The Precision Agriculture Based on Wireless Sensor Network with MQTT Protocol

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Abstract. Precision agricultural techniques are widely developed to monitor and control growth of plant in greenhouse. The use of greenhouses is suitable for the countries that have unpredictable weather e.g. Indonesia. The main monitors and controls in greenhouse are sensor networks and actuators. Some examples of the precision agriculture technique are monitoring of fertilizer needs and smart irrigation. This paper presents a development of precision agriculture based on Wireless Sensor Network (WSN) with Message Queuing Telemetry Transport (MQTT) protocol. The WSN system involves Internet of Things (IoT) technology to connect devices, collect and distribute information. IoT integration with cloud computing is aimed to overcome limitations of the IoT devices in remote monitoring and control. WSN development uses MQTT protocols that have advantages that are lightweight, simple, can run on a small bandwidth and more advanced compared to Hypertext Transfer Protocol (HTTP). In this paper the SHT3x and TSL2561 sensors are used to observe temperature, humidity and light intensity of the greenhouse. Test results of three sensors in data transmission speeds indicate that the MQTT protocol run with very small bandwidth. It can transmit data on the 4G network of AXIS provider with download capability of 0.02 kbps and upload 1.65 kbps. The average data transmission speed is approximately 1 second.

1. Introduction

A greenhouse is a construction building as a place to grow and protect plants from extreme weather (wind, rain, ultraviolet radiation) and insect disturbances and allows for urban farming [1][2]. Usually, the farming technique applied to the greenhouse is hydroponic techniques. Hydroponic techniques are techniques for processing plants without using soil as a medium of growth. This technique supplies the nutrients needed by plants through aqueous solutions. Some environmental factors that must be considered include oxygenation, salinity, temperature, light intensity, photoperiod, air humidity, pH and conductivity of nutrient solutions [3].

During the plant growth period, hydroponic farmers must monitor these factors. During this time, plant monitoring is carried out manually with a measuring instrument and comes to the location directly and the provision of plant nutrition based on the age of the plant, but this does not fully suit the needs of the plant. Because the plant cannot convey its condition directly at any time to the farmer. Efforts to adjust the needs in agriculture are known as precision agriculture. Precision agriculture is...
information and technology in agricultural processing systems by providing precision treatment to obtain optimum and sustainable benefits [4]. The realization of precise environmental conditions with human power is considered ineffective. Humans often forget and are inconsistent when doing repetitive work. Therefore, the automation control system is needed and can be consistently working to meet the needs of plants properly.

Several precision agricultural researches have been carried out including automation of fertilizer, intelligent irrigation, and smart greenhouse. The research utilizes technology including the application of the Wireless Sensor Network (WSN) in agriculture. WSN is a solution to facilitate the realization of precision agriculture in the field of information technology. WSN consists of 3 main components, namely sensor nodes, gateways, and software. Sensor nodes serve to provide data on environmental conditions. The data is delivered wirelessly through the gateway to be collected, processed and displayed using the software. [5]. The basic principle of using internet technology and WSN will be the basis for the application of the Internet of Things (IoT).

Internet of Things (IoT) connects objects to share data via the internet. IoT is often integrated with cloud computing to overcome the limitations of IoT devices and requires communication protocols in the process of sharing data. [6]. Communication protocols that support the internet of things are the MQTT Protocol (Message Queuing Telemetry Transport). MQTT protocols have advantages over other protocols such as HTTP (Hypertext Transfer Protocol). MQTT is lighter, able to run in low bandwidth, simpler, and more modern than HTTP which has low overhead protocol and runs on high latency [7].

Based on these descriptions, this research combines the advantages of similar research in the use of technology for agriculture precision. The purpose of the research is to build precision farming based on wireless sensor networks with the MQTT protocol. The system used to monitor and control environmental conditions consisting of temperature, humidity, lighting and plant nutritional needs in the greenhouse in real time. Integration using cloud computing provides broad access for users to monitor and control anywhere and anytime via the website.

2. Material and Method
This research utilizes the MQTT protocol for communication between wireless sensor network devices for precision agriculture. Communication protocols play an important role in realizing the system runs according to planning. The following is a description of system architecture and theories that support research.

2.1 The Proposed System Architecture

![Figure 1. Architecture of System](image-url)
The communication systems in precision agriculture design based on Wireless Sensor Network are very important to provide precision treatment, collect and receive monitoring data. In this research, we use the MQTT (Message Queuing Telemetry Transport) protocol. The MQTT protocol bridges the sending of sensor data to the cloud server for later data is stored in a database and displayed on a web page so that users can access it. In controlling greenhouse environmental conditions, the actuator will work with the help of sensor nodes. All activities in this precision agriculture system can be monitor by users through the web.

2.2 Wireless Sensor Network with Internet of Things

Wireless Sensor Network is an advancement in the field of micro-electromechanical system technology, wireless communication, and digital electronics. WSN consists of sensor nodes that are spread across a particular area and collaborate with each other to collect, process, and communicate through wireless channels about some physical conditions or environmental conditions[8][9]. Wireless transmission at WSN makes wiring simple and the cost of using wires decreases. Wireless technology will eliminate 20% - 80% of the physical costs of industrial installations[4]. The wireless network with internet technology in WSN node communication is a form of the Internet of Things application which is a form of M2M (machine to machine) communication development through internet communication [8][10]. Figure 2 describes the wireless sensor network structure in general. It consists of sensing units, processing units, transmission units, and power units[8][11].

![Figure 2. General Structure of Wireless Sensor Network](image)

2.2.1 Sensing Unit. This section consists of sensor nodes to monitor environmental conditions. This research uses three sensor nodes namely the SHT3x to monitor the temperature and humidity levels, then the TSL2561 sensor to monitor the level of light intensity, and the TDS sensor to monitor the level of plant nutrients.

2.2.2 Processing Unit. The processing unit consists of a microcontroller that has memory to process the program in it and perform commands to the device connected to it. The device is in the form of sensors and actuators as control objects. All sensor nodes are controlled by a microcontroller (Wemos D1 Mini) located at a certain position. This integrated Wi-Fi microcontroller will easily communicate with the internet of things. Other than that, it can also control the environment by controlling the actuator.

2.2.3 Transmissign Unit. Transmitting unit is a part consisting of communication media for sending and receiving data by WSN (Wireless Sensor Network) device. Devices used on WSN wireless networks such as television satellites, GPS, mobile units, wireless computers, Zigbee technology and other wireless communication devices. In this study using MiFi (WiFi Hotspot Router) as an internet client source (sensor node) to connect with cloud servers.

2.2.4 Power Unit. The power unit of precision agriculture based wireless sensor network (WSN) uses an AC power installation energy source. WSN actuator devices require the AC power while the
processing device uses DC power. Therefore, this research uses an adapter 220V AC to 5 V DC. The use of AC power installation is right for a sustainable system such as the WSN design.

2.3 Wireless Sensor Network to Precision Agriculture
Precision agriculture is information and technology in agricultural processing systems by providing benefits to obtain optimal and sustainable benefits. Wireless sensor network on the development of precision agriculture can be used to regular monitoring of changes in environmental conditions such as climate, hydrology, plant physiology, pests and others. Other than that, it can also act as a control in the provision of inputs for seeds, fertilizers, pesticides, and others. The WSN sensor node will help the data collection process to produce information for farmers. WSN can take the form of a data collection system and control system on agricultural machinery. This system is widely used in research projects and commercial products to provide solutions for monitoring plant status, regulating irrigation, fertilizer management, pest control, and automatic harvesting[8].

2.4 Internet of Things with Cloud Computing
Internet of Things (IoT) means connecting devices via the internet. By using IoT, users can control the tool anytime, anywhere. The role of cloud on IoT aims to provide storage and computing resources to overcome the limitations of IoT devices[12]. IoT applications have limitations because operators do not have standard specifications to follow and each operator installation can vary significantly from each other. So that's important to have a standard architecture to encourage uniform IoT rectification on the cloud platform. Besides that, some other limitations that IoT can overcome by the cloud are interoperability, scalability, security, availability and big data[6].

2.5 Communication System on Cloud MQTT Broker
The MQTT protocol is designed to minimize bandwidth and energy usage and be as simple and easy to integrate as much as possible. The MQTT component consists of clients, servers or brokers, publishers, subscribers, and topics. MQTT Client is any device that acts as a publisher or subscriber. The MQTT broker is responsible for receiving all messages, filtering, determining who requests the message and sending messages to the client. The Publisher is a client that issues messages to clients who subscribe through brokers while subscribers are clients who receive messages through brokers according to the requested topic. The topic here is message identity[13][14].

MQTT provides three transfer modes based on reliability, namely QoS level 0 (Non assured transmission), QoS level 1 (Assured transmission) and QoS level 2 (Assured service on applications). Level 0 QoS is the fastest transfer mode. At level 0 QoS there is only the publishing process and the MQTT protocol does not require a server to forward publication or no acknowledgment status. There is a possibility that the publication will be discarded, depending on the server. QoS level 1 adalah mode transfer default. Level 1 QoS is the default transfer mode. At level 2 QoS messages are always delivered at least once. If the sender does not receive an acknowledgment, the message is sent again until the publisher gets the message recognition status from the client. Level 2 QoS is the safest but slowest transfer mode. At level 2 QoS there are two message transmissions. The first transmission, the sender transmits and receives recognition from the recipient. The second transmission of the sender notifies the recipient that he can complete the processing of the received message[7].

![Figure 3. Communication with MQTT Protocol](image-url)
In this research, the MQTT broker is installed on the cloud so that all messages are stored and processed in cloud storage. The monitoring and control process in this study uses the QoS level 2 mode. In the process of monitoring environmental conditions, the sensor (publisher) in the greenhouse sends reading data to the MQTT broker. Then the MQTT broker sends the sensor data readings to the web (subscriber) according to the message request topic so that the user can find out through the website.

3. Result
Figure 4 shows the monitoring data of precision agriculture environment conditions communicated by the MQTT protocol from the Wireless Sensor Network device. This website page is created using nodered software that has been configured on the cloud. The web displays monitoring data in graphical form in real time from sensor readings. Standard environmental conditions are also available there to facilitate users in monitoring precision treatment so users can compare the state of the plant at that time with the needs of plants.

![Figure 4. Precision Agriculture Monitoring Website](image)

Communication through the cloud with the MQTT protocol in publishing data can be monitor from the MQTT broker with the help of PuTTY software using the python command. Data transmission testing is done by tracking three sensor data simultaneously and displaying the timestamp and topic data for each track data that occurs. All data transmission activities use the MQTT protocol can be seen in figure 5.

![Figure 5. Screenshot of The Data Transmission On Cloud MQTT Broker](image)
Figure 6. Screenshot of The Data Transmission From Serial Monitor Arduino

Testing the speed of data transmission with the MQTT protocol for monitoring sensor data to the website is done by comparing the serial monitor timestamp with the timestamp on the website database. The comparison object for the testing of this research uses three providers with different network speed conditions as described in table 1.

| PROVIDER     | TIME OF TRIAL | SPEEDTEST | DEF. |
|--------------|---------------|-----------|------|
|              |               | DOWNLOAD (Kbps) | UPLOAD (Kbps) |    |
| Telkomsel 3G | 30 s          | 2413      | 228  | Work |
| AXIS 3G 1    | 30 s          | 558       | 142  | Work |
| AXIS 3G 2    | 30 s          | 0,65      | 0,02 | Work |
| Ooredoo 3G 1 | 30 s          | 304       | 215  | Work |
| Ooredoo 3G 2 | -             | 16        | 90,1 | Fail |
| Telkomsel 4G | 30 s          | 7687      | 5001 | Work |
| AXIS 4G 1    | 30 s          | 1688      | 1154 | Work |
| AXIS 4G 2    | 30 s          | 0,02      | 1,95 | Work |
| Ooredoo 4G 1 | 30 s          | 256       | 354  | Work |
| Ooredoo 4G 2 | 30 s          | 2,29      | 2,35 | Work |

The use of a GSM provider is chosen to get the same network conditions that are used by many users. The results of the speed test indicate that on 3G and 4G networks from Telkomsel, AXIS and Ooredoo providers can run Wireless Sensor Network communications except when using Ooredoo providers with 16 Kbps and 90.1 Kbps upload capacity. This test shows AXIS 3G and AXIS 4G with the smallest upload and download capacity but can run WSN communication with this MQTT protocol.
Each data provider takes 30 seconds of data track with the current bandwidth as described in table 1. Then the time of data transmission from the data track for each sensor is taken on average. The graph on figure 7, it can be seen that the speed of transmission of data tracking sensors with the 3G / 4G network of each provider is almost the same or stable except when using Telkomsel and Axis providers on 4G networks that look unstable. From all provider, the speed of data transmission on Ooredoo 4G with a download speed of 256 kbps and upload 354 kbps is tested faster and more stable, while testing the most unstable and slow in the process of transmitting data using the Axis 4G provider with download speeds of 0.02 kbps and uploading 1.95 kbps.

4. Conclusions
The MQTT protocol deserves recommended as a communication protocol for the application of wireless sensor networks for precision agriculture. This matter is related to data communication in real time. In this research, the MQTT protocol can transmit sensor data approximately one second. This time depends on the ability to download and upload from each network provider.

The MQTT protocol can transmit sensor data to the smallest download and upload capabilities, namely on AXIS 3G networks (download = 0.65 kbps; upload = 0.2 kbps) and AXIS 4G network (download = 0.02 kbps; upload = 1.65 kbps ) However, the MQTT protocol cannot run the data transmission process on Ooredoo 3G's smallest bandwidth (download = 16 kbps; upload = 90.1 kbps).

Other than that, the ability to download and upload from each provider also affects the speed and stability of sensor data transmission by the MQTT protocol. In 3G network providers, the third sensor data transmission graph tends to be stable while 4G network providers tend to be less stable. The MQTT protocol is capable of running the fastest and most stable transmission on the use of the Ooredoo 4G network with 256 kbps download capability and 354 kbps upload. But it looks unstable and slow to use AXIS 4G providers with a download capability of 0.02 kbps and uploading 1.95 kbps.

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