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4 Levels of IoT Architecture for Smart Irrigation Rice Fields

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ABSTRACT

Water is one of the main components in the agricultural sector. Traditional irrigation systems are often inefficient and ineffective, which can lead to water wastage and require huge resources. Intelligent irrigation systems based on the Internet of Things (IoT) offer a solution to overcome these problems. The purpose of this research is to create a 4 Layer IoT architecture for smart irrigation in Gadon village. The method used in this research uses research and development methods, starting from literature study, field survey, design, assembly, and testing. Design of Internet of Things (IoT) architecture using ESP8266 for irrigation of rice fields in Gadon village Dlingo, Bantul. The design of this system aims to facilitate irrigation. This system utilizes IoT technology in its implementation. This system consists of four IoT layers, namely the Smart Things layer which consists of a water level sensor, water ph sensor, with control using ESP8266. Networks and Gateways layer, which consists of a router to connect smart things with the internet, Middleware layer, and Application layer which consists of an android application for the system interface. This system contributes directly to the form of convenience for farmers to manage irrigation of rice fields using ESP8266-based IoT applications. In addition, this system also provides water level information to facilitate farmers in the irrigation process.

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1. INTRODUCTION

Irrigation of rice fields is one of the important components of agriculture. Irrigation is a water structure in the form of a channel that serves to channel water to rice fields periodically. Irrigation is an infrastructure to increase land productivity and increase the intensity of harvest per year. The availability of sufficient controlled irrigation water is an input to increase crop production [1]. Irrigation is considered the artificial utilization of water. Water in the ground is extracted using different methods such as pumps, tubes, and sprays [2]. The main goal of irrigation systems is to minimize labor and resource requirements and maximize efficiency. Improving irrigation efficiency in agriculture is essential for sustainable agricultural production. Smart irrigation methods can improve irrigation efficiency, especially with the introduction of wireless communication systems, monitoring devices, and control techniques [3].

So far, irrigation in Gadon village is still done manually, so it still requires large resources during the process of irrigating rice fields. The problem when irrigation is done manually is that farmers must monitor the water discharge to match what the plants need, so it still requires large resources. The solution to this problem is the integration of IoT technology in agriculture, especially in irrigation. The implementation of IoT technology in irrigation can be realized in smart irrigation. The Internet of Things is a technology that can connect sensors and actuators by utilizing an internet connection [4] [5].

The Internet of Things (IoT) enables independent and secure connections and data exchange between real physical objects and applications as an interface [6]. The Internet of Things, allowing users to capture information from various sensor devices, can be used to improve services or enhance decision-making [4]. The Internet of Things (IoT) provides a simple framework to easily control online devices. Automation is a technique or system of controlling a process with electronic devices with reduced human involvement to a minimum. IoT transmits automated system data with a Wi-Fi connection [7] [8]. IoT is a network connection paradigm that provides seamless connectivity between physical and virtual objects for the development of intelligent services [9]. There are various IoT architectures, one of which uses 3 layers, namely the perception layer, network layer, and application layer [10]. IoT can be utilized in all fields of life, one of which is in agriculture. One of the implementations of IoT in agriculture is smart irrigation. The modern agricultural paradigm is carried out with the integration of the latest technologies, such as IoT, robotics, blockchain, embedded electronics, and automation, giving rise to the idea of smart agriculture [11]. One of the implementations of automatic plant watering is using Arduino. This automatic watering aims to determine the position of the soil moisture sensor, the optimal watering time length, and analyze the quality of the stored data [12].

Candra and Maulana built an intelligent irrigation system using Ardudino-based soil moisture and water level sensors. This system is made to regulate the volume of water through water level. The result is that the system can detect the water level. This system can provide information about the water level through LED light indicators [13]. Research on irrigation automation was also conducted by Mezouari. This research introduces an automatic irrigation system based on smart sensors that can be used to monitor mint plants or any plants by integrating several connected electronic devices and other useful instruments that are widely used in the IoT field. The system can detect soil moisture and temperature levels and automatically [14]. Research was also conducted by Tyagi to create an automatic irrigation mechanism that turns on and off the pump motor to detect the moisture content of the earth using a soil moisture sensor without human intervention. This smart irrigation system uses an Arduino microcontroller that is programmed to collect input signals according to soil moisture content, and the output is given to an op-amp that will operate the pump [15]. Irrigation research was also conducted by Rafique in developing an irrigation automation system. The objective of this project was to develop an intelligent irrigation and water management system for conventional agriculture. The project was carried out mainly to improve irrigation scheduling and also to overcome the problems of overwatering and underwatering in traditional irrigation systems [6]. The development of an automatic irrigation system is also done with a soil moisture sensor using wireless technology. Through the GSM Modem, the sensed water content data will be sent as SMS to the user. The system also sends SMS to the concerned number using a GSM modem [16].

The application of Wireless Sensor Networks (WSN) to irrigation was also carried out by Yatnalli. This research aims to reduce water usage by irrigating agricultural land that has low humidity levels. In this system, the Wireless Information Unit collects sensor information from the Wireless Sensor Network through the use of Wi-Fi. The system monitors soil moisture and controls water flow using solenoid valves depending on the set threshold [17]. While this research produces an IoT architecture design that is implemented in irrigation in Gadon village. It is expected that with the IoT system applied to irrigation in Gadon village, it can facilitate farmers in irrigating rice fields. The architecture implemented in Gadon village uses four layers. The author's contribution to this research is to provide a solution to facilitate farmers in managing rice field irrigation using ESP8266-based IoT applications. Farmers can irrigate rice fields only using an Android application that is connected to the smart things system via an internet connection. The difference with previous research is that this research implements a 4-layer IoT design applied to traditional irrigation, thus changing the paradigm in irrigating rice fields, which has been done by traditional methods. With the resulting application, irrigation can be done automatically and easily.

2. METHOD

The method used in this research starts with data collection. Data collection included literature studies on IoT applications in irrigation, identification of needs, and field surveys. Next, after the data is collected, proceed with system design. In designing this system, the selection of component types, both software and hardware, is adjusted to field needs. The next step is system implementation. At the system implementation stage, the hardware that has been designed is then assembled and tested on a laboratory scale. Sensor and actuator configurations are adjusted to field conditions. The final stage is to carry out analysis and evaluation. At this stage, the system that has been implemented is evaluated for its performance and ease of use. In general, the method used in this research can be seen in Figure 1 below.

Figure 1. Research stages

Initial data collection begins with a literature study, an interview process with potential system users, in this case, farmers, and observation. Observations are made by looking directly at the field where the system will be implemented. The development stage starts with designing, then creating the system. Evaluation consists of small-scale trials in the laboratory, which aim to determine the function of the system, whether it can work as desired. Hardware consists of actuators, controls, and sensors. Software consists of a system interface, which functions for communication between the user and the system. The hardware design scheme can be seen in Figure 2 below.

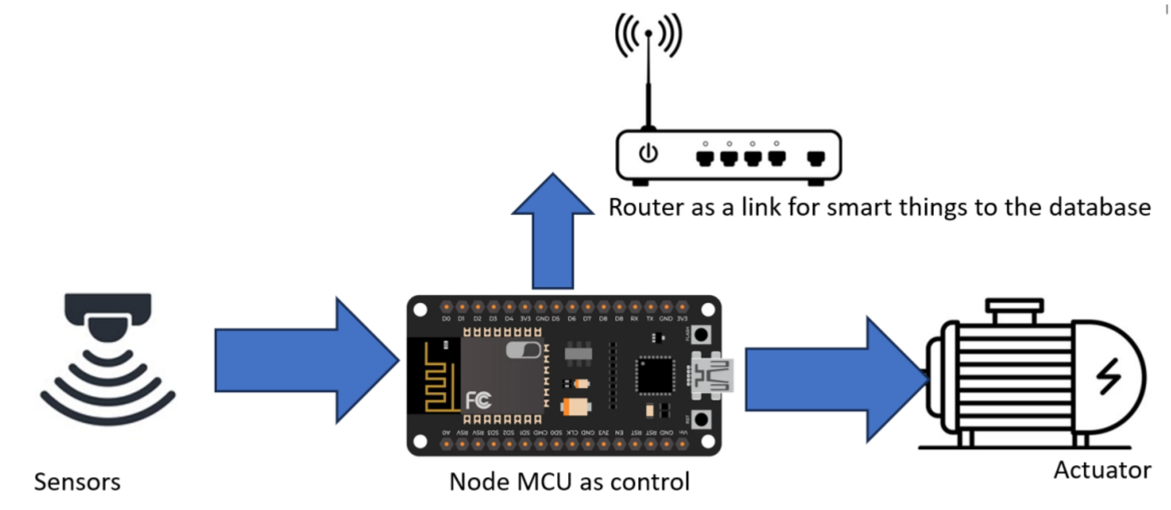

Figure 2. Smart irrigation hardware design scheme

This system architecture design uses 4 layers. The first layer is the Smart Things layer. The smart things layer consists of hardware control, actuators, and sensors. The sensors in this system use soil height sensors and soil moisture sensors. The controller in this layer uses an MCU node. Node MCU is a microcontroller that has been equipped with a wifi connection, so that it can be used to communicate via the internet. The IoT-based Node MCU platform is open-source [19]. The way smart things work is that the sensor provides information to the controller and forwards it to the actuator according to the desired program.

The second layer is the Networks and Gateways layer. This layer uses a router to connect to the internet connection. This layer is the connecting layer between the smart things layer and the middleware layer. The third layer is the middleware layer. This layer contains MQTT. MQTT is one of the standard application layer protocols for the Internet of Things. MQTT organizes a series of clients around a server called a broker, which sends published data to the receiver [20]. Layer 4 is the application layer.

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This application layer is directly related to the user. The IoT architecture applied to smart irrigation can be seen in Figure 3.

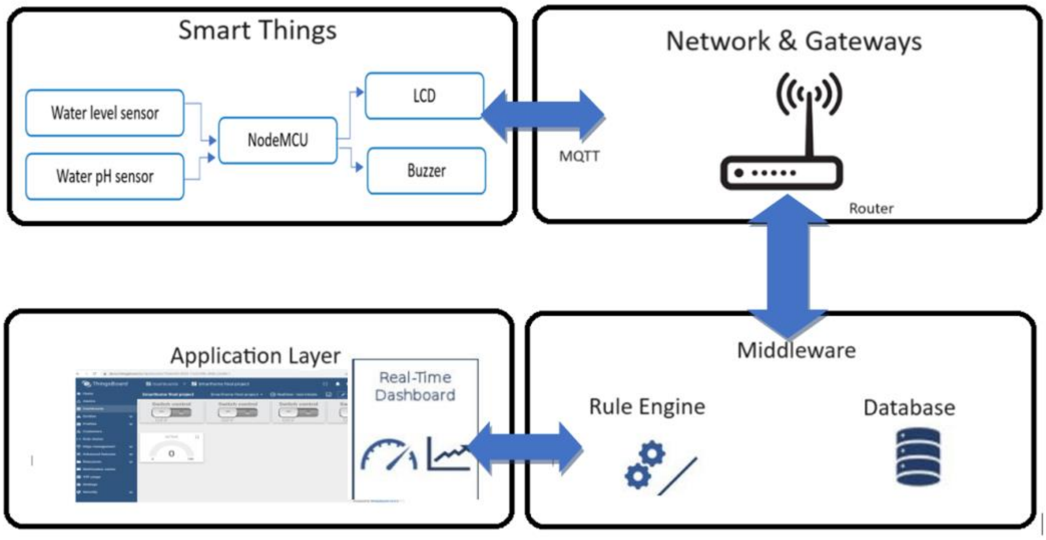

Figure 3. IoT architecture applied to smart irrigation

The wiring diagram for layer 1 can be seen in Figure 4 below. The smart things system consists of MCU nodes as controls, water sensors, and motor pumps as actuators.

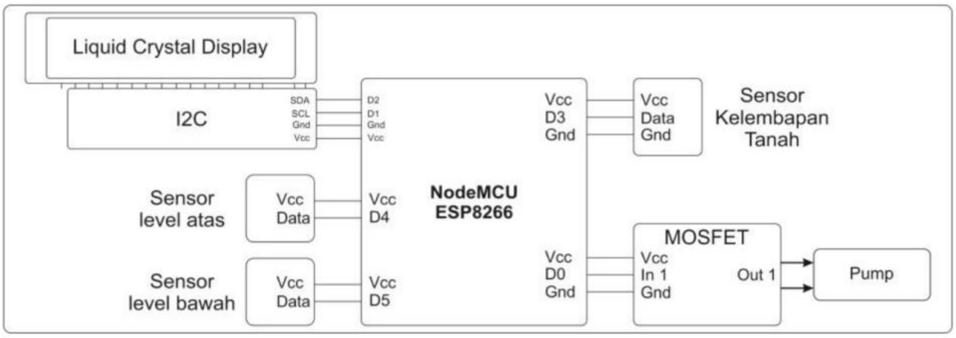

Figure 4. Wiring diagram for layer 1

Testing on this system is done on layer 1. Testing is done by testing the water level sensor and the humidity sensor. Testing aims to determine the performance of the sensor, whether it is working properly or not. Testing is done by detecting the sensor on a serial connection. From the test data, it is found that the water level sensor can work to detect the water level. Based on testing of the water level sensor, it can be seen that the results of sensor readings are used to determine the logic for opening the water pump. When the water level sensor is at logic 1, the pump motor will start. The water pump will turn off when the water level is at logic 0.

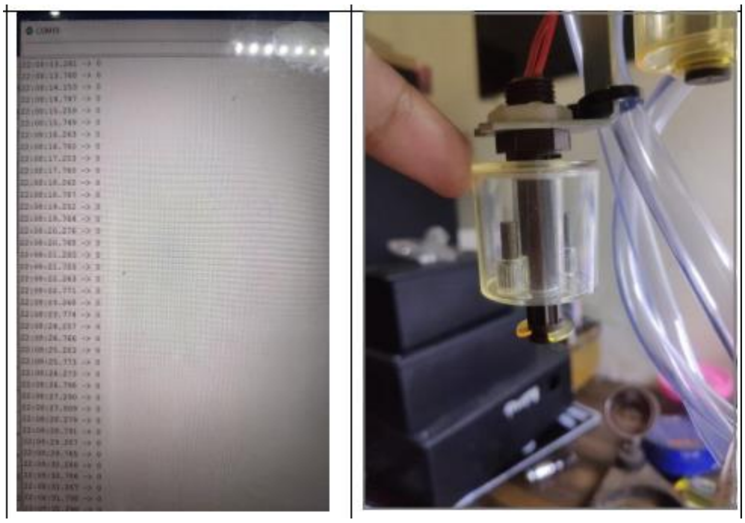

Figure 5. Water sensor testing process

Testing the soil moisture sensor aims to determine whether the soil moisture sensor is functioning properly or not. Testing is done by testing the function of the sensor. Based on the tests carried out on the soil moisture sensor, the soil moisture sensor works according to the program. The resulting sensor value is 1 when the sensor reaches the desired pH value. This digital value will then be processed on the microcontroller to drive the actuator.

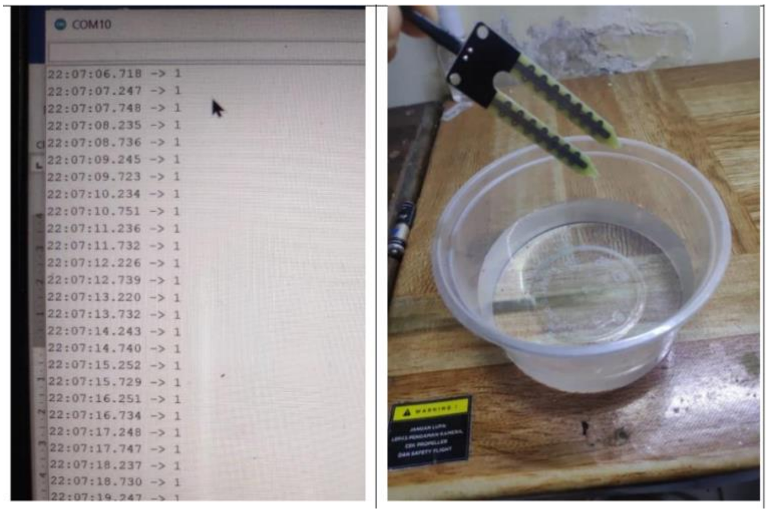

Figure 6. Humidity sensor testing

3. RESULT AND DISCUSSION

3.1 System Design

The hardware design produces a smart things layer consisting of an ESP8266-type microcontroller, which has been integrated with Wi-Fi, allowing internet connection with other devices. In addition, this system uses a water level sensor and a pH sensor. Then the hardware interface uses LCD and a buzzer as a hardware interface to the user. In the hardware design, internet connection settings are carried out by uploading the internet connection program into the ESP8266 microcontroller chip. The results of the hardware design can be seen in Figure 7 below.

Figure 7. IoT system hardware

The software design is made with an Android application. This software design will be a user interface, so that farmers can easily monitor rice field irrigation through the interface application. The information generated from this user interface is the height of the water level, humidity, and the opening and closing of the water faucet.

The 4-layer IoT system design in the Smart Irrigation System based on IoT Architecture using ESP8266 consists of 4 main layers: (1) Perception Layer. This layer consists of IoT hardware that is applied to the system. The control uses an ESP8266-type microcontroller, and the sensors use water level and humidity sensors. (2) Network Layer, in the Smart Irrigation System based on IoT Architecture using ESP8266. connectivity between the IoT device and the layer uses a Wi-Fi network. The reason for choosing to use wi-fi technology is the flexibility in the field. (3) Middleware Layer, for connecting between the perception layer and application layer in this system using the Things Board platform. (4) Application Layer, the application layer of this system uses an application developed with App Inventor. This interface allows users to monitor water levels and water humidity.

3.2 System testing

System testing is done to determine the performance of the system being built. Testing is done before implementing the system in the field. The systems tested are: (1) power supply system, (2) LCD display, (3) connectivity, and (4) sensors. The first test carried out is the power supply test. The power supply in this system uses an independent power supply, using solar panels connected to a battery to store the power. Power supply testing is done by testing the current entering from the solar panel to the battery. The measurement results can be seen in Table 1 below.

Table 1. Solar panel testing table

Time	Voc	Current from Solar Panel (A)
6.00	43,5	0,51
9.00	45,39	3,82
11.00	45,27	8,12
14.00	44,96	1,51
17.00	41,10	0.13

The next test is LCD display testing. The LCD used in this research is 16x2 characters. Testing is done by uploading a program that displays data on the LCD display. LCD test results can be seen in Figure 8 below.

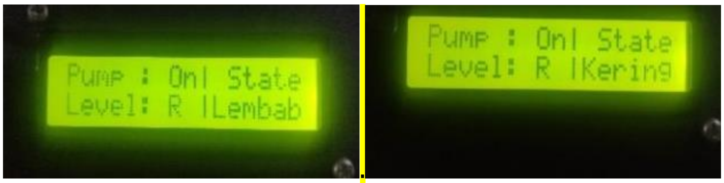

Figure 8. LCD display testing image. The LCD can display information according to the program execution.

Connectivity testing is done by viewing serial communication on the serial monitor displayed on the computer screen. Connectivity testing is successful if the serial monitor can detect data sent from the sensor to the ESP8266 microcontroller. The results of the sensor connectivity test can be seen in Figure 9 below.

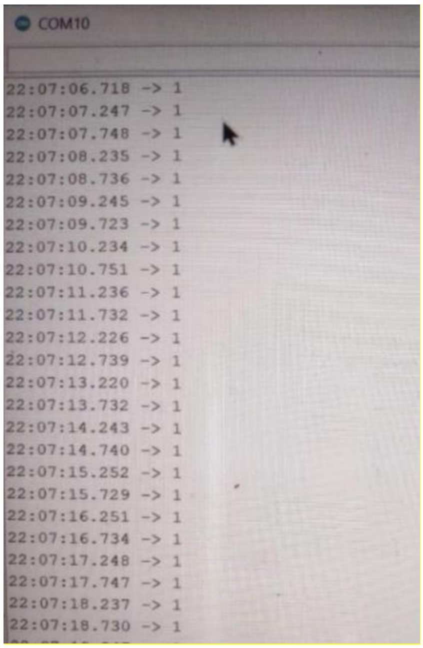

Figure 9. Sensor connectivity testing results

From the connectivity testing image above, the sensor can send data to the microcontroller and works according to the program created. The results of testing the water level sensor are obtained, the water level sensor can work according to the predetermined program. The sensor can provide notification to the user through the android interface. The results of the hardware design can be seen in Figure 10 below.

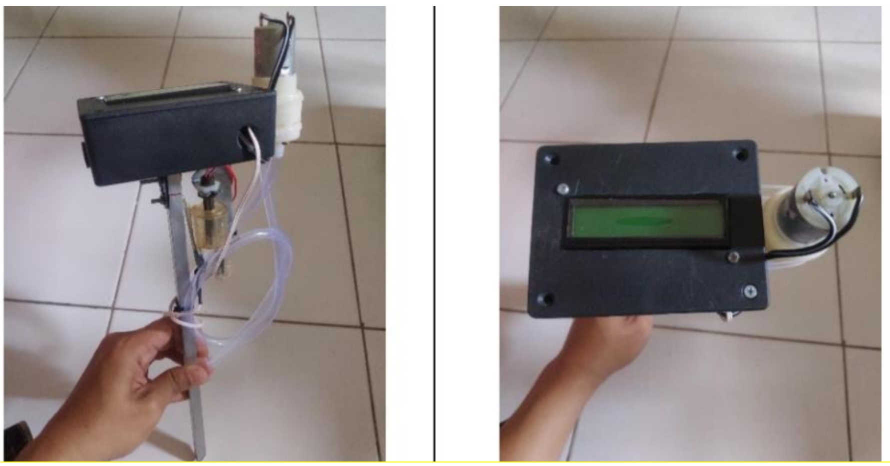

Figure 10. Hardware prototype

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From the design of the system made, the system can run normally during limited trials. Monitoring the water level has two conditions, namely the condition of the water level in the low level and the condition of the water level in the high level. Low and high-water level conditions. If the water level sensor detects water in a low condition, the microcontroller will process the sensor data, then send the data to the user interface via an internet connection. The process of sending data to the user goes through a layer 2 stage, namely a router that connects the internet from the smart things layer to the ISP, so that data can be sent to the gateway. The gateway then forwards the data to the application layer. The data transmission scheme is also the same for the soil moisture sensor.

3.3 Comparison of IoT-based smart irrigation system using ESP8266 and traditional methods.

The water level and humidity during the implementation of the ESP8266 microcontroller-based smart irrigation can be monitored directly using the system interface. Irrigation can also be done automatically using this system by simply pressing a button on the interface. This result is different when irrigating using conventional methods. Farmers must go to the fields to irrigate the rice fields. This requires large resources if, at any time, they must irrigate the fields. Based on user testing with the ease-of-use instrument, it was found that the system can be easily used by farmers. The questionnaire provided also indicated that the system can work as desired. With this smart irrigation application, farmers find it easier to irrigate rice fields compared to conventional methods.

In this study, we found that the IoT architecture implemented in Gadon Village had no problems during the limited trial. The test was conducted for two days with implementation in the field. When the water level is high, the system can send data to users through the Android application, so that users can find out information in the field in real time. The IoT-based smart irrigation architecture in Gadon Village is suitable for using a 4-layer architecture, although from observations in the field, it is also possible to use 3 layers. This is due to the needs in the field. Field needs are based on the effective use of components. The components used are expected to be as minimal as possible with maximum performance, so the selection of IoT architecture in smart irrigation in Gadon village is suitable to use 4 layers. The real contribution of this research is that the proposed 4-layer IoT architecture applied to the smart irrigation system using ESP8266 is accepted by users. This changes the paradigm of irrigating rice fields that were previously done conventionally; after this system is applied, irrigation becomes easy and adopts an automation system.

4. CONCLUSION

The main objective of developing a Smart Irrigation System based on IoT Architecture using ESP8266 is to facilitate farmers in the process of irrigating rice fields. The results show that the developed system can be used by users in the process of irrigating rice fields. Farmers obtain water level and humidity information by using the developed interface application. We hope that this new system will be used as a prototype of an IoT-based rice field irrigation automation system that automatically monitors the level of water level and humidity. The developed model is simple, efficient, and easy to implement. The model consists of 4 IoT layers, namely the smart things layer, which consists of an ESP8266 microcontroller, humidity sensor, water level sensor, then the network layer which uses a router to connect the Wi-Fi connection, then the middleware layer which uses the thingsboard application to manage the database, and the application layer as the system interface with the user. The researchers suggest conducting other experiments because each architecture has different characteristics, so there may be differences in performance when applied elsewhere. Future research can develop the ESP8266 microcontroller system as an IoT control with various sensors, so that the data needed for effective crop irrigation can be more accurate. The IoT system developed with the ESP8266 microcontroller can be applied to other types of irrigation, thus increasing the general applicability of the methods presented in this article.

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