Coal Mine Monitoring System Based on Wireless Technology and ARM

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***Abstract*: This paper designs a monitoring system for coal mine safety based on Zigbee wireless Technology. The monitoring system collects temperature, humidity and methane values underground of coal mine through Zigbee around the mine, and then transmits the data to information processing terminal based on ARM. The terminal sends the data to the ground through Ethernet, and then the monitoring centre monitors the data and publishes them to the LAN for remote users to inquire. If the data is ultra-limit, the system can send SMS to related personnel of safety. This system has realized the real-time monitoring of working surface.**

I.INTRODUCTION

THE existing monitoring systems underground of coal mine mostly use cable network. This kind of network has poor performance of expansion. The cables are easy to aging and wear, and have high incidence of failures. With the working surface expanded, a blind area for monitoring appears, and then the new cost for installation and maintenance is needed. When an accident happened, especially explosion, the sensors and cables usually were damaged fatally, and couldn't provide information for rescue search and detection events [1]. Wireless sensor network can solve the key issues of communication bandwidth, mobile data transmission, staff orientation, working surface real-time monitoring, synchronization monitoring and so on. This article designs a monitoring system based on Zigbee technology to build wireless sensor network. The sensor nodes will send the collected data to an embedded network controller based on ARM kernel through multi-hop method. And then the controller receives the data and sends them to the ground PC by the conversion of Zigbee protocol to Ethernet protocol. With the concept of M2M (machine to machine, machine to mobile, mobile to machine), the ground PC transmits the monitoring results to the mobile phones through GPRS, and the abnormal situations can be dealt with in time. In addition, the mobile inquiring service can also be supported.

II. DESIGN AND PROPOSAL FOR SYSTEM

Compared with the current wireless technology, Zigbee is more suitable for data collection. Zigbee is a new wireless network technology with short range and low rate. It is a technology between labeling technology and Bluetooth, and the cost is much lower than Bluetooth. It has its own standards. The sensors sent the data to computer by multi-hop method, and the communication efficiency is very high [2].

A. Monitoring System Structure

The system can be divided into monitoring management layer, underground data collection and transmission layer according to the location. Underground data collection and transmission layer can be divided into the Zigbee data collection network and information receiving and processing terminal. Overall plan of system is as shown in Figure 1.

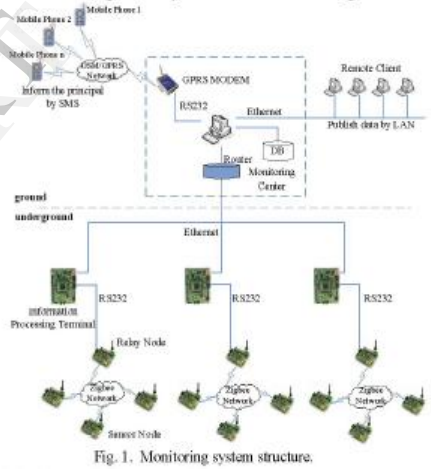

Fig. 1. Monitoring system structure.

1) Monitoring Management Layer

The monitoring management layer is on the ground, which includes the network monitoring center. The monitoring center composes of a monitoring IPC, routers, GPRS
MODEM hardware and monitoring management software.

The monitoring center is used to receive the collected data underground, process the data and assess the security situation underground at the same time. The centre also has a database management system, which can store and query history data, print report, and also control the Zigbee network underground.

The monitoring IPC is connected to the GPRS MODEM with the RS232. When the monitoring

data is abnormal, the system will send a warning message to the mobile phone of person in charge (user terminal), while users can also use the phone to send request message for the number of node and time according to the specified format to the management center, and then will receive the temperature and humidity information from the corresponding node and time. The monitoring centre can access to the LAN of mining area, and publish the data on the web for remote customers to inquire.

2) Data Collection and Transmission Layer

The data collection and transmission layer is underground of coal mine, which composes of various nodes. The nodes can be divided into three categories: Sink node: it has two applications: one is in charge of sending the data collected by sensor to information receiving and processing terminal and sending the orders to the nodes of sensor; the other is serving as the head-cluster, managing the data of cluster. Sensor nodes: they make charge of collecting methane concentration, humidity and temperature. Information receiving and processing terminal: it receives the local network data and sends them to the management center by Ethernet.

B. Network Topology of Wireless Data Acquisition

The space underground of coal mine is rather narrow, and the terrain is complex, which is impossible to spread nodes as on ground, so it is needed to take the configuration with fixed topology by manual [3]. According to the monitoring goal, it is divided into several regions. Then set a cluster head for each region. The heads of cluster compose network, and each cluster using a different channel. The communication radius of cluster head is longer than the communication radius of sensor node in cluster. In order to avoid the conflict of frequency, the distance between the cluster head d>2rs/3 [4] (rs is the communication radius of cluster head).In order to ensure the reliability of the communication each other, the distance between the head cluster rs>d>2rs/3. The topology is shown in Figure 2.

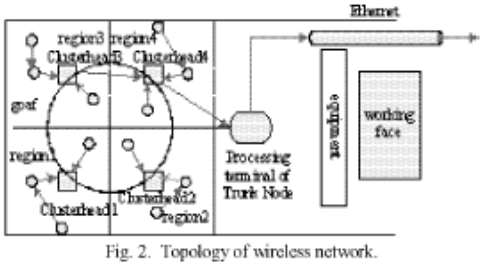

Fig. 2. Topology of wireless network.

III. SYSTEM HARDWARE DESIGN

A. Monitoring System Structure

The module of information receiving and processing terminal use the S3C44BOX microcontroller based on the
ARM7TDMI structure from Samsung, which integrates LCD controller, SDRAM controller, two serial interface controllers, PWM controller, 12C controller, IIS controller, real-time clock, AD transform, and other external control modules, and also provides Thumbl6-bit compressed instruction set and JTAG software debugging method, four kinds of power management mode [5].

The information receiving and processing terminal makes protocol conversion according to application. At least a RS232 is provided to connect with Zigbee node and two are designed in our project. In addition, a network interface must be provided to send the data to working surface. At the same time, ROM and RAM should be extended. The hardware structure of information terminal is shown in Figure 3.

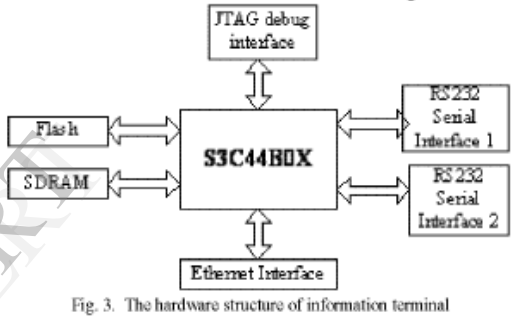

Fig. 3. The hardware structure of information terminal

B. Hardware Structure of Sensor Node

The hardware structure of sensor node is as shown in Figure 4. The controller uses the PIC1i8F4620 from Microchip Technology. It has the high quality, using a 16-bit
RISC instruction set. Its run-speed is the fastest among the current 8-bit single chips, possessing the capacity of completing 8x8 bit binary multiplication in a command cycle (minimum 160 ns); in some high-speed digital computing occasions it can replace the DSP chip. In addition, it has plentiful I/O control functions [6].

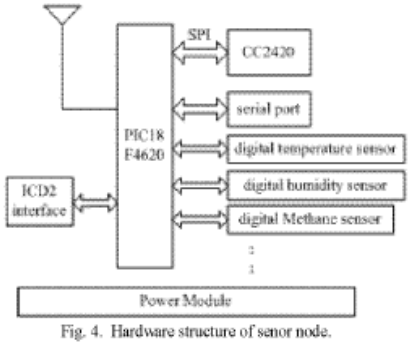

Fig. 4. Hardware structure of senor node.

The RF transceiver use the CC2420 RF transceiver from Chipcon, which realizes the

Zigbee protocol physical layer (PHY) and Media Access Controller (MAC) layer with 65,000 nodes and can be extended at any time. It has low power consumption, 250kbps speeds, fast waking time (<30 ms), CSMA-CA channel status detecting and other characteristics.

PIC4620 SCM connects with CC2420 through SPI BUS. The controller realizes the IEEE 802.15.4 MAC layer and the Zigbee protocol layer. It also includes the logic of specific application. It makes SPI BUS interact with RF transceiver [11].

The hardware structure of Sink nodes is basically the same with sensor node, only no having a variety of sensors. The energy of power module carrying is more than general sensor node carrying.

IV. SYSTEM SOFTWARE DESIGN

A. Software Design o f Information Receiving and Processing Terminal

The information receiving and processing terminal receives all the data from sink node through the serial port, and then sends them to the monitoring center by Ethernet. After program running, network card is initialized firstly to make necessary setting. If it is failed to initialize and then report errors. ARP request is sent three times continuously; if the response of ARP doesn't be received then error is reported. Then it waits to receive serial data. Next, it analyzes them to UDP data, adds them to the UDP data packet and then sends through Ethernet. The system realizes the content of UDP data segmentation mainly through the UDP upload the data frame. The frame format is as shown in Figure 5.

The overall program flow chart is shown in Figure 6.

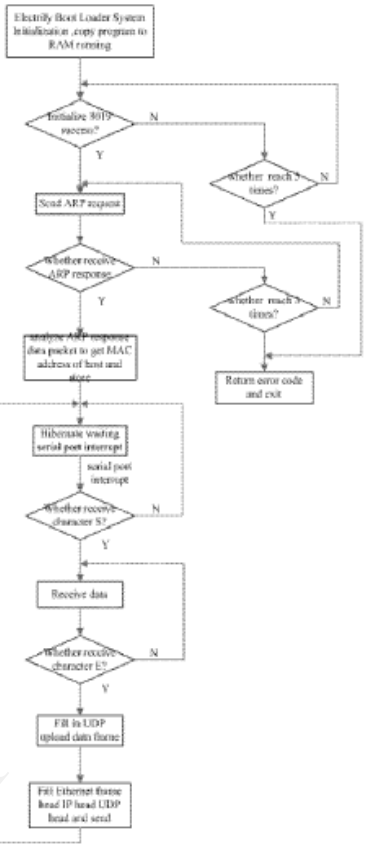

Fig. 6. Program flow chart of information receiving and processing terminal.

B. Software Design of Zigbee Node

The key of Zigbee node software design is to take full advantage of the Microchip protocol stack. Microchip protocol stack provides a large number of functions which can be user-friendly operated all levels layer of the protocol without caring the bottom layer. It can make the development process simplify to configure the protocol stack through ZENA, and then use the program template to design.

1) Software Design of Sink Node

The sink node works as a coordinator in the network. The sink node is initialized, and then it waits for the sensor nodes to join into the network. If the data have been sent, the data frame is sent to the information receiving and processing terminal through the serial port. If it uses as cluster-head, then data is sent with fusion of this cluster. In this paper, we will introduce the software design of connecting to the information receiving and processing terminal. The upload data frame format of sink node is shown in Figure 7. Program flow chart is shown in Figure 8.

Start mark Size 1B Content S	Node ID Size 1B	temperature Size 2B	Humidity Size 2B	methane value Size 2B	End mark Size 1B Content E

Fig. 7. The upload data frame format of sink node.

Start mark size 3B content UDP	Information type Size 1B Network Information Data Information	Node ID Size 1B	Temperature Size 2B	humidity Size 2B	humidity Size 2B	End mark size 3B content END

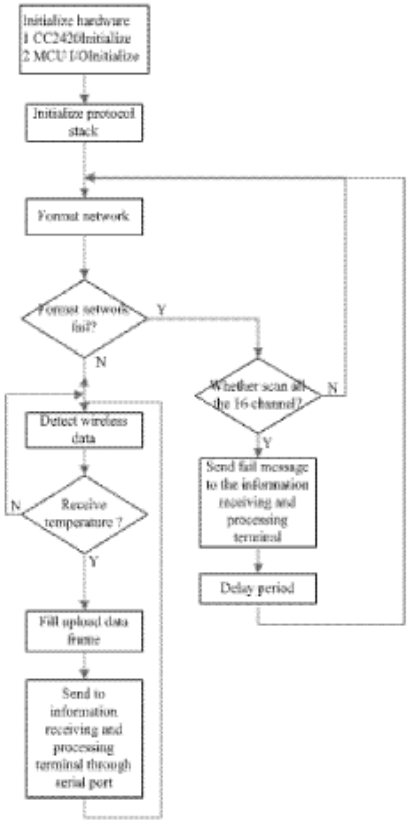

Fig. 8. Program flow chart of sink node.

2) Software Design of Sensor Node

Sensor node collects data cyclically, and then sends them to the sink node. Data transmission may be with the help of other sensor nodes or routing node. During Zigbee data transmission, we define two frame structures: KVP frame (Key Value Pair frame) and the MSG frame (Message frame) [7]. Both of the frame structures have cluster ID, and the KVP frame is stricter. KVP frame is a strict structure frame designed for transmitting a group of characteristic quantity, but the MSG frame is more freedom. In this paper we use MSG frame and its structure is shown in Figure 9.

Sequence Number	Transaction Length	Transaction Data

Fig. 9. MSG frame structure.

In the transaction data region of MSG frame, temperature, humidity and the value of methane concentration are included. The program flow chart is shown in Figure 10.

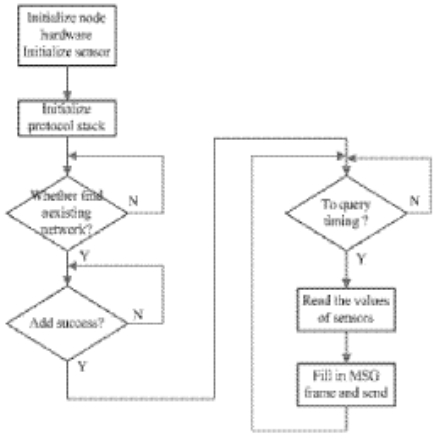

Fig. 10. The program flow chart of sensor node.

C. Software design of IPC

The software of monitoring centre system is mainly constituted by the following modules:

1) Module of Interface Management

The software of IPC should manage the Ethernet interface and serial port. Information receiving and processing terminal transmits the data to IPC through UDP. To communicate with information receiving and processing terminal, IPC software should establish Datagram Socket. Monitoring host sends and receives message through GPRS MODEM which is connected to the monitoring host through the serial port. IPC software sends AT command through the serial port to operate GPRS MODEM.

2) Display Module

The IPC software can display data of monitoring in real-time, show the connection status of nodes, and display nodes in the Zigbee network through graphics.

3) Database Management Module

Software should be able to store monitoring data and alarm information, which can be inquired at any time. It has the ability of printing reports such as the production reports in day/month/year or operation trend chart.

4) Alarm Module

It can provide High-Temp Alarm and Low-Temp Alarm of various types of failures, accidents and parameters. System can show the parameters of current alarm and look up the historical data of alarm.

5) SMS Send and Receive Module

It can automatically send messages to the person-in-charge when the data is out-of-gauge, and support inquires the historical data and current data.

The functional structure of system is shown in Figure 11

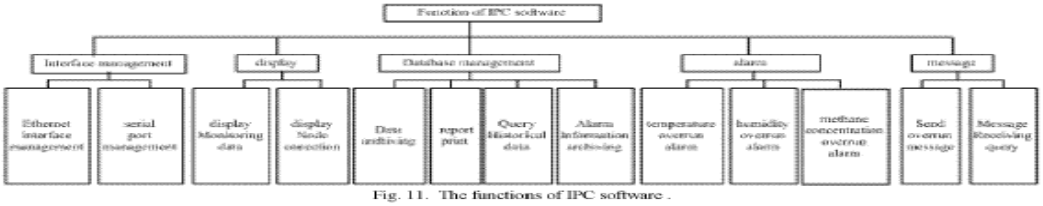

Fig. 11. The functions of IPC software .

V. ROUTING PROTOCOL DESIGN OF MINE SAFETYMONITORING SYSTEM

The routing protocol of IEEE802.15.4 / Zigbee protocol are designed on the base of AODV protocol, so the way of distributing data in the mesh network built by Zigbee is similar with the way of adhoc network. In this system all the nodes will send data to the information receiving and processing terminal, similar to a tree structure. So tree structure routing is more suitable for the system.

TinyOS Beaconing protocol is a simple protocol. Sink node periodically broadcast routing update message, and the node within rang of signal will be regard as a parent node and added into the routing table after receiving the updated information. Then broadcast again, and make up a root breadth priority tree with sink node. This way is simple and easy to use in the small-scale network, but it will increase the hop between a node and sink point in the larger network. The broadcast routing will consume the energy of network when updating message and the establishment of path is only in connection with the received beaconing. Because of weak optimization and poor expansion, the nodes around sink point easily become failure due to more data transmission and consume more energy. However, each node only saves its father node and son node, which saves the storage space.

Therefore following changes will be done on the basis of the TinyOS Beaconing [8] [9]:

(1) Root node does not require periodically routing update, because the nodes in the system are static and the topology structure is relatively stable.

(2) To prevent the imbalance caused by the nodes of the tree with too many child nodes and layers to consume excessive energy, the control of layers and child nodes is added. Through the NS simulation, network life-cycle can increase 10.02 percent, 13.07 percent higher than DSDV protocol.

(3) Transmit the acquisition data to its father node until to the terminal node. When requiring a node, the terminal node will find the virtual address in network from the routing table; calculate the address of the next hop node. Then the next hop node calculates its next hop according to the virtual address until to the destination node. the NS simulation, life cycle can increase 4.65 percent, 7.5 percent higher than DSDV.

(5) Add routing maintenance function to repair local routing. The NS simulation shows that it loses 15 packets before improvement, DSDV loses 16 packets, but by improving it only loses 1 packet under the same conditions.

(6) To prevent the energy of the nodes around information receiving and processing terminal consume too fast, these nodes are set as Zigbee routing nodes.

The simulation shows that the improved protocol has higher reliability and longer life cycle, which is suitable for mine safety monitoring application.

VI. CONCLUSION

The application of wireless sensor network will improve the safety of coal mine. The main advantages are as follows:

(1)The wirelesses are more flexible and can avoid the trouble of rewiring, because wireless network can meet the moving and changing of topology [1]. (2) It will greatly improve the performance and efficiency of data transmission of the coal mine safety system, and reduce the costs of extending the system. (3) In wireless sensor network, the old master-slave network can be transformed into the network without master to enhance the whole performance and stability of the existing sensor networks [3]. (4) The application of WSN can realize the real-time monitoring of working region.

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