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Development of Drip Irrigation Monitoring and Control System Model Based on the Internet of Things Using Android Applications

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Abstract—Background: Efficient water management is crucial for sustainable agriculture, particularly in regions with limited water resources. Drip irrigation systems, when integrated with the Internet of Things (IoT), offer a promising solution to optimize water usage and enhance agricultural productivity. **Objective:** This study aims to develop an IoT-based drip irrigation system to improve water efficiency and support small-scale farmers by providing a cost-effective and adaptable solution. **Methods:** The system employs multiple sensors to monitor key environmental parameters, including soil moisture, air temperature, and water levels in the tank. The collected data is transmitted to the ThingSpeak cloud platform via an Android application for real-time monitoring and control. Performance metrics such as sensor reaction time, solenoid valve response time, and pump response time were analyzed to evaluate system effectiveness. **Results:** Experimental findings show that the system effectively monitors and regulates irrigation, with an average sensor reaction time of 2.95 seconds, a solenoid valve response time of 2.75 seconds, and a pump response time of 2.3 seconds. The system successfully automates irrigation, ensuring optimal water usage. **Conclusion:** The IoT-based drip irrigation system enhances water resource management, increases crop yield, and reduces operational costs. While the system demonstrates high efficiency, further research could focus on scalability, integration with predictive analytics, and adaptation to different crop types and environmental conditions.

Keywords—Drip Irrigation System; Internet of Things; Android Aplication; ThingsPeak; Monitoring and Control

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I. INTRODUCTION

The development of Internet of Things (IoT) irrigation system technology enables farmers to solve the challenges related to agriculture and water management efficiently. By utilizing advanced sensor integration and network connectivity, farmers may accurately monitor crop and soil conditions and take necessary measures to optimize water usage [1]. Furthermore, employing this method actively promotes the cause of climate change. To mitigate the adverse effects on the environment and natural resources, farmers can modify their irrigation schedules based on accurate data on weather and soil conditions, connecting them with the specific requirements of their crops [2]. Therefore, the advancement of irrigation systems based on the Internet of Things (IoT) is focused on enhancing efficiency and promoting beneficial enhancements in agricultural output, reducing operational expenses, and protecting the environment[3]. Additionally, it aims to construct a more sustainable form of agriculture for the future. Furthermore, implementing an irrigation system based on the Internet of Things can help address concerns related to effectiveness and the control of water resources [4].

Several studies have been developed to manage and efficiently use water in irrigation systems. Research [5][6] has developed a decision-making system for water management in drip irrigation systems utilizing fuzzy logic technology integrated into IoT devices. Machine Learning technology [7][8], Deep learning [9], and Deep Reinforcement Learning (DRL) [10] were also developed to predict water needs and scheduling processes [11][12]. All the methods developed showed increased productivity and reduced water consumption compared to traditional methods. However, running an irrigation system with artificial intelligence requires a server that is fast in processing data for analysis to produce a decision. This process will impact the costs that need to be incurred; expensive costs make it difficult for small farmers to realize the implementation of the system. In addition, the dataset used to train the artificial intelligence system only uses data from one particular area, so it potentially cannot be used in other places with different conditions.

The issues described in the previous research, This research aims to develop a drip irrigation system utilising the Internet of Things (IoT). This inexpensive technology can be implemented in many agricultural settings. The drip irrigation technique was chosen for its ability to enhance water efficiency significantly [13]. Compared to conventional irrigation methods, it can potentially reduce water usage by 30% to 60% [14]. The Android applications used in this work are systems for monitoring and controlling drip irrigation conditions [15][16]. Furthermore, a microcontroller governs and acts as a channel for communication between sensors and applications. The Lolin ESP32 microcontroller is utilised [17][18]. Meanwhile, sensors are employed. These factors encompass soil moisture levels. The sensors analyze soil moisture

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levels, while the water pressure sensors track water pressure in irrigation channels [19][20][21]. Furthermore, the actuator comprises a solenoid valve [22] for regulating the water flow in the drip irrigation system and a relay [23][24][25] to turn on and off the water pump. The development of this irrigation system technology helps farmers, particularly small-scale farmers, to effectively manage water resources, enhance agricultural output, and decrease total operational expenses.

II. RESEARCH METHOD

The diagram above, Figure 1, shows the main stages in the development of an Internet of Things (IoT)-based irrigation system conducted in this research. The procedure comprises three primary stages: hardware and software requirements, system design, and system development, ending in an evaluation of the outcomes.

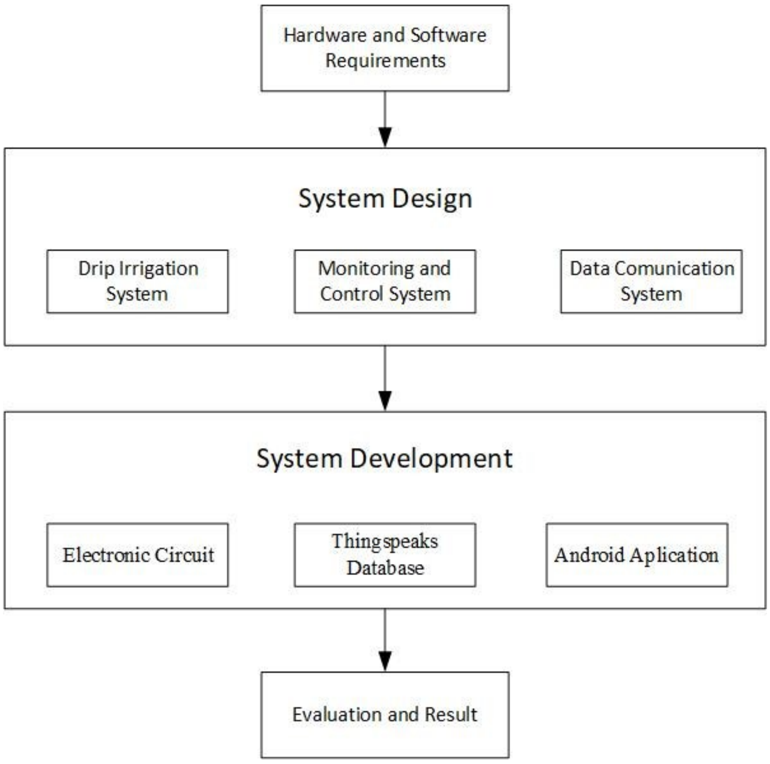

Fig 1. Research Stage

A. Hardware and software requirements

Hardware and software requirements for developing the system in this research are explained in the table 1 and 2 below.

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Table 1. Hardware Requirements

Hardware	Explanation
Lolin ESP 32	The microcontroller is responsible for storing temporary data sent by sensors before sending it to a database using wireless communication[26][27][28]. Apart from that, the microcontroller is also responsible for controlling the actuator.
YL 69	This is a sensor that functions to read soil moisture[29].
Selenoid Valve	functions as an automatic tap to connect and stop the flow of water in the irrigation system[30].
Water Pump	It is an actuator that functions to fill water into the tank.
DHT22	Sensors to monitor temperature conditions and the temperature of the surrounding area [23][31][32].
Relay	Switch to disconnect and connect the electric flow to the solenoid valve and pump.
Ultrasonis	Sensor that is responsible for measuring the availability of water in the water tank[33][34].

Table 2. Software Requirements

Software	Explanation
Arduino IDE	It is an open source text editor application used for programming microcontrollers (Lolin ESP32), the language used is C.
Thingspeaks	It is a cloud database platform that functions as real-time data storage generated by sensors.
VS code	It is a text editor used to create Android applications.

B. Drip Irrigation System

Figure 2 describes the design of the constructed drip irrigation distribution network. Water and fertilizer are stored in two reservoirs and distributed to multiple sub-areas or lateral pipes through the primary pipeline. Before the water enters the lateral pipe, there is a solenoid valve controlled by the system to regulate the opening and closing of the irrigation channel. There is also a water flow sensor that is tasked with calculating the volume and discharge of water that enters the irrigation flow so that users can estimate the water used in the irrigation process; in addition, there is an ultrasonic sensor that is tasked with monitoring and ensuring the availability of water in the storage tank, there is also a soil moisture sensor placed on agricultural land that functions to monitor and ensure the condition of soil moisture in normal conditions, there is also a DHT 22 sensor to monitor the temperature and humidity conditions around the irrigation area.

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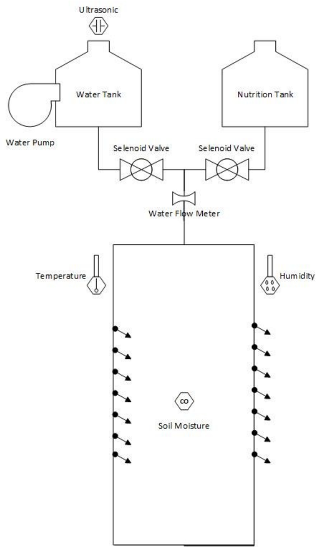

Fig 2. Design of Drip Irrigation System

C. Monitoring and Control System

Figure 3 shows the communication flow diagram of an Internet of Things drip irrigation system. This figure illustrates the interconnections of users, apps, databases, communications, controllers, sensors, and actuators. Below, we provide a detailed explanation of each component and the associated steps. (1) The user requests the Android application to monitor or control the drip irrigation system. The program offers the user data regarding the condition of the irrigation system and its immediate surroundings. (2) The Android app is a user interface that allows users to send requests to operate actuators (such as solenoid valves and water pumps) or get data. The application sends requests for environmental data to the database, including temperature, air humidity, soil moisture, water pressure in the tank, and irrigation system water flow. Once the application has retrieved data from the database, it presents the user with a report. In addition, the program issues control commands to the database for the solenoid valve and water pump. The database stores environmental data obtained from sensors, such as temperature, humidity, and other variables. The database retrieves the requested data in response to queries initiated by the Android application. In addition, the database receives control commands from the application and transmits them to the actuator communication components. The database receives sensor data, while the program sends commands to the controller via an internet connection. The database transmits sensor data and control commands to the controller through an internet connection. (5) The controller is responsible for utilising the analogue-to-digital converter (ADC)[27] to process the data received from the sensors. After processing the data, the controller returns a report to the database. In addition, the controller receives commands from the database to activate or deactivate the actuators, such as solenoid valves and water pumps and transmits these commands to the

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actuators. (6) The sensors collect data from the surrounding environment, such as air humidity, temperature, soil moisture, and other parameters linked to irrigation. The controller transmits the processed data to the database. (7) This arrangement's water pumps and solenoid valves are the actuators that control the drip irrigation system's water flow. The controller uses sensor data and user requests to transmit precise commands to the actuators, instructing them to activate or deactivate the solenoid valves and water pumps. (8) Drip irrigation system: The actuators ultimately apply control to this system. Activating the water pump and solenoid valve enables the drip irrigation system to supply water to the plants. This figure provides an overview of the sequential steps of an Internet of Things (IoT)--based drip irrigation system. Using an Android application, customers can monitor environmental conditions and control watering in real time using an integrated data processing and transmission system.

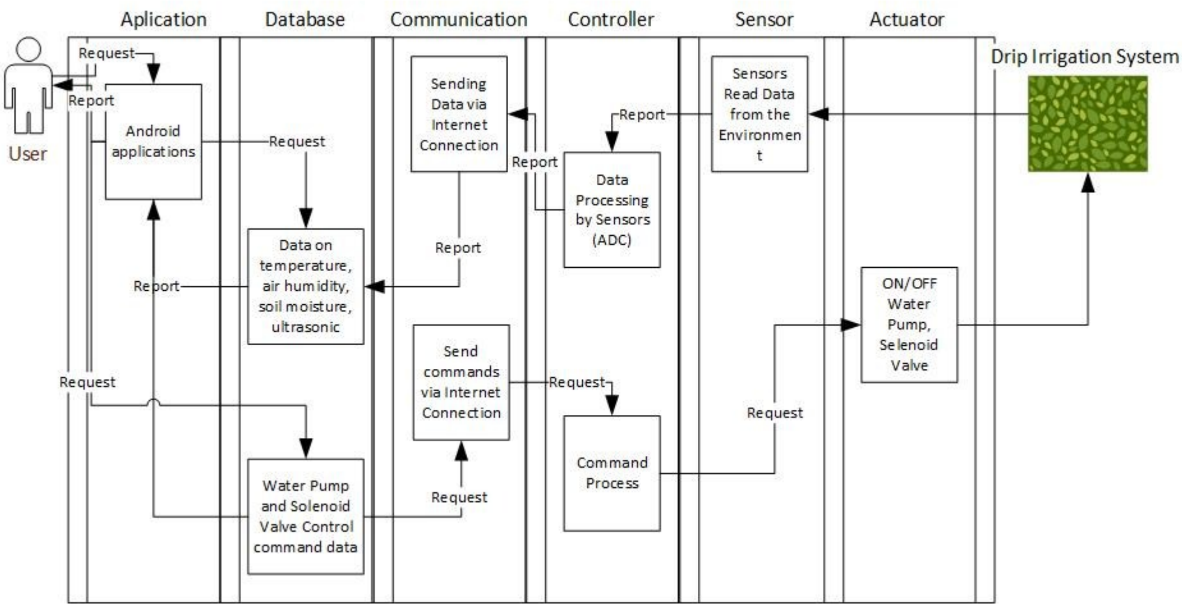

Fig 3. Drip Irrigation Monitoring and Control System Design

D. Data Communications System

Figure 4 shows the communication flow diagram of an Internet of Things drip irrigation system. This figure illustrates the interconnections of users, apps, databases, communications, controllers, sensors, and actuators. Below, we provide a detailed explanation of each component and the associated steps. (1) The user requests the Android application to monitor or control the drip irrigation system. The program offers the user data regarding the condition of the irrigation system and its immediate surroundings. (2) The Android app is a user interface that allows users to send requests to operate actuators (such as solenoid valves and water pumps) or get data. The application sends requests for environmental data to the database, including temperature, air humidity, soil moisture, water pressure in the tank, and irrigation system water flow. Once the

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Data supplied from connected devices is processed, stored, and analyzed using the cloud-based IoT platform ThingSpeak. This platform serves as a middleman between the Android application and IoT devices (ESP32 with sensors and actuators). ThingSpeak receives information gathered by the sensors and relays commands from the Android application. The ESP32 microcontroller is coupled to several sensors, including ultrasonic sensors, DHT22, soil moisture and sensors. Through the use of an internet connection, the ESP32 functions as a client to gather data from sensors and transmit it to ThingSpeak. The user can then access this data by using an Android application. The physical environment, including soil conditions, water pressure, temperature, humidity, and availability of water, is monitored by these sensors. Apart from the sensors, the ESP32 is also coupled to actuators, including water pumps and solenoid valves. These actuators are managed by commands from ThingSpeak, which the user can initiate through an Android application or by circumstances that the sensors detect. For instance, a command to turn on the water pump and irrigate the plants could be sent if it is found that the soil moisture content is low. There is no text provided. The diagram illustrates a distributed Internet of Things (IoT) system consisting of sensors and actuators that communicate through a cloud network called ThingSpeak. Additionally, the system uses an Android application as its user interface for monitoring and remote control purposes.

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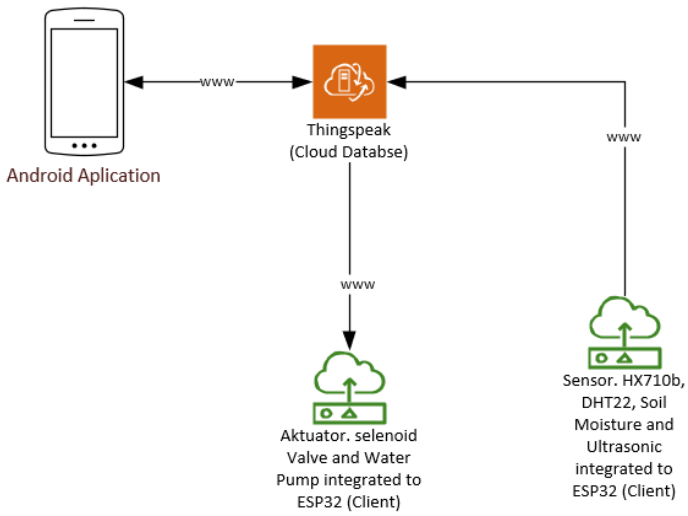

Fig 4. Data Communications System

III. RESULT AND DISCUSSION

A. Electronic Circuit

The electronic circuit utilized for the drip irrigation system's monitoring and control system is shown schematically in Figure 5. The circuit parts and their connections are explained as follows: (1) ESP32 microcontroller. The circuit's microcontroller, which is at its core, regulates and interprets data from various sensors and manages actuators like relays. Jumper cables are used to connect the ESP32 to a variety of sensors and actuators. (2) Sensor for Water Flow. Serves as a sensor for the lateral pipe's water flow rate. A data pin linked to the ESP32's digital input (GPIO 13) connects this sensor to the microcontroller. The ESP32's VCC pin serves as the source of electrical power needed by this sensor. (3) The ultrasonic sensor (HC-SR04) measures the tank's water level or distance. The ESP32 is linked to the four pins of this sensor—VCC, Trig, Echo, and GND- to measure distance. On the ESP32, the Triq pin is wired to GPIO 18, and the Echo pin to GPIO 19. (4) Soil Moisture Sensor: Irrigation requirements are calculated based on the data gathered from this sensor. This sensor is attached to the ESP32's analog pin GPIO 15 to read soil moisture readings. (5) Temperature and Humidity Sensor (DHT22): This sensor gauges the agricultural environment's temperature and humidity. The microcontroller is linked to three pins: GND, VCC, and data wired to GPIO 21. (6) Module for Relays. Three relay modules regulate the power flow to two solenoid valves and one pump, examples of external equipment. A signal from the microprocessor activates this relay, enabling automatic control of external equipment in response to situations that the sensor detects. (7) 12 volt, 2 amp power supply. The voltage required by the microcontroller and additional parts, like water pumps and solenoid valves, is

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supplied by this power source. A power cable directly connects the relay and extra parts for power distribution. (8) A cable for jumping. Positive voltage is supplied by the red cable (VCC). Ground is achieved by using the black cable (GND). The other colored connections carry the data signals between components and the microcontroller. These components provide a system that can be automatically monitored and controlled. The ESP32 microcontroller is connected to a sensor base, which informs the relay to activate or deactivate the actuator.

B. Android Application

Figure 6.a shows the Android application interface of the "Smart Drip Irrigation System (SDIS)," a drip irrigation system enabled by the Internet of Things (IoT). This application aims to actively monitor and regulate certain parameters associated with the drip irrigation system in real time. The subsequent text provides a detailed description of each component in the application display: (1) Water Supply: Indicates the reservoir capacity of water in the system, quantified in liters. The graphic depicts a quantity of 9 liters of water available for immediate consumption. (2) The air humidity indicator displays the air's relative humidity (RH) level in the monitored area. The atmospheric humidity in the photograph is measured to be 74%. (3) Air Temperature: Measures the ambient temperature near the irrigation zone. The recorded air temperature is 28.6°C, signaling the prevailing thermal conditions in the surroundings. (4) Soil Moisture: Indicates the soil moisture content, as measured in relative humidity (RH). The presented figure is 25%, which offers insights about the moisture levels in the soil. (5) Water Flow: Quantifies the velocity at which water moves through the drip irrigation system, denoted in milliliters per second (ml/s). The figure shows a recorded water flow rate of 0.0 ml/s, demonstrating the present absence of water flow in the system. (6) Volume: Displays the amount of water consumed or accessible in milliliters (ml). The indicated capacity is 1336.0 milliliters. (3) Device Set: This button enables users to configure the irrigation device according to their specific requirements. Users can execute additional configurations or adjustments to the system by activating this button. Figure 6.b illustrates the Android application interface used for managing the drip irrigation system. This display features two primary buttons that enable remote control of the hardware in the irrigation system. To activate or deactivate the water pump in the water tank, press button 1. To facilitate the opening and closing of the water channel in the drip irrigation system, press button

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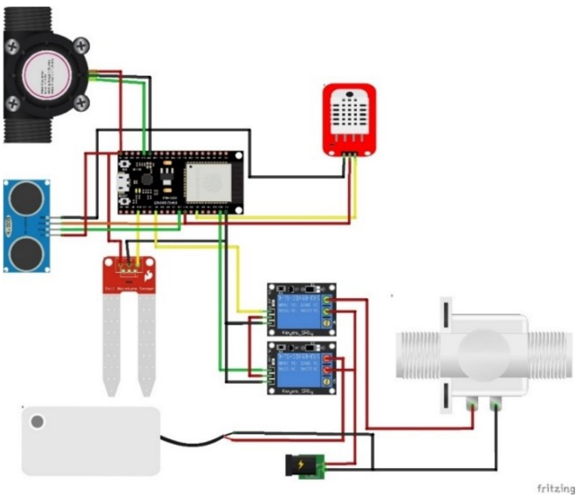
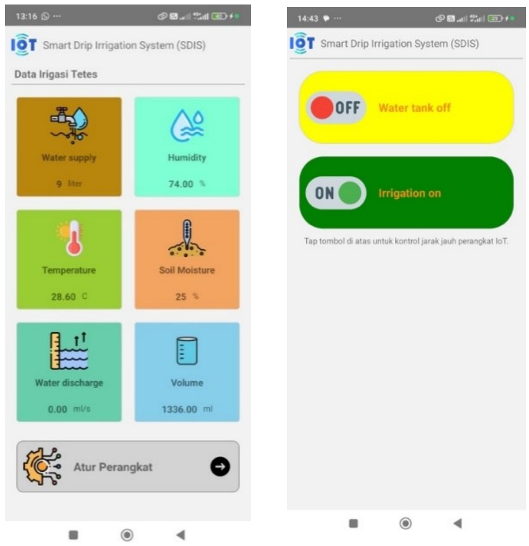


Fig 5. Electronic Circuit of Drip irrigation system



(a) (b)

Fig 6. Android Application

C. Thingspeak Database

The ThingSpeak platform presents comprehensive data on the operational parameters of the drip irrigation system, encompassing water availability, environmental factors (such as temperature and humidity), and system performance attributes (such as water output and volume). Real-time data monitoring enables users to control the irrigation system efficiently, assuring adequate plant water supply while minimizing resource wastage. Figure 7 illustrates a visual representation of multiple graphs on the ThingSpeak platform, which serves as a repository and monitoring system for real-time data from the drip irrigation system. Each graph corresponds to a distinct parameter being monitored by the system. Below is a detailed description of each graph: Water Supply: This graph displays the water supply statistics for the drip irrigation system, expressed in liters. The water supply was observed to have declined from approximately 11 liters to around 9 liters within the indicated period. Subsequently, the water supply reached a stable level of approximately 9 liters. The graph provided displays the air humidity, expressed as a percentage. The analysis indicates a decline in atmospheric humidity from approximately 77% to around 74% over the studied duration. Air Temperature: This graph illustrates the progressive rise in air temperature from around 27.8°C to around 28.6°C. This indicates a substantial variation in the local temperature within the given time frame. The presented graph displays soil moisture data expressed as a percentage. The dataset indicates oscillations in soil moisture ranging from approximately 26% to around 24%, with some little deviations across the studied time frame. Water flow: This graph displays the rate at which water flows through the drip irrigation system, quantified in milliliters per second (ml/s). The graph illustrates a conspicuous decline in water flow from around 0.6 ml/s to 0 ml/s, suggesting that the water flow has ceased during the

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measured time frame. The graph illustrates the available or used volume of water, quantified in milliliters (ml). The water volume rises from approximately 1000 ml to more than 1300 ml and then finds a steady state at that magnitude.

D. Appearance of the Drip Irrigation system prototype

Figure 9 shows a hardware circuit within a drip irrigation system with distinct primary components: The ESP32 serves as the central component in the circuit, acting as the system's central processing unit. It is responsible for managing and analyzing sensor data and regulating actuators. A 12 Volt adapter is employed to supply electrical power to the whole circuit assembly. The 12-volt voltage provided by the adapter is transformed into a voltage compatible with the other electrical components, particularly the ESP32, which necessitates a voltage of either 3.3V or 5V. The DHT22 sensor is utilized for the measurement of ambient temperature and humidity. YL-69 Sensor is a sensor designed to detect soil moisture. This sensor measures the moisture content in the soil and transmits its data to the ESP32 microcontroller. This data can be utilized to regulate soil moisture levels below a specified threshold. The 2 Channel Relay is an electronic switch that the ESP32 microcontroller may operate to regulate the pump and solenoid valve operation. The final gadget is an ultrasonic sensor designed to quantify the water storage capacity in the tank. Figure 10 shows the implementation of a drip irrigation system employed to water potted plants. The efficiency of this system lies in its direct delivery of water to the plant roots via emitters, therefore minimizing water wastage and optimally supplying the plants with the required amount of water. This approach is appropriate for small-scale agriculture, particularly in landscapes with restricted water resources. Furthermore, the system is completely operational through microcontrollers and sensors, enabling irrigation to be executed automatically with remote instructions, depending upon the soil or weather conditions identified by the sensors.

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Fig 7. ThingSpeak Database

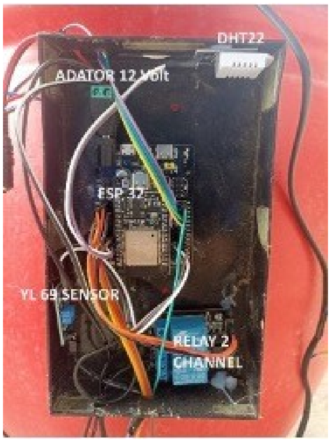

Fig 8. ESP32 microcontroller and sensor devices

Fig 9. Model of Drip Irrigation System

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E. Responsibility of inter-device communication

The investigation aims to evaluate the communication responsibilities between the Android application and the ESP32 microcontroller. 30Mbps bandwidth internet connection is utilized to facilitate communication between devices. The findings of this research are speed test of sensor data updates are presented in Table 3. The evaluation of 20 tests shows that the average data update time is 2.95 seconds. The average duration for testing the speed of the ON/OFF command on the solenoid valve and water pump is 2.75 seconds for the solenoid valve and 2.3 seconds for the water pump. The details of these results may be seen in Table 4. The estimated cost for system development is relatively cheap and within budget. The acquisition of tools such as a microcontroller and actuator sensor amounts to IDR 257,500. The development of a basic android application consisting of only three pages results in an approximate cost of IDR 300,000 when liquidated. The aggregate expenditure required for a single product amounts to IDR 557,500. With the acquisition of a monthly internet quota of IDR 25,000, this system exclusively transmits numerical data that will not significantly consume the available internet limit.

Table 3. Sensor Data Update

Testing	Times/Second
1	4
2	5
3	2
4	1
5	3
6	3
7	2
8	2
9	1
10	3
11	3
12	2
13	5
14	5
15	4
16	4
17	3
18	2
19	2
20	3
Average	2.95

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Table 4. Turn ON/OFF Actuator

Testing	Solenoid Valve	Water Pump
	Times/Second	
1	4	5
2	4	2
3	2	1
4	1	2
5	3	3
6	3	3
7	2	2
8	2	2
9	1	2
10	3	1
11	3	1
12	2	2
13	4	3
14	4	3
15	3	2
16	4	2
17	3	3
18	2	2
19	2	2
20	3	3
Average	2.75	2.3

IV. CONCLUSION

In this research, an Internet of Things (IoT)-based drip irrigation system was developed to improve water use efficiency and optimise agricultural productivity. This system is designed to be implemented in various agricultural environments at a lower cost, making it suitable for use by small farmers. In this research, the developed drip irrigation system uses multiple sensors to monitor soil and environmental conditions, such as soil moisture, air temperature, and water availability in the tank. Data obtained from these sensors is sent to the ThingSpeak cloud platform, which is then accessed by an Android application for monitoring and control. The test results show that this system can accurately monitor and control the irrigation process with a fast response time of 2.95 seconds on average for sensors, 2.75 for solenoid valves, and 2.3 for pumps. This is expected to help farmers manage water resources more efficiently, increase crop yields, and reduce operational costs. Overall, developing this IoT-based irrigation system offers an effective solution to water management challenges in agriculture, especially in areas with limited water resources.

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Several further works in this research including using additional sensors to measure water quality, which can also help ensure that the water used is safe for plants. The system needs to be designed to be more easily adopted by various agricultural scales, including larger land areas and environments with different weather conditions. Developing a more energy-efficient system using solar panels or more efficient batteries can reduce operational costs and increase system sustainability, especially in hard-to-reach areas. Since this system is IoT-based, improving security protocols to protect the data collected and transmitted is important. Using stronger data encryption and user authentication will help protect the integrity and privacy of the data. The user interface on the Android application can be further developed to provide more in-depth data analysis and clearer suggestions to users based on the data collected. This will make it easier for farmers to make decisions regarding irrigation. Integrating the system with a wider communication network, such as 5G technology, can increase the speed and reliability of data transfer, especially in remote rural areas.

Author Contributions: *Miftahul Walid*: Conceptualization, Methodology, Writing - Original Draft, Writing - Review & Editing, Supervision. *Hoiriyah*: Investigation, Writing - Original Draft. *Rofiuddin*: Software, System, Design. *Purnomo Hadi Susilo* : Curation Data. *Muhammad Hasan Wahyudi* : Literatur Review.

All authors have read and agreed to the published version of the manuscript.

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Data Availability: You can contact the authors if you are interested in this research.

Informed Consent: There were no human subjects.

Animal Subjects: There were no animal subjects.

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