Sensors & Transducers, Vol. 157, Issue 10, October 2013, pp. 240-247

www.sensorsportal.com

Sensors & Transducers

http://www.sensorsportal.com

Research on Railway Information Technology System Based on Internet of Things

[*] Ziling LIU, Xi LIU, Xifu WANG

School of Traffic and Transportation, Beijing Jiaotong University, 100044, China

[*] Tel.: +86 15120073549

[*] E-mail: zlliu@bjtu.edu.cn

Received: 11 July 2013 /Accepted: 25 September 2013 /Published: 31 October 2013

Abstract: Internet of things (IOT) is considered to be a new generation of information technology development direction. Its application in railway information construction has broad prospects. This paper analyzed railway information technology concept and its composition in the level of function. Through the analysis of the internal and external driving force of railway information system Evolution, the direction and path of railway information system evolution is presented, and the dynamic model of railway information system evolution is established. And according to China's railway information system construction and planning situation, it designed a plan of railway information system construction under the IOT environment. Finally it constructed a railway information technology system which based on the IOT technology, and provided a theoretical support to railway information construction, as well as put forward the prospects of different railway businesses' information development with the IOT technology. *Copyright © 2013 IFSA.*

Keywords: Railway, IOT, Information technology, Information system, System revolution.

1. Introduction

Based on computer and communication technology, railway information technology is mainly used for managing and dealing with variety of railway business information. It is designed to optimize railway business operation process, and improve efficiency and competitiveness of railway transportation. The wide application of information technology provides a strong technical support to the railway speed increasing, the construction of passenger dedicated line, and the reform of the railway management system. Supported by information technologies, railway information system is a man-machine system which is applied with IT in railway. It also represents the development level of railway informationization.

Combined with the characteristics of China's railway business requirements, the development of railway information system realized the historic leap of railway informatization, from weak to strong. The successful applications of TDCS, TMIS and a series of information systems, have made great progress in production, operation and management of railway transport. However, the information stuck, such as Information Island and Resource Island, seriously affects the development of railway informatization.

Railway is one of the most promising application areas for the Internet of things technology. It can cover the whole process of modern railway transportation production, from railway's information perception and recognition, the running trains' real-time monitoring, to the tracking and positioning of goods. It improves the level of the management of railway business, provides effective intelligence decisions for the rail and related departments, and improves customers' satisfaction and service level across the rail industry.

2. Summary of Railway Information Technology

2.1. Railway Information Technology Composition

Combined with its characteristics, from the aspect of the functional level, railway information technology can be divided into four parts, as shown in Fig. 1.

1) Railway information basic technology.

Railway basic technology mainly includes network technology and electronic technology, etc., and it is the foundation of the railway information technology. Network technology is jointly developed from computer technology, and is named as computer network technology; Electronic technology study on electronics, electronic circuit and its application, and it is the key support of the whole information technology.

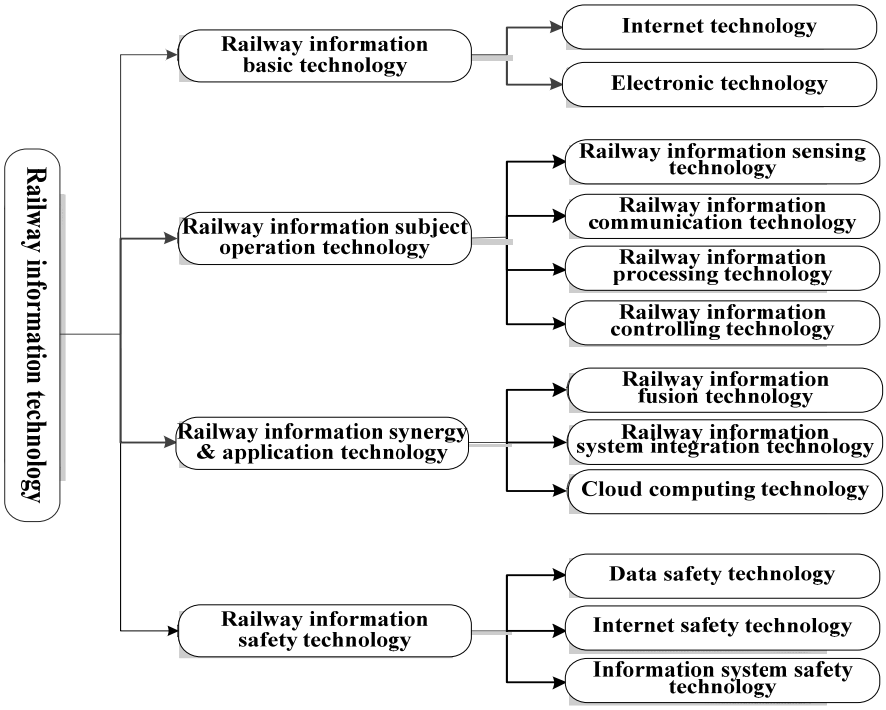

Fig. 1. Railway information technology composition.

2) Railway information subject operation technology.

According to the information processing, railway information subject operation technology can be divided into rail information sensing, communicating, processing and controlling technology. Railway information sensing technology mainly includes radio frequency technology, sensor technology, information visualization, 3S system, vehicle detection technology. Railway information communicating technology includes wire communication technologies (such as rapid and switch Ethernet, FDDI, ATM technology, optical fiber communication technology, etc.) and wireless communication technologies (such as wireless LAN, wireless access network, digital cluster and wireless train dispatching, etc.) [1]. Railway information processing technology uses computer, communication and other technologies to collect, code, compress and expand railway information, forming a hierarchical decision information. It mainly includes the database, data warehouse, data mining technology. Railway information controlling technology mainly includes automatic control, precision control, intelligent control, hybrid system modeling and simulation, system simulation, adaptive control, and RAMS technology, etc.

3) Railway information synergy and application technology.

Railway information synergy and application technology mainly includes information integration, information fusion and cloud computing technology, etc. Information fusion technology refers to the research on railway information acquisition, transmission, processing, and internal relations between information; Railway information system integration technology integrates hardware platform, network equipment, system software, tools and application software into a system with good cost performance; Cloud computing including data center management, virtualization, data processing, resource management and scheduling, QoS assurance, security and privacy protection, etc. [2].

4) Railway information safety technology.

Railway information safety technology mainly includes data security, network security, information system security technology, etc. Data security tech-

nology mainly includes damage resistant and illegal use of technology (such as data encryption, authentication, identification, etc.), disaster backup technology (such as the backup offsite backup storage, distributed storage technology, etc.). It aims to guarantee the integrity and effectiveness of data. Network security technology includes firewall technology, password technology, data signature and electronic authentication technology, etc., and is mainly to solve how to intervene control effectively, and how to ensure the security of data transmission. Information system security technology is mainly used to solve the flaws of the hardware, software, and eliminate the hidden trouble of the system. Information system security technology mainly includes the operating system security, database system security and system recording technology, etc.

2.2. Railway Information Technology Developing Tendency

Throughout the development of information technology in railway, from early single business application to whole railway network, from local application to whole railway application, information technology has achieved fruitful results in data communication network, information processing platform and other railway information infrastructure. With the upgrading of computer technology and network technology, it will develop in the direction of the following directions [3].

1) Intelligence.

Supported by sensing network and information platform, by means of intelligent computing, intelligent communication and intelligent control, intelligence is to realize the comprehensive integration of railway informatization and business in transportation organization, passenger and cargo sales, and other fields. It helps to form a comprehensive integrated system with widely perception, interconnection and interworking, and then provide quick intelligence service for road users. Such as intelligent adjustment of transportation scheme, automotive homing of locomotive, dynamic formulation of marketing strategy and so on [4].

2) Integration.

Integration is to integrate multiple autonomous, heterogeneous information system, to provide standard, modular, unified system, and guarantee the users' access to the information needed. Integration helps to speed up the development of railway information system and design, and build railway information sharing platform through the integration of railway information resources, so as to solve information island, improve the level of railway management and centralized control.

3) Association.

Through the interaction of things-to-things, human-to-things, by comprehensive perception, reliable transmission and intelligent processing on the object, association is to achieve intelligent identification and management. Association can realize automatic, fast and parallel, real-time and non-contact processing on railway vast amounts of information in the process of production. And through information sharing by railway integrated information platform, it can eliminate the information island and resource island, so as to achieve effective management of railway information of the whole network.

4) Integration.

Integration refers to realize timely delivery of information, thus to realize railway national railway longitudinal, transverse information resources, and integration of IT infrastructure, under the joint action of information resource sharing mechanism and information system integration. It can accelerate railway information, logistics and capital flow, and strengthen business coordination between different subjects, and then enhance railway transportation operation performance.

5) Standardization.

Standardization is the prerequisite to realize resource sharing between systems. With diversification of information acquisition and communication, the standardization of data presentation, database, network communication, information system hardware and software, helps to improve reliability and versatility of railway information technology.

6) Networked.

Network technology has a major impact on railway informatization. Because of network popularization, the railway department, stations and outside-road users can share information with real-time communications network covering the whole country, to realize information interconnection.

7) Virtualization.

Virtualization is to give full play to the advantage of cloud computing, to realize the centralized management of information resources. It can improve the quality of information and information systems services, railway business continuity, security of information infrastructure, and reduce investments of railway information system operations, and improve system maintainability.

8) Multimedia.

With the development of digital media technology and terminal integration, integrated processing of audio video, graphics, images, and interact with terminal equipment control combining with multimedia technology, help to achieve the dynamic, two-way interaction of man-machine information, realize visual management of train dispatching command, operation control, safety management and other businesses.

9) Platformization.

Infiltration of operating system, database, middleware and application software, integration of hardware and operating system software, is the symbol of railway information technology evolving towards integration software platform. Platformization can reduce the complexity of IT application, and adapt to flexible deployment of railway department, and the individual application requirements.

3. Analysis on Railway Information System Evolution

3.1. Evolutionary Dynamics of Railway Information System

Railway information system is the application of information technology in railway business. It constantly updates along with the development of railway information technology. Railway information system evolution is a result of combined driving forces. According to their different scopes, driving forces can be divided into the external driving force and internal driving force.

Effective supply of information technology and Railway industry management are external motives of railway information system evolution; and the railway business requirement is the inner motive of railway information system evolution. The direction and path of information system evolution are the result of these two motives. It evolves continuously from junior to senior, simply to complex. Evolution dynamic model of railway information system is shown as Fig. 2.

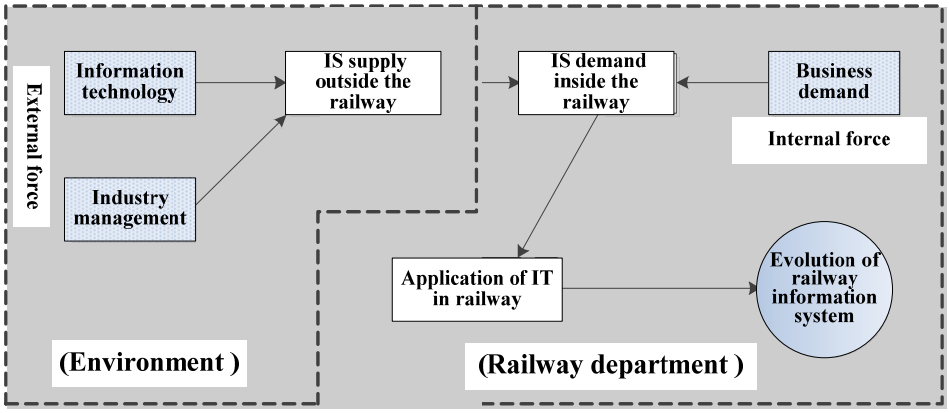

Fig. 2. Evolution dynamic model of railway information system.

1) External motives.

The external motives of Railway information system evolution reflect the railway development demands of railway informatization and intellectualization, including information technology, industry management and other factors. Among them, the information technology is the most dynamic external motivation factors of promoting the railway information system evolution forward.

a) Information technology.

The promoting function of information technology in railway information system construction is different from other factors. It's not only the core of the railway information system application technology foundation, but also can develop independently. Information technology becomes the most dynamic technical factor in the environment of railway development. The innovation of information technology and the rise of the Internet, both provide strong power in the evolution of the railway information system. Significant changes in information technology have great effect on the evolution and spread of railway informatization. For example, the invention of the embedded system promoted the automation of railway transport equipment, and greatly improved the efficiency of railway transport production, operational quality and reliability. The development of communication technology, especially the invention of the Internet technology, have greatly stimulated the demand of railway informatization, and also greatly expanded the content and scope of railway informatization.

b) Industry management.

Industry management plays an important role in railway information system evolution. Different phases of railway information systems need different roles of industry management. The industry management needs to adjust its role along with the development of the railway information system, to promote intelligent railway informatization. At the beginning of railway information system construction, in the aspect of informatization infrastructure construction, the function of industry management was irreplaceable. When it developed to a certain stage, the function of industry management focuses on the shaping of external environment, such as information legislation, taxation policy, training and services. Although in different periods, the role of industry management in railway informatization varies, overall, the long-term responsibility of industry management is to shape a good external environment for the development of railway informatization, and thus promoting the development of railway informatization.

2) Internal motives.

Railway business requirements include intelligent transportation production requirements, intelligent transportation security requirements, and intelligent

transportation service requirements, etc. Railway business requirements promote the evolution of railway information system, and the progress of railway information system promotes the efficiency of railway transportation, and thus it leads to a new round of railway information systems evolution and development.

a) Automated transport production requirements.

The enhancement of railway transport capacity is developing towards high-speed passenger transportation, overloading freight transportation and improvement of train operation density. While the automated transport production is necessary to integrate transportation resources and improve the efficiency of railway transportation. Intelligent railway transportation production uses technologies such as artificial intelligence and intelligent analysis and decision, to realize the comprehensive utilization of maintenance, engineering, vehicles, electricity and other related transportation resources. It also helps to realize the automatic establishment and adjustment of train marshalling plans, transport plans and running charts, and then to achieve a high level of information sharing and business collaboration, improving the production efficiency of railway transportation.

b) Intelligent transportation safety requirements.

With the increase of train speed and vehicle weight, it puts forward higher requirements on railway transportation safety. Besides intelligent train control and scheduling command, it must be able to dynamically grasp of fixed and mobile equipment service status, to realize the automation of safety monitoring. It needs to constantly promote intelligent detection sensors and safety monitoring information network, to realize a real-time collaborative detection monitoring of car to car, surface-to-surface, as well as the natural environment. It all depends on technologies of sensor networks, intelligent diagnosis and intelligent image recognition, fault analysis and alarm, with the support of Internet information network [5].

c) Transport service informatization requirements.

Railway should make full use of information advantages, to create a multimode, multi-channel, full range of marketing strategy and service platform, to satisfy passengers and cargo owners personalized, diversified transportation services requirements. These services include a variety of means of payment of ticket sales and freight handling, travelling intelligent navigation and information interactive services, status tracing of goods, seamlessly exchange and door to door service, etc. And these all need the support of advanced intelligent device and information technology.

3) Internal and external motivation mechanism

The huge railway transport demand stimulus the business demand for information system. When the railway IS requirements are solved by information technology and industry management, and IS supply helps to meet this demand, the railway department will generate the intention of information technology application, and then promotes the evolution of the railway information system.

IS demands within the railway and IS supply outside the railway work together to promote the evolution of railway information system. Only with them appearing at the same time, can the railway departments apply information technologies. Therefore, in the process of information system evolution, it's the consequence of dynamic balance of these two powers.

3.2. Evolutionary Path of Railway Information System Based on Phase Diagram

Evolutionary path of railway information system specifies the main motivation, basic methods of its evolution. Combined with the research of evolutionary dynamics, the evolutionary path of railway information system is put forward with phase diagrams theory. Under the effects of railway information system external and internal power, follow the principle of step-by-step construction and overall planning, the railway information system evolves from simple to complex, as shown in Fig. 3.

On one hand, this evolutionary path attaches great importance to the step-by-step construction under the impetus of various business requirements, realizing the revolution of the railway information system from junior to senior. On the other hand, with the technology of computer and communication, it strengthens the powerful impetus of industry management, and pays attention to design the top level of railway information system. Meanwhile, it accelerates the integration and sharing of railway information resources, to achieve rapid, orderly and sustainable development of railway informatization.

4. Railway Information System and Technology System Based on IOT

4.1. Railway Information System Construction Planning with IOT

Internet of things is a kind of network which uses sense perception to turn object properties into information. It interacts between information by the transport of media under the constraints of standard specification, so as to realize the control and management between objects. According to features of Internet of things technology, combined with the demands of China's railway information system construction and development to the Internet of things technology [6], this paper proposed a program of railway information system construction and planning under the environment of IOT [7], as shown in Fig. 4.

As showed in Fig. 4, the railway information system construction plan based on IOT includes seven parts, which are automated transport organization, intelligent scheduling command, capacity resource synergy, digital passenger transportation management,

IOT freight management, integrated safety management, and global information control.

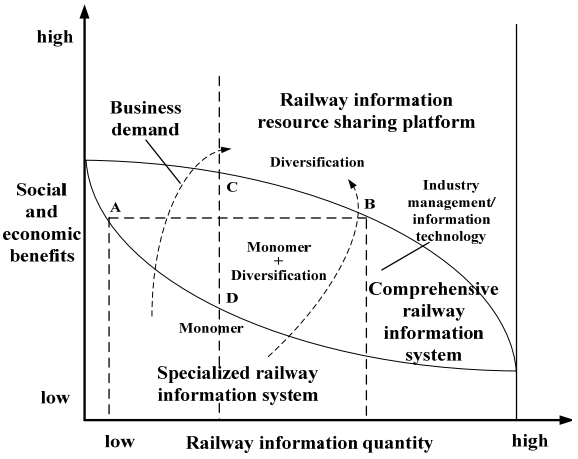

Fig. 3. Evolutionary path of railway information system based on phase diagram.

Railway information system construction and planning under IOT environment	Automated transport organization	·Automatic train operation system ·Automated passenger transportation organization system ·Automated freight organization system
	Intelligent scheduling command	·Intelligent planning and scheduling system ·Intelligent train scheduling system ·Intelligent locomotive scheduling system ·Intelligent passenger scheduling system ·Intelligent freight scheduling system
	Capacity resource synergy	·Locomotives management system ·Maintenance management system ·Electricity management system ·Vehicle management system ·Information resources management system
	Digital passenger transportation management	·Digital passenger ticket selling system ·Automatic passenger organization system ·High quality passenger service system ·Modern passenger transportation marketing system ·Digital passenger transport information management system
	IOT freight management	·Automated goods traffic organization system ·Modern freight marketing system ·Intelligent grouping plan system ·Digital freight information management system ·Intelligent transportation planning systems
	Integrated safety management	·Daily safety management system ·Train operation safety management system ·Safety early warning management system ·Rescue command management system ·Passenger/freight safety management system
	Global information control	·Digital information management system ·Automated information integration system ·Global information sharing system ·Comprehensive information platform

Fig. 4. Railway information system construction plan under the IOT environment.

4.2. Railway Information Technology System Based on IOT Technologies

Based on the IOT technologies and revolution of railway information system, combined with the construction planning of railway information system with IOT technologies, the railway information technology system based on IOT was built, as shown in Fig. 5. It's constituted by technology standard and five basic levels. Technology standard includes data management standard, user interface standard, operating system standard, information interactive standard and data transfer standard. Five basic levels can bottom-up divided into information perception layer, business management layer, IOT application layer, decision-making support platform layer and industry service application layer [8].

1) Information perception layer.

In information perception layer, the use of perception technology, coding technology, sensor technology, intelligent embedded technology can effectively manage the railway traffic organization, dispatching, freight and passenger management, security management and other resources. The status information of railway mobile devices (trains, locomotives, etc.), such as speed and location, can be comprehensively captured. Then it can realize the dynamic tracing management of mobile device, and the monitor of facilities such as tracks, stations and signaling equipment service status. It not only protects the security of trains running, but also maximizes the efficiency of resource utilization.

2) Business management layer.

Business management layer basically covers seven core businesses, including transport organization, dispatching, freight and passenger management, capacity management, security management and information controlling, as well as business management, decision analysis, statistical analysis and other ancillary operations. The increasing of business management levels needs the strong support of IOT's information perception, reliable transmission and intelligent possessing. The application of IOT technologies will effectively improve the efficiency of railway transport and quality of work, providing basis data and technical information for the visualization of transport, ultimately reducing railway operating costs, improving productivity, and upgrading the level of railway service [9].

3) IOT application layer.

The application of IOT technology in railway has widened the breadth and depth of railway information collection, achieved full domain controlling of mass railway information, and eliminated the information and resources island between the railway businesses, created basic conditions for railway integrated information platform. It then achieves to create a railway intelligent transport service system composed of automated transport organization, intelligent dispatch and command, collaborative transport capacity resources management, digital passenger management,

IOT freight management, integrated security control, and full domain of information control [10].

4) Decision-making support platform layer.

Decision-making support platform layer uses information sharing platform to get railway information resources, including in-road (ministries, departments, stations and depots) operation information, and off-road (passengers and shippers) demand information. Using data compression, conversion and processing through the service platform and cloud calculation platform, it increases the quality of industry decision makers. Through interactions of business marketing information between the trading platform and customer relationship management, it helps the railway sectors analysis the market, look for expansion opportunities. Railway sectors also serve for the whole industry by the business transactions and comprehensive information publish based on information data.

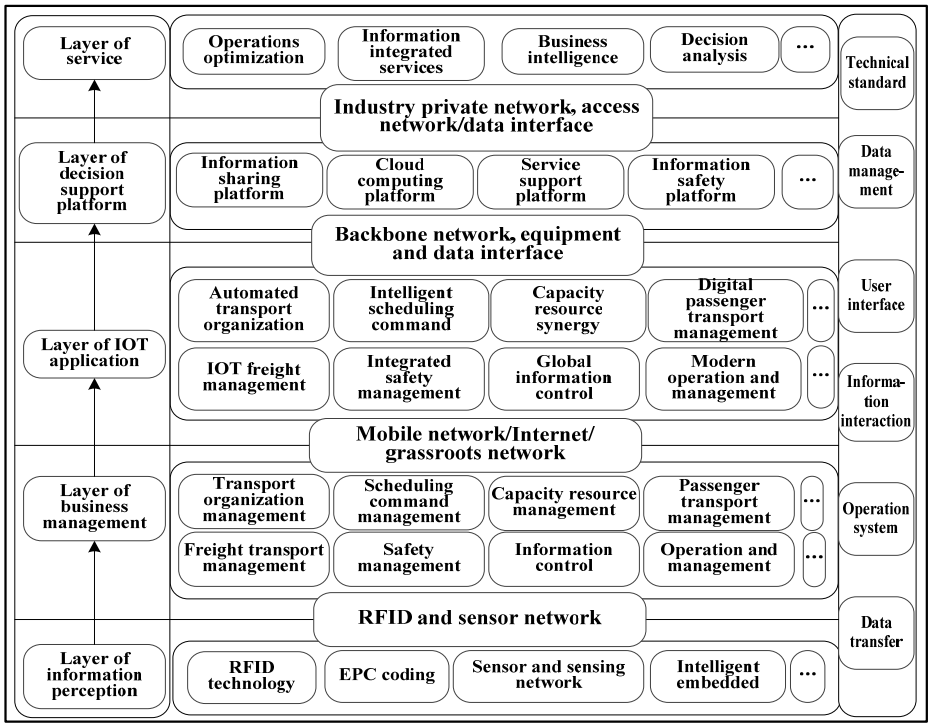

Fig. 5. Railway information technology system based on the IOT.

5) Industry service application layer.

By inserting the data resource applied with IOT into the application layer of industry service, and making unified IOT application standards, it can realize the application of IOT technology in the whole railway sectors, such as operations management, information service, business intelligence, and decision analysis, and provide development strategies for railway industry [11].

Information perception layer is the bottom of the IOT technology application in railway. It can provide comprehensive, accurate and effective information for the upper layers. Business management layer processes the collected information with information technology, to shorten the basic operation time, and improve the production efficiency of railway transportation. IOT application layer aims at achieving efficient control of railway transport organization and management, on the basis of information perception and business management layer. Decision support platform mainly processes and analyses all kinds of management information, providing intelligent decisions for railway departments. And each application of Internet of things technology in the railway departments of the service application layer data resource access to the industry, the realization of railway information resources integration and sharing, rail, road meet the diversified and personalized business needs.

5. Conclusions

This article starts with the concept and composition of railway information technology, and by analyzing the evolutionary dynamics of railway information system, it proposes the evolutionary path of railway information system based on phase diagram. According to the features of the Internet of things technology, combined with the present situation, planning and the demands for IOT of railway information system construction, it builds railway information system and technology structure based on Internet of things. With the help of the Internet of things, railway informatization construction is improving towards the comprehensive direction of intelligence and integration.

Acknowledgements

This work was supported by a grant from China's Ministry of Railways (2011X019-F).

References

[1]. Zhuo Wang, Limin Jia, China railway intelligent transportation system key technology system and strategy research, *Transportation Systems Engineering and Information Technology,* 2005, 5, 1, pp. 33-37.

[2]. Tao Feng, Jun Bi, Hongyu Hu and Hui Cao, Networking as a Service: a Cloud-based Network Architecture, *Journal of Networks*, Vol. 6, No. 7, 2011, pp. 1084-1090.

[3]. Jing-Qing Liu, Review of transportation informationization development in China, *China Railway*, 2, 2009, pp. 26-32.

[4]. Jun-Pei Ma, China railway informatization construction and prospect, *Transportation Systems Engineering and Information Technology*, 2005, 5, 5, pp. 1-5.

[5]. Laisheng Xiao, Internet of Things: a New Application for Intelligent Traffic Monitoring System, *Journal of Networks*, Vol. 6, No. 6, 2011, pp. 887-894.

[6]. Hanwu Shu, Railway transport information system and application, *China Railway Publishing House,* Beijing, 2008.

[7]. Ministry of railways of the People's Republic of China, Overall planning of railway informatization in China, 2009.

[8]. Xifu Wang, The Internet of things and logistics informatization, *Electronic Industry Press*, Beijing, 2011.

[9]. Xiaoliang Wang, Qi Bi, The application and development of IOT in railway transportation in China, *Railway Communication Signal*, 2010.

[10]. Sharief M. A. Oteafy and Hossam S. Hassanein, Resource Re-use in Wireless Sensor Networks: Realizing a Synergetic Internet of Things, *Journal of Communications*, Vol. 7, No. 7, 2012, pp. 484-493.

[11]. Du Wang, Feng Lin, Railway construction and operation research on Internet of things, *China Railway*, 7, 2012, pp. 19-22.