Design and Deployment of an IoT-Based Water Quality Monitoring System for Aquaculture in Mekong Delta

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***Abstract*—The Mekong River Delta is a key area for aquaculture production, providing over 66% of Vietnam's aquaculture production annually. However, large-scale cultivation and intensive farming have resulted in deterioration of aquaculture water quality and higher rate of aquatic animal diseases. Therefore, water quality control is the key to succeed an aquaculture management. This work presents the design and deployment of an IoT-based water quality monitoring system for Pangasius fish farming in Mekong Delta. The designed system allows farmers to monitor in real time the most important physico-chemical variables of the pond water. Especially, this work introduces a simple and effective approach for automatic cleaning sensor probes that helps improve sensor readings reliability and reduce maintenance costs.**

***Index Terms*—aquaculture, internet of things, mekong delta, sensors, water quality monitoring**

I. Introduction

Vietnam is one of the five countries with the largest aquaculture production in the world [1]. The aquaculture sector has been continuously growing in terms of farming area and number of farm ponds in recent years. The Mekong River Delta is a key area for aquaculture production, providing over 66% of the country's aquaculture production annually [2]. However, large-scale cultivation and intensive farming have resulted in deterioration of aquaculture water quality and higher rate of aquatic animal diseases. Therefore, water quality control is the key to succeed an aquaculture management. It determines feed efficiency, survival and growth rates of fish and shrimp in farm ponds. Continuous monitoring of the physico-chemical and biological parameters of pond water helps protect aquatic livestock from adverse environmental impacts, reduce catastrophic losses, and improve production yield [3]. Among them, the most important parameters to be monitored and controlled are temperature, dissolved oxygen, pH, and salinity. Currently, aquaculture pond monitoring processes are inefficient since it depends on farmer's experience and consumes a lot of time and labor costs. The measurement of pond conditions is usually performed only when farmers have observed abnormality in the water.

Recently, the rapid development of Internet of Things (IoT) technology has brought effective means to carry out real time water quality monitoring in aquaculture. Water quality monitoring systems based on IoT and wireless communication technologies have been widely studied around the world [4]-[14]. For these applications, sensor probes are continuously submerged underwater to timely record changes of pond water parameters. However, microalgae, organic growth and dirt can build-up on the probes over time if sensor maintenance is not regularly performed. Consequently, this causes negative impacts on the accuracy of measured data and the sensor lifetime.

This work presents the design and deployment of an IoT-based water quality monitoring system for aquaculture in Mekong Delta. The designed system, installed at 5 Pangasius fish farms in Vinh Long Province, allows farmers to monitor in real time the most important physico-chemical variables of the pond water. Especially, this work introduces a simple and effective approach for automatic cleaning sensor probes that helps improve sensor readings reliability and reduce maintenance costs.

II. Water Quality Parameters

TABLE I. Recommended Water Quality Parameters for Aquaculture

	Parameters	Unit	Acceptable levels
1	Dissolved oxygen (DO)	mg/L	≥ 3.5
2	pH		7 ÷ 9
3	Temperature	^{o}C	18 ÷ 33
4	Salinity	‰	5 ÷ 35

Along with controlling the quality of larval shrimp and fingerling, quality of aqua-feeds and feeding management, water quality control is also an extremely important factor in aquaculture. Water quality determines feed efficiency, survival and growth rates of shrimp and fish. Some parameters of water quality suitable for shrimp farming

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have been published by the Vietnam Directorate of Fisheries [15], shown in Table I.

Besides the parameters listed above, the Oxidation-reduction potential (ORP) is also one of the important environmental parameters for aquaculture. It reflects the cleanliness of the water and the ability to resolve pollutants in ponds, especially at the pond bottom. The ORP values suitable for aquaculture should be in the range of 150 to 250 mV [16].

Water quality depends on the quality of the water source, soil quality, feeding regime, weather, technologies and management regimes of the fish ponds. In aquaculture, continuous monitoring pond water quality allows farmers to have timely and suitable actions to maintain optimum pond water parameters.

III. System Design and Implementation

A. Operation Principle

The block diagram of the proposed IoT-based water quality monitoring system (named E-Sensor AQUA) for aquaculture is depicted in Fig. 1. The whole system can be divided into five main components: the Master control unit, Sensor nodes, Actuator controller, Smartphone apps and cloud Server.

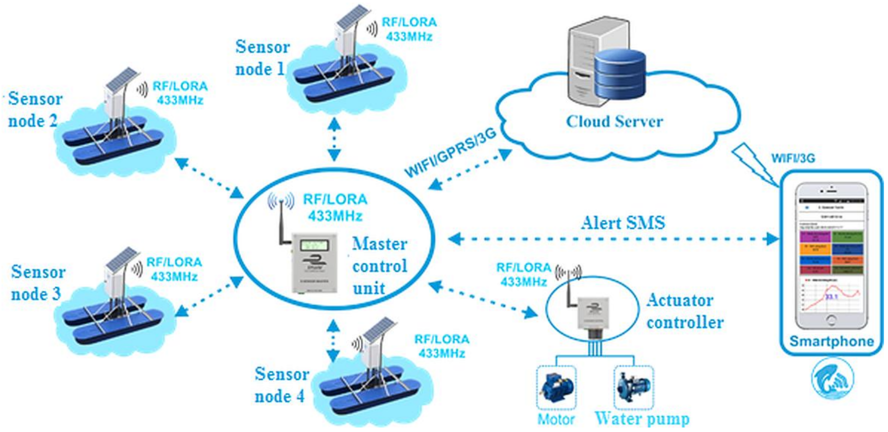

Figure 1. Architecture of the E-Sensor AQUA system.

❍ *Master control unit*: the electronic circuit serves as the central controller of the system. It consists of a microcontroller unit, a wireless communication module and a 433-MHz RF transceiver module. The 433-MHz RF transceiver modules perform data transmission between Master control unit and Sensor nodes. The Master control unit can manage up to 4 Sensor nodes installed at different ponds. The wireless communication module is used for connecting the Master control unit to the cloud Server via Wi-Fi/2G/3G networks. Sensor data gathered by Master controller unit can be uploaded to cloud Server every minute. The Master control unit can also send SMS alert messages to users when pond water parameters reach out of acceptable levels.

❍ *Sensor nodes*: This component consists of sensor probes, a microprocessor unit and a 433-MHz RF transceiver module. The sensor probes collect information about water quality parameters (such as pH, salinity, temperature, oxidation-reduction potential, and dissolved oxygen) and transmit them to the microprocessor for data processing. The data transmission between Sensor nodes and Master control unit is conducted using the 433-MHz RF link.

❍ *Actuator controller:* This component consisting of a microcontroller and 433-MHz RF transceiver module allows users to remotely control electric motors and water pumps at fish ponds.

❍ *Cloud Server:* Water quality parameters gathered from Sensor nodes are eventually sent to Cloud Server by the Master control unit for data storage and processing. In this work, the designed system uses ThingSpeak IoT platform [17] for storage and visualization of sensor data. Data exchanges between Sensor nodes and ThingSpeak cloud are carried out using the HTTP protocol with 128-bit AES encryption.

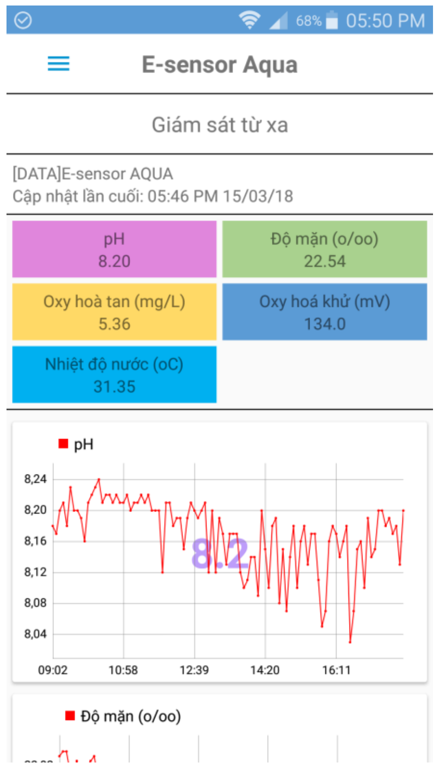

Figure 2. Pond water parameters displayed on a smartphone screen.

❍ *Smartphone apps*: We have developed a smartphone app (for both Android and iOS) that fetches the data from ThingSpeak channels and displays it on the screen of mobile devices (Fig. 2). This offers users the ability to access to the sensor database through mobile devices from anywhere and anytime. Moreover, this app also allows authority to preset threshold values for pond water parameters so that it will inform users if some abnormality occurs (Fig. 3).

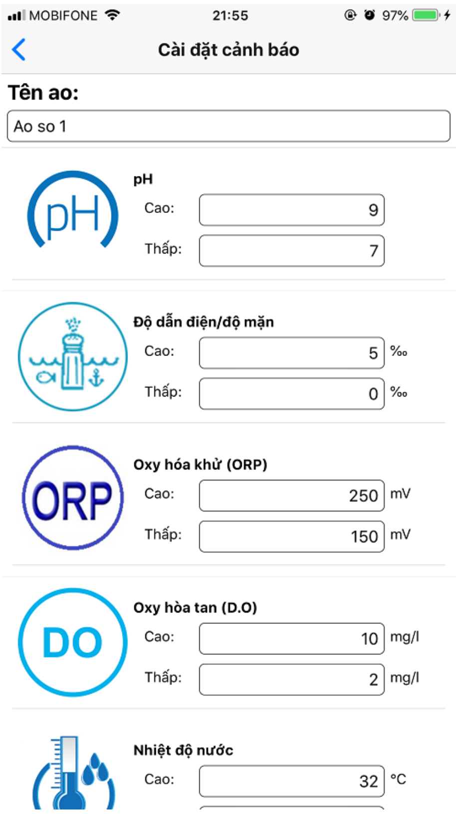

Figure 3. User interface for setting threshold values of water parameters.

B. Sensor Node Design

The electronic circuit board of Sensor nodes consists of a microcontroller unit, a power management unit, a RF transceiver module and sensor interfacing ports. It is fitted in a robust waterproof enclosure and powered by a 10-Wp solar panel with UPS battery. The electronic circuits, as shown in Fig. 4, are designed to meet operational requirements in hot and humid conditions. Sensor probes are connected to the circuit board via shielded cables and installed in middle of a perforated stainless steel cage and positioned at the depth of about 0.5 to 2.5 m in fish ponds (Fig. 5). These sensors collect water quality parameters, i.e., pH, salinity, temperature, oxidation-reduction potential, and dissolved oxygen. Industrial-grade and standard-certified sensors are used in this work to ensure high accuracy and reliability. The whole structure of Sensor node is mounted on floating buoys as shown in Fig. 6.

Due to tropical climate and high sediment water sources in Mekong Delta, sensing probes deployed in fish or shrimp ponds are quickly covered with fine dust, dirt particles and algae after being used a few days. As a result, this can cause incorrect readings from the sensors. To solve the problem, sensors need to be cleaned and calibrated frequently to maintain accurate measurement. In this work, we use a compressor pump connected to air caps via plastic pipes for creating air bubbles in water to clean dirt particles on sensor surfaces. Air caps have been specially designed and made to suit individual sensing probes, as shown in Fig. 7. Operation of the air pump is programmed to periodically perform the cleaning task. Experimental results have shown that the proposed solution can significantly reduce the frequency of manual sensor cleaning. This simple and effective method make it easier for technology companies in deploying sensor systems to aquaculture farms where farmers are not well-equipped with technical skills needed for sensor maintenance and calibration.

Figure 4. Electronic circuit board of Sensor nodes.

Figure 5. Sensor probes.

Figure 6. Sensor node in fish pond.

Figure 7. Sensor probes with air caps attached and air pump (small image).

IV. System Deployment

The designed E-Sensor AQUA system has been implemented to monitor water quality of 5 Pangasius fish ponds in Long Ho, Mang Thit and Tra On Districts, Vinh Long Province. Locations of the sensor system installation are depicted in Fig. 8.

Figure 8. Location of E-Sensor AQUA systems deployed in Vinh Long Province.

Figure 9. Typical graphs showing dissolved oxygen and temperature parameters.

Farmers can access to the ThingSpeak cloud server using mobile devices to supervise the state of water of their ponds in real time. Typical graphs displaying pH, salinity, ORP, dissolved oxygen and temperature parameters of pond water are shown in Fig. 9 and Fig. 10. One can observe that measured data are cyclic with differences between night and day times. This is a predicted pattern as sunlight directly affects physico-chemical parameters of fish ponds. In particular, dissolved oxygen levels in pond are much lower than acceptable values (3.5 mg/L) during night time. In day time, sunlight allows photosynthesis to take place. Algae and microorganisms create oxygen that will be dissolved in water. During the night, as oxygen is not produced anymore, it is consumed by fishes and rapidly decreases until the sun rises high again. This indicates that the aerators must be turned on at night to avoid the lack of oxygen in pond water. Besides, the low values of the ORP parameter also show that the water pond is in anaerobic conditions, stimulating the development of cyanobacteria, toxic to fish and shrimp. For this case, farmers should quickly improve water quality and clean the pond bottom. In addition, the system can also provide SMS notification to farmers when these parameters are outside acceptable ranges, as shown in Fig. 11. Farmers can thus take proper action to treat the fish in pond after receiving alert messages from the system.

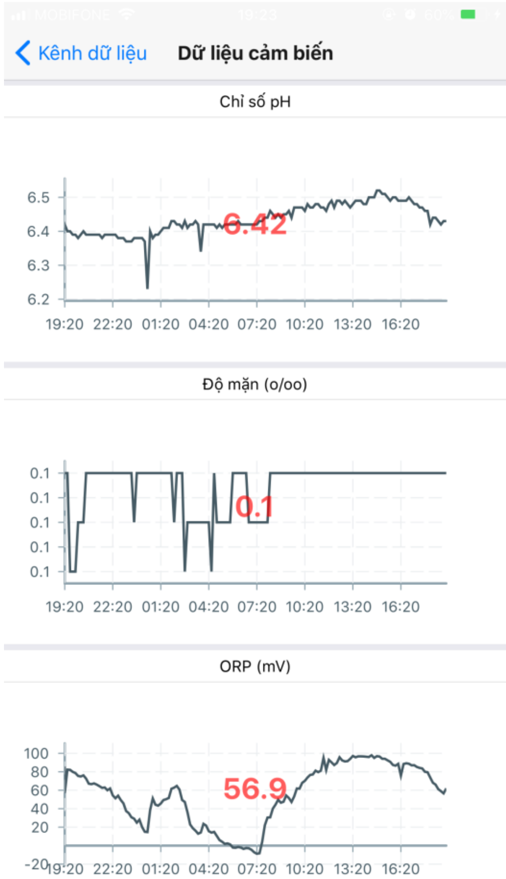

Figure 10. Typical graphs showing pH, salinity and ORP parameters.

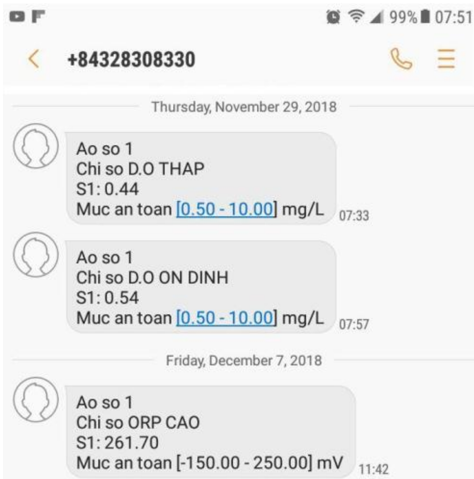

Figure 11. SMS alert messages on smartphone. ORP and dissolved oxygen values are outside acceptable ranges.

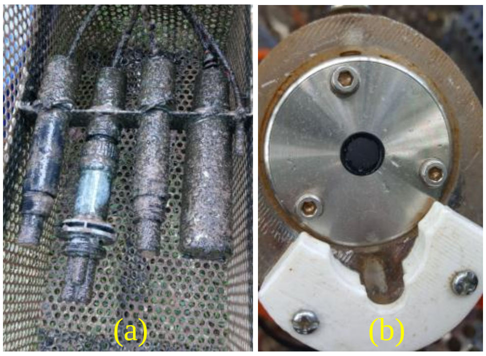

Figure 12. The effectiveness of the sensor probe cleaning: (a) without cleaning for 4 weeks and (b) DO sensor with automatic cleaning.

Fig. 12 shows the comparison between the two cases: sensor probes without using automatic cleaning and the one applying automatic cleaning technique. From Fig. 12a, it can be seen that the sensor probes are covered with dirt and algae after 4 weeks of use. In contrast, with the automatic cleaning, the dissolved oxygen sensor surface remains clean after being used for 2 weeks (Fig. 12b). This experimental result has proved the effectiveness of the proposed automatic sensor cleaning method.

V. CONCLUSIONS

In this paper, we presented the design and implementation of a water quality monitoring system for aquaculture based on IoT technology, named the E-Sensor AQUA system. The system offers farmers the ability to monitor in real time the most important water quality parameters of their ponds. We installed the E-Sensor AQUA system at 5 fish farm ponds in Mekong Delta for measuring pH, salinity, temperature, oxidation-reduction potential, and dissolved oxygen levels. We also proposed a simple and effective method to improve sensor readings reliability and reduce maintenance costs by using an automatic sensor probe cleaning mechanism. This solution helps make it more affordable for small-scale farmers in developing countries to apply hi-tech farming practices. For future work, we will focus our study on testing and optimizing the measurement mechanisms to extend the lifetime of sensor probes.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Luong Vinh Quoc Danh and Dang Vu Minh Dung conducted the system design and wrote the paper. Tran Huu Danh performed the system testing. Nguyen Chi Ngon held the responsibility of performing the design analysis and revising the manuscript. All the authors had approved the final version.

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