Study on key technologies of Internet of Things perceiving mine

WEI Qiuping\textsuperscript{a}, ZHU Shunbing\textsuperscript{a,b}, DU Chunquan\textsuperscript{a}, a*

\textsuperscript{a}School of Urban Construction and Safety Engineering, Nanjing University of Technology, Nanjing, 210009, China
\textsuperscript{b}Jiangsu Key Laboratory of Urban and Industrial Safety, Nanjing University of Technology, Nanjing, 210009, China

Abstract

Mine production is along with water, fire, gas and coal dust, roof and other complex natural disasters and with the characteristics of poor, dangerous working conditions. Internet of Things (IOT) as an emerging technology provides a new technique for safety and security to underground production. According to the needs of mine safety production, key technologies of Internet of Things are introduced. That the technologies are RFID technology used to label things, sensor technology used to percept things, intelligent technology used to think about things, and intrinsic safety technology. Mine IOT key technologies and the research content are analyzed in-depth which have provided a direction for the research and application of mine IOT. Emphasis on IOT fundamental theories research, breakthrough in core technologies and strengthen research on key technologies that all these will effectively promote technology innovation in mine safety production.

Keywords: mine; Internet of Things (IOT); perceiving safety; wireless sensor network (WSN); RFID-radio frequency identification; intrinsic safety

1. Introduction

Information technology has developed continuously in recent years and the nation has emphasized on mine enterprises security issues day after day and has strengthened supervision continuously. At present, China has a large number of medium-sized mines equipped with mine safety monitoring system. Promote the use of safety equipments has greatly improved Chinese mine safety situation. Owing to the specialties of mine production environment, recent systems can not meet the needs of mine safety production,

* WEI Qiuping. Tel.:+1-595-167-8732; fax: +0-000-000-0000 .
E-mail address:bbsandybbsandy@sina.com.
disasters precaution and emergency responses. But ahead of perception, advance to prevent and resolving risk situation are still grim. Once the accidents happened, due to the lack of reliable information of underground miners the efficiency of disaster relief and security ambulance is low and the result is not satisfactory. All these have seriously hampered China mine safety production. Hence it is necessary to study new technologies to settle mine safety production problems.

In recent years, IOT has developed rapidly. The functions of it for instance overall perception of information, reliable transmission of information and intelligent processing of information have achieved the object of intelligent control and management. The characteristics of IOT have provide effective guarantee for ahead of perception and precaution, advance to prevent and avoiding serious accidents in the field of mine safety production. These will also be effective measures to improve mine safety production. For these reasons, studying IOT application on mine safety production has significance and prospects.

2. The current research situation of IOT application on perceiving mine

At present, domestic and foreign countries have carried out a number of studies on IOT application on mine safety production.

The demonstration project constructed by Chinese company of IOT technology in the mineral has been implemented in Jiahe Coal Mine. Through sensing mine disasters signals the system can achieve early-warning and forecast for a variety of disasters and accidents. Also it can provide proactive safety.

In 2003, Willard South African Company posted RFID tags on miner’s cap to carry out mine management. Chen Rongguang and others who use RFID identification technology developed the first set of KJ69 mining personal positioning system to solve some problems such as location monitoring staff who go down to mine and automatic attendance statistics. Hundreds of sets have been applied in China [1]. The use and management rules of AQ1048-2007 coal miners management system which has proposed requirements about the installation, using, maintenance and management of underground coal mine working personal management system [2]. State Administration of Work Safety Administration of Work Safety Explorer (2010) 168 which provides for the construction of metal and nonmetal underground mine safety hedge the six systems time requirements. Medium-sized underground mining enterprises should construct and complete underground mine personal positioning system before the end of June 2012 and other underground mining enterprises should finish before the end of June 2013.

Throughout these studies, most of them are still in the stage of laboratory from a wide range of practical applications. In terms of the current application, there are still many problems of perceiving safety system to be solved, and the system should be completed to achieve better application. This is needed verification.

For the development and application of IOT technology, National Development and Reform Commission, Ministry of Science and the Ministry established a special fund in 2010. For instance, the research direction and object about the application of perceiving safety have been arranged in the 863 plan called the project of underground metal ore intelligent mining technique and next-generation broadband wireless mobile communication network of national major science and technology program [3].

3. Key technologies and research of IOT application on perceiving mine

IOT has four key application technologies which are RFID technology used to label things, sensor technology used to percept things, intelligent technology used to think about things, nanotechnology used to miniature things [4]. Mine production along with water, fire, gas and coal dust, roof and other complex natural disasters and with the characteristics of poor working conditions, dangerous, wireless transmission attenuation underground and electrical explosion-proof that all these specialties are restricting the surface
IOT technology applying to underground directly \[^{[5]}\]. Therefore, for the specialties of mines and the needs of mine safety production the mine IOT technology should be researched. Combining with the complex and dangerous characteristics of mine safety production environment, it is analyzed that the key technologies of IOT applied to mine safety production.

### 3.1 Identification technology

Underground mine production is referred to boring machines, motor vehicles, hoists, fans, monitoring and controlling, communication and other large mechanical and electrical equipments and products permitted by mine safety signs. Also it is referred that the whole process supervision of major key mining equipments’ production, transportation, storage, use and maintenance and the whole process control of mine safety explosives’ production, transportation, storage, brought back and use. Thus, the standards of mine IOT information encoding, transportation and processing are needed to be studied and established.

Identification technology covers object recognition, position and geography identification. Identification of the physical world is the basis of achieving comprehensive sense. Identification technology of IOT is based on two-dimensional codes and RFID identification. Object identification system is an important technology point of IOT \[^{[6]}\]. From the application point of view, the first needed solved problem of identification technology is object global identification. The standard object identification system of IOT is needed study to further integrate and compatible current varieties of sensors and identification methods and support for existing and future recognition programs.

**Ultra high frequency (UHF) radio frequency identification (RFID) system**

- **UHFRFID system implementation technology.** Study on different kinds of technology programs of 900MHz and 2.4GHz frequency bands UHFRFID system. Especially study on feasibility and design technology in the context of not to increase the transmission power of reader-writer and through reducing the power threshold of starting the label to increase its working distance.
- **UHFRFID system security technology.** Study on reliability technology and security mechanisms of passive RFID system to improve the label recognition accuracy in the interference condition with liquid, metal products, gas, and coal and provide complete confidentiality for data and anti-attack capability.

The theory and technology of optical identification (OID)

- **Study on capacity of optical bar code technology, remote sensing technology and high-sensitivity detection technology.**
- **Study on the principles of OID system including information recording method, information reading method and information modulation method.**
- **Study on OID system technology including the channel characteristics, coding decoding pattern, security encryption technology, the label code digital image processing and recognition, direction sensing and spatial positioning technology.**

### 3.2 WSN technology

Realize mine personnel precise positioning, automatic identification and meet accidents emergency relief and the management of coal miners. Realize man, machines and environment latch control of gas inspectors, safety inspectors, electrical fitter, blasting work, winch driver, shearer driver and pump operator and the equipments they operating and the working environment. Realize remote on the unmanned ground face. Reduce the needs of mine personnel. Implementation all of these should study WSN technology.

The use of multi-disciplinary knowledge integrated and cross to study on WSN technology. Solutions of key technologies of WSN networking, information awareness and airspace controlling are provided in the condition of miniaturization, reliability and limited energy supply. Studying WSN nodes design
technology and using embedded system technology to develop key nodes equipments to meet the application of underground mine IOT.

- Networking technology of WSN. According to different IOT application characteristics and considering communication modes between materials, objects mobility, information perceived frequency and delay performance or if there are infrastructure support and other a variety of factors, applicative networking model and its properties are researched. The time control, airspace control and logic control technologies of the network topology according to the requirements of low power operation have been studied [7-8].

- Technology of WSN link layer and network layer. Based on short-range wireless link characteristics on the complex environment, high density short message sending application features, and the characteristics of network topology which is controlled dynamic changing, Medium Access Control (MAC) layer protocol which can use network capacity efficiently and reduce energy consumption was researched. Take a research in routing protocol which can reduce the number of forward and improve network capacity and efficiency through the use of technologies of cross-layer design, network coding, single-hop multicasting [9-10].

- Technology of WSN QoS protection and reliability. Do studies in some technologies. A kind of technology can ensure nodes and networks working for a long time in harsh environment. The reliability technology can control the nodes perceived probability of false alarm. The one can detect failure nodes and the other can reduce the impact of failure nodes [11].

- Technology of WSN time and airspace control. Take a research in time synchronization technology which can support time tick between nodes, prohibit clock jitter and wander and meet the requirement of collecting information in real time. Study on location tracking technology and propose low-power node self-positioning technology and the technology of locating target in network domain [12-13].

- Effective transmission technology of information perceived by WSN. Researching and presenting awareness information compression and local aggregation technology through the use of digital signal processing technology. According to information types, importance, time and space relevance and other information scale to reduce redundancy of sending information and the consumption sources of nodes and networks.

- WSN nodes design technology. According to the requirement of the embedded intelligent system which is supplied by the limited energy to select appropriate hardware and software platform to develop key nodes equipments and gateway equipments to achieve cognition, computing, communication and security functions.

3.3 Intelligent technology

Mine in the process of geological exploration, designing, building well construction, safety production and management generated a lot of spatial data and corresponding attribute data. Mine safety production and management needs to three-dimensional express and analyze the basic information of the seam, roof and floor, rock and geological structure and some production information such as roadway measurement information, power supply, ventilation, drainage, transportation, mining, monitoring and communication [5], which require researching mine intelligent technology.

In IOT the intelligent technology is mainly responsible for analyzing the information content carried by goods in order to achieve the computer automatically disposed. The application of intelligent technology is embodied in the integrated applications of computer technology, precise sensing technology, GPS positioning technology. Intelligent technology application on mine safety production including artificial intelligence safety production information management expert system, intelligent control, computational intelligence and its application, data mining and intelligent decision-making, intelligent manufacturing, intelligent robots, comprehensive integrated intelligent system and safety production.
equipment training, etc. which can be well applied to the coal mines, non-coal mines, occupational hazards, emergency management, testing and inspection and accident investigation. These functions play a direct role in improving the staff working environment, reducing work intensity, improving job quality and work efficiency, curbing serious accidents and reducing casualties.

3.4 The core materials of information sensing and key technologies

These disasters for instance flooding, fires, gas explosions, dust explosions, cave, coal and gas outburst, toxic gases, dust often appeared in underground mine which always endanger the safety of mine workers. Existing information sensor technology has the function of perception and inspection hazards but it is low accuracy and difficult to meet the needs of mine safety production. So there is an urgent need to study information sensing core materials used to percept and inspect various hazards precisely and improve early-warning accuracy.

According to IOT application requirements in the domain of mine safety production new information sensing materials with characteristics of high sensitivity, high selectivity and rapid detection in allusion to chemical and biological materials for mine complex environment have been developed. Integrated use of materials science, biotechnology, information technology, nanometer science, interface science and many other disciplines as well as light, electricity, color and other technologies to develop new information sensors, particularly the biological sensors which simulation of biological recognition process need to be developed. The biological sensors can reach high requirement of IOT in aspects of sensitivity, selectivity, response speed, reliability, convenience and information obtained [14-15].

- Design and develop the core materials of information sensing. Based on organic semiconductor materials have response characteristics in light, electricity, magnetic and color that the structure of materials will be designed. The chemical sensing materials with characteristics of high sensitivity and high selectivity response to temperature, pH, heavy metals, toxic substances and explosion will be developed. Through simulation of biological system multi-point recognition model, design and develop biological sensing materials with characteristics of structural diversity, biological functions to greatly improve the detection selectivity and specificity.

- Chip high efficient chemical and biological sensors. Use a combination of organic semiconductor materials and a number of dimensions and the benefit features of different nanometer materials to finish the coupling of a number of related reactions inside nanometer-confined space to achieve recognition acquisition, signal transduction and cascade functions integration then to obtain chip high efficient sensors.

- Chemical and biological sensors application on the technology of IOT. According to the requirements of IOT application in the field of mine, establishment of practical chemical and biological sensor detection system for the early diagnosis of major diseases of mine workers and convenient treatment. Also it can access to human organs, tissues, cells, molecules and other levels in-depth to acquire biological information, and detect production dust, harmful gases, poor weather conditions, noise, vibration and other environmental pollutants and underground labor-intensive, incorrect work posture, poor lighting and other hazardous factors which will cause accidents.

3.5 Safety technologies of IOT application in mine

In coal production there is inevitably flammable and explosive gases. In event of achieving the explosive and flammable gases explosion conditions is bound to lead to accidents. So in these occasions there are stringent safety anti-explosion requirements. Coal mine gas explosion occurred must have three conditions, namely, a certain concentration (5% to 15%) of gas, greater than 12% concentration of oxygen and adequate ignition energy. In some high-gas coal mine at a short time the emission gas
concentration reaching the scope of explosion is inevitable and oxygen is essential to life. Therefore, the key to control gas and coal dust explosion is control of ignition energy.

The safety performance problem of electromagnetic during application has not been studied in-depth and comprehensively. So with particular emphasis on the electromagnetic explosion-proof and safety performance studies under coal mine environment are needed. IOT technology applications in the mine will introduce RFID, WiFi, ZIGBEE and other wireless communications technology and equipment to achieve mine mobile communications, personnel location monitoring, portable mobile devices wireless access. All kinds of devices underground transfer data to each other via wireless wave to provide techniques for underground safety production and management. However, wireless waves transmit information by the way of energy transmission. If wireless transmission power and energy of wireless devices can detonate gas is needed to analyze the safety characteristics of wireless waves igniting mine gas. Study on the limit power and energy of radio waves to detonate gas as well as the antenna, operating frequency, multiplexing methods, modulation and other effects. Take a research on the characteristics law of the antenna surface accumulation of electrostatic charge stored energy ionizing sparks igniting mine gas [16-17]. Through these researches develop intrinsic safety IOT devices such as RFID, WiFi, and ZIGBEE which are appropriate for applying in underground mines safety production.

4. Emphasis on IOT fundamental theories research and breakthrough in core technologies

IOT has the characteristics of strong association, high hybridity and uncertainty. For the IOT existing characteristics with IOT great application need and the specialties of system and construction sensing interaction, self-government high efficiency and safe and credibility IOT system as a target and spatial association, collaborative self-government and materialized credibility as a center, study on some related basic theories and methods. The figure 1 shows the diagram of basic theory of IOT.

At the while of studying on WSN, UHFRFID, OID, information sensing core materials, research institute should overcome a number of core technologies, strengthen the generic technology research and promote the application innovation and industrialization. Focus on strengthening the following technologies studies. (1) the system integrated technologies of IOT including functional integration, network integration, hardware and software interface integration and intelligent control, system-level software or middleware technology research and development. (2) IOT application abstract and

![Characteristics of IOT](image)

![Science Problems](image)

![Application Target](image)

Fig. 1. Diagram of basic theory of IOT

standardization technologies including the key technologies’ protocols and standards, platform software development environment, development tools, core framework and middleware technology research and
development. ③ Common supporting technologies including programmable technology, system testing, context awareness, privacy protection and other common technologies research and development and modern information communication, computer and network, advanced microelectronics, new materials, new energy and other infrastructure support technologies research and innovative applications.

5. Conclusions

• The technology of IOT application in underground mine can achieve precise environment perception and early-warning for flooding, fires, gas explosions, dust explosions, cave, coal and gas outburst, toxic gases and other various risk factors. Also the technology can achieve precise positioning and automatic identification for underground coal miners and early warning of major disasters. And it will play an important role in reducing mining surface staff, hidden dangers investigation, safety hedge, accident investigation, accident emergency, miners and equipment management. All these can effectively protect underground safety production.

• From perceiving mine safety industrial application point of view, the industry requires a high degree of attention to study on perceiving and identification technology and need to strengthen the key technologies study in WSN, RFID system, OID, the core materials of information sensing and chemical and biological sensors. Analyze the safety characteristics of wireless waves igniting mine gas. Study on the limit power and energy of radio waves to detonate gas as well as the antenna, operating frequency, multiplexing methods, modulation and other effects. Take a research on the characteristics law of the antenna surface accumulation of electrostatic charge stored energy ionizing sparks igniting mine gas.

• Set the researching and developing goal and content of IOT perceiving safety scientifically and deploy the researching and developing resources of IOT reasonably. According to the structure and application scenarios of IOT and combined with the need for mine safety production, considering the environment need for IOT application, in the field of mine safety production increase studies in multi-function and low-power wireless testing sensor technology and technology of IOT integration prevention system design and advance perceiving safety. Construction demonstration project of the technology of IOT perceiving safety such as tailings full life-cycle monitoring and control and mine major incidents monitoring, early-warning and emergency response.

References

[1] Planning Technology Division of State Administration of Work Safety. Technical reports compilation of 2007 Safety Production Excellent Scientific and Technological achievements Forum [R]. 2007. 9. (In Chinese)

[2] The industrial standards of People’s Republic of China safety work. The using and management standards of underground coal mine working personal management system [S]. AQ1048-2007, 2007. (In Chinese)

[3] Ning Huansheng. RFID major project and national IOT [M]. Beijing. Machinery Industry Press. 2010, 8: 217-222. (In Chinese)

[4] Commission of the European communities, COM (2009)278 final. Internet of things-an action plan for Europe, Brussels [EB/OL]. http://www.statewatch.org/news/2009/jun/eu-com-278-internet-of-things.pdf, 2010-12-10.

[5] Sun Jiping. Research on characteristics and key technology in coal mine Internet of Things [J]. Journal of China Coal Society. 2011, 36(1):167-171. (In Chinese)

[6] China Radio Frequency Identification technology policy- 2006 China Radio Frequency Identification technology policy white paper [OL]. Chinese Internet of Things. http://www.wlw.gov.cn/zsyd/zbxz/574678.shtml,2011-3-10. (In Chinese)
[7] YANG Shaojun, SHI Haoshan, LIU Lizhang. Analysis and Simulation of Wireless Sensor Networks [J]. Computer Engineering. 2006, 32(22): 116-118. (In Chinese)

[8] LI JianZhong, LI JinBao, SHI ShengFei. Concepts, Issues and Advance of Sensor Networks and Data Management of Sensor Networks [J]. Journal of Software. 2003. 14(10): 1717-1726. (In Chinese)

[9] ZHEN GuoQiang, LI JianDong, ZHOU ZhiLi. Overview of MAC Protocols in Wireless Sensor Networks [J]. ACTA AUTOMATICA SINICA. 2008. 34(3): 305-316. (In Chinese)

[10] W. Ye, J. Heidemann, D. Estrin. An Energy-Efficient. Medium Access Control with Coordinated Adaptive Sleeping for Wireless Sensor Networks [J]. IEEE/ACM Transactions on Networking, 2004. 12(3): 493-506.

[11] Li Jing, Wang Fubao, Duan Weiju. Research of TinyOS in Wireless Sensor Network [J]. Computer Measurement and Control. 2006. 14(6): 838-840. (In Chinese)

[12] Elson J., Romer K. Wireless sensor networks: a new regime for time synchronization [J]. ACM SIGCOMM Computer Communication Review, 2003, 33(1): 149-154.

[13] M. Vossiek, L. Wiebking, P. Gulden, J. Wieghardt, C. Hoffmann, P. Heide. Wireless local positioning [J], IEEE Microwave Magazine, 2003, 4(4), 77-86.

[14] DOLIN R A. Deploying the Internet of things[C]. International Symposium on Applications and the Internet, 2006:216-219.

[15] SUN Liming, LI Jianzhong, CHEN Yu, et al. WSN [M]. Beijing: Tsinghua University Press. 2005. (In Chinese)

[16] Liu Yulei. Discussion on the Relationship between Electromagnetic Waves Power and Coal Mine Gas Explosion [D]. Chong Qing, China Coal Research Institute. 2008. (In Chinese)

[17] Sun Jiping. Mine safety production monitoring and technologies [J]. Journal of China Coal Society. 2010, 35(11): 1925-1929. (In Chinese)