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A NOVEL FRAMEWORK OF WIRELESS SYSTEM NETWORK FOR WATER QUALITY MANAGEMENT

WIBOWO HARRY SUGIHARTO*[1], MUHAMMAD IMAM GHOZALI[1], HERU SUSANTO[2], MOCHAMAD ARIEF BUDIHARDJO[3] AND SURYONO SURYONO[4]

[1]*Informatic Engineering Study Program, Faculty of Engineering, Universitas Muria Kudus, Indonesia*
[2]*Department of Chemical Engineering, Faculty of Engineering, Universitas Diponegoro, Indonesia*
[3]*Department of Environmental Engineering, Faculty of Engineering, Universitas Diponegoro, Indonesia*
[4]*Department of Physics, Faculty of Science and Mathematics, Universitas Diponegoro, Indonesia*

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ABSTRACT

As an essential substance for every living creature, water needs to be properly maintained. Therefore, monitoring and managing water quality are very vital. This study proposed the novel framework using Wireless System Network to monitor the water quality in residential area. The parameters used in this study were temperature, pH, and total dissolved solid (TDS). This study used IaaS cloud computing service to display the data acquisition by real-time. Every sensor has been verified by comparing with probe sensor to indicate the accuration of the sensor. Furthermore, this study used multiple database. The collected data from sensor nodes stored in local data then going forward to cloud server using WSN for limitless scalability. The results of this study proved that the proposed sensor has a high accuracy in monitoring of pH, temperature and TDS parameters. The accuration level of pH, temperature and TDS parameters were 98.54%, 96.85% and 98.10%, respectively.

KEY WORDS : Water quality, Wireless system network, Sensor, Cloud computing, Metal oxide semiconductor

INTRODUCTION

Water is an essential substance in human life. Every living creature needs water as an essence of his life to survive (WHO, 2011). Water monitoring plays an important role to protect and manage water quality (Jin *et al.*, 2010. About 71% of our earth is covered by water (Alkandari *et al.*, 2011), but only 2.5% of the available water is fresh water (USGS, 2015) where up to 20% of world's population does not have access to safe drinking water (Yue and Ying, 2011). Therefore, monitoring and managing water quality is vital. The improvement of managing and monitoring water quality has started in ealry 2000 where a further improvement came with the advent of wireless sensor networks (WSNs). In past 10 years, several researchers have proposed WSNs implementation to monitor water quality (Zennaro *et al.*, 2009; Wang *et al.*, 2009; Yang and Pan, 2010).

Previously, the procedure for testing the quality of water was conducted by using traditional manual lab-base (TMLB) where the sample of water was collected and then transported to laboratory for analysis process (Bhardwaj *et al.*, 2015). But, TMLB approach presents several limitations. To address this limitations, researchers focus on this problem and lead to development of traditional manual in situ (TMIS) where the user put the in situ sensor to the water source to measure certain parameters on-site. However, this approach still left some limitations such is it cannot capture the water source quality continuously (Murphy *et al.,* 2015). For this limitation, researcher have started considering WSNs as an alternative solution. The main advantage of WSNs for water monitoring is that they do not need human presence to monitor (O'flym *et al.,* 2007; Zhang and Zhang, 2011). However, the network should provide and transfer data in timely manner (Chen, Jun-ming and Hui-fang, 2010).

WSNs show a good capabilities as self-organization, flexible network extension, low cost and low power (Jin, Ma, LV, Lou, and Wei, 2010). WSNs consist of a set of nodes with scanty power supplies to communicate one another (Xia, Tian, and Sun, 2007; Albaladejo, 2010). The WSN sensor node is equipped with sensor and microcontroller units, power supply, global positioning system (GPS), interface circuitry, processor and radio frequency transceiver (Faustine, 2014; Wang, Ren, Shen and Liu, 2016).

In the latest years, many researchers have conducted their research to identify different parameters that should me measured to determine the quality of water such as pH, turbidity, dissolved oxygen, residual chlorine detection, conductivity including salinity, total dissolved solids (Wagner, Boulger, Oblinger and Smith, 2006), temperature (Eckenfelder, 2001) fluoride (Analytical Technology Inc., 2015) calcium hardness and magnesium hardness (Cotruve, 2011), manganese (Connecticut Department of Public Health, 2015) sodium (Health, 2012), and oxidation reduction potential (Suslow, 2004). Many sensor models have been developed from several manufacturers to support the monitoring system and have been implemented by previous researchers. Different sensor models for different water quality parameters, such as Hach 1720 D, WQ730, WQ720 for Turbidity parameter, GLI PHD, WQ201, WQ101 for pH parameter and WQ401for dissolved oxygen parameter have also been used (Hall *et al.,* 2007; Xylem Inc., 2015). Sensor model for multiple parameters has also been developed. Other researchers have implemented low-cost WSN using arduino Mega 2560 (Libelium, 2014) and Arduino microcontroller.

Recently, the research area of WSN has focused on collecting data from sensor nodes and storing them into local database (Parra *et al.,* 2015). While monitoring of Fushun Reach River in China has started implementing a multiple database where the collected data in local database is transferred to database server via internet through GPRS cellular connection (Zennaro, 2009).

This paper proposed a novel design of water quality monitoring system based on WSNs. The framework design would be easy to be configured in single or multi parameters. The proposed design was also considered for low cost and low power with big capacity of network and user friendly interface by providing real-time data. This research also combined the multiple database where the data were stored in local database first then going forward to be stored over multiple database instance in the cloud using WSN for limitless scalability. The multi database is also important to prevent the potential failure caused by the loss of large number of small packet. As mentioned by Gill *et al.,* (2011), the loss of data occurred during failures where a large number of loss relative to the number of lost bytes. By implementing multiple database, the data stored in local data will be safe during network failures.

MATERIALS AND METHODS

The method steps in this study were preceded by taking the sample of each parameters for calibration test. The result of verification was then evaluated using percentage error. The specific steps was described in the following section.

Screening Parameters

The screening parameter were used to analyze the water quality of this study. Several parameters used in this study were temperature, pH and Total Dissolved Solid (TDS). Table 1 shows the definition and WHO standard of each measurement parameter (Albaladejo *et al.,* 2010).

Data Collection

This step was preceded by data collection as shown in Figure 1. The data was collected from monitoring of water quality in residential area using wireless sensor node station. The data then transferred to be displayed in the website. In transferring process, the sensor that connected with microcontroller in multi sensor acquisition send the monitoring data to be saved in master database, which was located in local server. Using the replication concept, the data were sent to replication database in cloud computing server. This process used HTTP Request/Response using IEEE 802.11bgn wireless network. MCU and wireless module used in this study were

Table 1. Measurement parameters properties

Measurement Parameter	Definition	WHO Standard (Drinking Water)
pH	Efective concentration of hydrogen-ion (i.e., pH=-log[H+1])	7-8.5 (preferably ≤ 8)
Temperature	Temperature impact DO content	15 °C (Drinking water supply)
Total dissolved solids (TDS)	Amount of small organic matter and inorganic salts	600-1,000 mg/L

ATmega32u4 (Arduino Leonardo) and Local server mini PC. Data security used was virtual private server. The result of acquisition station would be a basic data to be managed by online using online data acquisition. Thus, the data would be show the real-time data.

Error Verification

The verification process was conducted to evaluate the error level while calibration testing. The percentage error was formulated by using equation 1. The acuration of sensor acquisition was calculated using equation 2.

$$\overline{\% \, error} = \left| \frac{(X - X_i)}{X} \, 100\% \right| \quad .. (1)$$

where X denotes the observed variable and X_i denotes the predicted variables.

Sensor Accuration = 100% – % error .. (2)

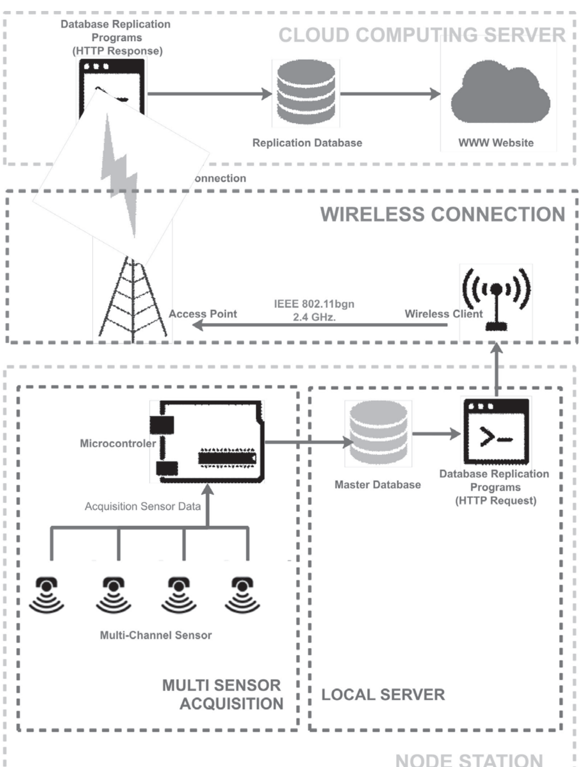


Fig. 1. Sensor acquisition data

where (% error) – denotes the mean error of each sensors.

Data Processing

The data processing of water quality was analysed by online in cloud computing using IaaS service, web design and MySQL database management. The design interface design of WSN monitoring system was shown in Figure 2.

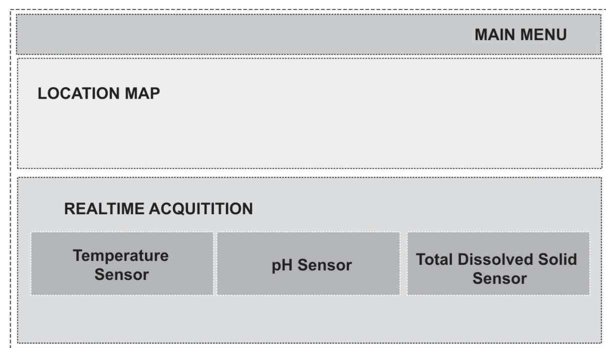


Fig. 2. Interface design of Water Quality Monitoring

DISCUSSION

The data acquisition system was made by building the hardware to support the framework. The data acquisition station was made as shown in Figure 3.

The acquisition station consisted of micropc and microcontroller that connected to signal converter of

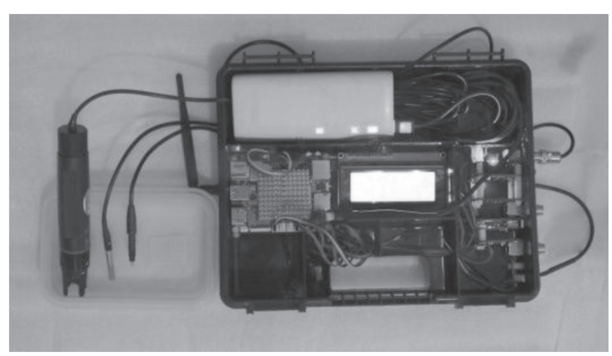


Fig. 3. The data acquisition system for water quality management

parameter as shown in Figure 4. Using 2.4 Ghz wireless connection, acquisition station send the data to cloud computing by http-request/response.

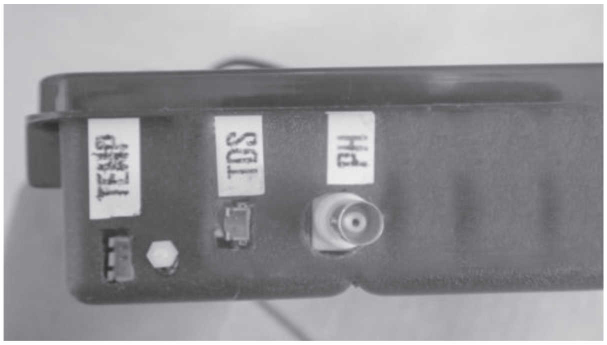
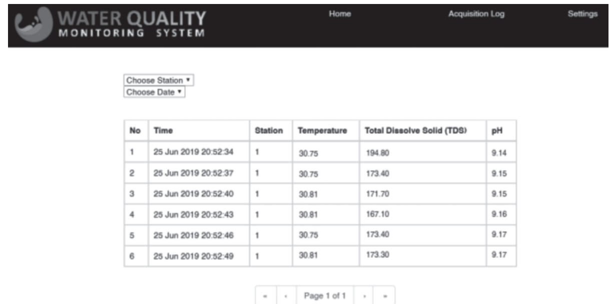


Fig. 4. Signal converter of parameter

Software as the main component in proposed framework, was developed using PHP programming language and MySQL as database. They worked in IaaS cloud computing service. The main function of this software was to display the data or acquisition station by real-time. The content of interface displayed were main page as shown in Figure 5 and acquisition log page in Figure 6.

The main page of user interface was displayed the real-time monitoring result of three sensors used in this study to analyse the water quality. While, acquisition log page showed the historical result of monitoring. This page was displayed in table and grouped by date.



No	Time	Station	Temperature	Total Dissolve Solid (TDS)	pH
1	25 Jun 2019 20:52:34	1	30.75	194.80	9.14
2	25 Jun 2019 20:52:37	1	30.75	173.40	9.15
3	25 Jun 2019 20:52:40	1	30.81	171.70	9.15
4	25 Jun 2019 20:52:43	1	30.81	167.10	9.16
5	25 Jun 2019 20:52:46	1	30.75	173.40	9.17
6	25 Jun 2019 20:52:49	1	30.81	173.30	9.17

Fig. 6. Acquisition log page

The data analysis resulted by each sensor was then evaluated by using different probe sensor according the parameter. The verification process of parameter used DS18B20 probe sensor by using mercury as shown in Figure 7. The verification result was shown in Table 2.

Table 2 shows the comparison between temperature sensor and probe sensor by using mercury as an object. There were found a minimum

Fig. 5. Main page of interface

Table 2. Verification result of temperature parameter

No	Sensor (°C)	Mercury (°C)	% error
1	29.25	29	0.86%
2	30.63	30	2.10%
3	31.75	31	2.41%
4	32.05	32	0.15%
5	33.57	33	1.72%
6	34.8	34	2.35%
7	35.46	35	1.31%
8	36.46	36	1.27%
9	37.86	37	2.32%
10	38.06	38	0.15%
		% error	1.46%

difference between those sensors. The (% error) of ten iteration was 1.46%. By using equation 2, the accuration of temperature sensor was 98.54%.

The verification process for pH sensor was conducted by comparing between the result of pH sensor and probe sensor using buffer pH solution.

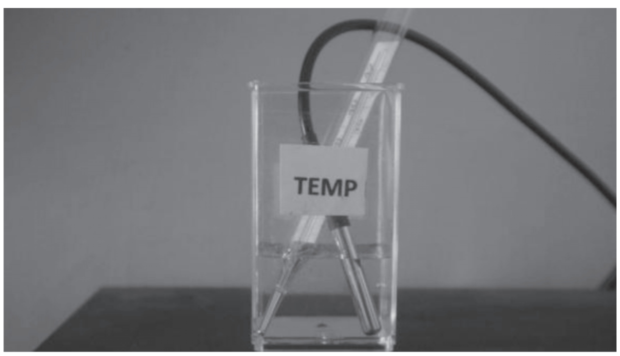


Fig. 7. Verification process between Temperature sensor and Probe Sensor DS18B20

Table 3. Verification result of pH parameter

No	Temperature	pH Sensor	Buffer PH Solution	% error
1	15	4.08	4.00	2.00%
2	20	4.24	4.00	6.00%
3	25	4.12	4.01	2.74%
4	30	4.26	4.01	6.23%
5	35	4.12	4.02	2.49%
6	15	7.16	6.90	3.77%
7	20	7.12	6.88	3.49%
8	25	7.05	6.86	2.77%
9	30	6.93	6.85	1.17%
10	35	7.03	6.84	2.78%
11	15	9.12	9.28	1.72%
12	20	8.88	9.23	3.79%
13	25	8.89	9.18	3.16%
14	30	8.76	9.14	4.16%
15	35	9.01	9.10	0.99%
	% error			.15%

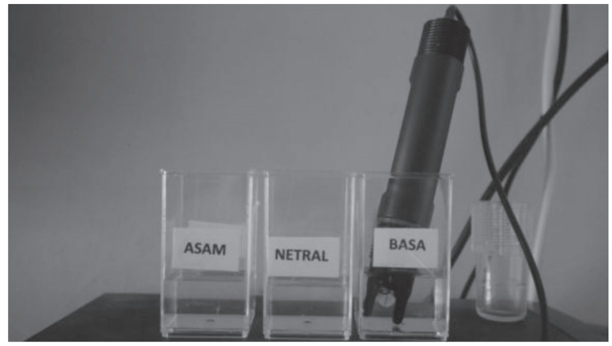


Fig. 8. Verification process between pH sensor and Probe Sensor using Buffer pH Solution

The verification process of pH sensor was managed by changing the temperature to ensure the capability of pH sensor. There were three kinds of pH level used in this verification, namely, normal and alkaline. The verification process was shown in Figure 8 and the results are presented in Table 3.

The pH sensor was examined in 15 iterations by changing the temperature within the range 250-350C and different level of pH water. The average of (% error) was 3.15 and the accuration level of pH sensor was 96.85%.

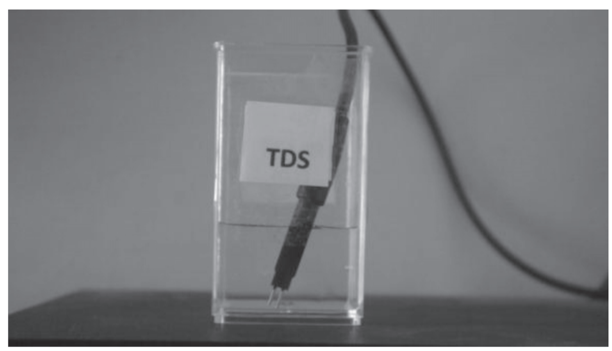


Fig. 9. Verification process of TDS sensor using buffer TDS Solution

The verification of total dissolved solids was conducted using probe sensor buffer TDS solution as reference for comparison. The verification process of TDS sensor verification was shown in Figure. 9. The result of verification was presented in Table 4.

The verification process of TDS sensor was conducted using 10 iterations by changing the temperature in range 0-30 ^{o}C. It was calculated and obtained the amount of (% error) was 1.90% and the accuration level of TDS sensor was 98.10%.

CONCLUSION

The verification process of each sensor was

Table 4. Verification result of TDS parameter

No	Temperature		Sensor TDS (ppm)	TDS Solution (ppm)	%error
1	0		746	758	1.58 %
2	5		901	876	2.85 %
3	10		983	999	1.60 %
4	15		1169	1122	4.19 %
5	20		1288	1251	2.96 %
6	23		1320	1329	0.68 %
7	24		1345	1358	0.96 %
8	25		1366	1382	1.16 %
9	26		1395	1408	0.92 %
10	30		1483	1515	2.11 %
		% error			1.90 %

obtained. The accuration level of temperature sensor, pH sensor and TDS sensor were 98.54%, 96.85% and 98.10%, respectively. The high accuration result of the sensor working indicates that the proposed novel framework of WSN in this study was capable to be applied as water quality monitoring system. The most contribution of this study was the novel design where the user can monitor the water quality in real-time. Furthermore, the result of monitoring analysis was displayed in user friendly interface and big capacity of storage.

This proposed framework design was capable and suitable to be placed in residential area to monitor the water quality. However, the parameter used in this study was limited. For the further research, the other parameters must be added to integrate the result of water quality. Also, this framework was designed for single station only. In the further research, the framework system will be developed to multi stations in order the monitoring activity can be carried out simultaneously in a number of different places.

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