Wireless monitoring system for temperature and humidity based on ZigBee

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Abstract

Traditional methods of environmental monitoring have the shortages including difficult network layout and low intelligent of node. A monitoring system for temperature and humidity was designed based on ZigBee (wireless network), with SHT11 (temperature and humidity integrated sensor) and CC2430 (wireless radio frequency module integrated with MCU). Data of temperature and humidity, collected at some acquisition terminals in SHT11 and CC2430, were displayed on monitoring host via centre node. By using solution of single chip ZigBee, the system was optimized with high precision, low power dissipation and simple equipment.

Keywords: CC2430 wireless network; monitoring temperature and humidity

1 Introduction

Environmental temperature and humidity are monitored in fields of biopharmaceutics, food processing, paper making and so on. Functions of current integrated intelligent sensors including such as linearization treatment, automatic temperature compensation and humidity calibration, provide favourable conditions for development of temperature and humidity monitoring system [1]. Wireless network can be easily built with ZigBee technology. Data are secure and stable during transmission with little influence from the terrible circumstance such as outside noise and strong magnetic field. In this work a wireless monitoring system for temperature and humidity was built with CC1010 (ZigBee wireless radio frequency module) and SHT11 (temperature and humidity sensor module). Measuring signal of local sensor is sent to monitoring terminal without setting quantities of temperature cables in conservatory. The system was optimized with real-time performance, high precision and overall treatment of nodes' temperature, as well as simplified installation and cost reduction.

2 Overall plan of temperature and humidity monitoring system

A star-like wireless sensor network was built with several ZigBee acquisition terminals and a ZigBee centre node (coordinator). Temperature and humidity sensor in the acquisition terminals collected environmental temperature and humidity data. The data were corrected by 8051 MCU embedded in ZigBee wireless radio frequency module [2]. Then, the corrected data were sent to centre node by wireless chips via ZigBee wireless network. All acquisition terminals have the same functions and implementation methods. Centre node was composed of a ZigBee wireless radio frequency chip and a USB module. As a network coordinator, the chip was responsible for generation, management and maintenance of the network. In detail, its duty included network address distribution for new equipment, access and departure of nodes, distribution and update of network security keys, etc. Furthermore, the chip should upload collected data to monitoring host, and send out orders from the host.

Monitoring host accepted all data of temperature and humidity and displayed them on PC screen for monitoring. The host periodically read serial port buffer and put data of from centre node into cache. Then, temperature and humidity data were extracted and decomposed by host. ID in each data packet was used to confirm data source. After that, the host displayed temperature and humidity information in real time. The host needed to judge residual energy through working voltage of acquisition terminal nodes. If the voltage was too low, the reliability of sensor data would be greatly reduced. And in that case there would be an alarm of battery replacement. Figure 1 shows structure of overall network.

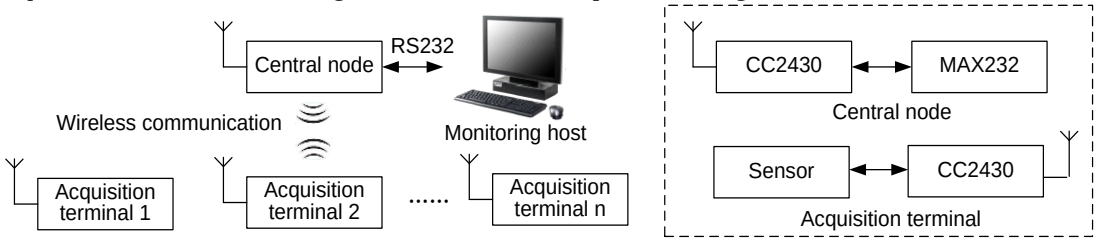

FIGURE 1 Overall design of the monitoring system

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3 Hardware of temperature and humidity monitoring system

3.1 DESIGN OF ACQUISITION TERMINAL HARDWARE

Acquisition terminal is composed of microprocessor module (with internally-integrated wireless radio frequency module), temperature and humidity data acquisition module and power module. Temperature and humidity data measured by sensor are processed by microprocessor chip and sent to centre node via wireless radio frequency. Figure 2 shows the structure of acquisition terminal. Instead of utilizing the combination of microcontroller and ZigBee, terminal with single ZigBee chip is optimized with high precision, low power dissipation and simple equipment.

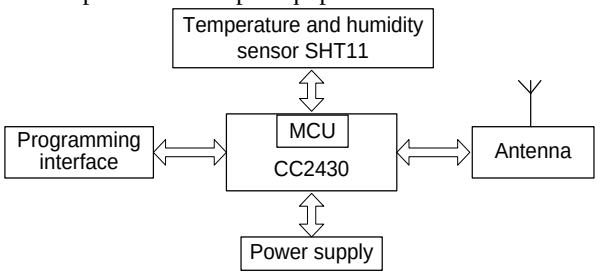

FIGURE 2 Overall block diagram of the acquisition terminal

3.1.1 Wireless RF transceiver chip CC2430 [3]

As core of acquisition terminal, CC2430 is a radio frequency chip produced by Chipcon, with low power dissipation and multiband. It is internally integrated with a 2.4 GHz RF transceiver of direct sequence spread spectrum, as well as an enhanced industrial microprocessor 8051. Microprocessor 8051 has an 8 KB RAM, a programmable flash memory, several timers (including a watchdog timer), a collaborative processor, a 32 KHz crystal oscillator sleep timer, 21 I/O connectors, power detection circuit and power on reset circuit.

CC2430 is also used in wireless radio frequency chip of centre node. Register RFMAIN determines receiving or transmission mode of chip. Seventh RXTX of 8-RXTX RAMAIN can be used to set modes: 0 as receiving mode and 1 as transmission mode.

3.1.2 Temperature and humidity sensor SHT11

SHT11, designed by Swiss Sensirion, is an integrative temperature and humidity sensor with two-wire serial interface. A capacitive polymer humidity sensor can detect the humidity, and energy gap temperature device is for temperature detection. Devices transform temperature and humidity information into weak electrical signals. Signals are amplified by operational amplifier and then directly sent into A/D converter, outputting digital signals via two-wire serial interface bus.

For convenience, debugging and calibration of data are implemented within chip. Besides, users can set measurement accuracy with resolution up to 8, 12 or 14 bits. CRC checking in chip ensures the accuracy of data transmission. Figure 3 shows the hardware connection diagram of SHT11 and MCU. Besides, DATA cable should be externally connected with pull-up resistor. Clock line SCK is used for communication between microprocessor and SHT11. SCK has no limitation of minimum frequency because its interface contains a whole static logic. If working voltage was higher than 4.5 V, frequency of SCK will be up to 10 MHz; else, maximum frequency of SCK will be only 1 MHz.

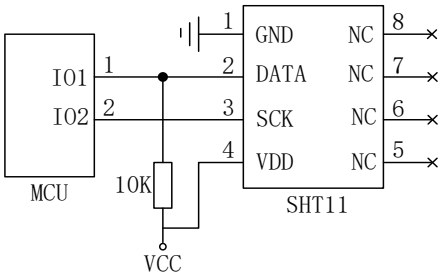

FIGURE 3 MCU connected with SHT11

3.2 HARDWARE OF CENTRE NODE

Centre node is composed of a ZigBee wireless radio frequency CC2430 and a USB MAX232. As a network coordinator, CC2430 can build, maintain and cease ZigBee wireless network [4]. CC2430 is connected with thirteenth pin $R1_{IN}$ and fourteenth pin $T1_{OUT}$ of MAX232 serial module with two serial lines - TXD0 and RXD0. Data are periodically sent to monitoring host via MAX232 USB (see Figure 4).

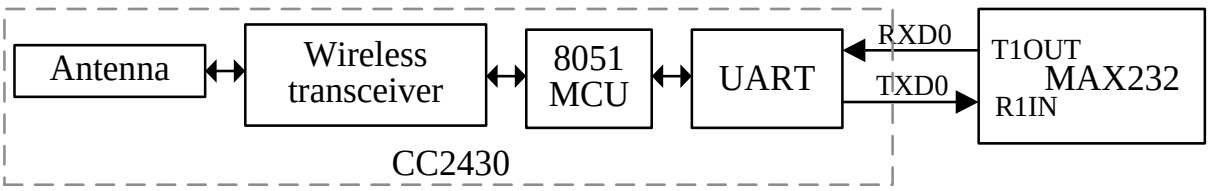

FIGURE 4 Block diagram of central node

CC2430 is regarded as the wireless module for acquisition terminal and centre node because it has four low power modes - PM0, PM1, PM2 and PM3. Largest power dissipation is on PM0 mode, while least power dissipation on PM3 mode. On normal state (PM0), wireless communication module will keep monitoring wireless channel to checks whether data have came. Wireless communication module is closed on other low power modes. Largest energy dissipation emerges on receiving state in normal work, while

slightly less on delivery state. Least energy dissipation results from dormant state. Therefore, system can enter dormancy as soon as possible for low power dissipation, with needless communication [5].

4 Design of system software

Software of system should have functions including building a ZigBee wireless LAN, collection, revision and delivery of temperature and humidity data, packaging, transport and display of each acquisition terminal data. Software design includes three parts, namely the design of acquisition terminal software, centre node software and upper computer system software.

4.1 SOFTWARE OF TEMPERATURE AND HUMIDITY DATA COLLECTION

After acquisition terminal is power on, it will initialize hardware module and ZigBee protocol stack. Then, node searches ZigBee network nearby for accession. Once accessed, terminal turns into low power mode.

Collection of temperature and humidity information included two types – automatic and manual collection. Automatic collection was based on timer at terminal. Timer started after setting an initial value. It would cause interruption when time came to the set value, and the measurement of temperature and humidity began. After measuring, data were sent out via radio frequency, with terminal entering low power mode. Timer was reset for next timing. Thus, automatic collection can be achieved with such circulation.

In manual collection, monitoring host will send out query demand to appointed terminal. Sensor started to collect and process temperature and humidity data once terminal identified the instruction. Then, data were immediately uploaded to monitor host, achieving manual collection. Figure 5 shows the collection flow.

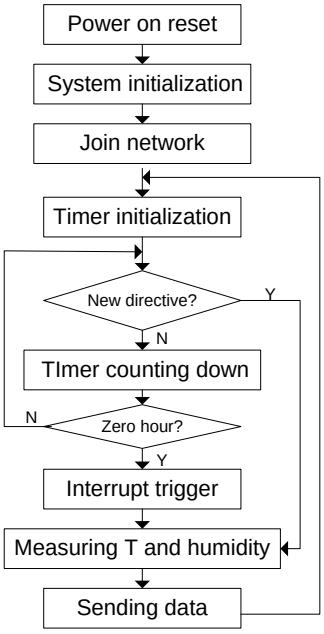

FIGURE 5 Flow chart of acquisition

SHT11 is a temperature and humidity integrated sensor with two measurement commands: 03H for temperature and 05H for humidity measurement. Temperature and humidity data, transferred from SHT11 to CC2430, were nonlinear relative value. The data was sent to centre node after linear compensation by using 8051 MCU embedded in CC2430 chip. Without correction and compensation, the data can be directly used by centre node, saving time on the correction of relative value. Humidity data of 12 bit was converted to actual humidity value. Relative humidity data N can be compensated with Equation (1).

$$RH_L = (-4 + 0.0405N - 2.8*10^{-6} N^2)\%, \quad (1)$$

where N is collected humidity data, and RH_L the transferred humidity value. For temperature's influence on humidity sensor, temperature correction for humidity sensor should be considered when actual temperature was far from 25°C (-77°F). Equation (2) was used for calculation of actual humidity value (represented as RH_T) with temperature compensation.

$$RH_T = RH_L + (T - 25)(0.01 + 0.00008N)\%. \quad (2)$$

Environment or other factors have little effect on SHT11 for its excellent linearity. Digital output of SHT11 can be directly transferred to temperature value with Equation (3). Value of d_1 was determined by working voltage of sensor, while value of d_2 was determined by resolution of sensor [6].

$$Temperature = d_1 + d_2 * SO_T. \quad (3)$$

4.2 SOFTWARE DESIGN OF CENTRE NODE

Software with star-like network topology was designed for centre node. As a coordinator, centre node had two major functions. One was to build a ZigBee wireless network. Web beacons were sent to domain spaces by CC2430 via antenna, so as to inform bound terminal nodes of establishment of wireless network.

Besides, acquisition terminal nodes should receive and reply requests for accession of network. PANid of request equipment was judged. If PANid was concordant, entrance of acquisition terminal was authorized, with an assigned unique 16 bit short address in network.

After ZigBee wireless network was built, acquisition terminal periodically sent temperature and humidity data to centre node via ZigBee wireless network. Useful information, such as temperature and humidity data and the unique short address, were extracted by centre node with accession of data packet. All the information from terminal nodes was processed to be a data packet with structure form. Then, data were then sent to monitoring host through MAX232 serial module. Figure 6 shows the process.

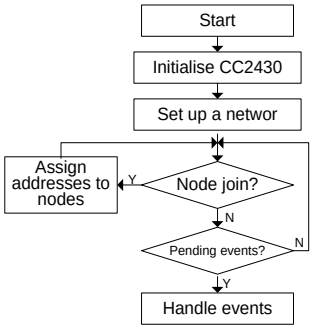

FIGURE 6 Flow chart of the main program in coordinator

4.3 SOFTWARE OF UPPER COMPUTER

PC was used as upper computer, mainly accepting data from centre node via serial port. Moreover, friendly human-machine interface should also be provided for real-time display of data, as well as storage management. Software of upper computer was developed by using VC++6.0 with Mscomm communication control. This control provided all functions of serial communication and achieved data reading or writing via serial port.

With simple programming and convenient debugging, the control encapsulated underlying operation procedure in the process of communication. Users only needed to set up and monitor properties and events of control. Asynchronous serial communication between users and applications can be easily achieved. Figure 7 shows the partial interfaces of monitoring software.

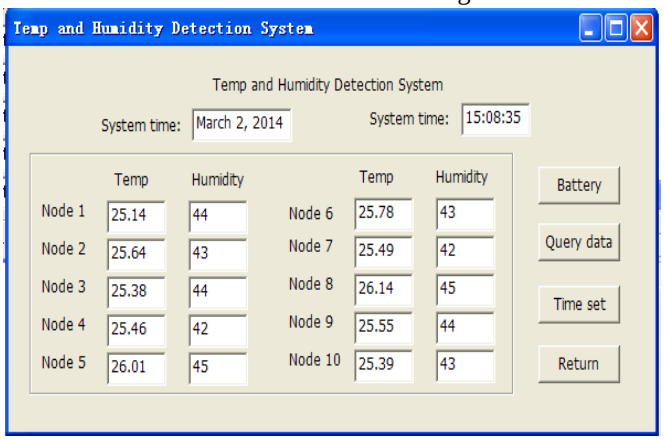

FIGURE 7 Temperature and humidity detection system

Temperature and humidity data management database was established with Microsoft Access 2003 in background. The database covered information of nodes number, temperature, humidity, acquisition time, etc. Table 1 was established in Access for the record and management of nodes formation.

TABLE 1 The node's information

Node number	Temp	Humidity	Battery power	Acquisition time
01	21	65%	48%	10:18:30

Data management of temperature and humidity acquisition terminal became convenient with the database design in this system. With friendly interface display, all databases of this system had functions such as adding, deleting and inquiry.

5 Experimental results

Two 1.5V batteries supplied power for centre node and ZigBee in the experiment. Different programs for centre node and ZigBee acquisition terminal nodes were downloaded by simulator before experiment. Ten acquisition terminals located in 10 different sites, with direct communication to centre node. Centre node was connected with computer via serial port, uploading received data to the computer.

Table 2 shows experimental data of 10 nodes. Test results showed that effective communication distance was about 50 meters in outdoors without obstacle. If there was an obstacle, communication in indoor was stable in 20 meters.

TABLE 2 Experimental values of temperature and humidity

	9:00		10:00		11:00		12:00		13:00		14:00	
Time	*T*	*H*	*T*	*H*	*T*	*H*	*T*	*H*	*T*	*H*	*T*	*H*
Node 1	25.0`4	45	25.45	43	25.87	44	26.01	45	26.31	44	26.28	45
Node 2	25.42	44	25.56	44	25.58	45	26.03	43	26.08	44	26.14	43
Node 3	26.01	43	26.13	42	26.42	43	26.55	44	26.64	43	26.58	43
Node 4	25.40	44	25.38	44	25.58	42	25.94	42	26.12	44	26.20	44
Node 5	25.14	45	25.28	44	25.31	43	25.33	43	25.39	45	25.48	44
Node 6	25.10	43	25.24	44	25.33	45	25.29	43	25.48	44	25.60	43
Node 7	26.14	43	26.18	43	26.20	43	26.33	43	26.38	44	26.46	43
Node 8	26.21	42	26.33	44	26.40	44	26.46	44	26.40	43	26.38	45
Node9	25.04	43	25.14	45	25.20	42	25.36	45	25.44	43	25.44	43
Node10	25.00	45	25.14	43	25.26	43	25.38	44	25.31	43	25.42	44

6 Conclusions

A ZigBee wireless network was built with ZigBee radio frequency chip CC2430. Data are sent and received on wireless, achieving point-to-multipoint data transmission and receiving. System can be utilized in many occasions to ensure the accuracy of data. With the same functions of wired temperature and humidity monitoring system, wireless system avoids the limitation of wiring, with low power consumption and high reliability. In empty place without obstacles, communication distance can reach as far as 50 meters, satisfying temperature and humidity monitoring.

Acknowledgement

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