Smart Greetthings: Smart Greenhouse Based on Internet of Things for Environmental Engineering

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***Abstract*— A greenhouse aims to provide optimum light and protect plants from the adverse climate which delivers an optimum environment for plant growth. A smart greenhouse is built with capability in environment manipulation. The smart device is installed in the greenhouse consists of many sensors, which measures environment parameters, such as temperature and air humidity. One of the environmental key parameters is temperature. The device uses this parameter to provide proper temperature for plant growth. The measured data is sent to the data server by utilizing the Message Queuing Telemetry Transport (MQTT) protocol through the Internet of Things (IoT) architecture. The smart device has succeeded in measuring parameters and performed environmental engineering. The temperature and air humidity sensors have average error measurements with values of 0.9 degrees Celsius and 7.22 percentage. Moreover, the device has been successful in transmitting the measured data by using the MQTT protocol.**

Keywords*— *Internet of Things, sensors, greenhouse, environmental engineering, MQTT

I. Introduction

Indonesia is an agricultural country that produces agriculture for domestic and foreign consumptions. One technology for this agricultural production is greenhouse technology. It can maintain environmental factors that increase plant growth, such as temperature, sunlight, soil moisture, and air humidity, by following with the needs that are compensated at an optimal level. Information and communication technology continuously evolves, especially technology-based on the Internet of Things (IoT) [1]. One of the implementations of IoT in agriculture is a smart greenhouse. A greenhouse is a building that is framed or formed bubbly, covered with a transparent or translucent material that can continue the optimum light for production and protect plants from adverse climatic conditions for plant growth. With smart technology, we aim to improve the control of critical parameters in a greenhouse in an efficient manner with or less human interaction. Temperature is one of the critical parameters in the greenhouse that significantly affects plant growth. It will be controlled by using a microcontroller in order to environmental engineering that provides a proper temperature of the growth. Furthermore, the concept of a smart greenhouse is the integration of greenhouse environment data, which is obtained from sensors, connected to the database through IoT architecture [2]. Data of parameters and controller is sent to the data server in Internet cloud by applying lightweight protocol of IoT, i.e., Message Queuing Telemetry Transport (MQTT) [3]. By utilization of Android smartphones, whether using an application or web browser, we can obtain many features such as reporting, input updates, and controllers can be accessed in real-time from anywhere using the Internet.

Much researches on greenhouse environment controlling have been conducted. In [4], the authors construct a controller that controls a small scale greenhouse. The controller manages some inputs and outputs of the temperature and humidity of the greenhouse in predetermined ranges. It applies fuzzy logic self-tuning PID. The authors model the greenhouse by utilizing MATLAB system toolbox. They deployed the controlled greenhouse locally, without remote application. In [5], the authors design an environmental manipulation of the greenhouse with a controller which optimizes the condition of plant cultivation. They implement ZigBee protocol communication in order to obtain a controlled greenhouse environment from adjacent sensors node. Meanwhile, there are numerous researches in IoT technology for many fields, such as in [6-11]. In [6], the authors proposed a wireless sensor network with IoT technology for a landslide warning system. They implement machine to machine communication, between node sensor to a database server, without human interaction. Data from sensors are sent through an internet connection using 3G/4G gateway. In [7] and [8], the authors designed a vehicle traffic analysis in IoT architecture. The designed system transmits analysis data from a camera node through an internet connection into a database server. In [9], the authors designed a system for mobile health monitoring using internet communication. They implemented sensor devices for measuring pulse, body temperature, and ECG signals. The measurement data then sent to the database server use the MQTT protocol. They use applications with a mobile device, which receives data from the database also by utilizing the MQTT protocol. In [10], the authors used the MQTT for system monitoring of uninterruptible power supply (UPS) in an extensive infrastructure. The MQTT is used due to a small size protocol in IoT-based communication. In [11], the authors developed a smart heater that applies the MQTT protocol. A water heater node sends its temperature, power consumption, and its status to cloud platforms by using the MQTT protocol.

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The main contribution of this paper is developing a smart greenhouse technology based on IoT, which is an environmental engineering system that provides a suitable environment for the growth of productive plants in greenhouses using integrated sensors and connected to the internet that provides accurate, real-time and reliable economic growth data parameters. The smart node performs environmental engineering of plant growth parameters, such as temperature and air humidity, autonomously by using ON-OFF controlling mechanism.

The remainder of this paper is constructed as follows. In the next section, the architecture of the designed system is exposed in detail. In Section III, the result of the designed system and discussions are elaborated. And in the last section, the conclusion of the paper is provided

II. THE ARCHITECTURE OF PROPOSED SYSTEM

In this section, we describe the architecture of the designed system based on IoT in detail. The designed system consists of three main domains, which are node domain, transmission domain, and data domain, as shown in Fig. 1. The first domain, which acts as the smart device, is located at the greenhouse. The second domain is the communication network for transmitting data from the first one. The last domain is the resource for collecting data from the first domain.

A. Node Domain

Node domain comprises sensors, Arduino microcontroller, valve, and water pump, which intelligently acts together as a smart device for controlling environmental parameters at the greenhouse. The smart device utilizes sensors of Soil pH, DHT22, and SEN 0193 as input parameters of the system. The Soil pH sensor measures pH (Power of Hydrogen) of the ground where the plants are cultivated. The soil pH is the degree of acidity used to express the acidity or basicity of the ground. The DHT22 sensor measures of two parameters, which are temperature and air humidity of the greenhouse space. Furthermore, the system uses temperature as the critical parameter of environmental engineering. A reference value of temperature will be set as the threshold, which is utilized as a trigger of environmental engineering. The SEN 0193 sensor is an analog capacitive device to quantify soil moisture of the ground at the greenhouse. This device has an operating voltage at a value range of 3.3-5.5V. The collected data of sensors is then sent to the microcontroller for further action. The designed smart device, which is installed in the greenhouse, is shown in Fig. 2

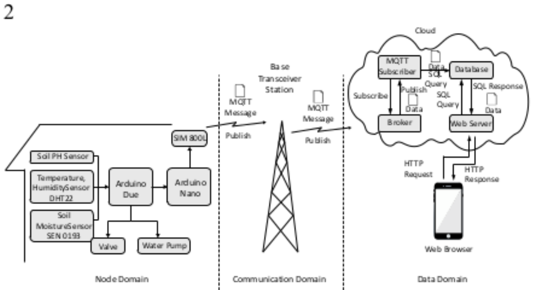

Fig. 1. The architecture of Smart Greetthings for environmental engineering

Fig. 2. The installed smart device for environmental engineering

B. Microcontroller Scheme

The smart device deploys Arduino Due and Arduino Nano as controllers for sensors, a water pump, and data communication. The designed scheme of the microcontroller circuit node is shown in Fig. 3. The system uses two microcontrollers with aims to share the load of sensor reading, processing, and data transmission. It is due to future preparation considerations. Data sensors are connected to Arduino Due to input pins, i.e., Second Line I/O. The display of measurement results (OLED) is connected to the communication part, i.e., SDA_20 and SCL_21. The engineering program is loaded into the microcontroller to run environmental engineering. The main parameter as the trigger of the engineering process is greenhouse temperature. In order to keep a proper parameter for plant growth, the system considers this parameter as the reference. The system sets a determined temperature as a reference value. If the sensed temperature exceeds the reference value, then the controller runs the water pump for spraying water inside the greenhouse. The data trigger is sent through Second Line I/O to relay. In the meantime, the data trigger is sent to the data server as the Output topic. This topic value either ON or OFF (1 or 0).

To provide data communication, the smart device equipped by SIM 800 module for cellular data communication. This module is installed into the Arduino Nano microcontroller. The monitoring data of engineered parameters are sent through this module. The data transmission to the server in IoT architecture applies the Message Queuing Telemetry Transport (MQTT) protocol. The transmission of temperature, air humidity, soil pH, soil humidity, and data output are performed continuously every 15 minutes.

C. MQTT Protocol

MQTT is a simple and lightweight messaging protocol designed for constrained devices and low bandwidth, high latency, or unreliable network. It is usually applied in wireless sensors network which has light message transactions. The protocol is built upon the principle of publishing messages and subscribing to topics. The sensors act as publishers, which publish messages to the queue in a broker. Then the broker proceeds the messages into the data server in the data domain. In our designed system, we utilize the io.adafruit.com server as a data monitoring server. The messages of temperature, air

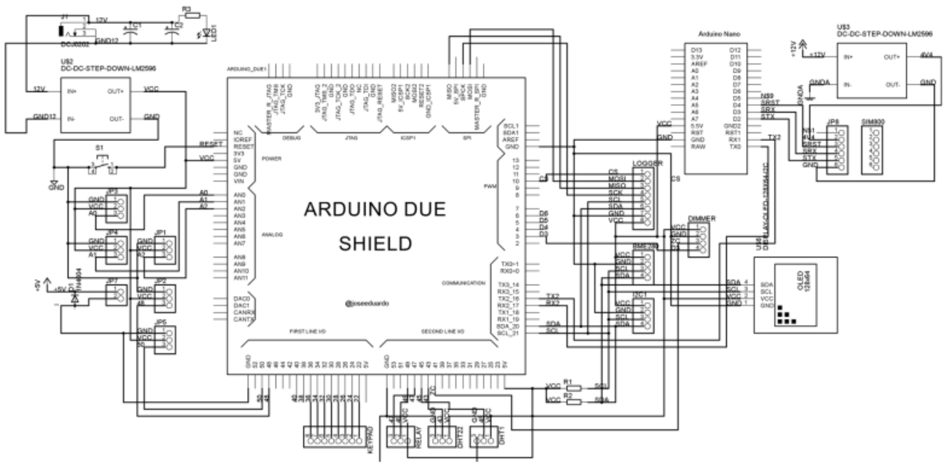

Fig. 3. The scheme of microcontrollers of Smart Greetthings.

Humidity, soil pH, soil humidity, and output are published into the server with topics TempGH, AirHumGH, pHGH, SoilHumGH, and Output, respectively. Implementation of publication in this protocol in io.adafruit.com server uses `Adafruit_MQTT_Publish` command, which can be written as follows.

```
Adafruit_MQTT_Publish TempGH =
Adafruit_MQTT_Publish(&mqtt,
AIO_USERNAME "/feeds/tempGH");

Adafruit_MQTT_Publish AirHumGH =
Adafruit_MQTT_Publish(&mqtt,
AIO_USERNAME "/feeds/airHumGH");

Adafruit_MQTT_Publish pHGH =
Adafruit_MQTT_Publish(&mqtt,
AIO_USERNAME "/feeds/pHGH");

Adafruit_MQTT_Publish SoilMoisGH =
Adafruit_MQTT_Publish(&mqtt,
AIO_USERNAME "/feeds/soilMoisGH");

Adafruit_MQTT_Publish Output =
Adafruit_MQTT_Publish(&mqtt,
AIO_USERNAME "/feeds/output");
```

III. Results and Discussions

In this section, we provide the measurement results of the devices of Smart Greetthings. The smart device is located at a greenhouse with a half-cylinder shape, as shown in Fig. 4. The greenhouse dimensions are width, length, and height with values of 2.5m, 5m, and 3m, respectively.

To examine the sensors of the smart device are working correctly, we provide two types of measuring values, which are measured value and datalogger value. The former value is read from the io.adafruit.com data server. It is the sensor measurement value that then sent to the data server. The latter value is obtained from datalogger, which is put inside of the greenhouse. The data logger provides features for temperature and air humidity measurements. These values are utilized as validations of the former values.

Fig. 4. The greenhouse where the smart device is located

Fig. 5 exhibits the measurement results of the temperature sensor, i.e., DHT22 sensor, which is obtained for 24 hours. The solid red line refers to the measurement of smart devices, while the blue dash line shows the data logger values. The values of device measurement are not exactly similar to that of datalogger measurement, but they are close to similar. The average measurement difference is with the value of 0.9^{o} Celsius. This graph indicates that the temperature sensor is working as expected.

Measurement of air humidity is exhibited in Fig. 6. Like the previous figure, the solid line points to the device measurement, while the dash one shows the data logger value. Generally, the form of both lines for 24-hours measurements is close to similar. Based on the recorded data, we obtain the average value of measurement difference is with a value of 7.22%.

Fig. 7 shows the graph of the Output topic, which is triggered by the temperature of the greenhouse. When the measured temperature value is higher than the reference value, then the Output value will be set with a value of 1. The Output value of 1.00 (ON) indicates the relay runs pump to spray the water for decreasing the greenhouse temperature. The figure exposes that at time 13.30 the temperature is higher than the reference value, i.e., we set 35^{o} Celsius, then

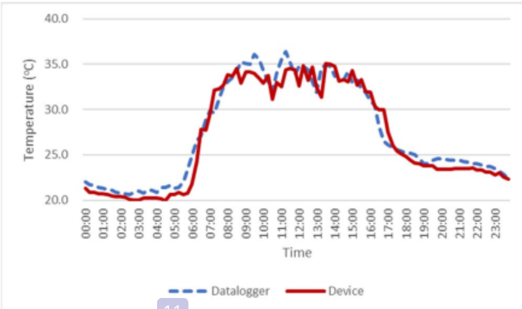

Fig. 5. Temperature measurement results of the device compared to datalogger values.

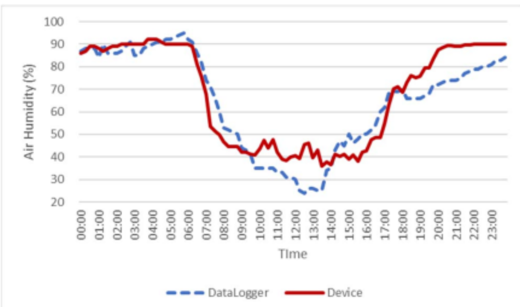

Fig. 6. Air humidity measurement results of the device compared to datalogger values.

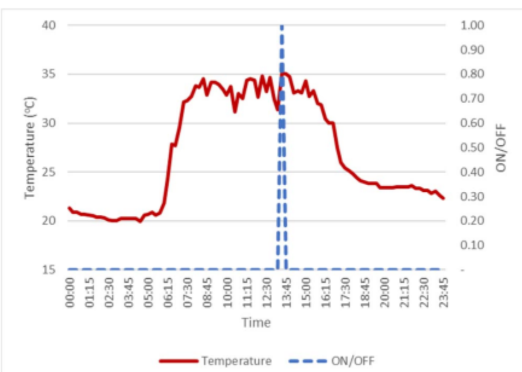

Fig. 7. The Output of measurement triggers (ON) the pump.

Fig. 8. Transmission of measured data at Smart Greetthings system using MQTT protocol.

The Output value is set 1.00; otherwise, the value is 0.00. Once the temperature is less than the reference value, the pump will stop spraying water in the greenhouse. In the next 15 minutes, i.e., at time 13.45, the Output topic has a value of 0.00, which indicates the temperature has been engineered lower than 35° Celsius.

The designed system of our research uses the MQTT protocol. The measured data are sent through the communication domain by using the MQTT protocol. Fig. 8 shows the capture of measured data transmission using the protocol, e.g., temperature and air humidity with values of 31.81° Celsius and 80.67%, respectively.

IV. Conclusions

A smart greenhouse system that can perform environmental engineering has been developed. It consists of a smart device, which carries out environment data measurement, data transmission, and environmental engineering. The parameters of environmental data are temperature, air humidity, soil humidity and soil pH at the greenhouse. The temperature and air humidity sensors have average errors by the value of 0.9°C and 7.22%, respectively. The designed system has succeeded in maintaining the temperature with the value that lower than the reference. In this research, data transmission applies the MQTT protocol, which is light and suitable for IoT architecture, through cellular data communication. The published data are then located at a data server that provides a broker for publishing the measured data.

Acknowledgment

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