LoRa-MQTT Gateway Device for Supporting Sensor-to-Cloud Data Transmission in Smart Aquaculture IoT Application

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***Abstract*—One of many services that could be developed with IoT technology and Wireless Sensor Network (WSN) is a smart aquaculture service. In order to establish the smart aquaculture service, in previous research we developed a sensor node equipped with LoRa communication module to observe several physical parameters of the aquaculture water including acidity, dissolved oxygen, turbidity and temperature level. As the number of collected data growth, an integration between the WSN and cloud based computing platform is required to handle the storage and processing of those collected data. One of the challenges faced in that integration is a limited LoRa communication module which is expected to be able to send sensor data directly to the cloud platform. Therefore, a gateway device which is able to act as a bridge between sensor node devices and cloud platform is required. This research proposes the design of LoRa-MQTT gateway device for supporting the sensor-to-cloud data transmission in smart aquaculture IoT application. In its main functionality, the gateway device receives collected sensor from sensor device using LoRa communication module, build a message and transmit them to the cloud based data storage server using MQTT protocol. From the functional and performance testing, the gateway can perform as a communication connector between sensor nodes and cloud based entity using both LoRa and MQTT protocols with reasonable performance.**

I. Introduction

Internet of Things (IoT) is a concept where a number of devices are able to communicate among each other with various protocol [6]. The growth of Internet of Things constantly supported by a concept of Wireless Sensor Network (WSN). WSN is a type of network which consists of smart sensor nodes that connected to each other by wireless network [8].

One of the services that can be developed with technology based on IoT and WSN is a smart aquaculture [13]. In this type of service, sensor nodes are equipped with some sort of sensors to observe a number of parameters which can affect the successful rate in aquaculture, such as water quality and physical air condition. The result of observation will be processed so that the system can recommend the best treatment to breeders, as well as doing an automatic treatment to the pond itself. In order to establish the smart aquaculture service, previous research have developed a sensor node to observe physical parameter of the water in an aquaculture pond [1]. The sensor node device was packed with three primary components, which are microprocessor, sensor, and communication module. A sensor node periodically takes observation data of physical condition of water such as acidity level (pH), dissolved oxygen, temperature, and water brightness with the attached sensors. As a result of testing, it has been discovered that the devices capable to do an acquisition to physical water parameter accurately. But over time, sensor data that have to be stored and processed by sink node are increased beyond the capacity and capability of device. Because both sensor node and sink node devices have limited computation resource, a cloud-based system is needed to do a large-scale data management [3], [7].

To realize the integration between IoT and cloud system, there are some challenges that have to be solved [11]. In communication aspect, besides having some advantages such as low power consumption and wide-area coverage, LoRa technology still has limitation so that it still can't send data directly to cloud devices. Communication protocol that were being used by LoRa is radio, so the system should have a device that act as a connector to send data to data center. That way, data acquisition result from sensor node can be managed and processed in cloud device. Because of that, intermediary system to integrate LoRa communication to cloud is needed, and later the system is referred as a gateway.

Previous research that have been done by Chang-le Zhong [4] in the publication titled "Study on IoT Architecture and Gateway Technology", stated that in general, gateway can connect different communication protocol. In other words, gateway can be used as a protocol converter. To connect gateway and data center, a communication protocol that is used to exchange information is needed. One of available protocol options to manage messages is MQTT. MQTT protocol is used because of reliability in terms of data sending and characteristics to support IoT such as low power consumption and minimum bandwidth used. This protocol works above TCP protocol and use publish-subscribe model. Publish-subscribe model was designed to be easy to implement, and qualified as

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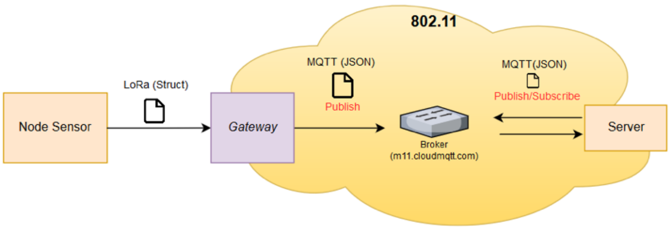

Fig. 1: General System Architecture.

open-source [12], [2].

In this paper, researchers develop a gateway as an intermediary node to send data from sensor node to server in cloud platform. Sensor node will send data to gateway by utilizing a LoRa communication module. Then, gateway will receive data from sensor node and forward it to server by using MQTT with publish-subscribe model. Gateway and sensor node will utilize microcomputer called Raspberry Pi because it has better computation among other microcontrollers. Testing parameter which will be conducted is gateway successful rate in terms of receiving and forwarding data to data center with distance, packet size, and time interval as variables.

II. Design of Proposed LoRa-MQTT Gateway

A. General System Architecture

Fig. 1 shows the general architecture considered in the system with four main actors :

1) sensor node acting as data producer which transmit the aquaculture related sensor data to gateway device using LoRa protocol.
2) sensor-to-cloud gateway acting as intermediary node that relay message from LoRa based sensor node to the cloud entity. In the MQTT perspective, this actor is acting as message publisher.
3) cloud based broker.
4) data storage server which receive published sensor data and store it to the database. In the MQTT perspective, this actor is acting as message subscriber.

The data flow considered in the system is illustrated in Fig. 2. At first, sensor node equipped with embedded computing device, various water monitoring sensors and LoRa communication module periodically collect several water physical information including pH, temperature, and dissolved oxygen. Upon collection, the sensor node sends those data to the gateway through LoRa protocol. In the other side, while receiving those sensor data, the gateway extract its structural data and build a JSON based message and send them to the broker. At the final step, broker relay those messages to all subscriber based on the topic similarity.

B. Sensor Node

The design of sensor node has some components that are used such as the LoRa communication module, sensor, and Raspberry Pi microcomputer. The design as illustrated in Fig. 3 that describes the system architecture on the sensor node side. There is a Arduino microcontroller acting as the brain of the system that used to run logic code of sensor node. The other is a component of the LoRa communication module that is used as a transceiver module between sensor node and gateway as well as several sensors which is employed to measure several water physical parameters including :

1) dissolved oxygen sensor to measure dissolved oxygen level.
2) water temperature sensor to measure water temperature.
3) pH sensor to measure water acidity level.
4) turbidity sensor to measure water clearness.

C. Gateway Device

Gateway has the main role in this research, which is as an intermediary for communication with sensor node and forwarding to the server. Therefore, it needs good design as the sensor node design can be seen in Fig. 4 that describes the system architectures on the gateway. There is a Raspberry Pi microcomputer as the brain of the system that used to run program code in python language in this architecture. Then, there is LoRa communication module that is used by gateway to be able to receiver data from then sensor node. 802.11 communication protocol is a network that used to send data to a server.

III. System Testing

A. Functional Testing

Functional testing was carried out to confirm the accuracy between functions created and system goals. The result of functional testing is shown in Table 1 below.

Number	Function	Result
1	Sensor node can retrieve sensor data	Succeed
2	Sensor node can send the data to gateway	Succeed
3	Gateway can receive data from sensor node	Succeed
4	Gateway can forward data from sensor node to server	Succeed
5	Server can receive data from sensor node	Succeed

B. Performance Testing

Testing was carried out in an area that could support the system, such as a field with minimum population and houses. In that area, sensor node and gateway have been placed at a height of 1.5 meters above earth surface, so that it could be easier to receive or send the data.

Performance testing focused on the successful rate of the gateway to forward received data from node sensor to destination. This parameter tested with 200 meters and 400 meters as distance variants; 44 Bytes, 56 Bytes, 80 Bytes and 128

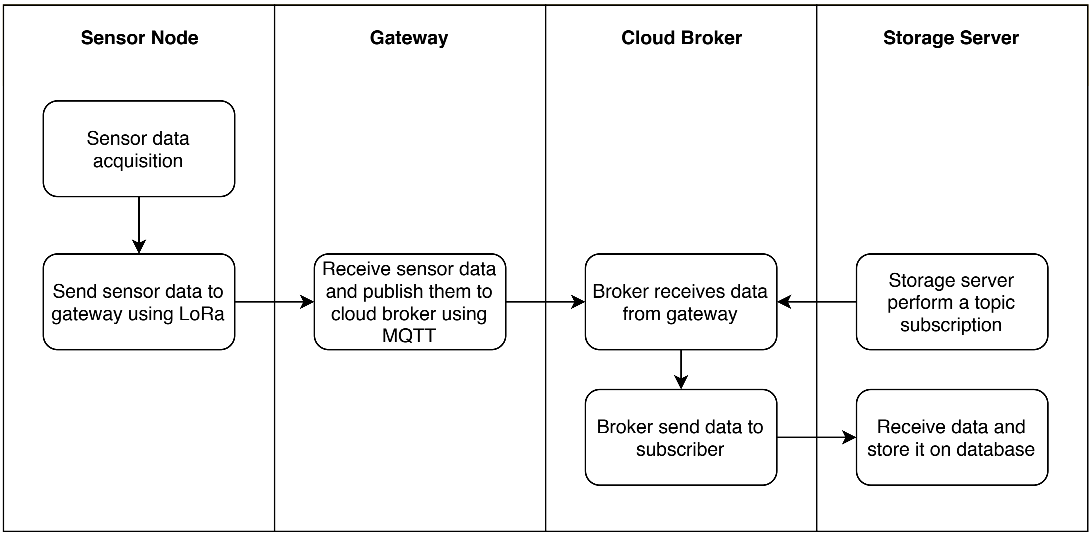

Fig. 2: Data Flow of the System.

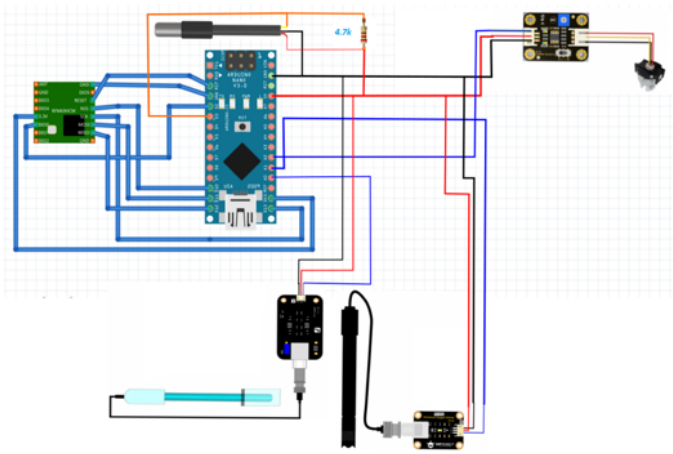

Fig. 3: Schematic of Sensor Node.

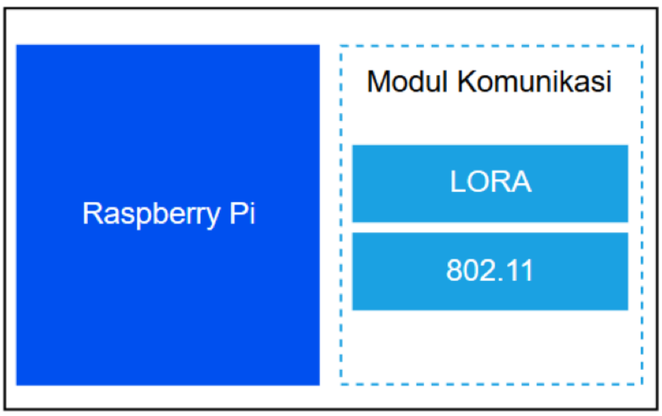

Fig. 4: Design of Gateway Device.

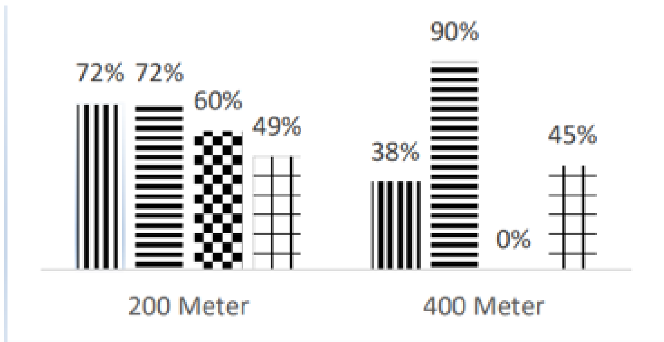

Fig. 5: Successful Transmission Rate for Time Interval of 0.5 seconds.

Bytes as packet size variants; also 0.5 seconds, 1 second, and 5 seconds as time interval variants. Testing conducted by sending 100 packets to each of distance variants, packet size variants, and time interval variants.

Fig. 5 is a testing result graphic that shows performance in time interval of 0.5 seconds in successful rate parameter. Difference in successful rate parameter of gateway to receive and forward packets to server in time interval 0.5 seconds at distance of 200 meters is 72% with packet size as long as 44 Bytes and 56 Bytes. In case of the packet size is 80 Bytes, successful rate decreased as much as 12% and when packet size is 128 Bytes, successful rate is 49%. Tests in distance of 400 meters show that successful rate is 38% with packet size of 44 Bytes and increased to 90% when packet size is 56 Bytes. But if packet size becomes 80 Bytes, successful rate decreased significantly to 0% and back up to 45% when packet size is 128 Bytes.

Fig. 6 is a testing result graphic that shows performance in time interval of 1 second in successful rate parameter. The difference that shown in Figure 6 is a representation of variations in packet size, distance, and result of successful rate. At the distance of 200 meters and packet size of 44 Bytes, there were 72% of packets received and forwarded

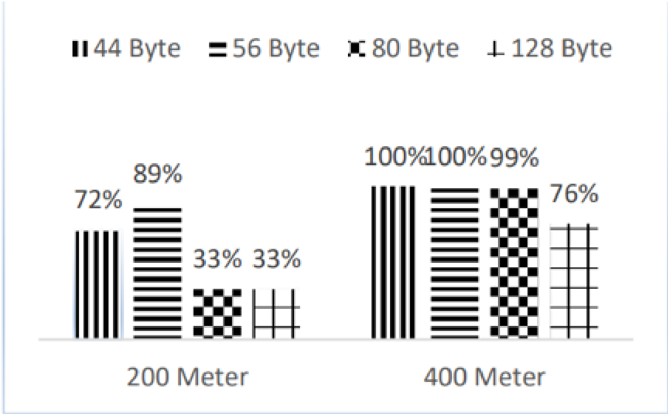

Fig. 6: Successful Transmission Rate for Time Interval of 1 second.

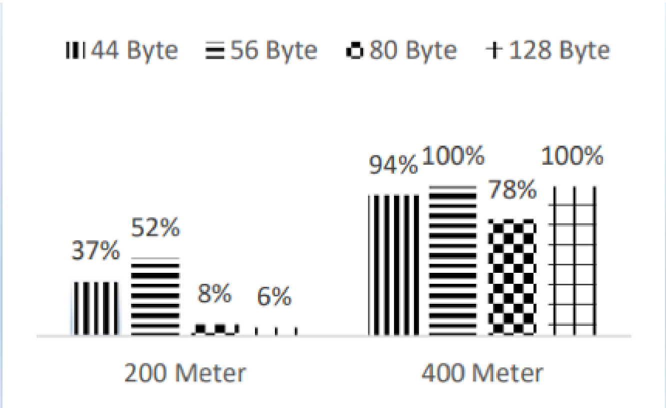

Fig. 7: Successful Transmission Rate for Time Interval of 1 second.

successfully to server by gateway. Successful rate increased to 89% if packet size of 56 Bytes were sent by sensor node. After that, the successful rate stayed in 33% for packet size of 80 Bytes and 128 Bytes. At the distance of 400 meters, result of successful rate is fairly stable at 100% to 99% when packet size of 44 Bytes, 56 Bytes, and 80 Bytes were sent. However successful rate decreased as much as 23% when packet size is 128 Bytes.

Fig. 7 shows a graphic that represent the result of testing in successful rate parameter at time interval of 5 seconds. The successful rate of gateway to receive and forward packets to server at distance of 200 meters is 37% when 44 Bytes packets were sent. If packet size changed to 56 Bytes, successful rate advanced as much as 15%, so it is become 52%. But the successful rate go down to 8% when packet size is 80 Bytes and 6% when packet size is 128 Bytes. Next, the result is improved at distance of 400 meters. Successful rate reached 94% with packet size of 44 Bytes and 78% when packet size of 80 Bytes were sent. However, when packet size is 56 Bytes, successful rate achieved 100%, as well as when packet size of 128 Bytes were sent.

IV. Conclusion

This research proposed the design of LoRa-MQTT gateway device for supporting the sensor-to-cloud data transmission in smart aquaculture IoT application. In its main functionality, the gateway device receives collected sensor from sensor device using LoRa communication module, build a message and transmit them to the cloud based data storage server using MQTT protocol. From the functional and performance testing, the gateway can perform as a communication connector between sensor nodes and cloud based entity using both LoRa and MQTT protocols with reasonable performance.

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