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DESIGN OF A WIRELESS AIR TEMPERATURE AND HUMIDITY MONITORING SYSTEM

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ABSTRACT

The paper presents a wireless monitoring system to measure environmental parameters. In this context, we proposed a wireless air temperature and humidity monitoring system which are of low-cost and easy to use. The system consisted of an 8-bit micro chip professional ATmega8 as the core control of the system, wireless transceiver module nRF24L01, and temperature and humidity sensor DHT11. Interface monitoring software was designed by Visual Studio. To assess the accuracy of the measuring equipment, thermometer and hygrometer DC107 was employed for standards. The air temperature and humidity data at the wireless monitoring system were highly comparable to those of the DC107. Energy saving solutions for remote equipment were also mentioned in this study.

Keywords: ATmega8, DHT11, module, nRF24L0, temperature and humidity monitoring, wireless sensors,

Thiết kế hệ thống giám sát nhiệt độ độ ẩm không khí không dây

TÓM TẮT

Bài báo trình bày kết quả nghiên cứu, chế tạo và khảo nghiệm một hệ thống giám sát không dây các thông số môi trường. Trong nghiên cứu này, chúng tôi đề xuất một hệ thống giám sát không dây các thông số nhiệt độ và độ ẩm không khí có giá thành thấp, thuận lợi cho người Việt Nam sử dụng. Hệ thống gồm một vi điều khiển ATmega8 làm hạt nhân, module truyền nhận sóng vô tuyến nRF24L01, cảm biến nhiệt độ độ ẩm không khí DHT11. Giao diện giám sát được thiết kế bằng phần mềm Visual Studio. Để đánh giá độ chính xác của thiết bị đo, chúng tôi sử dụng đồng hồ đo nhiệt độ và độ ẩm DC107 làm chuẩn. Các dữ liệu nhiệt độ và độ ẩm do hệ thống thu thập được khá chính xác so với các giá trị do mẫu thu thập. Giải pháp tiết kiệm năng lượng cho thiết bị ở xa cũng được đề cập đến trong nghiên cứu này.

Từ khóa: ATmega8, cảm biến không dây, DHT11, giám sát nhiệt độ độ ẩm, nRF24L01.

1. INTRODUCTION

The environment is one of the most important factors that significantly influences the development of agricultural crops. Monitoring environmental parameters such as temperature, humidity, light intensity, etc. has great practical value in agricultural production. Based on measurements gathered by monitoring systems, humans can adjust environmental quantities for the purposes of obtaining better production yields and minimizing the use of resources.

Monitoring systems have been evolving and improving for decades, and significant advancements have been made to make the systems more complete. The first were wired monitoring systems which provide solid security and reliability, and are cost-effective and speedy. However, the traditional wired monitoring systems also have some drawbacks such as a lack of mobility, difficulties with scalability, cable damage, and installation and maintenance costs (Lars Strong, 2016). Because of the above disadvantages, wired monitoring systems are also difficult to apply in agriculture systems that are usually done in large and complex areas. Recently, with the development of computer technology, measurement technology, and wireless communication technology, those traditional wired monitoring systems are gradually being replaced by wireless monitoring systems, which gather information about an object without making any physical contacts. Technological developments have led to the emergence of wireless sensor networks (WSNs) which have benefits such as being easier to physically deploy, easily scalable, becoming more cost effective, and having extended range capability. Hence, WSNs are useful in many fields: environmental monitoring (Akyildiz *et al*., 2002); intelligence building (Suh *et al*., 2008), biodiversity mapping, predicting natural disasters (Francisco-Fernández *et al.,* 2012), medicine and health care (Otto *et al*., 2006) and so on. In agriculture, the advent of WSNs spurred a new direction of research (Ruiz-Garcia *et al*., 2009). In recent times, WSNs are widely applied in various agricultural applications, for example monitoring environment in greenhouses and gardens (Kim *et al*., 2011), determining organic matter in the soil (Nguyen Van Linh, 2015), and creating a virtual fence to control cow herds (Butler *et al*., 2004). It can be seen that remote sensing is one of the most effective technologies used to solve the problems of monitoring and control in agriculture.

Recently, Ngo Phuong Thuy and Bui Dang Thanh have proposed a model of the wireless temperature and humidity monitoring for the agriculture warehouse at Vietnam National University of Agriculture (Ngo Phuong Thuy *et al*., 2016). The system was applied to collect indoor environmental parameters. ATmega16, sensor DHT11, nRF24L01 were used in this study. The system can collect temperature and humidity parameters in the warehouse at a distance of 20m. Data was exported as Microsoft Excel files. However, the tests in this study were conducted in a laboratory and no standard equipment was used to assess the accuracy of data collected by the system. Besides, the study has not evaluated the issue of energy savings in the system yet. Most current monitoring interfaces are only in English, making it difficult for Vietnamese farmers to use the systems. Creating a custom system helps solve this problem.

In this research, we propose a low-cost wireless air temperature and humidity monitoring system. The system was designed to measure outdoor environmental parameters. To create a system with a low cost, we choose electronic components that are available in Vietnam. ATmega 8 was selected because it meets the technical requirements while the price of this chip is half that of ATmega 16, thus, the cost of system is greatly reduced. Therefore, Vietnamese farmers have more opportunities for high-tech applications in production. Besides, in order to save energy, the remote sensor was set up in sleep mode. The monitoring interface utilizes the Vietnamese language making it easy for famers to understand. The monitoring software can also extract old data at any time as requested by users. The tests were carried out in both a natural environment and greenhouse. To assess the accuracy of the measuring equipment, we used thermometer and hygrometer DC107 data as standards. The results showed that the system worked well in the 400 m range and can be applied in agriculture.

The paper is organized as follows: Section 2 introduces the structure of the wireless monitoring system, electronic components used in the hardware, and principle diagrams. Section 3 describes the experiments and discussion about the results. Section 4 are the conclusions and some remarks.

2. MATERIALS AND METHODS

2.1. The overall structure of the system

The wireless air temperature and humidity monitoring system is illustrated in Figure 1. The system includes three parts: temperature and humidity sensor node, coordinator node, and computer node.

The sensor node is responsible for collecting temperature and humidity in a remote environment. The coordinator node receives data from the sensor node and transmits them to the computer. It also receives commands from the computer and sends them to the sensor node. The computer is utilized for saving and analyzing data.

2.2. The hardware design of system

In this section, the theoretical method was employed to study the wireless sensors. The structures of the terminal sensor node and coordinator node are shown as follows. The electronic components chosen and their hardware are also mentioned in this section.

2.2.1. The hardware design of terminal sensor node

Figure 2 shows the main parts of the temperature and humidity sensor node.

The sensor node includes five components: MCU, sensors, transceiver, power source, and display block.

* MCU

This system uses an ATMEGA 8 as the core hardware of the terminal sensor node and coordinator node. Some features of ATMEGA 8 are described as follows:

- 8kbyte of Flash program memory, 512 bytes EEPROM, 1 kbytes internal SRAM.

- 23 programmable I/O lines.

- Two 8-bit Timer/Counter, one 16-bit Timer/Counter; Real time counter; 3 PWM channels; 6 channels ADC in PDIP package; Two-wire serial interface; Serial USART; Master/slave SPI serial interface.

- Five sleep modes: Idle, ADC noise reduction, Power save, Power-down, and Stand by.

- Operating voltage: 4.5 - 5.5V.

This MCU can work normally under low-voltage events and can be used with the conditions of the battery supply.

* Temperature and humidity sensor DHT11

The DHT11 temperature and humidity sensor features a temperature and humidity sensor complex with a calibrated digital signal output. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component. Because of the 8-bit digital signal output, it connects to a performance 8-bit microcontroller. Technical specifications are shown in Table 1.

DHT11's power supply is 3 - 5.5VDC. One capacitor valued at 100 nF can be added between VDD and GND for power filtering. A single bus data format is used for communication and synchronization between MCU and DHT11. A complete data transmission is 40 bits. Data format: 8 bit integral RH data+ 8 bit decimal RH data + 8 bit integral T data+ 8 bit decimal T data + 8 bit check sum.

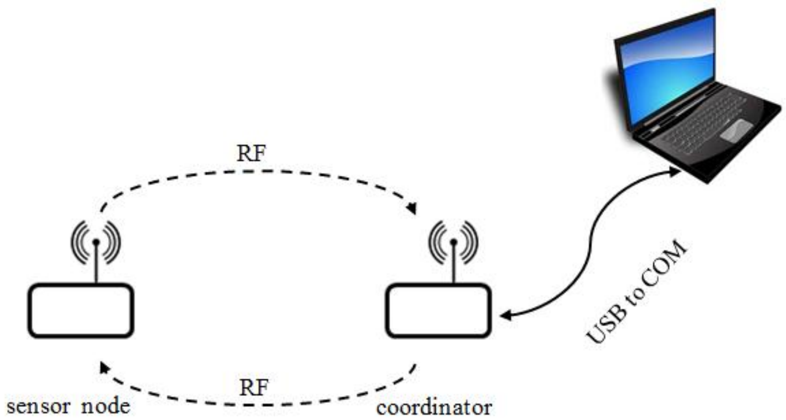


Figure 1. Structure of the wireless temperature and humidity monitoring system

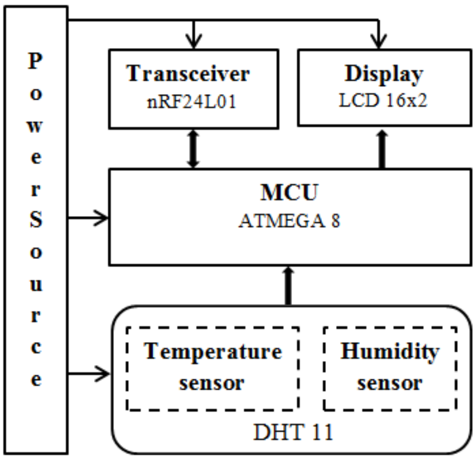


Figure 2. Terminal sensor node structure

Table 1. Technical specification of DHT11

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT11	20-90% RH 0-50°C	± 5%	±2°C	1	4 Pin single Row

When the communication between DHT11 and MCU begins, MCU will set Data single - bus voltage level from high to low, and this process takes at least 18 ms to ensure the DTH's detection of the MCU's signal, then the MCU will pull up the voltage and wait 20-40 µs for the DHT's response. Once the DHT detects the start signal, it will send a low - voltage - level response signal, which lasts 80 µs. Then, the program of the DHT sets the data single - bus voltage level from low to high and keeps it for 80µs for the DHT's preparation for sending data. When the DHT is sending data to the MCU, every bit of data begins with the 50µs low voltage level, and the length of the high voltage level signal determines whether the data bit is "0" or "1".

The 26-28 µs of high voltage means "0" and the 70 µs of high voltage means "1". When the last data bit is transmitted, DHT11 pulls down the voltage and keeps it there for 50 µs. Then the single bus voltage will be pulled up by the resistor to set it back to free status.

* nRF24L01

The wireless transmission circuit adopts the wireless transceiver nRF24L01, which is a single chip radio transceiver for the worldwide 2.4-2.5 GHz ISM band. The transceiver consists of a fully integrated frequency synthesizer, a power amplifier, a crystal oscillator, a demodulator, a modulator and an Enhanced Shockburst protocol engine. Some features of nRF24L01: on the air data rate 1-2 Mbps, digital interface (SPI) speed 0-8 Mbps, 125 RF channel operation, power supply range 1.9 - 3.6 V. Current consumption is very low, only 0.9 mA at an output power of -6 dBm and 12.3 mA in RX mode. Power saving is easy because of the Power-down and Standby modes.

* Power supply

Because the working voltage of the ATMEGA8, LCD, DHT11, and nRF24L01 are respectively 5V, 5V, 5V, and 3.3V, we used 7805 at a steady 5V and AMS 3.3 to create 3.3V. The system can use a battery supply or TP link supply.

2.2.2. The hardware design of coordinator node

The coordinator node is shown in Fig 3. It sends data to the computer and receives commands from the computer. In order to communicate between the ATMEGA 8 and the computer, this system uses the most common RS-232 communication interface. A USB to TTL serial UART cable is used. Each TTL-USB cable contains a small circuit board, which converts the TTL level to USB. The cable provides a fast, simple way to connect devices with a TTL level serial interface to USB.

2.3. The software design of system

The graphical method was used to design the principle circuits, printed circuit boards (PCBs), and programmable monitoring software.

The principle diagrams and PCBs of the system were designed by Orcad software. Code vision AVR compiler was used to program the MCU. Interface monitoring software was designed by Visual Studio.

The main algorithm flowcharts of the terminal sensor node and coordinator node are respectively illustrated in figure 4 and figure 5. Principle diagrams of the terminal sensor node and coordinator node, respectively, shown in figure 6 and figure 7. Figure 8 and figure 9 are the sensor node and coordinator node designed in the study. Figure 10 a and b are the windows of monitoring interface. The software uses Vietnamese, so it is very easy to use.

2.4. The sleep mode of remote sensor node

To increase flexibility for wireless sensors, these sensors often use batteries. However, batteries usually have a small capacity and a short life span, so saving energy is very important for the wireless sensor networks. In this design, the sleep mode for the remote devices have been installed. When it is unnecessary to gather data, users click the “Tat thiet bi phat” button. The command will be transferred from the computer to the remote sensor and takes the device into sleep mode. To wake it up, we click the “Bat thiet bi phat” button on the interface.

3. RESULTS AND DISCUSSIONS

This section presents the results of the study. Two experiments were performed to determine the working distance and accuracy of the wireless air temperature and humidity data. In these experiments, the sensor node collected data and transmitted it to the coordinator with RF 2.4Ghz (radio frequency wave). Then, data from the coordinator was sent to the PC through the serial port. The serial port was set to COM 3 or 4, the baud rate was set to 24.000 bps, the data was 8 bits, there was no parity, stop bit was 1 bit. In both experiments, the Thermometer and Hygrometer DC107 was used as the standard and the environment had obstacles.

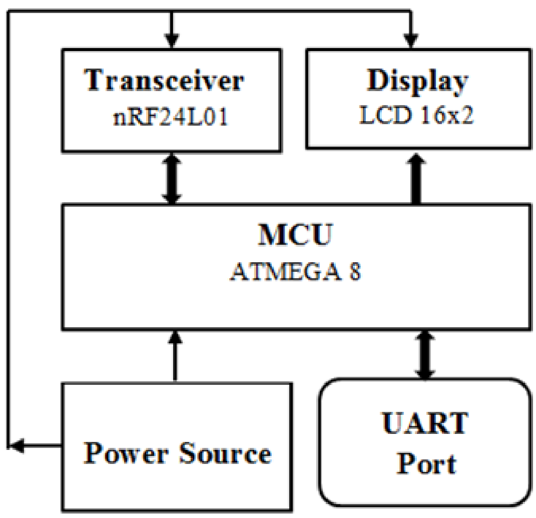


Figure 3. Coordinator node structure

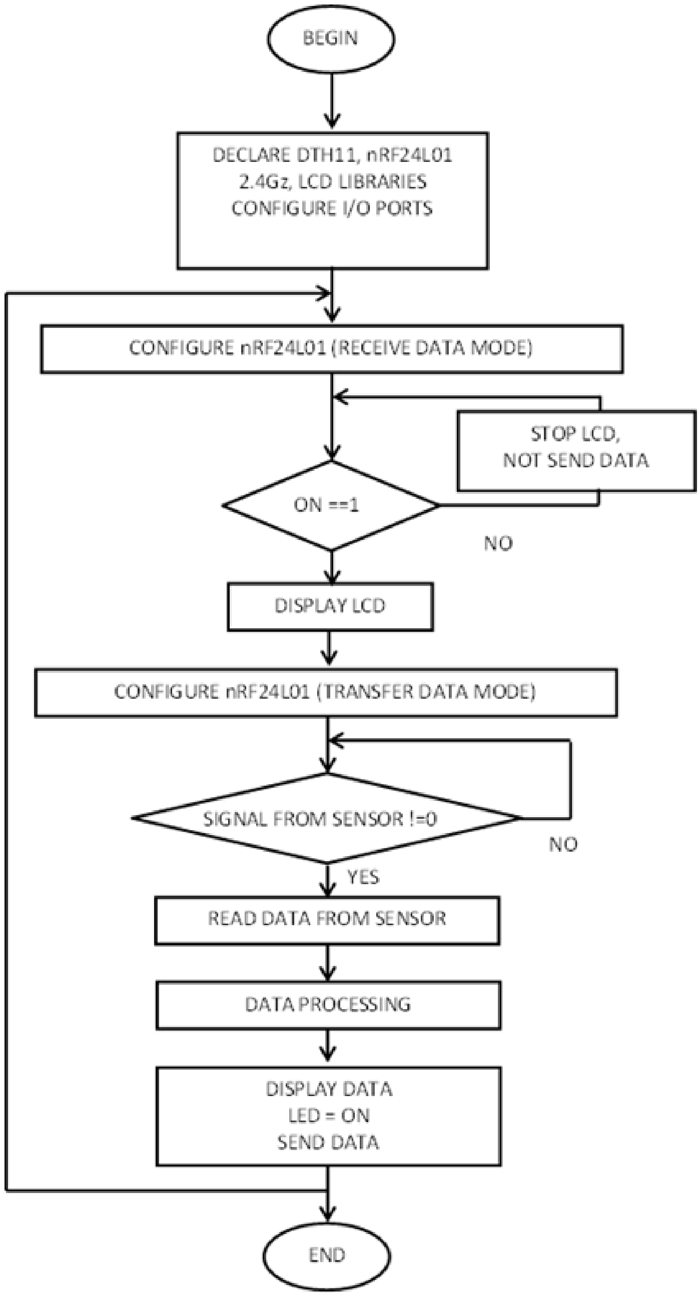


Figure 4. Algorithm flowcharts of terminal sensor node

In the first experiment, we initially put the sensor node and the coordinator 5 m apart from each other. Then we gradually increased the distance between the two devices. The results show that the system works best in a range from 0 to 400 m, outside this range there is no communication signal between devices.

In the second experiment, we carried out measuring air temperature and humidity in a natural environment and a greenhouse. The test in natural environment was done from 7 h 16 am to 7 h 16 pm on 05/12/2016. The sensor node was placed outdoors and the coordinator place in a laboratory (Figure 11, Figure 12). The distance between the two devices was about 200 m and there were obstacles. Data was measured once every hour. The measured values are shown in table 2. Figure 15 and figure 16, respectively, illustrate air temperature and humidity data gathered in this test.

The test in the greenhouse was performed on 05/19/2016 (Fig. 13, Fig. 14). Data was measured every 10 minutes from 8h45 am to 11h45 am. The measured values are shown in table 3. The parameters are demonstrated in figure 17 and figure 18.

By comparing collected data with the actual temperature and humidity meter, we can see that the measurement results were relatively accurate. Temperature error was less than ± 0.9°C and humidity error was less than ±1%RH.

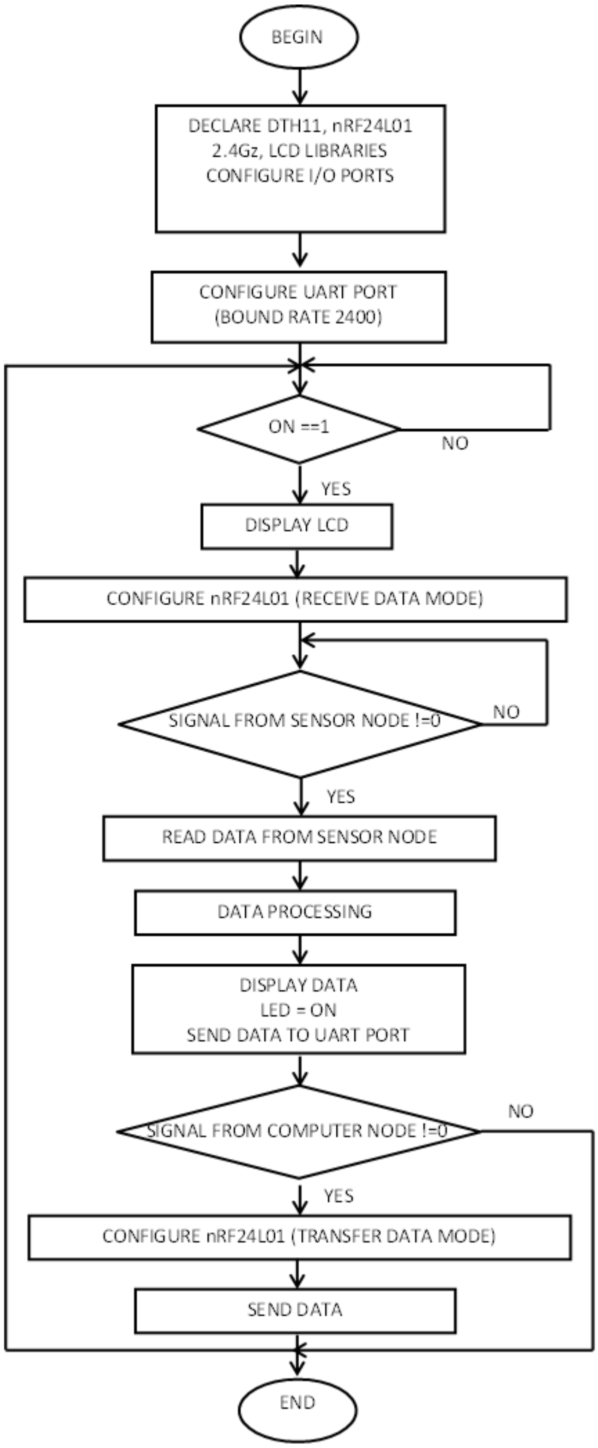


Figure 5. Algorithm flowcharts of coordinator

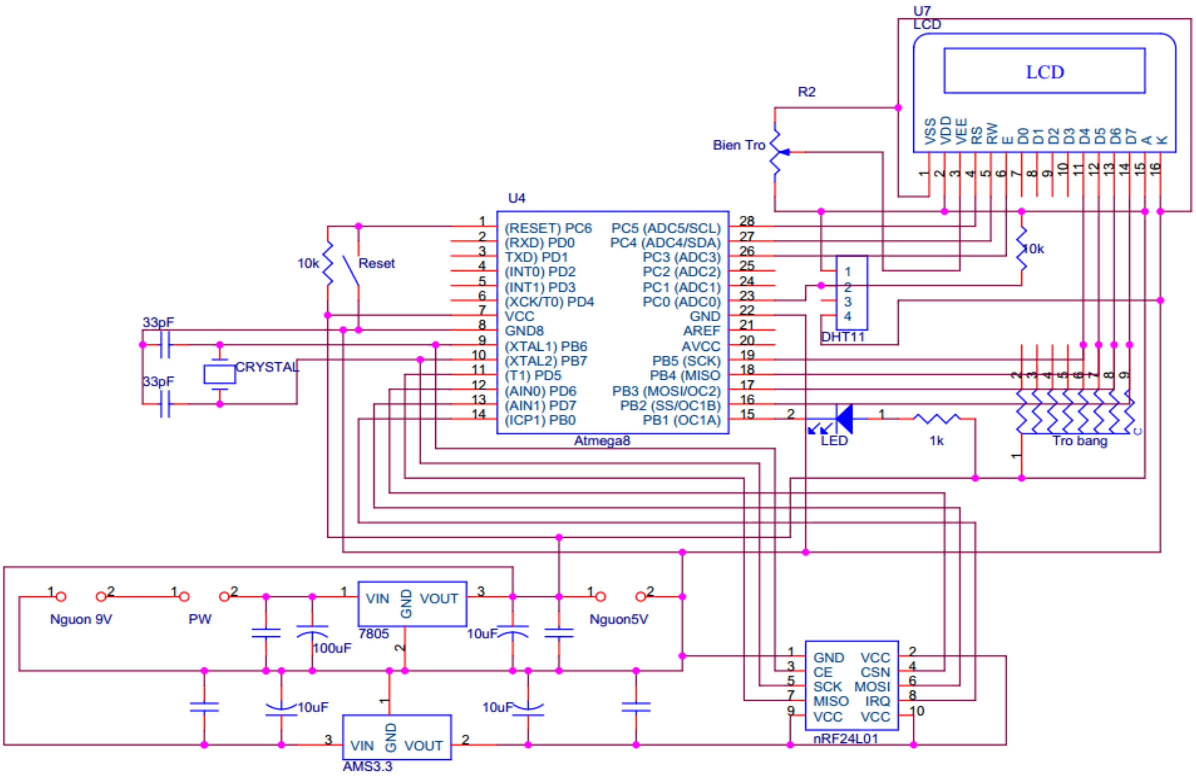


Figure 6. The terminal sensor node principle diagram

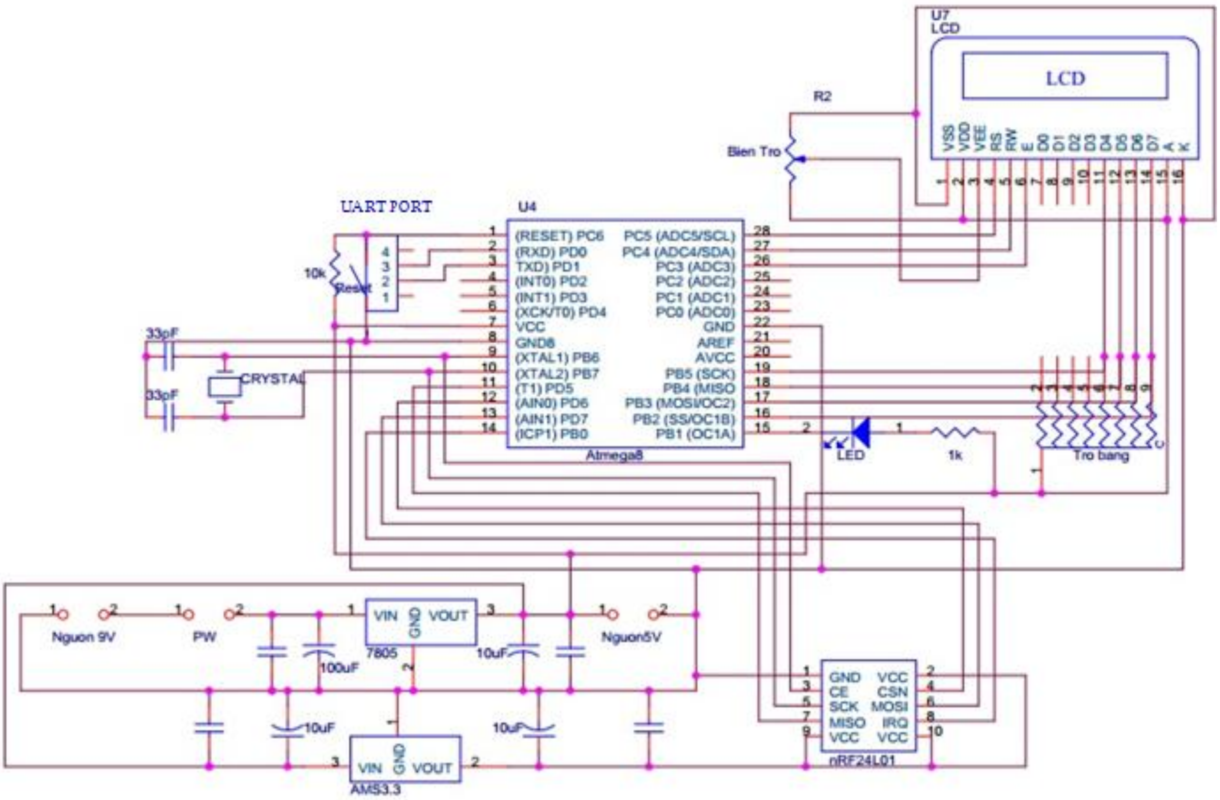


Figure 7. The coordinator node principle diagram

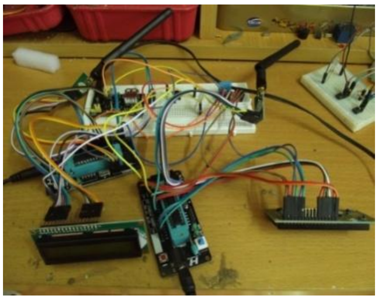
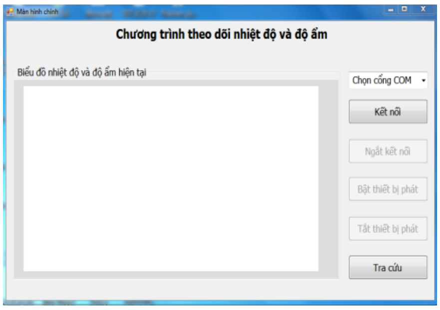
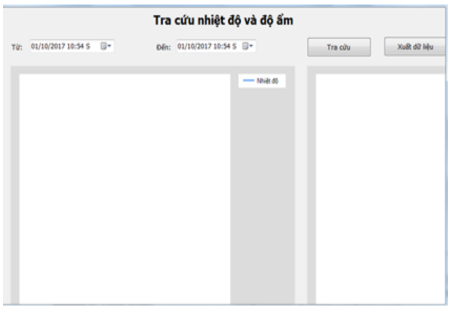


Figure 8. Test boards of sensor node and coordinator

Figure 9. Sensor node and coordinator node



a) Main interface window



b) History interface window

Figure 10. The monitoring interface

Figure 11. The sensor node in outdoor

Figure 12. The coordinator and PC in Lab

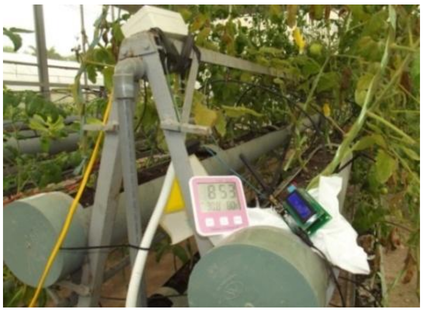


Figure 13. The sensor node in greenhouse

Figure 14. The coordinator in Nguyen Dang lecture hall

Table 2. Temperature and humidity gathered in a natural environment on May 5th, 2016

Time	Sensor node		Ther. and Hygro. meter		Error	
	T(°C)	Rh(%)	T(°C)	Rh(%)	ΔT(°C)	ΔRh(%)
7h16	28	82	28.7			
8h16	30	70	30.1			
9h16	31	66	31.2	66	0.2	0
10h16	31	63	31.8	63	0.8	0
11h16	34	61	33.6	61	0.4	0
12h16	31	67	31.4	67	0.4	0
13h16	31	69	31.1	69	0.1	0
14h16	32	69	31.6	69	0.4	0
15h16	31	72	31.7	72	0.7	0
16h16	31	72	31.1	72	0.1	0
17h16	30	80	30.6	80	0.6	0
18h16	29	74	29.9	73	0.9	1
19h16	29	81	29.6	81	0.6	0

Table 3. Temperature and humidity gathered in a greenhouse on May 19th, 2016

Time	Sensor node		Ther. and Hygro. meter		Error	
	T(°C)	Rh (%)	T(°C)	Rh (%)	ΔT(°C)	ΔRh(%)
8h45	31	81	30.5	80	0.5	1
8h55	31	80	30.7	80	0.3	0
9h05	31	72	30.8	74	0.2	2
9h15	32	69	32.5	69	0.5	0
9h25	32	69	32.6	70	0.6	1
9h35	32	69	32.8	67	0.8	2
9h45	32	68	33.1	66	1.1	2
9h55	32	66	33.6	65	1.6	1
10h05	33	62	33.9	63	0.9	1
10h15	32	66	33.2	65	1.2	1
10h25	35	58	34.7	60	0.3	2
10h35	37	63	35.4	60	1.6	3
10h45	34	62	34.7	61	0.7	1
10h55	35	57	33.5	59	1.5	2
11h05	35	56	36.1	55	1.1	1
11h15	35	57	36.5	55	1.5	2
11h25	35	56	35.8	56	0.8	0
11h35	36	57	35.4	57	0.6	0
11h45	37	50	36.1	55	0.9	5

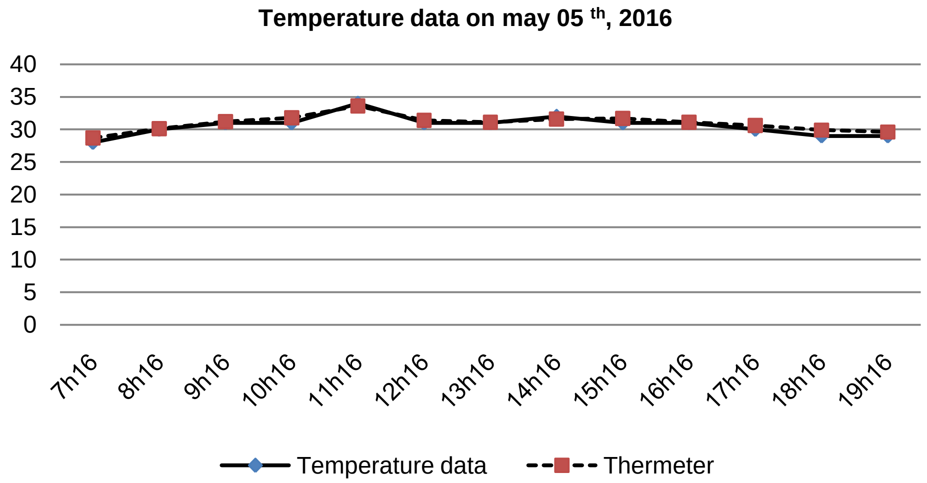


Figure 15. Temperature data on May 05th, 2016

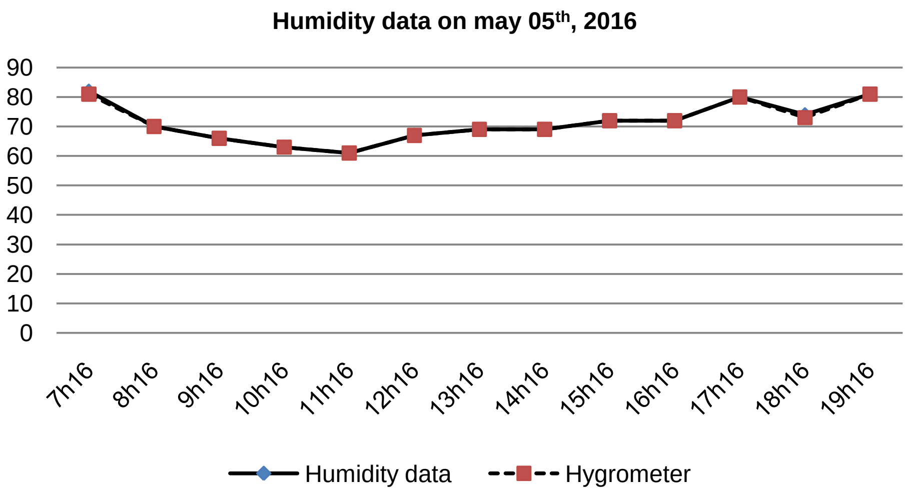


Figure 16. Humidity data on May 05th, 2016

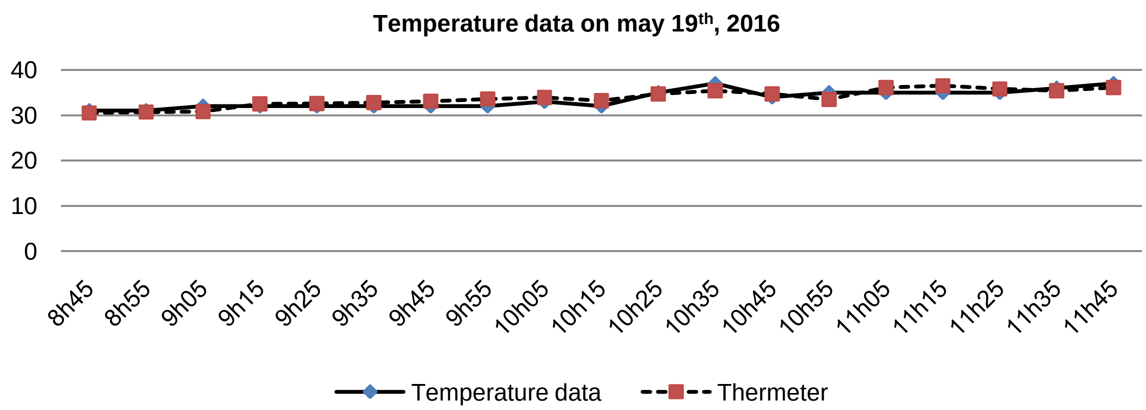


Figure 17. Temperature data on May 19th, 2016

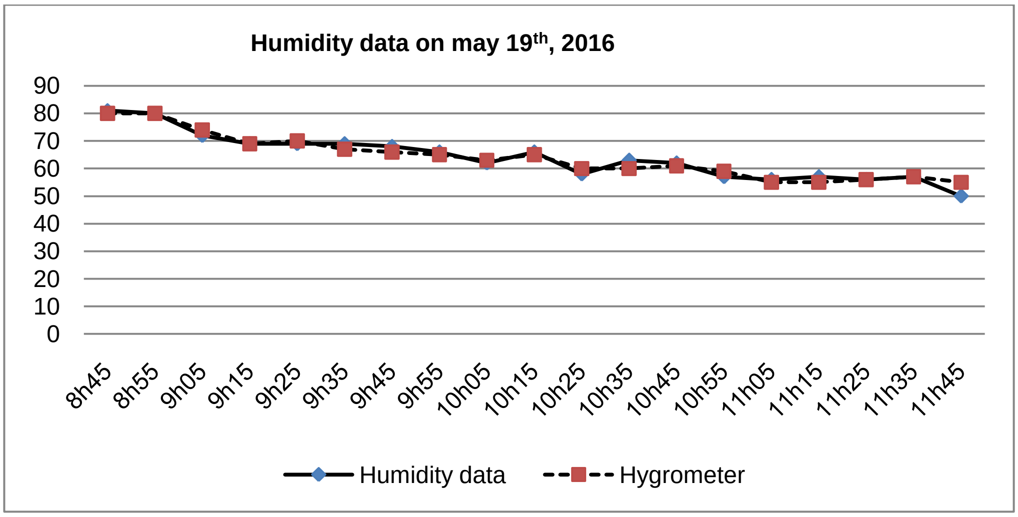


Figure 18. Humidity data on May 19th, 2016

4. CONCLUSIONS

In this study, a wireless air temperature and humidity monitoring system was developed and tested. From the experiment results, we confirmed that the designed wireless sensor module and monitoring system can be applied in monitoring temperature and humidity in a greenhouse and outdoor environment.

However, there are some problems that need to be studied more carefully in the futures. The first is studying the power consumption of this design. The second is integrating more sensors in the module. The third is developing an outer layer of hardware devices to make it so the system can withstand the severe conditions of the outdoor environment.

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