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INTERNET OF THINGS TECHNOLOGY FOR GREENHOUSE MONITORING AND MANAGEMENT SYSTEM BASED ON WIRELESS SENSOR NETWORK

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ABSTRACT

Agrotech plays an important role in the production of out-of-season fruits, flowers and vegetable as well as high value and sensitive plants. The greenhouse concept has been widely used in precision agriculture to acquire the best quality for the production of fruits or vegetables. However a fully automated system, taking into considerations the different phases of plant growth and the optimal requirement by the plants during these growth periods and cycle is not fully designed and available. The optimal plant growth depends on several parameters such as irrigation, soil moisture, humidity, and temperature, radiation of light, pH level, and CO^2. Thus, this project develops an automated scheduler system by considering with all optimal plant growth requirements for every each phase of the plant to ensure that all subjects (mango) will grow perfectly. Main hardware component within project is Memsic, Zigbee and smart phone for display while MP Lab and LabView are used for software elements. It is anticipated, by using this system labor and maintenance cost will be cheaper and the process of monitoring and collecting data or information is more easy and efficient.

Keywords: internet of things, wireless sensor network, scheduler.

INTRODUCTION

The Internet of Things (IOT) will be one of the most sophisticated technology trends of the next decade, with sweeping implications for business and policy maker. It is estimated that the potential economic impact of the IOT to be $2.7 to $6.2 trillion per year by 2025 through improved operational efficiencies as well as new revenue-creating products and services [1]. This indicates that the world will focus on IOT for various applications which includes agro-tech to increase production and quality of the product.

This project designs a concept of scheduling to monitor real-time plant growth and ensure it maintains optimum conditions by introducing interventions based on the growth phases. This concept of scheduling realizes a fully integrated and automated greenhouse monitoring and management system. This system is flexible to suit many types of plants in the greenhouse. A wireless sensor network (WSN) generally consists of a large number of low-cost and low-power multifunctional sensor nodes that are deployed in a region of interest. The sensor nodes communicate wirelessly over short distances and are capable of organizing themselves in an autonomous multi-hop mesh network [2]. Thus, WSN is used as part of the technology to be deployed in this system. These sensor nodes collect information about the greenhouse parameter and communicate over a network to a computer system which is called a base station [3]. Then the system will react according to the schedule that has been implemented.

Network architecture

The WSN was implemented using a tree topology in beacon enable mode (data being sent continuously without interruption) where sensors collected data and sent it to a base station which is the task manager of the network. The proposed WSN architecture is shown in Figure-1. A few sensor nodes serving as transmitter have been designed to collect, process, and transmit the data in real time. The system operates within a range of 100m from the base station and is suitable for monitoring of greenhouse.

The base station, which is the network coordinator manages the activities of the individual nodes by periodically requesting data. In addition to the data integration and analysis, the base station also relays processed data to display device [5, 6]. The base station equipped with an MIB520 for system coordination, a receiving Memsic and a WiFi module for wireless communication and data transmission over the 802.1b/g wireless network, which make it possible to access the data collected via the internet. In addition, the captured data inserted into MySQL database where LabVIEW is used to display data.

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Figure-1. Network architecture[2].

Mango crop selection

Perlis is known as the state in Malaysia that is famous for mango fruit. Perlis mangoes are a clone of MA 128 and is among the best breed in Malaysia which is known as Harumanis. Harumanis mangoes got its name from a fragrant aroma and the sweet taste. The main factor of these mangoes is different from others because of the production of mango that very limited and Harumanis is not suitable for growing in other states. [7] Mangoes crop needs a few basic requirements to grow well and giving a higher production is shown in Figure-2.

Figure-2. Mangoes crop requirement [8, 9].

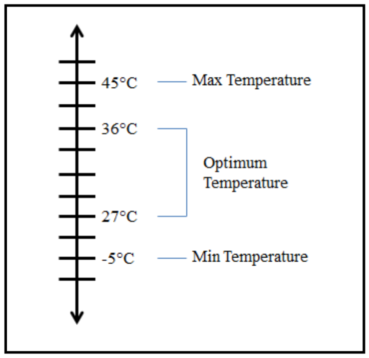

Figure-3. Temperature for mango tree [8].

Mango tree will grow and produce well in area within very high temperatures (45 °C) and very low temperature above (5 °C). However, when the maximum and minimum temperature exceed its value, vegetative growth ceases, especially if it is accompanied by low humidity. For optimum growth and production, the average maximum temperature should be between 27 °C and 36 °C as shown in Figure-3 [8].

The rainfall should also preferably not exceed based on the Table-1. The relative humidity and rainfall describe are ideal for the development of disease-free fruit, but unsuitable for optimum production because mango are produced under such low-rainfall conditions irrigation is of vital importance.

Table-1. Ideal distributed rainfall for developing disease-free fruit [8].

Month	Rainfall
January	140mm
February	140mm
September	50mm
October	85mm
November	110mm
December	140mm

In the tropical and subtropical regions, mangoes grow well at altitudes ranging from sea level to 1200m [8, 9]. However, production decreases at higher altitudes as shown in Figure-4. Mangoes also will grow best in soils with pH values of 6 to 7.2. At pH values lower or higher than 6 to 7.2, the trees may suffer trace element deficiencies, especially phosphate and potassium based on Figure-5.

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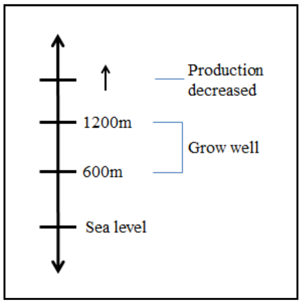

Figure-4. Elevation for mango tree[8, 9].

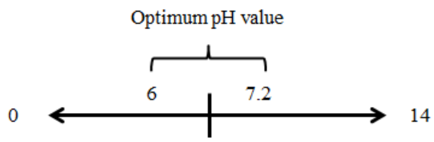

Figure-5. Optimum pH value of mango tree [9].

Greenhouse experimental setup

A. The greenhouse environment

This experiment was carried out at the UniMAP Agro-tech greenhouse based on Figure-6. The size of the greenhouse is 18mx80m based. The Harumanis mangoes are growing well in the greenhouse. Figure-7 shows the architecture of the system that divided into three main tasks which is measuring, calculating and adjusting [11, 14]. The measured values of the greenhouse climate variables are first converted from analog to digital and then transmitted to the computer. From the data received the system will calculate if there is maximum and minimum requirement not achievable at the control panel and it will adjust the requirement needed until it pass the optimum requirement value. [13]

Figure-6. Greenhouse at UniMAP Agrotech.

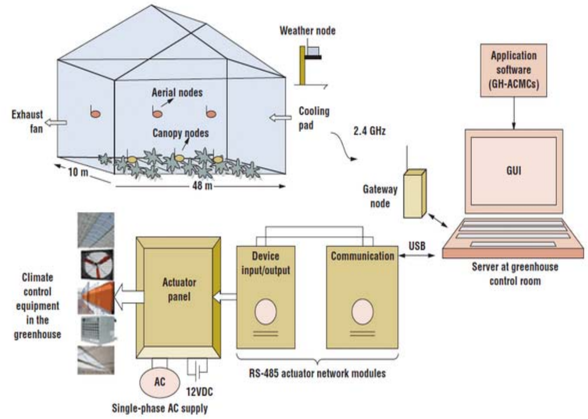

Figure-7. Architecture of the system.

B. Transmitter node

To achieve a powerful, efficient network, open source and low-power consumption hardware were used to implement the transmitter. The function of the transmitter node is summarized below [15]:

- Collect continuous and real time sensor data from each sensor
- Process the inputs from each sensor using corresponding sensor code
- Transmit the processed data to the base station periodically for further analysis and display.

Developed in conjunction with UC Berkeley and Intel Research Labs, the MTS400 and MTS420 offer five basic environmental sensing parameters and an optional GPS module shown in Figure-8. These sensor boards utilize the latest generation of IC-based surface mount sensors. These energy-efficient digital devices in turn provide extended battery-life and performance wherever low maintenance field deployed sensor nodes are required. These versatile sensor boards are intended for a wide variety of applications ranging from a simple wireless weather station to a full mesh network of environmental monitoring nodes. Applicable industries include Agricultural, Industrial, Forestry, HVAC and more.

Figure-8. MTS400 as nodes [15].

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1. Sensor

a) Temperature sensor

Temperature sensing technology is one of the most widely used sensing in the modern world. It allows for the detection of temperature in various applications and provides protection from excessive temperature excursions. Currently there are four different families of temperature sensors available on the market.

Figure-9. Integrated circuit (IC) temperature sensor [16].

Integrated circuit (IC) temperature sensor is semiconductor devices that are fabricated in a similar way to other semiconductor device such as microcontrollers as shown in Figure-9. In low cost application most of the sensor stated above is either expensive or require additional circuits or component to be used. However, IC temperature sensors are completed silicon based sensing circuits, with either analog or digital output. The IC temperature sensor is often used in applications where the demand is low [10].

b) Humidity sensor

A humidity sensor measures and regularly report the humidity level in the air. They can be used in homes for people with illness affected by excess humidity, as part of home heating, ventilating, and air conditioning system. Humidity sensor can also used in cars, office and industrial system, and in meteorology stations to report the predict the weather. When it comes to humidity sensing technology, there are 3 types of humidity sensor.

Figure-10. Capacitive humidity sensor [17].

Capacitive humidity sensors are widely used in industrial, commercial, and weather telemetry applications as shown in Figure-10. It consist of a substrate on which a thin film of polymer or metal oxide is deposited between two conductive electrodes. The sensing surface is coated with a porous metal electrode to protect it from contamination and exposure to condensation. The substrate is typically glass, ceramic, or silicon. The changes in the dielectric constant of a CHS are nearly directly proportional to the relative humidity of the surrounding environment [4].

c) Light sensor

Light from the sun is responsible for nearly all life on the earth. Sunlight fuels the process of photosynthesis where plants convert carbon dioxide and water into carbohydrate. Plant uses light in the range of 400 to 700 nanometers. This range is most commonly referred to as PAR (photo-synthetically active radiation). Monitoring PAR is important to ensure their plants are receiving adequate light for photosynthesis. Typical application includes forest canopies, greenhouse monitoring etc.

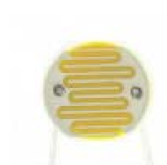

Figure-11. Light depending resistor [18].

Light Dependent Resistor (LDR) measure visible light as seen by human eye and it's similar to photometric sensors as shown in Figure-11. LDR is basically a resistor that has internal resistance increase or decrease depending on the level of light intensity impinging on the surface of the sensor.

d) Soil moisture sensor

Moisture is undesirable, whether it appears in agriculture, houses, packaging materials, textile, electronic appliance or food process. Moisture detection is important in a number of different situations. Measurements of soil moisture are useful for minimizing the amount of irrigation water applied for growing plants and for optimizing plant growth. Because of the importance of knowing the moisture content of materials, various techniques have been developed to measure it.

Figure-12. Frequency domain reflctometry (FDR) [19].

Frequency Domain Reflctometry (FDR) is sometimes referred as capacitance sensor as shown in Figure-12. Soil sensor probes use the FDR method of soil moisture measurement employ an oscillator to generate an electromagnetic signal that is propagated through the unit and into the soil. Part of this signal will be reflected back to the unit by the soil. This reflected wave is measured by

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the FDR probe, telling the user what the water content of the soil [6].

e) Carbon dioxide sensor

Carbon dioxide CO^2 is one of the most common by-products of living organism. The gas itself is safe in low concentration it could be life threatening. Measuring CO^2 is important in monitoring indoor air quality in many industrial processes. Two types of CO^2 detectors are available to measure CO^2 levels in the environment.

Figure-13. Electrochemical CO^2 sensor [20].

Solid state electrochemical (SSE) CO^2 sensor adopts a galvanic structure with a sodium ion conducting electrolyte of beta alumina, operating at 450°C as shown in Figure-13. Carbonate based sensing material is deposited on one side as a sensing electrode and counter electrode is attached on the other side as a reference electrode. When the sensor is exposed to the environment, the sensor will generate a voltage output with respect to the level CO^2 in the environment. Their application includes greenhouse, farming, landfill gas monitoring, indoor air quality motoring and hazardous area warning signals[12].

C. Base station

The base station was constructed using open source and low consumption hardware. The function of the base station is summarized below:

- To coordinate the transmitting nodes by sending periodic data request
- To receive data from all transmitting nodes in real time
- To relay the received data for display to the device as remote visualization

Figure-14. MIB520 as base station and gateway [21].

The MIB520CB provides USB connectivity to the IRIS and MICA family of Motes for communication and in-system programming. Any IRIS/MICAz/MICA2 node can function as a base station when mated to the MIB520CB USB interface board as shown in Figure-14.

In addition to data transfer, the MIB520CB also provides a USB programming interface. The MIB520CB offers two separate parts: one dedicated to in-system Mote programming and a second for data communication over USB. The MIB520CB has an on-board processor that programs Mote Processor Radio Boards. USB Bus power eliminates the need for an external power source [21].

RESULTS

The experimental work has been deployed in the greenhouse, available in the UniMAP Agrotech Greenhouse with 18m x80m dimension in order to monitor the micro climate conditions and controlling water irrigation. With reference to the following results obtained, the designed system presented in this work achieves its primary objective. It manages irrigation and soil moisture efficiently based on Figure-15.

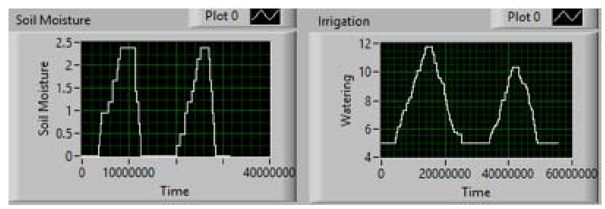

Figure-15. Soil moisture and irrigation graph.

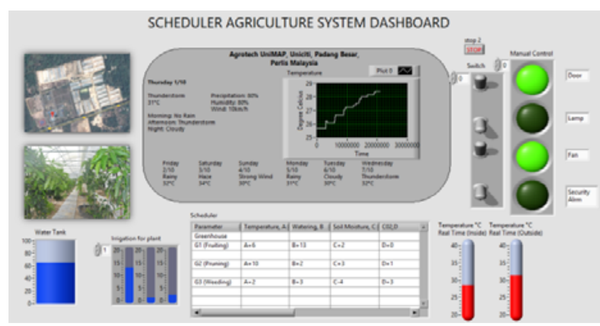

Figure-16. Dashboard of the system.

Figure-16 shows real-time dashboard of the system that can be accessed by using smartphone during the sensor data reading. It includes the sensor graph (irrigation and soil moisture), temperature, humidity, radiation of light (weather), cctv, and display map. MPLAB and LabVIEW software is used to run the program interface that transmits from the sensor to the main computer.

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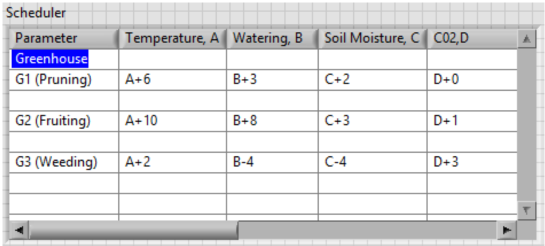
Scheduler

Parameter	Temperature, A	Watering, B	Soil Moisture, C	C02,D
Greenhouse				
G1 (Pruning)	A+6	B+3	C+2	D+0
G2 (Fruiting)	A+10	B+8	C+3	D+1
G3 (Weeding)	A+2	B-4	C-4	D+3

Figure-17. Scheduler of the system.

The system is monitored and automated with the parameter that have been chosen based on scheduler Figure-17. After implementating and testing the system, it shows good network connection between the sensors and the base station. Data is been recorded accordingly based on the parameter setting of each phase.

CONCLUSIONS

This paper presents on the IOT technology application in agriculture, and selected Memsic and Zigbee technology to achieve greenhouse management and monitoring. The system allows monitoring the condition of irrigation, soil moisture, humidity, temperature, and radiation of light which all the sensor collected periodic acquisition data in the greenhouse and send the data to the microcontroller. The data were sent from transmitter to receiver and display to device (smartphone/laptop/PDA). MPLAB and LabVIEW software were used for the programming ad interfacing process.

In future work, the system will use a multi-hop network to cover monitoring for entire greenhouse. This system also can be more specific for plant requirement by adding others sensor parameter such as pH level, fertilizer, air flow and oxygen. Additional cost occur in this system is MTS400 as nodes that attach to the sensor need to recharge. So, by developing solar technology and supply to the nodes inside the greenhouse it will consume less energy, cost effective and optimum periodic acquisition data receive. GIGlobal System for Mobile Communication (GSM) and Short Message Service (SMS) can also be integrated into the system. These extra features will allow the system to directly alert the user of any abnormal changes in the greenhouse environment through the transmission of a simple short text message, especially if the user didn't have internet connection to receive info from the system.

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