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Research on the Key Technology of the Internet of Things in Mine Based on Wireless Sensor

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In order to the problems such as high wiring maintenance cost in wire communication and difficulty in comprehensive monitoring for mines, this paper proposes a mine environment monitoring system based on wireless sensor monitoring network of Zigbee Internet of Things. First, mine structure, main disaster factors, monitoring system demand, current research situation at home and abroad and development trends are analyzed to determine the monitoring system function demand and performance demand. Schemes for different links are discussed too propose a system structure meeting actual engineering demand. Second, detailed software and hardware are designed for the system. The hardware involves monitoring node module division, hardware selection and detailed hardware circuit design. Detecting environment information by monitoring nodes are realized in the programming by analyzing various monitoring modules. Finally, the system is tested and the results show that the system can realize real-time monitoring, display and other functions for mine environment information with stable and reliable operation to meet the mine environment monitoring demand.

1. Introduction

At present, coal is the top 1 among three major energy sources in the world (Cai et al, 2017). China is a major coal producer as well as a disaster-prone country (Cheng et al, 2016). In recent years, as the state is pay more and more attention to coal mine production safety, research on new technology to ensure coal mine production safety has become a hot spot.

There are limitations in adopting wire transmission inside mining roadways for mine monitoring system. One limitation is difficulty and high cost extending cables the roadways with varying structure. The other is difficulty in arranging monitoring nodes in mobile machinery and some special corners to realize comprehensive monitoring for mines. (Deutsch and He, 2017). The technology of the Internet of Things is a network technology to connect any item with the Internet as agreed through radio frequency identification technology, infrared sensors, global positioning system, laser scanner and other information sensing devices for information exchange and communication too realize intelligent identification, positioning, tracking, monitoring and management. One of the typical technologies of the Internet of Things is to combine sensors with wireless networking technology to collect data through nodes and transfer information through network to build a wireless sensor network (Dong et al, 2017).

Currently, wireless communication technologies represented by ZigBee, Bluetooth and GPRS are rapidly applied to wireless sensor network to realize wireless environment monitoring and information collection (Ganz et al, 2015). Since ZigBee wireless communication technology is characterized by low power consumption, low cost and simple application, it has become the research focus of the Internet of things in mine monitoring.

This paper designs a mine environment monitoring system based on ZigBee technology.

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2. Overall design of mine monitoring system

2.1 System structure design

A wireless sensor network is built for real-time monitoring of mine environment, mainly composed of sensor nodes, central control nodes and environmental information monitoring nodes (He and He, 2017). Environment detection sensor nodes are distributed at a certain distance in the monitoring area to form wireless network in a self-organizing way to constitute the wireless network, in the form of collaborative perceive, collect and process specific information in network coverage area in a collaborative manner for real-time collection, processing and analysis of information at any position. Data is transmitted back to the central control point through multi-hop relay with Zigbee technology so that data in the whole area is transmitted to the remote-control center for centralized processing (Jara et al, 2013). In consideration of real-timeness and convenience, the system is connected to the Internet via GMS and Wifi for online real-time monitoring of the overall mine environment in the form of Web. The system block diagram is shown in Figure 1.

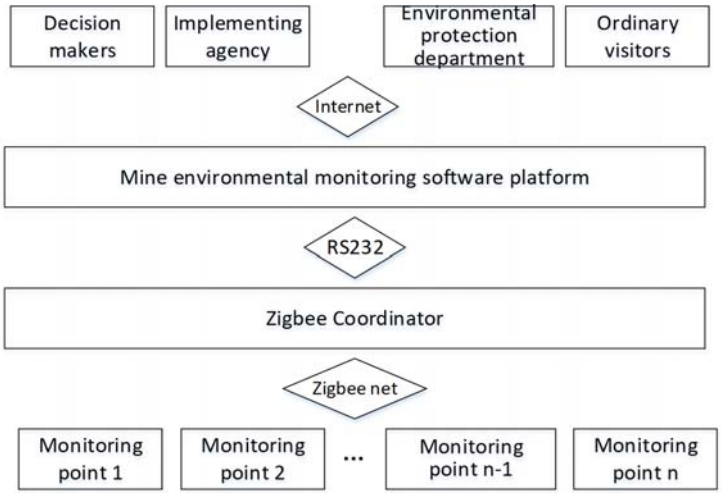

Figure 1: System of Mine Environment Online Implementation Monitoring

2.2 System function design

The upper computer queries the environmental information monitored by each monitoring node in turn by polling. The environment information which can be monitored by the corresponding sensors of monitoring nodes of the system are: methane and other gas concentration, temperature, humidity, wind speed and flame information (Jayaraman et al, 2015). The upper computer adopts Lab view to receive, store and display data.

(1) The inspection part of the sensors includes: real-time collection and alarm function of harmful gas concentration inside mines; real-time monitoring and alarm function of fire existence in various inflammable and explosive points in mines; natural wind speed detection and ventilation adjustment for vents and roadway corridors and other positions in mines; real-time collection and display function of the temperature and humidity in deep underground mining areas, personnel rest area in mines, various mining nodes and storage places for flammable and explosive materials.

(2) Standard Modbus protocol is adopted on RS-485 bus for communication between the monitoring nodes of network communication part hooked up to the RS-485 bus and the upper computer (Kaur, 2017) and ZigBee wireless communication is adopted for the monitoring nodes not hooked up to the RS-485 bus. It mainly has two functions. One is to send the query command from the RS-485 by the upper computer to the monitoring nodes of corresponding addresses through ZigBee wireless communication. The other is to send the monitoring data from the monitoring nodes through ZigBee wireless communication to the upper computer through the RS-485 bus.

(3) The LabVIEW software of the upper computer LabVIEW display part can display and store the of the monitoring data from monitoring nodes in a real-time manner and provide the historical data query function to facilitate acquiring historical data for analyzing downhole safety conditions by operators at any time (Li, et al, 2016). The upper computer is also equipped with a query command input box for operators to input a query command to view the real-time monitoring data and historical data curve of a monitoring node, realizing remote monitoring by operators.

3. Mine monitoring system design

3.1 Hardware system design

The electrical connection diagram of a monitoring node hardware is shown in Figure 2, including a processor module, a ZigBee wireless communication module, a RS-485 drive module, a gas sensor module, a temperature and humidity sensor module, a flame sensor module and a wind speed sensor module.

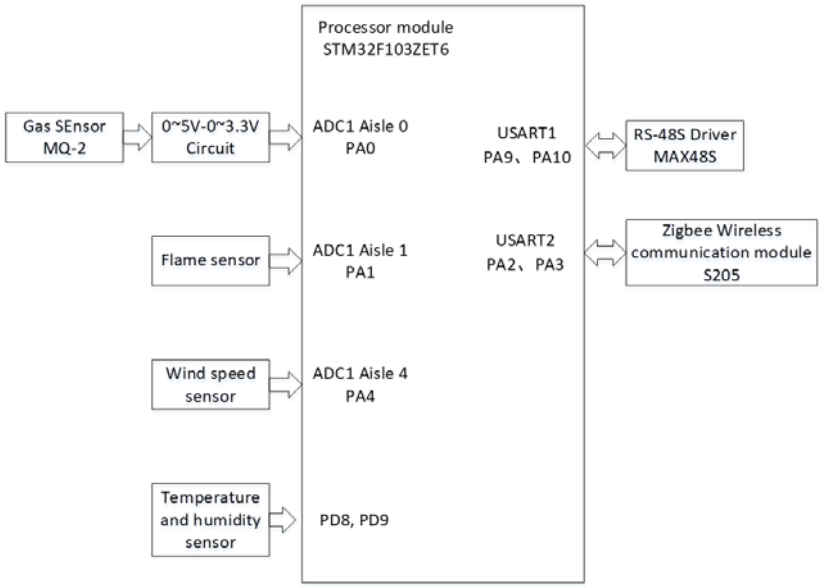

Figure 2: Monitoring node electrical connection diagram

(1) The microcontroller module adopts STM32F1-03VET6. STM32 is a high-performance, low-cost, low-power consumption processor based on Cortex-m3 kernel designed by ARM, a US company (Lin et al, 2017). The STM32 processor system mainly includes system reset circuit, clock circuit, power circuit and so on (Suto, et al, 2015). LM2576 is used to convert 5V to 3.3V and AMS1117-2.5 to convert 5V to 2.5V.
(2) Zigbee wireless communication module adopts the Wireless Anywhere (Shanghai Shuncom smart Technology Co., Ltd) SZ05, which can be a coordinating node, a routing node or a terminal node by setting parameters. The general transmission distance of the ZigBee module is 10-100m, but the visual transmission distance of SZ05 module can reach up to 2000 meters due to the increased emission power consumption (Usman, et al, 2017). 2.4GDSSS spread spectrum technology is adopted to enhance the anti-interference ability of nodes. The maximum baud rate can be set to 115200 with the antenna connected by a SMA. The device interface serve as the female connecter of SMA and SMA antenna interface as the male connector. Glue stick antenna, glass fiber reinforced plastic antenna or magnetic antenna may be adopted. The antenna may also be attached with radio frequency extension feeders.
(3) The sensor nodes in the mine monitoring system are the basis of system function realization, which completes mine parameter collection and self-organizing network of the wireless nodes in the same mine simultaneously, and sends and receives data information successfully (Wang et al, 2017). In addition to the requirements on indexes such parameter collection and power consumption from the sensor node itself, the requirements of the mine monitoring system on service environment, data transmission distance and speed are to be taken into consideration in the hardware design of sensor nodes (Xu et al, 2017). Functions, expansion capacity, cost and other factors of the mine monitoring system are to be comprehensively considered. See Figure 3 for the hardware diagram.

3.2 Software system design

ZigBee networking process: First, use the super terminal of the computer to configure parameters for each node, including the node type, networking type and node address, etc. Then, power-on nodes operate in accordance with the parameters configured on the super terminal, including networking type and node address (Xu et al, 2017). The node type may be central node, relay node, or terminal node at will, but there shall be only one central node in the same network. ZigBee modules in the same network must have the same type of network, network ID, radio frequency point, baud rate, check bit and data bit. And each module has a

unique module address, which is presented in 2 bytes. The center node address is 0000 which is fixed while the relay node and terminal may be any number between 0001-FFFF.

Since the ZigBee network of the system adopts mesh network, the network type of each node is also set to be mesh network. There are three sending modes, namely, broadcast, master-slave and point-to-point modes (Yang et al, 2017). Nodes send data received to STM32 through serial port. Since the return data frames in the system contain monitoring node address sent back, the data source address output of the coordinating data set to be no output. Since the routing node and the terminal node only receive data from the coordinate node, their data source address outputs are also set to be no output.

The wireless monitoring nodes for environment monitoring are initialized by energizing the nodes. ZigBee technology is used to build a wireless sensor network, which connects the coordinator and the software monitoring platform (Zhang et al, 2015). The wireless sensor nodes for environment monitoring in the wireless sensor network wait for upper level instructions at any time for data collection. The data is then uploaded to the system server through the sensor network for the upper level software to analyze the data. The detailed process is shown in Figure 4.

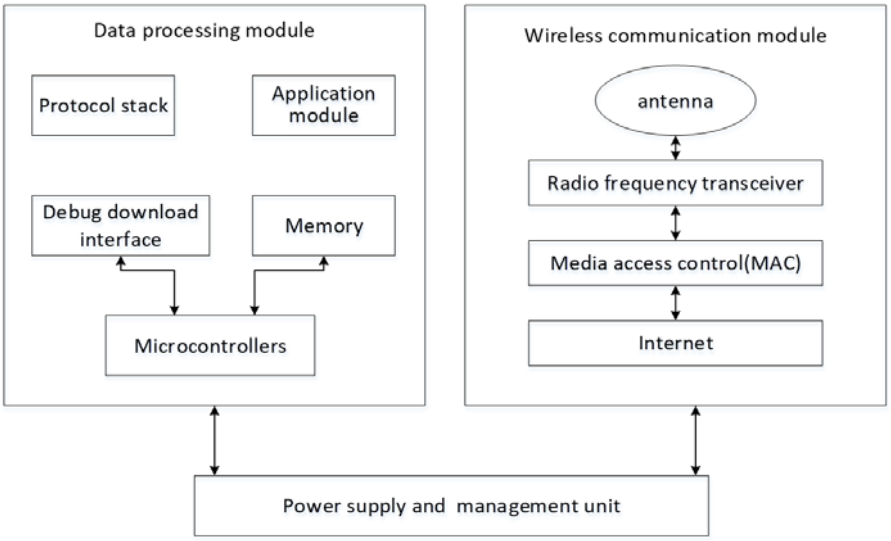

Figure 3: Connection of sensor hardware

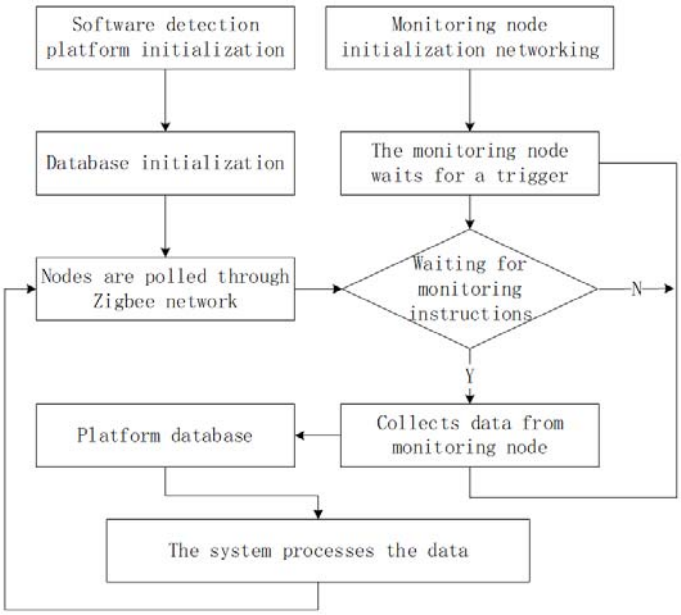

Figure 4: System operation flow chart

4. System testing

In the lab, wind speeds of different roadways in coal mines are simulated by varying the wind speed of a fan. A wind speed sensor outputs a voltage signal of 0-3.3V to a single-chip microcomputer, which calculates and displays the current wind speed in a real-time manner. When lit candles get close to the flame sensor, the flame sensor output voltage s inversely proportional to the distance between the flame and the sensor. Then the current flame can be calculated and displayed by the single-chip microcomputer in a real-time manner. (Zhang et al, 2016).

Despite a variety of gases to be monitored in mines, the most important is gas concentration followed by oxygen concentration, carbon monoxide concentration, etc (Zhou et al, 2013). The MQ-2 gas sensor adopted by the system can detect multiple gases. Considering environment limitations, a lighter gas is measured by the gas sensor. Move the lighter closer to the sensor and open the lighter to test the gases spaying out. The fuel used in the lighter are mainly combustible gases such as butane, propane and liquefied petroleum. To test whether the mine monitoring system can accurately and reliably monitor mine environment information, temperature and humidity data at different time from the monitoring system are recorded for in the test, as shown Table 1 and the monitoring data from the monitoring system at man-changed flame distances, as shown in Table 2.

Table 1: Monitoring data of temperature and humidity

		13:00	14:00	15:00	16:00	17:00
Measurements	Temperature(℃)	26.8	27.4	27.3	27.3	27.1
	Humidity(RH)	24.5	21.7	22.7	24.5	25.2
Actual value	Temperature(℃)	27.8	28.6	27.8	27.7	27.4
	Humidity(RH)	21.5	19.8	23.2	25.0	25.3

Table 2: The voltage value corresponding to different flame measurement distance

Distance(m)	0.02	0.1	0.5	1	1.5	2
Flame level	3	3	2	2	2	1

It can be seen from Table 6.1 that the measured temperature and humidity values by the mine monitoring system is close to the actual values, even at different time points, which suggests the monitoring system is accurate and stable in monitoring environment information. It can be seen from Table 6.2 that the mine monitoring system can accurately reflect changes in environmental information in a timely manner.

Therefore, the mine monitoring system can meet actual mine environment monitoring demand according to the experiment platform function test and experiment data accuracy and reliability test.

5. Conclusion

This paper proposes a mine environment monitoring system scheme based on ZigBee technology. The system structure and function principles are introduced and the overall design, and hardware and software system design are analyzed in detail. STM32 is adopted for the processor module, the ZigBee wireless communication module of Wireless Anywhere SZ05 for the ZigBee wireless communication to realize the process of inspecting environment information by driving the sensors by monitoring nodes through programming. This paper develops the communication mode of the monitoring system and the communication functions of the nodes, determines the realization process of ZigBee wireless communication of the monitoring system. Finally, a test system is made to test the realization of mine environment monitoring system functions and accuracy and reliability of data collected. The test results suggest that the system can display accurate environment monitoring information in a real-time manner with stable and reliable operation to meet the actual needs of mine environment monitoring.

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