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Research Article

One Kind of Application Mode in Coal Mine Safety Production Based on Wireless Sensor Network

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Abstract: A design scheme of coal mine safety monitoring system is proposed in this study, which combines wireless sensor networks as a representative of wireless technology and CAN bus technology represented by wired communication technology. It presents a design method of software system and hardware system. This system conquers the defect of wired networks, improving the security and stability of data transmission and meets the design requirements of Coal mine safety monitoring system, which contain low-cost, low power, low complexity. So, this system has certain feasibility.

Keywords: CAN bus, safety monitoring, sensor, sink node, Wireless Sensor Networks (WSNs)

INTRODUCTION

The research on MSNs mostly has been concentrated in national defense and military, environmental monitoring, agriculture, health service, intelligent traffic system and Remote power meter reading system, etc., (Chen and Liu, 2009). But there has been a few of researches on safety production of coal mining.

In the process of coal mining there are many security risks and a variety of security incidents have occurred, seriously jeopardizing the lives of miners. How to effectively measure mine gas concentration, temperature, humidity and wind speed in real-time monitoring of coal mine safety production will become an important issue. Currently, monitoring system of coal mine underground environment mainly uses cable transmission, which has many shortcomings, such as wiring complex, high cost, line dependence and poor mobility. In this study, we construct coal mine wireless sensor networks with capacity of self-organizing and self-repairing, which can effectively overcome the above disadvantages. WSNs which are low-cost and high reliability can achieve the goal of real-time monitoring physical parameters that are related to coal mine work and ensure production safety.

In the traditional coal mine safety monitoring system, the facilities and equipments of monitoring system have relatively fixed position, which makes the sensor nodes cannot be put in place to follow up the progress with the excavation, together with the complex environment in tunnels where cause the large degree of interference with the sensors and make monitoring system existed in name only and underground networks naturally have some difficulties in wiring. For these reasons, the officer cannot effectively supervise so that the accident cannot be warned. Therefore, the idea is to design safety monitoring system to follow up with the progress of the excavation of the place and to enhance anti-jamming ability to transmit mine information to the monitoring center staff timely.

OVERALL DESIGN OF SAFETY MONITORING SYSTEM

The coal mine safety monitoring system in this study is based on the combination of Wireless Sensor Networks (WSNs) and Controller Area Network (CAN) bus and is to achieve the goal of monitoring target parameters fully and timely and giving early warning in coal mine. The specific structure is shown in Fig. 1. Sensor nodes will be arranged into stationary sensor nodes and mobile sensor nodes. Wind speed sensor-GWF15 will be deployed in underground tunnels as fixed sensor nodes with the distance of 50 m each one and temperature and humidity sensor-SHT11 will be used as mobile sensor nodes carried by the miners who goes down. These nodes that are self-organized into a WSN will transmit the information collected to the Sink nodes, which is passed to the monitoring center.

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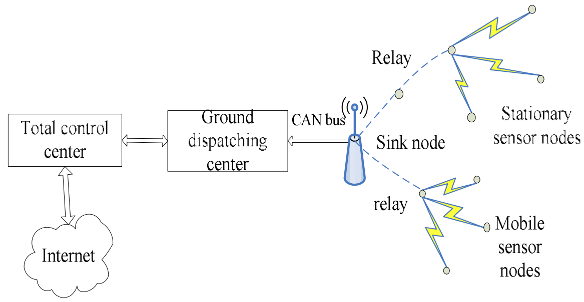

Fig. 1: Structure diagram of WSNs

WSN usually includes sensor node, relay node and sink node (Gao, 2008). Achieving data collection and multi-hop relay transmission is the main task of sensor node and relay node and sink node is used to complete collecting data and conversion between wireless signal and wired signal, with achieving access to Ethernet of CAN bus. Nodes which constitute a network of self-organization transmit monitoring data to sink node by the way of multi-hop relay technique and then, through the CAN bus, parameters target information will be sent to the local ground dispatching center (Zhan *et al*., 2006). According to the parameters target information collected in mine, ground dispatching center can monitor the coal mine in real-time, noticing changes in the parameters of targets at any time in sections of the coal mine, in order to make a sudden emergency response in a timely manner and send alarm messages to the dangerous zones based on accurate positioning technology. Ground dispatching center interconnect with the total control center through the internal private LAN, thus the total control center can monitor and manage all of coal mines in real-time. Meanwhile, the total control center will be connected with Internet, making the higher authorities checking and monitoring the overall information of safety production. Thus, it forms a coal mine safety monitoring system, a combination of wired and wireless, that enable monitor safety of both local and remote.

HARDWARE DESIGN OF WSN NODES

Hardware architecture of sensor nodes: Sensor node usually consists of sensor module, processor module, wireless communication module and energy supply module, among which the main structure is the processor module and wireless communication module (Wang *et al*., 2007). The node devices are designed in line with Zigbee technology within CC2430 RF transceiver. CC2430 follows the structure of the past chip CC2420, which integrates Zigbee RF front, memory and microcontroller. It uses an 8-bit MCU processor with 128 KB of RAM memory, also includes

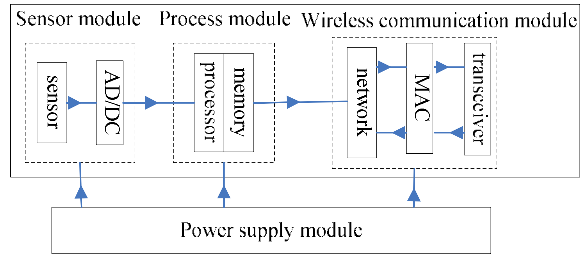

Fig. 2: Structure of CC2430

ADC, timer, AES128 co-processor, watchdog timer, 32 KHz crystal oscillator with sleep mode timer, power on reset circuit, Brownout detection circuit and 21 programmable I/O pins, plus wireless receiver. It is a development tool of anti-jamming with excellent sensitivity. The basic structure is shown in Fig. 2.

This structure of node not only eliminates the trouble of connecting the processor with wireless communication module, but also saves the cost of the node. It only needs to connect with needed sensor module through ADC access and through the I/O pins plus a miniature battery and then a design of WSN node module based on the Zigbee technology is completed, which saves considerable cost for the entire WSN monitoring system.

For the sensor node, the control chip is the core part of the device, because it coordinates the study of various parts (Liu and Zhang, 2010). Therefore, the choice of processor is essential. We select ATmega128L data processing module as a node microprocessor. ATmega128L has an advanced RISC core, which can execute most instructions in a single clock cycle. What's more, when the study performance is up to 16 MIPS at 16 MHz, it runs faster than most of the microcontroller. ATmega128L acquires the high-capacity of non-volatile program and data memory: 128 KB of in-system programmable FLASH, with Endurance of 10,000 times; 4 KB of EEPROM which has Endurance of 100,000 times; 4KB's on-chip SRAM. Therefore, it's sufficient enough to meet the requirements of the alarm program and data program.

Methane detection sensors use KGS-20 sensor which is a semiconductor-type gas sensor, specifically applying to the detection of combustible gas concentrations (Wu and Sun, 2009). The sensor is characterized by small size, low power consumption and the application circuit is very simple, alarm methane concentration ≥1%, response time of less than 20 sec, recovery time ≤30 sec, working temperature ranges between -15°C~+50°C and humidity is of not more than 97% RH, static power consumption is only 150 mW, the power consumption of the alarm state is 300 mW, using DC power supply voltage range of 3~5V, which is very suitable for detecting gas concentrations.

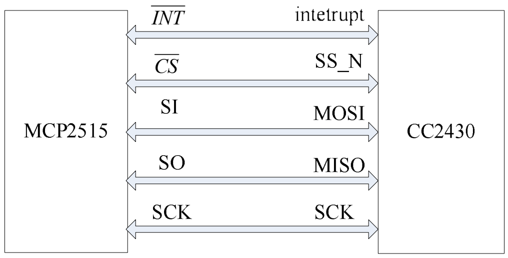

Fig. 3: Connection diagram of MCP2515 and CC2430

GFW15 wind sensor is a fixed intrinsically safety sensor, which is used to measure the speed of wind. The sensor is based on ultrasonic vortex theory and it uses the infrared remote control adjustment so that interference to the flow field around the sensor can be avoided during the course of calibration, which is to make the calibration more convenient and accurate. GFW 15 is the only one that uses unlimited read-write non-volatile memory chips, along with 24-h on-site data storage and query function (i.e., black box function). The main technical parameters of GFW 15 are as follows:

- Working voltage: 9~24 VDC
- Working current: ≤70 MA (18 V)
- Measuring range: 0.3~15.0 m/sec
- Fundamental error: ≤±0.3 m/sec
- Output signal: 200~1000 Hz
- Explosion level: intrinsically safe mine

Traditional analog temperature-humidity sensor needs to be calibrated carefully and complexly in the measurement of temperature and humidity and it requires the design of complex signal conditioning circuit and ADC circuitry, so it is not easy to apply (Wu *et al*., 2010). The study proposes to use a new type of digital temperature-humidity sensor SHT11, two wires serial interface, which can be used to measure relative humidity, temperature and dew point, characterized by digital output, free testing, calibration-free, free of the external circuit and so on.

Hardware design of sink node: Sink node is the core of first-level of WSNs. It is so powerful that it enables all the functions like the keyboard scan, LCD display, data backup storage, data protocol conversion and alarm to work. Sink node is designed to connect WSN with CAN bus. As with the sensor nodes, CC2430 is the core chip of the Sink node, which integrates a processor, memory and RF modules. As long as adding to a CAN controller, it can fulfill the protocol conversion between WSNs and CAN bus.

To simplify application design of CAN bus interface, as well as to improve the stability and efficiency of CAN bus communication, the CAN controller selects MCP2512. Microchip has introduced MCP2512 as an independent CAN controller with CAN bus control chip, which fully comply with CAN bus 2.0B technical specifications, together with industry-standard serial interface SPI. MCP2512, connected with the CC2430 by SPI, sets CC2430 the main mode and MCP2512 the slave mode. Connection diagram is shown in Fig. 3.

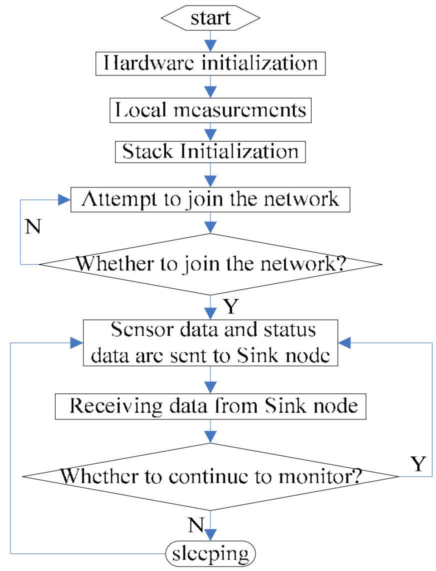

Fig. 4: Flowchart of sensor node

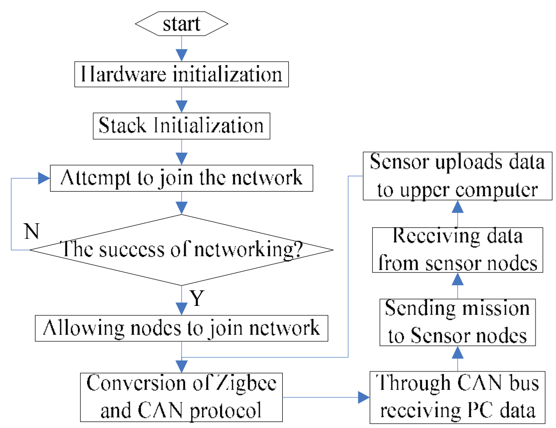

Fig. 5: Flowchart of sink node

DESIGN OF SOFTWARE ARCHITECTURE OF WSNs

Software design includes the sensor node software design, sink node software design and controlling software design.

Software design of sensor nodes: Sensor nodes will be primarily responsible for processing the collected data, then sends data to sink node, while receiving data from the sink node and do related operations based on those data. When there is no data to send or receive, it turns into sleep mode, so that the node power consumption is arriving at a minimum. The study flow chart is shown in Fig. 4.

Software design of sink node: On the one hand, Sink Node is responsible for establishing wireless networks; on the other hand, it combines two networks using different protocols together to achieve two kinds of communication protocol conversion between nodes and releases monitoring tasks of management nodes and forwards the collected data to the external network. Software flow chart of Sink node is shown in Fig. 5.

Design of monitoring software: Design of monitoring software, primarily done by the MFC, is responsible for display, analysis and preservation of the collected data. When the collected data is over pre-set alert levels, the monitoring system will issue a warning message.

CONCLUSION

In this study, we design a safety monitoring system that is used of MCU and it combines CAN bus with WSNs based on Zigbee. The obvious advantages are as follows:

- Sensor networks have a great number of nodes, with high distribution density and also have the capabilities of data fusion, thus it can save energy of the entire network and obtain more accurate information.
- When adding or removing some of the nodes, or changing in position of the nodes, or node failure, the network can repair itself and adjust the network topology without manual intervention and then we can make the whole system still work properly.

The results of this study will be served as foundation for a later research in Mine Internet of Things. The executive meetings of the State Council have made decision to pass the Safe production of the "Twelfth Five-Year Plan", which require to innovate new methods used in safety supervision of production and emergency work through applying the technology of Internet of Things which includes the electronic tags, fixed-mobile converged network and sensors, in order to further strengthen the enterprise to implement the main responsibility for safety supervision of production.

With the further development of technology, the real-time monitoring system, which is based on advanced industrial bus and WSNs, will be a better choice of safety production monitoring systems for coal industry.

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