Proc. of 2019 6th Int. Conf. on Information Tech., Computer, and Electrical Engineering (ICITACEE), Sep 26-27, 2019, Semarang, Indonesia

Automatic Sprinkler System for Water Efficiency Based on LoRa Network

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Abstract— **The agricultural sector is an important sector for economic growth in Indonesia. This was indicated by the data from the Indonesian Ministry of Agriculture that stated the Gross Domestic Product (GDP) from 2013 to 2017 in the agricultural sector grew by 9.90%. Based on this data, a research that could help farmers in terms of improving the quality of their crops by providing plants with sufficient water intake was made. With this system, farmers will be able to monitor soil moisture using a laptop or a phone. In this research we evaluate the QoS of the communication between LoRa device. This system works by using a LoRa device operating at 433 MHz paired on 2 Nodes and 1 Gateway. Each node will be given 3 soil moisture sensors that will monitor soil moisture. Then, the sensor data will be sent to the gateway via a LoRa device. In the controlling mode, LoRa average delay and data loss are 196.96 ms (node1), 207.39 ms (node2) and 4.45% (node1), 10.03% (node2). That monitoring value is good value based on ETSI standard. But, in the monitoring mode, LoRa average delay are up to 10 s and average data loss are 6.67% from node1 and 13.34% from node2.**

Keywords—LoRa, Wireless Sensor Network, Smart Agriculture

I. INTRODUCTION

The agricultural sector is an important sector for economic growth in Indonesia. This was indicated by the data from the Indonesian Ministry of Agriculture that stated the Gross Domestic Product (GDP) from 2013 to 2017 in the agricultural sector grew by 9.90%. Naturally, this economic growth also brought the inevitable demand of increased crop quality. Therefore the agricultural products in Indonesia is not only limited to fulfill the quantity of market, but also has good quality and suitable for consumption.

Effective watering practices potentially enhance the economic viability and environmental sustainability of agriculture sector [1]. Because, with effective watering the quality of the crop will be increase. In order to increase crop quality, one of the most important aspects to master are proper and effective watering. Plants will always need water and nutrients in their growth. These elements are thing that must be fulfilled and required to give the right composition of water and nutrients till can be absorbed in the soil. Plants will not be able to absorb when they are given excess of water, because the plants are already full of water. Rather if a plant get water less than needed, then the plant will die because water is a main composition of the plant's body. Therefore, very important to giving water as needed, because plants can only grow well if water meet the right amount and time. Automatic sprinkler system make the farmer able to sprinkling the plants with right amount and time to increase the plants quality.

This automatic sprinkler system works by using LoRa device. Communication between LoRa devices is highly important, because data from plants must be quickly received by farmers. Meanwhile, data which is not quickly received by farmers leads to difficulty for farmers to monitor and control in real-time. In addition, the data sent by a LoRa device must be ensured to be well received by the receiver, because data which cannot be reached by the receiver will cause the data drop. if the data drop, the value of data loss will increase. Therefore, this research aims to evaluate the Quality of Service (QoS) communication of LoRa devices which include delay and data loss.

This automatic sprinkler system is based on wireless sensor network. Wireless sensor network has been used at agriculture sector in the recent years. For example, In 2017 wireless sensor network is used at hydroponic NFT monitoring system [2]. The automatic sprinkler system can monitor and control watering use the soil moisture sensor. As for the wireless sensor network itself, we are using LoRa operating at 433 MHz for the node and gateway, which then will be placed on a patch of land sized 14 m × 26 m. This system using a device that connected to the internet and will provide features for farmer to be able to set the threshold of soil moisture. For example, if the soil moisture exceeds the limit set by the farmer, the system will automatically water the crops by using the sprinklers. With this system, farmers will finally have the ability to water the crops precisely and easily.

II. RELATED WORKS

In recent years, there were some researches about LoRa performance. For example, In [3] the authors used LoRa device for prototype smart irrigation system. The frequency that used of the LoRa device is 433 MHz. The system work with 3 end devices and 1 gateway. End devices will send sensor data to the gateway via 433 MHz radio network of LoRa. After gateway receive the data from end devices, gateway must send that data to the server via internet. To evaluate LoRa device performance, they did some transmission experiments. The gateway was installed on the roof of a building and end device was mobile from 1 km to 7 km with gateway. RSSI value was drop from -55 dBm to -120 dBm at the first 1 km and stable around -125 dBm.

In [4] the authors evaluate LoRa performance at 83 km2 urban area. They used 14 dBm transmit power, 12 spreading factors and 868 Mhz frequency of LoRa. In this experiment, they used a gateway device and a node device. They installed the gateway device at highest building there. The node device is mobile from 1 km to 8 km. Node device will send a data to the gateway periodically. RSSI of this experiment is -70 dBm with 13% packet loss in 2 km and drop to -150 dBm with 70% packet loss in 8 km.

In [5] the authors was made a temperature and humidity monitoring system at their campus. The node device was transmit the sensor data to the gateway 6 days non-stop. The gateway device was installed at the highest building in the campus. The distance of gateway device and node device is 834 m, 890 m, 1,100 m and 1,140 m. Packet loss in this experiment was up to 90%. This was caused by the gateway device installed near with 4G cellular base station. The transmission was interfenced by the transmission from 4G mobile communication.

In [6] the authors was made a sailing monitoring system based on LoRa. This system can monitor the environment of sea and sailboat, including the speed and direction of wind and current, the location and attitude of sailboat. This system consist of two sink nodes and a gateway. Sink node is installed at the sailboat. Sink node will send the data to the gateway and gateway will receive the data. In the first case, the sink nodes and gateway will moving with 400 m distance. In this case, the packet loss is 0.34%. In second case, the gateway was installed at 20 m high building and the sink nodes will moving. In this case, the packet loss is reach 63.26% at 3.4 km. The communication of this system still form one way communication.

There is only one way communication between nodes and gateway from the previous work. This research uses two way communication method between nodes and gateway comprise of monitoring and controlling for smart agriculture implementation.

III. System Design and Configuration

A. Parameters of LoRa

The communication between LoRa device must use the important LoRa parameters. The important LoRa parameters can be seen in TABLE I.

TABLE I. LoRa Parameters

Parameter	Value
Transmission Power (dBm)	17
Spreading Factors	9
Antenna Gain (dBi)	3

B. Hardware Configuration

This system works with 2 node devices and a gateway device. The communication between node device and gateway device is half duplex. The gateway device sends a command data to node device and node device send sensor data to gateway. The node is device that will measure and control the soil moisture according the threshold. There are three DFRobot V1.0 soil moisture sensors used for reading soil moisture levels. The result of soil moisture sensor is analog voltage that converted into digital data via an analog to digital converter (ADC) on Arduino Nano and send the results to the gateway device using a LoRa SX1278 module that connect to Arduino Nano. Communication between LoRa SX1278 and Arduino Nano uses Serial Peripheral Interface (SIP). The TTL converter component is used to convert 3,3 volt to 5 volt due to the difference voltage between Arduino Nano and LoRa SX1278. LoRa component operating using radio network at 433 MHz. Architecture of this system can be seen in figure 1.

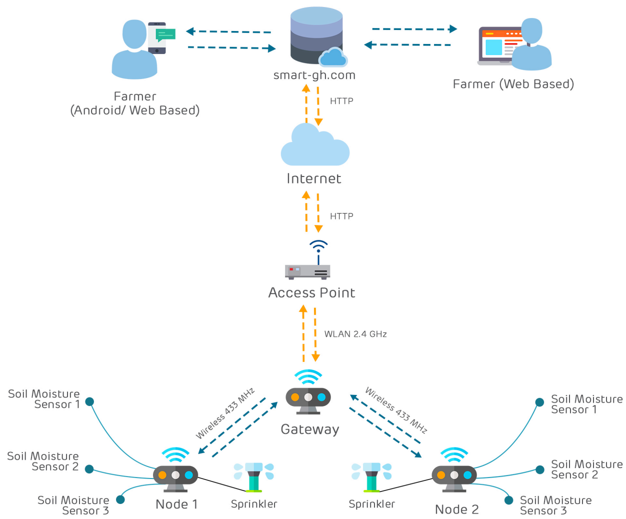

Fig 1. Architecture of Automatic Sprinkler System

Data transmission by the node device always need time data. the time data is used to know when data is sent and receive by the node. The block diagram of node device in figure 2.

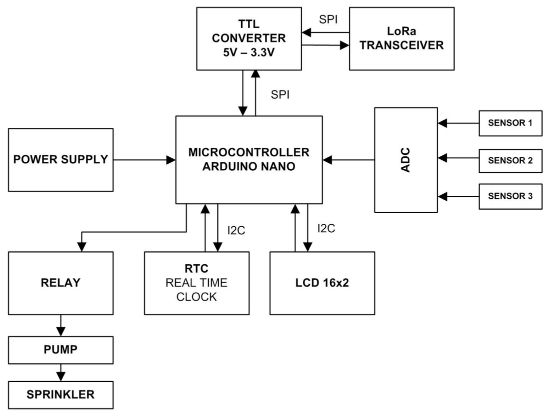

Fig 2. Block Diagram of Node Device

Figure 2 show the time on node device used Real Time Clock (RTC) component. RTC is a component that can calculate in real time. The result of RTC component is sent to the arduino nano using Interface Integrated Circuit (I2C).

Another component that use I2C interface is Liquid Crystal Display (LCD) which is output component as screen node device. Another function of node device is to keep soil moisture in agricultural with the water pump that connect to the relay. The water pump will be turned on when the soil is dry until the soil condition fulfill the threshold. After that the watering will be stopped by turning off the pump by the node device. Other than sending data to the gateway, this node will also control the soil moisture based on the farmer's settings by using a DFRobot V1.0 sensor.

The gateway device is a device set as a network coordinator and device that forward data from the node device to the server and take data from the server. The gateway device is set to be able to communicate with two node devices. Gateway device consist of LoRa SX1278 that operate at 433 MHz. Communication between NodeMCU ESP8266 and LoRa SX1278 by using Serial Pheripheral Interface (SPI). In this node TTL converter is not used because between NodeMCU ESP8266 voltage and LoRa SX1278 voltage are same at 3,3 volt. Function of LoRa component are as a network coordinator for send command and receive data from node device and also forward data from the node device to the server. Data can be sent by the WiFi ESP8266 module in NodeMCU ESP8266. The WiFi ESP8266 module will connect the gateway device to an access point which connect to internet, so the gateway can send data to the server. The gateway device also has a Liquid Crystal Display (LCD) which is an output component as screen of gateway device. A Real Time Clock (RTC) component as a real time timer. The block diagram of gateway device can be seen in figure 3.

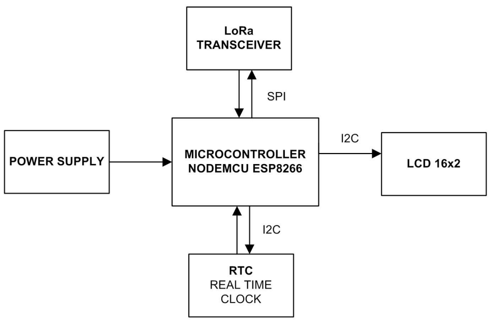

Fig 3. Block Diagram of Gateway Device

Each of this device will be place in agronomy department of Bawen 1 Vocaional High School. Placement and picture of the device in figure 4.

(a) Placement of The Device

(b) LoRa Gateway and LoRa Node

Fig 4. Placement of The Device

As for the layout, the gateway is placed on the hydrophonic NFT greenhouse to ensure a solid internet connection with an access point. The 2 nodes will be placed on separate patch of land. Node 1 is placed about 10 meters away from the gateway, while Node 2 is placed about 55 meters away from the gateway.

C. *Software Configuration*

Software in this research is using the Arduino IDE platform because each automatic watering system is based on a microcontroller

- *Gateway*: The gateway device as coordinator in-between local networks and internet networks. The flowchart of the gateway can be seen in figure 5.

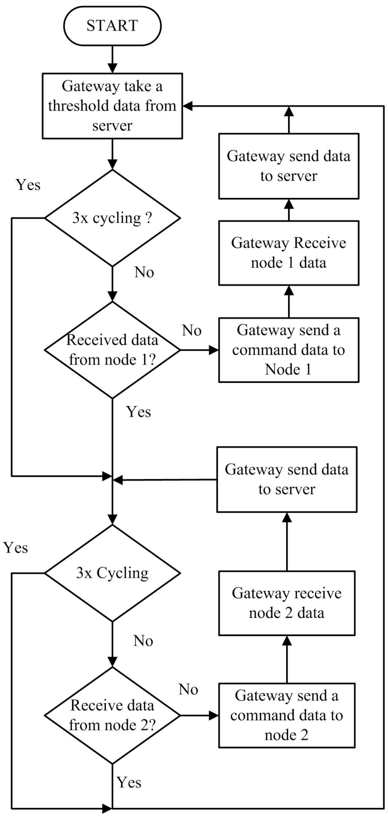

Fig 5. Flowchart of The Gateway

The gateway device always do to take the data, the maximum of soil moisture threshold, the minimum of soil moisture threshold and command to on or off the pump water. Data from the server will be broadcast to each node. The data sent by gateway device alternately for node 1 or node 2. The gateway device will get data sensor and other parameters from destination node and will send commands to each node for three times if the destination node doesn't respond. The gateway device will move from node 1 if it has been three times request and going to send the command data to node 2. The gateway device will also move from node 2 if it has been three times doesn't respond. The receive data will be forwaded to the server by gateway device.

- *Node*: the node is designed to wait for commands from the gateway. The node device will respond to measured of the soil moisture if receive command data from gateway device. But, if a node received a command that was not meant for that node, no processing will occur. The flowchart of the node can be seen in figure 6.

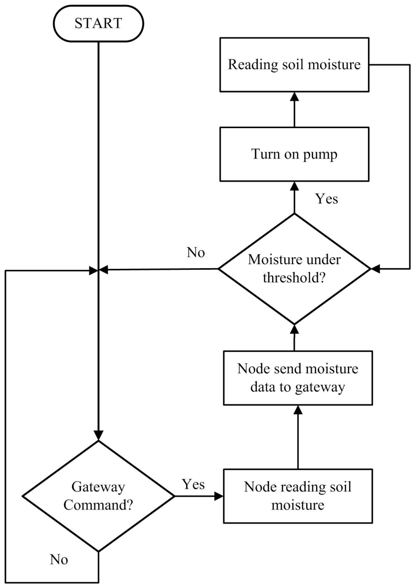

Fig 6. Flowchart of the Node

Command that has been received by the node device will be read. The node device will convert the command from gateway device, if the command is intended for the node device then it will read the soil moisture sensor and send it to the gateway device. The data received from node consist of contents of pump command. If there is an order to turn on the pump then node have to immediately turn on the pump. The pump is not turning on all the time but depend on the soil moisture sensor. The pump will turn on when the soil moisture less than threshold. The pump will turn on when the soil moisture less than threshold but if the soil moisture more than threshold the pump will turn off.

IV. Performance

A. Experiment of Delay Test

1) Delay of Controlling: The gateway will broadcast control commands to both nodes, so both nodes will always receive commands. The destination node will respond to measured of the soil moisture. But, if a node received a command that was not meant for that node, no processing will occur. So, this test measured and tested the time both nodes need to receive the commands. But that is not the only important thing in this test, though, as we also need to measure the delay between the nodes and server. TABLE II shows the measurement of delay test for nodes and gateway.

TABLE II. Measurement of Controlling Delay

Time (Hour)	Time	Average Delay (milisecond)	
		***Gateway – Node* 1**	***Gateway – Node* 2**
1	Morning	250	230.76
1	During The Day	62.5	250
1	Afternoon	100	153.84
Average Delay (millisecond)		196.96	217.39

Based on ETSI 1999-2006 delay standard the average delay of node 1 are 196.96 ms which is belong a good category because still on the range between 150 ms until 300 ms. The average delay of node 2 are 217.39 ms which is belong a good category because still on the range between 150 ms until 300 ms. The delay of both node device are good because the load given when transmit data is only 19 byte. Payload of 19 bytes is still small, so the time to transmit data from gateway to node still in the good category. The table of ETSI 1999-2006 delay standard can be seen in TABLE III.

TABLE III. ETSI 1999 – 2006 Delay Standard

Delay Category	Delay value	Index
Perfect	<150 ms	4
Good	150 - 300 ms	3
Medium	300 - 450 ms	2
Poor	>450 ms	1

2) Delay of Monitoring: Monitoring proccess of this system is started from node to server. The way from node to server is splitted by 2 hops. First hop is from node send data to gateway and second hop is from gateway send the data to server. TABLE IV shows the result of this test

TABLE IV. Measurement of Delay Test For Node and Server

Time (Hour)	Time	Average Delay of Node1 – Server (milisecond)		Average Delay of Node2 – Server (milisecond)	
		Node 1 - Gateway	***Gateway – Server***	***Node 2 - Gateway***	***Gateway-Server***
1	Morning	1,607	6,890	1,617	6,800
1	During The Day	1,745	6,781	1,800	6,944
1	Afternoon	1,649	6,789	1,783	6,667
Average Delay (millisecond)		1,668	6,819	1,765	6,801

Both of first hop or second hop from node 1 to server have a delay value that can be seen in figure 7.

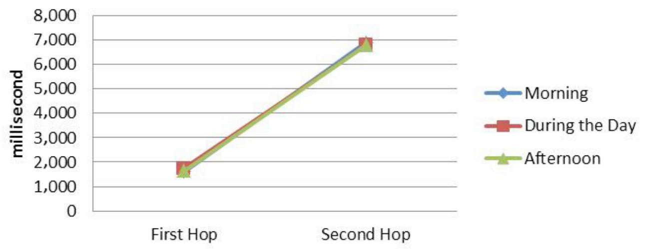

Fig 7. Graph of Monitoring Delay Node 1

Average delay of first hop are 1.6 second and then drastically up on second hop which is 6 second. Based on ETSI 1999-2006 standard, the delay value of the first hop belong to bad category, because the value more than 450 ms. The delay of first hop belong to bad category because the payload when monitoring system more than controlling system. Payload when monitoring is 108 bytes whereas payload when controlling is only 19 bytes. A large load data make LoRa devices taking longer to receive data. The average of second hop more than 6 second and also belong to bad category because more than 450 ms. Delay value is drastically up due to differences set time of the RTC on gateway with time on the server. Time setting on RTC can be slower than time setting on the server. Delay value on the second hop caused by many hop data passed than hop data passed on first hop. Many of hop make longer time to get the server.

The next test is measure delay hop from node 2. Both of first hop or second hop from node 1 to server have a delay value that can be seen in figure 8.

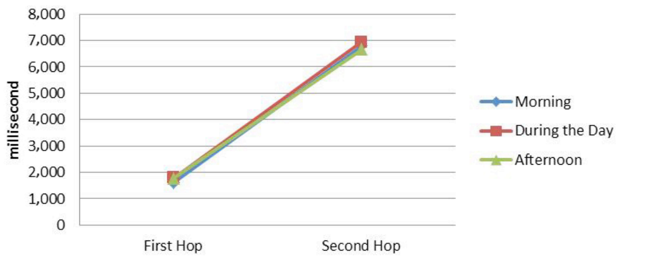

Fig 8. Graph of Monitoring Delay Node 2

Delay value of first hop from node 2 almost same with first hop from node 1. Delay value of firs hop from node 2 greater than delay of first hop from node 1. That delay value based on ETSI 1999-2006 delay standard belong a bad category. First hop of node 2 which has a greater delay value than first hop of node 1 caused of distance of node 2 farther than distance node 1 toward the gateway. The value of second hop from node 2 almost same with second hop from node 1. Delay of second hop from node 2 which has drastically up more than 6 second based on ETSI 1999-2006 delay standard is belong to bad category, that caused of difference time setting in RTC which is slower than time setting on the server. Delay of second hop is drastically up caused of many hop passed from gateway to the server.

B. Experiment of Data Loss test

The cause of the difference is LoRa device is located in the lowest layer of OSI Layer which will transmit data in form of bit data through medium of transmission. While form of packet only be seen in the thirth layer of OSI Layer, named network. Packet loss that can't be seen will be replaced by data loss parameters. There are 30 data that will trasmitted in every hour. So in this case will be test how much data that can be received by receiver.

1) Data Loss of Controlling: Data loss controlling is measure the amount of transmit data and receive data every time manually. This test is aimed to evaluate the performance of LoRa network in automatic sprinkler system from the gateway to two nodes. The illustration of this test can be seen in figure 9.

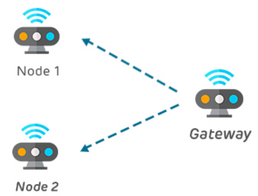

Fig 9. Illustration of Data Loss Test From Gateway to Node

The result of data loss test from gateway to node can be seen in TABLE V.

TABLE V. DATA LOSS TEST FROM GATEWAY TO NODE

Duration (Hour)	Time	Transmit Data	Receive Data		Average of Data Loss (%)	
		Gateway – Node	*Node 1*	*Node 2*	*Gateway – Node 1*	*Gateway – Node 2*
1	Morning	30	29	27	3.34	10
1	During The Day	30	29	28	3.34	6.67
1	Afternoon	30	28	26	6.67	13.34
Average of Data Loss (%)					4.45	10.03

Data loss test taken by the time of morning, during the day, and the afternoon in every hour. Data loss test from gateway device to node 1 in the morning is 3.34%. Data loss test from gateway device to node 1 during the day also 3.34% and then data loss test from gateway device to node 1 in the afternoon is 6.67%. Overall the average of data loss test from node 1 are 4.45%.

The next data loss test of node 2 taken by the time of morning, during the day, and the afternoon in every hour. Data loss test from gateway device to node 2 in the morning is 10%. Data loss test from gateway to node 2 during the day is 6.67% and data loss test from gateway to node 2 in the afternoon is 13.34%. Overall the average of data loss test from node 2 are 10.03%. Data loss value from gateway to node 1 or node 2 will be compared with ETSI 1999-2006 that can be seen in TABLE VI. Based on ETSI 1999 – 2006 data loss standard, the average of data loss test from node 1 are 4.45% is belong to good category. Good value of data loss caused by the position of node 1 to the gateway so close which is 10 meter, so the value belong to good. So, the average of data loss test of node 2 are 10.03% it is also belong to good category. Data loss value of node 2 more greater because the distance of node 2 to gateway is further which is 55 meter.

TABLE VI. ETSI 1999 – 2006 DATA LOSS STANDARD

Category	Data Loss	Index
Perfect	0 – 2 %	4
Good	3 – 14 %	3
Medium	15 – 24 %	2
Poor	> 25 %	1

2) Data Loss of Monitoring: The next test focused on node to server that can be seen on figure 10.

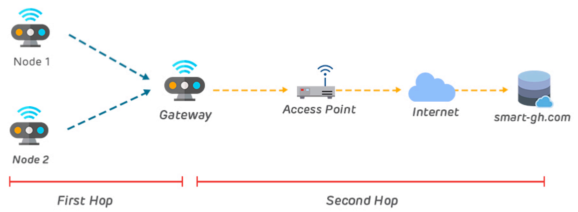

Fig 10. Illustration of Data Loss Test From Node to Server

Figure 10 show the transmit data should through many hops to the server. This test to evaluate performance of te automatic sprinkler system. In this case, data loss measured from node to server. The result of data loss test from node to server can be seen in TABLE VI. Data loss test from node 1 to the server in the morning is 6.67%. Data loss test from node 1 to the server during the day is 3.34% and data loss test from node 1 to the server in the afternoon is 10%. Overall the average of data loss from node to server are 6.67%. The next test is data loss test from node 2 to the server. Data loss test from node 2 to the server in the morning is 10%. Data loss test from node 2 to the server during the day is 13.34% and data loss test from node 2 to the server in the afternoon is 16.67%. Overall the average of data loss test from node 2 to the server are 13.34%. For comparison purposes, we put the relevant ETSI standards in a TABLE VI.

TABLE VI. DATA LOSS TEST FROM NODE TO SERVER

Duration (Hour)	Time	Transmit Data	Receive Data		Average of Data Loss (%)	
		Node 1,2	*Node 1-Server*	*Node 2-Server*	*Node 1-Server*	*Node 2-Server*
1	Morning	30	28	27	6.67	10
1	During The Day	30	29	26	3.34	13.34
1	Afternoon	30	27	25	10	16.67
Average of Data Loss (%)					6.67	13.34

V. CONCLUSION AND FUTURE WORK

In the controlling mode, LoRa average delay and data loss are 196.96 ms for node 1, 207.39 ms for node2 and 4.45% for node1, 10.03% for node2. The delay and data loss of controlling communication between LoRa device is good based on ETSI Standard. In the monitoring mode, the data loss is 6.67% for node 1 and 13.34 for node 2. That value is good based on ETSI Standard. But, the delay of monitoring communication is up to 10 seconds. That delay value is poor based on ETSI, this is caused by the data transmitted is larger than data on controlling mode and because the time on RTC is not same with the time at the server. Cloud computing is used in this research to control soil moisture, for the next research EDGE computing can be added to reduce delay for both monitoring and controlling system.

VI. ACKNOWLEDGEMENT

We would like to thank to Directorate of Research and Community Service, Directorate General of Research and Development for Indonesian Ministry of Research, Technology and Higher Education for supporting this research.

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