

Monitoring water quality using star topology wireless sensor networks

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Abstract. The main purpose of this paper is how to implement wireless sensor networks (WSNs) using the star topology for water quality. This system using three devices. Two devices are the data transmitters and one device are the data receiver. Each device uses a NRF24L01 wireless module. There are two sensors that are temperature and Power of Hydrogen (pH) for each transmitter device. Each transmitter device can send temperature and pH data directly to the receiver. Receiver collects data from transmitter and sends it using serial communication to personal computer for monitoring. The result in the experiments is the data can be sent properly. The temperature sensor has an average error of 1.26 percent from 10 different data experiments. Data from the pH sensor test results explain that the pH sensor has an average error rate of 1.88 percent. The wireless module NRF24L01 can transmit data up to a distance of 30 meters. WSNs system using star topology has worked well and can be used in aquaculture ponds.

1. Introduction

Bangka Belitung Islands is a province surrounded by lakes form by ex-mining. Actually, It can be used as shrimp farming land. The farmers at Bangka Belitung Islands, generally farm in artificial ponds. Lack of technological touch in the shrimp farming causes minimum results. Both of water temperature and pH conditions are the most important things in shrimp farming. The inconsistent weather make the water conditions change rapidly. Therefore, by creating the monitoring system of both is expected can help the shrimp farmers to avoid the failure when harvest time is coming. Some of the researches show, wireless system using wireless RF Modules Xbee Pro type 802.15.4 are only able to send data with a distance of 48 meters. This is certainly not effective when the law of aquaculture has a distance of more than 48 meters [1]. These tools are used to help the quality control of water ponds based on wireless sensor networks such as acidity (pH) sensor, temperature sensor and Xbee PRO as ZigBee standard of wireless communication media. The acidity (pH) sensor results test are 1 to 14, its accuracy above 90% [2]. The water conditions of the lake are observed via online by using sensors without any cables. The accuracy at temperature are gained at ± 0.05 pH and 0.5°C [3]. The Op-Amp circuit can be applied to the temperature and pH sensors for water quality observation. As the results, the accuracy obtains 2°C accuracy results for the $0\text{--}40^{\circ}\text{C}$ accuracy range [4]. The research of using Wireless Sensor Network (WSN) method has been carried out with a web display [5].



Three different scenarios were examined to test the data transmission performance. The results proved that the wireless mesh network was reliable and robust [6]. Network connectivity is a crucial factor that must be taken into consideration in designing future solutions [7]. System controls the sleep schedule and the number of links to minimize the power consumption while satisfying an acceptable delay constraint [8]. This is necessary to address the shortcomings of the existing WSN solutions for WQM applications due to the inefficiency - such as short communication range and high power consumption - of the legacy communication networks often combined with the WSN systems in WQM applications. Long range and low-power communication networks are desired in WQM applications [9].

This analysis discusses how to design a device that can read water quality with temperature and pH sensors. In its application, each sensor can transmit data wirelessly. The star topology system is applied to the communication of each sensor to the data center.

2. Communication system

Each pond has a different size. For example, Vaname shrimp ponds are generally 5×15 m in size thus it needs to put more than one sensor. Each receiver devices reads the temperature and pH data then sends it directly to the server using wireless. The system used is a wireless sensor network with a star topology.

2.1. Wireless sensor network

WSN (Wireless Sensor Network) is a wireless network that consists a collection of sensor nodes and spread over certain areas. Each sensor node has a function to collect data and information, then it will be sent to the server or base station. The sensor node consists of a radio transceiver, microcontroller, and a battery as an energy source. WSN prioritizes low power consumption and in the design, there are a lot of sensor nodes or coordinator nodes, again it is expected that this network can work for a long time. WSN is a wireless network that uses sensors to monitor physical and environmental conditions.

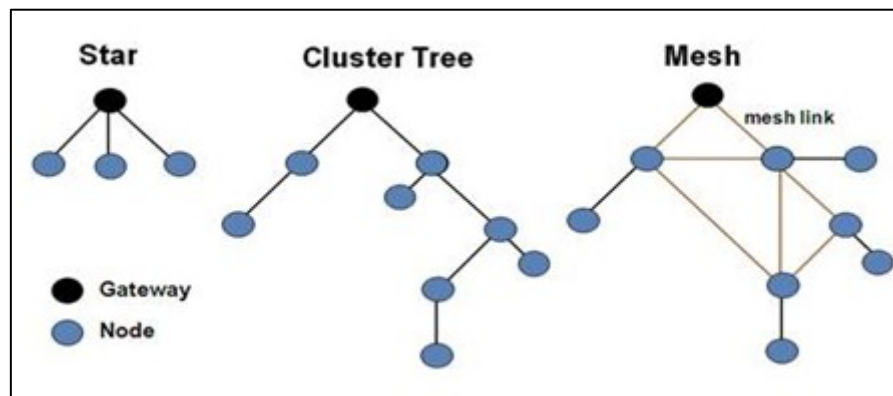


Figure 1. Topology in wireless sensor network [8].

2.2. Star topology

Star topology is a communication topology, where each node connects directly to a gateway. A single gateway can send or receive a message to a number of remote nodes. In star topologies, the nodes are not permitted to send messages to each other. This allows low-latency communications between the remote node and the gateway (base station) [8]. Star topology system is shown in Figure 2.

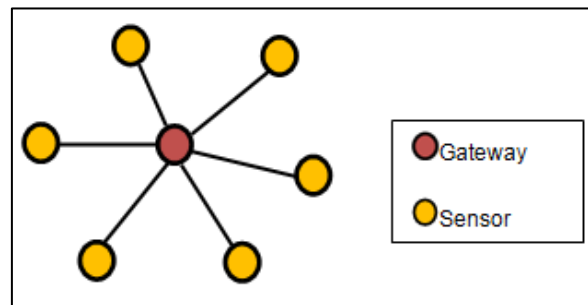


Figure 2. Star topology system.

3. Design System

3.1. Devices system design

In order to avoid obstacles during the implementation it is necessary to make an overall tool design. Each hardware and software component are selected by reference to the specifications. Each component must be compatible with the other components. The overall tool system design can be seen in Figure 3. There are 2 sensors namely temperature and pH for each pool. It aims to get the temperature value to represent the entire ponds. Each sensor has a microcontroller as data processor, the other is wireless transmitter as a sender of data to the central computing. All of the data get in a database then displayed to the monitor. The operator can observe the quality level to the temperature and pH of the water of each sensor.

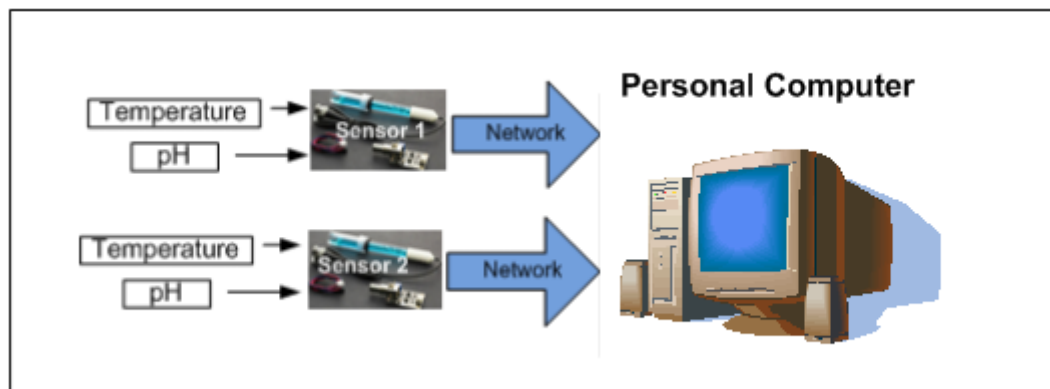


Figure 3. Overall tool system design.

3.2. Water temperature and pH sensors design

In one sensor system consists of temperature and pH sensors, Arduino Uno and wireless modules. Data received from the sensor is still analog, so it needs to be processed using a microcontroller. The analog data that gained from the sensor is converted to digital using the Analog to Digital Converter (ADC) of the microcontroller pin. After that, the data is sent to the data center wirelessly using the NRF24L01 wireless module. The hardware design can be seen in Figure 4.

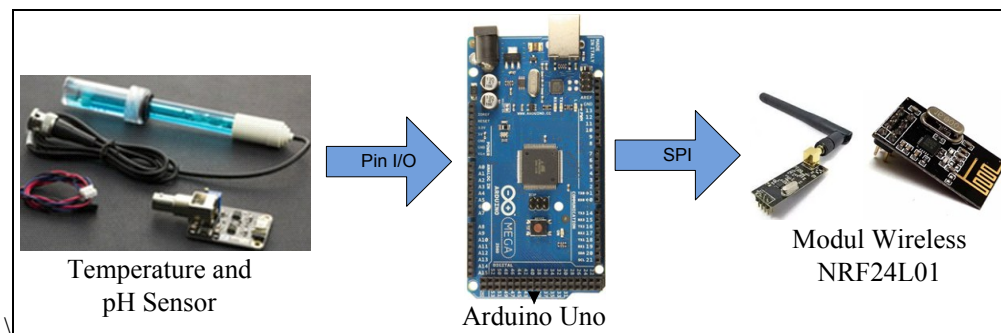


Figure 4. Hardware sensor design.

3.3. Communication system design

The data transmission for each sensor uses the NRF24L01 wireless module. It can use in 125 different channels which gives the possibility to have 125 modem networks that work independently in one place. Each channel has maximum 6 addresses, or each unit can communicate with up to 6 other units at the same time. Data communication systems can be seen in Figure 5. All data is received by one receiver, then it sends the data to the personal computer using serial communication.

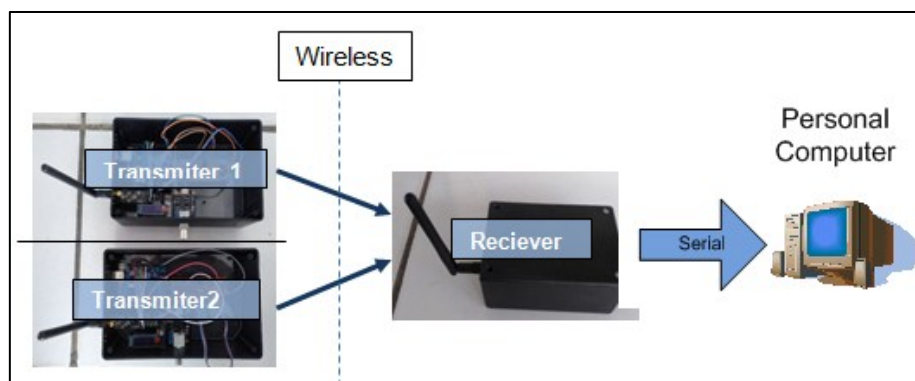


Figure 5. Data communication system.

4. Results and discussion

There are 3 types testing in this study by applying star topology method. The testing is using 2 sensor devices that considered to represent a pond. The function test of each sensor is still on a laboratory scale.

4.1. Experiment for temperature sensor

Water temperature experiments is using two DS18B20 temperature sensors and a temperature measuring instrument at the same time. There are only 5 water samples but at the observation there use 10 water samples. Both two DS18B20 temperature sensors installed in two different boxes. The following Table 1 is the results of experiments from water temperature tests that have been carried out.

Table 1. The results of water temperature experiments.

No	Temperature Sensor (°C)		Average	Thermometer (°C)	Error	Error (%)
	Temperature Sensor 1	Temperature Sensor 2				
1	30.87	31.19	31.03	31,60	0,57	1,80
2	71.50	71.56	71.53	71.40	0.13	0.18
3	28.75	28.94	28.84	29.30	0.46	1.50
4	26.25	26.50	26.37	26.70	0.33	1.20
5	43.06	43.88	43.47	43.40	0.07	0.16
6	36.75	36.88	36.81	37.30	0.49	1.30
7	36.50	36.75	36.62	37.20	0.58	1.50
8	55.81	56.63	56.22	55.10	1.12	2.03
9	32.19	32.31	32.25	32.60	0.35	1.07
10	27.44	27.69	27.56	28.10	0.54	1.90
The Average of Error Percentage						1.26

Table 1 explained that sample 1 uses plain water. After measuring it using both temperature sensors and one temperature measuring instrument, the temperature values obtained in sample 1. The temperature values can be seen in Table 1. The average temperature sensor is obtained from the calculation of the two temperature sensors using the following equation:

$$\bar{X}_{stemp} = \frac{temp1 + temp2}{2}$$

Where \bar{X}_{stemp} is the average of temperature value, temp1 is the temperature on sensor 1 and temp2 is the temperature on sensor 2. The experiments that have been carried out on sample 1 have an error value. The error value can be seen in Table 1. The error percentage value (% error temp) is obtained from the calculation of the average temperature sensor and temperature measuring instrument using the following equation:

$$\% error temp = \frac{\bar{X}_{stemp} + r_{temp}}{r_{temp}} \times 100\%$$

Where r_{temp} is real temperature of the measuring instrument. Then all the temperature error percentages ($\bar{X}_{\% error temp}$) are averaged using the equation below:

$$\bar{X}_{\% error temp} = \frac{\% error temp [1] + \dots + \% error temp [10]}{10}$$

4.2. Experiment for pH sensor

In testing the pH of water using 5 water samples used. Sample 1 uses a mixture of water with a pH powder of 4.01. Sample 2 used a mixture of water with a pH of 6.86. Sample 3 uses a mixture of water with a pH of 9.18. Sample 4 uses crystalline water with a pH of 8. Sample 5 uses le mineral water with a pH of 7.2-7.7. This study uses two sensors with the same pH meter temperature sensor, the pH meter

sensor is placed in two different boxes. The following Table is the results of experiments from the water pH trial.

Table 2. The Results of Water pH experiments.

No	Sensor pH meter		pH Meter	Average of pH Meter Sensor	Error Percentage
	Sensor pH Meter 1	Sensor pH Meter 2			
1	4.66	4.22	4.31	4.44	3.01%
2	7.48	7.01	7.13	7.24	1.54%
3	9.16	9.21	9.27	9.18	0.97%
4	8.63	8.11	8.52	8.37	1.76%
5	8.47	7.83	8.33	8.15	2.16%
The average of percentage error					1.88%

The Table above explained that sample 1 uses water pH 4.01. After measuring using both a pH meter sensor and a pH meter, the pH value of water in sample 1. The pH value of the water can be seen in Table 4.2. The average pH meter sensor is obtained from the calculation of the two pH meter sensors.

$$\bar{X}_{spH} = \frac{pH1 + pH2}{2}$$

Where \bar{X}_{spH} is the average of pH, pH1 is the pH on sensor 1 and pH2 is the pH on sensor 2. The experiments that have been carried out on sample 1 have an error value. The error value can be seen in Table2. The percentage error value (% pH error) is obtained from the calculation of the average pH sensor (\bar{X}_{spH}) and the pH meter (r_{pH}) using the equation below:

$$\% \text{ error } pH = \frac{\bar{X}_{spH} + r_{pH}}{r_{pH}} \times 100\%$$

Where r_{pH} is the real temperature of the measuring instrument. Then all the percentage error pH ($\bar{X}_{\% \text{ error } pH}$) is averaged using the equation below:

$$\bar{X}_{\% \text{ error } pH} = \frac{\% \text{ error } pH [1] + \dots + \% \text{ error } pH [10]}{10}$$

4.3. Communication system

WSN trial on star topology capability is using the NRF24L01 wireless module by sending data with distance differences. Each transmitter is set at a distance from the receiving device. The experiment began with 5 meters to 30 meters. Data shows that the device still receive the datas that the results of data sent by the transmitter device. It shown in Table 3.

Table 3. Data transmission test results.

No.	Distance (m)	Data sent		Data received	Status
		Transmitter 1	Transmitter 2		
1	10	1	2	1,2	Sent
2	20	1	2	1,2	Sent
3	30	1	2	1,2	Sent
4	40	1	2	1,2	Sent
5	50	1	2	1,2	Sent
6	60	1	2	1,2	Sent
7	70	1	2	1,0	Unstable
8	80	1	2	1,0	Unstable
9	90	1	2	1,0	Unstable
10	100	1	2	0,0	Not Sent

5. Conclusions

This paper has explained how the application of wireless sensor networks using star topology for Water Quality. Each device can directly send temperature and pH data directly to the receiver. The result explains that the temperature sensor has an average error of 1.26% from 10 different data experiments. Data from the pH sensor test results explain that the pH sensor has an average error rate of 1.88%. The wireless module uses the NRF24L01 type and can transmit data up to a distance of 60 meters. WSNs system using star topology has worked well and can be used in aquaculture ponds.

6. References

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