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Field Trial and Performance Evaluation of IoT Smart Aquaculture Monitoring System for Brackish Water Shrimp Farm

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ABSTRACT

In present time, it is common for any monitoring system to incorporate Internet of Things (IoT) to provide online real-time data. In this project, smart aquaculture monitoring system was developed by combining Wireless Sensor Network (WSN) and Wi-Fi module. In order to verify the system performance, the smart aquaculture monitoring system was tested at actual site located at Fisheries Research Institute (FRI), Gelang Patah, Johor. Three types of sensors (pH, dissolved oxygen and temperature) were deployed in a shrimp pond to monitor the water quality continuously in real-time. The data collected by this system is further analyzed to understand the system stability for different setup. From measurement performed at the site, optimum working condition of system was successfully identified. The system able to provide reliable and accurate data when compared to commercial device used by FRI. Implementation of a smart online monitoring system reduces the use of manpower for monitoring and ensures the water quality is maintained at the acceptable level.

Keywords: Internet of things, wireless sensor network, water quality, dissolved oxygen

1. INTRODUCTION

In the world of aquaculture, water quality control is needed to maintain the optimum conditions for the health and growth of the aquatic lives preserved and is one of the factors determining every successful aquaculture [1]. Quality of water also important in order to maintain and increase the quality of aquatic productions. However, water quality has been badly affected by industrial, agriculture, deforestation and other human [2]. Excessive use of animal manure and chemical fertilizers in agriculture industries cause nitrogen and phosphorus pollution in nearby water streams. The abundance amount of the soil nutrients may cause detrimental health effects to aquatic animals such as fish and shrimp. Moreover, the water quality inspection methods used today are limited in term of in-situ measurement as the water samples typically need to be tested in laboratory. Besides, the sample of water should be taken several times in a day by the operators and further brought back sample for lab testing. In addition, water quality dynamic may result in possibility that the contaminant only appears at particular time before it washed away. This paper reports an application of water monitoring system based on Internet of Things (IoT) and Wi-Fi technologies for continuous and vigilant monitoring. The system collects real-time data and allows users to retrieve it from cloud through mobile phone and PC. The real-time data provides timely information to user, therefore allowing quick responses to any incidents.

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2. BACKGROUND OF STUDY

Previous works related to water quality monitoring are reviewed in this section. An online monitoring system for shrimp aquaculture using wireless sensor network is reported in [1]. The proposed system involved with online data acquisition, transmission and data processing. The system uses Arduino Uno as a microcontroller, which is connected with multiple sensors including pH, temperature and DO sensor. The result is displayed in various online platforms such as twitter, WhatsApp and website. In addition, the system that is equipped with dissolved oxygen (DO) sensor to give indicator when paddle wheel aerator needs to be switched on. Apart from DO, the other parameters which are considered for shrimp aquaculture are the pH, temperature and salinity. The optimal value of DO for shrimp cultivation is typically between 4 and 5 ppm. On the other hand, pH indicates the level of acidity or alkaline water, the optimum pH value for shrimp cultivation is from 7.5 to 8.5. In term of temperature, the ideal temperature level is between 28 and 31°C. In other related work, a low-cost water quality monitoring system based on Atmega 328 is reported in [3]. Multiple sensors are connected to the system for measurement of pH, turbidity, temperature and flow sensor. The system incorporated IoT and Wi-Fi technologies which allowed real-time water quality monitoring using Blynk application platform. In different work, an IoT monitoring system was implemented by incorporating Radio Frequency Identification (RFID) system, Wireless Sensor Network (WSN) and Internet Protocol (IP) communication into a single platform for water quality monitoring purpose [4]. The WSN node was tested in actual lake located at Universiti Sains Malaysia (USM) campus. The system utilizes UHF 920 MHz transceiver provided by XBee-Pro S3B RF module.

3. PROJECT METHODOLOGY

3.1 Site Location

Initially site survey was carried out to find suitable location of this study. One of the visited locations was Fisheries Research Institute (FRI) located at Gelang Patah, Johor. This research institute engaged in research related to brackish water pond aquaculture. The 50 acres brackish water site consisted of a large number of ponds for several aquatic species such as shrimp, groupers, sea bass, clamps and many more. For shrimp farming, concrete pond was used instead of large pond with cages. From the visit, the suitable pond and area were identified for the first installation. A set of smart aquaculture monitoring system was installed at a strategic point after considering several factors. Figure 1 shows the aerial view of the research institute taken from google maps

Figure 1. Aerial view of Fisheries Research Institute, Gelang Patah from Googlemaps

3.2 Infrastructure and Network Survey

Since the system uses wi-fi module, wi-fi network coverage is essential to receive and transmit data. The developed system consists of sensor node and network gateway. The main function of sensor node is to take the reading and measure water quality parameters. While gateway part is responsible for data transmission from the sensor node to cloud, to allow data to be displayed in mobile application. The typical distance between sensor node and gateway must be less than 900 m to ensure uninterrupted reading from the sensor node [4]. At the same time, network coverage from internet provider must be stable and strong. Based on the network survey at the site, we identified that there were 3 available network providers which are Celcom, Digi and Unifi, in which Unifi service was chosen eventually. The gateway and wi-fi router were place close to the electrical supplies. While the sensor node was powered by 30 W solar panel and can be placed close to the pond. In this case, the length of sensor cable can be reduced.

3.3 System Installation

First, the system configuration was performed by setting few details such as the wi-fi address and password. Thus, the connection between the sensor node and gateway was established. Then the smart aquaculture monitoring system was installed on a custom plinth to ensure good stability in extreme weather. The system was able to retrieve information continuously from all sensors. System was set to display/update data in application for every 8 minutes. Figure 2 below shows installed aquaculture monitoring system.

Figure 2. The installed smart aquaculture monitoring system

3.4 Data Collection

After the installation, the data was collected by the system. The flow of data collections starts with taking the reading of parameter from the shrimp pond by the system. Then the data collected was sent to cloud server to be displayed on website and mobile application through internet provider. Figure 3 below shows the flow of data collection by the system.

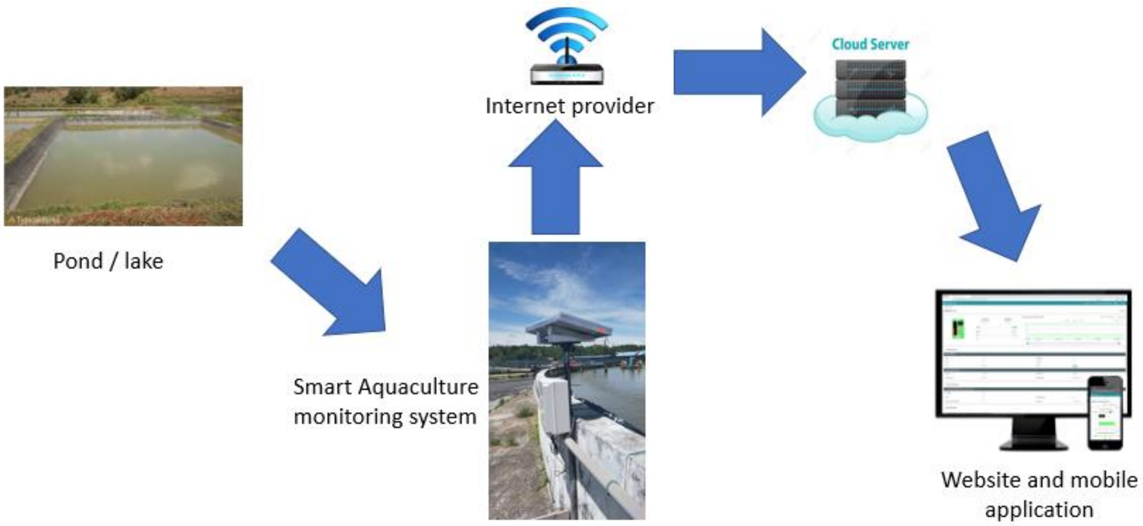

Figure 3. The flow of data collection by the system

4. RESULTS AND ANALYSIS

All the measured parameters from the Smart Aquaculture Monitoring System were compared with the data obtained from manual measurement made by the FRI using the conventional instrument. We examine the effect on network stability by testing the distance between the sensor node and gateway. The first measurement was conducted at a shrimp pond by placing the Wi-Fi router 600 m away from the sensor node. The testing was conducted for about 20 minutes from 15:30 PM until 16:51 PM. Figure 4 shows the collected data from the testing.

From Figure 4, it is apparent the data which consists of potential hydrogen, dissolved oxygen and temperature is highly unstable. Although the distance is still within recommended distance [4], there were obstruction elements such as trees and buildings at the site which cause insufficient signal strength. From series of testing, the distance from the gateway and Unifi router to the sensor node was 100 m in order to establish strong signal coverage for reliable data acquisition. The data shows that the reading was significantly improved by reducing the distance between the router and the sensor node. The sensors were further monitored for the next 24 hours, result has shown that the data was consistent throughout the measurement. Figure 5 shows an example of a stable data obtained when the distance from gateway and Unifi router to sensor node was set at 100 m. The sensor readings were recorded in every ~8 minutes. It is evident that the data is consistent and free from errors.

Record	Date	Sensor Node	Potential Hydrogen (pH)	Dissolved Oxygen(mg/L)	Temperature (°C)
9005	2020-11-29 15:30:54	1001	0	1001	0
9006	2020-11-29 15:35:48	1001	6.69	4.69	28.37
9009	2020-11-29 15:46:33	1001	6.67	5.89	28.37
9011	2020-11-29 15:52:13	1001	0	1001	0
9012	2020-11-29 15:57:14	1001	6.66	6	28.44
9014	2020-11-29 16:02:41	1001	6.7	5.93	28.44
9016	2020-11-29 16:08:33	1001	0	1001	0
9017	2020-11-29 16:13:35	1001	6.58	6.02	28.44
9019	2020-11-29 16:18:54	1001	6.51	5.93	28.44
9021	2020-11-29 16:24:29	1001	0	1001	0
9023	2020-11-29 16:35:10	1001	6.58	5.8	28.44
9025	2020-11-29 16:40:30	1001	6.57	6.01	28.44
9026	2020-11-29 16:45:59	1001	6.5	11.02	28.44
9028	2020-11-29 16:51:08	1001	6.51	8.17	28.44

Figure 4. The obtained data when distance between Wi-Fi router was set 600 m away from the sensor node

Record	Date	Sensor Node	Potential Hydrogen (pH)	Dissolved Oxygen(mg/L)	Temperature (°C)
9850	2020-12-02 11:26:46	1001	6.62	4.02	28
9851	2020-12-02 11:34:18	1001	6.69	4.11	28
9852	2020-12-02 11:41:53	1001	6.73	4.24	28.06
9853	2020-12-02 11:49:33	1001	6.69	4.34	28.06
9854	2020-12-02 11:57:14	1001	6.63	4.44	28.06
9855	2020-12-02 12:04:51	1001	6.57	4.52	28.12
9856	2020-12-02 12:12:31	1001	6.59	4.59	28.19
9857	2020-12-02 12:20:11	1001	6.54	4.63	28.19
9858	2020-12-02 12:27:52	1001	6.34	4.66	28.25

Figure 5. The obtained data when distance between Wi-Fi router was set 100 m away from the sensor node

Figure 6 shows the plot of temperature, pH and dissolved oxygen for 43 consecutive measurement data. With 8 minutes duration between successive measurement, the total duration shown in the plot is around 5 hours and 44 minutes. The plot indicates the temperature is increased from 27.4°C to 29.3°C, while pH and dissolved oxygen are moderately fluctuated. The unstable data is different to the incorrect data. Unstable data is indicated by the invalid or null number of the measured parameter. The unstable data is caused by unstable signal coverage at the sensor node. Meanwhile, the incorrect data is caused by lack of sensor calibration. The incorrect data may not be recognized from the measured data. The data need to be compared from measurement collected from other sensors. Table 1 shows the daily average data for 3 days obtained from our smart aquaculture monitoring system. The data is then compared to data obtained from the FRI measurement system which is shown in Table 2. It is evident that the measured data from both systems are close to each other. Furthermore, the parameters value is close to the recommended value used for shrimp farming. Typically, sensor calibration is done at least once a week when deployed in brackish water. For remote area monitoring with limited broadband coverage, it is more practical to use GSM technology.

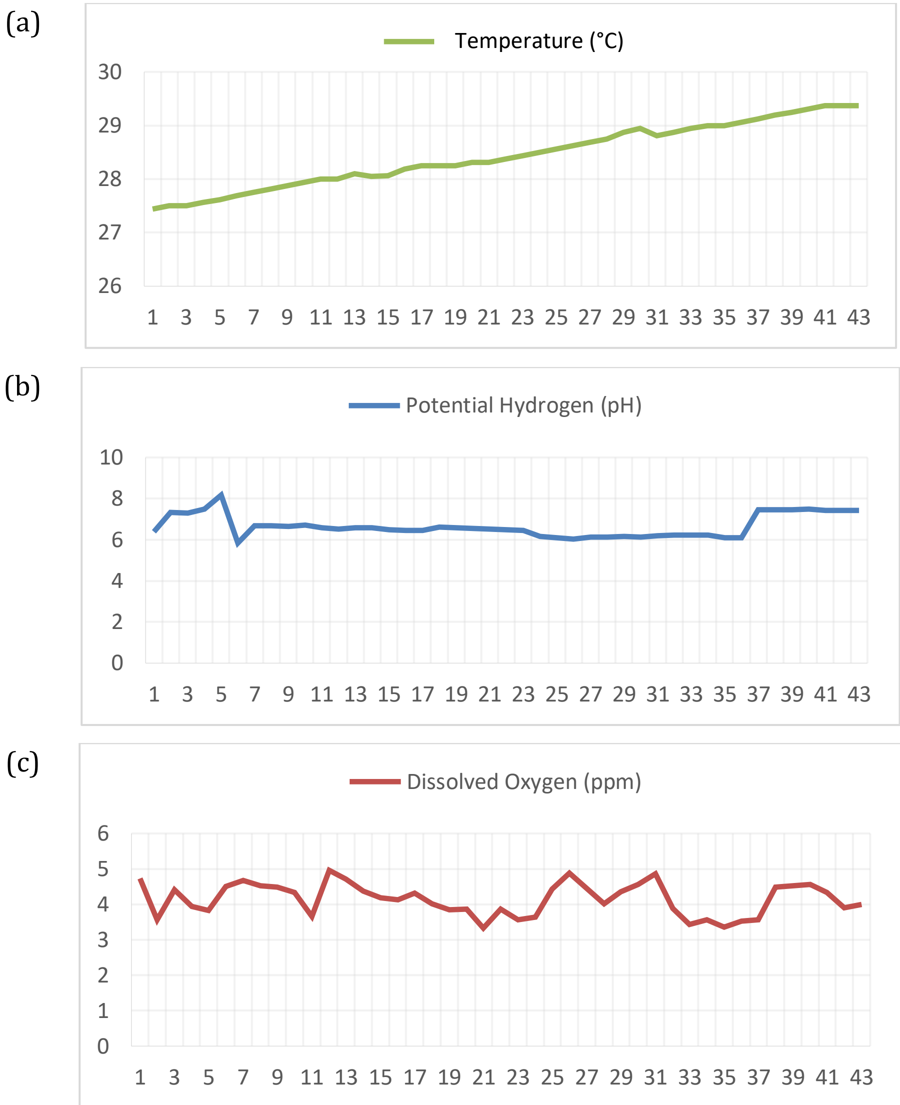

Figure 6. The measured parameters when distance between Wi-Fi router was set 100 m away from the sensor node, (a) temperature, (b) potential hydrogen and (c) dissolved oxygen

Table 1. Data collected from the smart aquaculture monitoring system

Day	Average pH	Average DO (ppm)	Average temperature (^oC)
1	7.00	4.51	27.67
2	6.86	4.65	28.57
3	7.34	4.20	27.36

Table 2. Data collected from FRI measurement system

Day	Average pH	Average DO (ppm)	Average temperature (^oC)
1	7.52	4.513	28.77
2	7.48	4.657	28.45
3	7.50	4.003	28.49

5. CONCLUSION

The smart aquaculture monitoring system was tested at actual site for pH, dissolved oxygen and temperature monitoring. Some system limitations have been identified and the optimum working condition also have been understood. At a stable operation, the data collected by the system was found to be accurate and reliable, comparatively verified by a commercial manual measurement device used by FRI and local farmers. This system is highly useful for aquaculture industries as it provides convenience monitoring of important water parameters. The parameters data can be directly monitored and examined from desktop computer or personal mobile phone. This will allow farmers to react in a timely manner if water condition does not meet the required standard. Since the system does not require human presence at the site it reduces a lot of manpower for monitoring work. This will contribute to the significant cost saving and improve the quality of the product.

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