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Wireless Sensor Network and Internet of Things (IoT) Solution in Agriculture

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ABSTRACT

This paper presents the technology of Active Radio Frequency Identification (RFID) and Wireless Mesh Sensor Network (WMSN) that will be used in agriculture. In this paper, ZigBee technology platform is applied in 2.45 GHz and active RFID to sustain the WSN by developing a fully automated IoT solution in agriculture for irrigation system. The system includes a plurality of sensor nodes installed in a crop field sending an ID, which are embedded sensor and WSN that work on ZigBee 2.4 GHz platform. The ID was sent to act as a signal of soil in dry condition of a specific area to a reader at base station. The pump stations will use information from base station to sprinkling water in the specific area of the dry state automatically. The automatic control system is very practical in agriculture but most of it is based on schedule and timer regardless of soil condition and temperature. Therefore, wireless automated irrigation system for efficient water use and production is proposed.

Keywords: WSN, RFID, ZigBee, Agriculture, Sensor

INTRODUCTION

Agriculture is an industry that uses a lot of water throughout the world. This resource should be used in an efficient way without affecting the production (Jiber et al., 2011). The obstacles in measuring and monitoring water usage and inefficient irrigation systems due to human control are the main contributors to this situation. The farmers are aware that water shortage or over watering may damage the yield. They need to understand when and the amount of water is needed for specific crops (Jiber et al., 2011).

Most farmers have little knowledge of their farm and they are unaware of the methods to improve their productivity of agricultural practices. All these conflicts make it necessary to think of resolve support systems for agriculture (Jiber et al., 2011). In

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order to overcome this problem, Wireless Mesh Sensor Network (WMSN) and active Radio Frequency Identification (RFID) for agriculture monitoring control are applied. In this study, we proposed an automated irrigation system with full real-time remote monitoring and control system in the farm. The system replaces human-to-human (H2H) and human-to-machine (H2M) to machine-to-machine (M2M) architecture, which is embedded with active RFID. It has moisture sensor and monitoring devices that are required for the farming data such as soil moisture and condition.

WMSN combines the reliability of hardwiring with the versatility of wireless networking in spite of having to compromise the speed. In addition, WMSN consists of cost efficient, battery-powered sensor modules and embedded networking intelligence (Zulkifli Et al., 2011). The communication that hinders optimal production output ZigBee is a growing technology that will create advantages in the agriculture industry (Zulkifli Et al., 2011).

The development WMSN application in agriculture gives it potential to increase efficiency, productivity and profitability while decreasing unintended effects on crops and the environment in agriculture production (Ruiz-Garcia et al., 2009). The real time information from the irrigation area will contribute a solid base for farmers to change consideration at any time rather of taking decisions based some assumed average condition (Ruiz-Garcia et al., 2009).

MATERIAL AND METHOD

Radio Frequency Identification (RFID)

RFID is one of an operative automatic identification technology for different things. The ultimate function of RFID is the capability to trace the position of the tagged things. RFID Technologies composes of tags, reader and computer, which acts a host and comes in all shapes, sizes and read ranges. It is also thin, flexible and can penetrate between paper and plastic. The tag has an identification number and a memory that stores data such as manufacturer, product type and environmental data such as temperature, humidity of an object (Mustafa et al., 2013). In the RFID applications, the tags are attached into objects that are to be tracked (Mustafa et al., 2013).

RFID is the most utilised in the real-time locating system in agriculture applications. It becomes a choice for farmers due to its low cost. RFID tags come in two forms, active and passive. In this, in spite of using the same RFID technology, they are dissimilar in many forms. In this system, active RFIDs are used to send ID that works on Zigbee platform to readers at the base station. It can be seen that active tags are controlled by a battery formed into the tag, which allows data to be transmitted over long distances compared to passive RFID. The read and write distances are much longer than for passive tags. The active RFID has a small battery built–in to the tag, which works as an internal power source. The batteries can sometimes be replaceable or the unit will be replaced after certain period of time, which is normally between 1 year and 7 years.

Active tags can operate at higher frequencies such as 455MHz, 2.45 GHz, and 5.8 GHz. The active RFID broadcasts by itself. The passive RFIDs are of low cost and low range,

while relics on the reader supply the energy to power the tag. The read range is limited and it is difficult to read through metal or liquid. By comparing these two active and passive tags, in this research we provided active RFID to use in the real-time irrigation monitoring system.

The RFID systems operate in low frequency, high frequency, and ultra-high frequency. Frequency relates to the radio wave sizes is used to transmit between RFID systems components. The Low Frequency (LF) band covers frequencies from 30 KHz to 300 KHz. Generally, the LF RFID systems operate at 125 KHz or 134 KHz. This frequency band provides a short read range less than 0.5m, and has slower read speed than the higher frequencies, yet is not very sensitive to radio wave interference. While the High Frequency (HF) band ranges are from 3 to 30 MHz, most HF RFID systems operate at 13.56 MHz with read range up to 1.5 m (Lee et al., 2009).

RFID is not only used for human to machine or machine to human, but the requirement for to machine communication has expended. Thus, the attribute is suitable to be used for monitoring agriculture environment. In the irrigation system, monitored embedded system comes into a new platform for farmers to spend their energy, money and time, which will take place only when there is a requirement of water. In this proposed system, an active RFID based on 2.4 GHz Zigbee Platform is used to send ID to the reader to recognise the node that sends data for irrigation and fertilisation processes without human intervention.

ZigBee Technology

ZigBee, which was originated in 1998, is based on the IEEE 802.15.4 standard and pioneered by ZigBee Alliance, which was formed by several companies interested in defining low cost, low power, and wireless network standard (Lee et al., 2009). ZigBee can support large number of nodes providing a low cost global network. The IEEE defines only the PHY and MAC layers in its standard, while ZigBee defines the network and application layers, application profile and security mechanism. Due to this design, the consumption of power is minimal and the battery life span is longer.

Zigbee supports three topologies, which are star, mesh and cluster-tree, as shown in Figure 1. In star topology, each end node is connected to the coordinator and communication is carried out by the Zigbee Coordinator (ZC). In mesh topology, each device communicates with any other device within its radio range or through multi-hop. In cluster tree topology, there is a single routing path between any devices (Kalaivani et al., 2011). In the Zigbee application, it is mostly used for mesh topology. In spite of that, for the proposed system monitoring mesh topology was chosen. The various sense data from moisture sensors go to WMSN, that integrates with RFID tag and sprinkler will turn into a node. On the farm, there are plenty of nodes and each node will communicate through this ZigBee technology platform. Based on that, the reader will read the sensor data and stores the data to the server, which is used by a farmer for monitoring. In the proposed system, field monitoring uses 2.4 GHz operating frequency nodes for the purpose of study.

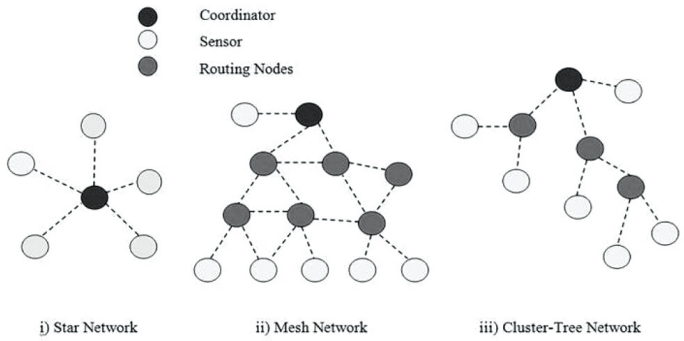

Figure 1. ZigBee Topologies [9]

Wireless Sensor Network (WSN)

Wireless network refers to the technology to communicate and access the internet without cable connection between computers and other electronic devices. Sensor Network has contributed to several applications, and awareness has expended to implement the technology into the agriculture environment. WSN is one of the most important technologies in the 21st century (Mendez & Mukhopadhyay, 2013). WSN is an assembly of a number of low-power, low-cost, multipurpose sensor nodes communicating wireless upon a short distance (Sazak et al., 2013).

The difference between a WSN and a RFID system is that RFID devices have no cooperative capabilities, while WSN allows different network topologies and multihop communication (Ruiz-Garcia et al., 2009). WSN can cut down the effort and time needed for monitoring environment (Mendez & Mukhopadhyay, 2013). As a result, money, water and labour costs can be reduced. The technology allows for remote measurements such as temperature, humidity, soil moisture and water level (Mendez & Mukhopadhyay, 2013). There seems to be increased development towards wireless outcomes in comparison to wired-based systems. Figure 2 shows the concept of wireless monitoring that is to be applied in the agriculture environment.

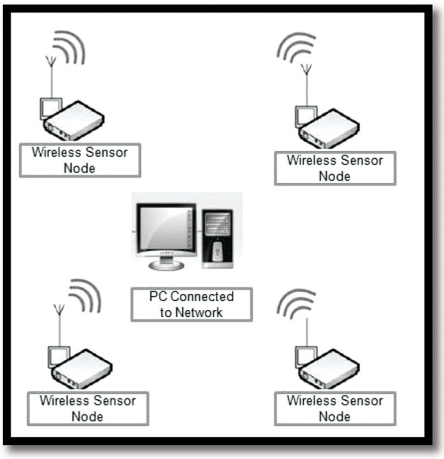

Figure 2. The Concept of Wireless Monitoring

This systems provides a full network coverage in large facilities such as a big farm, typically massive lengths of cabling that leads to remarkable return on investment. WSN provides an intelligent platform to gather and collect data from the sensor nodes that can detect and interact with the physical environment (Zulkifli et al., 2011). Using a wireless mesh as a backbone network simplifies installation and provides an affordable medium (Zulkifli et al., 2011). WSN can be used to identify soil moisture to admit the irrigation system and identify where and when to irrigate. It helps in maximising crop yield and elevates profit (Mendez & Mukhopadhyay, 2013). Irrigation system requires temperatures, water level, humidity sensors and moisture sensor; in this proposed system, however, moisture sensor and temperature sensor are used to detect soil moisture.

Moisture Sensor

Measuring the soil moisture is important in agriculture to help farmers to conduct their irrigation systems effectively. For this reason, farmers are able to use less water to irrigate crop as it is able to grow yields and the quality of the crop. Moisture sensor can read the amount of moisture nearby in the soil surrounding it properly. In this proposed system, sensor node and sprinkler will be attached together. Table 1 shows the functionality of the sensor. When a sensor detects low water level in the soil, sprinklers will supply more water. If the sensor detects excess water in the soil, sprinklers will supply less water. More water is needed when the sensor is dry and this causes the soil to conduct electricity easily (less resistance), while dry soil conducts electricity poorly (more resistance). Embedding the technology with moisture sensor can save and reduce water consumption. Using the moisture sensor, water does not need to function or irrigate when the sensor has the right amount of water.

Table 1
How the sensor works

Item	Condition	Min	Typical	Max	Amount of water
Output	Sensor in dry soil	0%	~	30%	High water
	Sensor in humid soil	30%	~	70%	Medium water
	Sensor in water	70%	~	85%	Low water
	Sensor in water	85%	~	95%	No water

IOT – THE PROPOSED REMOTE MONITORING SYSTEM

The remote monitoring systems are promoting IoT solution working on WSN embedded with RFID technology. The system communicates with hardware and software automatically to send data in the farm. The solution is proven and can therefore be implemented from planting to harvest as a tool for appropriate irrigation tactic to improve crop yields. Besides, the WSN nodes can effectively collect data as well. Remote monitoring for irrigation and fertilising using WSN and RFID can ensure a good quality crop yield. In spite of the stressful environmental conditions, it increases the application efficiency of irrigation systems by 50%. The collaboration has been made with local farmer company that runs the herbaceous plants on a farm located in Ipoh, Perak. This collaboration facilitates research and development of this project, while helping the company to increase productivity and reduce operating costs.

In this system, automatic irrigation systems are developed in the farm to collect the data from moisture sensors placed in the field. The farm will be monitored through the wireless sensor network that is integrated with the active RFID at the field. WSN will sense and monitor the environment like soil moisture and temperature. The coverage area for the experiment is 10 acres, in which 20 nodes are required in this Roselle farm. The systems proposed are very intelligent where the node always sleeps in standby mode. If the sensor senses soil in dry, the node will be activated to work in the mesh network between the other nodes to send ID to the reader. The end device of active RFID shown in Figure 3 is embedded with the sensor that represents wireless network sensor ID that works on Zigbee 2.4 GHz platform. The ID sent to the reader at the base station is used to recognise and allocate which nodes are sending data to the irrigation process automatically.

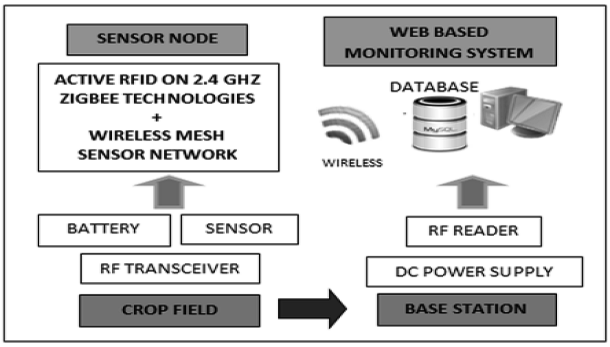

Figure 3. The reader at the base station receives ID from the sensor node

The full concept of the system shown in Figure 4 are active RFID on 2.4 GHz Zigbee platform and moisture sensor are embedded together to become one sensor mesh node. The moisture sensor collects data from the soil, which will be processed before sending via wireless to the controller for further action. The sprinkler will supply water based on the condition of soil. The data that are processed will be sent through the computer for monitoring by the farmers. The farmers can monitor their farm anywhere using internet connectivity by phone or computer. All the systems in the farm are connected to each other via wireless. The messy cabling like conventional method is not used anymore because it will be disturbing an irrigation process.

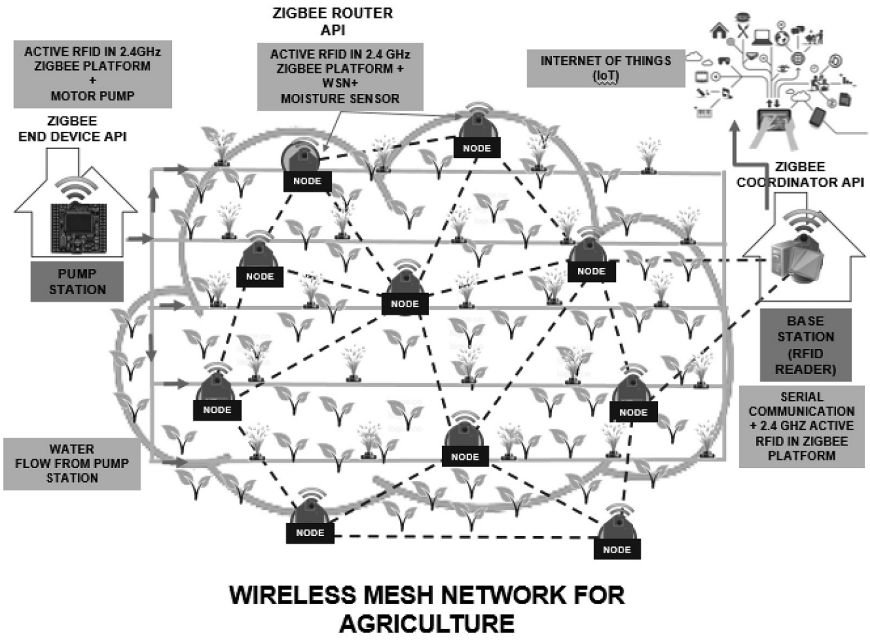

Figure 4. The concept of the system

RESULTS AND DISCUSSION

Figure 5 illustrates the data that will be shown in monitoring base station. A comparison was made within five months at two different areas; one using automatic irrigation and the other using manual irrigation. From the data collected, it can be concluded that using the proposed system on the farm has its benefits. Water usage can be reduced approximately up to 50% when the embedded technology is used compared to the conventional method. In this system, the sprinkler will supply water when the moisture sensors give a signal with the right amount. Sensor in range 0-30% makes the sprinkler supply a large volume of water because the soil is in a dry state. Therefore, it needs a 100% amount of water. Meanwhile, when the sensor is in the range of 30-70%, the sprinkler will reduce water intake by 50% and supply an average volume of water to the soil. This range saves a whole sum of water. The sprinkler will stop the water supply when the moisture sensor sends data of about 85-95%. In this condition, the soil is wet so there is no need for water to be supplied. Thus, farmers can reduce water consumption. The conventional method uses the same amount of water when it needs to irrigate every day. Over irrigation can cause the death of plants and production of farm to be affected badly. In particular, this can affect the revenue of farmers as well since water is wasted and over irrigation may cause damages to the plants. Besides that, the irrigation processes need a number of workers for the conventional method, as it is time consuming.

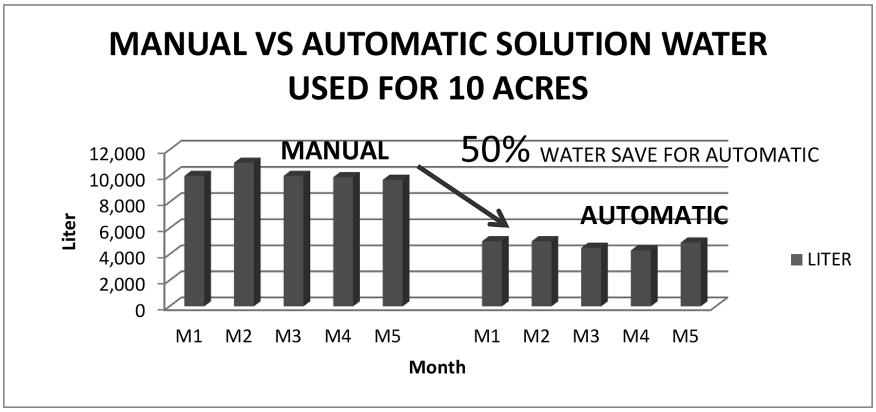

Figure 5. Data collected from the wireless sensor node

WSN has a capability to represent inherent soil variability, which is present in the fields with more accuracy than the currently available system. Thus, the benefit for the farmer is a real-time support system that allows maximising their productivity while saving water. WSN also removes the obstacle to wire sensor stations over the field and decreases the maintenance cost (Zulkifli et al., 2011). The advancement of WSN applications can affect agriculture by increasing profitability, productivity and efficiencies, while minimising unconscious impacts to the environment in many agricultural production systems (Ruiz-Garcia et al., 2009). The real-time information from the fields will afford a solid base for farmers to plan strategies at any time. Instead of taking decisions based on some hypothetical average condition, a precision farming approach recognises differences and adjusts management actions accordingly (Ruiz-Garcia et al., 2009).

CONCLUSION

By introducing RFID Technology and WMSN in the farming industry, growing crops and plants can be greatly optimised. WMSN reduces the wiring and piping costs, and facilitates installation and maintenance in large areas. The use of technology in agriculture is important, particularly to increase production apart from decreasing labour cost and water requirements. Thus, the WMSN technology obviously performs the most technology to improve the current irrigation systems. Soil moisture sensors are constantly improving and becoming affordable and appropriate for massive deployment in the WMSN applications.

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