# High Speed Railway Integrated Maintenance Logistics Monitoring System Based on the Internet of Things Technology

**Alhossein Mohamed, Peng Qiyuan**

*Abstract*— **The paper introduces the management process and composition of high speed railway integrated maintenance logistics monitoring system based on Internet of Things technology and Matlab simulation and field test on the critical technical problem of the monitoring system, i.e. reader-reader collision. The research results show that for the high speed railway integrated maintenance logistics monitoring system provided with less than 5 readers which are based on probabilistic power control algorithm, such readers can monitor a range exceeding 3.5m with favorable effect by relying on the embedded software, thereby ensuring the feasibility of the system.**

***Index Terms*— High speed railway (HSR); Internet of Things (IOT); maintenance logistics monitoring; Matlab simulation**

## I. INTRODUCTION

By the end of 2012, Chinese HSRs have covered a total operating kilometrage of more than 8000km, with 10000km more under construction. The total kilometrage and operating kilometrage have ranked first in the world. The scientific and technological innovation level of railway has been obviously improved. Academician of CAS Wang Mengshu has proposed three key issues with respect to HSR operation, i.e. "flexible" catenary, wheel-rail and signal system and huge maintenance force [1], and the management of maintenance safety of HSR is particularly important. Japan, France and Germany prefer Two-level or Three-level hierarchical management mode, i.e. railway administration, regional bureau and integrated maintenance depot while China applies separation mode of management, inspection and maintenance [2]. Currently, information, network, internet and IOT technologies have enabled the information to be widely used as the bases for control and decision-making through data acquisition, transmission, processing and sharing. The information-based maintenance management can realize the real time management of maintenance by integrating the management of engineering, electrical and power supply systems [3]. The HSR integrated maintenance logistics monitoring system based on the IOT technology is to safeguard the supervision of construction status within the occupied line and line security after the railway construction and effectively supervise the workers, materials and tools within the occupied line through IOT technology. In addition, such system can ensure the real time monitoring of occupation status of the occupied line and no workers and materials left in the guard fence after the construction, guaranteeing safe driving in HSR.

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## II. SYSTEM STRUCTURE DESIGN

The HSR integrated maintenance logistics monitoring system refers to a set of complete monitoring system for line maintenance logistics with computer as the core, which is a combination of hardware and software. The system is composed of equipment tags (passive RFID tag and QR code), electronic packing case for small parts, access control identifiers for service passage and warehouse outbound, hand-held terminal (HHT), long-range passive RFID tag reader, repeater, data transmission channel, transmission interface and relevant monitoring software[4].

The main operation principle is that the master computer transmits the maintenance or urgent repair work order to HHT and access control identifiers for service passage and warehouse outbound; gives information about warehouse outbound, permit to work on track (passive RFID tag or QR code), track workers and quantities of materials.

Track workers, materials, tools and instruments are equipped with passive RFID tags for identification. Therefore, they can be automatically logged in when passing through the access control identifiers for warehouse and service passage or through HHT. The identifiers upload all the information received to the master computer for recording and can give audible and visual alarm in case of data discrepancy with the data from the master computer. The electric door can open and close under the control of access control identifiers for passage and can only be opened and closed when the data is identical.

HHT has stored QR codes for access control identification in it, which can operate the electric door separately. In addition, HHT can record the traveling path of track workers which can be used to track any left materials on the track. The access control identifier for service passage is provided with two long-range passive RFID tag readers for identifying the direction.

Master computer and access control identifiers for warehouse and service passage can communicate with each other.

Dispatching offices, railway stations, public security departments and HSR maintenance departments within the jurisdiction of the railway administration can know the online status of workers, materials and tools in real time through interconnected public communication network.

## III. System Function Design

The development of logistics monitoring system involves the management process of HSR integrated maintenance logistics monitoring, Radio Frequency Identification (RFID) and transmission technology, barcode technology, embedded software, electronic circuit and management software for logistics monitoring.

### 3.1 Logistics monitoring management process

According to the management system relating to railway maintenance[5], the management process of HSR integrated maintenance logistics monitoring includes:

(1) The maintenance or urgent repair order, as well as the order permitting to work on track is given;

(2) The maintenance or urgent repair order is given according to dispatching offices of railway administration; the quantities of track workers and materials are advised and the workers are requested to check and confirm the contents;

(3) The maintenance or urgent repair work order is transmitted to HHT and access control recognizers for service passage and warehouse outbound; the information about warehouse outbound, permit to work on track (passive RFID tag or QR code), track workers and quantities of materials is given;

(4) The small tools and materials are packed and installed with passive RFID tags for identification according to the information received by HHT, and then are confirmed through HHT by scanning;

(5) Workers, large materials and various tools and instruments are installed with passive RFID tags separately;

(6) Workers, large materials, various tools and instruments and tool kits with RFID tags are automatically logged in when passing through the access control identifier for warehouse or through HHT when leaving the workshops and warehouse in work district. All information is transmitted to the long-range terminal for recording. In case of inconformity with the maintenance or urgent repair work order in master computer, the access control identifier for warehouse sends audible and visual alarm;

(7) Access control recognizer for service passage shall scan the permit to work on track stored in HHT. The access door can only be opened when the information is correct. In addition, the workers and materials on track can be automatically logged in through the identifier or HHT. All information is transmitted to the long-range terminal for recording. The recorded information about workers and materials is then transferred to related access control recognizer for service passage;

When it is found that the incoming materials are not logged in by the access control recognizer for warehouse, the access control recognizer for service passage will give an alarm.

The access control recognizer for service passage is provided with long-range readers A and B, so the service doors can only be opened in the sequence of A-B.

(8) The access control identifier for service passage gives audible and visual alerts when work time is up, gives the alarm for the workers and materials not departing from the track within required time and automatically logs out the departed workers and materials which can also be logged out by HHT. All information is transmitted to the long-range terminal for recording;

In case of inconformity, the access control identifier for service passage will give audible and visual alarm.

The access control recognizer for service passage is provided with long-range readers C and D, so the service doors can only be opened in the sequence of C-D.

(9) Workers, large materials, various tools and instruments and tool kits with RFID tags is automatically logged out when passing through the access control identifier for warehouse or logged out through HHT when leaving the workshops and warehouse in work district. All the information is transmitted to the long-range terminal for recording;

(10) The travel path is tracked and recorded with GPS positioning function of HHT;

(11) A single operation is completed.

### 3.2 Function analysis of logistics monitoring management software

The HSR integrated maintenance logistics monitoring system is a computer-oriented system relying on RFID technology and combining hardware and software, realizing the real-time tracking and intelligent management of whole HSR integrated maintenance logistics process[4]. Its main function is to realize the information sharing from the issuance of maintenance order to the completion of maintenance. Fig.1 shows the basic functions of system.

The function modules of management software for HSR integrated maintenance logistics monitoring based on IOT include the modules of system management, tag management, identifier management, alarm processing, dispatching and command management, online logistics management, as well as access control for inbound and outbound and arrival at/departure from the track.

System management: Login control and data backup.

Tag management: Tag login and logout.

Identifier management: Identifier login and logout.

Alarm processing: Alarm query and release.

Dispatching and command management: Terminal information management, task level and type, state of EMU line, workers and material information, alarm by information comparison.

Online logistics management: Online workers; workers locating and tracking; online time limit alarm and online logistics path playback.

Access control for inbound and outbound: Place, time, workers, materials and alarm by information comparison for inbound and outbound.

Access control for arrival at/departure from the track: Place, time, workers, materials and alarm by information comparison for arrival at/departure from the track.

## IV. Information Reader-reader collision

The high speed railway integrated maintenance logistics monitoring system based on IOT technology refers to a set of complete line maintenance logistics monitoring system that combines hardware and

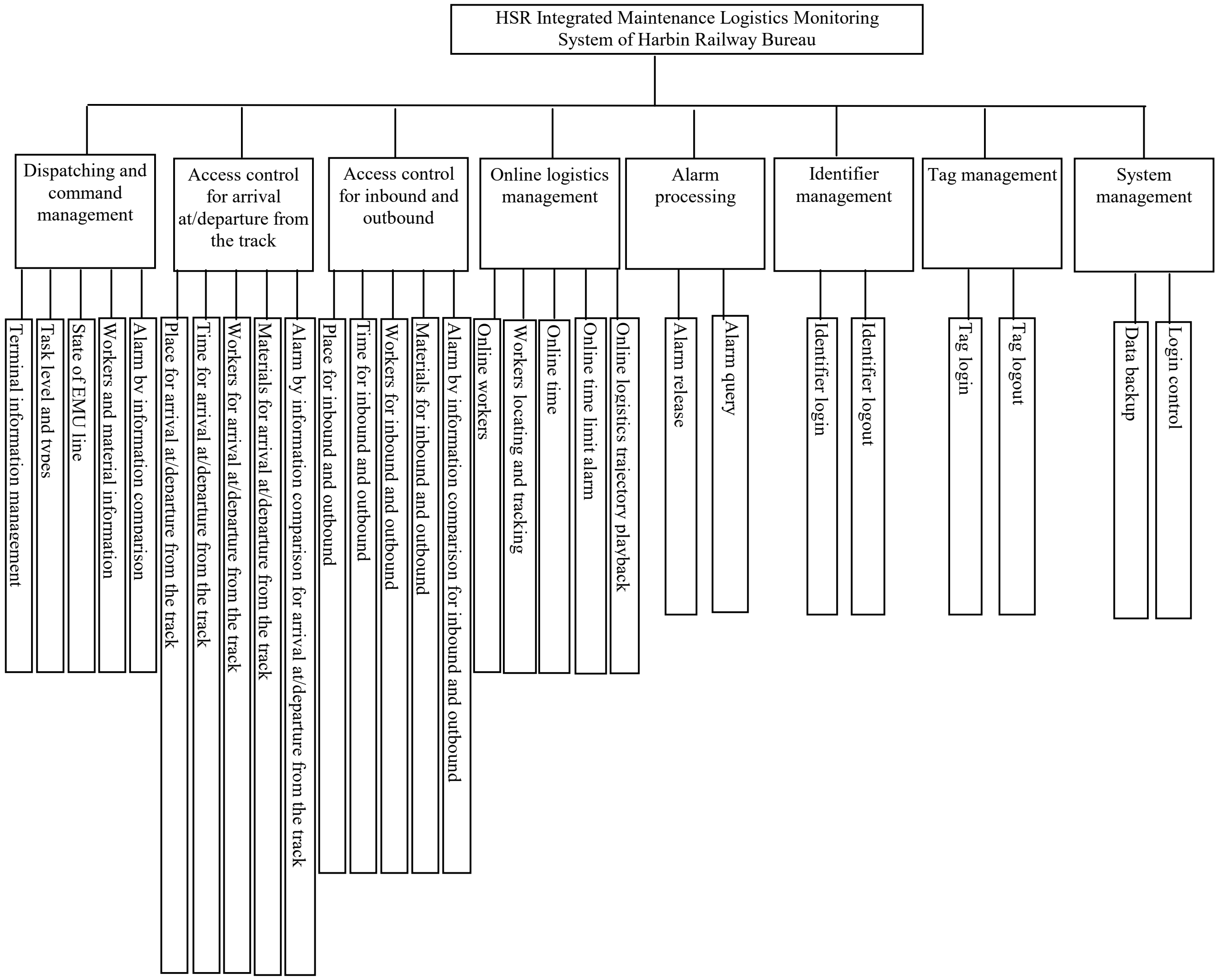


Fig. 1 Function Modules of Monitoring Management Software

software, with computer as the core. The system covers many fields. The three issues: (1) management process of high speed railway integrated maintenance logistics monitoring, (2) RFID tag-reader collision, and (3) reader-reader collision are the core issues of the system. The management process of high speed railway integrated maintenance logistics monitoring has been discussed in Sub-section 2.1, and RFID tag-reader collision can be solved by Manchester Algorithm and patrol [4].At present, synergetic planning algorithm and power control algorithm are mainly adopted to solve reader-reader collision [5]. The paper proposes a probabilistic power control (PPC) algorithm for solving the reader-reader collision. Previous studies are limited to the collision among more than 5 readers. The readers of high speed railway integrated maintenance logistics monitoring system are mainly located at line access, generally including 2~5 readers. According to the theory of PPC Algorithm, the PPC Algorithm has been simulated in MATLAB for 2~10 readers in the paper. Then, the theory was verified practically through field test.

### 3.1 PPC Algorithm for 2~10 readers

MATLAB simulation

The simulation environment was established in Matlab. The power of reader was set as 0~30dB as per ISO15693 Standard and signal-noise ratio (SNR) threshold was 12dB. Multiple readers adopted randomly distributed network topology, with the number ranging from 2 to 10, and the minimum distance between readers was 3.5m. The desired reading range for multi-readers was assumed to be 2.5 m. The simulation result is shown in Fig. 2.

The probability density distribution of $\beta$ is shown in Fig. 2. Power distribution can be controlled to obtain a desired distribution of reading range by changing the parameters of $\alpha$ and $\beta$.

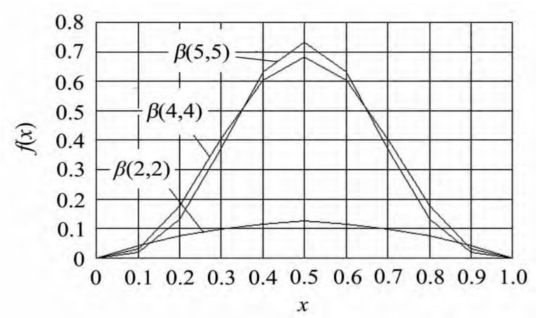


Fig. 2 Distribution of Power $\beta$ of Readers

When the minimum distance between readers is 3.5m, the simulation result of reading distance is shown in Fig. 3.

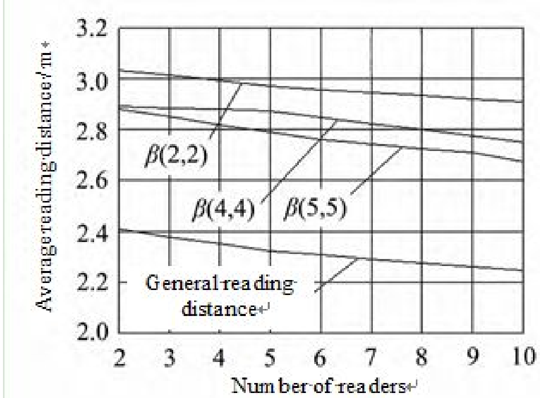


Fig. 3 Reading Distance (Minimum Distance between Readers: 3.5m)

The simulation results show that the reading distance calculated by PPC Algorithm is generally longer than that calculated without using the Algorithm, and the reading range of reader increases. Under the same network, the reading power of reader is distributed as $\beta$ (2, 2), $\beta$ (4, 4) and $\beta$ (5, 5). The minimum distance between readers is between 2.6m and 3.2m, when the number of readers is less than 5. Therefore, with the embedded software, the readers of high speed railway integrated maintenance logistics monitoring system can monitor a range beyond 3.5m effectively.

4.2. Test on logistics monitoring system

With regard to reader-reader collision, a field test was performed at high-speed line access in Shuangcheng North Railway Station within the jurisdiction of Harbin Railway Bureau with the devices and corresponding master computer software of "high speed railway integrated maintenance logistics monitoring system based on IOT technology". PPC Algorithm was adopted for the readers.

Test purpose: Testing the reader-reader collision

Testing devices and system setup: See Table 1.

The field test was performed at high-speed line access in Shuangcheng North Railway Station within the jurisdiction of Harbin Railway Bureau. The setup of field test devices is shown in Fig. 4.

Table 1 Field Test Devices

| SN | Description | Model | Qty. | Unit | Remarks |
|---|---|---|---|---|---|
| 1 | Transmission interface | | 1 | Set | Self-made |
| 2 | Recognizer | | 2 | Set | Self-made |
| 3 | Long-range RFID card reader | AOSID-0702 | 6 | Set | |
| 4 | Special long-range passive UHF-RFID tag | AOSID-0835 | 200 | Piece | |
| 5 | Industrial RFID hand-held set | AOSID-0813 | 1 | Set | |
| 6 | Cable | | 2000 | m | |
| 7 | Computer | | 1 | Set | |
| 8 | Power strip | | 5 | Each | |

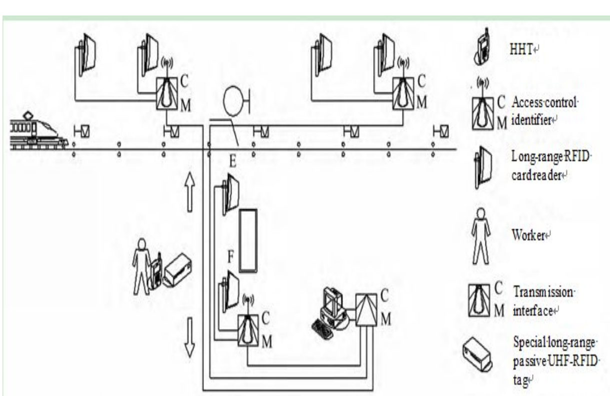


Fig. 4 Setup of Devices for Field Test at High-speed Railway Access in Shuangcheng North Railway Station of Harbin Railway Bureau

Test method:

Make the distance between long-range RFID card readers longer than 7m; place 20, 30, 40 and 50 special long-range passive UHF-RFID tags in the packing cases respectively; divide the workers into 4 groups and let them pass through the service passage and track of high-speed railway repeatedly 10 times; then let the master computer software record the identification effect of them respectively.

The test results show that the misreading rate is zero.

## CONCLUSION

The paper introduces the management process and composition of monitoring system of high speed railway integrated maintenance logistics monitoring system based on IOT technology and provides Matlab simulation and field test on the critical technical problem (reader-reader collision) of the system by probing into the status quo of management of high speed railway integrated maintenance logistics in China. The research results show that, when there are less than 5 readers (PPC Algorithm-based) with the minimum distance between reader of 2.6~3.2m for the high speed railway integrated maintenance logistics monitoring system, with the embedded software, the readers can monitor a range beyond 3.5m effectively, further justifying the feasibility of the system.

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