Zigbee-based wireless gas monitoring sensor alarm system in coal mine

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Abstract. In view of the underground monitoring and monitoring system of coal mine, wired data transmission has been used in the past, but there are some disadvantages such as complicated wiring work, large amount of labor, fixed network structure which is not convenient to meet the dynamic requirements and low stability. Therefore, this study designs a monitoring system based on ZigBee wireless sensor network, wireless transmission, strong mobility, high reliability, low power consumption, strong real-time performance, etc, can be real-time monitoring of the coal mine environment parameters, including downhole temperature, humidity and gas concentration, and the acquisition of information sent by ZigBee wireless transmission way. STM32F103RBT6 is adopted as the wireless network processor in the system, which is responsible for establishing the network and transmitting data. NDIR HC sjh-5 CUBIC gas concentration sensor to collect underground mine data; Wireless SZOS embedded wireless communication module is used as the wireless sending and receiving port to enhance the wireless sending power. The software architecture adopts ZigBee protocol stack. The research shows that the proposed ZigBee wireless sensor network based coal mine underground gas monitoring system can help improve the real-time monitoring level and reduce safety risks in the complex and special environment of coal mine underground.

1. Introduce
Along with the country to the coal mine safety production work day by day taking seriously, the coal mine modernization management demand, the coal mine safety monitoring system more and more manifests its importance. Currently, a lot of mine production in China still in the cable sensor receives a monitoring and control terminal, this way adds to the cost and is not conducive to the overall detection and control, some places due to environmental factors can't laying cable sensor and control terminal, prone to monitor the blind spot, lead to the existence of potential safety hazard[2-3]. Therefore, a wireless monitoring device with strong mobility, high reliability, low power consumption and strong real-time performance is very necessary to meet the requirements of most mine monitoring environment. In order to achieve this goal, this paper studies a monitoring and sensing system based on ZigBee wireless sensor network, which can monitor environmental parameters in coal mine underground in real time, mainly monitor gas concentration in coal mine, and send data information through ZigBee wireless transmission mode[1].
2. Wireless Sensor Network

Wireless Sensor Network (WSN) is a multi-hop self-organizing Network system formed by a large number of micro-sensors deployed in the monitoring area through Wireless communication. It can cooperatively perceive, collect and process the information of the perceived objects in the area covered by the Network and send it to the observer. Wireless sensor network is a network system integrating monitoring, control and wireless communication. Environmental impact and energy exhaustion, the node is prone to failure; Environmental interference and node failure can easily change the network topology[3]. In general, most sensor nodes are stationary. In addition, the energy of wireless sensor network nodes, as well as their own processing capacity, storage capacity and communication capacity are very limited. The primary goal of traditional wireless network design is to provide high quality of service and efficient utilization of bandwidth. The primary design goal of wireless sensor network is energy efficient utilization, which is one of the most important differences between wireless sensor network and traditional network.

2.1. The structure of wireless sensor network

Wireless Sensor Network is mainly composed of three parts: server of remote control center, sink node, communication base station node and Sensor node. There are a large number of small sensors in a wireless sensor network, and each sensor is a network node, which constitutes a network. Most of the time, the network nodes are in a static state, and there is no need to consider the movement in space. Only a few nodes move to meet the needs of the measurement environment and make position adjustment. In this network, all nodes cooperate with each other to obtain the surrounding environmental information through node monitoring, roughly process and fuse the collected information, and finally transmit and summarize it to the sink node. The communication base station sends the received data to the remote control server for processing[4].

The composition and functions of wireless sensor network are shown in table 1 below:

| Remote control center | At the top level of wireless sensor network, it manages and summarizes the whole network. |
| Communication base station node | The intermediate network layer of wireless sensor network is responsible for transmitting the data collected by sensor nodes to the server side of remote control center. |
| Sensor node | At the bottom of the whole network, responsible for data collection and alarm. |

In wireless sensor networks, an arbitrary measurement nodes are random, they will spontaneously form a sensor network, any sensor node can roughly processing and fusion collected or information from other nodes, they have their own way of routing, able to jump to more to collect information and forwarded to nodes. The sink node has powerful data processing capability and wireless communication capability, which can transmit data information to the base station in a timely and reliable manner[2]. The base station can send the data to the server of the remote control center through satellite or Internet. The controller obtains the data through the server of the remote control center and manages the whole network. The connection of each part of wireless sensor network and the realization of the whole network are shown in figure 1.

![Wireless sensor network structure](image_url)
3. ZigBee protocol stack downhole data structure

3.1. ZigBee protocol stack
The basic software architecture of the network node of the protocol stack is based on IEEE 802.15.4, a certified wireless communication standard[6]. At a higher level, the software architecture of any ZigBee network consists of four basic protocol stacks: the application layer, the network layer, the data connection layer, and the physical layer. The application layer is the highest and the physical layer is the lowest, as shown in figure 2 below:

![Basic Software Architecture](image)

ZigBee's protocol stack is very compact. The storage capacity of full-function protocol is no more than 32K bytes, while that of simple function protocol is about 6k bytes. In addition, the fully functional equipment also needs additional RAM to store information such as the coal mine wireless sensor database, routing transmission table and equipment matching table of node equipment. In the application process, ZigBee protocol stack needs to solve the problem of data link access from the aspects of application technology layer and network data layer to ensure that the physical layer can meet the requirements of protocol control. The specific composition needs to meet the requirements of physical layer and data link layer control[6]. The hierarchy is shown in figure 3. Coal mine equipment object.

![ZigBee protocol underground coal mine stack](image)

4. The establishment of wireless sensor network

4.1. Sensor nodes in wireless sensor networks
In the whole wireless sensor network, the sensor node is the most basic and important functional unit, which has the functions of data acquisition, data fusion and forwarding. The components of sensor nodes are different and vary according to application. The typical sensor node is shown in figure 3.
which is composed of four parts: data acquisition unit, processor unit, data transceiver unit and power supply unit.

![Structure of sensor nodes](image)

The main functions of wireless sensor gas sensor node are monitoring and collecting gas concentration information, data information fusion and relay. In wireless sensor network, in order to make the whole measurement network have a very strong expansibility, the hardware and software design of each sensor node must be strictly unified, have a standard external interface, and have the same software control program, the only difference is the network node number that plays the role of identification. In this way, the number of sensor nodes can be increased or decreased freely and flexibly, and the scale of wireless sensor measurement network can be expanded or reduced[5].

Considering the characteristics of mine underground working environment and high density of sensor nodes, wireless sensor network gas measurement sensor nodes must meet the following principles[5-6].

1. low cost
   The higher the density of sensor distribution, the higher the measurement accuracy. Therefore, the number of network nodes in the area to be detected is relatively large. If the price of a single network node is relatively high, the cost of the entire network is too large to be applied on a large scale.

2. low power consumption
   In the measurement node, the power supply unit is the most basic unit in the whole measurement node, providing energy for the whole node. Each sensor node carries very low power, once the power is out, the node will not work. Therefore, power consumption must be considered.

3. flexibility and extensibility
   In wireless sensor network, the scalability of the whole measurement network should be guaranteed. Therefore, the hardware and software design of nodes must be strictly unified, and the standard external interface should be adopted. In this way, the number of network nodes can be increased or decreased freely and flexibly, and the scale of wireless sensor measurement network can be expanded or reduced.

4. wireless sensor network has strong self-healing ability
   Based on the above four principles, zigbee-based sensor network nodes are selected in this study. Zigbee sensor network is composed of various sensor nodes into a multi-hop network through wireless communication, and has the advantages of simple networking, small cost, strong self-organization ability and powerful expansion, which is very suitable for the construction of information platform for gas sensor detection in the coal mine environment.

4.2. Gas sensor unit
The sensor selected in this study is the infrared sensor NDIR HC sjh-5 CUBIC developed by Wuhan Sifang Photoelectric Technology Co., LTD., a professional company in the industry.

NDIR HC sjh-5 CUBIC working principle:
The infrared light source in the sensor emits infrared light of a specific intensity. When passing through the gas chamber filled with a certain concentration of gas, the gas absorbs a part of the light of a specific wavelength and reaches the infrared detector through the crystal filter. There are two crystal
filters, one for the characteristic wavelength of gas and the other for everything except the characteristic wavelength of gas. A pair of thermoelectric detection elements with temperature compensation performance acquire optical signals and convert them into electrical signals, as shown in figure 5. The NDIR HC sjh-5 CUBIC sensor’s filter has a central wavelength of 3.3 microns and can transmit up to 80% of its light at the central wavelength, which corresponds to the infrared absorption wavelength of the gas.

Figure 5. NDIR HC sjh-5 CUBIC working principle

NDIR HC sjh-5 CUBIC this gas sensor has a strong stability and good anti-interference, in addition to its long life, in addition, its optical part is not exposed to the air, to avoid dust and water covered in the optical parts caused fault to the sensor[7].

4.3. Design of data processing unit

The processor unit is mainly responsible for data collection and processing, as well as the control of the wireless communication module. After comprehensively considering multiple factors such as power consumption, stability, processing performance and cost of the system, STM32F 103RBT6 microcontroller is selected in this study, which is a 32-bit processor with low power consumption.

In consideration of the zero point correction, calibration data recovery and other operations of the sensor, different buttons are finally selected to control the selection of the above operations, and different leds are used to indicate each operation.

4.4. Wireless communication unit and power supply

Wireless SZOS embedded wireless communication module is selected, which integrates the standard rf transceiver and microprocessor, and adopts the standard serial data communication measurement mode.

Power supply side, the working voltage of SZOS need 5 V, MCU power supply voltage of 5 V, wireless sensor nodes each unit and the sensor work at the same time need two voltage of 3.3 V and 5 V, OP77AZ need to plus or minus 15 V, so for each sensor node selection of 24 V battery, can meet various measurement nodes continuous uninterrupted work for a long time.

5. Conclusion

ZigBee technology is developed from sensor network. In view of the complicated underground environment of coal mine and the difficulty in cable layout, ZigBee has a strong wireless networking capability. ZigBee wireless communication technology is adopted to replace the traditional cable communication mode, making the monitoring range more extensive and the monitoring mode more flexible. ZigBee nodes are divided into RFD, FFD and PAN. It is very suitable for special environment in coal mine and monitoring the environmental parameters in coal mine. Therefore, ZigBee network-based wireless sensor network in coal mine will make safety monitoring in coal mine more automatic, networked and intelligent, and further effectively guarantee the safety of underground workers.

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References

[1] Wang Hao, Li Uc, Shi Jintao. Research on channel allocation and routing technology in multi-interface wireless network. Science & Technology information, 2014, 35: 24-25.
[2] Yan Bing. Coal mine safety monitoring system in underground analysis and application [J].
Technology and Market, 2014, 10: 126-128.

[3] Hao Xiaochen, Ghang Yaxiao, Jia Nan, Liu Yin. Virtual game-based energy balanced topology control algorithm for wireless sensor networks [J]. Wireless Personal Communications, 2013, 69(4): 1289-1308.

[4] Si haifei, Yang zhong, wang dai. Research status and application of wireless sensor networks [J]. Mechanical and electrical engineering, 2011(42): 16-20.

[5] Zhao zhonghua, huang fuwei. Wireless sensor network management technology [J]. Computer science, 2011 (1) : 14-18.

[6] Jin guangchao, peng chenglin, zhao dechun, et al. Soil moisture monitoring system based on ZigBee [J]. Sensors and Microsystems, 2008(10): 13-15.

[7] Qin lei. Coal mine safety monitoring system based on wireless sensor network technology [D]. Wuhan: huazhong university of science and technology, 2007.