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Implementation and analysis of hybrid communication for monitoring and control for android-based smart farming

Moh. Abdullah Anshori, Septriandi Wirayoga*, Hadiwiyatno, Sri Wahyuni Dali

*Faculty of Electrical Engineering, State Polytechnic of Malang, Indonesian

* 🖂 yoga.septriandi@polinema.ac.id

ABSTRAK

Farmers are forced to water each crop individually or wait to switch off the water pump. To avoid this, water management needs to be optimized—that is, it needs to be done on schedule, in the appropriate quantity, and throughout a wide area in an effective manner. That is hybrid communication between online and offline communication. To run this system will use 3 nodes, for details 1 node in the irrigation section, 1 node in the monitoring section of land and soil quality, and 1 node in the section to control data or can be said to be a semi-server to give commands to 2 nodes offline. To see if the system still communicates with each other and runs according to the block diagram that has been designed, an Android application will be made to monitor the system. Where if there is a failed data update or data change in the results of the automation system, a notification will come out to check the system as a whole. To support this research, several sensor calibrations were carried out which resulted in an average accuracy level above 90 percent. For the overall system test, 10 experiments were carried out at different times to see the reliability of the system.

Keywords: WSN; microcontroller; farm; IOT; hybrid

1. INTRODUCTION

In Indonesia, agriculture/plantations are the main source of food. In agriculture/plantations, water is one of the most important components to fulfill the needs of plants [1]. The arrangement of the distribution or flow of water according to a certain system in the garden/plantation land is called irrigation. The need for water in each land varies depending on the size of the land and the condition of the land, whether it is dry, semi-arid, humid, or wet. This condition affects the water required for irrigation of the land. In addition, the technology is still done manually and requires a lot of time just to irrigate the plants, making it ineffective. For example, farmers have to wait to switch off the water pump or water the fields one by one. To get around this, water management must be optimized, namely on time, in the right amount, and on target, and also cover a large area so that it is efficient [2].

As for research related to applications to open and close floodgates automatically that have previously been carried out, the study described the telemonitoring of automatic irrigation floodgates [3], but in the study, the interface used is a web where the web must be accessed via a PC or laptop where the tool can be said to be less effective. Due to the use of a PC or Laptop itself, not all users have a laptop or PC, to access it also requires space. There is also previous research on technology-based garden watering automation but only uses one device which is constrained by the use of the internet when the tool is moved [4].

Therefore, this research proposes a system that can automatically regulate water for citrus orchards based on soil nutrient needs and the time required using 2 communications in the system. The system model is hybrid communication [5] which is between online and offline communication. At the irrigation end of the citrus garden, there is also a node that functions as a bridge connecting the other 2 nodes. To run this system will use 3 nodes [6], for details 1 node in the irrigation section, the 1st node in the monitoring section of land and soil quality [7], and the 2nd node in the near section to control data or can be said to be a semi server to give commands to 2 nodes offline [8]. While the 3rd node will receive commands from the 2nd node to perform watering by turning on the pump [9]. To see if the system still communicates with each other and runs according to the block diagram that has been designed, an Android application will be made to monitor the system. Where if there is a failed data update or data change in the results of the automation system, a notification will come out to check the system as a whole [10].

2. METHOD

In the research that has been made, it uses several stages of work so that it can produce an appropriate system. The stages themselves are described in Figure 1.

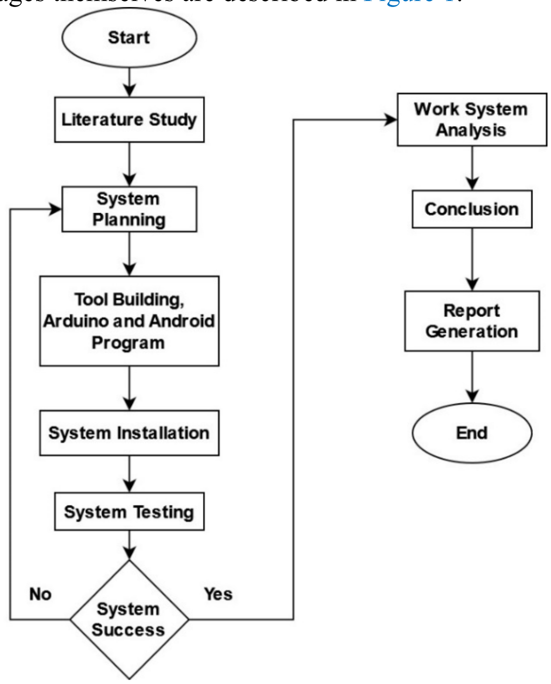

Figure 1. Research Step

The picture on above explains several stages such as a literature study about the system and then proceeding with system planning. After the system is planned, there will be a process of making the system and evaluating the performance of the system. In planning the system, device search and calibration [11] will be carried out before it is made into a whole system. For the calibration process, a sample test of the land used and the placement of the land will be shown in Figure 2. The system as a whole will be shown in Figure 3. Where this figure describes the device used in each node.

Figure 2. Place experiment test

Where node 1 contains the watering system, node contains the monitoring system, and node 3 contains the server system. Figure 3 is a block diagram of the system used to complete this research.

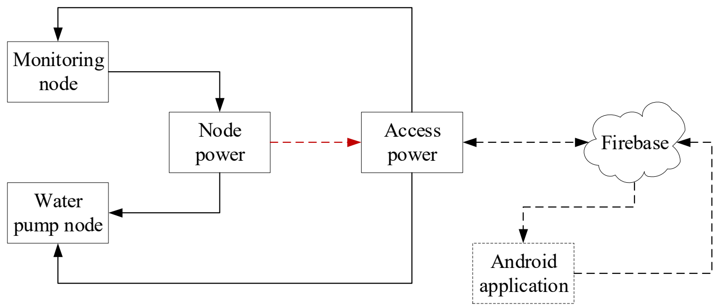

Figure 3. Block system diagram

Figure 4 is the content of the watering node where there is a microcontroller that functions to regulate the relays connected to pump A and pump B. This research uses 2 pumps because for watering citrus land has 2 kinds of water content in watering. The microcontroller is connected to NRF24L01+ to receive information from the server node to water or not. Figure 5 is the content of the monitoring node where there is a microcontroller connected to a sensor that can determine the quality and condition of the soil. The reading results by this sensor will be sent to the server node as a reference to give watering commands to the watering node. Figure 6 is the content of the server node where there is a microcontroller connected to NRF24L01+ as a server giving commands to the watering node and receiving data from the sending node. The system that runs automatically here will be directly seen in the application that will be used to monitor and control. The application can be accessed from an Android cellphone connected to the internet [12]. So that the system when receiving data that the land value drops but the status does not water it will be given a command remotely using the application created.

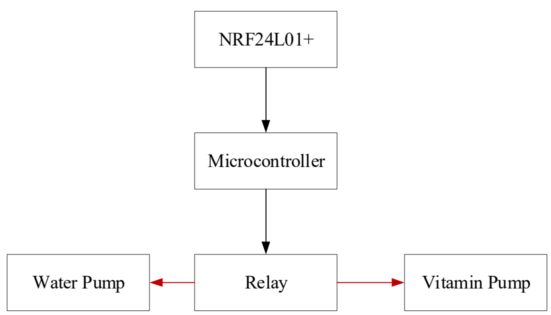

Figure 4. Water pump node

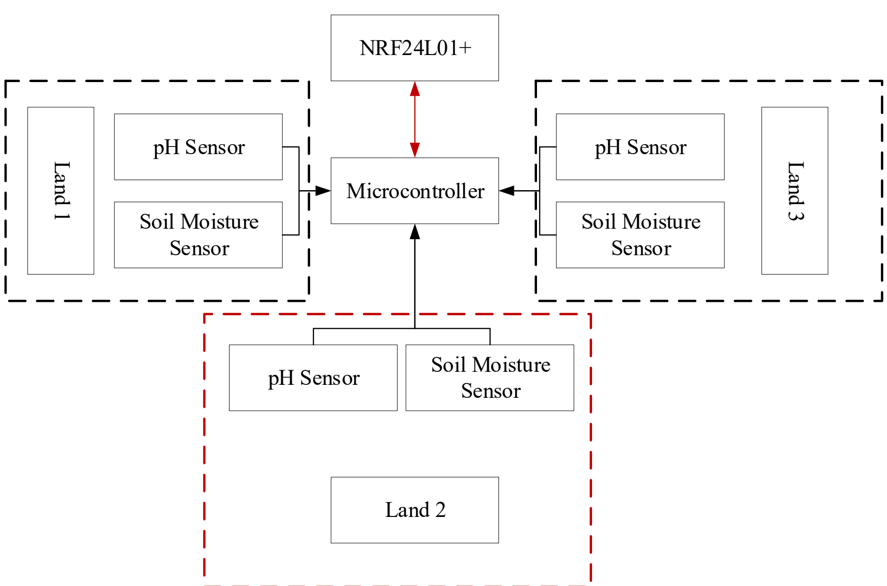

Figure 5. Monitoring node

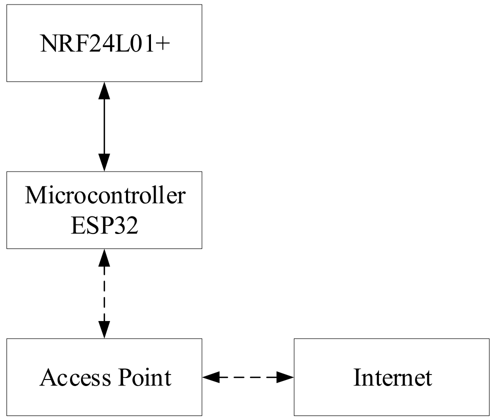

Figure 6. Node server

3. RESULT AND DISCUSSION

This section will explain the results of the research which consists of 3 sub-sections. First is the display of the hardware used, and second is the display of the software that has been made. Third is the result of calibration and overall system testing.

Hardware implementation photo

Figure 7 is a node for the monitoring process which contains 3 soil pH sensors, 3 Soil Moisture Sensors, 1 NRF24L01+, and 1 ESP Microcontroller with its board. The soil pH sensor is used to measure soil pH levels. Soil Moisture Sensor to measure soil moisture in percent, NRF24L01+ to send or communicate data with the server, while the ESP Microcontroller is the brain in this node.

Figure 7. Monitoring Node

Figure 8 shows the node for the watering process, where in this node there are 2 pumps, 1 2-channel relay, 1 NRF24l01+, and 1 ESP Microcontroller with its board. The pumps will be activated and deactivated using relays connected to the ESP Microcontroller as needed.

Figure 8. Monitoring node

The next displays Figure 9, namely 1 ESP Microcontroller and 1 NRF24L01 + which functions to connect the server node with the monitoring node and water pump node.

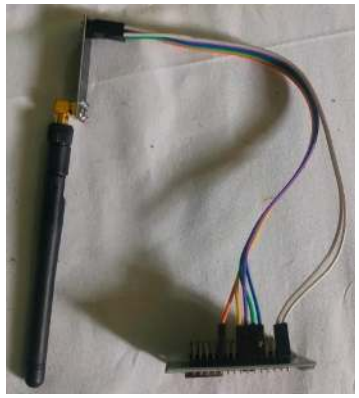

Figure 9. Server Node

Android Application

Figure 10 shows the application that has been made. Where there are 2 displays here, namely the usual monitoring display and the display when there is a watering process. The flush button function is used to force watering if the humidity continues to fall below the specified threshold.

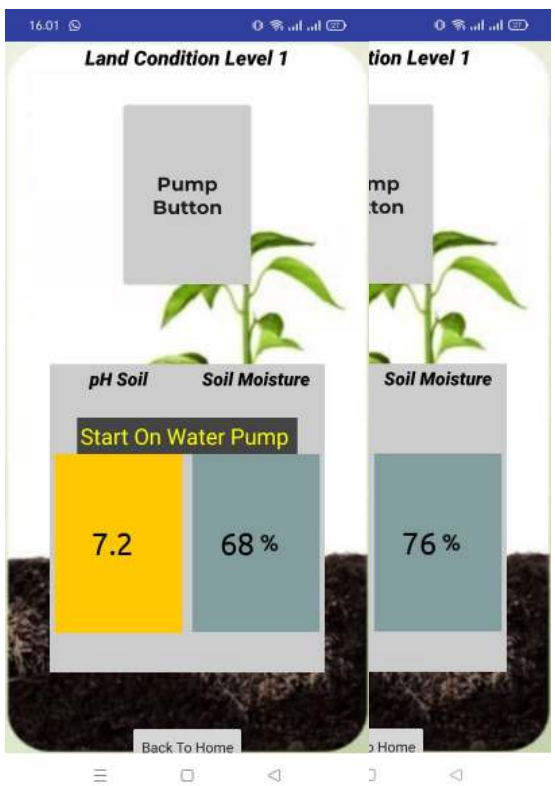

Figure 10. Application android

Sensor calibration test

The soil pH sensor, moisture sensor, and NRF Test Network for Offline Communication were calibrated as a consequence of the sensor testing. After calibration, the results are utilized to make sure the sensors have a high level of accuracy. The first step is config sensor data reading [13]. Table 1 provides an analysis of the soil pH sensor's performance. The table indicates that the sensor is suitable for use in various applications. This conclusion is drawn from a comparison with a standard pH meter. The results of this comparison show that the sensor's readings have a margin of error between 1.52% and 1.64%. This relatively small range of error highlights the sensor's precision. In addition to the range of error, the table also presents the average error recorded by the sensor. The average error is found to be 0.90%, which further supports the sensor's accuracy. Such a low average error is significant, as it suggests consistent performance across multiple measurements. The high level of accuracy makes the sensor a reliable tool for assessing soil pH levels. Overall, the data in Table 1 confirms that the soil pH sensor is an effective and dependable instrument.

The soil moisture sensor has been evaluated for its suitability for use. According to the data presented in Table 1, the sensor's performance was compared with a standard soil meter. The comparison yielded promising results. Specifically, the sensor's readings showed a margin of error ranging from 0.61% to 0.63%. This narrow range of error suggests a high level of precision in the sensor's measurements. Moreover, the average error recorded across the tests was 0.61%. This consistent average error further underscores the sensor's accuracy. Such precision is crucial for reliable soil moisture assessment. Given these results, the sensor proves to be a dependable tool. Overall, Table 2 confirms that the soil moisture sensor is well-suited for practical applications.

Table 1. Soil pH sensor calibration result

No	Soil pH Sensor Value	Soil pH Meter Value (%)	*Error* (%)
1	6.3	6.4	1.59
2	6.2	6.3	1.61
3	6	6	0
4	6.5	6.6	1.54
5	6.1	6.2	1.64
6	6.4	6.4	0
7	6.4	6.5	1.56
8	6.5	6.5	0
9	6.6	6.6	0
10	6.6	6.7	1.52
	Error Average		0.9

Table 2. Humidity sensor calibration result

No	Soil Humidity Sensor Value (%)	Soil Humidity Meter (%)	*Error* (%)
1	79.5	80	0.63
2	80.5	81	0.62
3	80.5	81	0.62
4	80.5	81	0.62
5	81.5	82	0.61
6	81.5	82	0.61
7	81.5	82	0.61
8	81.5	82	0.61
9	81.5	82	0.61
10	81.5	82	0.61
	Error Average		0.61

Testing nRF24L01 in line of sight conditions

RF24L01 testing under line-of-sight circumstances. In an open environment with no barriers separating the two components as shown in Table 3.

Table 3. Results of the nRF24L01 distance test in Line of Sight conditions

Range (m)	Delivered Packet	Received Packet	Packet loss	Delay (s)
10	50	50	0%	0.55
20	50	50	0%	0.87
30	50	50	0%	0.97
40	50	50	0%	1.2
50	50	50	0%	1.46
60	50	49	2%	2.42
70	50	49	2%	2.82
80	50	48	4%	3.64
90	50	48	4%	3.94
100	50	47	6%	4.12
110	50	45	12%	5.29

The maximum communication distance is 110 meters, as indicated in Table 3. At a distance of 120 meters, the server is unable to receive data [14]. The amount of packet loss rises as the distance between the two modules grows. Every data rate option has benefits and drawbacks. Using a faster data rate option will shorten the data transfer process; however, if a longer communication distance is required, a high data rate will lower the maximum communication distance due to the lower receiver sensitivity. as opposed to utilizing a low data rate.

Overall system testing

After testing several systems and components regularly [15], tests were carried out for several days for the planned growth process of the orange seedlings. The results of system testing are shown in Table 4. The data presented in Table 4 demonstrates that the system is operating effectively according to the specified coding instructions. Out of 32 observations, the watering mechanism consistently performed as intended, adhering to the pre-set standards [16]. This indicates a high level of reliability and accuracy in the system's functionality. The average pH value recorded across these observations was 7.15, which is slightly above 7. This pH level is considered optimal for plant growth, particularly for citrus seedlings, as it ensures the soil remains slightly alkaline, which is beneficial for nutrient absorption.

Moreover, the system maintained an average humidity level of 77.13 percent, well within the ideal range for citrus seedlings, which is between 70% and 80%. This consistent humidity level suggests that the system is effectively managing environmental conditions, which is crucial for the healthy development of the plants[17]. By keeping the humidity within the safe range, the system helps to prevent issues such as dehydration or fungal growth, which can occur if the humidity falls outside the optimal range. The overall results in Table 4 highlight the system's capability to maintain conditions conducive to plant growth, ensuring the health and vitality of the citrus seedlings. These findings underscore the importance of precise control in agricultural systems for maximizing plant health and yield.

Table 4. Testing system result

No	**Day**	**Time**	**Soil pH**	**Soil Humidity (%)**	**Sprinkler Action**
1	Wednesday, 2 March	7:00 AM	7.3	72	No Need
		4:00 PM	7.1	61	Ordinary Water
2	Wednesday, 9 March	7:00 AM	6.3	65	Flush with Vitamin Water
		4:00 PM	7.6	74	No Need
3	Wednesday, 16 March	7:00 AM	7.2	83	No Need
		4:00 PM	7.2	81	No Need

No	Day	Time	Soil pH	Soil Humidity (%)	Sprinkler Action
4	Wednesday, 23 March	7:00 AM	6.5	72	Flush with Vitamin Water
		4:00 PM	7.6	88	No Need
5	Wednesday, 6 April	7:00 AM	7.1	84	No Need
		4:00 PM	6.8	71	Flush with Vitamin Water
6	Wednesday, 13 April	7:00 AM	7.5	71	No Need
		4:00 PM	7.5	85	No Need
7	Wednesday, 20 April	7:00 AM	7.8	76	No Need
		4:00 PM	6.8	73	Flush with Vitamin Water
8	Wednesday, 27 April	7:00 AM	7.6	88	No Need
		4:00 PM	7.4	85	No Need
9	Wednesday, 4 May	7:00 AM	6.2	69	Flush with Vitamin Water
		4:00 PM	7.4	76	No Need
10	Wednesday, 11 May	7:00 AM	7.3	84	No Need
		4:00 PM	7.2	78	No Need
11	Wednesday, 18 May	7:00 AM	6.7	72	Flush with Vitamin Water
		4:00 PM	7.5	89	No Need
12	Wednesday, 25 May	7:00 AM	7.4	84	No Need
		4:00 PM	6.4	69	Flush with Vitamin Water
13	Wednesday, 1 June	7:00 AM	7.4	75	No Need
		4:00 PM	7.1	81	No Need
14	Wednesday, 8 June	7:00 AM	7	76	No Need
		4:00 PM	6.6	72	Flush with Vitamin Water
15	Wednesday, 15 June	7:00 AM	7.6	88	No Need
		4:00 PM	7.4	74	No Need
16	Wednesday, 22 June	7:00 AM	7.5	83	No Need
		4:00 PM	6.7	69	Flush with Vitamin Water
	Average		**7.15**	**77.13**	

4. CONCLUSION

After all the explanations are given, it can be concluded that the soil pH sensor, soil moisture sensor, and NRF communication network have been successfully calibrated and tested with results showing a high level of accuracy. The soil pH sensor shows an average error rate of 0.90% with a margin of error between 1.52% to 1.64%, indicating that it is highly accurate and reliable for measuring soil pH. Similarly, the soil moisture sensor, which shows a very small error margin between 0.61% to 0.63% and an average error of 0.61%, confirms that it is also very suitable for use in practical applications. The NRF communication network has a maximum effective communication distance of 110 meters, but at a distance of 120 meters, data cannot be received properly, indicating an increase in data packet loss as the distance increases. In addition, the designed automatic irrigation system also demonstrated effective and reliable performance, with an average soil pH of 7.115 and an average humidity level of 76.4375%, both of which are within the optimal range for the growth of citrus seedlings. This shows that the system is capable of maintaining ideal environmental conditions for plant growth, making it reliable for more precision agriculture. Although the system is already running well, further optimization can be done on the environmental control aspect to ensure more specific conditions according to the needs of different crop types, and to improve overall agricultural yields.

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