Designing Top Layer in Coal Mine Internet of Things

Enjie Ding\textsuperscript{1,2}, Shimin Feng\textsuperscript{1,2}

\textsuperscript{1} National Joint Engineering Laboratory of Internet Applied Technology of Mines, China University of Mining and Technology, Xuzhou 221008, China
\textsuperscript{2} IoT Perception Mine Research Centre, China University of Mining and Technology, Xuzhou 221008, China.

Email: E-mail: enjied@cumt.edu.cn

Abstract. The booming development of the mine IoT requires the planning of the mining technology from the top layer. This paper interprets the "top layer design of mine internet technology" compiled by the State Administration of Work Safety last year. This paper analyzes the technical background and core content of the top-level design from the aspects of design idea, development status, challenge, strategic goal, core technology, implementation route and guarantee. This provides a reference that helps the scientific researchers in the mining industry and technological managers to read, understand and use the ideas of "top layer design". The demonstration project in Jiahe coal mine proves the feasibility and the effectiveness of the ideas.

1. Introduction
The Mine Internet of Things (IoT) can support mining enterprises to realize a ubiquitous perception of mines and intelligent decision-making. It is an important basis for industry administration departments to improve supervision and law enforcement and management [1]. Since the beginning of the 2010, the concept of mine IoT has been widely recognized by the government, the academia and the enterprises [2]. Its connotation and extension continue to expand and deepen, and constantly allow solutions for mine IoT concepts. These solutions have been gradually put into operation with demonstration applications in several large mining industry groups across the country. The productivity and safety levels of mines have been greatly improved [3]. At the same time, Mine IoT gives birth to a large number of emerging industry clusters, which helps create a clear economic and social value. This paper interprets the design idea, main content, key field and implementation of the top-level design of Mine IoT and provides a reference for scientific researchers in the mining industry and technological managers to read, understand and use the ideas of "top layer design".

2. The design concept
For a long time, in the process of construction and application of mine safety in China, information technology failed to be integrated into the core business and process of safety production, and the business flow and information flow failed to reach the deep fusion and organic connection, which affected the effect of the work safety informatization to some extent [4] The information of mine safety production is difficult to collect effectively, as is the accuracy of data as all kinds of safety information are filled manually. The authenticity of information and the accuracy of data are difficult to guarantee. The mine safety monitoring data has not been effectively utilized and mined, with a large amount of data being idle.

Guidelines are as follows. Firstly, we must clarify that the goal of top-level design of the mine IoT technology is to start the overall design from the high end. Secondly, we need to avoid the problems of network independence, lack of unified planning and standards, duplication of
investment, closed system in the applications of mine IoT. Thirdly, the overall planning and design is not aimed at a particular mine, but only the general design goal. Fourthly, we need a unified and open mine support platform for IoT service [5] to achieve the information interaction and seamless link between the people and the objects, the objects and the objects, and to implement the real-time control of the mine, accurate managements and scientific decision-making, to support researchers from different disciplines to carry out research work on it, and for it to be accessed by different service providers [6].

3. The Systemic Approach

3.1 The Main Contents of Top Layer Design. This is shown schematically in Figure 1.

3.2 The Development Status and Challenges of mine IoT. To clarify the development status of the mine IoT top layer design is used. Although the mine IoT has shown good adaptability to mines and has broad application prospects, the overall status is more about "sensing" and "transmission". There are too few studies on "awareness" and "application". We need to broaden and deepen the research on the perception level, the transport layer, the application layer and public technology. The perception layer is the forefront of the mine IoT and is responsible for the task of perceiving data [7]. However, the sensors in the current mine are still limited to specific subsystems. The lack of distributed and networked mine sensing technology and applications make it impossible for us to achieve distributed monitoring and control. This kind of "islanding" implementation method greatly increases the difficulty of perceptual data fusion and reduces the trustworthiness of perceptual data. The transport layer is a "neural" channel that senses the steady and reliable transmission of information. It is the key to connect the perception layer and the application layer. It generally includes two main parts: the backbone network and the perceptual network. However, the backbone network of each mine is the 1000M (10G for individual coal mine) of industrial automation network. These industrial Ethernet networks do not have the capability of accurate time synchronization for the whole network, thus cannot provide time-based services (such as the real-time tracking and management of events occurring in the whole mine). Therefore, it is necessary to develop a new type of mine awareness network.

The applications of the application layer is the ultimate goal of mine IoT construction and deployment. They are important tools for data presentation, operation management, decision support and service provision. From the point of view of mine safety, the single factor reveal only one-sided reasons for disasters. We should deploy a number of subsystems, focus on the important observations and achieve the fusion analysis. Only in this way can we fully reveal the
multi-coupling of disasters and achieve the accurate and timely pre-disaster warning. However, for the public, there are still many problems that need to be solved. In particular, there are not enough research on the formulation of standards and thus we need to work on the formation of a series of mine standards for the IoT.

3.3 The Strategic Goal of mine IoT. This is that the new sensors and intelligent “objects” of mining have been rapidly growing to form a semantic Web based on mine intelligent "things" after around a decade of development. Mine cloud computing and mine big data are widely used to form the mine “cloud” or "fog" computing service platform. The new service system and the value chain gradually improve and the sustainable mining ecological environment is initially formed. The core of the strategic goal is to form the semantic mine object and the mine service platform, and make the mine development sustainable. We aim to achieve better semantic expression, information fusion, knowledge mining and semantic calculation of mine object and perceptual data through the unified mine IoT platform technology, cloud computing service and big data technology. In this way, the information will be effectively used and value-added. In particular, we can empower the system with the capability of early safety warning, the virtual reproduction of events, thus can significantly improve the mine production efficiency and safety standards.

3.4 The Key Development Areas for Mine IoT. In view of the strategic goal of Mine IoT, we need to make breakthroughs in the key technologies, provide five major perceived services, and build "cloud" and "fog" platforms to promote standardization. The five key technologies include developing miniaturized intelligent devices, clarifying the detailed rules of radio wave propagation in the mine roadway, studying the cloud computing platform system and big data platform construction strategy, studying the semantics, and studying the mining IoT security mechanism, privacy protection strategy and constructing a reliable network for the mine IoT. The mine IoT will focus on four aspects, i.e. "people, machine, environment and management", and provide the corresponding perception services. Implementing the cloud platform and fog platform for the management and open services of mine is an inevitable method for mine IoT to exert its full potential. Thus standardization is the necessary step to ensure the orderly and healthy development of the mine IoT industry and to ensure the open interconnection of the mine IoT products.

4. The Implementation and Security Measures: Demonstration at Jiahe Coal Mine
The Jiahe coal mine is located in Xuzhou, Jiangsu province. The demonstration project was funded by the government. The research group spent about one month conducting a field study and prepared the blueprint for the project in Jiahe coal mine. The researchers determined the subsystems of the whole system and the indicators of the performance, as well as the specifications for data exchange. The group made a plan to integrate the subsystems. The system was tested in the real-world environment. After the software debugging, the system ran successfully and the performance was greatly improved. The whole system was composed of three subsystems, i.e. the human monitoring subsystem, the equipment monitoring subsystem and the environment monitoring subsystem. As shown in Figure 2, the moving targets including the miners and the vehicles were being tracked. Meanwhile, the environment parameters were being monitored. When the temperature was too high, the alarm was activated, indicating an emergency. The underground equipment monitoring system is shown in Figure 3. We can see whether the equipment was working properly or not. According to the geological conditions of Jiahe coal mine, the microseismic monitoring system was set up. It was composed of the data collection subsystem, the recorder subsystem, the analyser and the demodulation measurement probes. The system shown in Figure 4 successfully helped monitor the microseismic activity.
5. Conclusions
It is necessary to fully understand the development status of mine IoT and the difficulties of mine IoT, clarify the strategic development goals, accurately plan the development direction of the core key technologies, and formulate a clear roadmap of the development. Mine IoT is a platform for cooperation and win-win among all industries and departments. The top layer design of Mine IoT technology is a good opportunity for a win-win solution. It pointed out the direction for the development of mine IoT science and technology. The demonstration project in Jiahe coal mine shows the feasibility and the effectiveness of the ideas of the top layer design.

References
[1] Enjie Ding, Zhikai Zhao. The current situation of mine IoT and the development trend [J]. Industry and Mine Automation, 2015, 41(5):1-5.
[2] Jianguo Han. The research on the key technologies for the construction of shenhua intelligent mine and the demonstration [J]. Journal of China Coal Society, 2016, 41(12):3181-3189.
[3] Qingsong Hu, Shen Zhang, Lixing Wu. The localization of moving targets in the coal mine: challenges, current situation and trends [J]. Journal of China Coal Society, 2016, 41(5):1059-1068.
[4] Shen Zhang, Enjie Ding, Zhao Xu. The second talk on the IoT and perception mine——perception mine, digital mine and integrated automation of the mine [J]. Industry and Mine Automation, 2010, 36(11):129-132.
[5] Shen Zhang, Tao Zhang. On the structural platform and service platform of mining material networking. Industry and Mine Automation, 2013, 39(1):34-38.
[6] Jianquan Yao, Enjie Ding, Shen Zhang. The vision of perception mine IoT and developing trends [J]. Industry and Mine Automation, 2016, 42(9):1-5.
[7] Qingsong Hu, Lixing Wu, Shen Zhang. Deployment and energy consumption analysis of locating WSN in coal mining surface [J]. Journal of China University of Mining Technology, 2014, 43(2):351-355.