# Embedded Wireless Dissolved Oxygen Monitoring Based on Internet of Things Platform

Wasana Boonsong
Department of Electrical Education, Faculty of Industrial Education and Technology, Rajamangala University of Technology Srivijaya, Songkhla, Thailand
Email: wasana.b@rmutsv.ac.th

***Abstract*****—**Recently, Internet of Things (IoT) applications are distributing into many areas, such as industry and agriculture. This article presents the embedded wireless Dissolved Oxygen (DO) monitoring system based on IoT platforms. The module contains two types of data sensing, which are water temperature and DO sensors. Both devices are embedded with a wireless IoT module using NodeMCU-ESP8266, an integration WiFi-Microcontroller on a single board. The proposed IoT-DO monitoring system detects information data from the aquaculture pond environment. Namely, the parameters studied are water temperature and DO values. The cloud internet network collects and stores the experimental data and link to the users. The relationship between both parameters is analyzed using Statistical Package for the Social Sciences based Pearson correlation coefficient theory. The findings found that the water temperature and DO values are negatively related, with a statistically significant .05. Water temperature is the principal affection to other parameters of water. In this work, the DO value is studied to relate the water temperature. It was found that when the water temperature increases, the DO decreases accordingly and vice versa.

***Index Terms*****—**IoT, DO, Pearson correlation Coefficient

## I. Introduction

Recently, Internet of Things (IoT) applications are distributing into many areas, such as industry and agriculture. IoT can improve productivity from Artificial Intelligence (AI) devices and including various types of sensors. It matches with all things that are connected and work on an internet cloud service platform. Therefore, there is no question that the convenience of IoT will become an essential section of future human life. Especially, with the appearance of the coming generation 5G network communications featuring with high speed and large capacity, which can contain a lot of data through internet cloud with very low latency and advanced efficiency is multi-connectivity. Moreover, the 5G-based IoT services and applications will spread into many fields, such as automotive [1], remote monitoring mechanism [2], ultra-high-definition in AI-driven fog computing [3], active queue management using IoT application [4], etc.

This application proposes the embedded IoT-DO monitoring for the critical indicators of water quality. The IoT-DO sensor measures the oxygen content in water in real-time accuracy and transmits the monitored data results back to a central database or water monitoring platform. The quality of free oxygen present in the water, which is studied about this entitle regarding the oxygen is vital for the survival of aquatic lifeforms. The primary purpose of creating the IoT-DO monitoring device is about the ability to automatically and accurately measure DO in a body of water by using the primary IoT tool offers several benefits over the traditional method

Manuscript received April 15, 2021; revised August 18, 2021.
doi:10.12720/jcm.16.9.363-368

## II. Proposed Wireless IoT-DO Monitoring System

This research entitles essential to acknowledge the wireless IoT-DO monitoring device with WiFi microcontroller NodeMCU-ESP8266 device. The proposed embedded device is the object that builds the unique computing system. This system may connect to the internet network and generally runs as a single application. The proposed IoT-DO monitoring system can connect through the cloud internet service, and it able to communicate through other network devices.

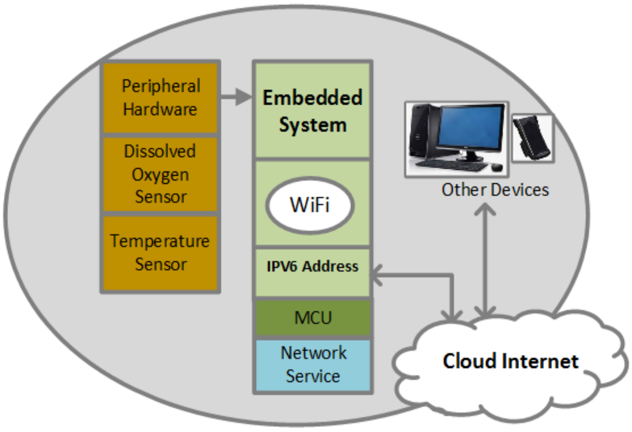


Fig. 1. The proposed structure of embedded IoT-DO monitoring system.

Fig. 1 presents the proposed structure of the embedded IoT-DO monitoring system. The IoT-DO monitoring system can be of type microprocessor, which contains an integrated circuit (IC). The virtual device of the embedded system is the NodeMCU-ESP8266 microcontroller. The ESP8266 is a very user-friendly and low-cost device to provide internet connectivity to a project. The module can work both as an access point, which can create a hotspot, and as a station that can connect to WiFi [5]. Hence, it can easily fetch data and upload it to the internet, making the

©2021 Journal of Communications 

Internet of all Things as easy as possible. Moreover, it can also pick data up from the internet by using API's hence the IoT-DO monitoring device could access any information available on the internet. The IoT-DO monitoring device is shown in more detail as follows.

### *A. Wireless IoT-DO Sensor Module*

This subsection presents the wireless IoT-DO sensor connection. Oxygen can enter a water system in several ways. These methods are generally categorized as surface-aeration and sub-surface aeration. Namely, oxygen from the atmosphere can dissolve and mix into the water's surface. Atmospheric surface aeration could include the wind surrounding the water's surface, movement from streams, waterfall, or similar water flow [6]. Thus, in the aquatic pond, oxygen occurred from an oxygen generator installed into the pond. The amount of an oxygen generator depends on the size of an aquatic pond. DO requirements in aquatic animal respiration-related aquatic organisms absorb molecular oxygen from water and use it to oxidize organic compounds and release energy for doing biological work. In respiration, which aquatic animal needs to expel carbon dioxide, the resulting waste [7].

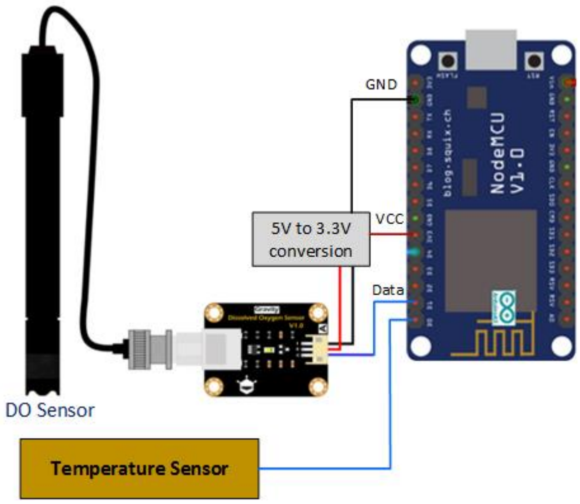


Fig. 2. Wireless IoT-DO sensor connection diagram.

NodeMCU-ESP8266 is applied for processing above several functions. It is an open-source firmware and development kit that assists in the create IoT-DO device product. Moreover, NodeMCU is developed to make it easier to use advanced API for hardware IO. Thus, API can reduce redundant work for configuring and manipulating hardware. It is designed like Arduino hardware Input-Output (IO) and lowest cost WiFi MCU that ESP8266 [5]. Fig. 2 shows the NodeMCU-ESP8266 with their primary function on each GPIO pin. This research used two digital I/O for the water temperature sensor port, and another DO sensor.

Besides, algae and other underwater lichen create dissolved oxygen through photosynthesis, and they release oxygen into the water. Hence, it can be said that oxygen is then consumed by fish and also important aerobic bacteria that can break down excess nutrients in the water.

In the further section, the experimental results are presented in which show the relationship between DO and temperature in water. Moreover, further information relating to oxygen aeration is available here.

### *B. Proposed Wireless IoT-DO Monitoring Work Flow*

This subsection presents the system operation of wireless IoT-DO monitoring. Fig. 3 demonstrates the operation flowchart of the developed system. The water temperature and DO sensors provide sensed information data to the wireless IoT microcontroller unit at every set time. The operating system started from the initial IoT-DO device to the internet network. Both sensors detect the temperature and DO values. Then, the wireless IoT microcontroller unit will process information data received from sensing units. On one side, the data will be displayed by LCD module, and at the same time, another side will be transferred to an internet cloud network. In case the information data is an abnormal condition, then the operating system will alarm the user. Usually, in case the DO value in the water is not in the 5-6 ppm range, decided that it is in the abnormal condition. It needs to be noticed and resolved immediately. Thus, the water in the local pond is observed based wireless real-time monitoring system on an IoT platform.

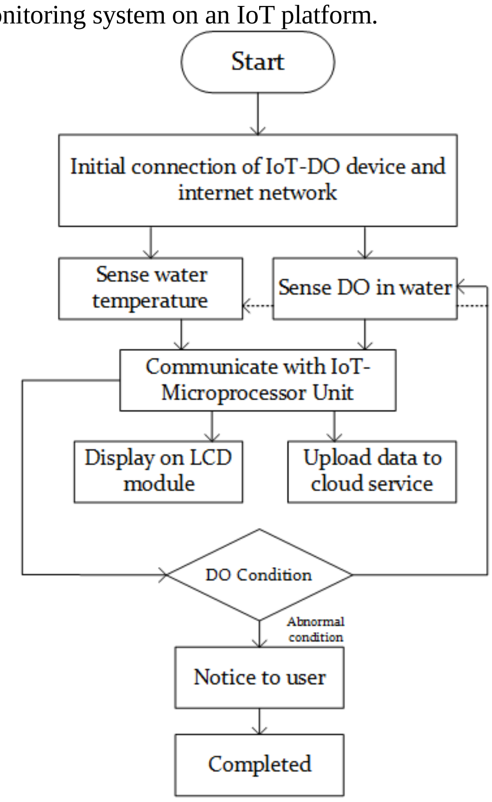


Fig. 3. Proposed system flowchart of wireless IoT-DO monitoring system.

## III. Experimental Results and Discussions

This section presents the test of IoT-DO devices that can monitor the continuous change of temperature and oxygen values in water. The embedded IoT-DO system is designed for telemonitoring of water characteristics. The parameters studied in this article are DO and temperature.

### A. Temperature in Water

The temperature of the water is an essential variable in aquatic animal ponds. It affects other parameters such as DO and pH, depending on the quantity of solar radiation, air temperature, air humidity, or even though the temperature of the water passing through the culture unit. Namely, the temperature is the most important variable that affects aquatic animal organisms' growth and survival [8]. Thus, water temperature levels can be caused by a vast number of factors, both natural and anthropogenic. Natural causes include weather, groundwater inputs, and turbidity. On the other hand, anthropogenic causes include removal of streambank vegetation that previously provide shade, impoundments (body of water confined by a barrier).

The DS18B20 temperature sensor model was adopted for this project. It is a digital thermometer that provides 9-bit to 12-bit Celsius temperature measurements. This sensor probe only requires one wire for the primary data line of transmitting temperature reading from the sensor to the NodeMCU-ESP8266 unit. Moreover, it contains 64-bit serial code, which makes an advantage for the users to adopt DS18B20 embedded on wireless IoT microcontroller board. The Carel passive NTC temperature probe has a length of 50 mm and a diameter of 6 mm. Once it is connected to the NodeMCU-ESP8266, it then provides a resistance value that is converted to temperature by the microcontroller unit on the IoT board. The temperature sensor DS18B20 ranges between 10 ℃ to 40 ℃ is considered. The measured voltage is proportional to the temperature with either a negative temperature coefficient (NTC) or a positive temperature coefficient (PTC). Namely, the correlation is not linear in the large temperature. However, it is still compensated for the Steinhart-Hart equation [9].

### B. DO in Water

DO is an amount of oxygen ($O_2$) dissolved in water. It indicates the health condition of the water ecosystem. Oxygen is vital to all forms of life, including aquatic life, which is used by plants and animals for respiration and by aerobic bacteria in the decomposition process. Thus, it can be in the range of 0-18 parts per million (ppm). Generally, the most natural water is support to be in the DO value only 5-6 ppm to survive a diverse population. In the proposed prototype presented herein, the DO kit ATLAS SCIENTIFIC is adopted because it is the perfect calibration equipment for hydroponics and standard lab use. Furthermore, it offers the highest level of stability and accuracy through its compact DO monitoring system.

### C. Relationship between DO and Temperature Values

This subsection declares the relationship between temperature and DO values that were tested in an indoor aquatic animal pond. The monitoring tested was run for a period time of 24 hours, starting from 8.00 am to 7.59 am in the next day. The 24 hours test time for the whole day and night can analyze the relationship of both parameters precisely.

Fig. 4. Water temperature monitoring test for crab culture pond in an indoor site.

Fig. 4 shows the monitoring of temperature and DO in the blue crab hatch since in the zoea stage [10]. The experimental results are summarized in Table I below:

TABLE I: DATA MONITORING TEST IN THE AQUACULTURE POND FOR 24 HOURS

| No. of Test | Time | Temperature (℃) | DO (ppm) |
|---|---|---|---|
| 1 | 1.00am | 24.14 | 8.95 |
| 2 | 2.00am | 24.38 | 8.72 |
| 3 | 3.00am | 24.74 | 8.87 |
| 4 | 4.00am | 24.96 | 8.12 |
| 5 | 5.00am | 24.87 | 8.12 |
| 6 | 6.00am | 25.78 | 8.17 |
| 7 | 7.00am | 25.13 | 8.02 |
| 8 | 8.00am | 26.85 | 8.01 |
| 9 | 9.00am | 27.52 | 7.59 |
| 10 | 10.00am | 28.83 | 7.83 |
| 11 | 11.00am | 28.33 | 7.66 |
| 12 | 12.00am | 28.12 | 7.63 |
| 13 | 13.00pm | 29.38 | 5.73 |
| 14 | 14.00pm | 29.68 | 6.13 |
| 15 | 15.00pm | 30.98 | 7.32 |
| 16 | 16.00pm | 29.56 | 7.49 |
| 17 | 17.00pm | 29.34 | 7.65 |
| 18 | 18.00pm | 28.23 | 7.56 |
| 19 | 19.00pm | 28.55 | 7.85 |
| 20 | 20.00pm | 26.33 | 8.15 |
| 21 | 21.00pm | 26.44 | 8.03 |
| 22 | 22.00pm | 25.33 | 8.12 |
| 23 | 23.00pm | 24.37 | 8.56 |
| 24 | 24.00pm | 23.66 | 8.64 |
| **Average** | | **26.90** | **7.872** |

Table I shows the results of data retention within one day. Thus, it is to efficiently analyzed and monitor the water temperature and DO levels. It is drawn and displayed in the form of the graph, as in Fig. 5.

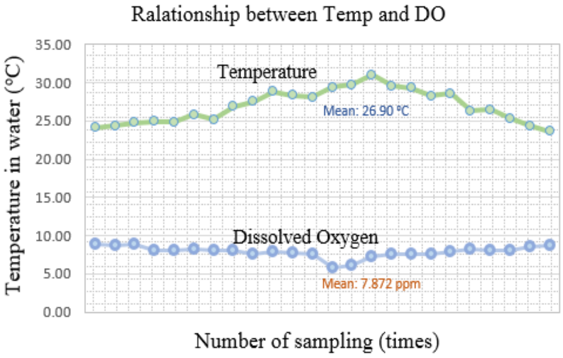


Fig. 5. The 24 hours test time for the whole day and night because can analyze the relationship of both parameters precisely.

The findings in Fig. 5 indicated that both parameters, water temperature and DO, were slightly negatively related. Namely, when the water temperature rises, the DO value decreases accordingly and vice versa. In addition, to confirm the collected data results of the experiment and achieve its credibility. Thus, the SPSS program was applied for statistical analysis. Additional information is shown in the following subsection.

### *D. Data Analysis using Statistical Package for the Social Sciences (SPSS)*

This subsection highlights data analysis using Pearson correlation coefficient (*r*) to analyze the relationships between both variables of water temperature and DO. Then, the Pearson correlation coefficient is defined as follows [11].

$$r_P = \frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)\left(Y_i - \bar{Y}\right)}{\sqrt{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2 \sum_{i=1}^{n}\left(Y_i - \bar{Y}\right)^2}} \tag{1}$$

where r = correlation coefficient

x = set of scores from water temperature variable

y = set of scores from DO variable

N = the number of pairs of scores

Usually, the correlation coefficient is scaled between -1 to +1. When *r* is close to 0 means, there is little relationship between variables. On the other hand, when *r* is farther away from 0, either the positive or negative direction. Moreover, when *r* closes to +1 means more extraordinary the relationship between the two variables. The analyzed results are shown in Fig. 6.

**Correlations**

| | | TEMP | DO |
|---|---|---|---|
| TEMP | Pearson Correlation | 1 | -.786** |
| | Sig. (2-tailed) | | .000 |
| | N | 24 | 24 |
| DO | Pearson Correlation | -.786** | 1 |
| | Sig. (2-tailed) | .000 | |
| | N | 24 | 24 |

**. Correlation is significant at the 0.01 level (2-tailed).

Fig. 6. The relationship of water temperature and DO variation.

The results reveal that the temperature variable affects the DO value. The water temperature and DO values are related by statistical analysis of -.786**, which is quite close to -1. It can be summarized that the water temperature and DO values are entirely negative correlations. Based on the individual test, using the IoT-DO monitoring system found that when the temperature is high, the DO value declines. Namely, those two variables are slightly negatively related. Moreover, the results were plotted into the graph form, as shown in Fig. 7.

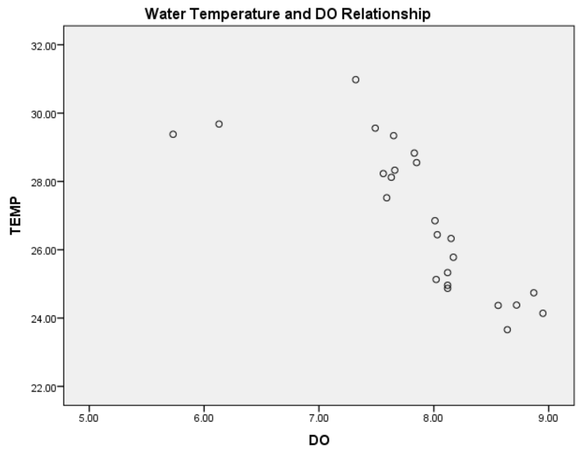


Fig. 7. The relationship of water temperature and DO variation.

According to the time variables, the relationship of DO and temperature parameters under the aquatic pond was close to 7.5 to 8.0 ppm at about 25 to 30 ℃. Based on the individual results were consistent with the study of N. A. Hussain (2021) and Boonsong. W (2021) [12], [13]. The referred study of Boonsong. W also mentions the relationship of both parameters in the opposite direction. Moreover, the descriptive statistics of the SPSS program was proved their reactions at -732.** value, which was very similar to the current experiment. Namely, both experiments are consistent, and it seems to agree in the same way.

### *E. Data Acknowledgement on Internet of Things Platform*

In this section, the data acknowledgment on the Internet of Things platform is declared about its benefits. IoT is unlocking efficiencies solution. This function assists in increasing production uptime, and it also can help to reduce operational risks. The Internet of Things applied for fisheries agriculture because it supports collecting and analyze data from connected assets, people, and places to deliver actionable insights in an industrial environment.

The concept of digital data transformation through IoT solutions for discovering how to improve farming operations, enhance enterprise workplaces and connect devices across broad areas.

LINE is a nifty app, and it is a chat app turned social media platform launched and dominant in Japan [14]. Out of characteristics of LINE qualification, it can be used to display the tracking information, which matched with software programming of Arduino IDE-IoT DO sensor device. The structures of the LINE application as shown in Fig. 8 below:

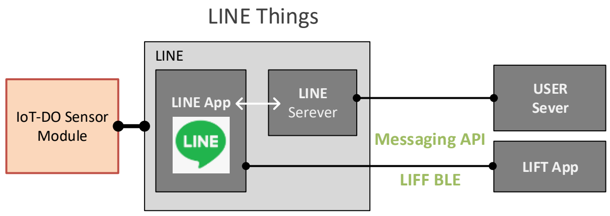


Fig. 8. The relationship of water temperature and DO variation.

Fig. 8 shows the traditional LINE Things platform that connects IoT-enabled devices to LINE's ecosystem. It allows offline devices to connect to bots and Web services. In this application, the data is acknowledged through the LINE App on the user's smartphone. Namely, there are three major functions are provided with LINE Things:

- Registering of LINE Things-compatible devices through LINE Application.
- Operating LINE Things-compatible devices via API through LINE front-end Framework (LIFF)
- Automatic connection and communication with LINE Things-compatible devices to bots and Web services.

The IoT-DO sensor device has increasingly played a role in the farming field. Especially in the industry ear time that has applied IoT technology with various data monitoring which to be able to link into machines and human being together. In order to get accurate and efficient information, reduce the time (downtime) in checking the water condition. Thus, IoT-DO sensor device was set up instead of manual operation in the farming process. It can reduce the cost of labor cost hiring, increase the safety of the operator and efficiency of work, and work productivity of products. Users can receive a piece of information from the aquatic pond with real-time monitoring and any place.

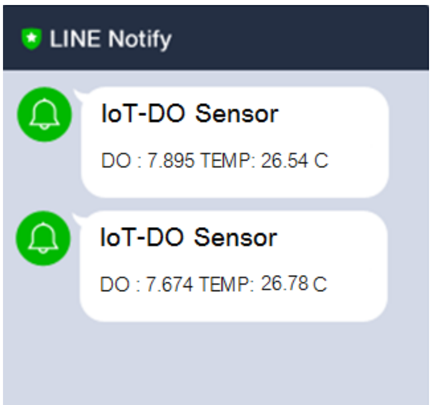


Fig. 9. Samples of information tracking displaying on LINE App.

Soon, many sections will be developed wirelessly connected via IoT technology and display applications. LINE App is utilized to display tracked information. It is firmware running on the devices include application software as well as the system software itself.

## IV. Conclusions

The proposed wireless IoT-DO monitoring system is useful for the smart farming field. It is used for tracking information data of quality water condition, which reduces human resource attending with the concept of M2M communication. However, human resources is still an important section that looks after the aquaculture pond using water quality monitoring. The proposed system can be fulfilled and improve aquaculture and fishing in the community. Moreover, the data collected in this approach can benefit aquatic environmental monitoring for collecting useful knowledge to establish an environmental model—the design of this sensor deployment strategy used for long-duration monitoring, analysis of micro-aquatic environmental changes.

## Acknowledgment

The author would like to grateful to the fiscal research grant under the Rajamangala University of Technology Srivijaya, Songkhla, Thailand, which supported the development of built-in house devices. Besides, the person who supports and shares the knowledge of crab culturing both indoor and outdoor conditions, Director Chamnan Marnin at Learning Center for Hatching of Crabs, Ban Hua-Khao Community, Singha-Nakon District, Songkhla Province, is appreciated.

## Conflict of Interest

This research article is carried out for only sharing knowledges of the proposed wireless dissolved oxygen monitoring system used in the crab culturing center, which “The authors declare no conflict of interest”.

## References

[1] G. Eason, B. Noble, and I. N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” *Phil. Trans. Roy. Soc. London*, vol. A247, pp. 529–551, April 1955.

[2] J. Yong, T. Masahiko, F. Kenji, and K. Ved P, “A lightweight and secure IoT remote monitoring mechaism using DNS with privacy preservation,” in *Proc. 16th IEEE Annual Consumer Communications & Networking Conference*, 2019, pp. 1-2.

[3] J. Wen, L. Bing, W. Yuqin, Q. Rui, and Y. Zheming, “Crowd V-IoE: Visual internet of everything archetecture in AI-Driven fog computing,” *IEEE Wireless Communication*, 2020, pp. 51-57.

[4] K. Jonathan, H. Suong, A. Grenville, and Philip Brance, “Using active queue management to assist iot application flows in home broadband networks,” *IEEE Internet of Things Journal*, vol. 4, no. 5, pp. 1399-1407, 2017.

[5] S. L. K. Probo and L. Yuan, “Implementation of air conditioning control system using REST protocol based on NodeMCU ESP8266,” in *Proc. International Conference on Smart Cities, Automation & Intelligent Computing Systems Yogyaharta*, Indonesia, 2017, pp. 126-130.

©2021 Journal of Communications

[6] MTG. (2020). Measuring Dissolved Oxygen (DO) with IoT. [Online]. Available from World Wide Web: https://www.manxtechgroup.com/measuring-dissolved-oxygen-do-with-iot/
[7] E. C. Boyd, "Dissolved oxygen requirement in aquatic animal respiration," *Global Aquaculture Advocate*, 2018, pp. 1-4.
[8] E. C. Boyd, "Water temperature in aquaculture," *Global Aquaculture Advocate*, 2018, pp. 1-5.
[9] Z. Zheren, H. Qin, and L. Rui, "Using two kinds of consensus control to solve the energy equalization problem of battery pack," in *Proc*. *34th Chinese Control Conference*, 2015, pp. 28-30.
[10] B. Wasana, A. Oluseye, J. Juthamas, and R. Kanlaya, "Real-Time dissolved oxygen monitoring based on the internet of smart farming platform," *Journal of Theoretical and Applied Information Technology*, vol. 98, no. 19, pp. 3193-3192, 2020.
[11] X. Honghui, and D. Yong, "Dependent evidence combination based on shearman coefficient and pearson coefficient," *IEEE Access*, vol. 6, pp. 11634-11640, 2018.
[12] N. A. Hussain, L. F. Lazem, A. K. Resan, M. A. Taher, and A. A. Sabbar, "Long term monitoring of water characteristics of three restored southern marshes during the years 2005, 2006, 2007 and 2008," *Basrah Journal of Science*, vol. 28, no. 2, pp. 216-227, 2010.
[13] W. Boonsong, "Internet of things for enhancement the quality of community: Case study of aquatic nursery in songkhla lake basin," *Przeglad Elektrotechniczny*, 2021, pp. 138-140.
[14] M. Steinberg, "LINE as super app: Plaltformization in East Asia," *Social Media + Society*, 2020, pp. 1-10.

Copyright © 2021 by the authors. This is an open access article distributed under the Creative Commons Attribution License (CC BY-NC-ND 4.0), which permits use, distribution and reproduction in any medium, provided that the article is properly cited, the use is non-commercial and no modifications or adaptations are made.

**Asst. Prof. Dr. Wasana Boonsong** graduated with the highest education from University Sains Malaysia (USM) in 2016. Her research areas are Embedded systems, data monitoring, RFID, WSN, and Internet of Things applications.