USB protocol is handled by the module

Figure 3 Gateway module connected to PC

Sensor module

Depending on the parameter to be measured some of the sensor modules available to the SENSEnuts platform include: sensor TL module which measures temperature and light. The sensor module is mounted on top of the radio module for sensing the temperature and light of the area of the greenhouse.

Figure 4 Sensor module

- SENSEnuts GUI

SENSEnuts GUI is a program that runs on Windows Operating System. It is used to program the SENSEnuts Radio Modules as well as display the data received from the network made up of sensor motes. The GUI is a collection of three separate programs (see fig.5.6), performing a separate function, namely Device Programmer, SenseLive and Print Window. When we start the GUI, the default program that opens is Device Programmer.

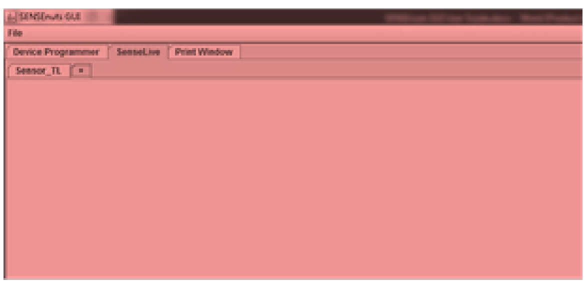

Figure 5. SENSEnuts GUI

- Programming SENSEnuts motes

Depending on whether a device is to act as PAN coordinator, coordinator or RFD in the network, the device is configured according to the algorithm written in C language using Eclipse IDE. The steps below are taken in programming the motes

a. Open the SENSEnuts GUI program
b. Connect the device to the PC through the gateway using the mini USB cable
c. Once detected the message "Device found" will be displayed on the GUI
d. Click on browse option to go to the location of the compiled binary file
e. Select the bin file to be flashed and click on Download button and wait until the microcontroller is programmed.
f. On the process of flashing the radio, a LED blinks continuously
g. Once completed the blinking stops and the device is now ready to be use in the network

- Data collection

Sensor_TL is a section of the GUI that presents the real-time data as receive from all the motes in the network. It displays the Node ID, the temperature in "degree Celsius" and the light intensity in "lux". This part of the window saves the data in SQL format. Hence the data can be analyzed later with the help of SQL queries.

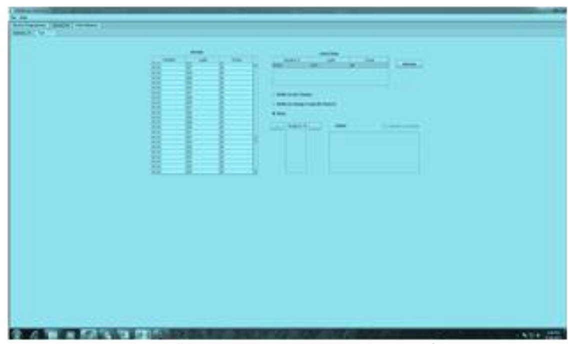

Figure 6 Live data display on PC from sensor nodes in the Greenhouse

CONCLUSION

The use of wireless sensor network to automatically acquire the greenhouse microclimate using the SENSEnuts platform has presented a solution to the possibility of the crop damage when utilising the manual method of greenhouse monitoring.

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