Observation of greenhouse condition based on wireless sensor networks

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Abstract. Along with increasing years, meeting food needs in Indonesia continues to experience improvements. This is because it is not balanced between the rate of population growth and the amount of food production. In order to help increase food production and improve the quality of food, modern technology in agriculture is needed, one of which is a greenhouse. Most greenhouses still use manual watering systems that have not been supported by technology that utilizes an automatic watering system and is accompanied by a monitoring system, temperature and humidity control and greenhouse soil moisture using wireless sensor network communications. By spreading 6 nodes at each point and each node equipped with 3 sensors, it is expected that the greenhouse monitoring and control process will be more thorough. The results of temperature testing at the greenhouse before using the wireless sensor network and after being implemented have increased by 23%. This also applies to the value of air humidity has increased by 4% and soil moisture by 1.20%.

1. Introduction

Indonesia is an agricultural country because the majority of Indonesia's population works in the agricultural sector. Agriculture has an important role to meet the needs of the population which is increasingly increasing. Based on the survey results of the 2010-2035 National Development Planning Agency (Bappenas), Indonesia's population in 2010 reached 238.52 million. The number of births reached 5 million while the death rate was 1.52 million. So that Indonesia's population in 2011 increased by around 3.4 million to 242 million. With the amount of population growth increasing every year, this causes the consumption of food will also increase but it is not yet supported by the availability of land and the unavailability of agricultural products all the time making the supply of agricultural products unable to meet the needs of the population. In addition, local agricultural products are of below the food industry standard. So it is necessary to import agricultural products to meet the needs of the population [1].

In order to help increase food production and improve the quality of food, modern technology in agriculture is needed, one of which is a greenhouse. In a greenhouse, farmers can plant a type of horticultural crop without knowing the season. In a greenhouse a farmer can plant a type of horticultural crop without knowing the season, and can maximize plant growth and can prevent pests and diseases that are often experienced by plants. This is very different from the situation of plants that are outside the greenhouse. Plants that are cultivated without protection will be susceptible to disease and pests [2].

Most greenhouses still use a manual watering system that is not yet supported by technology that utilizes an automatic watering system and is accompanied by a monitoring system, temperature control, and humidity and soil moisture of the greenhouse by using wireless sensor network communication (WSN). By using a monitoring system and air quality control system, this aims to monitor air quality. When air quality is low, the node will carry out monitoring and cleaning of air quality, this aims to ensure the air quality in an environment [3,4].

Wireless Sensor Network (WSN) is a distributed sensing network consisting of many sensor nodes. Sensor nodes work with one another with self-organization [5] and are responsible for monitoring environmental information (such as temperature, vibration, and pressure) in the WSN [6]. Sensor nodes usually get energy from microcells. Therefore, computerize, storage and communication capacity is limited [7].

In this paper uses WSN to observe conditions in the greenhouse in the form of temperature, humidity and soil moisture. By using 3 sensors namely air temperature, humidity, and soil moisture. By spreading 6 nodes at each point in the greenhouse it is hoped that the monitoring process will be more thorough. In addition, by creating this system it is expected to be able to provide information in real-time from the results of monitoring conditions in the greenhouse and more efficient use of human energy.

2. Methods

The system is implemented in a greenhouse, consisting of several nodes, gateways, and servers. Nodes, gateways, and servers use wireless transmission media. The wireless transmission media used in this system is the NRF24L01 wireless module. Data from each node is sent via the NRF24L01 wireless module and finally, all data is collected at the gateway. Then the gateway sends all data to the server. This aims to be able to store data sent by each node [8]. The working system of this system is shown in Figure 1.

Figure 1 it can be seen that After detecting environmental information using sensors, each node will send information to the gateway through wireless communication technology with the NRF24L01 wireless module, then the gateway sends data to the server with the same radio communication module. After the data is stored on the server, then the software that has been installed on the server will display the results of environmental monitoring in the greenhouse [9]. In this observation, wireless sensors are used to monitor any changes that occur.

The wireless sensor is a radio integration with traditional sensing transducers (for example strain gage and displacement sensors). Many differences in technology used in wireless communication, one of which is the radio communication system used today is a digital radio communication system. In other words, the data must first be encoded in digital format before modulation on the wireless channel [10]. After being encoded, the data will be transmitted using multi-hop routing techniques.

One feature of WSN communication systems are using multi-hop routing techniques. By using multihop routing techniques, sensors are placed according to the topology used or just any. For example, there are five sensor nodes placed inline (inline) in a WSN implementation, call it from left to right as sensor 1, sensor node 2, sensor node 3, sensor node 4 and sensor node 5. Assume sensor node 1 has the result data scan to be sent to sensor node 5 (as the receiving node). Then automatically the process of sending data will pass sensor node 2, sensor node 3 and sensor node 4. These three nodes act as an intermediate sensor node (router) with a multi-hop routing process [11]. Each source node in the cluster sends its message to the nearest node on its way to the cluster head order to minimize transmission energy (multihop). The advantage of using multi-hop routing technique is that it can be used on a large scale and is not limited by the scope of an area [12]. Multi-hop routing technique is an efficient routing technique in the use of energy for communication between nodes [13]. Three parameters are monitored namely air temperature, humidity, and soil moisture.

Monitoring air temperature greatly affects a part of the development process of a plant including photosynthesis of a plant, transpiration, light absorption, respiration, and flowering. In general, plants will develop if the air temperature of a plant is met. Plants will be hampered growth if the air temperature needed by plants is insufficient [14]. Then, the humidity functions as a substitute for the lost moisture of plants. The rate of transpiration in plants will be reduced significantly when the amount of humidity decreases. Transpiration is the process of releasing water in the form of water vapor through the stomata and cuticles into free air (evaporation). So the faster the rate of transpiration means the faster the transportation of water and nutrients, and vice versa. The respiration takes place through plant parts that are connected with the outside air, namely through leaf pores such as stomata, cuticle holes, and lenticels by plant physiology [15]. While the level of soil moisture depends on several factors, including soil conditions, air circulation, air humidity and temperature around the environment. The reduced water content in the soil is caused by drainage that occurs during the dry season. Drainage is a natural mass of water discharges that occur on a surface. When the roots of a plant cannot make optimal water absorption, this cannot keep up with the rate of transpiration that occurs in plants. Therefore we need consideration in controlling the level of soil moisture [16]. The design of this paper is shown in Figure 2.

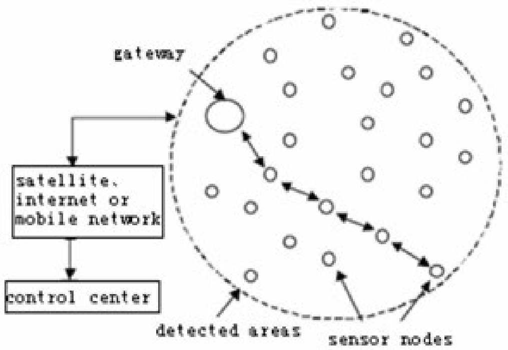

Figure 1. The Wireless sensor network works.

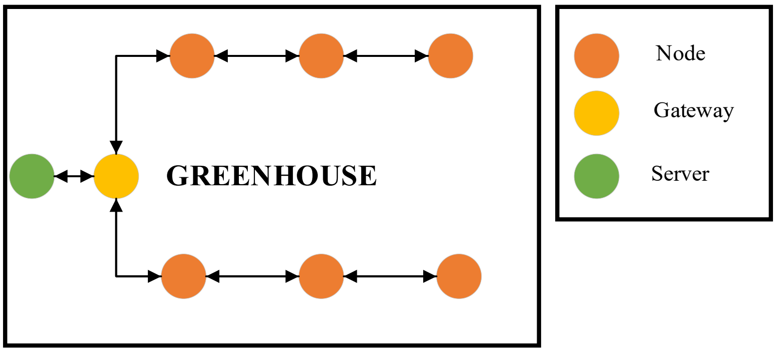

Figure 2. System design.

Figure 2 it can be seen that the design of the implementation of the tool consists of nodes, gateways, and servers. Each node consists of an Arduino nano microcontroller, DHT11 air temperature and humidity sensor, a soil moisture sensor and an NRF24L01 module. While the gateway consists of Arduino nano microcontroller and NRF24L01 module. The gateway functions to collect data from each node and forward it to the server. The server consists of raspberry pi 3. The server functions as a place to store data from the gateway and displays the results of reading data from each node.

In the implementation of the tool, the node is installed by a predetermined design with a distance between the nodes as far as 2 meters. The results of the installation of control nodes are shown in Figures 3 and 4. Figure 3 (a) shows the location of the installation of the tool in the greenhouse. The tool is mounted on bamboo, it is intended that the device nodes are not exposed to water coming out of the sprayer. While Figure 3 (b) shows the devices used in a node.

(a) (b)

Figure 3. (a) Location node installation, (b) devices on the node.

3. Result and discussion

The distance testing of the NRF24L01 module is done by testing point to point communication. The NRF24L01 module uses 3 output power parameters, namely an output power of 0 dBm, -12 dBm and -18 dBm. The results of communication distance testing using the NRF24L01 module are shown in Table 1.

Table 1. Results of NRF24L01 module distance testing.

	Output Power Transmission		
	0 dBm	-12 dBm	-18 dBm
Power Received (dBm)	0	-12	-18
Distance (meter)	25	14	4,5

From the point-to-point communication, test results show that the maximum range of NRF24L01 modules is 25 meters for an output power of 0 dBm. For experiments that use an output power of -12 dBm, a distance of 14 meters is obtained. As for the output power of -18 dBm, the range is 4.5 meters.

In testing the DHT11 sensor done twice, namely before the installation of the system and after the installation of the system. It aims to compare the temperature and humidity of the air before and after the installation of the system. Monitoring temperature and humidity are done every 1 hour. This aims to determine the spread of heat in the greenhouse and sensor testing data retrieval is done during the dry season so that the sensor value for the air temperature obtained is quite high. The results of air temperature testing using a DHT11 sensor before and after the system is installed are shown in Table 2.

Table 2. Results of air temperature sensors before and after installing the system.

No.	Time	Temperature (^{o}C)		Wall thermometer (^{o}C)	Deviation (%)	
		Before	After		Before	After
1.	06.00	25	25	25	0	0
2.	07.00	30	30	29	3,44	3,44
…	…	…	…	…	…	…
7.	12.00	48	46	46	2,12	0
8.	13.00	48	46	46	0	0
9.	14.00	45	44	44	2,27	0
...	…	…		…	…	…

Table 2 shows that the highest temperature in the greenhouse is 48 ^{o}C which occurs at 12.00 and 13.00. As for the lowest temperature in the greenhouse is 25 ^{o}C which occurred at 06.00. And the average value of the percentage deviation from the results of testing the air temperature sensor is 1.80%. Furthermore, air temperature testing is done after the system is installed or equipped with automatic water spraying using a sprayer. The results of air temperature testing using a DHT11 sensor after the system is installed are shown in Table 2. It is a decrease in air temperature after the installation of the system by 2^{o}C to 1^{o}C that occurred at 12.00 to 14.00. This is due to the spraying of water that is turned into dew by a sprayer. This system works at 12.00 to 14.00 this is because the program on the system has been set air temperature. So when the air temperature rises quite high, then this system will work by spraying water through a sprayer. From the results of testing the temperature of the system after installing the system obtained a decrease in the average deviation value from 1.80% to 1.46%. The results of testing humidity in the greenhouse before and after installing the system using the DHT11 sensor are shown in Table 3.

Table 3. Results of the humidity sensor before and after installing the system.

No	**Time**	**Value Sensor (%)**		**Reference (%)**	**Deviation (%)**	
		Before	**After**		**Before**	**After**
1.	06.00	75	75	74	1,35	1,35
...	...	...	...	...	...	...
7.	12.00	40	44	44	0	0
8.	13.00	32	36	36	0	0
9.	14.00	35	39	38	2,94	2,63
...	...	...	...	...	...	...

From Table 3 shows that the greenhouse air humidity test results obtained the lowest air humidity is 32% which occurred at 13:00 while for the highest humidity is 75% that occurred at 06.00 and has an average deviation value of 1.00%. Then the air humidity test that has been installed by the system is carried out. The results of air humidity testing using the DHT11 sensor after the system is installed are shown in Table 3. It shows that there is an increase in air humidity by 4% from the test results before the installation of the system that occurred at 12.00-14.00. This is due to the automatic spraying of water by a sprayer that can increase the humidity of the air and reduce the temperature in the greenhouse. With the increase in humidity inside the greenhouse, the temperature of the greenhouse will decrease, which is 2°C to 1°C at 12.00 and 14.00. And the average value of deviation has decreased from 1.00% to 0.97%. As for testing the soil moisture sensor, it is based on the amount of water intensity that is splashed on the greenhouse grounds. The soil moisture sensor test results are shown in Table 4.

Table 4. Results of the soil moisture sensor before the system is installed.

No.	Water (mL)	Temperature (°C)	Soil Meter (%)	Measurement	Deviation (%)
1	Dry	1023	0	1020	0,29
2	50	665	4	663	0,30
3	100	310	7	308	0,64
4	150	230	11	228	0,87
…	…	…	…	…	…
11	500	164	95	163	0,61
12	550	150	100	148	1,35

From Table 4 shows that the value of the sensor when the soil is dry is 1023 and the value of the soil sensor when given a water intensity of 550 mL is 150 so that the average value of the percentage deviation is 1.20%.

In the next test carried out testing the WSN network that is attached to the server. The server will display the results of reading sensor data from each node installed in the greenhouse. The software used on the server is putty. The putty software display when testing the WSN network is shown in Figure 4.

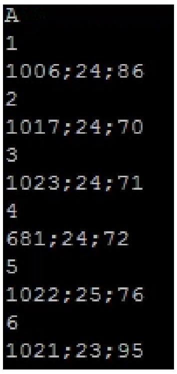

Figure 4. Network testing.

Figure 4 displays the results of reading sensor data on each node. In the first order, the putty displays the results of reading the soil moisture sensor data, air temperature, and air humidity. As the results displayed on node 1, shows a value of 1006 which is the result of a soil moisture sensor reading, a value of 29 is the result of an air temperature sensor reading and a value of 75 is an air humidity sensor reading.

4. Conclusion

From the results of this paper, it can be concluded that the percentage of temperature testing deviation in the greenhouse before using the conditioning system increased by 23% while the humidity value also increased by 4% and the soil moisture parameters by 1.20%. With these results, the observation and conditioning of the greenhouse are getting better and is expected to increase the yield of plants in the greenhouse.

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