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Water Quality Monitoring System for Aquaponics and Fishpond Using Wireless Sensor Network

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Abstract**:** ***The higher the human population, the higher the demand for food supply from the agriculture sector. However, healthy and environment-friendly plant-based food production is very time-consuming. Water quality checking by the human resource is no longer efficient in the presence of technology today. Thus, a water quality monitoring system for aquaponics and fishpond is proposed in this study adapting the use of Wireless Sensor Network (WSN), Message Queuing Telemetry Transport (MQTT) protocol, and Wi-Fi signal. The completed system was successfully tested and implemented at the Malaysian Institute of Sustainable Agriculture (MISA). The devices send measurements to a base station which hosted a web server which can be viewed both locally and via the Internet. Results show the system is practical in use as it is both stable and reliable with 5 seconds maximum measurement refresh rate on its dashboard. Thus, reduces human dependency for monitoring the water quality of both the aquaponics and fishpond. Human resource can then be allocated to more crucial roles. Room for improvement includes complete use of solar renewable energy, adding Wi-Fi extender for large scale implementation, and equipping the Raspberry Pi with a cooling fan. This is the step forward to modernising agriculture.***

Keywords**:** ***Aquaponics, fishpond, monitoring system, MQTT, water quality, WSN.***

I. INTRODUCTION

As the human population grows today, so as the demand for food supply from the agricultural sector. Plant-based foods take more time to produce compared to meat-based [1]. In addition, society today is concern on healthy food which includes vegetables and the environment from plantation as various information is at their fingertip [2]. This arises from the awareness of the danger of eating food which is sprayed with pesticides. Furthermore, the pesticides used in plantation causes soil pollution which also pollutes any nearby water source such as lakes and rivers [3]. Aquaponics is an efficient food production mechanism which combines both plant and fish farming together in a harmony environment. Technology today had advanced rapidly beyond our imagination ten years ago. However, the local agricultural sector is still far behind compared to other industrial sectors in adapting technology in production [4]. Since agricultural activities involve many routines, adapting remote monitoring had potentials in increasing efficiency in food production [5]. Currently, human resource is inefficiently allocated for water quality checking routine instead of focusing on a task which is incapable to be handled by computers. Thus, a water quality monitoring system for aquaponics and fishpond using Wireless Sensor Network (WSN) is proposed in this study to reduce water quality testing routine by MISA's staff besides increasing their efficiency in task assignments.

Design of wireless connectivity solution was based on several past works. Works by [6], [7], and [8] uses Zigbee wireless technology in their solution for smart farm monitoring system using IoT, implementation of a connected farm for smart farm, and IoT based smart irrigation monitoring and controlling system respectively. Zigbee is quite costly and a little more complex in term of usage compared to Wi-Fi. A work by [9] uses Wi-Fi signal as data transmission platform in adapting WSN for modern agriculture. It has the advantage of low-cost and easy implementation. A work by [10] uses Message Queuing Telemetry Transport (MQTT) protocol for smart agriculture has the advantage of rapid data transmission. A work by [11] adapted the use of WSN for smart farming has the advantage of efficiency in data collection for various sites. Based on the several designs presented, application of WSN using MQTT via Wi-Fi was chosen as the best solution design for this study's application.

II. METHODOLOGY

This study focuses on hardware and software development which also includes experimentation on the system. Fig. 1 shows the flow of the study.

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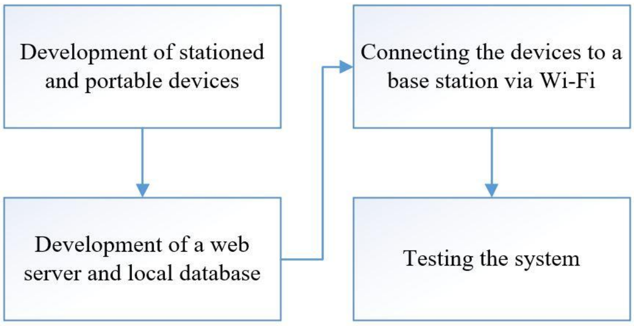

Fig. 1. The flow of the study.

A. Hardware Design

A Raspberry Pi 3 Model B+ microcomputer which comes with a built-in Wi-Fi module is placed in an office as a base station for data collecting and hosting the monitoring system's web server. It can also utilise a personal computer for basic office tasks. A 32GB microSD card is used for the Raspberry Pi as it is sufficient for an operating system and local data storage. A standard Raspberry Pi casing is used for protection of the microcomputer. Fig. 2 shows a stationed water quality measuring device is used for aquaponics.

Fig. 2. The stationed device for aquaponics.

While a portable water quality measuring device is used for a fishpond which is also known as iFloat as shown in Fig. 3 in testing. The three devices are connected via Wi-Fi to a portable 4G modem which supports virtual servers for port forwarding to allow remote access of the monitoring system. Placement of the Wi-Fi modem is also crucial to ensure all the devices are covered within its Wi-Fi signal range. Since the Raspberry Pi is hosting the webserver, the stationed and portable devices only have to send measurements to the Raspberry Pi via Wi-Fi. Thus, a WeMos D1 board is used for both devices as it is Arduino Uno compatible and has a Wi-Fi module together. In addition, the portable device uses a 12V 1.2Ah lead-acid battery for powering up and a small solar panel for recharging it in daylight. While the stationed device which includes an automation system for the aquaponics' Light-Emitting Diode (LED) and water pump uses a direct power supply.

Fig. 3. The portable device in testing.

B. Software Design

Raspbian Buster operating system (OS) is used on the Raspberry Pi as it is the latest and official OS. Docker which is a container-based environment was set up on the OS. Portainer was installed and run on the Docker to give it a user-friendly interface. A time-series database (TSDB), InfluxDB was installed and run on the Docker to store measurements from both the stationed and portable devices locally in the Raspberry Pi's microSD card since it has a sufficient storage space. For data visualisation, Grafana web server was installed and run on the Docker which retrieves measurements stored in the database and displays it according to the user's configuration on the webserver. In term of wireless data transmission, Message Queuing Telemetry Transport (MQTT) publish-subscribe-based messaging protocol is used via the Wi-Fi connection between the Raspberry Pi, stationed, and portable devices. Furthermore, JavaScript Object Notation (JSON) format is used in the data transmission. The Raspberry Pi subscribes to a topic in which the stationed and portable devices publish its measurements via the respective WeMos's Wi-Fi module. A Python code script was made and run on the OS for subscribing and listening to the topic for any measurement publish by the stationed and portable devices. In addition, the Python script stores the received measurements in the database for visualisation. The flow of data is shown in Fig. 4. Aside from that, port-forwarding is made on the Wi-Fi modem to allow external connection to access via the Wi-Fi modem to the webserver. A free Dynamic Domain Name System (DDNS) service provider is used to link between the Raspberry Pi's dynamic public Internet Protocol (IP) address and the webserver's host port to allow remote user access.

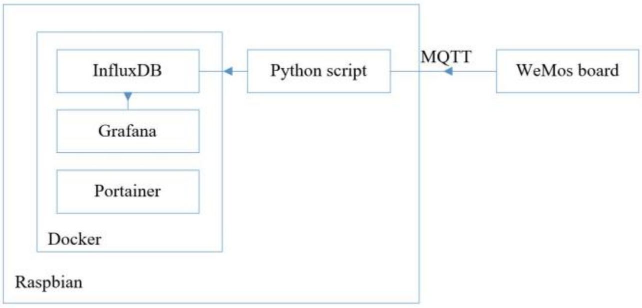

Fig. 4. The flow of data.

C. Experimentation

Tests were carried out on-site at the Malaysian Institute of Sustainable Agriculture (MISA), a foundation focuses on urban and organic farming. The Raspberry Pi was placed in the office, the stationed water quality measuring device was set up on aquaponics, and the portable water quality measuring device was placed in a fishpond. The portable Wi-Fi modem was placed at a central location between all the devices as shown in Fig. 5 to ensure its Wi-Fi signal range is within range of all the devices. The system was run at a 24-hour basis to observe its reliability and performance.

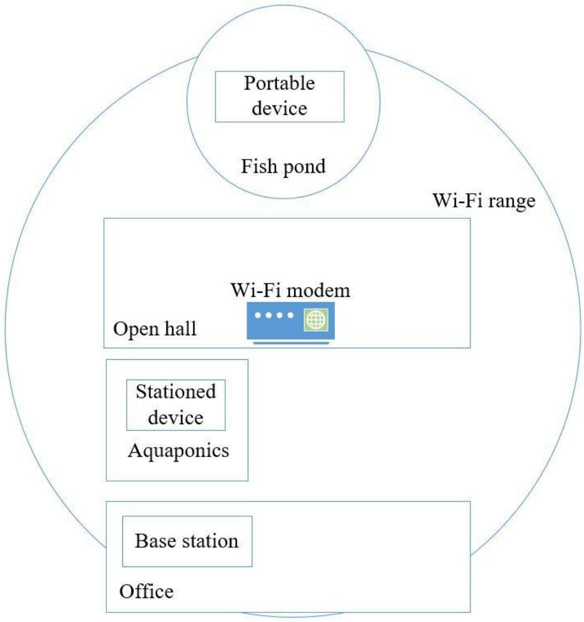

Fig. 5. Position of devices in MISA.

III. RESULTS

The stationed and portable water quality measuring devices successfully sent their measurement to the Raspberry Pi. The measurements are then successfully displayed on the hosted web server as shown in Fig. 6. The measurements include water pH level, water and ambient light level in Analogue-to-Digital Converter (ADC) value which ranges from 0 to 1023. In addition, the system also includes the Raspberry Pi's disk space usage, CPU temperature, and CPU usage level. This is to monitor the Raspberry Pi's health status as the base station of the system.

Fig. 6. Grafana dashboard for the stationed device before integrated with the portable device.

Table I shows the selected measurement period of the stationed device every 6 hours on the 22nd and 23rd of July 2019. The pH level is high around the 00:00 hour of 23/7/2019 due to the MISA's staff adding lime powder to reduce the acidity of the water. In the other hand, the water level is steadily decreasing throughout the period due to vaporisation. While ambient light level shows a very low level at midnights and very high level at middays.

Table- I: Selected measurement period of the system

Date	Time (24 hour)	pH	Water Level	Light
22/7/2019	00:00	2.5	147.2	119.8
	12:00	2.7	126.3	945.6
23/7/2019	00:00	13.7	111.7	120.9
	12:00	2.9	89.6	947.0

While Fig.7 shows the measurement of the portable device after integration into the dashboard. Furthermore, the system has successfully run for a week without having any data lost or technical problem on the webserver. Moreover, measurements are sent at an average one second per reading from each of the two water measurement devices. Thought the webserver's maximum refresh rate for new readings is 5 seconds which is acceptable for this study's application. The Raspberry Pi's still have a significant storage space upon running for a week and its average temperature measurement is still acceptable although sometimes it's quite high. In addition, the user can choose a time range of measurement to be displayed and suitable refresh rate of the dashboard. The webserver also can be accessed locally and via the Internet for user convenient. Thus, the webserver is stable and reliable for a continuous twenty-four seven monitoring system.

Fig. 7. Grafana dashboard for the portable device after integration.

IV. CONCLUSION

The wireless monitoring system is successfully developed with a base station, a stationed water quality monitoring system for an aquaponics and a portable water quality monitoring system for a fishpond. The monitoring system utilises the fast responding MQTT protocol to send data wirelessly to a Raspberry Pi as a base station for local storage and visualisation. Using open-source software, a webserver is hosted locally on the Raspberry Pi and extends its accessibility via the Internet. The completed system was successfully tested and implemented at MISA's aquaponics and fishpond. Based on the experimental results, the system proofs to be stable and reliable for use at site. Thus, reducing MISA's staff routine task of checking the water quality of both the aquaponics and fishpond. Nonetheless, room for improvement is always open wide. A large battery and solar panel can be used to supply power to the stationed device instead of using the direct power supply in support for using renewable energy and cut electricity cost. For large scale implementation of the system which covers a wide area, several Wi-Fi extenders can be used to increase the range of the local Wi-Fi network signal. It is recommended to provide the Raspberry Pi with casing including a mini fan to cool it down as its temperature will rise upon an increase in user activity on the microcomputer. Application of technology in agricultural sector improves the efficiency of food production to support the growing population's food demand. This is a small step towards smart farming that is actively being promoted today and attract the young generation to get involved in developing it.

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Muhamad Farhan Mohd Pu'ad graduated with a bachelor's degree in Electronics-Computer and Information Engineering and a master's degree by research mode in Electronics Engineering from International Islamic University Malaysia (IIUM). He was appointed as a research assistant at the Department of Electrical and Computer Engineering, Kulliyyah of Engineering, IIUM in 2019. He then proceeds his career as a Research and Development Engineer in a smart home development company. His area of interest is in the application of the Internet of Things (IoT) and image processing based Artificial Intelligent (AI).

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