Advances in Computer Science Research, volume 89
2019 International Conference on Wireless Communication, Network and Multimedia Engineering (WCNME 2019)

Design and Implementation of A PM2.5 Dust Detection System Based on ZigBee

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***Abstract*—According to the requirement of air quality (dust) detection in classroom and laboratory, a dust concentration detection system is designed. The system is based on bidirectional wireless communication technology and uses single chip computer as processor. It collects the concentration of dust particles in the air and air temperature and humidity information using DSM501 sensor system. In this paper, a wireless sensor network for monitoring dust concentration and environmental temperature and humidity is established by Zigbee technology. The detected information is transmitted to the host computer through wireless network for analysis and statistics. The PM2.5 concentration, temperature and humidity in classroom or laboratory air are measured and displayed. The comparative experiment proves that the consistency of the instrument is not more than 25%.**

Keyword—PM2.5; temperature and humidity; SCM; wireless transmission; ZigBee

I. INTRODUCTION

PM2.5 refers to particles smaller than or equal to 2.5 microns in diameter in the atmosphere, also known as particulate matter that can enter the lungs. PM2.5 is generally used to denote the concentration of dust or drifting dust in ambient air whose diameter is less than or equal to 2.5 um [1] [2].

The monitoring system of PM2.5 monitoring station is complex and its cost is usually over several hundred thousand RMByuan. Large monitoring systems cost more. A hand-held PM2.5 concentration detector has been developed. The devices are easy to carry and the measuring process is intuitive and simple. But it can only provide online real-time results detection, and has no data analysis and statistics functions[3].A small monitoring system has been developed in this paper. It monitors dust concentration in classroom or laboratory in real time, Analysis and statistics of data transmitted by wireless to computer host, Display PM2.5 Concentration, Temperature and Humidity with Terminal Computer, Measurement data can also be displayed or stored by other media such as mobile phones.

II. OVERALL DESIGN OF THE SYSTEM

A. Composition of the System

Dust sensor module and temperature and humidity acquisition module are used in the system. Real-time collection of dust concentration, temperature and humidity information, Transmission to computer host by wireless transmission system of single chip computer (SCM), Data analysis, calculation and statistics are carried out by the host computer.

A Wireless Sensor Network Based on ZigBee Technology with Low Power Consumption, Low Cost and High Stability, It is used to monitor dust concentration and air temperature and humidity[4]. Using Netbeans as the development environment, TWaver Java software package is selected to make the graphical display of monitoring data more beautiful. ZigBee is used in typical periodic, intermittent and low reaction time data transmission[5].

The schematic diagram of the system is shown in Figure I.

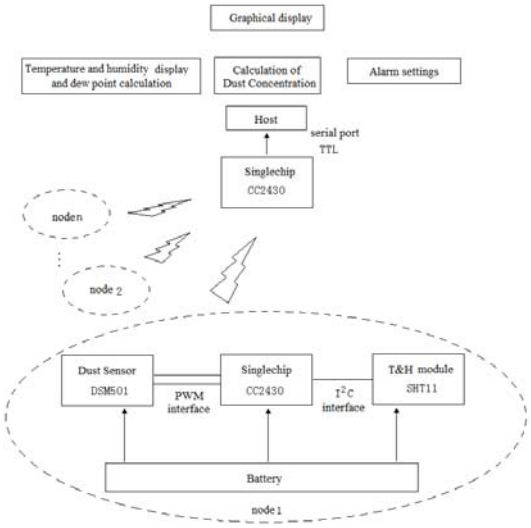

FIGURE I. SCHEMMATIC DIAGRAM OF THE SYSTEM

B. Workflow of the System

The workflow of the system is as follows:

①Building network: Connection between dust sensor, temperature and humidity sensor and front-end MCU; Establishment of Connection between Receiver MCU and PC (via USB interface); ②Receiving MCU and PC host begin to work, Prepare to build wireless networks and wait for front-end nodes to join, After the connection is established, Node information is fed back to the PC host; ③Open PC host software and wait for data transmission; ④ Power up front-end acquisition equipment; ⑤The PC host receives the address information of the front-end equipment through the receiving MCU, Wireless transmission network has been established; ⑥The system software analyses and calculates the received dust concentration, temperature and humidity information, and displays them with graphical results.

III. HARDWARE DESIGN OF THE SYSTEM

The main hardware of the system includes DSM501 dust sensor, SHT11 temperature and humidity sensor, CC2430 single chip computer.

A. CC2430 Single Chip Microcomputer

CC2430 MCU mainly realizes wireless transmission between sensor module and computer host [6].The transmission frequency is designed to be 2.4 GHz. The appearance of CC2430s circuit structure are shown in Figure II.

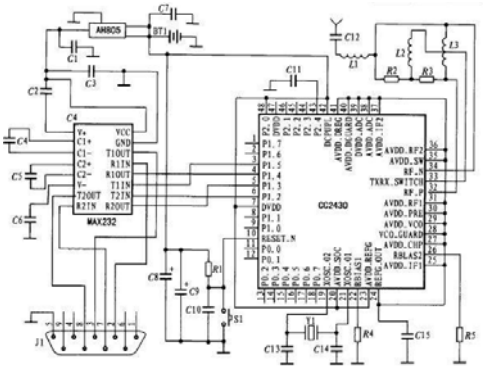

FIGURE II. APPEARANCE AND CIRCUIT STRUCTURE OF CC2430

B. Dust Sensor

The principle of DSM501 is based on particle counting [7].The principle of the dust sensor are shown in Figure III.

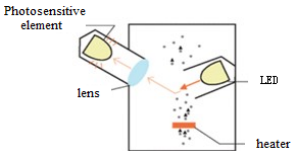

FIGURE III. PRINCIPLE OF THE DUSTSENSOR

The PMW signal is shown in Figure 4.The PWM signal waveform output by the sensor in 30 seconds (a measurement cycle) is shown in the figure. The relationship between the low pulse rate of dust sensor and the number of dust particles is linear, The characteristic curve is shown in Fig.5, Low pulse rate = (LT/UT) ×100%.The parameters of PM2.5 can be calculated as long as the low pulse rate per unit time is calculated and the number of detected particles can be obtained by referring to the characteristic curve [8].

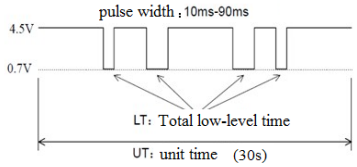

FIGURE IV. PWM WAVEFORM OF DUST SENSOR

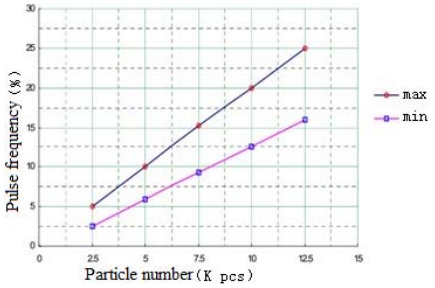

FIGURE V. THE CHARACTERISTIC CURVE

DSM501 Sensor Can Detect Particles More than 1 Micron in Diameter. It covers cigarettes, dust, fungi, pollen and so on in the air. Sensor built-in heater, can automatically inhale air. It is compact in size, light in weight and easy to install and use. The electrical parameters of DSM501 are shown in Table I.

TABLE I. ELECTRICAL PARAMENTERS OF DSM501 SENSOR

Electrical parameters		DSM501 Module
Range of operating voltage		DC5.0±0.5V
Output mode		PWM Pulse width modulation
output voltage	Low level (with particles)	0.7V(max1.0V)
	High Level (Clean Air)	4.5V(min4.0V)
The ability to detect the smallest particles		1μm
sensitivity		15000 个/283ml
Maximum operating current		90mA
Humidity range	Storage environment	0 to 99%RH
	work environment	0 to 95%RH
temperature range	Storage environment	-20℃ to 80℃
	work environment	-10℃ to 60℃
Stabilization time		About 1 min after the heater power is switched on

C. SHT11 T&H Sensor

SHT11 temperature and humidity sensor[9] adopt CMOS and sensor fusion technology. It can output digital temperature and humidity information in real time, the accuracy can reach about 2%~5%. It can meet the needs of system design.

SHT11 includes temperature and humidity sensor, amplifier, A/D converter, calibration memory (E2PROM), RAM, state register, serial interface, control unit, heater and low voltage detection circuit. The output of calibrated relative humidity and temperature can be given. With dew point value calculation output function. The resolution of humidity output is 14 bits, the resolution of temperature output is 12 bits. It can be programmed to 12 bits and 8 bits. It has the function of data transmission verification. The appearance of SHT11 temperature and humidity sensor is shown in Figure VI.

FIGURE VI. TEMPERATURE AND HUMIDITY SENSOR

IV. PREPROCESSING OF SENSOR SIGNAL

The data acquired by the sensor can be pre-processed before it can be input into the MCU and finally displayed on the PC. For the dust sensor, the percentage of the low level in every 30 seconds is the final required dust concentration data.

For temperature and humidity sensors, the collected signals need to be compensated linearly [10].

V. SOFTWARE DESIGN OF SYSTEM

The system software is divided into two parts: the ZigBee network software[11] and the system background processing software[12].

ZigBee wireless communication software is an important part of the whole software. Through this software, the functions of acquisition, reception and transmission of monitoring data can be realized, use C language as design language. This software transplants Z stack protocol and can support ZigBee system solution of CC2430.

The background processing software of the system realizes the functions of receiving, analyzing and statistic, on-line display and so on. It can ensure the friendliness and manageability of man-machine interface. The system software flow chart is shown in Figure VII:

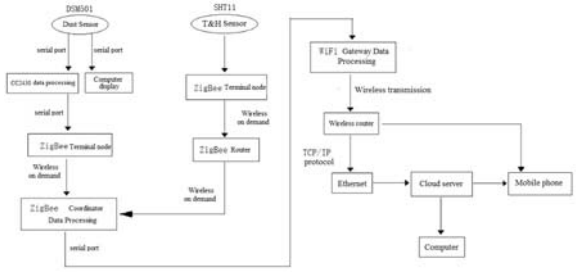

FIGURE VII. FLOW CHART OF SYSTEM SOFTWARE

This software design implements the following functions:

1. System login: System login requires user name and password. There are two types of users: system administrator and ordinary user;

2. User Management (System Administrator only): System Administrator can accomplish the functions of establishing, authorizing, editing and deleting ordinary users;

3. User operations: Users can complete data acquisition, display and change user passwords and other operations;

4. Monitoring Point Settings: Users can select monitoring points, add or delete a monitoring point, and set alarm threshold for each monitoring point;

5. Data browsing: Users can choose to browse current and historical data, and view alarm history records, etc.

VI. IMPLEMENTATION OF THE SYSTEM

The hardware connection of the system is shown in Figure VIII.

(a) Simulated test in laboratory box (b) Hardware Connection

FIGURE VIII. CONNECTION DIAGRAM OF THE SYSTEM

Firstly, the power supply is connected with the CC2430 wireless transmitter, and then the dust sensor and the temperature and humidity sensor are connected with the CC2430 wireless transmitter unit to form a front-end monitoring point.

The self-made USB interface board (realizing serial communication function) is connected with the C C2430 wireless receiving unit, and the receiving end is formed by connecting the USB port and PC.

The monitoring point equipment is placed in the laboratory environment which needs to be monitored, and the power supply of the front-end monitoring point is turned on, the system is started, and the wireless communication network of the monitoring point and the receiving end is established. Open the background processing software of PC to start the monitoring function. The system monitors the dust concentration, air temperature and humidity and other related information and displays them in real time. The interface of data acquisition and monitoring display is shown in Figure IX.

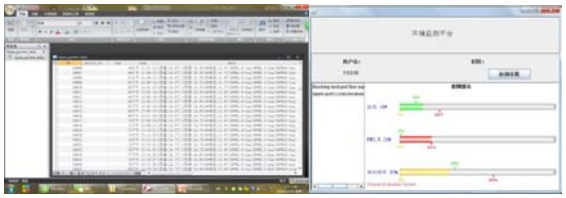

FIGURE IX. DISPLAY OF MONITORING

VII. DISCUSSIONS

The system uses CC2430 MCU as processor and low cost sensor module to collect dust concentration and air temperature and humidity information. A wireless sensor network for monitoring dust concentration and environmental temperature and humidity is established by ZigBee technology. The monitoring information is transmitted to the host computer by wireless mode, which realizes the wireless monitoring and display of PM2.5 concentration, temperature and humidity in classroom environment.

The experimental study shows that the consistency of the output signal of DSM501 sensor is poor[13],The measured value in the laboratory is about (+35%). Because DSM501 is an infrared dust sensor, its internal infrared LED light scattering particle signal is weak, so it can only detect more than 1 micron particles. The measurement accuracy is insufficient. In addition, DSM501 only uses heating resistance to drive the sampling air flow, and the number of sampling is small. The data calculation is completely handed over to the upper computer. Even after optimization design, it is difficult to achieve consistency less than (+20%) [14].The research

shows that the reasons affecting the consistency are the sensitivity of the photosensitive element, the focal length of the lens, the speed of the fan and so on. If the laser dust sensor is used, because of its own high performance CPU, the fan or blower is used to collect a large amount of data, and then the counting algorithm is analyzed, the data consistency of the laser dust sensor is better than that of the infrared dust sensor[15][16][17].

The system implemented in this paper only displays the information of dust concentration, temperature and humidity in real time, and has no data statistical analysis function. In the follow-up, we will study the statistics of monitoring data and the graphical display of analysis results. It can form a complete system of real-time acquisition, real-time display and analysis and statistics.

ACKNOWLEDGMENT

The paper is supported by the scientific research project of Beijing Polytechnic (projectcode YZK2016036; 2017Z004-009-KXZ; 2018Z002-020-KXZ).

REFERENCE

[1] Wang Wei et al. Study on the status and characteristics of atmospheric environmental pollution in China. Environmental Science Research, 2000, 13 (1).

[2] Environmental Air Quality Standard. Chinese National Standards 3095-2012.

[3] Yang Wang Jiayu Li He Jing Qiang Zhang Jingkun Jiang Pratim Biswas. Laboratory Evaluation and Calibration of Three Low-Cost Particle Sensors for Particulate Matter Measurement Aerosol Science and Technology.2015,11.

[4] Tan Long. Design of Environmental Monitoring System Based on Wireless Sensor Network. Heilongjiang Environmental Bulletin，2005,29(2).

[5] Dong Wei et al. Design of PM2.5 Pollutant Monitoring System Based on Cloud Platform .Computer Era，2016,2.

[6] QST Youth Software Training. ZigBee Technology Development: Principle and Application of CC2530 Single Chip Microcomputer. Tsinghua University Press, 2015.

[7] DSM501 User Manual. http://www.elecfans.com/soft/32/2016/20161217459991.html.

[8] Yang Ling et al. Study on the transmission characteristics of light scattering signals from dust particles. Photoelectron Laser, 2000,11(1).

[9] Li Min, Mengchen. Digital temperature and humidity sensor SHT11 and its application. Application of MCU and embedded system, 2011.

[10] Liu Jie. Design of Temperature and Humidity Controller Based on SHT11 Digital Sensor. Consumer Electronics, 2014.

[11] Heinzelman W, Chandrakasan A. Energ y Efficient Communication Protocol for Wireless Microsensor Networks[C] .In: Proceedings of the 33rd Hawaii Inter national Co nference on System Sciences. Maui: IEEE Computer Society,2000: 3.

[12] Guo Yuanbo et al. ZigBee technology and application CC2430 design, development and practice. National Defense Industry Press, 2015,8.

[13] Tao Zhuo et al. Parameter setting of atmospheric particulate matter concentration monitoring device based on DSM501 sensor. Computer measurement and control, 2015,4.

[14] Li Lifen et al. Environmental Monitoring and Control System Based on Embedded System. Modern Electronic Technology, 2017,19.

[15] Zhao Binchen et al. Design and implementation of a PM2.5 auxiliary monitoring system. Environmental Engineering, 2015,5.

[16] Huang Yongliang et al. Design and implementation of PM2.5 detection device for indoor air quality. Heilongjiang Science and Technology Information, 2016,9.

[17] Wang Ning et al. Intelligent PM2.5 Detector for Laser Sensors. Laser Magazine 2017.