Performance Evaluation of Integrated Moisture with ZigBee Mesh Network for Automated Irrigation System

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Abstract

This paper presents an automated control system act as machine to machine (M2M), without human intervention base on real time environment of temperature and soil moisture for irrigation in agriculture. Automatic control system is very practical in agriculture but most of it based on schedule and timer regardless of soil condition and temperature. Therefore, wireless automated irrigation system (WARIS) is proposed as a solution in agriculture for irrigation system to suit any crop. In order to build an effective system in farm, an embedded various technologies such as sensors, Zigbee 2.4GHz, Wireless Sensor Network (WSN) and the Automated Intelligent System are designed in farm to control the amount of water for each crop automatically. This intelligent system is very practical due to the design and development of the real time embedded system. This automatic control system can save about 50% of water and labor cost since it required only one farmer to control the whole farm if necessary.

Keywords

Irrigation, Agriculture, WSN, Zigbee, Moisture Sensor

1. Introduction

Water is a resource that all living species need. It is therefore very precious and has to be used in moderation to be preserved for the generation to come. Agriculture is an industry that uses a lot of water throughout the world. This resources should uses in an efficient way without affecting the crop production [1]. Most of the time, this resource is not used efficiently and substantial amount of water are wasted. Most of the farms are contributed from lack of monitoring and manual irrigation system.

In the conventional irrigation system, the farmer has to watering their plants by follow a schedule for different crops [2]. The difficulties in monitoring and control the water usage by human control are the main factors in this situation. In line with this reason, this invention proposed an automated control irrigation system with full real time remote monitoring and control system to the crops in the farm. The system replaces the human-to-human (H2H) and human-to-machine (H2M) to machine to machine (M2M) architecture. These inventions aim to enhance the agriculture sector's contribution by increasing the high quality of crop production with lower cost.

2. Technology overview

2.1 Wireless Sensor Network

Wireless network refer to the technology to communicate and access the internet without cable connection between computers and other electronic devices. Sensor Network has been contributed to several of the application and awareness has expended to implementation of technology into an agriculture environment. WSN is one of the most important technologies in the 21st century [3]. WSN is a assembly of a number of low-power,

low-cost, multipurpose sensor nodes communicating wirelessly upon a short distance [4]. Wireless technology enables management to have a proper understanding of the condition of the field in real time [5]. In agriculture, WSN can reduce the effort and time required for monitoring a particular environment.

2.2 ZigBee

ZigBee which is formed by several companies interested in defining low cost, low power, wireless network standard which is originated in 1998 is based on the IEEE 802.15.4 standard and pioneered by ZigBee Alliance [6][7]. ZigBee can support large number of nodes providing a low cost global network. ZigBee is also a growing technology that will gain more advantage in automatic irrigation control system [8].

In this WARIS system, XBee Series 2 by Digi International has been chosen. The XBee is the product based on ZigBee protocol. This module does not need too much power and it can provide a reliable way to communicate between two or more devices. It interfaces to a host device through a logic-level asynchronous serial port [9].

Through its serial port, the module can communicate with any logic and voltage compatible UART, or through a level translator to any serial device [10]. This module can be configured with the AT (Application Transparent) mode or API [11]. A key component of the ZigBee protocol is the ability to support mesh networking. In a mesh network, nodes are interconnected with other nodes so that multiple pathways connect to each node [12][13].

2.3 Soil Moisture Sensor

The important things for the farmer to observe the water supplied to the crops properly by measuring soil moisture. For that reason, farmers are able to use less water to irrigate crop by using automatic irrigation system. It is able to grow yields and increase the quality of the crop besides can save a lot of water. Soil moisture sensor can sense the amount of water in the soil around it accurately. In this WARIS system, ZigBee 2.4GHz and moisture sensor from Cytron as shown in Figure 1 below are used as a node in the farm.

Figure 1. Resistive soil moisture sensor

In table 1 shows the functionality of the moisture sensor. If moisture sensor sense voltage value below than 1.04V, it shows that the soil is dry and the sprinklers will supply more water. If the moisture sensor sense excess water in the soil and the voltage value is between 1.04V- 2.43V, sprinklers will supply less water. Likewise, voltage value between 2.43V – 3.3V shows that the soil is in wet condition that means the sprinkler will stop irrigate. By implement embedded technology of WSN and ZigBee 2.4GHz with moisture sensor will save and reduce water consumption about 50%. Water will be supplied when it needed only by using this automatic irrigation system.

Table 1: Functionality of the moisture sensor

	Voltage (V)		
Condition	**Min**	**Typical**	**Max**
Sensor in dry	0 V	˜	1.04 V
Sensor in humid soil	1.04 V	˜	2.34 V
Sensor in water	2.43 V	˜	3.3 V

The working principle of this resistive moisture sensor is by reading the resistance to get the moisture level while the sensor probes will pass current through the soil [14]. Figure 2 below shows how the connection to the soil moisture sensor to the Xbee pin. From Xbee, data will be sent to the server and read by reader to process and make decisions.

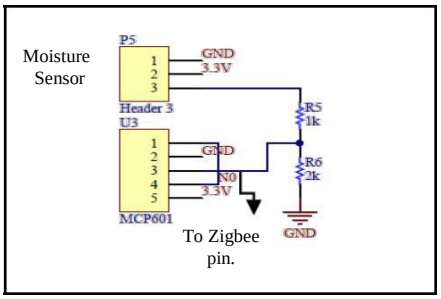

Figure 2. Connection for the soil moisture sensor with ZigBee 2.4GHz

3. System Architecture

In this proposed research describes a web based monitoring system that collects data using a new architecture of embedded technology and then relays this data to the server at the base station. In this server, the data are stored and analyzed in order to provide system make self-decision making process. This process is the capabilities of Machine to Machine (M2M) communicate where hardware and software interchange information based on WSN platform. Figure 3 below show the proposed architecture of WARIS at the farm.

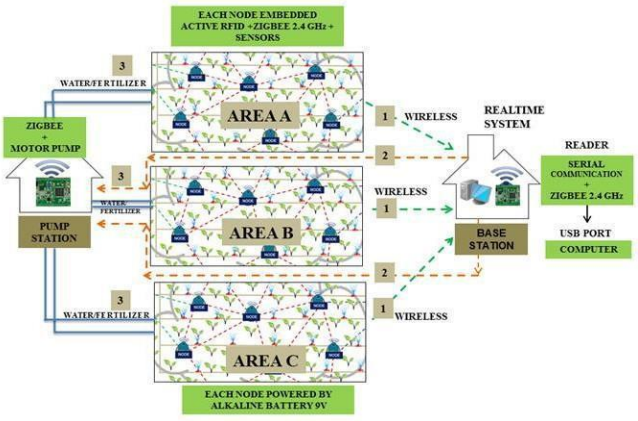

Figure 3. Automated control system architecture in farm

The embedded of the irrigation system with XBee and moisture sensor are installed at each area A, B and C of farming using mesh network to send data to the reader at the base station. After getting information from each sensor node, web based monitoring system at the base station make a decision and sends back the information to

an actuator at pump station to irrigate the farm. This proposed WARIS can operate in flexible design where it's capable working in battery mode and power supply mode. Beside that, embedded microcontroller design for sensor node open for more than one input and output where sensor can add more for future design and research. Figure 4 shows the soil moisture sensor tested on real plant.

Figure 4. Test for soil moisture sensor

The software which used in this research was NetBean Ide and MYSQL Workbench to develop system Java has been presented in Figure 5. The system will control the farm automatically based on operation, area and crop schedule set by the user. Combination of hardware and software provides an automatic irrigation system that can be implemented at relatively low cost and which extremely user friendly with the use of Zigbee network [2].

Figure 5. Interface of WARIS system

4. Result

In this section present the result from the relative moisture sensor performance test and the water used before and after implementing WARIS in the farm.

The formula shows below is the technique for dry basis to determine the soil moisture content. The relation moisture content, *m.c.* in soil samples, in percentage is calculated by following formula:

_____ m.c.(%)= 100%

where and are the weight of water and weight of dry soil sample respectively [15].

Figure 6 below shows the graph of ADC value versus output voltage. This graph was plotted based on the sensor specification given by its datasheet [16].

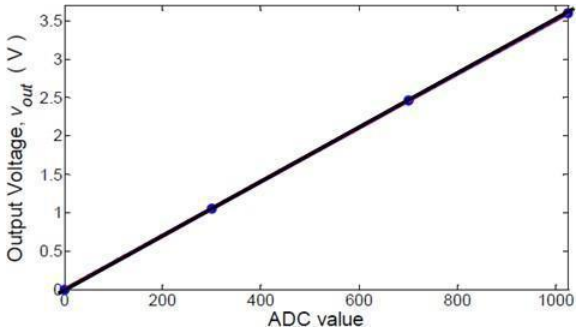

Figure 6. Output voltage,V versus ADV value

From the Figure 6, the graph shows that data from output voltage,V versus ADV value is linearly comparative. It prove that the soil moisture that was applied in WARIS system is very accurate againts the sensor system.

The results will be strengthened and comparison was made with the performance test of microwave reflectometer sensor done by Kok Yeow You [17].

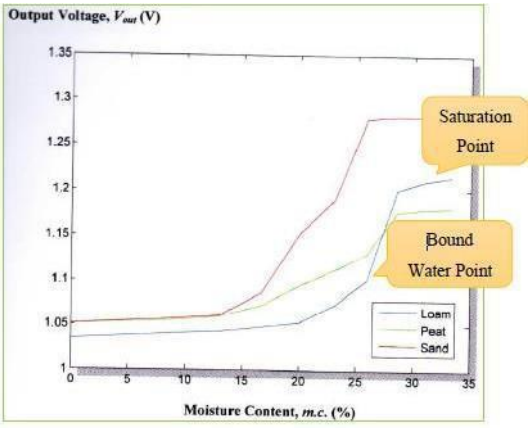

Figure 7. The performance test of microwave reflectometer sensor [17]

From the Figure 7 above shows that the voltage is about 1.04V for loam soil (soil suit all types of plant) is below 30% of moisture content. Besides, the ADC value given is 300 for dry soil and it is equivalent with 1.04V or 29% from the performance test. The value is the identical. So, this verified that the moisture sensor used in WARIS is good and working accurately.

By embedded moisture sensor with WSN and Zigbee, an automated real time system can run appropriately where farmer can save more water usage and money besides increase crops production. In manual irrigation, the farmer has to maintain to observe on irrigation schedule which is different types of crops. Fungal disease and other infection in plants also cause of too much watering. Therefore, by using WARIS that control the irrigation from the remote monitoring, irrigate at each crop when it needed only based on soil moisture condition automatically without human intervention. It is quite important to observe the soil moisture by using the sensor to avoid over watering plants.

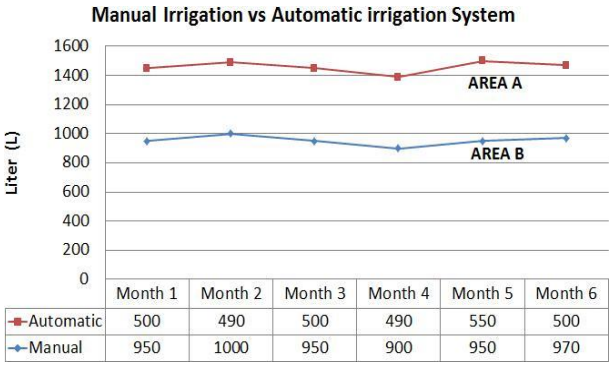

Figure 8. Comparison using manual and automatic irrigation

Figure 8 shows data was collect over 6 month in farm by using manual irrigation and automatic. The test was setup at two difference area where area A is using manual irrigation while Area B is using proposed system. Each area have own tank to be measured every month. From the data collected, it can be summarize by using WARIS in the farm has huge benefits. Farmer can save a lot of money and water. Water usage can be reduced approximately up to 50 % when the embedded technology is used compared to manual method.

5. Conclusion

The uses of WARIS as an automated real time control system for irrigation in farm had applied to growth the crop and save water by monitoring the soil moisture and delivering information for farmer to monitor. The farmer also can save more money by reducing water used and workers. Besides that, the use of WSN instead of the wired connection over the farm still function in any type of environment for monitoring the crops.

6. Acknowledgements

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References

Campbell, C. S., Campbell, G. S., Cobos, D. R., Bissey, L. L., , "Calibration and evaluation of an improved low cost soil moisture sensor," *Available At: http://www.Decagon.Com/Education/Calibration-and-Evaluation-of an-Improved-Low-Cost-Soil-Moisture-Sensor-13492-01-an/*, pp. 1–13, 2009.

Eady, F., *Hands-On ZigBee: Implementing 802.15.4 with Microcontrollers*. Newnes, 2010.

Hebel, M., and Bricker, G., , "Getting Started with XBee RF Modules," *Parallax inc*, 2010. O. Abiodu and A. Kayode Francis, "Wireless transmission of biomedical signals using the Zigbee technology," in *2013 IEEE International Conference on Emerging & Sustainable Technologies for Power & ICT in a Developing Society (NIGERCON)*, 2013, pp.187–190.

"International Journal of Electronics, Communication and Soft Computing Science and Engineering." [Online]. Available: http://www.ijecscse.org/. [Accessed: 11-Jan-2016].

Jiber, Y., Harroud, H., Karmouch, A., "Precision agriculture monitoring framework based on WSN," *2011 7th Int. Wirel. Commun. Mob. Comput. Conf.*, pp. 2015–2020, 2011.

Lee, J. S., Chuang, C. C., Shen, C. C., , "Applications of Short-Range Wireless Technologies to Industrial Automation: A ZigBee Approach," in *2009 Fifth Advanced International Conference on Telecommunications*, 2009, pp. 15–20.

Mendez, G. R., Md Yunus, M. A., Mukhopadhyay, C., "A WiFi based smart wireless sensor network for monitoring an agricultural environment," in *2012 IEEE International Instrumentation and Measurement Technology Conference Proceedings*, 2012, pp. 2640–2645.

Rashid, R. A., Arifin, S. H. S., Rahim, M. R. A., Sarijari, M. A., and Mahalin, N. H., "Home healthcare via wireless biomedical sensor network," in *2008 IEEE International RF and Microwave Conference*, 2008, pp. 511–514.

Science, C., C. Sciences, "An event-driven WSN MAC protocol design based on active node and dynamic time slot allocation," pp. 812–824, 2013.

"SN-M114 Getting Started Guide - Google Docs." [Online]. Available: https://docs.google.com/document/d/1rZqOKwrOyLjYn1R7uMbhSt2F1rXxyqSD7eYipLu5CME/edit. [Accessed: 30-Nov 2015].

Thakur, D. S., Sharma, A., and Sharma, D. K., , "A Low Cost Design & Monitoring Of Automatic Irrigation System Based On Zigbee Technology," *Int. J. Eng. Res. Technol.*, vol. 2, no. 5, pp.1112–1121, 2013.

You, K. Y., Lee, C. Y., Then, Y. L., Chong, S. H. C., You, L. L., Abbas, Z., and Cheng, E. M., "Precise Moisture Monitoring for Various Soil Types Using Handheld Microwave-Sensor Meter," *IEEE Sens. J.*, vol. 13, no. 7, pp. 2563–2570, Jul. 2013.

Yusoff, M. F., Ibrahim, B. S. K. K., Hamzah, H., Kadir, H. A., "Development of Air Conditional Route Wireless Inspection Robot," *Procedia Eng.*, vol. 41, pp. 874–880, 2012.

Zulkifli, C. Z., Abdullah, R. M. T., and Ismail, W., "Wireless Mesh Network in Integrated Web Base Monitoring Systems for Production Line Automation," *Springer Berlin Heidelb.*, vol. 62, pp.7–15, 2012.

Zulkifli, C. Z., Ismail, I., Rahman, M. G., , "Implementation of Embedded Active RFID with Wireless Mesh Sensor Network for Industrial Automation," *Electronics World*, 117(1908), 2011.

Biography

Che Zalina Zulkifli is an Associate Professor in Computer Department, Faculty of Arts, Computing and Creative Industry at Sultan Idris Education University, Malaysia. She had over 18 years professional teaching experience as a lecturer and active researcher in the Electronics & Electrical Engineering, Information Technology, Embedded System, Industry Creative & Networking area. Experience as a Test Engineer in the multinational company. Her research projects have been collaborated with multinational company which contributes to a network that lead to new ideas and concrete research project. The developed automation projects that focused on Sensor Monitoring, Embedded System, Software, IoT and Wireless Communication fields have been successfully adopted by the industry to date. A total of more than a million Ringgit has been generated as an income to the University mainly from the Research grant, Commercialization of research innovative products and also the services as a principle consultant. Expertise in the agriculture sector with new invention to improve the crop production adopted high technology. Sincerely dedicated to the very wise in the green project about recycling and reusage of waste. She has won several international awards and national award. She has developed confidence and interest in researching and teaching areas to enhance Creative Innovation in Engineering, Science & Technology.

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