Implementation of Lora and CoAP Protocol in Hydroponic Plant Water Pump Control

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Abstract. Hydroponics is the cultivation of plants without using soil media, but using water media that contains nutrients and minerals. To observe the growth parameters of hydroponic plants, it is still necessary to come directly to the hydroponic site and provide the nutrients needed manually. In time efficiency, the use of Internet of Things (IoT) is needed so that there is no need to come directly to the hydroponic site. LoRa is a Low Power Wide Area Network (LPWAN) communication system. This research uses sensor nodes, middleware, and client nodes as well as the Constrained Application Protocol (CoAP) protocol for clients to access the value of sensors to control automatic pumps so that nutrients for plants can be given directly without the need to come to the hydroponic site. The result of the implementation is that the water pump control can run properly until the plants can be harvested. The performance testing is done so that LoRa can transmit data at a distance of 1 km with an RSSI value of -114 dBm.

Keywords: CoAP, Hydroponics, Internet of Things, LoRa

1. Introduction

The Internet of Things is a concept using the means of the Internet so that daily activities can be interconnected and can interact between devices with up to billions of devices [1]. Broadly speaking, the Internet of Things is a way of embedding the necessary hardware into the objects we want to control so that these objects can interact, such as an example of a door that can be opened through the voice of a certain person, a device that can automatically water plants [2], the performance of the Internet of Things must also go through the internet network so that they can interact with each other. The application of the Internet of Things is usually used in several fields [3].

The Internet of Things is becoming a major communication paradigm that can spread to many different applications [4]. The Internet of Things can be connected to various sensors, vehicles, and homes through the help of an Internet connection so that users can share information, the flexibility of the Internet of Things has led to many rapid developments to improvise data accessibility, efficient use of resources and communication between devices [5]. The rapid growth of society and the increasing industrial world have led to many aspects of daily life being adopted into the Internet of Things paradigms, such as smart cities, smart homes, healthcare, transportation, and
agriculture [6].

However, the rapid growth of the Internet of Things has a new problem, namely resource-constrained. Resource-constrained itself is a limitation of a system that includes computing, resources, communication, or range limitations, so a lighter communication protocol is needed so that connected devices can communicate with each other [7]. Communication protocols are very important to manage data flow to determine how IoT devices interact with each other to avoid device performance limitations or resource-constrained, so the Internet Engineering Task Force (IETF) standardizes lightweight communication protocols [8]. With the development of machine-to-machine (M2M) communication, so many types of communication protocols have been standardized for the benefit of IoT use, such as Message Queuing Telemetry Transport (MQTT), Extendible Message Persistent Protocol (XMPP) and Constrained Application Protocol (CoAP), of all types of communication protocols, only CoAP operates using the UDP protocol [9].

Hydroponics is the cultivation of plants without using soil media, but using water media that contains nutrients and minerals [10]. Parameters that need to be observed so that the growth process of hydroponic plants is not disturbed are temperature, light intensity, pH content, and the amount of nutrient density [11]. The hydroponic system is easier to maintain because it does not involve weeding and soil processing and also the process of plant care is cleaner because it does not use animal manure fertilizer media [12].

The procedure of observing the parameters of the hydroponic plant system still uses the traditional system, namely the observer will come directly to the location of the hydroponic plant and then will check the parameters that need to be observed using the tools needed if there is a parameter value that is outside the reasonable limits of the hydroponic plant, then the addition of liquid will be done according to the needs [13]. So that the process of taking parameter values can be done without having to come directly to the location of hydroponic plants, a system is needed that can check the parameter values of temperature, light intensity, pH content, the amount of nutrient density and humidity, in addition to checking parameter values, the system can also fill the required liquid automatically and the system can also send the results of these values to the observer, so that the observer does not need to review directly periodically.

Monitoring of hydroponic plants using a system that can monitor without having to go to the location of hydroponic plants has been implemented, the monitoring uses the Zigbee protocol to send sensor data containing monitored parameters, namely temperature and humidity, pH, Electrical Conductivity (EC), water temperature and water level [14], but the use of the Zigbee protocol has the disadvantage that the distance range is very limited, the Zigbee range ranges from 0 - 110 meters [15]. This becomes a problem when monitoring hydroponic plants requires a distance of more than 110 meters, so from these problems, it is necessary to use a protocol that can overcome the shortcomings of Zigbee, namely the LoRa (Long Range) protocol.

LoRa is a Long Range which is Low Power Wide Area Network (LPWAN) communication system that can transmit data over long distances (5km - 15km), besides being superior in terms of distance, LoRa also has lower power consumption compared to using Zigbee [16].

The monitoring system from research [17] also has the use of aquaponics in the Internet of Things with hydroponic kale plants. Based on this research, it is explained that the use of hydroponic plants is combined with raising fish so that it can be interpreted that aquaponics can overcome land limitations, and limited water sources and improve food security. The system built uses fuzzy logic. However, the research is
only based on monitoring, there is no action taken when the reasonable limit value of the liquid requirement of the hydroponic plant changes outside the normal value and is only based on the fuzzy datasheet that has been collected.

From these problems, this research will implement a peristaltic automatic water pump control mechanism or dosing pump so that the liquid that comes out through the water pump can be controlled and uses the LoRa protocol so that the delivery distance does not need to be close and the CoAP protocol for clients to access sensor data can even be through remote access.

2. Method

The method used in this research includes system design, architecture design, and system implementation as can be seen in Figure 1.

![Flowchart of research method](image1)

Figure 1. Flowchart of research method

2.1 System Design

The system to be built consists of sensor nodes, middleware, and client nodes.

![System design](image2)

Figure 2. System design
Middleware functions as a destination for sensor nodes in sending data and as a data forwarder to client nodes.

In Figure 2 the sensor nodes consisting of Arduino Uno, peristaltic water pump, pH meter sensor, light intensity sensor, TDS sensor, and humidity temperature sensor will send data to the middleware consisting of Raspberry Pi and LoRa module, when the sensor nodes already have data values on each sensor, the LoRa in the Arduino will communicate with the LoRa that has been installed in the middleware section. The data will be received by Raspberry, where Raspberry also functions as a CoAP server, when a client node makes a CoAP request, the CoAP server will respond and the data will be sent to the client node using the CoAP protocol.

2.2 Architectural Design

The system to be built consists of sensor nodes, middleware, and client nodes. Middleware functions as a destination for sensor nodes in sending data and as a data forwarder to client nodes.

In Figure 3 is the placement of the sensor node which will be placed close to the hydroponic water reservoir while the middleware node will be placed on the 1st floor. The distance between the sensor node and the middleware node is 200 meters, this distance will continue to be tested by changing the distance of the middleware node based on the distance testing scenario that will be carried out later.

![Figure 3. Architectural design](image)

2.3 System Implementation

System implementation is divided into 3 parts, namely sensor node implementation, middleware implementation, and client node implementation. Sensor node implementation includes hardware implementation for sensors and communication modules, as well as software to send data to the middleware.

In Figure 4 the sensor node in this study consists of two Arduino Uno microcontrollers, four sensors, consisting of one DHT22 sensor to measure temperature and humidity, one TSL2561 sensor to measure light intensity, one DFRobot SEN0244 sensor to measure density in minerals, one pH meter sensor to measure acidity, three peristaltic water pumps to drain the liquid and the LoRa HopeRF96 communication module which is used to send sensor data to the middleware with a frequency of 915MHz.
The middleware implementation includes an implementation for receiving data from sensor nodes and forwarding data that has been obtained from sensor nodes to be sent to client nodes.

Figure 5 shows the middleware implementation in this study consisting of LoRa and Raspberry Pi modu devices that function as gateways to receive data from sensor nodes and which also act as CoAP servers and send the data to client nodes in the form of response requests.

The implementation of the client node includes requests for the intended data. Node Client implementation in this study consists of installing the Zerotier application to be able to do remote access and also be able to see the value of the sensor node.

3. Results and Discussion
3.1. Functional Testing

Functional testing is done by sending data from the sensor node to the middleware and the results of the sensor node in the middleware are sent to the client node.

In Figure 6 there are the results of sending data on the client node, the data is obtained by the middleware which has previously been sent data in advance by the sensor node.
Middleware can be used as a bridge request using the CoAP protocol from the client node and the LoRa protocol from the sensor node.

In Figure 7 there is a sensor node consisting of a TDS sensor, pH sensor and three peristaltic water pumps that have been placed into one place and all sensors can work properly, especially the water pump which can open or close automatically based on the value of the TDS sensor and pH sensor.

### 3.2. Communication Testing Node Sensor-Middleware-Node Client

The communication process is carried out using the LoRa protocol and the CoAP protocol. Testing communication between sensor nodes, middleware, and client nodes using two different protocols, namely LoRa and CoAP. In Figure 8 the use of LoRa between the sensor node and the middleware is successfully carried out, then the sensor node data that has arrived will be sent to the client node using the CoAP server including lux, temperature, humidity, ppm, and pH values.

```
LoRa Initializing OK!
Tambah pH
Tambah TDS
&alc2&0.00@0.00@alc3$
' with RSSI -121
```

In Figure 9 based on the results that have been obtained, data transmission using two different protocols can be successfully carried out, namely using LoRa for sensor nodes and CoAP for client nodes so that the middleware can become an intermediary for data transfer and system monitoring can be carried out.
After the sensor node sends data and LoRa is successfully connected, the middleware will receive the data and the Raspberry will act as a CoAP server as shown in Figure 9.

![CoAP server communication](image)

**Figure 9. CoAP server communication**

### 3.3. Remote Access Testing

The process of remote access testing is carried out using the ZeroTier application that is already installed on mobile devices.

![Remote access](image)

**Figure 10. Remote access**

In Figure 10 there are results that client nodes can access middleware to view data values from sensor nodes using networks outside the hydroponic area. The remote process is done simply, namely the client node can do remote ssh to the middleware to see the data value of the sensor node. ZeroTier is a private network virtualization so that it can connect devices that are far apart and have different IP into one network. From the tests that have been carried out to do remote access, it is not complicated, only need to install ZeroTier to the device to be used, namely the client node and middleware, the two devices must be registered into the ZeroTier account that has been created so that remote access can be done.

### 3.4. Performance Testing

Performance testing consists of delay, throughput, and RSSI testing. In Figure 11 the first packet experiment using a wifi network has a delay value of 0.00871570s while the second packet using a mobile hotspot has a value of 0.00808762s. Based on the reference from the TIPHON category, it can be concluded that the use of the CoAP protocol both
using a wifi network and a mobile hotspot via a cellphone can transmit data quickly so that the results of delay testing carried out using the Wireshark application fall into the excellent category.

<table>
<thead>
<tr>
<th>Packet</th>
<th>Network</th>
<th>Delay (s)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WiFi</td>
<td>0.0087157</td>
<td>excellent</td>
</tr>
<tr>
<td>2</td>
<td>Mobile Hotspot</td>
<td>0.00808762</td>
<td>excellent</td>
</tr>
</tbody>
</table>

**Figure 11. Delay quality**

![Figure 12. Throughput testing](image)

**Figure 12. Throughput testing**

Figure 12 shows that of the 15432 packets that have been recorded using Wireshark, there are 2888 CoAP packets in Wireshark. The first experiment produced a throughput of 8.9136Kb/s. While in the second experiment of 15612 packets that have been recorded, there are 3760 CoAP packets and produce a throughput of 8.8781Kb/s. Based on the tests that have been tested, it is possible to send data to the hydroponic area.

**Figure 13. RSSI testing**

In Figure 13 RSSI testing is done to find out how much the value of LoRa's power to receive data at a distance, based on Figure 13. it can be seen that the value will get smaller when 100m away, which has a value of -85dBm, 400m has a value of -101dBm and 1km is worth -114dBm. From the test results it can be seen that the further the distance between LoRa devices to communicate, the greater the dBm value obtained so that packet delivery can be disrupted.

4. **Conclusion**

Based on the results of research on the implementation of LoRa and COAP protocols in hydroponic plant water pump control, it can be concluded that:
The water pump control system works well through three pumps consisting of pH Up, pH Down, and A & B mix pumps. When the TDS sensor value has a value that changes down, the A & B mix pump will turn on simultaneously and will turn off when the value is at the normal value, and when the pH has a change up or down outside the normal value, each pump from the pH will turn on according to the needs of the plant liquid.

The implementation of data transmission uses a sensor node consisting of two Arduino Uno microcontrollers and a LoRa communication module with a frequency of 915Mhz. Middleware can function properly as a connector so that data from sensor nodes is sent using the LoRa protocol and answers request from client nodes using the CoAP protocol.

Delay for sending middleware data and sensor nodes has a very small delay value of 0.00871570s and 0.00808762s and falls into the excellent category, while Throughput has a first trial value of 8.9136Kb/s and 8.8783Kb/s. At a distance of 100m, the RSSI value is -85 dBm, at 400m is -101 dBm and 1km is -114 dBm.

Suggestion

Based on the research process that has been carried out for the development of further research, there are several suggestions, namely:

- Trying to change plant species, as each plant has a different fair value limit.
- Using other protocols to communicate between different devices.

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