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Coal and Gas Outburst Monitoring System Based on WSN

Ming Deng [a,b*], Qinhua Chen [b]

[a]College of Computer & Information, Fuyang Normal College, Fuyang 236041,China
[b]School of Mechanical Engineering, Anhui University of Science & Technology, Huainan 232001, China

Abstract

Based on small-scale and low-cost devices, Wireless sensor networks (WSN) achieves processing, storing, sensing and communicating. It can be applied in the physical dimensions of monitoring environment real-time monitoring, sensing and collecting. After analyzing the existing problems of monitoring technology on coal and gas outburst, the layer model of WSN-based monitoring system was proposed for coal and gas outburst. The emphases were put on sensor nodes and sink nodes. And the software design of micro-sensor was presented as well. Monitoring experiment results show that WSN is suitable for coal and gas outburst monitoring system for its low influence on environment, massive data acquisition and high detection precision. The new monitoring system, which combines WSN and coal mine safety monitoring and measuring system , makes up for deficiency of traditional monitoring techniques. It is an effective measure is to control coal and gas outburst danger source and eliminate the hidden trouble of gas accident. The study developed the technology of coal and gas outburst preventing.

Keywords: coal and gas outburst; WSN; sensor node; information processing

China is one of the countries prone to the most serious disaster of coal and gas outburst in the world. There are 199 coal and gas outburst accidents in total from January in 2000 to December in 2008, and the total casualty is 1063[1]. In the current, coal and gas outburst monitoring is mainly based on the empirical data of mining and some parameters of coal bed. The monitoring operability, timeliness and accuracy cannot satisfy the requirements of mining and safety management. Although the sudden change may appear after blow up or when cutting coal, the gas emission has certain regulation for a given working face in coal mine. At high-gas district, the change of gas emission may happen before the dynamic phenomenon induced by the gas. It reflects higher stress district existing and being in unstable state. Based on statistical data of the annual cases occurred at home and abroad, a lot of phenomenon often happen before or during coal and gas outbursts, such as gas emission abrupt increase, ups and downs and so on. And thus, coal and gas outburst can be monitored based on gas-detected.

Wireless Sensor Network is made up of a large amount of micro sensor nodes deployed in monitored region. The movable sensor nods have the characteristics of strength in the wireless communication and computation capability. This network can complete TT&C (tracking telemetering & command) and communication for one target [2-3]. And WSN is a feasible way to monitor coal and gas outburst for coal mine. This paper constructs a new outburst monitoring system based on WSN. It can inspect the sites which are inaccessible to traditional wire monitoring system and process monitoring data online.

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1. The summary of wireless sensor networks

Wireless sensor networks (WSN), which is a novel class of computing and a new spot of information technology, is made up of a large amount of inexpensive micro sensor nodes deployed in monitored region. Integrated sensor nodes can inspect, collect, process and transmit data of perceivable objects within the coverage of network by perceiving and controlling parameters. This kind of nodes has the functions of calculation, wireless communication, sensor and control. The WSN has drawn more and more attentions in the environmental monitoring field within the last few years.

Compares with the traditional real-time coal mine monitoring system, WSN has many advantages [4-6]:

(1) Nodes of WSN-based monitoring systems are usually deployed in bad environments (goaf, outburst area and gob caving band etc.), where traditional network facilities are difficult to be arranged. With distribution routing protocol and distributed algorithm, sensor nodes can be reconfigured and communication link can be established dynamically.

(2) Sensor nodes may be out of work at any time because of different causes such as modes exchanged between work and sleep, power exhausted, condition changed, awareness object moved. Consequently, topology structure of WSN is apt to change constantly with nodes communication interrupted.

(3) Since sensor nodes are miniaturized, the battery power of them is very low. What's more, they are often used in some formidable or unreachable circumstance. When the device is run out of the power, it brings the trouble of battery replacement. So, in order to reduce energy consumption and lengthen operating time, sensor nodes use the inter mitten working pattern. That means, once nodes receive no orders or data, they will choose to sleep, and on the contrary, they will work.

2. Design of coal and gas outburst monitoring system based on WSN

2.1 The architecture design of WSN

The WSN for coal and gas outburst monitoring consists of sensor nodes, sink nodes and manager nodes [7]. Fig.1 shows an architecture design of a monitoring system. A large amount of sensor nodes are deployed at working face with the tendency of outburst, and form the low level network by self-organization. They are responsible for collecting gas content. Each node of the network makes communication only with its adjacent node. The date-packet sent by each node in accordance with the agreement of the relevant multi-hop configuration is delivered to sink nodes, which are arranged in main roadways. Then the sink nodes transmit data to manager nodes on ground by wire network. Data will be processed and analyzed there, thereupon realizing the real-time monitoring of blind field in wire measurement. At the same time, the manager nodes may send orders to underground low-level wireless network.

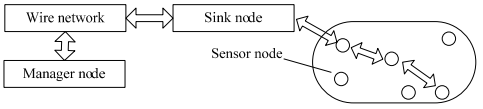

Fig.1 Architecture of coal and gas outburst monitoring system based on WSN

2.2 The hardware design of sensor nodes

A WSN node is a kind of micro miniature embedded system. What it transmits to a gateway is not raw date from environment, but the data needed handling. To set up a WSN for environment temperature monitoring, sensor nodes should work reliably and effectively, and miniature nodes designed must have low cost and low power consumption. The sensor node designed in the outburst monitoring system consists of a sensor module, a data processing module (memory, controller), a wireless communication module (wireless transceiver), and an energy module (battery or power). Fig.2 shows a hardware design of a sensor node.

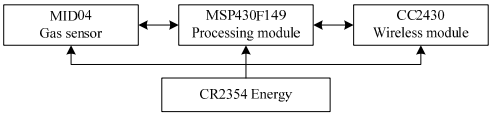

Fig.2 Architecture of a sensor node

In the monitoring system, the controller, the "computational engine" of WSN nodes, takes the charge of collecting and processing data, decides when to send and receive data, and judges the work of actuator. A kind of ultra low power consumption processor TI's MSP430F149 is used, which can work reliably and stably in bad environment. It is a special microprocessor chip facing embedded system applications with 16-bit CPU and high-efficiency RISC system. At 8MHz clock rate, the instruction period can reach 125ns. The chip is equipped with abundant peripheral modules, and has many different sampling methods and high sampling speed. The CC2430, adopted in the monitoring system, is a system-on-chip designed for IEEE 802.15.4(Zigbee). With 2.4GHz RF transceiver, enhanced 8051MCU, 128KB Flash ROM and 8KB RAM integrated in, the chip can provide an effective and reliable data rate of 250 Kbps [8]. The intelligent infrared gas sensor MID04 is used for outburst monitoring system. It has the characteristics of large dynamic detection range, rapid response time, high selectivity and so on. In order to meet the requirement of nodes small in volume, the micro miniature lithium-ion battery CR2354 is adopted. The output voltage is 3V, and the capacity is 530 mA.h.

2.3 The software design of WSN nodes

Software design are includes mainly signal acquisition software design and data analysis software design. The signal acquisition software runs on information wireless collection nodes of WSN. It is mainly responsible for data collection and wireless transmission via wireless communication module. The principle of light weight, modularization and local cooperation should be adhered to when software designed. At the same time, in order to adapt to the change of requirement and dynamics of WSN, the software must ensure very good adaptability.

Due to the limited power supply, sensor nodes have to switch between sleeping mode and awake mode at a low duty cycle to extend the network life-time. The sensors are on sleep to save energy and microprocessors stop working when there is no received signal. And wireless communication module remains accepting state with low current. When the instruction received from sink nodes or neighboring nodes, sensor nodes get into working automatically and wake up neighboring nodes. When the instructions are completed, the nodes come back to sleep state. Fig.3 shows the operation process of the sensor nodes.

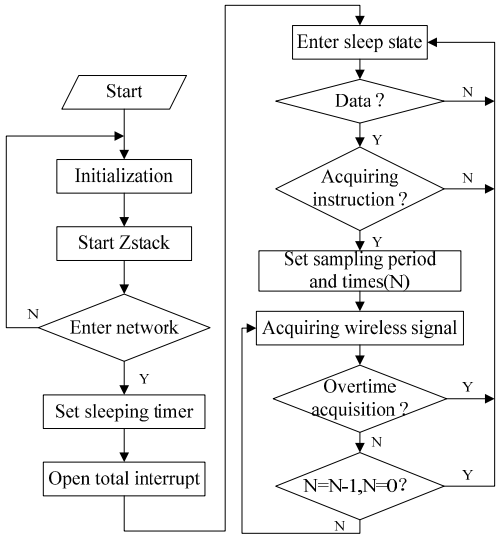

Fig.3 Operation process of the micro-sensor nodes

After node initialization, the ZStack protocol stack can work. When the nodes succeed in entering into the network, sleeping timer will be set and the interruption will be opened. Then the nodes come into sleep state and keep low power operation. As wireless information is monitored, the nodes will analyze and determine it. If the information received is effective, sensor nodes will be wake up and take the working pattern of collecting. At the

same time, the sampling period and times (N) are set. And then, the system collects and uploads the cycle of wireless monitoring information. This procedure continues until the times of collection are designated. The nodes enter sleep mode automatically after the end of the working.

The data analysis software works on remote computer. It is in charge of data receiving and recovery, network parameters setting and management. It also provides data interfaces for multilevel users.

3. Case analysis

The Panyi Coal Mine of Huainan Mining（Group）Co. Ltd is an oversize mine with annual coal capacity of 3 Mt. The main coal seams, NO.13-1 seam, No.11-2 seam and No.8 seam, are all high gas outburst seams. The mine experienced 25 coal and gas outbursts until 2007. The No.1551 (1) heading face, located in East No.3 Mining Area, was identified as bursting area and started working on June 27, 2009. In order to verify the feasibility of framework design of outburst monitoring proposed in this paper, field testing was taken at the No.1551 (1) heading face. Fig.4 shows the design of test.

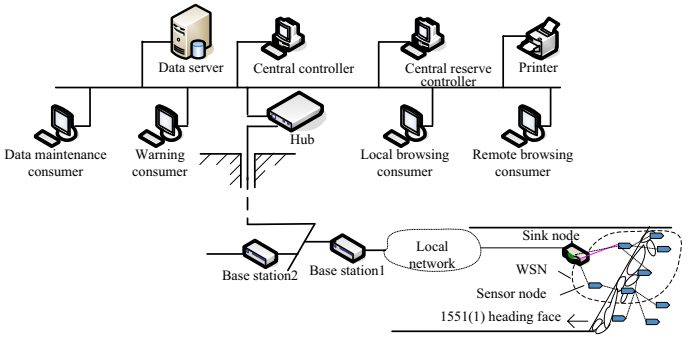

Fig.4 Test of WSN-based outburst monitoring system

Fig.5 shows the gas emission changing image of the No.1551 (1) heading face. The image was drawn based on the data acquired from the monitoring system.

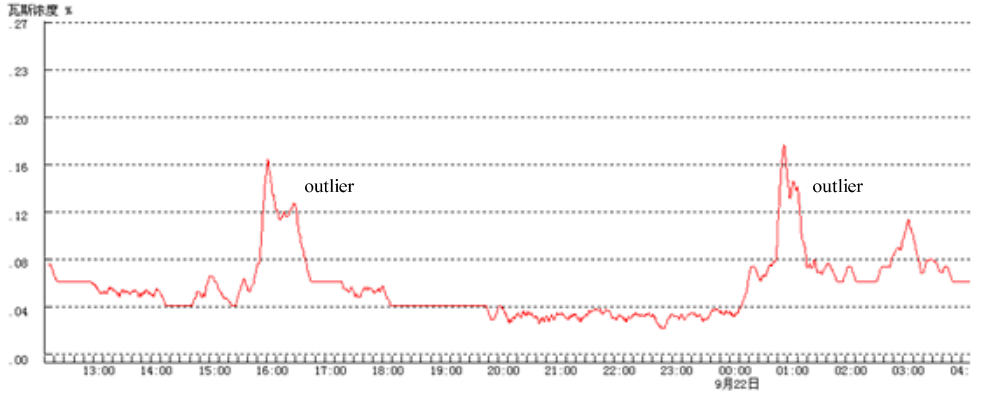

Fig.5 Sampling signal of No.1551 (1) heading face in Huainan Panyi Coal Mine

Fig.5 gives the characteristic of gas emission. During normal working conditions, the change of gas emission is small, and the gas concentration variation curve is plane and remains at 0.04%. At 16:00 on September 21, the gas emission concentration enhanced abruptly to 0.16%. After about 30 minutes it was back to normal. And then at 1:00 on September 22, what happened above appeared again. Related to the producing condition of the No.1551 (1) heading face, the obviously abnormal gas emission was caused by the change of production process and production progress. The long-lasting abnormal change of gas emission, the continuous rising tendency of the signal curve and

frequent fluctuating change are all warning information of coal and gas outbursts. And the cause must be found through exploration and analysis. Relate solutions must be put forward to eliminating hidden coal and gas outbursts.

4. Conclusions

On the basis of presented safety monitoring control system, a new system for coal and gas outburst monitoring was put forward base on wireless sensor network. The test results show, gas emission time-series can indicate the characteristic of coal and gas dynamical system. And the coal state in working faces of bursting area can be identified by analysis of signal received from WSN. The conclusion is a supplement to coal and gas outburst forecasting. And it will promote to research WSN used in coal mining safety monitoring.

For the complicate mine environments, lots of work is to be done, such as framework design, system testing.

Acknowledgements

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