Performances Analysis of IoT Based Smart Greenhouse System

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Abstract - *Greenhouse is one of the systems in agricultural fields that are built on a form of walls and roofs that covered by a transparent material to maintain the temperature and humidity for the growth of plants. However, the traditional implementation of the irrigation system required higher human interaction, cost and water consumption. This project aims to develop a prototype of the smart greenhouse system that is able to measure the temperature, humidity and soil moisture using the IoT system while the performance of the system is analyzed. Moreover, this prototype system uses the solar power system to supply the electricity to the electronic components. By determining the right size of greenhouse, then the project continued with developing a module for temperature, humidity, soil moisture and power consumption. After that, a module for developing the mobile application is designed using MIT App Inventor along with the web hosting platform which is the 000webhost. Following that, the data from the temperature, humidity, soil moisture and power consumption are analyzed to identify the performance of the smart greenhouse system. Therefore, this prototype able to provide the information of temperature, humidity and soil moisture through the mobile application using the IoT system.*

Keywords: *Greenhouse, IoT, Solar, Agriculture*

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I. Introduction and Review of Article

Greenhouse is one of the technologies in agriculture field which is built on a form of walls and roofs that are surrounded with UV film as it is highly affected by the surrounding conditions [1], [2]. The greenhouse is implemented to achieve the best plant quality and fruit production with a different environment that give a huge impact on economy growth to a country [1]. However, there are a few problems that are faced in agriculture sector which the different plants required different amount of light, temperature, humidity, moisture and fertilizer usage that only known by an expert in this agriculture fields [3]. Therefore, the right amount of temperature and humidity inside the greenhouse can affect the consistency of the plant growth while helps reducing the operational cost of production [4], [5].

Nowadays, a greenhouse with automated irrigation system is ready to be implemented and replaced the human interaction as it can increase the effectiveness of the plant production since the traditional technique are no longer applied in this modern era technology [6], [7]. All the data regarding the temperature, humidity and soil moisture can be monitored with the help of the sensors and Internet of Things (IoT). Moreover, the data can be monitored using the mobile application along with the IoT system as it is the effective and efficient method to implement the automating operation in the aspects of farming and agriculture fields [8]. The automated system enabled water pump to turn on depending on the value from the soil moisture sensor as it is the best way to help reducing the usage of the water in this agriculture sector [9]. Besides, the ventilation fan is one of the mechanism to force exchange of air taken from the outside into the greenhouse, thus reducing the temperature inside the greenhouse to achieve the best results of the plant production [10].

In addition, this technology involved the electronic components to perform all the operations including transmitting and receiving the data from the sensor, push the data to the server and triggered the output devices based on its condition. As the electronic components needs electricity to power-up the whole system, the solar power is the best alternative to be used in the greenhouse system compared to the power source from AC 240V as it has the unlimited source of energy that can be harvested all around the world [11], [12]. Furthermore, the cost of solar panel is consistently decreasing over the year as it is encouraging to apply for various applications such as powering street lights, water heaters and alarm system [12].

A. Background Studies on the Agriculture Technology

From the previous research, there is a lot of people try to invent a new technology for the irrigation system in agriculture and the comparison of every system is presented as in Table I. Nianpu Li [11] is one of the inventor that proposed a paper titled the IoT-based hydroponic greenhouse that utilizes five types of sensor which are the humidity and temperature sensors, light sensor CO_2 sensor in the air, as well as EC and pH sensors, and dissolved oxygen sensor in the water. The data from the sensors are sent, updated and stored on the local host via *ZigBee*. According to the author, the reason of using *ZigBee* as the IoT platform because of the characteristics of the system that can handle mesh topology with very-low power consumption [11]. A paper written by Hassan [1] using the same IoT platform as Nianpu Li [11] and the only difference between both projects is in term of the number of sensors and the various types of actuator used in the agricultural system.

Other than that, Nurulisma [9] also proposed a paper in which the system focuses to control the water consumption in agriculture field with IoT-based system. The development of this project is different compared to the research proposed by Nianpu Li [11] as the data collected from the sensor will be uploaded to the *ThingSpeak*.com and Firebase cloud.

Meanwhile, a system proposed by Nandhini [13] used various type of sensors such as soil moisture, pH, temperature, PIR and pressure sensor. This project used GSM Module to communicate with the agriculture system as the device can operate for a distance of 35 kilometers [13].

There is also a paper approaches a different IoT platform for their project. In the paper by Sharmila [14], the greenhouse system operated with Amazon Web Service (AWS) cloud as the IoT platform which is used to store the data obtained from the sensor.

Overall, the technology in agriculture and farming sector have improved over the year. All the recent research regarding the development of the IoT in this agriculture field has a same goal which is to solve the issue about the human interaction, power consumption and water usage [8]. Table I shows the comparison between 5 different projects regarding the agricultural system that using the IoT technology including this current project that located at the last row in the table. The comparison elements comprised the type of agriculture, sensor used, IoT platform and also the additional features.

From Table I, it is clear to see that all the projects used the humidity and temperature sensor to measure the surrounding temperature as it is the important factor in the growth of plants [5]. Besides, two out of three projects are categorized into the irrigation system while the remaining are classified as the greenhouse system and none of them using the solar controller as a power supply for the whole agricultural system.

II. Methodology

The development of the of greenhouse system is shown as in Fig. 1 which the NodeMCU forms the brain of the system that control everything from the input sensor until the output devices. The data from the soil moisture sensor will turn on the water pump while the exhaust fan will trigger depending on the temperature value that have been set. Besides, the value soil moisture sensor, temperature and humidity sensor can be monitored through the mobile application where data from the sensor will be stored in the server. All the electronic devices were powered up using the solar power system. Along that, MAX471 voltage and current sensor module is used to collect the data for power consumption as shown in Fig. 2.

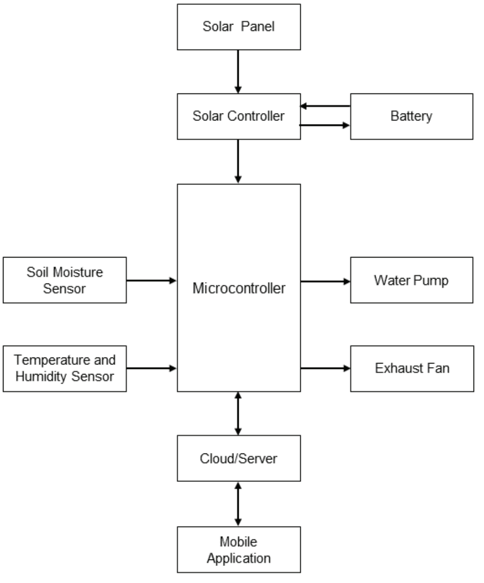

Fig. 1. Block diagram of the system

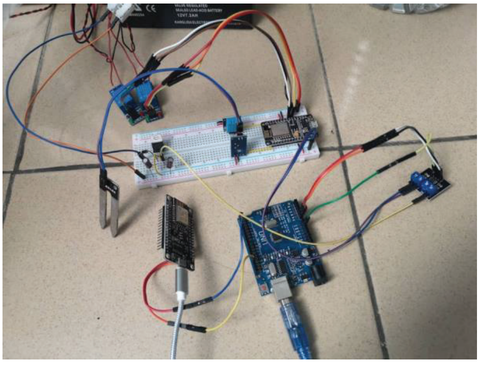

Fig. 2. Circuit connection for measuring voltage and sensor

TABLE I
VARIOUS AGRICULTURE SYSTEM COMPARISON

Author/Year	Project Title	Type of Agriculture	Sensor Used	IoT Platform	Additional Features
Nandhini (2017) [5]	Arduino Based Smart Irrigation System Using IoT	Irrigation	• Soil Moisture • pH • Humidity • Temperature • Pressure • PIR	• Custom Web Application	• GSM Module • LCD Display
Hassan (2019) [1]	A layered IoT architecture for greenhouse monitoring and remote control	Greenhouse	• Humidity • Temperature • Light • Soil Moisture • Salinity • Dew • Pesticides • Fire • CO2	• *ZigBee* Technology	• Actuator
Sharmila (2019) [6]	Automated Smart Greenhouse Environment Using IoT	Greenhouse	• Humidity • Temperature • Light • Soil Moisture • pH	• Amazon Web Service (AWS) Cloud	• Ethernet Shield • GSM Module
Nianpu Li (2019) [7]	Smart Agriculture with an Automated IoT-Based Greenhouse System for Local Communities	Greenhouse	• Humidity • Temperature • Light • pH • EC • CO2	• *ZigBee* Technology	• Actuator • CO2 generator • Dehumidifier • Air-Conditioner • Pump system
Nurulisma (2019) [3]	Smart Irrigation System Based on Internet of Things (IoT)	Irrigation	• Soil Moisture • pH • Humidity • Temperature • Pressure	• *ThingSpeak* • Firebase	• Water Pump
Zulhakimi (2020) Current project	Performances Analysis of IoT Based Smart Greenhouse System	Greenhouse	• Humidity • Temperature • Soil Moisture	• *000webhost* server • *MIT App Inventor*	• Water Pump • Solar System • Exhaust Fan

III. Results, Analysis and Discussion

There are three parts for this project which is hardware, database and server, and mobile application. For the hardware, the circuit consists of NodeMCU, temperature and humidity sensors, soil moisture sensor and solar power system. Furthermore, the www.*000webhost*.com is used for database and server which provides the phpMyAdmin that can be used to create and structure the table of the database. Then, the PHP file is created in order to run the desired command to the database. The files need to be uploaded to the *000webhost* account to make it online. Lastly, the *MIT App Inventor* is used to design the mobile application where the layout and component of the application are designed before the operation of each component is set. After that, the mobile application is connected to the database through the server.

A. Analysis of Temperature Data

The temperature data can be viewed on mobile application which is shown in Fig. 3. The mobile application shows 20 recent data in descending order. The data displayed along with the date and time which updated for approximately every 30 seconds. Moreover, the user can view the temperature data in the form of graph by clicking the 'Show Graph' button underneath the temperature data. The graph will be displayed in mobile application as shown in Fig. 4. The graph is designed in the specific web URL where the data are collected from the database and the mobile application called the web URL to display the data.

Next, the temperature data are collected where the indoor greenhouse is located at Universiti Teknikal Malaysia Melaka (UTeM). The purpose of analyzing the temperature data is to determine the range of temperature inside the greenhouse that suitable for a specific plantation.

The temperature values obtained from the sensor were analyzed for 24 hours (1 Day) with 2495 data which is shown in Fig. 5. Referring to the figure, the time shown is in UTC time zone which need to be converted to local Malaysia time by adding 8 hours. The conversion of time is important in collecting data to ensure the data is valid and meet the real-time data to be analyzed.

The data in Fig. 5 shows that the temperature values range between 27.5°C and 30°C. The highest temperature value reaches to 29.7°C range time from 12:28:16 (4:28:16) until 15:13:58 (7:13:58). Meanwhile, the lowest temperature occurred at 3:18:56 (19:18:56) to 3:45:16 (19:45:16) with the temperature value of 27.7°C. The average value of the temperature data in a day is 28.67°C.

Overall, the indoor greenhouse is suitable for a plant that surrounded by the temperature values between 27.5°C and 30°C such as corn plantation [15]. Moreover, this greenhouse is not suitable for tomato production as the optimum range for this plant is between 21°C to 24°C [10]. The mechanism that can control the temperature known as ventilation fan is needed for certain plantations which allow the outside air to flow into the greenhouse. Thus, the ventilation fan can be set to turn on until the temperature inside the greenhouse achieves the optimum range for a specific plant.

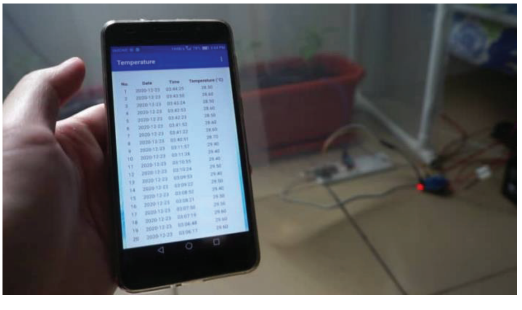

Fig. 3. Temperature data obtained from the sensor

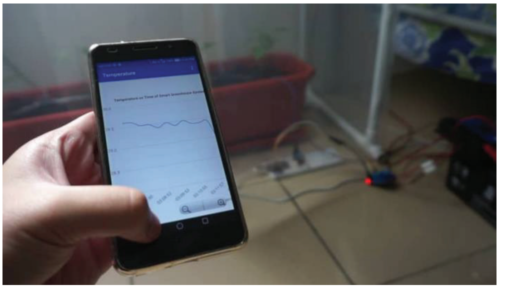

Fig. 4. Graph for temperature vs time

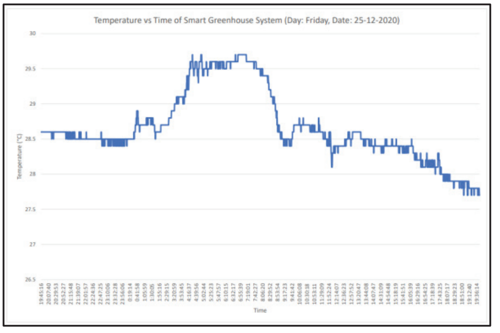

Fig. 5. Temperature data vs time

B. Analysis of Humidity Data

The humidity data are obtained from DHT11 sensor where the data are collected at UTeM. The data can be viewed on mobile application as shown in Fig. 6 which shows the 20 most recent data in descending order as the previous temperature data. The data are displayed with the date and time and updated for approximately every 30 seconds. Underneath the humidity data, there is a button named 'Show Graph' that enables user to click and view the humidity data. The graph will be shown as in Fig. 7. This graph also obtained from the web URL that allow the mobile application to display the humidity data.

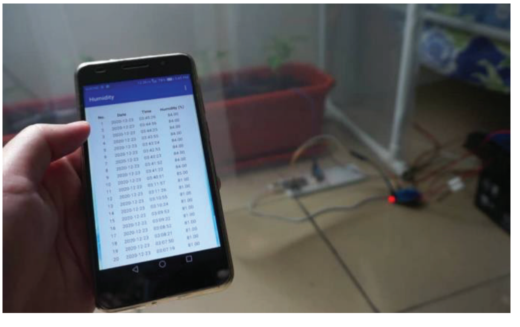

Fig. 6. Humidity data obtained from the sensor

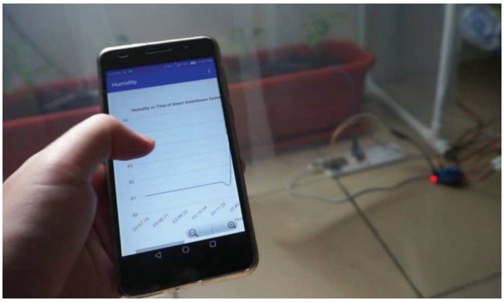

Fig. 7. Graph for humidity vs time

Furthermore, the collection of data is analyzed using Microsoft Excel to generate graph and calculate the average value of the data. Therefore, the humidity data were collected for 24 hours (1 Day) which has a total of 2495 data as shown in Fig. 8. Referring to Fig. 8, the humidity data ranges between 75% and 95%. From the graph, the maximum peak in the humidity data occured between 9:05:59 (1:05:59) to 9:28:22 (1:28:22) with 92% while the lowest humidity value is 78% that occurred between 15:17:18 (7:17:18) to 15:22:56 (7:22:56). Next, the average value of the humidity in a day is 84.22%.

Overall, the relative humidity of air inside the greenhouse gives a huge impact for the growth of plant [5]. Fig. 8 shows that the distribution of the humidity inside the greenhouse varies over time. Thus, the suitable plant can be applied to the indoor greenhouse that meet the suitable humidity air inside the greenhouse with the average of 84.22%.

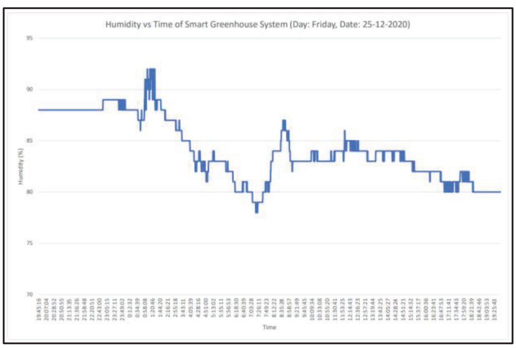

Fig. 8. Humidity vs time

C. Analysis of Soil Moisture Data

The soil moisture data were obtained from the soil moisture sensor which is taken at UTeM. The sensor is placed under the soil to measure the water content in a form of a percentage. The soil moisture data can be viewed in the mobile application which shows the 20 most recent data in descending order. The data obtained is shown as in Fig. 9 where it isdisplayed along with the date and time in order to notice the latest data. The data will be updated for approximately every 30 seconds.

To view the soil moisture data in a form of graph, the user can click the 'Show Graph' button underneath the soil moisture data. Next, the graph will be displayed in the mobile application as shown in Fig. 10. As the graph was designed in a specific web URL, the mobile application needs to call the web URL in order to display the data.

For the analysis of soil moisture sensor, the data were collected in 24 hours (1 Day) with a total data of 2495 which in shown as in Fig. 11. For analyzing purpose, the water pump is set to turn on for 2 seconds and dispense 67 ml of water to the plant where the soil moisture sensor is placed 1.5 cm from the plant and 4 cm deep in the soil. The water pump was triggered at 2:35:20 resulting in the highest soil moisture value occured at 2:35:48 with 92.08%. Next, Fig. 11 shows the trend of the data are decreasing over the time for the next 24 hours. Furthermore, the lowest value of the soil moisture is 83.19% occured at 2:28:13.

The collected data ranges between 82% and 94% with the average value of the data is 85.03%. Overall, the soil moisture value varies depending on the plant and the exact amount of soil moisture is determined by the expert people in the agriculture fields [16]. Therefore, the greenhouse system can set to turn on the water pump at a certain level of soil moisture depending on the average value needed by a plant in a day. For example, by referring to Fig. 11, the system can be set to turn on the watering system if the soil moisture value is lower than a minimum data obtained (83.19%).

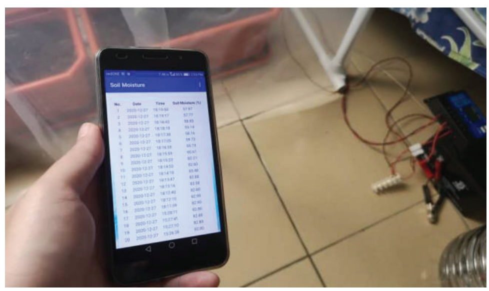

Fig. 9. Soil moisture data

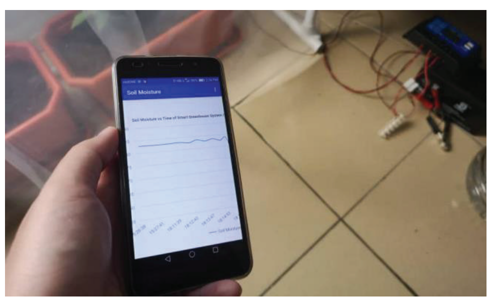

Fig. 10. Soil moisture data in a form of graph

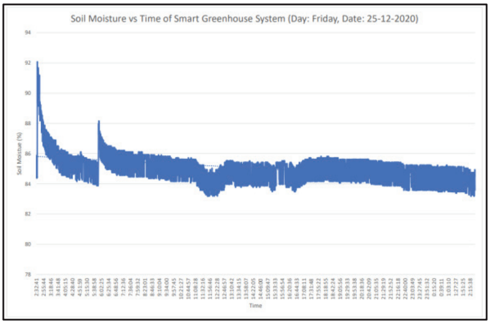

Fig. 11. Soil moisture vs time

D. *Analysis of Power Consumption*

The power consumption of the system is determined by multiplying the amount of voltage with the current. The data is gathered in 1 hour with a total of 2415 data as shown in Fig. 12. The data measure the power consumption for NodeMCU with DHT11, soil moisture sensor and two relays without considering the water pump and ventilation fan.

Overall, the average power consumption of the electronic devices is 0.25 W per hour. If the board runs for 24 hours, the total power consumption is 6 W. Meanwhile, the power consumption for the water pump is 4.2 Wh while ventilation fan is 3.6 Wh which is known from the specification of each device. This prototype system using 12 V, 7.2 Ah lead acid battery with a capacity of 86.4 Wh and it is charged directly from the solar panel that are able to draw the maximum of 30W per hour through the solar charger controller. Besides, the solar charge controller able to manage the maximum current of 10 A which is compatible to the solar panel as it produces the maximum current of 2.5 A. For example, if the maximum power that can be harvested by the solar panel per day is 60 W which is equivalent to 2 hours of maximum charging, the 12 V, 7.2 Ah lead acid battery is suitable for this system as the solar system able to charge the battery for more than 60% of its capacity.

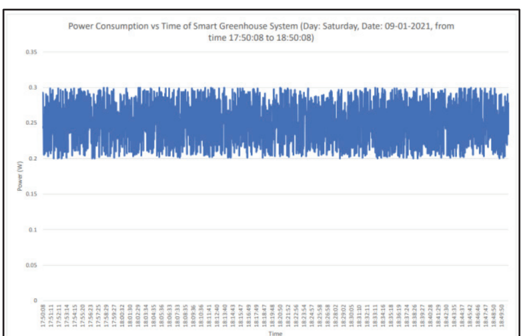

Fig. 12. Power consumption vs time

If the water pump and ventilation fan are turned on 1 hour a day, the power consumption for the green house system is 13.8W which is a 15% value from the capacity of the battery. Moreover, the depth of discharge of the battery capacity plays an important part in determining the battery lifetime where the less of discharge rate the better the battery lifetime [17]. Therefore, the power consumption for the greenhouse system meets all the specification of the solar power system.

IV. Conclusion

Overall, the objective of this project is achieved where the prototype of the smart greenhouse was developed and the system able to measure the temperature, humidity and soil moisture using the IoT system. Moreover, the performances of the smart greenhouse system are analyzed using the IoT system.

This prototype able to read the temperature, humidity and soil moisture data and displayed using the mobile application. At the same time, this system able to receive the data from the sensor and store the data into the database table which allowed the mobile application to display the data to the user. Besides, the analysis of the data collected proves that this prototype system shows a good performance in terms of power consumption. The entire process requires the connection of internet which is one of goals in developing the IoT system. Moreover, the whole project uses the solar power system to supply the electricity to the electronic components. As the solar power system is one of the renewable energy that can be harnessed all around the world, it provides an alternative to reduce the global warming [18]. Thus, it achieves one of 17 United Nations Sustainable Development Goals (SDGs) which is goal number 7 that ensure access to affordable, reliable, sustainable and modern energy for all in terms of the improvement of energy efficiency [19]. Therefore, this project is successful since the objectives of this project are achieved.

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