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An Applied Study on Railway Safety Monitoring based on Internet of Things

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Abstract. Based on the existing Internet of Things (IOT) technology, information systems and the application status of the IOT in domestic and international Railway Safety Monitoring and targeted at railway informatization and intelligence, this paper comes up with the IOT architecture in the Railway Safety Monitoring of China, makes application designs in the multi-dimension of sense nodes of the IOT, reasonable signal path sharing and full fusion and sharing of induction information and analyses the effects and suggestions of the application of the IOT on passenger stations, freight stations/marshalling yards and the railway line. This is further complemented with some research results that illustrate how IOT can be extended or used to tackle the problems of Railway Safety Monitoring. This paper aims to accelerate the construction and improvement of railway security system and promote the safety foundation construction of railway.

Keywords: Internet of Things , RFID ,Railway Safety Monitoring .

1. Introduction

The Internet of Things, a modern information industry, swept the whole world and drew extensive attention on a large number of people (L. Atzori, A. Iera & G. Morabito,2010). Now, the IOT technology in China has been applied to rail transportation, parking spaces recognition and so on. In February 2012, the Ministry of Industry and Information Technology Ministry official release of the Internet of things "twelfth five-year" development plan, which marks the completion of the top-level design of China's Internet of Things Industry. The IOT in the railway industry is mostly concentrated in the terminal network level, ignoring the overall architecture standards. Considering the status of China's railway safety monitoring developments, it has far-reaching significance to build the IOT application architecture in China's railway safety monitoring.

The concept of the Internet of Things first appeared in the book "The Road Ahead" by Bill Gates, published in 1995.So far, the academic community does not have an accurate definition of the concept of the IOT. On the basis of previous studies, this paper proposes the IOT is a network, which achieves intelligent identifying, locating, tracking, monitoring and managing through information sensing device, just as radio frequency identification (RFID), infrared sensors, global positioning systems, laser scanners and video identification system, according to the agreed protocol, any goods and connected to the Internet for information exchange and communication.

Judging from the objects and processes of the communication, the core of the IOT is the information exchange between Man to Machine and Machine to Machine. It should be emphasized that the IOT is not a new network. The overall perception of the IOT is based on a variety of existing information collection, from kinds of sensing devices and other information systems, to do better, richer and more complete information sharing. Complete reliable information exchange and sharing by the object access information network, relying on a variety of communication networks, no matter anytime or anywhere. Analyze and process mass data and information with a variety of smart computing technology, in order to accomplish intelligent decision-making and control.

The development of science and technology continue to promote the development of the Internet of Things technology. At present, many scholars have explored the architecture of the Internet of Things and put forward different architectures, according to the different application points of view and research directions. The representative are the World Wide Web (Web of Things, WOT) system structure (DUQUENNOY S., & GR MAUD J.J.G, Vandewalle, Smews., 2009), EPC architecture, ITU architecture (Liu Qiang, Cui Li & Chen Haiming,2010), as well as independent architecture (PUJOLLE,G.,2006) and M2M architecture. Currently, the more representative architectures of the IOT are EPC Global Internet of Things architecture supported by Europe and the United States and Ubiquitous ID (UID) of Things system supported by Japan (Wei Pingping, 2012). China is also actively involved in the study of the architecture of the IOT, who is actively formulate standards and architecture of the actual situation of the social development of the IOT.

As can be seen from these IOT application system standard modes, the system architecture of the IOT is generally constituted by a three-tier system--the sensing layer, network layer and application layer. Sensing layer , in the lower end of the whole system, the main role is the perception and object recognition, acquisition and capture information. The network layer is located in the middle position of the system as a whole, is universal service infrastructure of the IOT. The application layer is located in the top of the system, and the key is how to achieve social information sharing and protection of information security. It combines the IOT application architecture with industry-specific applications, achieving applications within the industry.

United States, Europe, Japan, South Korea and other countries with higher information technology capabilities and the higher level of informationization and intelligentization of the depth and breadth of the IOT application of the safety monitoring take the leading position in the world. Disaster prevention and safety monitoring system in Europe and Japan is in the leading position, which ensure the safety of the train travel effectively by the detection of the natural environment and equipment. The high-speed rail disaster prevention and safety monitoring system in Germany and France can achieve real-time monitoring of the environmental information of the train, snow storm and litter, to ensure traffic safety. In addition, Japan's high-speed rail disaster prevention and safety monitoring system can also be achieved earthquakes, floods, foreign body invasion limited to special locations such as tunnels, bridges and stations monitoring. And Spain carried out experimental application of optical fiber sensing technology in railway safety monitoring system for real-time monitoring of rail temperature, the speed of the train and train information.

What’s more the United States and Japan are in the experiments and applications of UAV (Unmanned Aerial Vehicles)technology. U.S. Department of Transportation exemplary UAV-based remote sensing systems will be applied to quickly obtain the image of the road transport network and information obtained for quick analysis. In Japan the use of UAV for post-disaster investigations, used in conjunction with the sensor base of scientific research data used to obtain the complex terrain.

China has attached great importance to railway security monitoring technology research and application. As early as in the 1970s, China had already begun the development work of the Infrared Hotbox Detection system. Since the 1980s, with the rapid development of modern control technology, communication technology and computer technology, security and surveillance technology are widely used to prevent train aggressive signal, bus fire, vehicle fuel-axis, line up rail off the rails, snow storm disasters, landslides and so on. China has developed and promoted the use of automatic train stop device, train speed monitoring device, buses infrared Hotbox Detection device, rail flaw detector, track dynamic detection car. Through scientific and technological means, the security situation of China's railway traffic has been effectively improved.

Name	System Function	Application Time
High-speed railway disaster prevention and safety monitoring system (Zhang Weijun, 2010)	Monitor the information of earthquake, natural disaster, rail temperature , Embankment safety, mobile devices and alarm	Put into operation since 2009
THDS (Trace Hotbox Detection System)	By vehicles bearing temperature real-time detection; Alarm on hot axle vehicles; with train number and car number for tracking, realize accurate forecast for thermal shaft van car number (Han Zengsheng & Zhang Guangming, 2007).	Development began in 1970, Beginning in 1980
TADS (Trackside Acoustic Detection System)	To prevent early railway freight car rolling bearings fault, mainly focus on the detection of truck rolling bearing outer ring raceway roller, etc[8]	Development began in 2003, Beginning in 2004
TPDS (Truck Performance Detection System)	Do dynamic testing of vehicle safety indicators, focuses on the detection of derailment coefficient, wheel weight load shedding rate, wheel tread abrasion, peeling and cargo overload, partial load	From September 2003 until now
TFDS (Trouble of moving freight car detection system)	Use of Rail-side high-speed camera, dynamic tests to run trucks, realizes auxiliary Train Inspection.	From 2004 until now
TCDS (Train Coach Diagnosis System)	Through a wireless or wired network, the monitoring information to the terrestrial transmission and aggregation, form the real-time passenger safety monitoring operation diagram.	From 2004 until now
TWDS	The online dynamic automatic detection of wheel dimensions and treads defective condition.	Development began in 2002, Beginning in 2006

Rail temperature and temperature stress real-time monitoring of network transmission system	Fixed-point and real-time monitoring to track temperature and ambient temperature by means of transmission, automatic wireless (SMS) to achieve real-time monitoring and transmission of the track and ambient temperature	From May 2005 until now
The Railway Construction dynamic detection system	Professional real-time dynamic detection of Public Works infrastructure and the surrounding environment which affect the safe operation of trains technical indicators and related information.	From April 2007 until now
Railway overloaded freight train and loading condition monitoring system	Dynamic detection of loading gauge and status of freight train, the auxiliary cargo inspection job preflight and improve the re-examination targeted.	From 2004 until now
Railway freight train loaded state HD monitoring system	Monitoring the train on both sides and the top	From October 1999 until now
Railway transport of dangerous goods safety monitoring system (Stations)	Manage and monitor the railway stations of dangerous goods transport information	From 2008 until now

1. Table 1. the statistics of China's railway safety monitoring system

In recent years, with the continuous improvement of passenger's train travel speed and travel quality requirements, a large number of state-of-the-art technology-based security monitoring equipment gradually come into the safety of the railway system. On the basis of infrared Hotbox monitoring, China has continued to develop the automatic monitoring system of the vehicle running state, realized the automatic monitoring for overloads and unbalanced load of freight trains, Part of the train wheels on the parameters and wheel fault. In the mountain railway, China has developed a forecast wind, rain, mudslides, landslides and other natural disasters Safety Monitoring Device. These advanced and reliable security monitoring equipments have become a means of protection of safety of the railway irreplaceable. Currently, the IOT technology Has been applied in the field of railway safety monitoring in disaster prevention and safety monitoring, vehicle 5T systems (shorted for THDS, TADS, TCDS, TPDS and TWDS), comprehensive detection of high-speed railway trains and video surveillance and other aspects.

2. IOT Hierarchy Architecture in Railway Safety Monitoring

2.1. the IOT Hierarchy Architecture

The IOT hierarchy architecture in the railway safety monitoring from the sensor, transmission, service angle, vertically divided according to the function can be divided into the application layer, the network layer and the sensing layer, as shown in the specific structure shown in Figure 1. The sensing layer includes a variety of real-time data-aware acquisition equipment, and the underlying sensor network which realizes transmission of putting these data into the LAN in the railway safety monitoring. The network layer is responsible for the railway of Things network transmission of the real-time acquisition data, including the transmission of Things WAN remote data collection network, local area network, and the IOT data acquisition equipment transmission network of organizations. The application layer is the network layer real-time access to the information, applied to the field of railway safety monitoring system for the protection of railway safety.

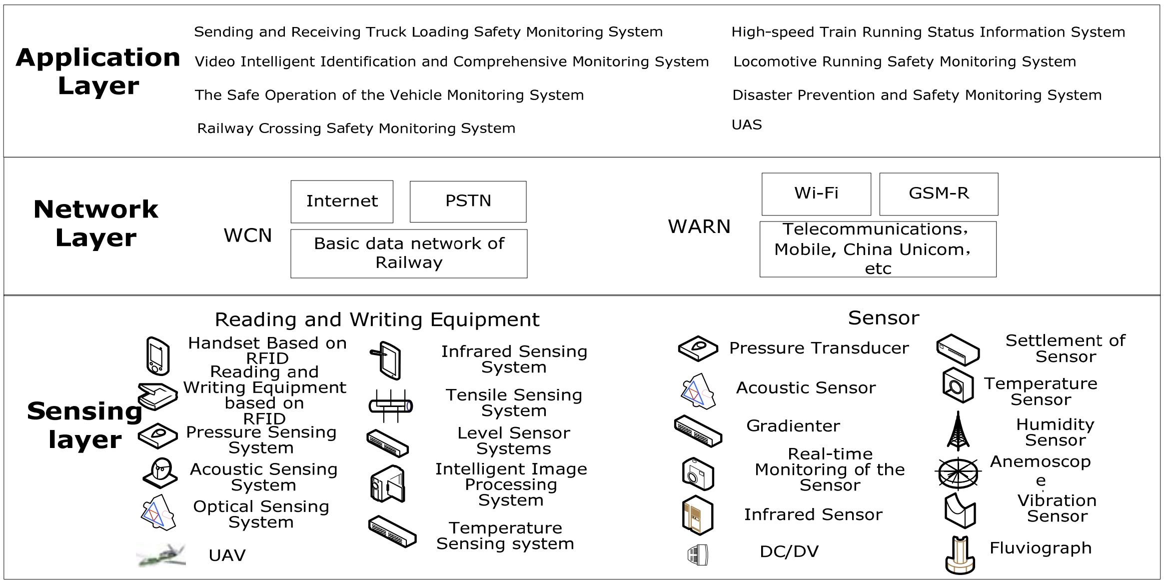

Fig. 1. The IOT Hierarchy Architecture in the railway safety monitoring

2.2. Sensing Layer

The Sensing layer architecture is shown in the bottom of figure 1. Sensing layer device, including various types of sensors, RFID tags and readers, IC card reader, mobile terminals, smart handheld machines, is mainly used in railway data collection, sending and receiving, automatic controlling and mobile data processing and controlling.

The sensor applications and functions in the field of railway safety monitoring are shown in Table 1.

Name	Function
anemograph	Determine potential impact wind brings to the safe operation of the railway
hyetometer	Get the rainfall information to determine its impact on railway lines, bridges, etc.
water level indicator	Get along hydrological information to determine its impact on railway lines, bridges, etc.
infrared sensor	Discrimination of foreign invasion events on stations, lines and crossing
pressure sensor	Measurement of train acceleration, pressure and force
acoustic sensor	Analyzing the information of train bearing damage
temperature sensor	Temperature information perception on trains, locomotives, etc
humidity sensor	Analysis of the disaster information along the train line
vibration transducer	Measuring the acceleration, tilt, vibration and shock of the trains
wheel detector	Monitor and control train information
Temperature sensor	Perception of train axle temperature information
Digital camera, video camera	Monitor the railway animals, and staff activities to achieve the timely identification of illegal or dangerous

Table 1. The sensor applications and functions in the railway safety monitoring

During the building of sensing layer in the field of railway safety monitoring of the IOT, what needed is to promote the application of RFID in the field of rail transportation equipment and trackside equipment identification, to achieve universal recognition of fixed RFID readers and handheld readers. Promote the application of digital cameras, digital video cameras and intelligent image recognition system in the specific personnel identification, identification of dangerous actions. Promote stress, tension, level meter, hydrological sensors buried in the railway line bridge and tunnel construction and delivery of installation, the establishment of real-time monitoring of health and safety of the railway line bridge and tunnel system. Promote the application of infrared recognition system at the station, crossing on the bridge surrounding Tunnel to achieve real-time recognition of foreign invasion. And promote the application of UAV in selecting line, along the lines of security, disaster relief and other fields.

Gradually promote the integrated application of the IOT data acquisition equipment and data transmission. The integration of the IOT sensor is the development trend of the IOT technology. The railway trackside sensing and monitoring equipment is more and more. Basically a device that collected a data transmission lines need to be laid separately. Various types of the rail beside sensing data acquisition device for monitoring the safety of the railway should be gradually encouraged to achieve the integration of RFID, acoustics, temperature, image sensing and data acquisition, in order to reduce the trackside equipment. Sensing data underlying transports centralization, to facilitate the acquisition and the management and maintenance of data transmission equipment.

2.3. Network Layer

Network layer architecture is shown in the middle of figure 1. It is divided into two components of a mobile communication network (MCN) and a wide area remote network (WARN), as shown in figure 2.

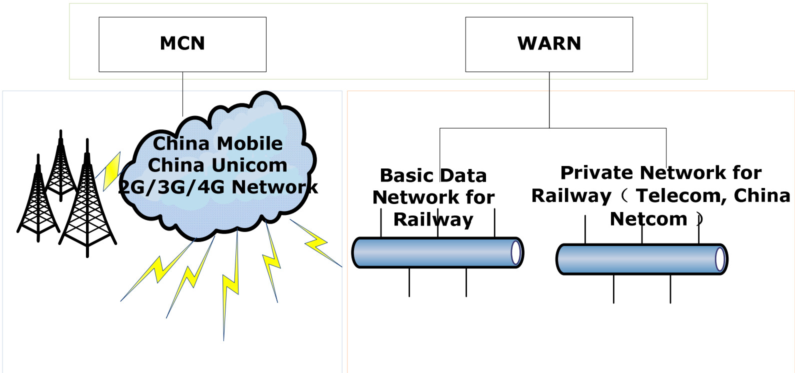

Fig. 2. The network layer architecture of the IOT Hierarchy Architecture in the railway safety monitoring

WARN is a basic data network for railway. When existing railway basic data network bandwidth is difficult to meet for high frequency real-time video, images and a large number of sensor data, Telecom, China Netcom and other network should be used to achieve a private network for in the premise of railway data security.

MCN mainly uses the GSM-R. When GSM-R is difficult to provide sufficient bandwidth on train-ground communication of High-speed rail train on-board safety monitoring, Intelligent hand-held wireless identification and data processing in Freight Station/Marshalling Yards, 2G/3G/4G mobile network of Telecom, China Unicom or China Mobile can also be used to achieve a private network form in the premise of railway data security.

In some smaller areas of Stations, Wi-Fi can also be used to build a wireless LAN in order to realize the transmission of sensor data, handhelds, etc. For some areas concentrated by a large number of sensors, it is allowed that equipments of manufacturers build self-organizing network such as ZigBee to achieve the centralized transmission of sensor information.

2.4. Application Layer

The application layer system construction diagram is shown in the top of Figure 3. With the implementation and integration of information systems through the application layer, achieve the goal of creating "safe railway" and the establishment of the self-induced security road network.

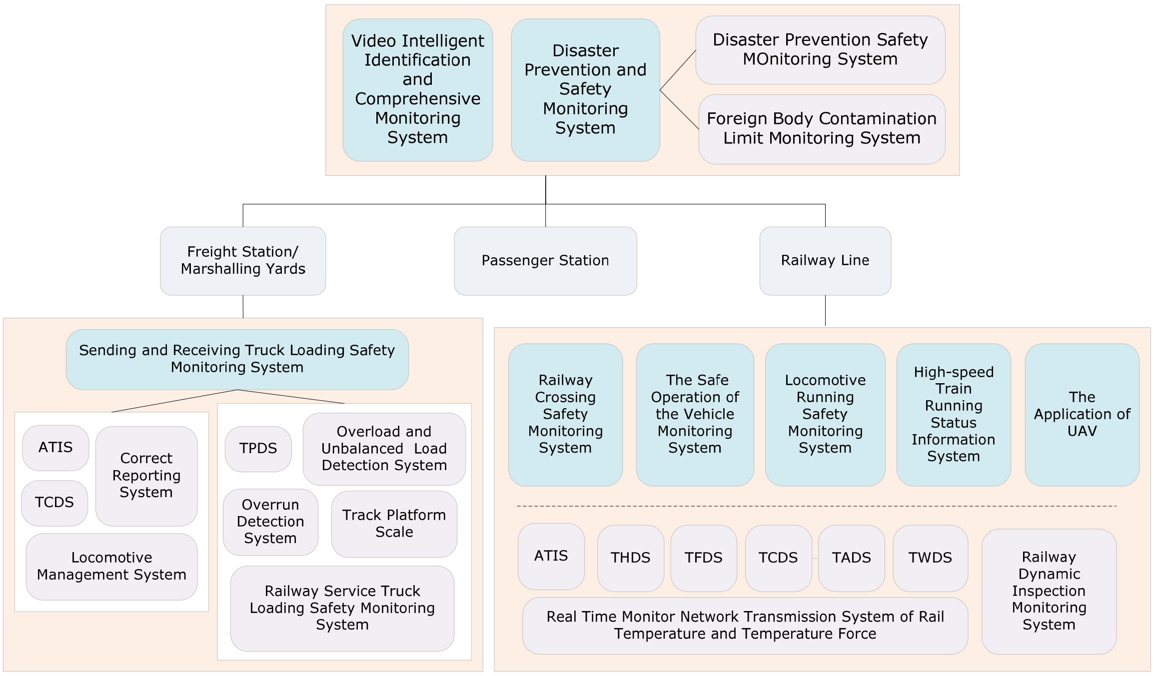

Fig. 3. The application layer architecture of the IOT Hierarchy Architecture in the railway safety monitoring

According to the existing information systems in the field of railway safety monitoring survey research, this paper proposes eight areas of application in the field of safety monitoring based on the IOT. They are video intelligent identification and comprehensive monitoring system, disaster prevention and safety monitoring system, sending and receiving truck loading safety monitoring system, railway crossing safety monitoring system, the safe operation of the vehicle monitoring system, locomotive running safety monitoring system, high-speed train running status information system, and the application of unmanned aerial vehicles. for a the field of railway safety monitoring network application layer the building specific reference. These applications provide a specific reference as a matter of the field of railway safety monitoring network application layer construction.

During the development of the application layer, we need to promote the application of sensor data fusion. To achieve sensing data at all levels, from bottom to top sharing, to achieve the integration of applications in each system in a safe and controlled under the premise of the progressive realization of the railway system as taken with the use of various types of sensor data .

At the same time, we must strengthen the intelligent application of massive sensor data. With using a large data processing methods and technology, achieve the rapid timely processing of railway massive network data. In the environment of all kinds of sensor data fusion and centralized, do research related to intelligent data processing, judgment, forecast and early warning model. Gradually we will have an integration system, which can timely response correlation processing requirements, to achieve real-time perception and monitoring of the security condition of the whole road.

3. Effects of the IOT Application

3.1. Passenger Station

The main task of the passenger station is to organize passengers safely, accurately and conveniently to get on or off the train, and to organize trains safely, on-time arrival and departure, and to provide passengers with comfortable conditions of service. In addition to management factors, railway equipment, personnel and the environment are the three main factors affecting the safety of passenger station.

As shown in figure 4, to promote the application of video intelligent identification and comprehensive monitoring system in railway passenger station, improving and updating existing data reading and writing equipment and sensors is needed. When come into the station, rail IC card should be used to check in by Automatic Fare Collection System (AFC). In some stations face automatic identification equipment should be installed for law enforcement needs of the public security departments. Improve the application of the digital cameras, digital video, intelligent image monitoring system and intelligent video surveillance system in the identification of specific persons, dangerous section recognition. And foreign body contamination limit infrared sensor should be installed in the passenger stations near the railroad tracks to prevent pedestrian and foreign matter strayed into the railway track. At the same time, the information of the license plate number of Automatic Train Information System (ATIS), which is combined with Automatic Equipment Identification (AEI) and wheel detector, should be more shared with the other security monitoring system.

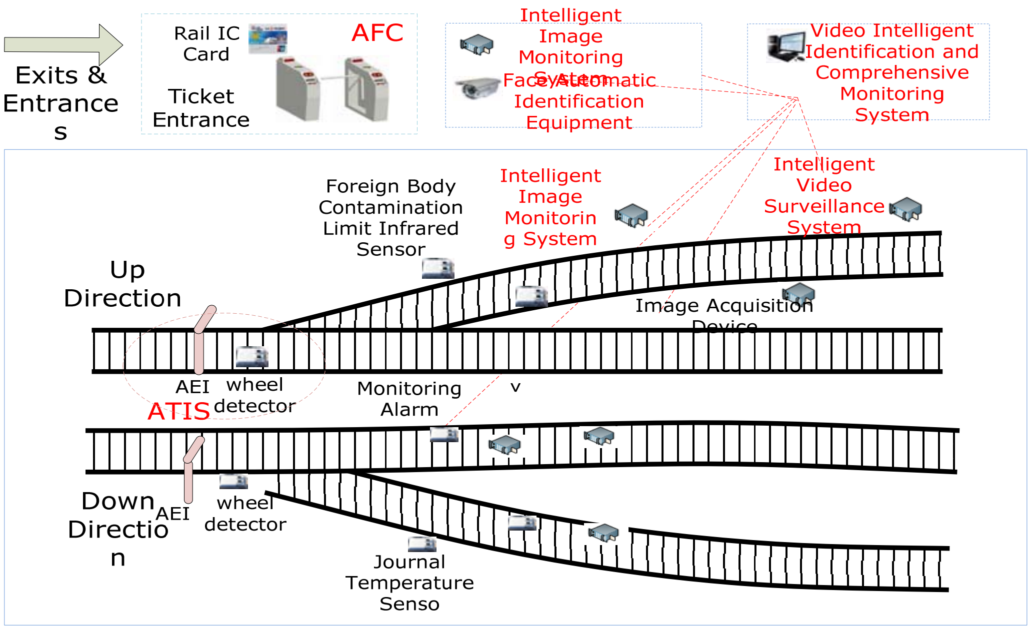

Fig. 4. The application in passage station

3.2. Freight Station/Marshalling Yards

Freight Station is the main railway stations in China. To enhance the quality of service of the freight station and improve freight service level is part of the informatization construction of Freight Station/marshalling yards.

As show in the figure 5, the application of the IOT technology in the freight station /marshalling yards is to adjust and optimize security monitoring, which mainly reflected in the application of integrated video intelligent identification and monitoring system and sending and receiving truck loading safety monitoring system. To promote the application of the IOT technology in the freight station/marshalling yards, the goal is to achieve security monitoring of the cargo inspection job. Through the integration of Overload and unbalanced load detection system, rail weighbridge, overrun detection system, Truck Performance Detection System (TPDS) and railway sending and receiving truck loading safety monitoring system, as well as four information system which are correct reporting system, vehicle management system, ATIS and Train Operation Dispatching Command System (TDCS), the freight station /marshalling yards will achieve seamless connection. Cargo screening handsets should be put into use in the goods inspection from the ground crew, and then the records of the problem-train will be uploaded to the secure centralized monitoring system for cargo inspection station. In some smaller areas of stations, Wi-Fi can also be used to build a wireless LAN in order to realize the transmission of sensor data. Eventually, we will achieve to monitor the whole process of cargo screening work.

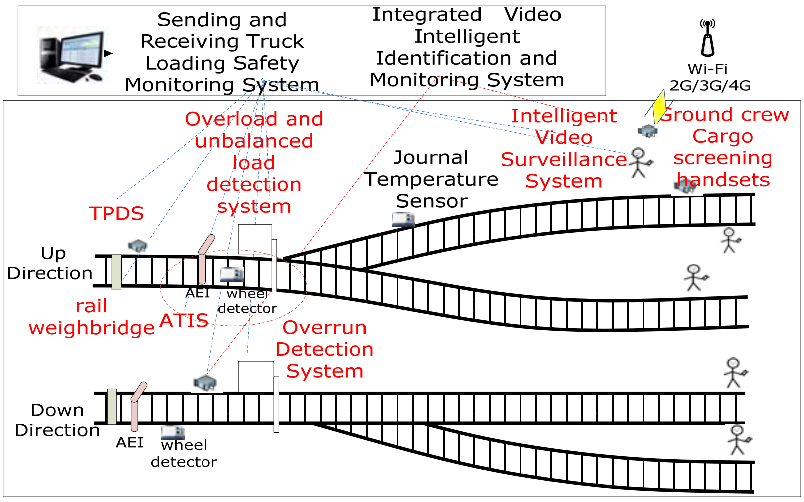

Fig. 5. The application in Freight Station/Marshalling Yards

3.3. Railway Line

The IOT applied in railway line is depicted as shown in figure6. In the propulsion of the application of railway security surveillance of the IOT, we need to gradually promote the integration of the IOT data acquisition and data transmission, so as to achieve security surveillance information system integration.

With the application of the IOT technology in the railway line, the following specific functions will be achieved. With High-speed train running status monitoring system , which helps to monitor and diagnose the security condition of the key parts, cars, rails, routes and grid of the EMUs, dispatchers and maintenance department can get information through Train-ground communication system timely. In this way, it will tracks the real-time status of high-speed trains and guarantees their safety, and at the same time, it can also provides data to the supervisors timely and reliably so that to help making decisions for matures like repairing and rescuing.

By Comprehensive monitoring system for the safe operation of the vehicle， we can get the early warning information of the integration of the locomotive safety monitoring and comprehensive analysis information. Integrate 5T system, and unify deployment of integrated trackside monitoring equipment to car safety, achieving information sharing and the seamless connection with Accurate reporting information system, ATIS, TDCS .Establish a unified, complete safe operation of the vehicle alarm evaluation and treatment systems, for supporting the safety of vehicle operation vigilance and vehicle maintenance guidance.

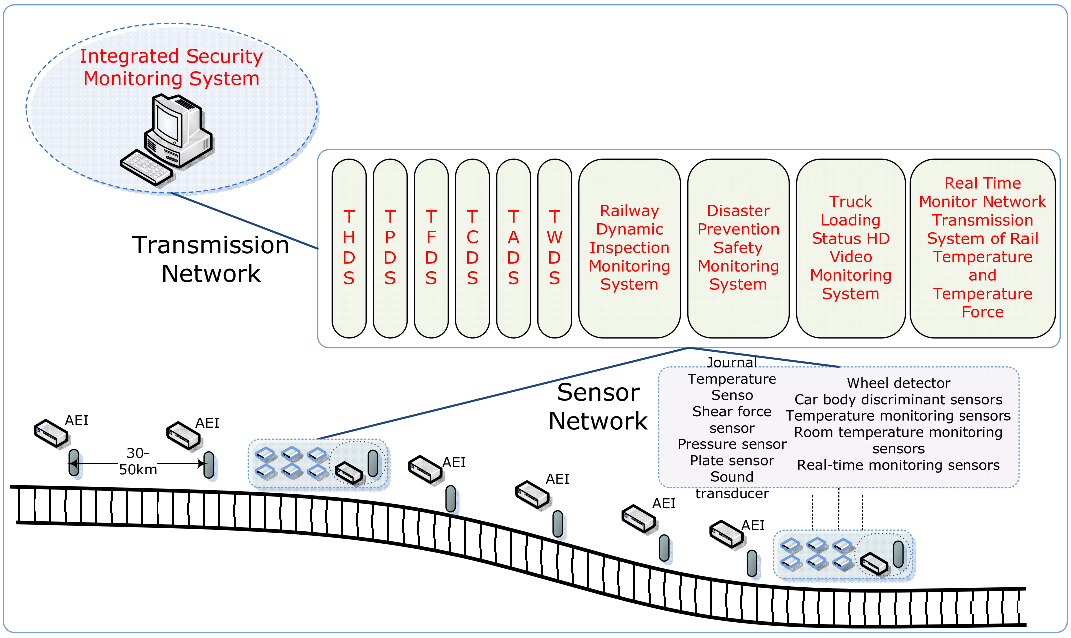

Fig. 6. The application in railway line of the IOT Hierarchy Architecture in the railway safety monitoring

With Railway Crossing safety monitoring system, which puts the IOT technology into use of railway level crossings, provides video surveillance and early warning function.

With the disaster prevention and safety monitoring system， focus on detection of real-time health and safety status of line, bridge, tunnel and station as well as the across the railway bridge, the fall from viaduct, the rockfall from tunnel. The system will provide Natural disasters information and foreign body contamination limit alarm message to Scheduling department and infrastructure maintenance department, which can improve the decision-making level in the case of disasters and emergency response capabilities. Railroad in adverse geological conditions and harsh climate areas, to increase automatically laid rainfall, snow, wind, landslides and other monitoring points. Take analysis of the real-time monitoring data in all-round and multi-angle way. And review with video surveillance system. At last, combined with Train control system and traction power supply system to form a linkage alarm and control output.

4. Conclusions

Railway safety monitoring and management plays an important role of railway development as well as national and social stability. The IOT technology applied in the railway safety monitoring can effectively resolve the status of railway safety decentralized monitoring. This paper describes with the application of the IOT technology to use data fusion, intelligent acquisition to get data in sensing layer, by rail proprietary and complementary line transmission, to achieve a comprehensive, integrated railway safety monitoring and management program at the application layer. However, let the IOT technology applied to every corner of the railway safety monitoring, we still have a long way to go.

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