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Multi node sensors for water quality monitoring towards precision aquaculture

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Multi node sensors for water quality monitoring towards precision aquaculture

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Abstract. Shrimp culture is carried out by ponds in open areas, especially near coastal areas. The ponds water condition or water quality has a significant impact on the shrimp culture. There are also frequent problems among these shrimp ponds, such as crop failure caused by bad water quality. The water quality monitoring in shrimp ponds is often done manually by the farmer in periodical times. The water quality monitoring that is done manually tends to be impractical, requires high worker wages, and has a high human error rate. With the advances in the field of Information Technology, data may be retrieved through sensors and collected into a server. Then the data may be processed and visualized in order to support precision aquaculture using the Internet of Things (IoT). Precision Fish Farming (PFF) or precision aquaculture is a concept that applies control-engineering principles to aquaculture industries. The PPF concepts allow farmers to have the ability to monitor, control, and document biological processes in aquaculture farms. This research aims were to design and build a multi node sensor and master board to monitor water quality in real time using the prototyping method. The system consists of several sensors for monitoring temperature, pH, and salinity in shrimp ponds that are installed at each node. Nodes are actively sending data to the master board. This model is done to reduce the need for direct data access to the internet. The monitoring system is tested in PB Tunas Baru shrimps pond in order to check if the system may work properly. The sensor is set to retrieve pond water quality data every 5 minutes in a total 100 minute period. The result shows that the model works properly, and the means value of the total error rate for the salinity sensors, pH, and temperature sensors consecutively is 1.65%, 1.25%, and 0%. This information allows the farmers to maintain the water quality precisely in aim to produce high quality shrimp crops toward the precision aquaculture concepts.

1. Introduction

Indonesia is the largest archipelago country in the world, with a coastline of 95,181 km and an area of marine waters reaching 5.8 million square kilometers, which is 71% of the total area of Indonesia. Therefore, with the vast coastline area, the fisheries sector has become one of the leading sectors. Shrimp has become one of the leading of Indonesia's fisheries sector. Shrimp has an export value of around US \$ 1.5 billion, which is higher than fish and seaweed, which are US \$ 1 billion and the US \$ 0.2 billion, respectively [1]. Shrimp culture is carried out by ponds in open areas especially near coastal areas. The ponds water condition or water quality has great impact to the shrimp culture. There are also frequent problems among these shrimp ponds such as crop failure caused by bad water



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quality. Apart from disease, erratic weather can also result in poor water quality in the shrimp ponds, thus affecting shrimp growth. Poor water quality results in decreased appetite for shrimp and slower shrimp growth. So that more attention is needed to maintain water quality in shrimp ponds. Water quality that needs to be considered in the growth and life of shrimp is changes in temperature, salinity, dissolved oxygen and the degree of acidity or pH (Potential of Hydrogen) content in water.

Shrimp are aquatic invertebrates that are very sensitive to changes in water quality. Shrimp have certain water quality standards to support survival rate and optimal growth. The water quality parameters in shrimp ponds measured by the system are water salinity, temperature, pH, and dissolved oxygen levels. In semi-intensive shrimp culture, there are several parameters of maximum water quality, including: dissolved oxygen levels ranging from 1.8 - 3.5 mg/l, free carbon dioxide levels ranging from 4.9 - 6.6 mg/l, pH ranges from 5.63 - 6.64, temperature values range from 26 °C - 29 °C, and salinity values range from 16-18 ppt [2]. Monitoring of pH and water temperature in shrimp pond culture is very necessary to be able to assist shrimp farming entrepreneurs in monitoring the actual conditions that occur in the water quality in the pond at that time.

The water quality monitoring in shrimp ponds is often done manually by the farmer in periodical times. The water quality monitoring that is done manually tend to be impractical, require high worker wages and a high rate of human error. The advances in the field of Information Technology, raw data can now be retrieved through sensors and the data is collected into a server for further processing and visualization for precision aquaculture. Precision Fish Farming (PFF) is a concept that apply control-engineering principles to aquaculture industries. The PFF concepts allow farmer to have ability to monitor, control and document biological processes in aquaculture farms[3]. The concept of developing real-time monitoring to support the concept of the 4.0 industrial revolution, especially in the fisheries sector, was also initiated by the internet of things (IoT) concept. The concept consists of sensors that connected to NodeMCU as controller board to monitor pond water quality. The NodeMCU then sends the data directly to a database on the internet. The data stored in the database may be displayed on the monitoring application. Thus the data can be seen in real time by farmers for precision aquaculture to monitor the water quality. [4]

Based on the problems and concepts mentioned above, in this paper, we designed and developed a water quality monitoring system to monitor shrimp ponds in real time. The results are to support the concept of precision aquaculture in water quality monitoring. The system developed consists of several sensors for monitoring temperature, pH, and salinity in shrimp ponds installed at each node. Each node is actively sending data to the master board by using radio data communication. This model is designed to reduce the need for direct data access to the internet as the enhancements to the previous concepts mentioned above.

2. Methods

To develop the system we are considered using prototyping method. Prototyping method is one of software engineering method which is done in stages and communicated between developers and users. Each stage can quickly give the user an idea of how the system works even though not all parts are complete. The process of making a prototype is called prototyping. By using this method, every step is taken to make the prototype as fast as possible so that it can be communicated to the user so as to get feedback from the user to improve the prototype that has been developed. The prototyping method has a stages that can be seen in Figure 1 [5]. By using this method, it is hoped that the process of working with the system being developed can be carried out in a short time and meet the needs of farmers. The stages in this prototyping model consist of a quick plan, modelling and quick design, construction of prototype, deployment delivery and feedback and finally communication. The process is carried out several iterations so that the final form desired by the user can be fulfilled.

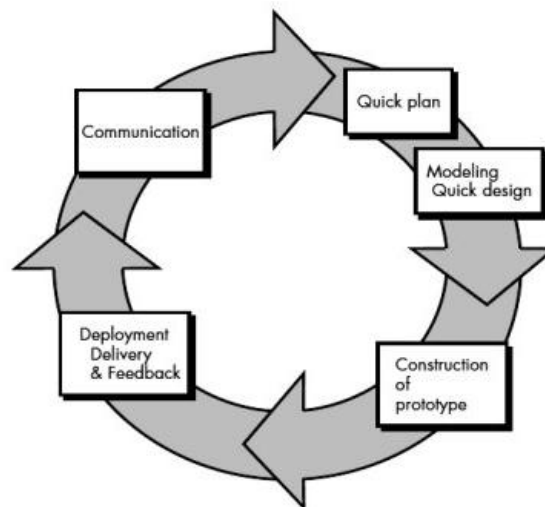


Figure 1. Prototyping Method

Data presented in this paper is collected from PB Tunas Baru Shimp Pond that's located in Jalan Pesisir Canti, Desa Canti Kecamatan Kalinda Kabupaten Lampung Selatan depicted in figure 2. The scenarios for water quality monitoring is by placed the node on each monitored ponds. The probe sensors then placed into the water. The nodes then actively sensing the water quality every 5 minutes and send the data through radio communication to the master board. The master board then collect the data form the node and send it to the cloud data base for further information displayed in monitoring applications.

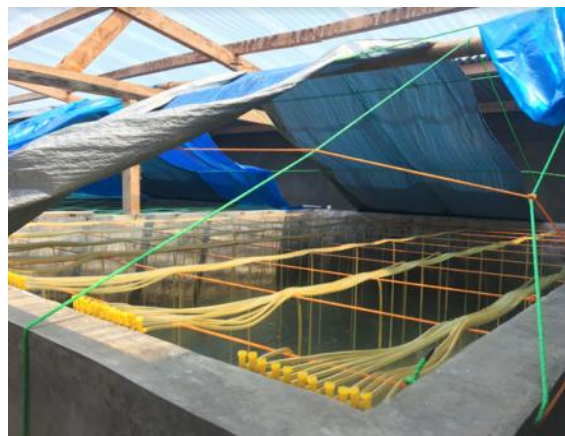


Figure 2. PB Tunas Baru Shrimp Pond

3. Results and discussion

3.1. Related works and quick plan

The work in [6,7] discuss the use of wireless sensor networks (WSN) for monitoring water quality. The design consisted of several sensors equipped in WSN nodes that collected the data and sent it to the base station/sink node or gateway. A base station is a device that responsible for capturing and providing access to the data from all nodes. It is also may sometimes provide a gateway services to allow the data to be access or managed remotely. The monitoring application then gets the data from the cloud to display it in monitoring device. The research in [8] uses WSN (wireless sensor network) concepts to build a monitoring system. The monitoring system consisting of several sensors, microcontrollers and wireless communication between nodes with low power and low cost device for remote water quality monitoring in wide area. The study show that the WSN concept may deployed successfully to monitor water quality parameter such as dissolved oxygen (DO), hydrogen ion

exponent (pH), conductivity, turbidity, depth of water, and temperature. The data then are transmitted between the nodes to the base station (BS) in a self-organizing wireless sensor network using water quality sensor module.

The study in [9] design an integrated online water quality monitoring system for shrimp aquaculture. The system has been applied specifically to monitor the DO (Dissolved Oxygen) and pH parameters in several shrimp aquaculture pond. The research aim was to reduce energy consumption using an automatic aeration system. The system created the optimum water condition for the shrimp aquaculture. The collected data from the sensor at each pond may also be accessed by SMS gateway and transmitted to the master station using radio communication. The work in [10] provide information to design of Pond water quality monitoring system Based on internet of things. The design consisted of sensors that sensing the ponds water quality controlled by Arduino. The controller then sent the data to the monitoring device. The monitoring application may show the data to the user and made an interpretation to control the pump and aerator automatically in order to create stable water quality. This study in [11] made a system for measuring water parameters in shrimp ponds. The initial stage was carried out in Sriminosari village, limited to pH and temperature parameters. The monitoring is carried out online so that information on the condition of pond water in several ponds is measured in real time. The IoT prototype developed in this service activity consists of a NodeMCU V3 Lolin microcontroller as a processing unit and a router based on the 4G WiFi modem. The data obtained later will not only be displayed in real time on Google Sheets, but will also be stored in databases in the Google Drive storage system, so that the monitoring data can be used for further purposes. Based on field test results, it shows that the IoT devices installed provides accurate and consistent measurement data information. Based on the concepts and related works mentioned above, we designed a water quality monitoring system to monitor shrimp ponds in real time. The system developed is consists of several sensors for monitoring temperature, pH, and salinity in shrimp ponds that are installed at each node. Each nodes are actively sending data to the master board by using radio data communication. This model is designed to reduce the need for direct data access to the internet as the enhancements to the previous concepts mentioned above.

3.2. Modelling and Quick Design

Internet of things (IoT) is a concept in which certain objects have the ability to transfer data through a network without requiring human-to-human or human-to-computer interactions. By using IoT, a person can interact with an object remotely. Basically, a system can be called to be IoT, it must meet a minimum of 4 components, namely the first one must have a device/sensor that functions to get and collect data from the environment. The second one must have connectivity that functions to send the data obtained which is then stored to a cloud or server. Furthermore, after the data reaches the cloud, the data will be processed using certain software. The last component that must be had is the user interface, the results of the information will be displayed in a certain way to be useful for the user [12].

Figure 3 depicts the high level design concept of multi node water quality monitoring system. Each node may monitor the level of water quality in pond. The node is equipped with pH sensor, temperature sensor, salinity sensor and dissolved oxygen sensors. The data then collected by the node controller and displayed int the LCD display in each node device. The node may also send the collected data to the master board through the radio communications via nRF24L01. The master board is equipped with the selection display to show the data for each node. The master board also connected to the internet to send the data to the cloud database using Firebase [13]. The monitoring application is installed in android smartphone to monitor the data in realtime [14]. The monitoring application may show an alert if the water quality parameter below or above the threshold.

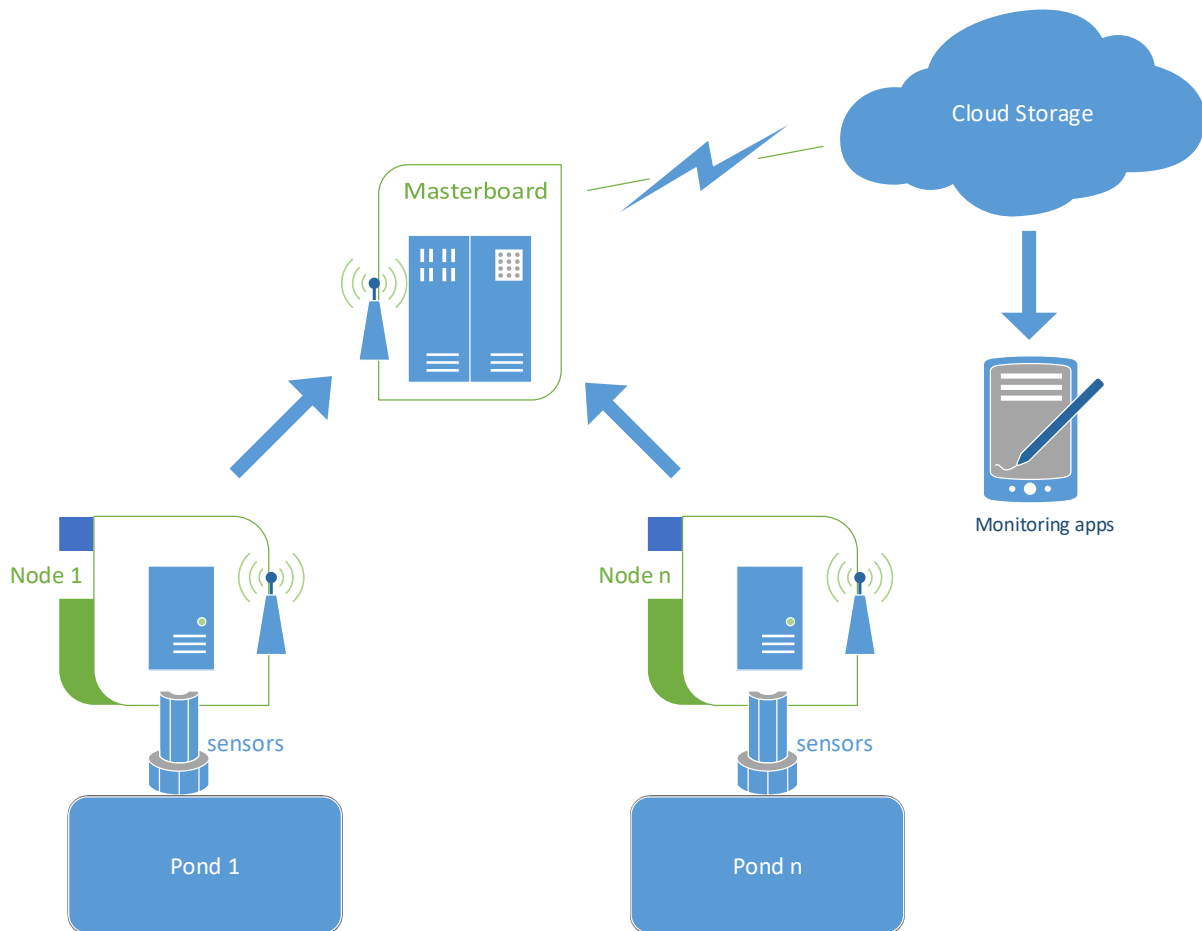


Figure 3. Multi node water quality monitoring design concepts

3.3. Construction of Prototype

Figure 4.a depicts component of the node devices in the shrimp pond water quality monitoring system is placed in a panel box. In the box number 1 is the Arduino uno which functions as a controller to process the data that has been taken with the sensors [15]. Box number 2 is a module of the pH sensor and temperature sensor connected to the Arduino uno and box number 3 is radio data communication nrf24l01 which is connected to the Arduino uno. Nrf24l01 functions to send data obtained from the node to the master board. Figure 4.b show the collected data from sensor in the LCD display in each node. Figure 5.a depicts a master board that is used to receive data from each node and send it to the internet. The master board will be placed in an area that is well accessible to the internet so that data received from nodes can be sent directly to the internet. In box number 1 there is a 20x4 lcd which functions to display the data received from each node and in box number 2 there is nrf24l01 which functions to receive data from each node. Figure 5.b shows the detailed components on the master board monitoring system for shrimp pond water quality. In box a is the Arduino Mega as a controller on the master board device. Box b is the Wemos D1 module which functions as an internet modem device. In box c is nrf24l01 which is directly connected to Arduino Mega. In box d is a 20x4 LCD along with the i2c module which connects directly to the Arduino Mega.

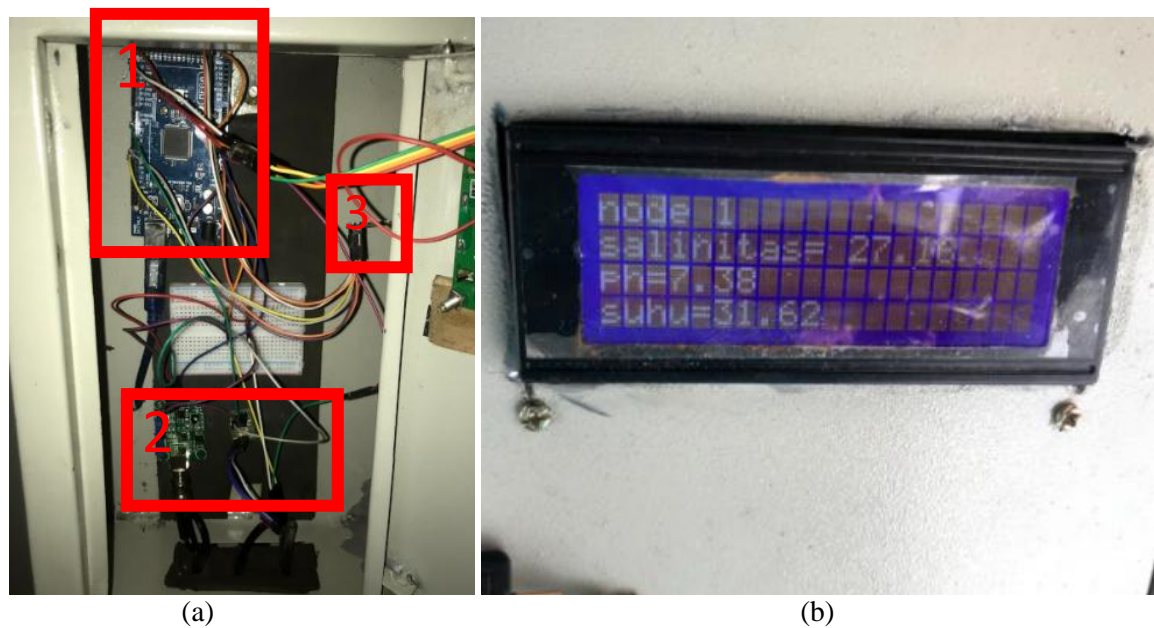


Figure 4. (a) Node devices box panel (b) Node data display

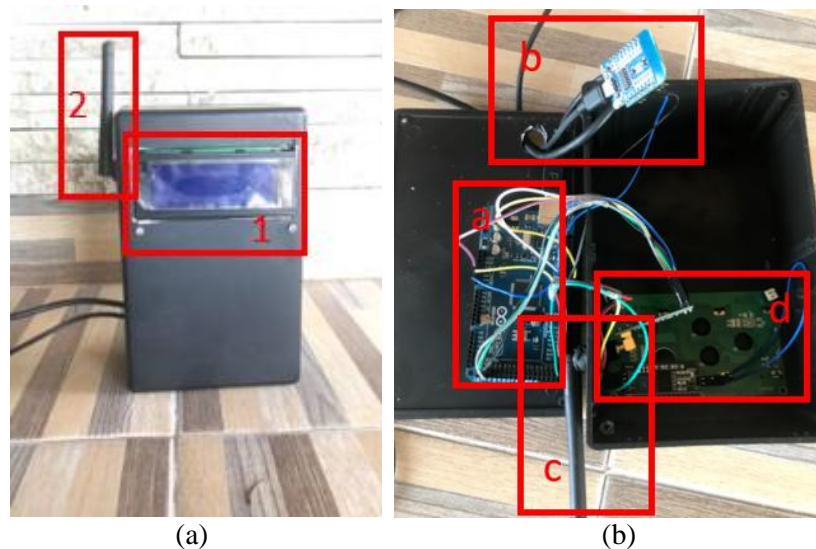


Figure 5. (a) Master board devices box panel (b) Detailed components master board devices

3.4. Deployment and delivery

The scenarios used in this research is the node collect the pond water quality using sensors with every 5 minutes interval and send the data to the master board. Table 1 show the data collected by the sensor using the node devices. The data that collected by the node sensors is compared with the salinity meter, pH meter and thermometer to analyse the error rate. The error rate is calculated using equation 1 below.

$$\text{Error rate} = \left(\frac{\text{data collected by sensor} - \text{data collected by calibrator}}{\text{data collected by sensor}} \right) \times 100\% \quad (1)$$

The results show data sensors may collect the water quality and the radio communication between node and master board working properly to send the data. The table also show that error rate is minimal below 3% in average. The salinity sensors show the highest error rate among the others. This is happened because the salinity sensors must be cleaned up periodically to ensure the sensor accuracy.

The salinity sensor probe is need to dipped the pond for sensing the data, this condition made the probe greatly influenced by the salt content in a longer time duration. The ponds environment and weather condition has the large influence to the water quality time by time. The data collected by the sensors provides precision information about the quality of the water in real time. Therefore, the farmers may take the corrective action in order to make the water quality better.

Table 1. Measure pond water quality data

No	Time	Salinity Sensor (Ppt)	Salinity Meter (Ppt)	Error rate	pH Sensor	pH meter	Error rate	Temp. Sensor ($^{\circ}\text{C}$)	Thermo meter ($^{\circ}\text{C}$)	Error rate
1	13:25	31	30	3%	7.3	7.3	0%	31	31	0%
2	13:30	30	30	0%	7.2	7.3	1%	31	31	0%
3	13:35	30	30	0%	7.3	7.3	0%	31	31	0%
4	13:40	31	30	3%	7.5	7.3	3%	31	31	0%
5	13:45	32	31	3%	7.5	7.3	3%	31	31	0%
6	13:50	31	31	0%	7.5	7.3	3%	31	31	0%
7	13:55	32	30	6%	7.4	7.3	1%	31	31	0%
8	14:00	32	31	3%	7.5	7.3	3%	31	31	0%
9	14:05	31	31	0%	7.3	7.3	0%	31	31	0%
10	14:10	32	32	0%	7.4	7.3	1%	31	31	0%
11	14:15	32	31	3%	7.4	7.3	1%	31	31	0%
12	14:20	31	31	0%	7.4	7.3	1%	31	31	0%
13	14:25	32	31	3%	7.4	7.3	1%	31	31	0%
14	14:30	32	31	3%	7.4	7.3	1%	31	31	0%
15	14:35	31	31	0%	7.4	7.3	1%	31	31	0%
16	14:40	31	31	0%	7.4	7.3	1%	31	31	0%
17	14:45	31	31	0%	7.4	7.3	1%	31	31	0%
18	14:50	32	31	3%	7.4	7.3	1%	31	31	0%
19	14:55	31	31	0%	7.4	7.3	1%	31	31	0%
20	15:00	32	31	3%	7.4	7.3	1%	31	31	0%

The master board then send the collected data to the cloud storage via internet modem. The master board and node model is made for low lost and internet traffic efficiencies. Multiple node may deploy and master board collected the data locally by using radio data communication. The android based mobile application is made for monitoring the data in real time. Multiple pond may monitor within single application installed in smart phone. Figure 6.a show the monitoring application on the android smart phone. If the temperature, salinity and pH values exceed normal limits, namely temperature 26°C - 32°C , salinity 10ppt - 25ppt and pH 7 – 8, the colour of the value in the application become red and the application will send a notification warning that water quality parameter exceeds normal limits shows in figure 6.b. The farmers may modify the threshold value to meet their requirements. The ability to monitor and document the water quality condition is one of precision aquaculture concepts. This ability allows the farmers to maintain the water quality precisely in aim to produce high quality shrimp crops.

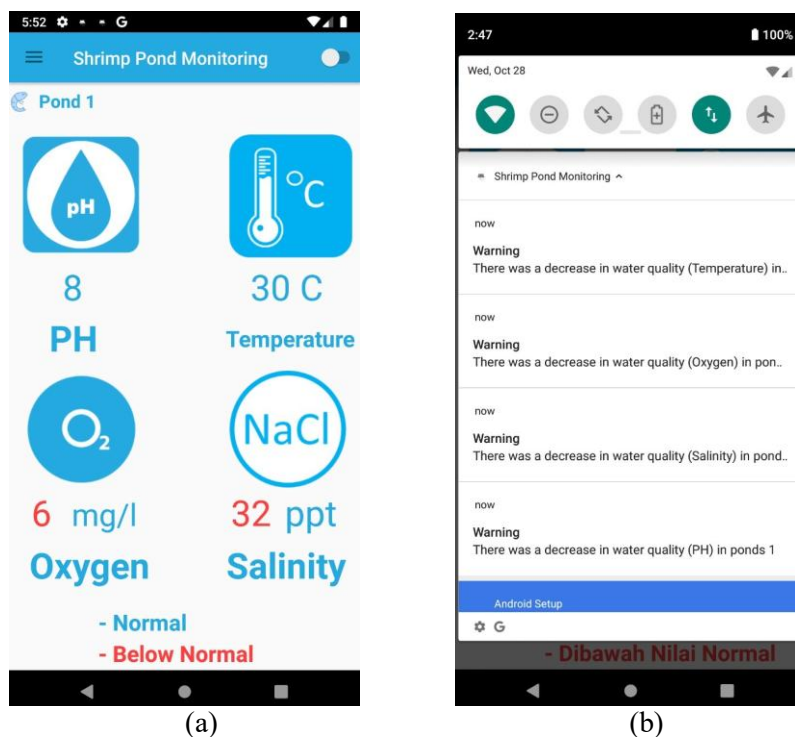


Figure 6. Monitoring application

Overall, based on results mentioned above the multi node sensors for water quality monitoring is work as expected. Therefore, it can be used to measure water quality of ponds and monitor the collected data via mobile applications. This developed model has similarity function with the works in [6–8] since we adopt the wireless sensor network method. However, the node developed in this research using Arduino board equipped with sensors and display. Thus, the farmers may see the data also in the node devices located in the ponds if they are not brought the smartphone as the monitoring devices. With this models we also enhanced the work in [9–11] by using multi node sensors the internet communication cost is reduced since data from node to the master node send locally using radio communication. The data collected by the sensors is displayed in the node, master board also into smartphone devices installed the monitoring applications.

The table results show water quality measured in shrimp pond in PB Tunas Baru. We may calculate the accuracy of the system by using equation 1. The means value of total error rate for the salinity sensors is 1,65%. However, the salinity sensors probe need to cleaned out in certain amount of time since the probe gets oxidized and affects its accuracy. The means value for pH and temperature sensors consecutively is 1,25% and 0%. It means the monitoring system developed in this research has good prospect to be used in pond monitoring system in order to support precision aquaculture concepts.

4. Conclusions

The system made for the pond water quality monitoring using a multi node sensor and masterboard working properly. The average error for the salinity sensor is 1.65%, the pH sensor is 1.25%, and the temperature sensor is 0%. The average sensor shows that the accuracy of the sensor is very good. The monitoring application may show the data collected by the sensor and sent an alert message if the water quality parameter is exceeded the standard limit. This information allows the farmers to maintain the water quality precisely in aim to produce high quality shrimp crops toward the precision aquaculture concepts.

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