Temperature and Humidity Monitoring System using Wireless Based Xbee on Hydroponic Plants

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Abstract. This research discusses temperature and humidity monitoring systems using wireless Xbee module-based microcontrollers carried out in hydroponic plants. Microcontroller has functions for storing programs in electronic circuits. Xbee has a function for wireless communication devices that work on the 2.4 Ghz frequency with a range of 1500 meters. The technique used in this study used two Xbee modules, which are used as the sending node and receiving node. The sending node is as the controller. It used the Arduino module which is connected to the DHT 11 sensor as input and Xbee as the sender. The receiver node as a data processor consists of Xbee module connected to the Arduino module and LCD to display data. In this research, the results of comparison of DHT11 sensors with a Thermo-Hygro measuring device with an average temperature error of 0.75°C and 3% humidity. The results of testing the four DHT11 sensors outside the room get an average value of 28.94°C with humidity test results in the room 29.14°C and 58.86% with an Xbee range of 70 meters. Wireless design of temperature and humidity monitoring systems based on Xbee communication is successfully implemented in hydroponic plant cultivation.

1. Introduction
Several things become obstacles in conventional farming systems in Indonesia. One of the obstacles in Indonesia is a tropical country with less supportive environmental conditions, such as high temperatures and humidity throughout the year which tend to increase the growth of pests, weeds, and diseases. Demand for horticultural commodities such as fruit, vegetables or even medicine continues to increase along with the increasing needs and population. It is necessary to make a regulation regarding the production system environment to create land that supports plant growth [1]. The way to produce these products with high and continuous quality and quantity, one of them is by cultivating a hydroponic system and using a greenhouse as a place for cultivation of plants [2]. Hydroponic means Hydro = water, and Phonic = workmanship. In general, it means an agricultural cultivation system without using land but using water containing nutrient solutions. Green house is a small house shaped structure made of plastic, glass, or glass translucent material that aims to manipulate environmental conditions and maintain optimal plant growth. Some of the advantages of hydroponic cultivation includes plant density per unit area can be doubled to save land use [3, 4]. Product quality such as shape, size, taste, color, cleanliness can be guaranteed because the nutrient requirements of plants are supplied in a controlled and maximum manner in a greenhouse [5, 6].

In this process, plants need monitoring in environmental parameters that interact directly with plants, one of it is monitoring temperature and humidity on the land. The problems faced in conditioning the land are important for monitoring temperature and humidity during sustainable crop cultivation. Facing this is difficult for officers or someone who is carrying out hydroponic cultivation
to continuously monitor the temperature and humidity of the land directly. Therefore, from these problems, it is necessary to have a system of monitoring temperature and humidity parameters that facilitates plant conditioning. Based on the description above, the microcontroller system is suitable to be implemented in a software and hardware to perform tasks in minimizing resources. This temperature and humidity monitoring system uses DHT11 sensors as the input data and used to determine the condition of crop land. Monitoring is easier to do with wireless transmission. Wireless communication is effective communication without being interrupted by long cable lines. Various kinds of tools to support wireless communication that are often used, namely Bluetooth, Wi-Fi, infrared, Xbee, etc. This study used the Xbee tool to conduct wireless communication. Xbee is part of the ZigBee protocol with the standard used is IEEE 802.15.4, operating at a 2.4 GHz frequency with a range of up to 1,500 meters [7, 8]. As mentioned above, the temperature and humidity monitoring system wirelessly using a microcontroller-based Xbee can be an alternative to overcome the problems described above.

The main purpose of using a microcontroller is to control the operating system that uses a fixed system, stored in a ROM, and does not change during the life of the system [9]. Several studies have been carried out related to the temperature and humidity monitoring systems wirelessly, one of it is the temperature and humidity monitoring system applied to mushroom cultivation based on the ATMega328 microcontroller [10]. This research has the main objective to implement the Xbee module on the microcontroller in order to detect temperature and humidity in the hydroponic plant environment.

2. Method
This study used the prototype concept [11] where microcontroller is needed. It has a function for storing programs in electronic circuits. Xbee has a function for wireless communication devices that work on the 2.4 GHz frequency. There are two nodes XBee module in this study, namely the sending node and the receiving node. The sending node as the controller uses the Arduino module which is connected to the DHT 11 sensor as input and Xbee as the sender. The receiver node as a data processor consists of Xbee which is connected to the Arduino module and LCD to the display data (see Figure 1).

![Figure 1. System design scheme](image)

Figure 2 explains designing the sensor node section and coordinator node section, then designing is done in the software section.
3. Results and Discussion
This test consists of three stages, sending node testing, receiving node testing, and the thoroughness test. Testing the sending node includes testing the response of the sensor and the accuracy of the sender's wireless, while the testing of the receiving node includes testing the accuracy of the receiver's wireless and testing the viewer for temperature and humidity data values. The next stage is the overall test, which is a combination of testing between the sender and the recipient [12].

3.1 Testing of Sensor Response
The sensor response-testing phase is done by comparing the results of DHT11 sensor measurements with a Thermo-Hygro digital measuring device. This case is done in a room using one DHT11 sensor in three minutes for 30 minutes. DHT11 sensor testing can be seen in Table 1.
Table 1. DHT11 Sensor testing

| No. | Temperature (℃) | Humidity (%) | Temperature (℃) | Humidity (%) | Temperature (℃) | Humidity (%) |
|-----|-----------------|--------------|-----------------|--------------|-----------------|--------------|
| 1   | 30              | 46           | 29,8            | 45           | 0,2             | 1            |
| 2   | 29              | 50           | 29,5            | 55           | 0,5             | 5            |
| 3   | 28              | 55           | 28,2            | 53           | 0,2             | 3            |
| 4   | 30              | 45           | 29              | 48           | 1               | 3            |
| 5   | 30              | 46           | 30,5            | 45           | 0,5             | 1            |
| 6   | 28              | 58           | 29,2            | 56           | 1,2             | 2            |
| 7   | 28              | 55           | 29,5            | 58           | 1,5             | 3            |
| 8   | 30              | 50           | 30              | 46           | 0               | 4            |
| 9   | 29              | 52           | 28              | 55           | 1               | 3            |
| 10  | 27              | 55           | 28,4            | 50           | 1,4             | 5            |
|     | Average         |              |                 |              | 0,75            | 3            |

DHT11 sensor testing is a process with a Thermo-Hygro digital comparator. Tests are carried out in the room where the AC is on. The test results obtained an average temperature and humidity error value of DHT11 0.75 ℃ and 3%.

3.2 Testing of Wireless Shippers and Recipients
The wireless testing stage is a testing process between the Xbee sender and Xbee recipient. This test is done by testing the sending of data in the form of writing on the virtual terminal layer where there is software to configure Xbee namely XCTU. Xbee testing is done in a room with a sturdy barrier such as a wall and others. The test data obtained is as follows, the sender Xbee stored in a room with a sturdy barrier in the form of a wall can produce a considerable distance. The resulting range reaches around 80 meters but at a distance of 90-100 meters, the data cannot be sent. The results of testing the sender and receiver Xbee range are in Table 2.

Table 2. Xbee range test results

| No. | Range (meter) | Status   |
|-----|---------------|----------|
| 1   | 10            | Delivered|
| 2   | 20            | Delivered|
| 3   | 30            | Delivered|
| 4   | 40            | Delivered|
| 5   | 50            | Delivered|
| 6   | 60            | Delivered|
| 7   | 70            | Delivered|
| 8   | 80            | Delivered|
| 9   | 90            | Not Delivered|
| 10  | 100           | Not Delivered|

3.3 Overall Testing
Overall testing is a combination of testing two nodes, namely the sensor as input connected to the microcontroller and the sending Xbee. Node is Xbee receiver that is connected to the microcontroller to the process data. Then, the data is displayed on the LCD layer. The overall test is a step to get the
data from the test results with good results, whether the tool is in accordance with the design or vice versa. The first experimental phase is carried out by sending data from the sender to the recipient outside the room without using a barrier. The method of testing is done by varying distance variations. Tool testing was carried out at the location of hydroponic cultivation in CV. Alam Pasundan on October 22, 2016.

The results of outdoor testing without obstructions are in Table 3. The average measured temperature of 28.94 °C and humidity of 59.06% obtained the results of these tests from 13.00 WIB until 14.30 WIB. In addition, sensor data can be sent from the sender to the receiver up to a distance of 240 meters. The second experiment, carried out by changing the place of sender and receiver, in this experiment, the sender is placed in a hydroponic room, while for the receiver placed in a different room with a sturdy barrier such as a wall. The results of this second experiment are found in Table 4. The test results show that the average measured temperature is 29.14 °C and humidity is 58.86%. The measurement results obtained a range of 70 meters.

| No. | Range (m) | Temperature (°C) | Humidity (%) | Status | Alarm |
|-----|-----------|------------------|--------------|--------|-------|
|     |           | S1  | S2  | S3  | S4  | R     | S1 | S2 | S3 | S4 | A     |
| 1   | 30        | 28  | 27  | 27  | 30  | 28   | 47 | 59 | 53 | 56 | 53,75 | Delivered | OFF |
| 2   | 60        | 29  | 28  | 29  | 29  | 28,5 | 55 | 61 | 55 | 60 | 57,75 | Delivered | OFF |
| 3   | 90        | 28  | 30  | 31  | 30  | 29,75| 50 | 57 | 62 | 65 | 58,5  | Delivered | OFF |
| 4   | 120       | 28  | 29  | 30  | 29  | 29   | 58 | 55 | 60 | 60 | 58,25 | Delivered | OFF |
| 5   | 150       | 30  | 30  | 29  | 31  | 30   | 67 | 61 | 58 | 57 | 60,75 | Delivered | ON  |
| 6   | 180       | 31  | 30  | 28  | 29  | 29,5 | 65 | 59 | 58 | 60 | 60    | Delivered | OFF |
| 7   | 210       | 28  | 29  | 28  | 29  | 28,75| 65 | 60 | 60 | 60 | 61,25 | Delivered | OFF |
| 8   | 240       | 28  | 29  | 27  | 28  | 28   | 65 | 60 | 61 | 63 | 62,25 | Delivered | OFF |
| 9   | 270       | -   | -   | -   | -   | -    | -  | -  | -  | -  | -     | Not Delivered | OFF |
| 10  | 300       | -   | -   | -   | -   | -    | -  | -  | -  | -  | -     | Not Delivered | OFF |
|     |           |     |     |     |     |      |     |     |     |     | Average | Delivered |

Average: 28.94 | Average: 59.06

S1-S4 : Sensor 1 until sensor 4
A : Average
Table 4. Indoor test results (with a barrier)

| No. | Range (m) | Temperature (℃) | Humidity (%) | Status | Alar m |
|-----|-----------|-----------------|--------------|--------|--------|
|     |           | S1   | S2   | S3   | S4   | R    | S1   | S2   | S3   | S4   | A    |        |
| 1   | 10        | 28   | 28   | 28   | 30   | 28,5 | 46   | 58   | 50   | 55   | 52,25 | Delivered | OFF    |
| 2   | 20        | 30   | 31   | 29   | 31   | 30,25 | 55   | 61   | 57   | 62   | 58,75 | Delivered | ON     |
| 3   | 30        | 28   | 30   | 31   | 29   | 29,5 | 50   | 57   | 62   | 65   | 58,5  | Delivered | OFF    |
| 4   | 40        | 28   | 29   | 30   | 30   | 29,25 | 58   | 55   | 60   | 62   | 58,75 | Delivered | OFF    |
| 5   | 50        | 29   | 28   | 28   | 29   | 28,5 | 67   | 61   | 58   | 57   | 60,75 | Delivered | OFF    |
| 6   | 60        | 31   | 30   | 28   | 29   | 29,5 | 65   | 59   | 58   | 58   | 60    | Delivered | OFF    |
| 7   | 70        | 28   | 29   | 28   | 29   | 28,5 | 65   | 67   | 60   | 60   | 63    | Delivered | OFF    |
| 8   | 80        | -    | -    | -    | -    | -    | -    | -    | -    | -    | -     | Delivered | OFF    |
| 9   | 90        | -    | -    | -    | -    | -    | -    | -    | -    | -    | -     | Delivered | OFF    |
| 10  | 100       | -    | -    | -    | -    | -    | -    | -    | -    | -    | -     | Delivered | OFF    |

Average 29,14 Average 58,86

S1-S4 : Sensor 1 until 4
A : Average

4. Conclusion
The results of designing a temperature and humidity monitoring system wirelessly based on Xbee communication have been successfully implemented in the cultivation of hydroponic plants. The system is designed using the DHT11 sensor as an input, Arduino Uno acts as a microcontroller, Xbee as the data sender and receiver wirelessly, and the LCD viewer layer. The test results show the sensor is able to detect temperature and humidity with an average error of 0.75℃ and 3%. In addition, the data can be sent and received wirelessly with a range of outdoors without a barrier reach a distance of 240 meters while the range in the room with a barrier reaches 70 meters. A better system model should be developed in order to improve the accuracy of detection systems developed.

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