

IoT-based Water Quality Monitoring System for Soft-Shell Crab Farming

Muhammad Niswar*, Sonny Wainalang*, Zahir Zainuddin*, Yushinta Fujaya†, Zaenab Muslimin*, Ady Wahyudi Paundu*, Shigeru Kashiwara‡ and Doudou Fall‡

*Department of Informatics, Faculty of Engineering, Hasanuddin University, Indonesia
{niswar}@unhas.ac.id

†Department of Fisheries Science, Faculty of Marine and Fisheries Science, Hasanuddin University, Indonesia
{yushinta}@unhas.ac.id

‡Graduate School of Science and Technology, Nara Institute of Science and Technology, Japan
{shigeru, doudou}@is.naist.jp

Abstract—Farming of soft shell crab has been practiced in south-east Asian countries such as Indonesia. In the crab farming, a poor water quality increases the mortality rate of the crab in the pond. Then, in this paper, we propose a design and implementation of a water quality monitoring system for crab farming using IoT technology to give awareness to a farmer for maintaining acceptable levels of water quality in the pond. Hence, it contributes to increase the survival rate of crab and achieve higher yield of soft shell crab. Our proposed system uses a LoRa-based wireless sensor network and a lightweight Message Queuing Telemetry Transport (MQTT) protocol for exchanging messages between small embedded devices, mobile devices, and sensors. The system mainly consists of sensor node as publishers, and Raspberry pi MQTT broker, and mobile client devices as subscribers. The sensor nodes are built with small embedded devices, LoRa wireless interface, and water quality sensors, i.e., water temperature sensor, pH sensor, and salinity sensor. We also setup a web-based monitoring application using node-red dashboard for accessing water quality levels remotely.

Index Terms—Internet of Things, Water Quality Monitoring, Aquaculture, Crab Farming, MQTT

I. INTRODUCTION

Blue swimmer crab (*Portunus Pelagicus*) and Mud crab (*Scylla serrata*) are species that commonly cultivated to produce soft-shell crabs due to their great demand in domestic and export market. Soft-shell crabs are harvested when they have just molted to prevent their shells from being hardened. However, cultivating soft-shell crabs cannot be done easily. Traditional crab farming experienced high mortality rate of crab larvae and adult crabs due to poor water quality. References [1], [2] described the effect of water temperature and salinity [2] for development of blue swimmer crabs. Authors in [1] stated that temperature had a strong influence on survival rate of blue swimmer crab larvae, where the survival of larvae is greatest at constant temperature of 22.5°C and 25°C and larvae failed to develop at constant temperature of below 20°C. Authors in [2] conducted experiments to determine the optimal rearing conditions of the water temperature and salinity on the survival rate and molting of larvae stage until the 1st-day juvenile crab of the blue swimming crab. The experiment results show that larvae required an optimal rearing condition under a constant water temperature at 30°C and salinity of

30 ppt for better survival and molting. The aforementioned research prove that water quality plays an important role in the survival of the crab larvae and adult crabs. Therefore, this research proposes an IoT-based system that can monitor the water quality in the pond to give awareness to the farmer to maintain the acceptable level of water quality to reduce the mortality rate of crabs.

II. WATER QUALITY PARAMETERS

To increase survival rate of larvae stage and adult crabs, we need to consider the following three water quality parameters and maintain the acceptable levels of these parameters for crab farming.

A. Water Temperatures

Reference [1] shows that temperature had a strong influence on survival rate of blue swimmer crab larvae, where the survival of larvae was greatest at constant temperature of 22.5 °C and 25 °C and larvae failed to develop at constant temperature of below 20 °C. While experimental results in [2] show that the optimal rearing conditions of the water temperature on the survival of larvae stage until the 1st-day juvenile crab of the blue swimming crab is under a constant water temperature at 30 °C.

B. Salinity

According to [3], salinity is a key water quality parameter that contributes to the survival of mud crabs. Their studies showed that the sudden drop of salinity from 29.6‰ to 10.4‰ was affected by the survival of the crab from 87% to 45% in between 30th-day to 45th-day. Therefore, we consider salinity as one of water quality parameters in this study.

C. pH

pH stands for potential of hydrogen; it measures acidity or alkalinity of water-soluble substances. The pH value ranges from 1 to 14 with value of 7 as the value of neutral point. If the pH value is less than 7, it indicates acidity. On the otherhand, if the pH value is greater than 7, it indicates alkanity. A pH around 8.5 was found to be the optimum for larval rearing of the mud crab *Scylla paramamosain* [4].

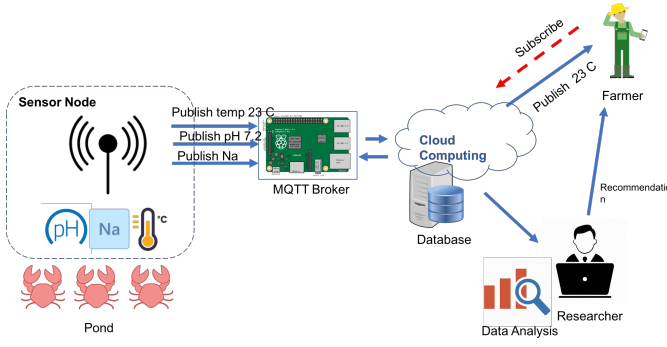


Figure 1. IoT-based Monitoring System

III. RELATED WORK

Several researchers have proposed a water quality monitoring system for aquaculture. Reference [5] designed a prototype of water quality monitoring for aquaculture based on ZigBee-based wireless sensor network and the Internet of Things (IoT). Sensing data is transmitted through the ZigBee network and stored in cloud-based database. The cloud-based database provides sensing data visualization of dissolved oxygen, pH and water temperature through desktop and mobile application. Reference [6] also designed a wireless sensor network based on ZigBee for aquaculture monitoring which they deployed in a fish pond for collecting water quality parameters, i.e., dissolved oxygen, water temperature, pH and water level. They provided monitoring software system using LabWindows/CVI for displaying and analyzing acquired data sensors. Reference [7] proposed a smart water quality monitoring system using GSM network to transfer sensing data to a cloud server. The system measures water temperatures, pH, Oxidation-Reduction Potential, and conductivity. Four different water sources were tested to validate the measurement accuracy. In our research work, we developed a water quality monitoring for crab farming since raising crabs requires a great deal of attention to their environment in order to increase survival of crab in the pond.

IV. SYSTEM DESIGN

We developed an IoT-based water quality monitoring system for blue swimmer and mud crab farming. Our proposed system consists of small embedded devices (Raspberry and Arduino), multiple water quality sensors and LoRa wireless interfaces. The system uses a lightweight Message Queuing Telemetry Transport (MQTT) protocol for exchanging messages between small embedded devices, mobile devices, and sensors. We use water temperature sensor, pH sensor, and salinity sensor for monitoring the water quality in the pond. Sensors are connected to small embedded devices and a Mosquito based MQTT broker is established for remote monitoring. Moreover, we also established a cloud-based database for storing data from sensors and produce datasets for forecasting to increase the yields of soft shell crabs as well as for research and

scientific discoveries. Figure 1 shows our proposed system architecture of IoT-based monitoring system.

We use a node-red [9], i.e., an open source and flow-based programming tool to connect IoT devices, APIs, and services. This tool provides a visual programming approach allowing developers to connect nodes, i.e., predefined code block written in HTML and JavaScript, to perform a task. The connection of different types of nodes, i.e., input nodes, function nodes, and output nodes, creates a flow that is represented in JavaScript Object Notation. Figure 6 shows the node diagram for collecting pH parameter from sensor and displaying node-red-dashboard.

The following are descriptions of system components:

A. Sensor Node

Sensor node (SN) consists of small embedded devices (Arduino MEGA 2560) connected to LoRa Shield with 915MHZ antenna and water quality sensors, i.e., water temperature sensor, pH sensor, and salinity sensor, for collecting the water quality parameters as shown in Fig. 2. Since SN will be deployed in the pond, we installed solar cell 20 WP 12V connected to UPS battery to power up the sensor node. Figure 3 and Table I show the complete deployment of SN in the pond and its technical specification details, respectively.

B. Gateway Node/MQTT Broker

Our proposed system uses a lightweight Message Queuing Telemetry Transport (MQTT) protocol for exchanging messages between small embedded devices, mobile devices, and sensors. The MQTT is a publish/subscribe messaging protocol that runs on top of TCP/IP. In this system, we use an open source Mosquito-based MQTT broker [10] that can be implemented from low power computation device to full servers. MQTT broker also plays as a gateway node, i.e., small computation device (Raspberry pi 3) with LoRa wireless module (LoRa Hat), for SN as shown in Fig. 4. The MQTT works as follows: First, SN acts as a publisher publishing messages on a topic including temperature, salinity and pH. Client (farmer or researcher) subscribes to a topic of interest and the broker distributes the published message to the client that subscribed on that topic. The clients can monitor the water quality once they subscribe to interested topic/water quality parameter on the site. The broker also distributes the published message to the cloud-based database via the available network such as 3G/4G networks; hence, the client can access the published message from outside, not just in the on-site. Table II shows the technical specification details of gateway node/broker.

C. Monitoring and Notification System

We setup a web-based monitoring system using UI nodes from node-red dashboard (ui_gauge and ui_chart) as shown in Fig. 5. Figure 6 shows the flow diagram for pH monitoring system in node-red. When the client subscribes to a topic of interest, e.g., pH, to the broker, the broker publishes the pH to the client and node-red displays pH parameter obtained



Figure 2. Sensor Node



Figure 3. Sensor Node in the pond



Figure 4. LoRa Gateway / MQTT Broker

from the broker in real time, and it can be accessed through PC and mobile device. Our system also provides an email notification to farmer when water quality parameters reach out of acceptable level. Hence, the farmers can take proper action to treat the crabs after they receive the email notification from the system. Figure 7 shows the flow diagram for email notification system in node-red.

V. PERFORMANCE EVALUATION OF MQTT BROKER

In our proposed monitoring system, MQTT broker plays an essential role in distributing published message to the client. Therefore, we need to evaluate the performance of MQTT broker in terms of the number of subscribers that can be accommodated by a single broker. In our experiment, we deployed three SNs as publishers in the crab pond located in district of Barru, South Sulawesi province, Indonesia. Figure 8

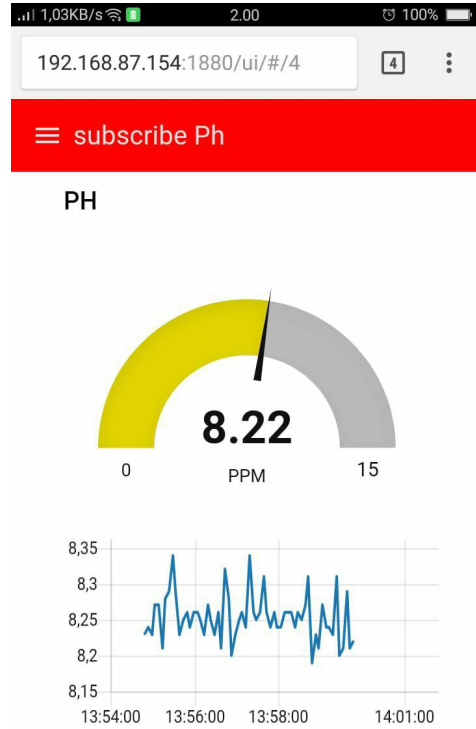


Figure 5. Web-based Monitoring using Node-Red Dashboard

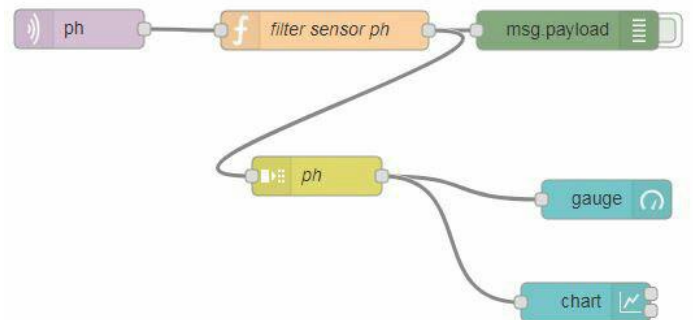


Figure 6. Flow Diagram for monitoring pH

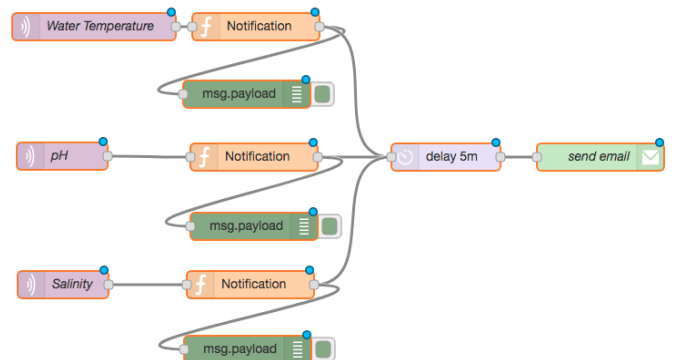


Figure 7. Flow Diagram for Email Notification

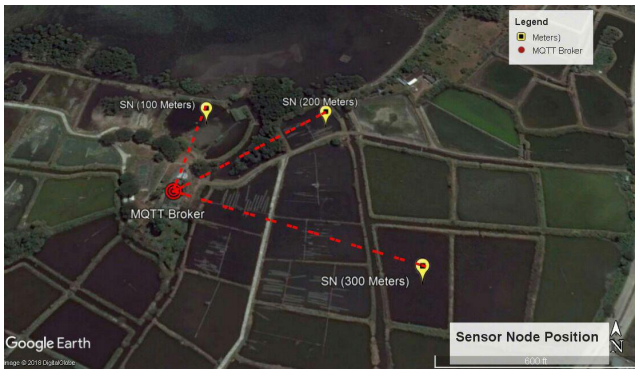


Figure 8. Network Topology

Table I
SENSOR NODE TECHNICAL SPECIFICATION

Microcontroller	Arduino MEGA 2560
Wireless Interface	LoRa Shield with 915MHz Antenna
Sensors	Water Temperature, Salinity, pH
Battery	12 V 18AH Rechargeable Sealed Lead Acid
Solar Cell	20 WP 12V
Packet Size	17 bytes
Transmission Interval	60 seconds

shows the SN placement in the crab pond. Every SN publishes three water quality parameters, which is SN sends 17 bytes of packet size every 60 seconds to the broker. No packet loss occurs from SN to the broker since SN sent tiny amount of packet size and they are located within radio range of LoRa. We evaluated the performance of the broker by measuring its CPU usage against the number of subscribers. The evaluation aims to obtain the adequate number of subscribers that can be handled by a single Raspberry pi broker. In this experiment, we setup subscribers from one to 30 and each subscriber subscribes to a topic on salinity in the broker via Wi-Fi connection. Figure 9 shows that the CPU usage increase as the numbers of subscribers increases. When the number of subscribers reaches 25, node-red has difficulty in displaying `ui_gauge` and `ui_chart` and loses connection when subscribers reaches 30. This indicates that Mosquito-based MQTT broker works at the maximum CPU usage of 31% of the four-core of Raspberry pi. Therefore, we can conclude that the adequate number of subscribers can be handled by a single Raspberry pi MQTT broker is less than 25.

Table II
GATEWAY NODE/BROKER TECHNICAL SPECIFICATION

Microprocessor	Raspberry Pi Model 3 B+ (armv71)
RAM	1 GB
OS	Raspbian Stretch 4.9.59-V7
Running Services	node-red, rf95 server, and mosquito
Wireless Interface	LoRa Hat/GPS with 915MHz Antenna
MQTT Broker	Mosquitto-based MQTT (QoS level 0)

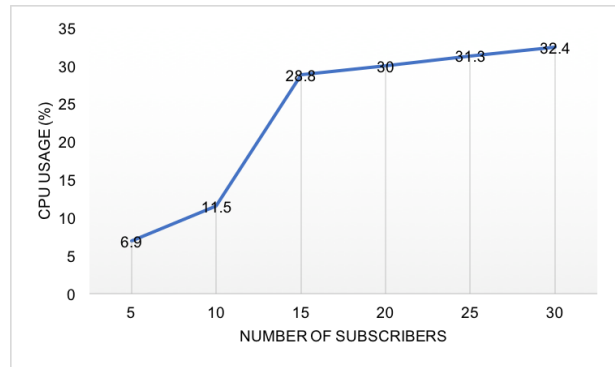


Figure 9. Broker CPU Usage vs. Number of Subscriber

VI. CONCLUSION AND FUTURE WORK

In this paper, we proposed a water quality monitoring system for crab farming based on IoT. Our system aims to assist the farmer in cultivating soft-shell crabs by carefully monitoring the water quality. We built the system with low-cost small embedded system, sensors, and LoRa wireless interface. It measures the water temperature, salinity, pH level of water in the crab pond. We also setup a web-based monitoring application using node-red dashboard for displaying water quality parameters in the graphical user interface. We conducted experiments to evaluate the adequate number of subscribers that can be handled by the single Raspberry pi broker, and the experiment result shows that the single Raspberry pi MQTT broker can handle at most 25 subscribers.

In the near future, we will integrate this monitoring system with a water circulation system to improve the water quality in the pond so that it will reduce farmers' intervention in maintaining water quality in the pond.

Acknowledgement: This work was supported by JICA C-BEST Grant, Nakajima Heiwa Foundation, and NAIIST Grant.

REFERENCES

- [1] Simon R. Bryars, Jon N. Havenhand, Effects of constant and varying temperatures on the development of blue swimmer crab (*Portunus pelagicus*) larvae: Laboratory observations and field predictions for temperate coastal waters, *Journal of Experimental Marine Biology and Ecology*, Volume 329, Issue 2, 2006, Pages 218-229.
- [2] Ikhwanuddin, Mhd & Azra & Talpur, Mir Allah Dad & Abol-Munafi, Ambok & mohd Long, Shabdin. (2012). Optimal Water Temperature and Salinity for Production of Blue Swimming Crab, *Portunus pelagicus* 1st Day Juvenile Crab. *AAAL Bioflux*. 5. 4-8.
- [3] Pedapol, Sandeep & Ramudu, Kurva. (2014). Effect of water quality parameters on growth and survivability of mud crab (*Scylla tranquebarica*) in grow out culture at Kakinada coast, Andhra Pradesh. ~ 163 ~ *International Journal of Fisheries and Aquatic Studies*. 2. 163-166.
- [4] Nghia, T. T., Wille, M., Binh, T. C., Thanh, H. P., Danh, N. V. and Sorgeloos, P., 2007. Improved techniques for rearing mud crab *Scylla paramamosain* (Estampador 1949) larvae. *Aquaculture Research* 38(14), 1539-1553.
- [5] C. Encinas, E. Ruiz, J. Cortez, and A. Espinoza, "Design and implementation of a distributed IoT system for the monitoring of water quality in aquaculture," 2017 *Wireless Telecommunications Symposium (WTS)*, Chicago, IL, 2017, pp. 1-7.
- [6] Daudi S. Simbeye, Jimin Zhao, Shifeng Yang, "Design and deployment of wireless sensor networks for aquaculture monitoring and control based on virtual instruments," *Computers and Electronics in Agriculture*, Volume 102, 2014, Pages 31-42.

- [7] A. N. Prasad, K. A. Mamun, F. R. Islam and H. Haqva, "Smart water quality monitoring system," 2015 2nd Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE), Nadi, 2015, pp. 1-6.
- [8] K. R. S. R. Raju and G. H. K. Varma, "Knowledge Based Real Time Monitoring System for Aquaculture Using IoT," 2017 IEEE 7th International Advance Computing Conference (IACC), Hyderabad, 2017, pp. 318-321.
- [9] <https://nodered.org/>
- [10] <https://mosquitto.org/>