Greenhouse Micro Climate Monitoring Based On WSN with Smart Irrigation Technique

Mahmoud Shaker, Ala'a Imran

Abstract**—**Greenhouse is a building, which provides controlled climate conditions to the plants to keep them from external hard conditions. Greenhouse technology gives freedom to the farmer to select any crop type in any time during year. The quality and productivity of plants inside greenhouse is highly dependent on the management quality and a good management scheme is defined by the quality of the information collected from the greenhouse environment. Therefore, Continuous monitoring of environmental variables such as temperature, humidity, and soil moisture gives information to the grower to better understand, how each factor affects growth and how to manage maximal crop productiveness. In this piper, we designed and implemented climate monitoring with irrigation control system based on Wireless Sensor Network (WSN) technology. The designed system is characterized with friendly to use, easy to install by any greenhouse user, multi-sensing nodes, multi-PAN ID, low cast, water irrigation control and low operation complexity. The system consists of two node types (sensing and control) with star topology on one PAN ID. Moreover, greenhouse manager can modifying system parameters such as (sensing node addresses, irrigation upper and lower control limits) by updating corresponding data in SDRAM memory. In addition, the designed system uses 2*16 characters. LCD to display the micro climate parameters values of each plants row inside the greenhouse.

Keywords**—**ZigBee, WSN, Arduino platform, Greenhouse automation, micro climate monitoring, smart Irrigation control.

I. Introduction

THE plant growth is mainly affected by the surrounding environment parameters like Humidity, Temperature, carbon dioxide concentration, Light intensity, water and fertilizers supplied by irrigation. These variables have direct influence on crop healthy and productivity especially in the regions where the climatic conditions are extremely harsh or no plants can be grown outside. To solve this problem, Greenhouse cultivation is used. It provides controlled environment conditions around the plants and Protect crop from external hard conditions. by this job, greenhouse become a very interested technology to obtain optimal growth of plants, improve crop quality far from diseases and it enables farmers to select any plant in any place at any time [1], [2]. Most of the typical systems have mostly been developed based on wired utilities. The wired systems limited easy installation and extension ability and increased maintenance costs. Therefore, wireless technology eliminates this limitation [3].

Wireless Sensor Network (WSN) is becoming an important solution for greenhouse environment management. It is a collection of sensors and actuators devices linked by a wireless medium to carry out distributed sensing and acting functions. Each node in the WSN is composited from four subsystems working to gather to perform node's task with limitation in power source [4], [5]. Generally, WSN provides advantages in cost, size, power, flexibility, and distributed intelligence.

Many wireless technologies are now available on the market and support wireless sensor network applications. Among these emerging wireless technologies, ZigBee was reported as one of the most exploited wireless technologies. ZigBee is an open and global standard aiming at a low rate, low cost, low power consumption and self-forming wireless communication [6].

The aim of this practical work is the optimization of the production process inside the Greenhouse through the monitoring of the climate conditions close to or surrounded plants and controlling irrigation water by using a modern wireless sensor network. The designed system is tended to be cheap, friendly in use, install by any greenhouse user, and robust.

II. Overall System Design

We developed Micro climate monitoring system for greenhouse plants with a new irrigation system as shown in Fig. 1.

Star network topology is established to monitor the micro climate close to plants and control irrigation process as shown in Fig. 1, system deployment includes multi-WSN each one is responsible to monitor and control one plants row inside the greenhouse. The system is mainly consisted of two node types; sensing node and control node. Sensing nodes are deployed inside the greenhouse among plants to measure climate parameters (Temperature and Humidity). Each sensing node transceiver module is configured to work as ZigBee end device (ZED). On the other hand, Control node is fixed near to the solenoid valve. It is responsible to drive actuators, start network, and manage network data traffic.

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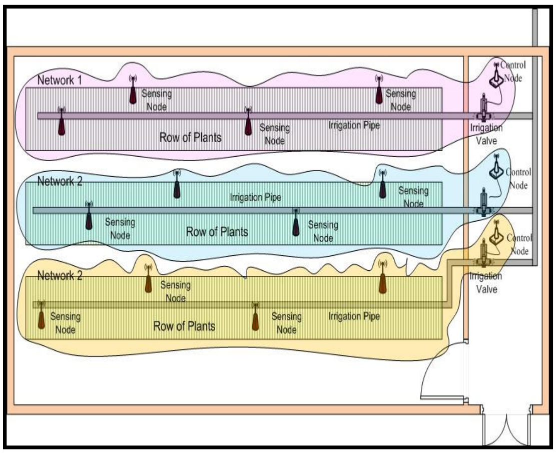


Fig. 1 Overall system layout

III. System Implementation

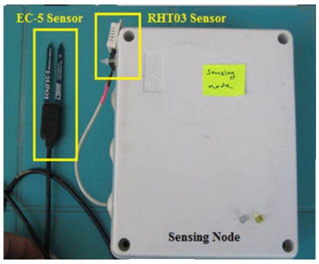
As shown in Fig. 1, the present system is contained two node types. In the following sections each node will describe in details.

A. Sensing Nodes

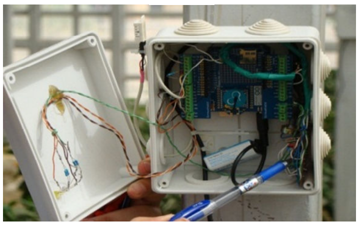
The practical work to design each sensing node as shown in Fig. 2 consists of hardware and software parts. The following paragraphs describe each part:

- Sensing Subsystem

DHT22 and EC-5 sensors are used to measure humidity, temperature, and soil moisture respectively. DHT22 sensor [7], as shown in Fig. 3, is digital output humidity and temperature sensor manufactured by Shenzhen Shijibaike Electronics Co., Ltd. It has fast response time, good accuracy, and high resolution. Moreover, it uses one wire protocol to transfer data to processor subsystem.



(a)



(b)

Fig. 2 Sensing node (a) Sensing node with environment sensors (b) Sensing node circuit

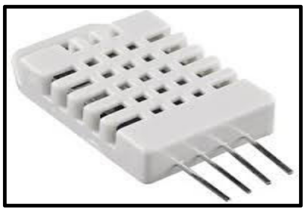


Fig. 3 DHT22 sensor

EC-5 sensor [6], as shown in Fig. 4, is a FDT type working at 70MHz frequency. EC-5 measures VWC from 0 to saturation and allows accurate measurement of all soils with a wide range of salinities.

According to its characteristics, the maximum and minimum values of the analog output from EC-5 sensor depend on excitation voltage value. So the excitation voltage stability is a very important factor in the sensor accuracy. Since the voltage available 3.3V so it is necessary to design a circuit with an output of stable 2.5V, we designed an electronic circuit to ensure excitation voltage stability as shown in Fig. 5.

Fig. 3 EC-5 Sensor

- Processor Subsystem

Amega382P microcontroller [8] is used to process data coming from sensor subsystem or communication subsystem. We select this type of controller due to several reasons includes flexibility in programming, energy consumption, durability, and low-price. Arduino platform is used to drive this controller.

Both sensors are stilled inactive all the time and the controller uses control signal to enable one sensor at a time to read sensor data. by this mechanism, power consumption is achieved.

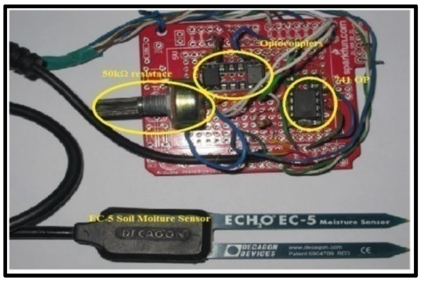


Fig. 4 Practical excitation circuit for EC-5 sensor

- Communication Subsystem

In this work, XBee series 2 is used as transceiver module [9]. XBee module is manufactured by Digi International® Inc. XBee module is designed to operate within the ZigBee protocol and support the unique needs of low-cost, low-power wireless sensor networks. X-CTU is used program to configure this module as follow:

- ZigBee end device.
- Cyclic sleep mode.
- Specific personal area network ID.
- Set the coordinator address (Control node) as destination address.
- Select PAN ID by using variable resistance (bot).
- Power Subsystem

9V (350 mAh) battery is used to power each sensing node. In order to extend node life and save power consumption, the designed system includes:

i. All sensors are inactive. When controller needs to know a specific parameters value, it enables the corresponding sensor for short period (sensor response time), read sensor output, then turns sensor OFF again.
ii. Atmeag328P spends almost time in sleep mode. It wakes up immediately when serial data received via UART port. We used Ideal sleep mode at the same time, we disable all function which they are do not use in this project such as Timers, Analog Comparator, Serial Peripheral Interface, Two Wire Interface module, and watch dog timer.
iii. XBee is configured to enter cyclic sleep mode.
iv. The system enter long waiting period (more than 20min) before starting a new cycle.

- Software

The microcontroller program is explained in Fig. 5. The node still waits serial data from UART to wake up and start collecting environment data. Finally it sends collected data in packet to control node.

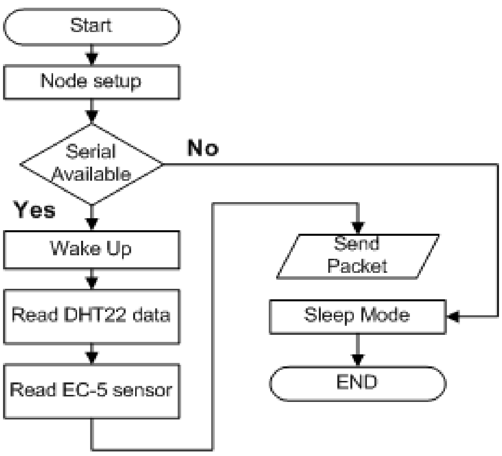


Fig. 5 Sensing node flow chart

B. Control Node

The control node has the following tasks:

- Selects PAN ID.
- Collects data from sensing nodes and calculates average value for each measured parameter.
- Display the average values of (temperature, humidity, soil water content) in the LCD.
- Display valve status.
- Saves the threshold values of irrigation control process.
- Perform control functions and drive actuator.
- Set the total number of sensing nodes in the network.

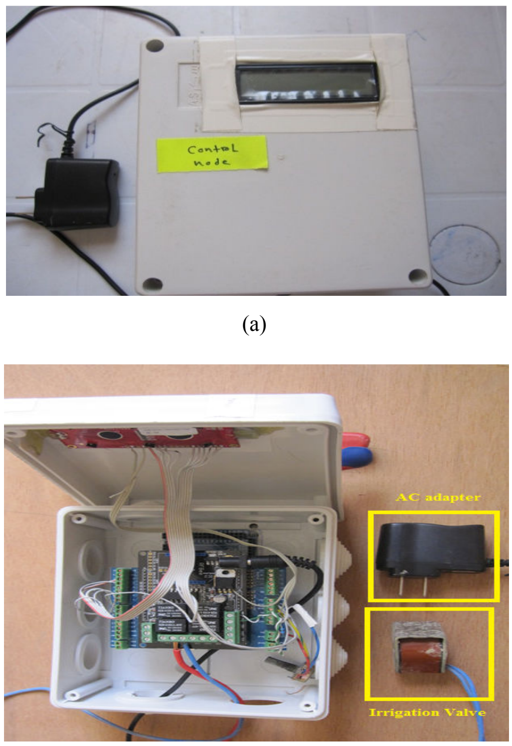
Fig. 6 shows control node. Similar to sensing node, control node consist of hardware and software parts. These parts are:

- Actuators Subsystem

Control node implemented actuator subsystem instead of sensor subsystem. Two actuators types are used with this node, relay and 2*16 characters LCD. Relay is used to drive the irrigation valve while LCD is used to display the collected average values of each greenhouse parameters in the one network and valve status.

- Processor Subsystem

Atmega328P microcontroller is used to process collected data from sensing nodes, control irrigation valve, and display parameter average value on LCD screen. On other hand, the controller loads both sensing node addresses and control thresholds from SDRAM memory.



(a)

(b)

Fig. 6 Control node (a) LCD screen on control node (b) Control node with irrigation valve and AC adapter

- Communication Subsystem

XBee series 2 module is used here also. It is configured to work as ZigBee coordinator in the network. When the controller needs to communicate with specific sensing node (ZigBee end device), it firstly sets the address of that sensing node as a destination address on the control node (ZigBee coordinator) then it can send/receives packet. All sensing nodes addresses which the control node deals with are stored in SDRAM memory. If the greenhouse manager required to modifying the network topology, it should modify addresses table in the SDRAM.

- Power Subsystem

Control node is powered by voltage supplying AC line. So that power saving is not important here and the control node stills wake up all the time.

- Software

The microcontroller program flowchart is illustrated in Fig. 7 and can be summarized in the following points:

- Reads addresses of sensing nodes and irrigation control thresholds from the SDRAM.
- Sets PAN ID by using variable resistance (bot) (AT command mode is used to configure XBee PAN ID from the controller) as shown in Fig. 8.
- Sets transmission destination address depending on addresses table.
- Sends beacon message to each sensing node.
- Wait sensing node response then read received data.
- Perform average algorithms.
- Perform control algorithm.
- Display collected data on the LCD.

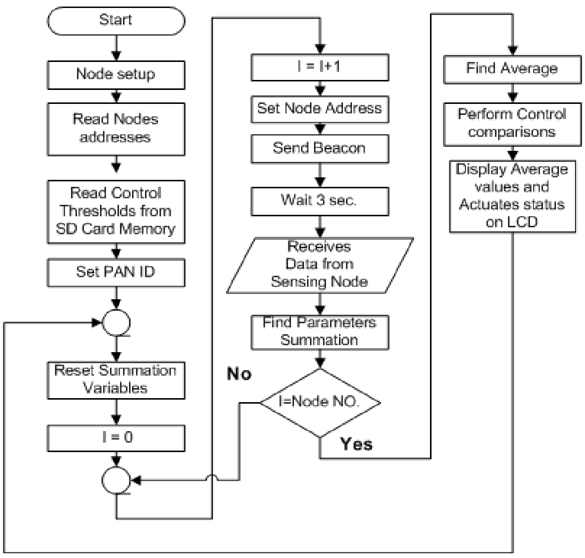


Fig. 7 Control node flow chart

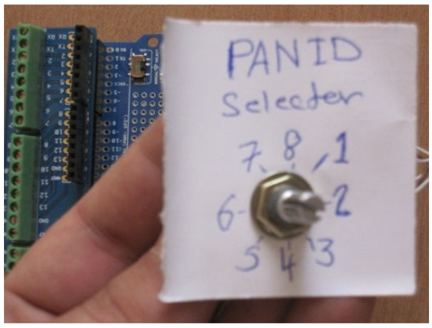


Fig. 8 Control node PAN ID selector switch

IV. System Operation

The operation steps of the designed system are shown in Fig. 9. These steps are summarized as follows:

- The network starts to work after control node turn ON.
- After that, ZigBee network coordinator (XBee module at control node) starts to establish ZigBee network.
- Set XBee module PAN ID using AT command mode.
- The controller starts to load all system information from the SDRAM. System information sets by greenhouse manager according to system and plants requirements. This information includes table of sensing node addresses, irrigation thresholds, and total number sensing nodes.
- The control node starts to send series of beacon messages to different destination addresses to collect information from sensing nodes.
- While coordinator node receives the response of beacons from each node, it preforms averaging algorithm.
- At this moment, all the information is available at the control node to control irrigation water. It starts to compare the soil moisture average value collected by all sensing nodes with its corresponding upper and lower limits which it has been set by the user. By this method, the coordinator node takes decision to turn actuator ON or OFF.
- Display collected average value on the LCD with valve status.
- Finally, control node enters waiting period for 30min. when this period finished, it starts anew monitoring and controlling cycle.

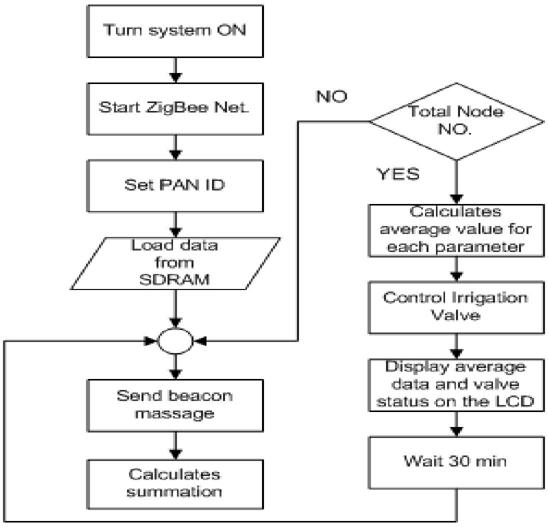


Fig. 9 System operation flowchart

V. Results

The experimental work has deployed in the greenhouse available in the college of agriculture / university of Babylon with (20m*10m) dimension as shown in Fig. 10 in order to monitor the micro climate conditions and controlling water irrigation. According to the following results obtained, the designed system presented in this paper gives very excellent results and manages irrigation process efficiently.

Fig. 10 Practical system deployment

The system monitored real-time temperature, humidity, and soil moisture as shown in Fig. 11. After implementation and testing the designed system, we show that it was stable and no error detected.

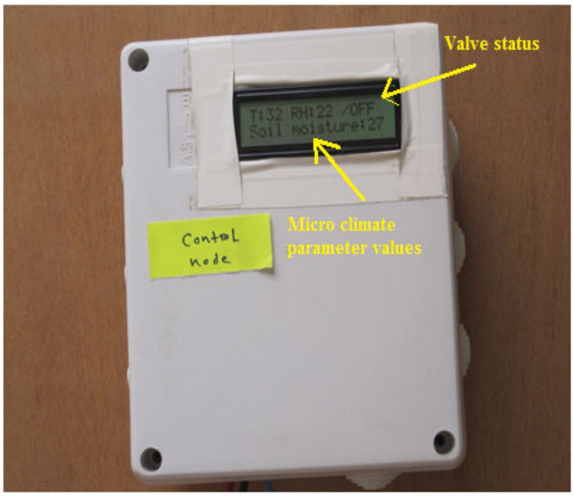


Fig. 11 Monitoring micro climate parameters and irrigation valve Status

Fig. 12 shows the micro climate conditions monitored by the designed system for 16 hour.

VI. Conclusions

During the realization of the presented work in the aspects, design and implementation, the following points are concluded:

1. The interesting in WSN comes from the good features of this technology such as small size, cheap devices, mobility, scalability, and low cost with respect to instillation or maintenance. Typically, WSN are using to collect, process, control, and monitor scattered information wirelessly over large area.
2. ZigBee protocol is emerging wireless technology. It supports low cost, low data rate, low power consumption, communication range about (40m), self-organize, and self-healing. So that, it is best choose to use with WSN.
3. The quality and productivity of plants inside the greenhouse is highly dependent on the management quality. Therefore, continues monitoring of the conditions near to the plants and water irrigation adjusting will allow for maximum crop yield.
4. In this work, we designed micro climate monitoring and irrigation control system based on WSN. The system has the ability for real-time monitoring the temperature and humidity surround plants and controlling soil water contain to obtain maximum crop growth in the greenhouse.
5. The system depends on high accuracy and short time response sensors to collect climate data to extend life time of the system.
6. The designed system supports multi-sensing nodes. We performed this option to increase system reliability; the greenhouse manager can add, remove and relocate sensing node according to needing after deployment. He/she should select same PAN ID on both sensing node and control node and let the system work.

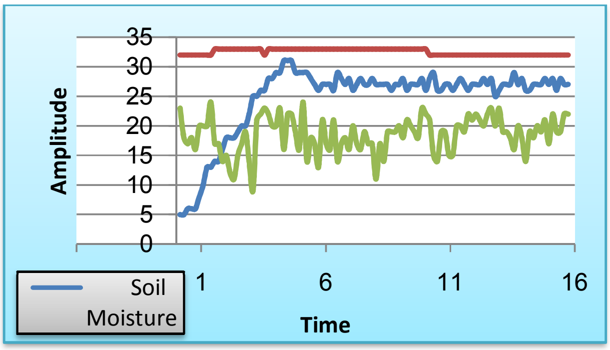


Fig. 12 Micro climate monitoring results

7. Greenhouse manager can modify the total number of sensing nodes, irrigation control thresholds, and sensing nodes address easily by modifying corresponding valve in the SDRAM and insert it in control node.
8. The system was installed practically in 20m*10m*5m prototype greenhouse of agriculture faculty/Babylon University. The obtained results were expected, satisfied many specialists from agriculture faculty praised the results and they tell us that the system is very efficient.

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