Research Journal of Applied Sciences, Engineering and Technology 6(20): 3772-3777, 2013
DOI:10.19026/rjaset.6.3590
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: January 10, 2013 Accepted: January 31, 2013 Published: November 10, 2013

Research Article

The Safety Production Monitoring System Based on LTE in Coal Mine

Shuqi Wang
School of Communication and Information Engineering, Xi'an University of Science and Technology, Xi'an 710054, China, Tel.: 13992886489

Abstract: A new safety production monitoring schemes and emergency rescue communication system based on LTE technology for coal mine is introduced, which mainly responsibility is conveying video data of disaster scene and ensuring the two-way communication of mobile terminal and emergency communication car. The schemes include to use of TDD full-duplex mode to make uplink configuration as much time slot resources as possible, SC–FDMA for uplink multi-access technologies and OFDMA for Downlink. Considering the terminal ability, MIMO antennas of uplink and downlink antennas is available. At the same time we adopt HARQ and adaptive modulation coding technology to improve reliability and transmission efficiency. The Performances of link level are simulated aiming at transmitting schemes. Respectively use QPSK, 16QAM, 64QAM three methods of modulation, the simulation results show that the LTE technology can satisfy the requirements of data rate, BER and delay for wireless communication under emergency environment in coal mine.

Keywords: Coal mine, emergency rescue, Long Term Evolution (LTE), safety production monitoring

INTRODUCTION

Coal is the important resources in china, which is depended on underground mining mainly. But the high gas and flooding can add to the danger of production environment for worker. The accurate real time monitoring in coal mine is very important for the safety of people and production equipment. The production safe for mine has become to the main incident that the nation and company focus on gradually. In order to improve the production safety and management efficiency, The real time monitoring in the underground of coal mine for detailed environment parameters, that is an effective means to prevent mine accidents. The modern wireless communication technology will play an important role of the security of the coal industry.

According to the application system structure of digital mine, safety production monitoring system is established and the structure of monitoring management information system is analysis (Xiaobing and Feng, 2009; Zhao *et al*., 2007). The coal mine mobile application solutions which is supported by SP based on TD-SCDMA are analyzed, the network structures of surface and underground are established according to the application of mine remote monitoring in detail. The wireless interface standard are studies based on the structure of digital mine the workflow in application server is suggested (Wang *et al*., 2009). According to the status of coal mine underground communication, the mine wireless data acquisition Terminal based on TD-SCDMA is designed and implemented. The Terminal can realize fast, long-distance transmission of acquisition data, ideal for coal mine detection system (Zhang and Liu, 2011).

LTE have more technical advantages in broadband wireless communications technology: 100 Mbps for Downlink peak rate and 50 Mbps for uplink peak rate, the higher spectrum efficiency than TD-SCDMA, Overall system architecture support group domain business, this ensure the quality of real-time business service, solve the backward compatibility problems and reduce the network delay etc. From the perspective of application, according to LTE communication mobile technology, this study analysis and design a city safe water emergency rescue wireless transmission schemes that based on the 3GPP LTE standard and give an analysis of its simulation performance (Liu *et al*., 2010; Zhao *et al*., 2008; Kyung-Yul, 2010; Yu *et al*., 2011).

This study provide a basis real time monitoring technology for coal mine production application based on the LTE network opening provide effective evidence.

LTE APPLICATION STRUCTURE IN COAL MINE

LTE have more technical advantages in broadband wireless communications technology, Remote real time monitoring for safety production in coal mine based on LTE can obtain the detailed environment parameters information of production place and video information of tunnel working surface at any time and transmit to the monitoring centre. The system is mainly composed

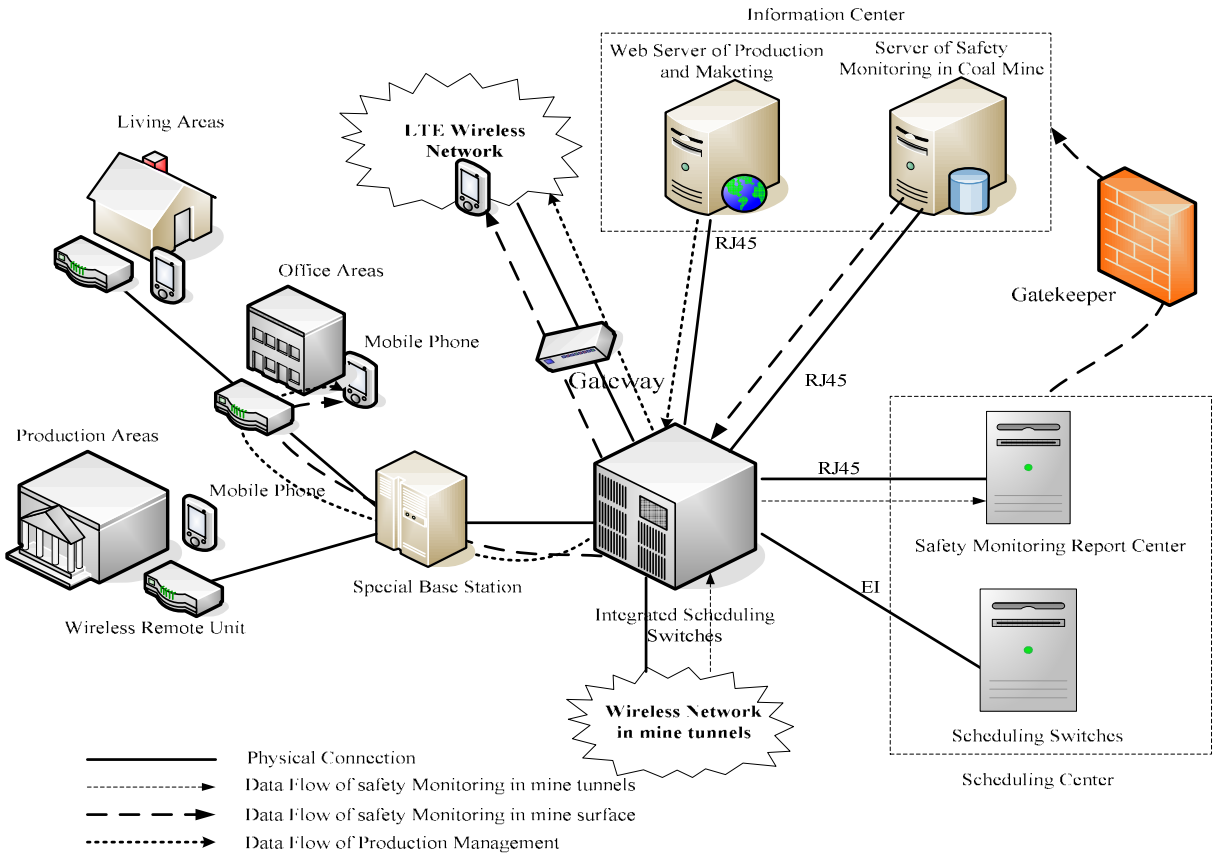

Fig. 1: LTE platform of ground in coal mine

of LTE platform of ground and LTE networks in mine underground part. The monitoring process is accomplished as follows: firstly, gathering the monitoring data using different production environment sensors and RFID station of workers in underground place; secondly, then this information is collected through the monitoring platform according to the standard data structure. The administrators can utilization the LTE remote monitoring equipments could receive and display these data using the good wireless interface between worker and mobile client terminal, which is transmitted by client server, in same time, rapid calling and information inquiring, can be provided quickly.

Many of workstations are set as server for coal mine terminals of underground, LTE mobile terminal are clients. In this scheme, LTE mobile terminal and LTE PC server transmitted the information through LTE wireless mobile network. The network service quality is provides according the quality of whole public LTE system. Mobile network of wireless LTE could provides not only the protect data width for service, but also can provides performance guarantee for all the platform and system.

The real time monitoring technology for coal mine production application based on the LTE network are shown in Fig. 1 and 2, in which, the system are mainly composed of LTE platform of ground and LTE networks in mine underground part. The ground platform is term architecture can refer to either hardware or software of coal mine monitoring centre,. The architecture of LTE system always defines its broad outlines and may define precise mechanisms as well. LTE networks in mine underground completed the information obtain and transmitted in limited wireless channel, which included the different production information. The performance of channel is bad for the complex noises of tunnels.

In the platform of digitization mine, which includes many kinds of service application server of coal mine, such as safety monitoring, early warning and location system server and production operation management system server to make data information of multi-application server of coal mine inosculate highly with mobile service of communication system. J2EE technique supporting wireless application is not only with good stepping across platform and integration ability, but is combined with J2ME technique well, the information transmission doesn't need extra mark. Thus, adopting J2EE technique to develop mobile special network server terminal of coal mine based on LTE. In server terminal, using multithread to deal with

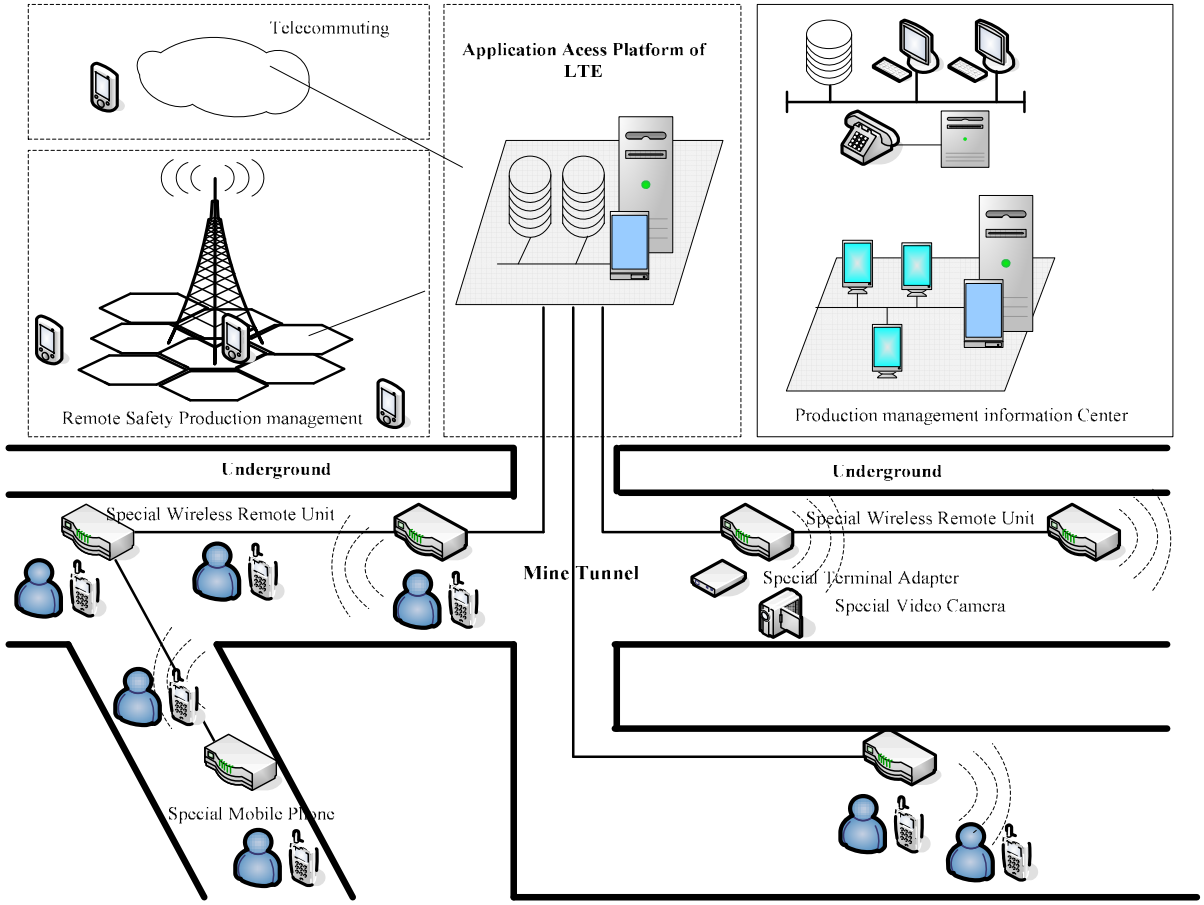

Fig. 2: LTE networks in mine underground

network communication, data mining, user login, user register and personal information's modification module. Multi-instruction stream can be allowed to carry out in program; each instruction stream is called one thread, dependently each other.

After the application program of server terminal is started, one part thread is used to obtain and process sensor's data of production place and make real time data saved in part buffer, when new data is coming the old data is renovated with the new data. The other part is used to process login verification, when verification is passed, be in charge of communication with LTE terminal, send real time data to LTE mobile phone terminal, renovate and save last time data operated on the mobile phone terminal RMS; when LTE mobile phone terminal is starting, starting interface process thread is used, server terminal sends proper starting interface to mobile phone terminal according to interface size of LTE mobile phone; when new user needs to register and personal information needs to be amended on server terminal, corresponding thread must be started as well, which can protect new user or information amended and renovated by user and provide users login verification etc.

DATA PROCESS AND TRANSMISSION

Process of uplink data: The uplink data process of physical transmission in safety production monitoring schemes and emergency rescue communication system describes in Fig. 3, including the data processing by terminal and receiving terminal. The dotted line in the figure express the layer L2 and L3 above the physical layer (L1), the small circle on dotted line express Service Access Point (SAP) which connect L1 with high layer, such as ACK/NACK, HARQ message respectively sending or coming from the high layer. Through the small circles express this information interaction in the figure.

Key technique of uplink transmission:

Frame structure: LTE standard defines two frame structures: Frame Structure 1 (FS1) and Frame Structure 2 (FS2), respectively based on Frequency Division Duplex (FDD) and Time Division Duplex (TDD). The characteristics of this system is the less data of downlink which include voice call, control information and small amount of data information, while the larger quantity of uplink data which mainly

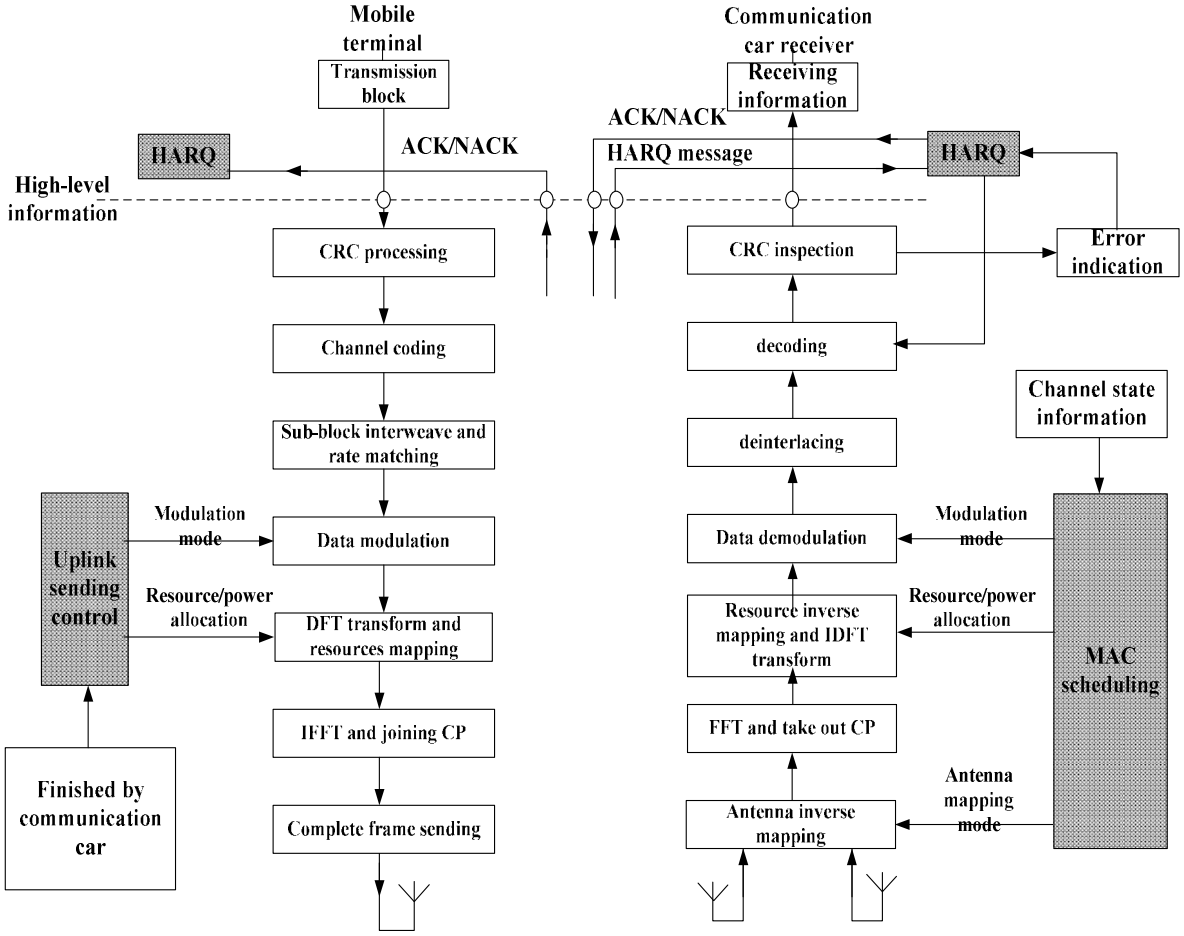

Fig. 3: Process of uplink data transmission

include video upload, voice calls and also a small amount of data and control information. So we adopt wireless frame structure 2 that based on Time Division Duplex (TDD) mode.

MIMO: The terminal of this system equipped with two antennas and a power amplifier, the two antennas couldn't work together and we choose only one for signal transmission at a certain time. Then equipping with two antennas at the receiving terminal communication car, so they formed a 2*2 MIMO structure, we only consider the existence of single uplink transmission link. At the same time it supports the uplink multi-user MIMO.

Power control: Because the system use SC-FDMA as uplink multi-access technology, uplink signals of different terminals in system are mutually orthogonal, uplink power control only use for compensating channel path loss and shadows decline. When the uplink channel quality of one terminal decreased (such as the obstacle or the distance that too far with the information centre or communication car), the car could instruct the terminal to increase sending power according needs of that terminal. We adopt the way of slow power control which the frequency of this method is less than 200 Hz.

HARQ: This system adopts Incremental Redundancy (IR) HARQ, that is, through the first transmission sending information bit and a part of redundancy bit and through re-transmission sending additional redundancy bit. If decoding unsuccessful at the first transmission, we can reduce the channel coding rate by retransmission more redundancy bit, thus to achieving higher decoding success rate. If we cannot decoding correctly with the retransmission redundant bit, transmission again and again. Along with the increase number of retransmission times, the redundancy bit accumulates ceaselessly and the channel coding rate decreases continuously, thereby we can get the better decoding effect.

Uplink synchronous: Due to we adopt SC-FDMA transmission technology at uplink transmission, the sub-carrier is orthogonal with each other, so the terminal make the uplink signal orthogonal by using

different sub-carrier. In order to keeping the orthogonally, we must ensure that each terminal signal have the same receiving timing. This can be realized by controlling terminal to adopt different uplink Timing Advance (TA), namely that far distance terminal from the communication car sending earlier and the close one sending later, thus each terminal signal can almost arrive at the communication car simultaneously. As long as a terminal send uplink data, the communication car can estimate it's uplink receiving timing, then resulting the Uplink Timing Control Signalling aiming at this terminal.

While the terminal haven't send uplink data temporarily, it can also send uplink synchronized signal periodically to maintain the uplink receiving timing estimate of the communication car, so when the terminal need to send uplink data it don't need additional time for uplink timing synchronization. In this instance, the biggest refresh rate of Timing Advance (TA) is 2 Hz, the smallest particle size (resolution) of TA signalling is 0.52 μs, adopting the method of adjustment in one step. The communication car can measure TA by the uplink SRS (the channel detection RS) that send by the terminal, when the case without uplink data transmission.

Process of downlink data: The safety production monitoring system physical process about system uplink data transmission includes the data processing by terminal and receiving terminal. The dotted line in the figure express the layer L2 and L3 above the physical layer (L1), the small circle on dotted line express Service Access Point (SAP) which connect L1 with high layer, such as ACK/NACK, HARQ message respectively sending or coming from the high layer. Through the small circles express this information interaction in the figure.

It mainly transmits control signalling that the downlink of the emergency rescue wireless transmission for water supply based on LTE, it's easier to realize than uplink. Downlink transmission model is a reverse process of uplink transmission.

Downlink of system is a pair of multiplex transmission, data from the sending antenna can be received by every mobile terminal and the terminal distinguishes the different terminals' data by OFDM technology. Due to the very small volume of downlink data, the low requirement about channel rate and most of the single are control single, it needs the higher reliability, two antennas at sending terminal and receiving terminal.

It nonuser spatial multiplexing and beam forming, only choose transmission diversity to effective improve the SNR of receiving signal and then improve the coverage. It is the same as uplink in system parameter configuration: 15 kHz for sub-carrier spacing, 1.0 ms

Table 1: Main simulation parameters

Parameters	Values
Bandwidth	20 MHz
Sub-carrier bandwidth	15 kHz
Sampling frequency	30.72 MHz
FFT	2048
Number	1664
Sub-carrier per terminal	1200
The RB per terminal	100
RB time-field range	1 time slot
Time slot per sub-frame	2
OFDM symbol per TS	7
CP length	4.6875 μs
Channel coding	Turbo
Channel coding rate	1/3
Modulation mode	QPSK/16QAM/64QAM
Multipath channel model	Spatial channel model

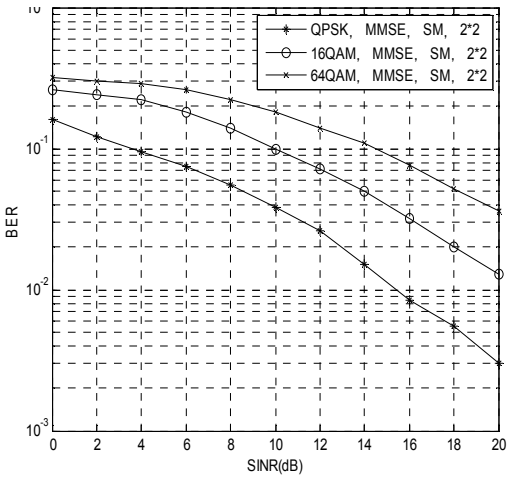

Fig. 4: The uplink performance of different modulation mode

for TTI and 20 MHz for system bandwidth. Its modulation mode also the same as uplink's that according to different signals choose from QPSK, 16 and 64 QAM, but in order to guarantee the reliability of control information we can just satisfy the transmission requirement by using low-order QPSK modulation method.

Its way of terminal sub-carrier allocation is more flexible than uplink's, it support localized type and distributed type at the same time. MIMO for downlink includes transmission diversity, beam forming and spatial multiplexing, 2*2 for antenna configuration that 2 antennas for sending and 2 for receiving. This system adopt OFDMA technology for downlink, Downlink HARQ adopt multiple processes of stop-and-wait way to realize, namely to one of the HARQ process, the process suspended before we meet the ACK/NACK feedback, then deciding to send new data or resend old data according the receiving ACK/NACK. The downlink HARQ is a self-adapt and asynchronous mode. Self-adapt means it can self-adaptive adjust the Resource Block (RB), Method of Modulation, the Transmission Block Size, the Retransmission Cycle and such parameters of each retransmission according to wireless channel conditions.

Downlink transmission is similar with the uplink transmission in information processing for sending terminal and receiving terminal. Because of downlink adopts OFDM multi-access technology, it without the DFT processing of uplink SC-FDMA. The data method of modulation, resources mapping and antenna mapping of downlink transmission is through the scheduling of MAC (Media Access Control) layer to complete too.

PERFORMANCE SIMULATION

The link level simulation is in view of the uplink of safety production monitoring scheme for coal. The main system parameters in the simulation follow LTE standards are shown in Table 1. MIMO antennas are 2*2. Length of Wireless frames is 10 ms, Length of Sub-frame is 1 ms.

BER performance of different modulation mode shown in Fig. 4, in the same SINR, the BER performance of 64 QAM is super than 16 QAM and QPSK and in the same BER of 10^{-2}, the SINR of 64 QAM is low 4 dB than 16 QAM and 8 dB than QPSK. Though frequency utilization rate of 64 QAM is higher than 16 QAM and QPSK, but QPSK is used for worse channel, 64 QAM requires the most high channel quality.

CONCLUSION

The development of digitization water supply quickens information construction of water enterprise, but synthesized monitoring system is the core of digital water enterprise system. LTE techniques are adopted in the study, designing remote monitoring and emergency rescue scheme of water supply based on LTE.

The uplink transmission model of the emergency rescue system for city water industry is analysis and physical layer process about system uplink data transmission describes which provide technical basis for application of LTE in safety production of water enterprise. Thus, it is convenient to monitor information and obtain monitored information fast for managers, which improves real-time and reliability of monitoring system for emergency rescue.

According to the above analysis of present countryside logistics, this study points out that two-way forward logistics is development tendency of rural logistics. Based on the characteristics of two-way forward logistics and traditional mixed integer programming model, giving an example, we set up a new model with help of Lingo software to locate the optimal rural distribution center. The model will play an important role in saving the cost of rural logistics and developing urban and rural economy.

ACKNOWLEDGMENT

The author thanks the anonymous reviewers for their valuable remarks and comments. This study is supported by Ph.D Foundation of Xi'an University of Science and Technology and the Foundation of Shaanxi Educational Committee (No. 09JK588).

REFERENCES

Kyung-Yul, Y., 2010. Design of a channel estimator for the LTE system based on the multirate signal processing. Trans. Korean Inst. Elec. Eng., 59: 2108-2113.

Liu, D., T. Lei, Z. Ma, Y. Li and Y. Wang, 2010. Design and implementation of configurable FFT/IFFT in the LTE system. J. Xidian Univ., 37: 813-816, (In Chinese).

Wang, S., X. Han and A. Wang, 2009. Application of TD-SCDMA in monitoring systems of coal mine. Safety Coal Mines, 11: 73-75, (In Chinese).

Xiaobing, H. and T. Feng, 2009. Application research of safety monitoring system in digital mine. Safety Coal Mines, 2: 4-6, (In Chinese).

Yu, L., X. Wang and J. Liu, 2011. An improved rate matching algorithm for 3GPP LTE turbo code. Proceeding of the 3rd International Conference on Communications and Mobile Computing, pp: 345-348.

Zhang, X. and L. Liu, 2011. Design of TD wireless data acquisition terminal of coal mine underground. Elec. Sci. Technol., 24(9): 108-110, (In Chinese).

Zhao, A., B. Li and J. Lu, 2007. Digitized mining system model and its application. J. Eng. Design, 5: 423-426, (In Chinese).

Zhao, C., J.B. Robert and Z.G. Tong, 2008. Peak-to-average power ratio and power efficiency considerations in MIMO-OFDM system. IEEE Trans. Commun., 12: 268-270.

3GPP TS 36.211 V8.6.0. Evolved Universal Terrestrial Radio Access (E-UTRA). Physical Channels and Modulation (Release 8).

3GPP TS 36.201 V8.3.0. Evolved Universal Terrestrial Radio Access (E-UTRA). LTE Physical Layer-General Description (Release 8).

3GPP TS 36.213 V8.6.0. Evolved Universal Terrestrial Radio Access (E-UTRA). Physical Layer Procedures (Release 8).