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Design of Environmental Monitoring System for Livestock Transport Carriage Based on STM32 and ZigBee

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Abstract: *In view of the situation that it is impossible to monitor the carriage environment during the transportation of livestock, a set of environmental monitoring system for livestock transportation carriage based on STM32 and ZigBee is designed. The system is mainly composed of STM32F103 micro-control system, ZigBee wireless communication module, multi-channel sensor module, display module, buzzer alarm module, key module and power module, which can realize the functions of collection, transmission, display of temperature and humidity of the carriage, carbon dioxide concentration, abnormal alarm and so on. The test results show that the system operates stably, safely and reliably, and has high practical value.*

Keywords: *livestock transport; ZigBee; STM32; monitoring system*

At the current stage, due to the change of market supply and demand in the breeding industry, the demand for cross-regional transportation of livestock is also increasing. Slaughtering, off-site fattening, and introduction of breeding livestock are the main reasons for livestock transportation. Worldwide, about 60 billion animals are raised for food each year, most of them transported to the slaughterhouse. is the typical pattern and production mode of the beef cattle industry of our country that the northern cattle and southern cattle with different places for finishing. The consumption habits, industrial pattern and regional advantages have led to the long existence of the industrial pattern and production mode of the northern cattle and southern cattle with different places for finishing in our country, which makes cattle transportation the main body of the large animal transportation in our country. Because of the regional difference of breeding level and scale in our country, the introduction of breeding stock must carried out through transportation[1,2].

However, in the process of long-distance transportation, livestock are susceptible to environmental factors and stress syndrome, which leads to mental depression or hyperactivity, fever, fatigue and weakness, coma and even death of livestock. If not controlled, it will bring great economic losses to farmers or buyers. Therefore, how to effectively monitor the changes of temperature, humidity and gas concentration in the carriage during the transportation of livestock has become a key issue in the logistics of livestock preservation[3,4].

In order to improve the above situation, a set of environmental monitoring and alarm system based on STM32 and ZigBee is designed for livestock transport carriages, which can realize synchronous real-time acquisition and transmission, display temperature, humidity, carbon dioxide concentration in the carriage and abnormal alarm.

1. System overall design

The system is based on STM32F103 micro-control system, ZigBee wireless sensor network and multi-channel sensor, and is divided into two parts: mobile monitoring terminal and vehicle-mounted main control display terminal. The overall structure of the system is shown in Figure 1.

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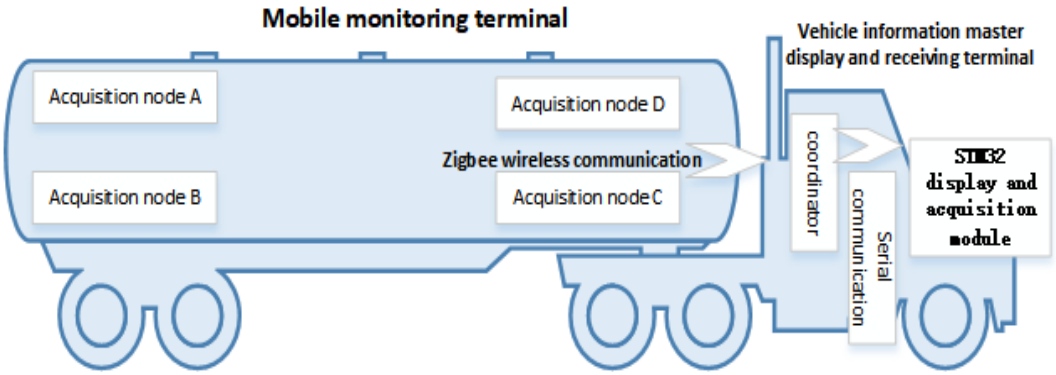

Figure 1: Overall system structure

The mobile monitoring terminal is mainly composed of ZigBee-based terminal nodes and coordinators. Terminal acquisition nodes are installed inside the carriage of livestock transport. Each terminal acquisition node is attached with temperature, humidity and carbon dioxide concentration sensors, which are responsible for collecting data of temperature, humidity and gas concentration in the carriage. The coordinators are mainly used as sink nodes to receive data sent by each terminal acquisition node in the carriage and send them to the vehicle-mounted main control display terminal.

The on-board main control display terminal is placed in the cab and mainly composed of STM32 embedded module. Its main function is to receive data transmitted by the mobile monitoring terminal coordinator, display the environmental conditions in the carriage in real time through the display screen, and display the alarm when the sensor state exceeds the alarm threshold, and prompt the following personnel through the buzzer.

2. System Hardware Design

The system hardware is mainly divided into Zigbee sensor network module and STM32 display and acquisition module.

2.1 Design of terminal collection node

The terminal acquisition node and coordinator are designed with TI's CC2530F256 as the core processor. CC2530 is a system-on-chip solution for IEEE802.15.4, ZigBee and RF4CE operating in the 2.4GHz band. Theoretically, its wireless transmission distance is 0 to 400 meters, and the transmission speed is up to 250kbps. It integrates an enhanced 8051CPU core and high-performance RF transceiver chip to meet the requirements of low power consumption and low cost of the system. The performance parameters of the CC2530 are as follows:

(1) The 8051 CPU core supports SFR, DATA, CODE/XDATA three different memory access bus modes, 8-KB SRAM and 256KB Flash ROM to ensure low power consumption and non-volatile program storage.

(2) There are 5 power supply modes, namely active mode, idle mode, PM1, PM2, PM3, which can provide different operation modes according to different needs and power consumption.

(3) Multi-functional 5-channel DMA provides efficient data transmission and operation.

(4) The ADC has 8 independent channels and supports 7-12 bit resolution.

(5) There are 21 universal digital I/O ports, 2 serial communication interfaces, and 2 timers. The CC2530 chip is equipped with the enhanced 8051 core, which has strong compatibility and can be compatible with analog-to-digital converters, serial ports, various sensors and external modules. CC2530 chip has stable and secure data sending and receiving function, which can meet the needs of this design.

TI company has integrated most of the functions in the CC2530 chip, so the peripheral circuit is relatively simple, the core peripheral circuit design is shown in the figure, in the design of most I/O ports reserved and led out, so that different circuit components can be connected according to different functional requirements[5-7].

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DHT11 digital temperature and humidity sensor is a temperature and humidity composite sensor with calibrated digital signal output. It applies special digital module acquisition technology and temperature and humidity sensing technology to ensure that the product has reliability and excellent long-term stability, low cost, relative humidity and temperature measurement, fast response, strong anti-interference ability, long signal transmission distance, digital signal output, accurate calibration. The sensor includes a capacitive humidity sensing element and an NTC temperature measuring element, and is connected to a high-performance 8-bit microcontroller. Can be used for HVAC, dehumidifier, testing and testing equipment, consumer goods, automotive, automatic control, data recorder, weather station, home appliances, humidity regulator, medical, other related humidity detection and control.DHT11 temperature and humidity sensor mainly relies on digital signal acquisition technology and temperature and humidity sensing technology to collect data, consisting of a resistance humidity measurement element and a NTC temperature measurement element, and connected with a high performance 8-bit microcontroller. In the design, each ZigBee terminal node is connected with a DHT11 temperature and humidity sensor, the temperature and humidity data collection accuracy is high, strong stability. Its accuracy humidity ± 5%RH, temperature ± 2 °C, range humidity 5% to 95%RH, temperature -20 to +60 °C.

JW01-CO2-V2.2 carbon dioxide sensor module is a digital sensor based on UART communication, the detection of CO2 present in the air using gas sensing sensors has good selectivity and no oxygen dependence, and has a long life. Built-in temperature compensation; Serial output value.the test range is 350 to 2000PPM.

2.2 On-board display hardware design

STM32F767 is a controller core with low power consumption, high performance and low cost designed by STMicroelectronics for embedded applications. There are many series, such as basic series, enhanced series and complementary series. This design uses the STM32F767 embedded development board produced by Star Wing Electronic Technology Company. The development board uses ARM Cortex-M7 enhanced core as the processor, uses 6-stage pipeline, and the performance can reach up to 5CoreMark/MHz. The STM32F767 development board has 512K SRAM, 512M NAND FLASH, and 512M NAND FLASH. With TFTLCD controller, USB high-speed interface, audio interface, SD card interface and other rich peripheral resources. The rich interface of STM32F767 can fully meet the design requirements of this system, and the 3.5 inch SPI touch display screen matched with STM32F767 is used as the display device. The buzzer is a simple structure horn, often used in a variety of electronic products, such as prompts, alarms and music and other occasions, when the data collection value exceeds the threshold, the buzzer emits a "beep" alarm sound; Otherwise, the buzzer doesn't go off. The key is a kind of mechanical control element that can be recovered. It is often used to control the switch of the circuit. The design uses four independent keys: respectively to achieve the switch between different parameters, threshold adjustment and close the buzzer alarm function[8].

3. ZigBee Wireless Communication Software Design

ZigBee is a short-range communication protocol based on IEEE 802.15.4 technical standard, which has the characteristics of short-range, low power consumption, low rate, low cost, duplex wireless communication and so on. As an open wireless standard, its transmission rate is between 20 and 250kbps, each ZigBee network can connect a maximum of 65536 terminal devices, any terminal node failure, other nodes can work normally. ZigBee aims to provide a foundation for Internet of Things (IOT) interaction, which is mainly designed for low-speed sensor integration systems and industrial control, it is widely used in building security, remote control, industrial control networks, remote meter reading, PC peripherals and many other fields. Compared with Bluetooth, Wi-Fi and other short-range wireless communication technologies, ZigBee communication transmission distance is longer, the longest transmission distance can reach 200m. ZigBee node network Node types consist of three types of network devices.

(1) Coordinator: It is responsible for building the ZigBee network, issuing addresses and managing and defining other functions of the network.

(2) Router: Router is a fully functional ZigBee node. It can not only join the existing network, but also send and receive routing information to play the role of connecting the preceding and the following.

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(3) Terminal node: The terminal node is essentially a simplified version of the router, it can connect to the network, send and receive data information, in addition, it does not act as an intermediate messenger node for any other device, the terminal node can use relatively simple hardware, can be intermittent power supply into the sleep mode to save energy. At the same time, the end node needs a coordinator or router as its parent device. The reason why ZigBee is so widely used in the field of sensor networks is due to its strong networking capabilities, which can support star topology and tree extension.

The coordinator node is not only the data receiving and sending center of the whole wireless network, but also the builder and maintainer of the network. After powering on, the coordinator node first initializes the ZigBee protocol stack and hardware; then starts to build the network, mainly including channel scanning, channel selection, node address allocation and other orderly operations; finally selects the terminal node to join the network. If the coordinator node receives the command to request to join the network, it will select the appropriate channel allocation logical address and return the allow command to the terminal node that sends the request command. After successfully establishing the network, when the coordinator node detects the spatial data, it will receive the data and transmit it to the data monitoring system STM32F103 through the serial port. The terminal node is the data collection node of the whole wireless network, which sends the water quality parameter data packaged by the data collection system to the coordinator node through the ZigBee wireless network. After powering on, the terminal node first initializes; then scans the channel, if there is a wireless network and a coordinator node, it will immediately connect to the coordinator node for confirmation; finally, after successful connection, it will send the data to the coordinator node according to the ZigBee wireless network communication protocol. It can wait for instructions when idle and is in a dormant state[9,10].The coordinator node software flowchart is shown in Figure 2.

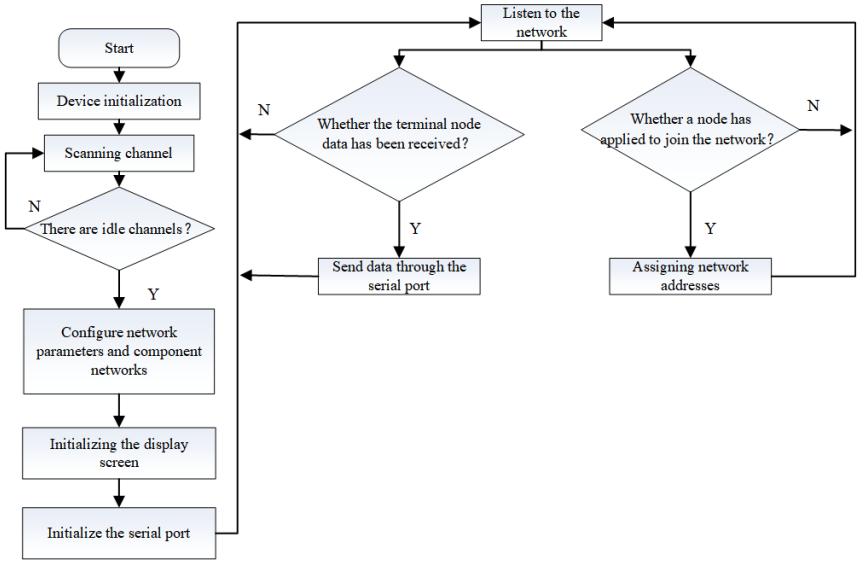

Figure 2: The coordinator node software flowchart

4. System Debugging

The overall hardware connection is shown in Figure 3.The hardware test is mainly to test the circuit of ZigBee terminal acquisition node and coordinator. Firstly, compare the schematic diagram to check whether the circuit connection of the terminal node and coordinator is correct, and check whether there are virtual solder, missing solder, pin path and short circuit in the hardware module. After checking the power test, first observe whether the indicator light is normal and whether the chip temperature is in the normal index range. After that, the multimeter is used to measure the voltage values of each I/O pin and power input and output pins of the module. After all-round detection, the parameters of ZigBee terminal acquisition node and coordinator node meet the requirements. The coordinator is connected to the STM32 single chip through serial communication, and the coordinator is started to form a network. When the terminal node and the coordinator are successfully connected to the network, the STM32 single chip receives data and displays the data collected by the node in real time through the display screen. When the collected data exceeds the threshold, the buzzer alarms.

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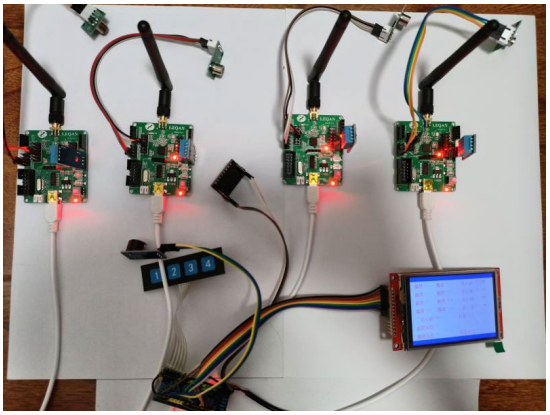

Figure 3: Overall hardware connection

5. Conclusion

The rapid development of electronic information technology has brought new opportunities for the cross-regional transportation of livestock. This topic makes full use of embedded technology, wireless network technology and sensor technology to design a set of environmental monitoring system based on STM32 and ZigBee for livestock transportation carriage. It realizes the functions of synchronous real-time acquisition, transmission, display of carriage temperature, humidity and carbon dioxide concentration, and abnormal alarm. Aiming at the shortcomings of the current livestock transportation process, it can greatly reduce the difficulty of monitoring and effectively reduce the economic loss caused by livestock death.

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