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Online ISSN : 2776-3374
Print ISSN : 2776-3102

JURNAL KONSTELASI

Konvergensi Teknologi dan Sistem Informasi

KONSTELASI

Special Issue
Seminar Konstelasi Bali 2026

Editorial Team

Information

Vol. 101 No. 101 (2026): Special Issue Seminar Konstelasi Bali

Published: 08-03-2026

Articles

Information

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KONSTELASI: Konvergensi Teknologi dan Sistem Informasi

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Online ISSN: 2776-3374 | Print ISSN : 2776-3102

Data Transmission Performance on IoT Based Monitoring System of Soil Acidity and Moisture Levels in Chili Plantation

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Abstract. IoT technology is a development of automation technology that is very helpful in agriculture in maintaining plant health efficiently. It helps farmer in crop monitoring, livestock tracking, weather monitoring, automated irrigation, precision steering, greenhouse automation, and field mapping, remotely via Internet connection. This study will evaluate data transmission performance of IoT technology that is applied in agricultural, especially in chili plantation. The result of this study is that data error performance is acceptable as more than 98% data can be received with no error and the delay performance is more than 2,5 seconds and need to be improved.

Keywords: IoT, Data Transmission, Soil Acidity, Soil Moisture, Chili Plantation.

1. Introduction

Automation technology in agriculture is very helpful in maintaining plant health efficiently. Further development of automation technology in agriculture involves IoT technology. Smart irrigation system ensures that the plants stay healthy using efficient automatic watering methods [1]. System also prevents overwatering, so that it will save water usage. Artificial Intelligence (AI) and Robotic Process Automation (RPA) will enhance automation capabilities of IoT based technologies for monitoring the crop field [2]. Controlling all of these operations will be through raspberry pi. IoT technologies also offer significant advantages in enhancing agricultural practices [3]. It helps farmer in crop monitoring, livestock tracking, weather monitoring, automated irrigation, precision steering, greenhouse automation, and field mapping.

Implementation of IoT technology in agriculture is expanding in the greenhouse and urban farming sector. Smart greenhouse monitoring and control system can monitor and control the micro climate for optimal plant growth [4]. This system can be adapted to various greenhouse sizes and plant needs. IoT technology in urban agriculture practices enable efficient and sustainable food production in urban areas [5]. The model can be implemented using a rooftop garden as a platform for growing vegetables and fruits. This innovative solution of urban farming aims to answer food security challenges and promote sustainable agriculture practices. While smart farming offers significant benefits, this IoT technology implementation has some challenges, such as high investment costs, data management, technical expertise, data security and privacy concerns, and connectivity issues in remote agricultural areas [6].

Many studies in IoT technology for smart farming, especially in the chili plantation sector, have been done to increase productivity and resource efficiency. Soil fertility measurement and mapping are used to improve irrigation efficiency [7]. Soil fertility is the main factor in cultivating chili peppers. The study has been conducted by combining soil moisture sensors, temperature sensors, and location sensors. Simple IoT technology for chili farming has been proposed for improving agriculture yield by designing of an affordable irrigation and fertilization system [8]. Fertilization system spreads fertilizers to the root directly, so that it reduces the amount of fertilizers required and cost.

IoT-based monitoring system that is designed to control temperature and soil moisture on small scale chili plants has been proposed to increase irrigation efficiency [9]. A study has been done to propose monitoring and control tools for watering chili plants remotely using Blynk Application on Android smartphone [10]. Moreover, web based monitoring data from IoT supported chili farm has been proposed to monitor microclimate that is suitable for chili growth [11].

Some studies try to increase the accuracy of data transmitted from IoT devices to IoT platform and help the system to accurately decide on how the actuators react or classify the data from sensor by using artificial intelligence embedded in the system. The study aims to specify chili plants diseases and determined which soil is optimal for chili cultivation has been done using Convolutional Neural Network [12]. Unfavorable climatic conditions often affect the chili plants growth. Applying a drip irrigation system can contribute to overcome this problem [13]. In this study, fuzzy logic is used to provide appropriate decisions on air temperature, humidity, and soil moisture data in chili and expected to overcome the problem of water shortages due to climatic condition. Another research underscores the importance of adopting modern agricultural techniques, including drip irrigation integrated with IoT devices and machine learning-based predictive models, for enhancing chili yield growth [14].

From the above description, it is clear that most of previous studies related to the use of IoT technology in chili farming aims to increase productivity with efficient irrigation and fertilization as well as accurate disease detection with the help of machine learning and fuzzy logic. The performance of data transmission from sensors to IoT platforms has been discussed only in [11], especially in the application of IoT technology in chili farming fields. This study will evaluate data transmission performance on IoT based monitoring system in chili plantation. The data used in this study is soil acidity and moisture data that are transmitted from IoT device to the server of IoT platform. The aim of this study is to have better understanding on the data transmission performance in IoT system, so that for the next work, we can optimize the transmission speed and accuracy of received data at the server end.

2. System Model

2.1. Block Diagram

The system consists of four parts; sensors, processing unit, actuators, and IoT platform in the clouds. Block diagram of the system is depicted in figure 1.

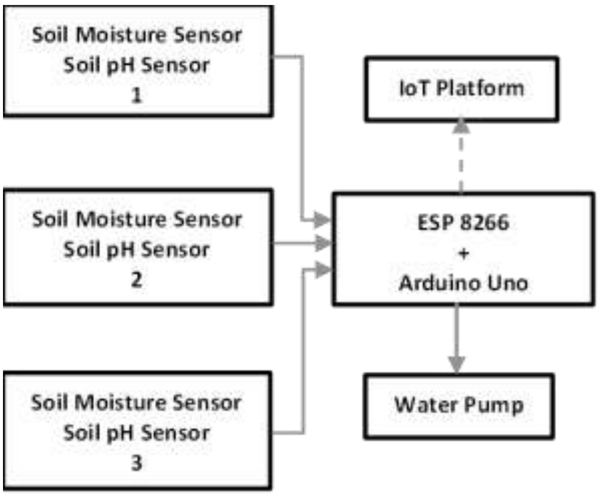

Figure 1. Block diagram of the system

There are three sensor distribution points. These three sensor points are spread across a 25 square meter chili plot (2,5 meters wide x 10 meters long). These three points are located every 2.5 meters in the center of the plot. The location of the chili field is in the yard of a house in a rural area with a Wi-Fi access point approximately 15 meters from the IoT device.

Each of sensor point consists of two sensors, soil moisture sensor and soil pH (acidity) sensor. This study used ceramic sensor with resistance principle (YL-69) as soil moisture sensor [15]. This type of sensor is used in most of previous studies. Soil pH sensor (MZ143) that was used in this study is electrochemical sensors using conductometric system [16]. This type of sensor is a generic soil pH sensor that is used in most of previous studies. This study uses the same sensor as previous studies because with different sensors, there is no information regarding the sensor specifications related to the parameters to be measured in this study, such as sensor response time.

The three numbers at the bottom of each sensor block indicate that the sensors are placed at three different points in one small agricultural land location for modelling the system. Processing unit uses Arduino Uno as the main controller and ESP 8266 as internet connectivity unit. Actuator that is used in this study, to neutralize soil moisture and acidity, is water pump. All the data that are gathered from sensors and processed in Arduino Uno are transmitted via internet to IoT platform server using Wi-Fi connectivity provided by ESP 8266. ESP8266 was chosen over other microcontroller, such as ESP32 because it is more affordable, suitable for simple projects, has lower power consumption in normal mode, and is easier to program using the Arduino IDE.

2.2. Testing Points

Transmitted data is taken from the serial monitor from ESP 8266 output point, while received data is taken from the IoT platform side. The direction of data transmission from IoT devices to IoT platform can be depicted in figure 2. Communication protocol that is used in this study is Message Queuing Telemetry Transport (MQTT) on the application layer and use Wi-Fi instead of Bluetooth, LoRaWAN, NB-IoT and other protocol. This kind of protocol has not been much elaborated and discussed in the previous studies, even in [11].

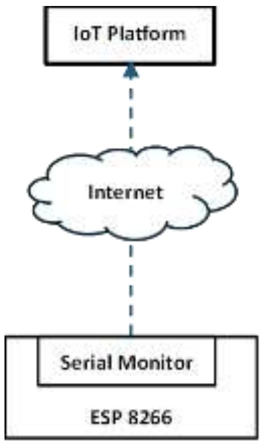

Figure 2. The direction of data transmission.

2.3. Data Collection Design

The data that are used in this study are sensor data that has been processed by Arduino Uno, which are soil moisture sensor and soil acidity sensor data from three different points. Data were taken three sampling times a day, that were in the morning, afternoon and evening. At each sampling time, data were taken 10 times and then averaged for further processing.

In the morning, data were taken at 08.00 – 09.00 AM, while in the afternoon, data were taken at 12.00 – 01.00 PM. Data were also taken at 04.00 – 05.00 PM in the evening. Soil moisture sensor data were taken on a different day from soil acidity sensor data.

There are two types of data transmission performance that are retrieved in this study, namely average data error and average transmission delay. The data error is calculated from the difference between the value of the data received by the IoT platform (r_x) and the data transmitted from ESP 8266 (t_x), divided by the value of data transmitted multiplied by 100%, as in:

$$data\ error = (r_x - t_x)/t_x \times 100\% \quad (1)$$

Transmission delay is calculated from the time the data is received on the IoT platform (T_r) subtracted by the time the data is transmitted from the ESP 8266 (T_t), as in (2). The summary of data collection design is tabulated in table 1 and table 2.

$$transmission\ delay = Tr - Tt\ \text{(s)} \quad (2)$$

Tabel 1. Data Collection Design for Data Error Rate

Placement Point	Data Error
1	Average of 10 data collection
2	Average of 10 data collection
3	Average of 10 data collection
Overall error average	Average of all 30 data

Table 2. Data Collection Design for Transmission Delay

Placement Point	Delay
1	Average of 10 data collection
2	Average of 10 data collection
3	Average of 10 data collection
Overall delay average	Average of all 30 data

3. Result and Discussion

An example of the raw data results from measuring data error can be seen in table 3 and an example of the raw data results from measuring transmission delay can be seen in table 4. Data in table 3 meets equation (1) and can be used to fill table 1. Table 3 shows soil acidity (pH) level that were measured from soil acidity sensor. Data in table 4 meets equation (2) and can be used to fill table 2.

Table 3. Example of Raw Data of Data Error

No	Data transmitted	Data received	Data Error
1	5,5	5,5	0,00%
2	5,21	5,25	0,77%
3	5,56	5,56	0,00%
4	4,55	4,55	0,00%
5	4,12	4,15	0,73%
6	5,05	5,2	2,97%
7	5,07	5,07	0,00%
8	5,12	5,12	0,00%
9	5,12	5,12	0,00%
10	5,23	5,3	1,34%
		Average	0,58%

Tabel 4. Example of Raw Data of Transmission Delay

No	Transmitted time	Received time	Delay (s)
1	08:15:10	08:15:12	2
2	08:15:12	08:15:13	1
3	08:15:14	08:15:15	1
4	08:15:16	08:15:17	1
5	08:15:17	08:15:19	2
6	08:15:19	08:15:20	1
7	08:15:20	08:15:22	2
8	08:15:22	08:15:24	2
9	08:15:24	08:15:26	2
10	08:15:26	08:15:28	2
		Average	1,6

3.1. Average Data Error

Average data error taken from soil acidity sensor can be seen in table 5 and figure 3. After averaging all the data from three sampling times, the minimum average data error is 0,22% and the maximum average data error is 0,86%. This error value is still acceptable, considering that maximum error is under 1%. Most of the data can be received with no difference value from transmitted data.

Figure 3 shows that maximum average data error occurs in the afternoon. Maximum data errors occur during the afternoon time due to increased network activity and user density in the same bandwidth of the same network. This leads to more interference, data collisions, and a high load on the network infrastructure, thus degrading signal quality and increasing the data errors. Conversely, evening conditions are better for data transmission due to lower activity and less interference.

There was only one internet provider in the test area, so there was small possibility of interference from other Wi-Fi signals. The RSSI indicated that the signal strength received from the access point was still very high, considering the distance between the IoT system and the access point was only 15 meters. This suggests that information distortion occurs due to transmission issues from the access point to the internet network to the server and vice versa.

Table 5. Average of Soil Acidity Data Error

Placement point	Morning	Afternoon	Evening
1	0,20%	0,86%	0,00%
2	0,58%	0,86%	0,65%
3	0,78%	0,86%	0,00%
Average	0,52%	0,86%	0,22%

Average data error taken from soil moisture sensor can be seen in table 6 and figure 4. After averaging all the data from three sampling times, the minimum average data error is 0,79% and the maximum average data error is 1,97%. This error value much higher than average data errors from soil acidity sensor. However, most of the data, more than 98% data still can be received with no difference value from transmitted data and this is still acceptable.

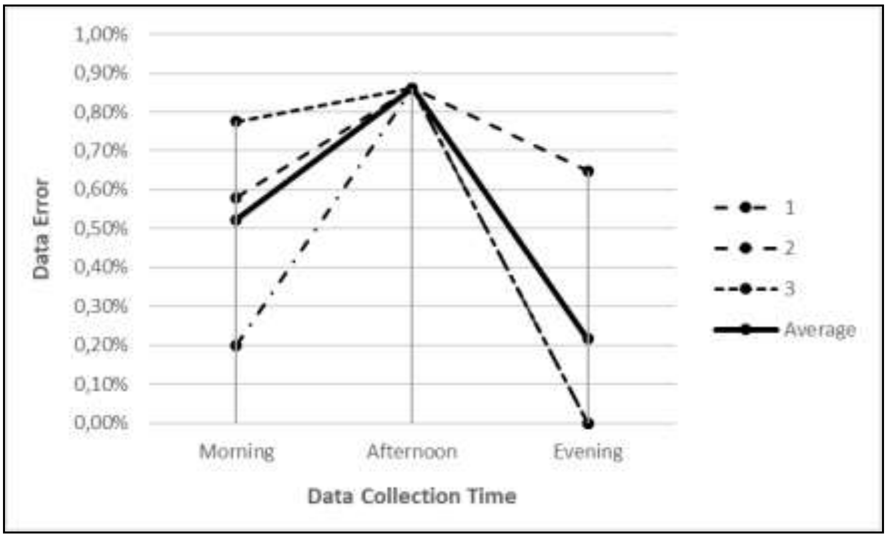

Figure 3. The trend of data error of soil acidity level.

Table 6. Average of Soil Moisture Data Error

Placement point	Morning	Afternoon	Evening
1	1,22%	2,33%	0,00%
2	1,20%	2,41%	1,18%
3	1,16%	1,16%	0,00%
Average	1,20%	1,97%	0,79%

Figure 4 shows the same trend with Figure 3. Maximum average data error occurs in the afternoon, while minimum average data errors occur in the evening. The same reason as in soil acidity can be used to elaborate these errors; increased network activity and user density that degrading signal quality.

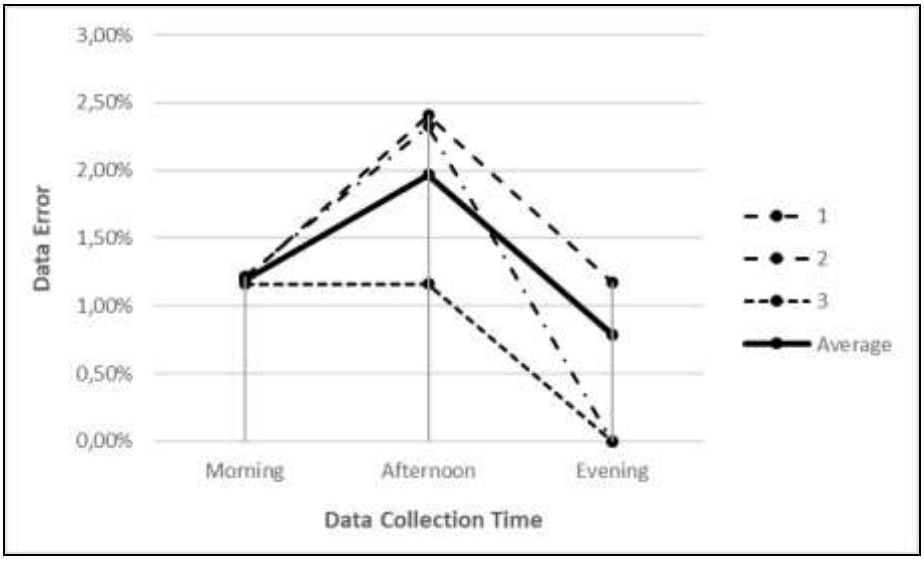

Figure 4. The trend of data error of soil moisture level.

3.2. Transmission Delay

This section will discuss second performance parameter of this study, that is transmission delay. The average of transmission delay for soil acidity sensor data can be seen in table 7, while the trend during three data collection times can be seen in figure 5. After averaging all the data from three sampling times, the minimum transmission delay is 2 seconds and the maximum transmission delay is 2,67 seconds. This delay value is high enough to make the transmission time slot is not synchronized and increasing the data error. This delay is not acceptable because it is the result of calculating all the data. This means that some data has a delay of more than 2,67 seconds. The theoretical model of delay for Edge Sensor Network (ESN) model with the lightest load is about 1 second, while for Wireless Mesh Sensor Networks (WMSN) model it is about 2 seconds [17].

Like figure 3 and figure 4, figure 5 also has the same trend, that is the maximum average transmission delay occurs in the afternoon. Long transmission delays in the afternoon occurs due to increased user numbers and network activity, which causes congestion on network infrastructure, such as cables or routers. This slows data transfer because there are many data requests that must be processed simultaneously. Conversely, evening conditions are better for data transmission due to lower user numbers and network activity.

Tabel 7. Average of Soil Acidity Data Transmission Delay

Placement point	Morning (s)	Afternoon (s)	Evening (s)
1	1,6	2,5	2,5
2	2,3	2,8	2,1
3	2,1	2,7	2,7
Average	2,00	2,67	2,43

The average of transmission delay for soil moisture sensor data can be seen in table 8, while the trend during three data collection times can be seen in figure 6. The same delay performance occurs as in soil acidity sensor data. Average delay is more than 2 seconds, which is quite high and not acceptable.

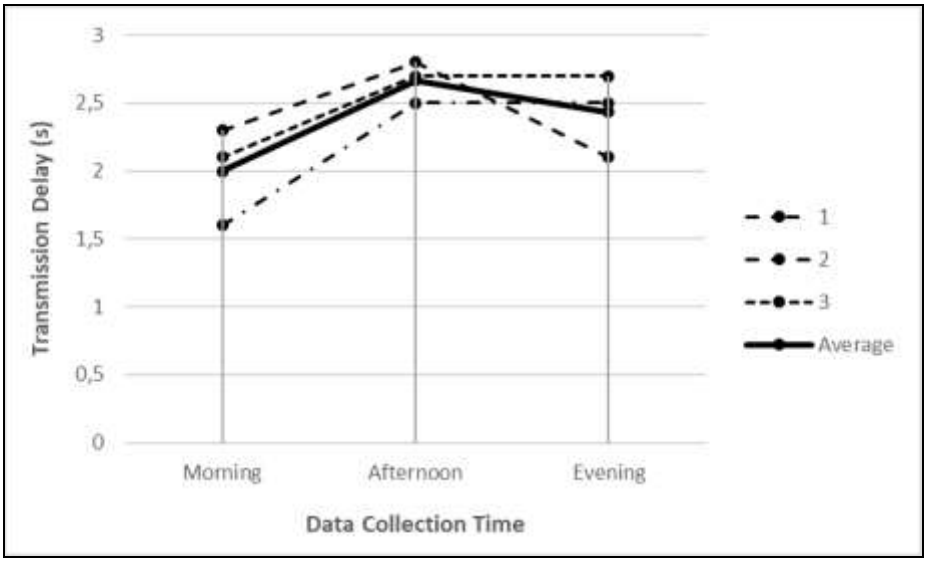

Figure 5. The trend of transmission delay of soil acidity data.

The same trend of transmission delay also occurs for this soil moisture sensor as all previous trend, that is the maximum average transmission delay occurs in the afternoon, while minimum average transmission delay occurs in the evening. The same reason as in soil acidity can be used to elaborate this delay.

Table 8. Average of Soil Moisture Data Transmission Delay

Placement point	Morning (s)	Afternoon (s)	Evening (s)
1	2	2,4	2
2	2,1	2,5	2,5
3	2,3	2,4	2,1
Average	2,13	2,43	2,20

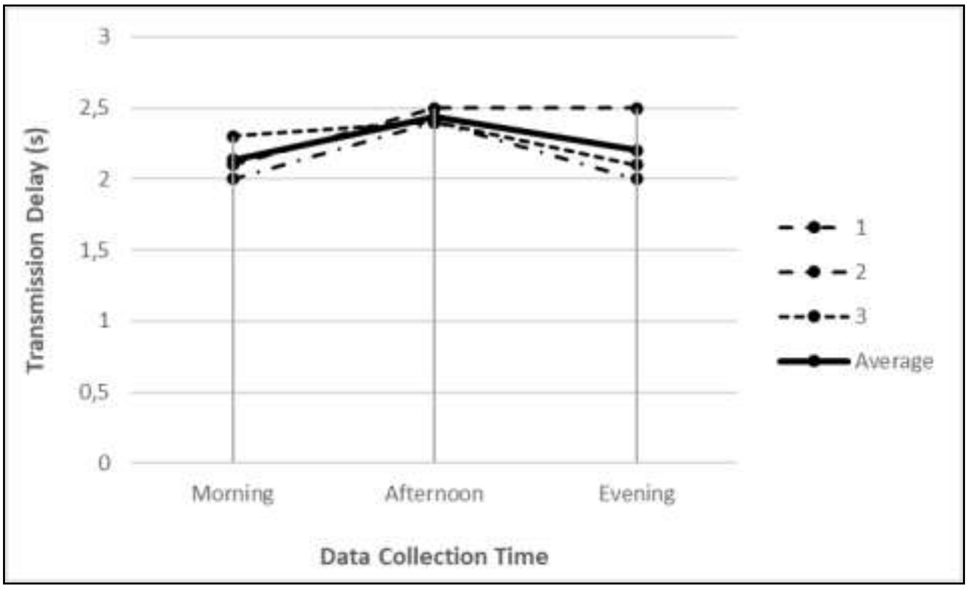

Figure 6. The trend of transmission delay of soil moisture data.

4. Conclusion

The performance of data transmission in the IoT system for chili plantation has been evaluated using soil acidity sensor data and soil moisture sensor data. The result of this study is that data error performance is acceptable as more than 98% data can be received with no error. However, the delay performance of this system is not good as maximum value of transmission delay is more than 2,5 seconds in the afternoon. Data transmission performance still needs to be improved by increasing component scalability and service coverage. Furthermore, using higher-quality and more powerful components is also possible. Comparing various protocols is also necessary to determine which protocol is most suitable for improving performance, particularly delay.

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