2016 International Conference on Applied Mathematics and Mechanics (ICAMM 2016)
ISBN: 978-1-60595-399-1

Locating and Tracking System of Underground Miner Based on IOT

Wen-li JI* and Kang SUN

Communication and Information Engineering College, Xi'an University of Science and Technology, Xi'an, China

*Corresponding author

Keywords: Tracking system, RFID, WSN.

Abstract. Research on locating and tracking miner based on internet of things (IOT) will play a big role in miners' safety and accident rescue in mine. In this paper, we analyzed the network architecture of locating and tracking system, and proposed the method that locates one tag attached to miner underground by multiple readers, the reader is treated as a wireless node in WSN. We designed software of this system, which has functionalities querying miner information, locating miner, tracking miner, managing tag and reader.

Introduction

China's government strengthened the supervision of mine safety state in production in the 21st century. But the miners always used the fundamental appliances underground mine. The accidents happened frequently. According to the statistics, the death toll of coal mine accidents in China is four times of coal mine accident deaths in the other countries millions of tons' coal, mortality rate is 160 times that of the United States [1].

With the vigorous promotion by the governments, essential communication mode based on industrial Ethernet provides a real-time, reliable backbone transport network for the coal mine integrated automation system. China's coal mining enterprises also have set up all kinds of safety production monitoring system that play important roles in monitoring the equipment, environmental disaster and so on [2]. Due to the complex environment of underground, the miner and environment parameters is not able to be detected by cable network. The IOT provides a new approach to the safety of production and disaster forecasting in coal mine.

Key Technology

As a technique the IOT has wide application prospects, the goal is to perceive the world to connect each other at any time and at any place. Wireless sensor network is one of the solutions to solve the so-called "last mile" problem. It is a multi-disciplinary field, which consists of nodes of micro sensor that has the capability of perception, computing and communication. These nodes form multi-hop and self-organizing network by wireless communication mode. WSN is to be used in environmental monitoring and protection, aviation and aerospace placement control, military targets positioning and tracking in research field[3][4][5].

The WSN is appropriate for complex working environment. For the reason that wireless sensor has the characters of small size, high anti - interference, reliability, low cost, easy installation, etc.; it can also share information with existing safety monitoring system[6]. In addition, the WSN is not appreciably affected by air temperature, humidity in underground mine. But research has shown that there was problem of precision about locating personnel and equipment underground mine by only WSN, especially in a coal face.

RFID (Radio-Frequency-Identification) is a technology that uses electromagnetic field to transmit non-contact information, for purposes of automatically identifying and tracking tags attached to object. RFID can work in a variety of harsh environments, and supports multi-target recognition. Human didn't disturb identifying work.

A simple RFID system includes tags containing miniature antenna and readers. Each tag has a unique ID number. The reader exchanges information contactless with a tag. The reader antenna transmits a radio frequency signal to the electronic tags. RFID tag receives this signal through their antenna, the energy that comes from signal invoke integrated circuit chip in RFID tag, and transmit information to the reader wirelessly. Under non-line, the reader can read and write tag quickly within the coverage of it, and identify some targets at the same time. The successful application of these RFID provided valuable experience about miner location. At present, there are many scholars to research RFID positioning [7]. Chang proposed new method to locate access hole underground pipe based on RFID technology.

Framework of Locating and Tracking System in Underground Coal Mines

Networking Model

The network of this system is composed by existing industrial Ethernet and wireless sensor network. We use existing industrial Ethernet to transmit the data because the data transfer rate is high and the stability of system is increased in a mine. The reader communicates with the server through existing data-bus of monitoring system in tunnel. The WSN is laid in tunnel, the sink nodes connect to multifunction sub-station which connects to server by data bus.

The node in the tunnel can be classified two categories, one is sensor that collects security parameters and transmitting information for underground monitoring, the other is the node that contains the reader. The miner carried on tags, the reader reads the tag-data and transmitted to multifunction sub-station via wireless sensor network. The tag-data and monitoring parameters can transfer to position server through industrial Ethernet. Readers collaborated with the other reader by WSN. The RFID reader are located at fixed site to track miner or things by WSN. The system can be flexibly expanded due to using WSN. For example, we can layout some wireless nodes in tunnel where we cannot layout wired nodes. The monitoring data can be transferred to server by WSN.

The information of miner and tag was stored in database. When the miner was near or go through reader in tunnel, the information saved in tag can be read and transmitted to server computer in real time. Monitoring system can simultaneously display attribute information of miner and equipment. We could track miner and equipment by algorithm for the localization. The information of historical route was stored in the database. Network topology of the system shown in Figure 1.

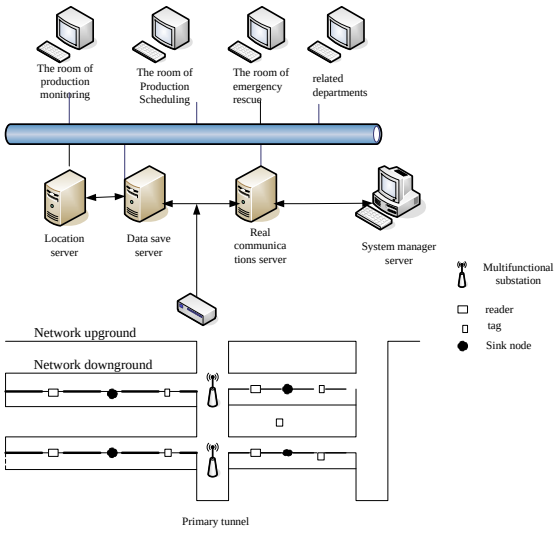

Figure 1. System network topology.

System Position Strategy

The equipment of system is integrated RFID reader and sensor nodes, passive RFID tags and the sink,

and functional sub-station. Integrated RFID reader and sensor node structure is shown in Figure 2. The main structure of this node includes a control system, central processing system, RFID modules and communication modules. The electronic tag included feature information of miner and equipment, and had a unique identification code, attached to the surface of an object. The antenna can be embedded in the communication module [8]. In this paper we propose to realize tracking miner in tunnel by RFID and wireless sensor network.

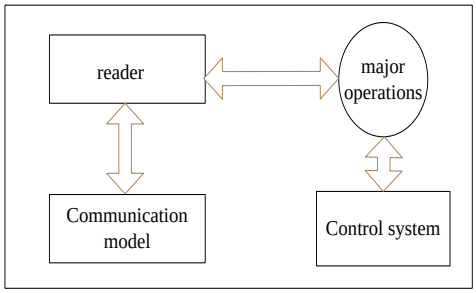

Figure 2. System node structure diagram.

This algorithm depended on fixed reader position when layout in the mine, location information of reader can be stored in the location information server. Readers and tags have unique ID identification number; we assume that the reader will collect tag information in every ten minutes. Each tag's information contains three properties for tracking (reader ID, tag ID, read time). The system will store the tracking information in the form of real-time database tables in the position information server.

The basic principle of Algorithm is to determine three readers which were max weighted by relevant strategy in tracking information table. As the location Information of the Reader is confirmed, we calculated the tag position based on signal strength of RFID system and positioning algorithm of free space propagation model [9-10], the information is stored in the tables which recorded the current miners' position and the historical moving data.

Following is the voltage signal strength free space propagation model:

$$P_{Ri} = \frac{P_t \bullet G_t \bullet G_{ri} \bullet \lambda^2}{4\pi D_i^2} \tag{1}$$

We set the power of the i reader received is P_{Ri}, transmitting power of tag was described P_t, G_t, G_{ri} represented Labels and the i reader antenna gain, D_i expressed the distance between tag and i reader. In read system, we can get the P_{Ri}, and other amounts were known, we could calculate the distance between reader and label.

As mentioned above, we could calculate the distance d1, d2, d3 between the readers R1, R2, R3 and the Label according to the Model. We use the maximum likelihood estimation method to calculate the accurate position of the tags. We assumed that the 3 readers' coordinates are (x1,y1),(x2,y2),(x3,y3), the coordinate of tag which need to be position is (x ,y). Then we can get the following formula:

$$\begin{cases} (x_1 - x)^2 + (y_1 - y)^2 = d_1 \\ (x_2 - x)^2 + (y_2 - y)^2 = d_2 \\ (x_3 - x)^2 + (y_3 - y)^2 = d_3 \end{cases} \tag{2}$$

Then we can get:

$$A = \begin{bmatrix} 2(x_1 - x_3)(y_1 - y_3) \\ 2(x_2 - x_3)(y_2 - y_3) \end{bmatrix}, X = \begin{bmatrix} x \\ y \end{bmatrix}$$

$$b = \begin{bmatrix} x_1^2 - x_3^2 + y_1^2 - y_3^2 + d_3^2 - d_1^2 \\ x_2^2 - x_3^2 + y_2^2 - y_3^2 + d_3^2 - d_2^2 \end{bmatrix} \quad (3)$$

Available point coordinates:

$$\hat{X} = (A^T A)^{-1} A^T b \quad (4)$$

The Feature Design and Implementation of the System

The system which is developed by using B/S mode and SSH development framework includes WSN subsystem, real-time positioning analysis subsystem and disaster relief subsystem. The system can achieves to generate and manage tag information, to query miner information and positioning, and to display location of miner by using WebGIS technology.

WSN Subsystem

Wireless sensor network subsystem is divided into two parts: wireless sensor network node management and WSN network management.

Wireless sensor network subsystem provide network environment for localization of underground miner and equipment, and help to monitor the tunnel working environment and the entire mining area. It is mainly in charge of storage the type and the specific installation position of wireless sensors. WSN network management mainly is responsible for monitoring and recording the effectiveness of the equipment, network topology, router and Information and network maintenance. The subsystem could unify management each node of sensor, monitor and maintain network equipment, to ensure underground sensor could failure-free operation [11-12].

Real-Time Positioning Analysis Subsystem

Real-time positioning subsystem includes: tag management, location information management and positioning display. We could manage and maintain an electronic tag information which was first written in the table, such as name, job number, age, team information and mining equipment.

Location information management can provide query function that query underground personnel and equipment attribute information and path of the history records, the results in the form of graphs and reports are showed. Location display can present the position of miner and equipment in real time, and track the goals. Real-time positioning subsystem can provide data which could be analyzed to use in disaster relief subsystem.

Disaster Relief Subsystem

When a disaster occurs, the disaster relief system can analyze disaster grade by stored data, and can provide the best evacuation routes to miner. By analyzing the miner location and monitoring data, we can provide details of the miner distribution patterns, to save time to rescue the lives of people.

Summary

This paper discussed framework of this system firstly, focused on research and design of underground personnel tracking location algorithm, and completed the design and implementation of related software system. The results of research provide a basis for further studying application of IOT in mine. It shows from operation that this system is stable and reliable. In later work, we take into account the impact of special underground environment to the algorithm. We need abstract underground effect parameters, and perfect mathematical model about positioning strategy.

Acknowledgements

This research was financially supported by Special Foundation for the Shaan'xi Province education department under Grant No. 14JK1478.

Research positioning key technology based on RFID and Underground Mine moving target Rescue.

References

[1] Ye Chencheng, Jingzhong Xiao li. Underground personnel positioning system based on RFID [J]. Journal of Wuhan University of Technology. 2010.32(15):148-152.

[2] Sun yanjing, Qian jiansheng, Li shiyin, Dou Linming. Theory and key Technology for Mine Internet of Things [J]. Coal Technology.2011.39 (2):69-72.

[3] Qian Jiansheng, Ma Shanshan, Sun Yanjing. Design on Mine Comprehensive Automation System Based on Internet of Things [J]. Coal Science and Technology. 2011.39(2):73-76.

[4] Sun Yanjing, Zuo Haiwei, Qian Jiansheng, etc. For coal mine production safety networking applications mode and Key Technologies[J]. Coal Science and Technology. 2013.41(1):84-88.

[5] State Administration of Production Safety Supervision and Center for International Cooperation. The world's major coal-producing state in coal mine safety situation and accident cases [R]. 2010.

[6] Cheng Jun. The implementation and application of underground personnel positioning system [J]. Journal of Anhui University of Technology, 27:150-154.

[7] Sun Enji, Li Zhongxue, Li Cuiping. The real-time 3D localization and hazard warning platform based on the RFID and WSN in underground mine[J]. Journal of Safety Science and Technology.2009, 5(3):36-40.

[8] Lining, Shao Shiquan. A research of multi-robot fish cooperation system based on Zigbee and RFID [J]. Journal of Southwest University for Nationalities. 2011.37(5):235-238.

[9] Yang Gong Jian, Liu Yong, Hanjian Song, etc. Research on indoor tracking algorithm for RFID network [J]. Computer Engineering and Applications. 2010.46(36):114-117.

[10] YunWon Chung. Modeling and Performance Analysis of Movement-Based Group Location Management Using RFID Sensing in Public Transportation Systems [J]. Sensors 2012, 12, 16077-16098.

[11] Krystyna Dziadak, James Sommerville, Bimal Kumar. RFID based 3D buried assets location system[C]. ITCon, 2008, 13, Vol.13(2008):155-165.

[12] Felix C. P. Hui, Henry C. B. Chan, and S. H. Fung. RFID-based Location Tracking System Using a Peer-to-Peer Network Architecture[J]. Lecture Notes in Engineering & Computer Science, 2014,2209(1):135-140.