Development of IoT for Automated Water Quality Monitoring System

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***Abstract*— The need for water consumption not only for humans but also the other living things as natural supporting elements for continuity of life. Water consumption depends on the availability of water resources like rivers, lakes, and reservoirs. Certainly, water becomes limited natural resources most of them because of water pollutions. It is necessary to manage water quality to fulfil the sustainability of water functions as natural resources, we create an integrated system based on Internet of Things to measuring the water quality by developing environmental water management monitoring system using sensors. The use of raspberry pi as an embedded system will help in the manufacture of detecting sensors device and the use of remote communications technology can help the interaction of sending data between things. The result is the IoT water quality monitoring system can be operated as an automated water monitoring system for surface water and it's real-time online.**

Keywords—Internet of Things, Surface water, Development sensor device, River water quality, Water river monitoring, real time online.

I. Introduction

How important the role of water for the life of living beings, not only for humans and even other living things need water as one of the supporting elements of the continuity of life in every living creature. Actually, water is an unlimited natural resource, because water sources can be obtained from several water sources. According to the Surabaya regulation No. 2 of 2004 on the definition of water that all water contained in or derived from sources both above and below the soil surface, including sea water utilized on land and sources of water are places and containers water, both above and below the soil surface, including the aquatic, springs, rivers, swamps, lakes and reservoirs [1]. Nowadays, the increasing population growth causes the demand for clean water consumption to increase. Demand for increased water availability and consumption if not matched by standard water quality and water pollution causes water to be a limited natural resource and always degraded.

Referring to Local Regulation of Surabaya City No. 2 Year 2004 regarding management of water quality and pollution control that water is natural resource that must be utilized to fulfill the livelihood of many people, therefore need to be preserved and sustainability of water function especially at source water to improve human well-being. To conserve water function it is necessary to manage water quality and control water pollution wisely by taking into account the interests of present and future generations as well as the ecological balance. To realize the sustainability of water function, the various control of water pollution has been done. However, there are still a handful of people littering, disposal of industrial sewage into rivers, as well as untreated household waste. Various water problems, both directly and indirectly, have caused increased water pollution.

In realizing the environmental ecosystems that play a role in the management and processing of water sources for the better, several studies have been done to determine the water content. Water content in an environmental system can be known by manual, where the process is done by taking samples of water using tools such as glass, scoop, and other tools such as bottles. The results of water samples taken, checked using the laboratory to determine the water content. This manual process takes about 1 to 30 days depending on what parameters you want to measure and examine. The results obtained from the manual procedure depend heavily on how skilled and observational the process of measuring water is. In fact, the current process of measuring water quality parameters performed by most of Perusahaan Daerah Air Minum/PDAM (water utility company) and Balai Lingkungan Hidup/BLH (Center for the environment) is still done manually, and water sampling is done periodically. In addition to using manual procedures, only a few water quality measurements are performed in an automated method using a water sensor to determine water quality. This is because the cost for using the sensor is not cheap, and another reason is some of the sensors and its use is still not maximal.

Sukaridhoto, etc. their research build portable water monitoring system with similar devices. They collect the data from sensors and send the data to the cloud [2]. Shifeng Fang with his associates, built a system of monitoring the environment to monitor climate change in mainland China in the XinJiang region [3]. The system uses air sensors, humidity and precipitation. The article titled "An Integrated System for Regional Environmental Monitoring and Management Based on Internet of Things".

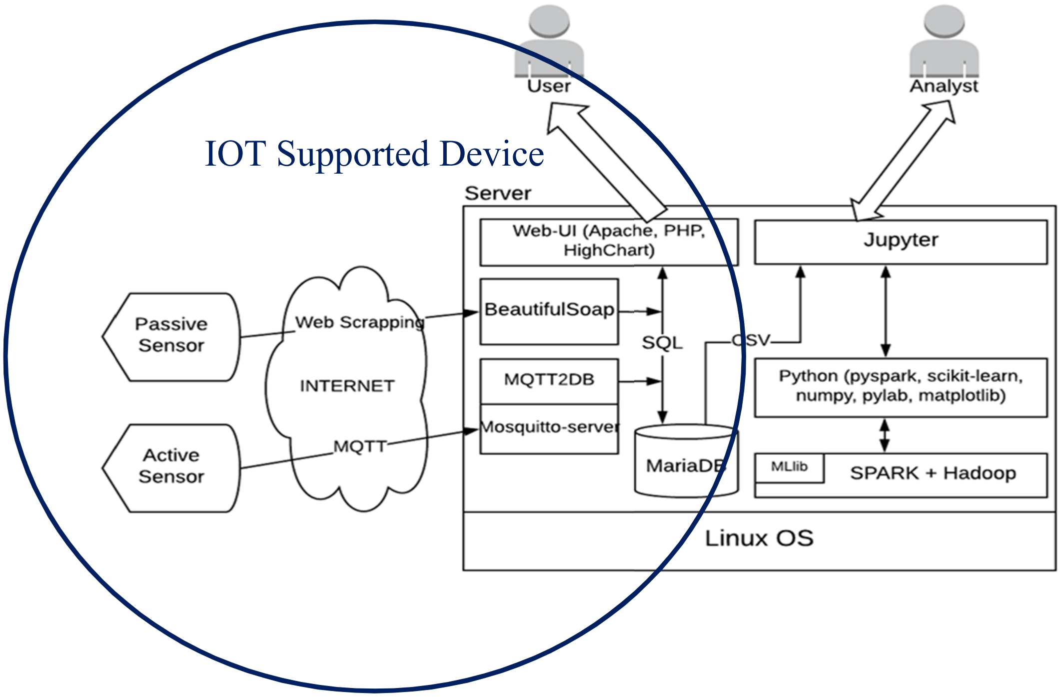


Fig. 1. System Design

Fig. 2. Research Location

By implementing the use of Internet of Things (IoT) technology supported by data retrieval method using sensors, embedded systems and the use of remote communication technology can help simplify the water quality parameters.

II. Research Methods

A. System Design

In this research, it has a system design as depicted in Fig. 1. The location of data collection is at the river water source of Kali Surabaya. We put the sensors before the intake on the water gate of PDAM KARANG PILANG. Referring to research in the previous paper by our research group while do some research to get the data from passive sensor using web scraping through the paper, "Web scraping for Automated Water Quality Monitoring System: A case study of PDAM Surabaya" [4].

In this research, the author combines Internet of Things technology consisting of YSI 600R water sensor, raspberry pi 3 as embedded system, and 4G communications.

B. Research Methods

In this study, the research method has been carried out as illustrated in Fig. 3. In the early stages, after making observations with the study literature and survey conducted location permissions for the process of data retrieval. Furthermore, the preparation of infrastructure and create Web UI (User Interfaces), then create database system for IoT Platform.

After the development of database system done, then get the data from passive sensor using Web Scraping technique and also get the data from active sensor using Python serial programming. Then transmission the data to the database system using MQTT protocol. So that the development of IoT sensor devices can be view as the IoT platform can be obtained the results status sensor monitoring system from these sensor data.

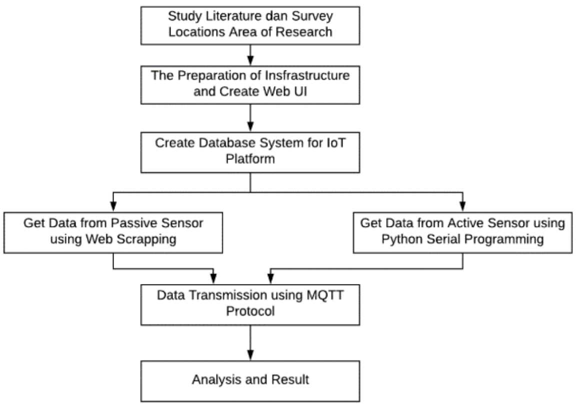


Fig.3. Research Methods of Development IoT Platform for the water quality sensor device.

C. Python Serial

In this research, to retrieve data from YSI600R [5] water quality sensors connected via serial port RS232 used Python programming [6]. In python, it has own module to fetch data via serial port called pySerial. The used of pySerial provide the communication parameter include 8 bits, Non-parity, and 1 stop bit or commonly abbreviated as 8N1. The data transfer rate that used in this research was 9600 bps. By using Raspbian OS the serial identified by /dev/ttyUSB0 when pySerial calls modules with serial import to read and write the data.

D. SQL lite and MariaDB

In this research, for application data logging local authors using RDBMS application is known as SQLite[6]. SQLite can directly read and write on a disk storage. Also, because SQLite is a very practical library, so SQLite can run well on limited memory environments such as raspberry pi 3. For another DBMS system for the development of database system, we used MariaDB which is used for enterprise, because MariaDB already supporting high availability, security, interoperability, etc [7].

E. MQTT

In this research, for efficiency of the data transfer for Internet of Things system, we used the MQTT protocol (Message Queue Telemetry Transport Protocol) [8]. The MQTT protocol is a network protocol that uses the publish/ subscribe concept in its data transmission, usually for sending messages between "Internet of Things" devices. MQTT platform broker is a mosquito [9]. The use of MQTT which is only designed to publish and subscribe message with minimizing the use of network bandwidth and device resources requirements, especially application usage for IoT. There has been a lot of research about implementation apps using MQTT such as application DIY Smart Trash for IoT open platform [10].

III. RESEARCH RESULT AND ANALYSIS

In this section, we explained about research result and analysis which including the implementations of IoT Sensor device, read and get the data from passive and active sensors.

A. Get the data from passive sensor by using web scrapping

In this stage, using previous paper about the web scrapping [4]. We have built and develop logging data during the research. The research location of data collection using the output of water quality parameter in the river water source of Kali Surabaya, which near intake area on the water gate of PDAM KARANG PILANG. The research area location is shown on Fig. 2. During the observation on this research, there is no logging data for this sensor things, so we built and made database to pull data for logging data water quality parameter to became data input.

B. Collecting data from Active Sensor

In this stage, we also has made the Internet of Things device consisting of a series of sensors that use water quality sensor and connected with embedded systems equipped with software that serves as a data processing unit of the sensor and send data to a data center using a 4G connection. The Sensor IoT system, we built can be shown in Fig. 4. In this system we combined things, using Raspberry Pi type B, YSI 600R Sensor, Modem wifi 4G, and Adapter Input 5 Volt and 12 Volt.

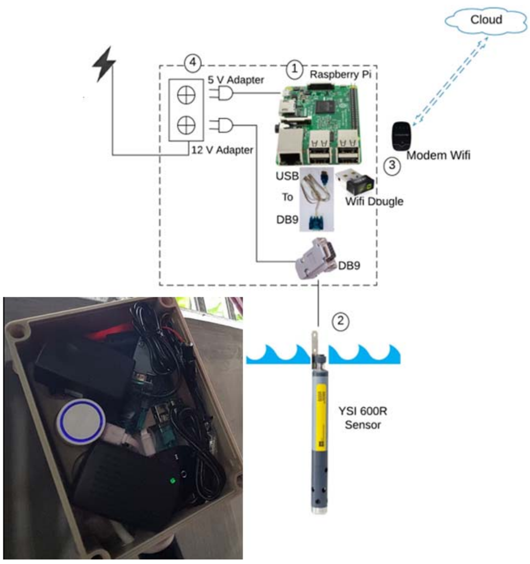


Fig. 4. Design Supported Sensor for IoT

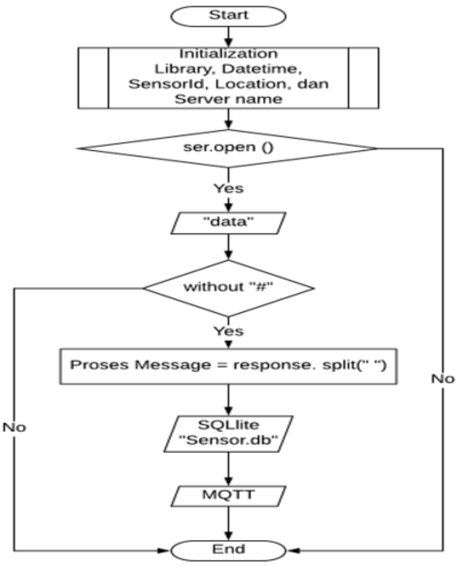


Fig. 5. Flowchart Watermond Application

In this IoT development, the raspberry pi 3, model type B. The embedded system is used as a data processing center where the Rapsbian operating system has been modified and an addition of *watermond* application is used to retrieve data and transmit water quality data from the sensor, then processed so that data can be stored in the local database temporarily using SQLite and MQTT protocols for the process of sending data to a bigdata server. The data retrieving from the YSI Sensor in every 4-5 seconds and then save it temporary to locally database SQLlite. By using data communication MQTT protocols, this *watermond* application sends the keyword in the form of string "data" so that the sensor directly gives feedback in the form of water quality data coming from the sensor. *Watermond* applications that have been made this all running on the background process. In connecting between IoT device system with database server, this research using Modem 4G as its communication network. In addition, in case of damage to the connection, watermond applications can stop sending data and only store locally. If the connection can be done automatically watermond applications can send data back to the database server. The following is flowchart of watermond application, which describes the data retrieval, processing and transmission of sensor data shown in Fig. 5.

C. Collection and retrival of data

In this research, water quality sensor connected to the raspberry pi type B and the sensor is able to send data by using MQTT protocols, we called the active sensors. To be able to store incoming data into MQTT Broker into the database, required a connection into the database server. In here, we built a Python-based MQTT2DB application has been developed to transmit data from sensors received in the MQTT Broker into the DBMS. When receiving messages from MQTT brokers that receive data from MQTT Publisher, MQTT2DB sort messages in and perform SQL Insert into the DBMS. In this research, also used sensor WTW IQ SensorNet 2020 XT as passive sensor, where the sensor can not send sensor data to the big data server. So the big data server needs to download data that is on this sensor to be entered into the database in the big data server. The passive sensor in this study has a web-based output running on the sensor. The data displayed in HTML format and structured in a table. So we need a mechanism that can sort the sensor data from HTML based table and store the data taken in the database. By using web scrapping [2], we can get all data from the sensor using the beautiful soup library with Python programming language. In this research, Sensor YSI 600R using as active sensor, which can be shown in Fig. 6.

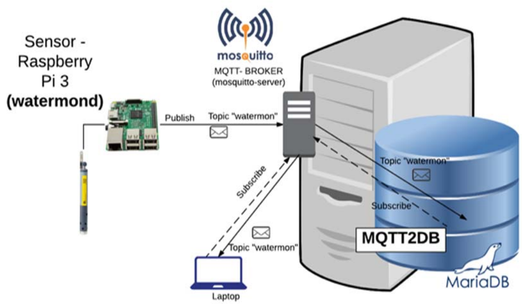
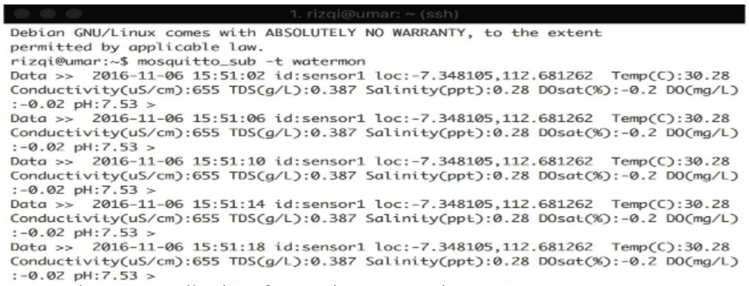


Fig.6. Sensor with Raspberry Pi 3 Model B using as Active Sensor.



```
1. rizqi@umar: ~ (ssh)
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
rizqi@umar:~$ mosquitto_sub -t watermon
Data >>  2016-11-06 15:51:02 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
Data >>  2016-11-06 15:51:06 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
Data >>  2016-11-06 15:51:10 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
Data >>  2016-11-06 15:51:14 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
Data >>  2016-11-06 15:51:18 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
```

Fig.7. Data collections from active sensor using mosquitto_subscribe

Fig. 8. The location between PDAM Surabaya, Ngagel, with water reservoir Karang Pilang

IV. Result Discussion and Recommendation

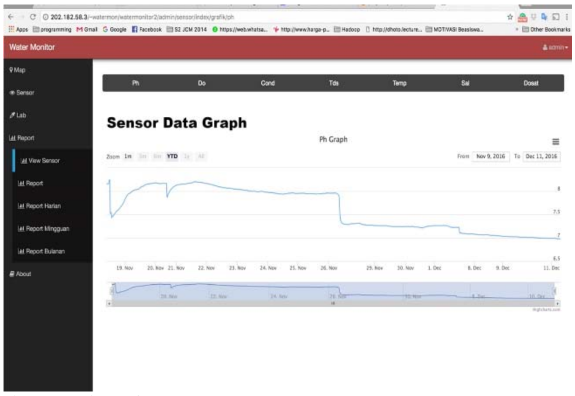


Fig. 9. Web UI for sensor YSI 600R

Data sensor types, we have several data types of sensors namely: sensordb, datasenkp, and datasenng. First sensordb data, this data is obtained from YSI 600R sensor installed in river waters in Karang Pilang area. This location is adjacent to the water intake of PDAM Karang Pilang. This data is taken with the aim of obtaining the status of raw water conditions used by PDAM. Data is taken 24 hours continuously with the frequency of data retrieval 4-5 seconds until the sensor data once reading the data and can be read clearly in database system. The data format sent contains information: date and time, sensor id, location (latitute, longitude), temperature, conductivity, TDS, salinity, DO saturation, DO, and pH. The transmitted data can be seen in Fig. 7.

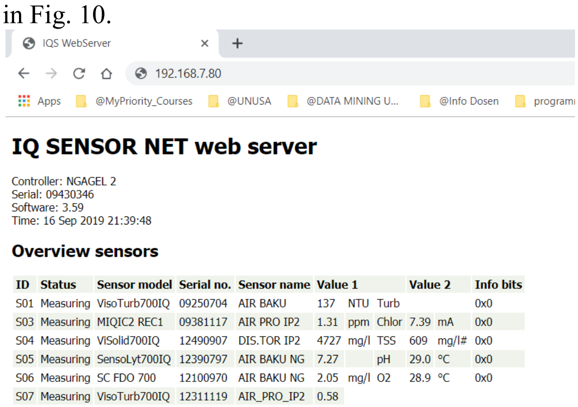
The second data used in this research is the data from sensors located in the reservoir of PDAM for the location of Karang Pilang and Ngagel. This Data is derived from the WTW IQ SensorNet 2020 XT sensor installed in the PDAM. The Sensor runs for 24 hours, the data is taken with a web scraping technique with a retrieval time of 4-5 seconds. Data from Ngagel has parameters among others: Turbidity for raw water, Chlorine for production water, TSS, raw water pH, DO raw water, Turbidity water production. Data from Coral Pilang has a Turbidity parameters of raw water, Turbidity water production and Chlorine water production. Karang Pilang Data is referred to as datasengkp, and data from the sensors located in Ngagel is called datasenng.

A. *Web UI from active Sensors Device Monitoring System*

In this research, we built web-based UI using PHP and HighChart Javascript that are used to display graphics from the sensor live or within the time frame. The dashboard of Web UI from sensors device monitoring system can be shown in Fig. 9.

B. *Get Data from passive Sensors Device Monitoring System*

In previous research [4], the passive sensors device monitoring system can be shown in the web dashboard in Fig. 10.



IQS WebServer

192.168.7.80

Apps | @MyPriority_Courses | @UNUSA | @DATA MINING U... | @Info Dosen | programi

IQ SENSOR NET web server

Controller: NGAGEL 2
Serial: 09430346
Software: 3.59
Time: 16 Sep 2019 21:39:48

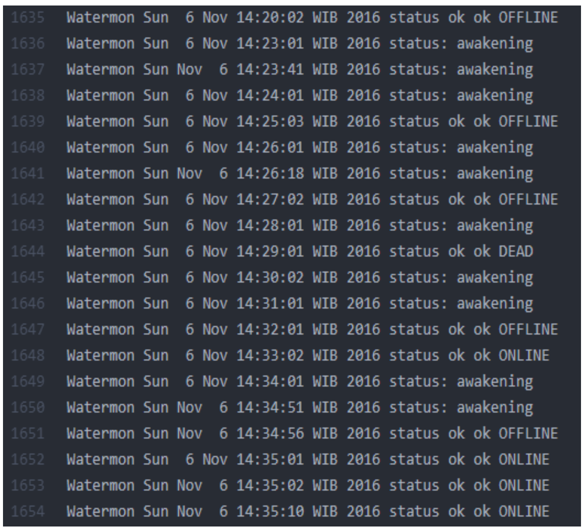
Overview sensors

ID	Status	Sensor model	Serial no.	Sensor name	Value 1			Value 2		Info bits
S01	Measuring	VisoTurb700IQ	09250704	AIR BAKU	137	NTU	Turb			0x0
S03	Measuring	MIQIC2 REC1	09381117	AIR PRO IP2	1.31	ppm	Chlor	7.39	mA	0x0
S04	Measuring	ViSolid700IQ	12490907	DIS.TOR IP2	4727	mg/l	TSS	609	mg/l#	0x0
S05	Measuring	SensoLyt700IQ	12390797	AIR BAKU NG	7.27		pH	29.0	°C	0x0
S06	Measuring	SC FDO 700	12100970	AIR BAKU NG	2.05	mg/l	O2	28.9	°C	0x0
S07	Measuring	VisoTurb700IQ	12311119	AIR_PRO_IP2	0.58					

Fig. 10. Passive sensors web dashboard

C. *Watermon applications*

In the Watermon application, we built program to show the sensor status connection to datacenter while getting the data from the sensor and if the status of connection identified as OFFLINE, the data will be save it as temporary to SQLite and sending the data again to database system on server if the status of connection identified as ONLINE. The report status of the sensor connection can be shown in Fig. 11 and the process local-write data while the connection is not ready or offline can be shown in Fig.12.



```
Watermon Sun  6 Nov 14:20:02 WIB 2016 status ok ok OFFLINE
Watermon Sun  6 Nov 14:23:01 WIB 2016 status: awakening
Watermon Sun Nov  6 14:23:41 WIB 2016 status: awakening
Watermon Sun  6 Nov 14:24:01 WIB 2016 status: awakening
Watermon Sun  6 Nov 14:25:03 WIB 2016 status ok ok OFFLINE
Watermon Sun  6 Nov 14:26:01 WIB 2016 status: awakening
Watermon Sun Nov  6 14:26:18 WIB 2016 status: awakening
Watermon Sun  6 Nov 14:27:02 WIB 2016 status ok ok OFFLINE
Watermon Sun  6 Nov 14:28:01 WIB 2016 status: awakening
Watermon Sun  6 Nov 14:29:01 WIB 2016 status ok ok DEAD
Watermon Sun  6 Nov 14:30:02 WIB 2016 status: awakening
Watermon Sun  6 Nov 14:31:01 WIB 2016 status: awakening
Watermon Sun  6 Nov 14:32:01 WIB 2016 status ok ok OFFLINE
Watermon Sun  6 Nov 14:33:02 WIB 2016 status ok ok ONLINE
Watermon Sun  6 Nov 14:34:01 WIB 2016 status: awakening
Watermon Sun Nov  6 14:34:51 WIB 2016 status: awakening
Watermon Sun Nov  6 14:34:56 WIB 2016 status ok ok OFFLINE
Watermon Sun  6 Nov 14:35:01 WIB 2016 status ok ok ONLINE
Watermon Sun Nov  6 14:35:02 WIB 2016 status ok ok ONLINE
Watermon Sun Nov  6 14:35:10 WIB 2016 status ok ok ONLINE
```

Fig. 11. Report Status Offline, Awakening and Online of Sensors Device Monitoring System

```
Local-Write to SQLite file /home/pi/watermon/sensor.db
Test
OFFLINE: 2016-11-03 12:16:28 sensor1 -7.348105 112.681262 29.18 515 0.310   0.23   4.5   0.34  7.24
Serial-Write: data.
Serial-read: # data
Serial-Write: data..
Local-Prosesing Data
['2016-11-03', '12:16:32', 'sensor1', '-7.348105', '112.681262', '29.18', '515', '0.310', '', '', '0.23'
, '', '', '4.2', '', '', '0.32', '', '7.23']
Local-Write to SQLite file /home/pi/watermon/sensor.db
Test
OFFLINE: 2016-11-03 12:16:32 sensor1 -7.348105 112.681262 29.18 515 0.310   0.23   4.2   0.32  7.23
Serial-Write: data.
Serial-read: # data
Serial-Write: data..
Local-Prosesing Data
['2016-11-03', '12:16:36', 'sensor1', '-7.348105', '112.681262', '29.17', '516', '0.310', '', '', '0.23'
, '', '', '4.1', '', '', '0.31', '', '7.23']
Local-Write to SQLite file /home/pi/watermon/sensor.db
Test
OFFLINE: 2016-11-03 12:16:36 sensor1 -7.348105 112.681262 29.17 516 0.310   0.23   4.1   0.31  7.23
Serial-Write: data.
Serial-read: # data
Serial-Write: data..
Local-Prosesing Data
['2016-11-03', '12:16:41', 'sensor1', '-7.348105', '112.681262', '29.17', '516', '0.310', '', '', '0.23'
, '', '', '4.0', '', '', '0.30', '', '7.23']
```

Fig. 12. The proses local-write while the sensor connection to datacenter is offline

```
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
rizqi@umar:~$ mosquitto_sub -t watermon
Data >>  2016-11-06 15:51:02 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
Data >>  2016-11-06 15:51:06 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
Data >>  2016-11-06 15:51:10 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
Data >>  2016-11-06 15:51:14 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
Data >>  2016-11-06 15:51:18 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
Data >>  2016-11-06 15:51:23 id:sensor1 loc:-7.348105,112.681262  Temp(C):30.28
Conductivity(uS/cm):655 TDS(g/L):0.387 Salinity(ppt):0.28 DOsat(%):-0.2 DO(mg/L)
:-0.02 pH:7.53 >
```

Fig. 13. Collection and retrival of data

In the data retrieval, by using MQTT protocols, the sensor role as MQTT publishers and send data to database server that have install as Mosquito-Server which role as MQTT broker. By using topic "watermon" that only MQTT publisher and MQTT broker can communicate each other. In Fig.13 shown collection and retrieval of data sensor. From the result, we can achieve real-time data monitoring.

D. Collection and retrival of data to datacenter

In the process of sending the data collection using insert SQL data through MQTT protocols and white it while inserting data into MariaDB (database server). The report status monitoring system while inserting data into MariaDB can be shown in Fig.14.

```
watermon 0 Data >>  2016-11-21 00:52:36 id:sensor1 loc:-
7.348105,112.mqtt2db Mon Nov 21 00:51:01 WIB 2016 running
681262  Temp(C):29.05 Conductivity(uS/cm):409 TDS(g/L):0.247 Salinity
(ppt):0.18 DOsat(%):-2.4 DO(mg/L):-0.19 pH:8.14 >
Insert SQL 2016-11-21 00:52:36 sensor1 -7.348105,112.681262 29.05 409 0.247
0.18 -2.4 -0.19 8.14
watermon 0 Data >>  2016-11-21 00:52:41 id:sensor1 loc:-7.348105,112.681262
 Temp(C):29.05 Conductivity(uS/cm):408 TDS(g/L):0.246 Salinity(ppt):0.18
DOsat(%):-2.4 DO(mg/L):-0.19 pH:8.14 >
Insert SQL 2016-11-21 00:52:41 sensor1 -7.348105,112.681262 29.05 408 0.246
0.18 -2.4 -0.19 8.14
watermon 0 Data >>  2016-11-21 00:52:45 id:sensor1 loc:-7.348105,112.681262
 Temp(C):29.05 Conductivity(uS/cm):409 TDS(g/L):0.246 Salinity(ppt):0.18
DOsat(%):-2.4 DO(mg/L):-0.19 pH:8.14 >
Insert SQL 2016-11-21 00:52:45 sensor1 -7.348105,112.681262 29.05 409 0.246
0.18 -2.4 -0.19 8.14
watermon 0 Data >>  2016-11-21 00:52:49 id:sensor1 loc:-7.348105,112.681262
 Temp(C):29.05 Conductivity(uS/cm):409 TDS(g/L):0.247 Salinity(ppt):0.18
DOsat(%):-2.5 DO(mg/L):-0.19 pH:8.14 >
Insert SQL 2016-11-21 00:52:49 sensor1 -7.348105,112.681262 29.05 409 0.247
0.18 -2.5 -0.19 8.14
```

Fig. 14. Report status monitoring system while inserting data into MariaDB using MQTT

V. CONCLUSIONS

In this research IoT platform has been built which consists of water condition monitoring sensor, embedded system capable of processing sensor data and sending to data center, data transmission with MQTT protocol. The system monitoring of Automated Water Quality Device using passive and active sensors that shown in the research result and discussion that report all status monitoring system from Things to Things connections through internet while sending data and transmission the report status using MQTT protocol. For next stage of research plan is combine the IoT Platform with application of Big Data System to classified river water quality using classification analysis.

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