Successful Cases of LTE Application in Multi-Service Bearing for Rail Transportation
Contents

■ Application Requirement Analysis
■ Technology Selection and Solution Design
■ Scientific Research Achievements and Innovations
Background

The capacity expansion of Shen-Shuo Railway has been completed, Zhun-Chi Railway is to be operated, and the reformation of Shuo-Huang Railway with an annual capacity expansion to 350 million tons is nearly finished. Therefore, Shuo-Huang Railway must support the large-scale carrying of twenty-thousand-tonnage heavy-haul trains to meet the transport requirements of Shenhua Group on independently constructed railways. One of the required projects is to deploy a wireless communication platform to support the operation of such trains.
High Requirements on Wireless Communications System by Twenty-thousand-tonnage Heavy-Haul Trains

Now: 5,000-10,000 tons per train

800 MHz+400 KHz wireless communication system
Short transmission distance and low bearable data traffic

Goal: 20,000 tons per train

Mobile Broadband communication system
Expansive coverage, high data rate, and low latency
System security, meeting the requirements for synchronized multi-locomotive operations

Necessity Analysis

● **800 MHz+400 KHz wireless communication system:**
  ✓ This system provides wireless-connected transmission channels for ten-thousand-tonnage trains. The length of a ten-thousand-tonnage train in use is 1,400 m and the distance between two locomotives is about 700 m. This system can essentially cover such a communication distance.
  ✓ After twenty-thousand-tonnage heavy-haul freight trains are put into operation, the train length will be more than 2500 m and the distance between two locomotives will be over 1400 m. In this case, the 800 MHz+400 KHz system is inadequate to support the communication distance and the reliability greatly decreases.
  ✓ To prevent long trains with heavy loads from longitudinal impacts, controllable train tails should be able to actively exhaust airs, interacting with the brake operations of locomotives. The train tails need to communicate with the main locomotive and the distance between them will be over 2500 m. The 800 MHz+400 KHz system is incapable of supporting such a communication.

● **GSM-R restriction:** Local railways cannot use the GSM-R frequencies. The GSM-R is designed for the GSM system and has mature technologies. But the technologies lag behind those of the LTE system.
Early-Stage Demonstration Analysis of Wireless Communication System Reformation

- Taking into consideration of both Shuo-Huang Railway's requirements and the current status of wireless communication system, a new mobile communication system is required urgently for Shuo-Huang Railway to realize its mobile services.

<table>
<thead>
<tr>
<th>Category</th>
<th>Service Type</th>
<th>Specific Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Real-time security data information</td>
<td>Locomotive wireless connection, train-tail control</td>
</tr>
<tr>
<td>2</td>
<td>Non-real-time text data information</td>
<td>Dispatching orders, wireless train number verification, other common train-to-ground data services</td>
</tr>
<tr>
<td>3</td>
<td>Voice communications</td>
<td>Dispatching communication, other railway business communication</td>
</tr>
<tr>
<td>4</td>
<td>Video data information</td>
<td>Train-to-ground mobile video Surveillance</td>
</tr>
</tbody>
</table>

- To meet the requirements of twenty-thousand-tonnage heavy-haul freight trains, Shuohuang researches a lot on the feasibility of wireless communication systems and compares multiple RATs, such as WiMAX and LTE:
  - Research on a series of technologies for heavy-haul transportation with large axis weight on Shenhua railways – new mobile broadband communication system researches
  - Xiaojiao-to-Xibaipo test segment of new mobile broadband communication system for Shuo-Huang heavy-haul railway
  - Research on standards of new mobile broadband communication system for Shuo-Huang heavy-haul railway.
  - Network service running tests in Xiaojiao-to-Xibaipo test segment
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Milestone for New-Generation Broadband Mobile Communications System

Start
CREEC and Huawei analyze the feasibility of adopting a new communications technology for heavy-haul transport.

2010

Technology Selection
Hosted by Shuohuang, Huawei and CREEC conduct researches and analysis and selected LTE for the system.

2011

Technological Joint Venture Build-up
CREEC and Huawei form a technological joint venture, responsible for building up the all-service test platform of Huawei Shanghai R&D center and the pilot segment.

2012.2

Pilot Segment Deployment
The pilot segment between Xiao Jiao and Xi Bai Po is deployed.

2012.10

First Test
The four major services of Shuo-Huang railway pass the test.

2012.11

Second Test
The test aims to further verify service performance and communications service quality.

2013.01

Acceptance by RITT
RITT of MIIT performs acceptance tests. Network performance meets expectations.

2013.04

Third Test
The test covers network redundancy, switchover, and error tolerance. The results meet expectations.

2013.10

2010

Third Test
The test covers network redundancy, switchover, and error tolerance. The results meet expectations.

2013.10
Basis for LTE Application in Shuo-Huang Railway

Feasibility Analysis

- **Spectrum resources ready**
  - A 10 MHz bandwidth (1785–1795 MHz) along railways has been obtained.

- **LTE satisfying mobile communication requirements for heavy-haul transportation**
  - High reliability, high-speed data transmission, low latency, and satisfactory mobility performance

- **Advantages of LTE**
  - More than ten KPIs, including end-to-end latency, related to railway safety are much better than those in GSM-R.
  - Commercial application of LTE around the globe is spreading, and the advantages in the industry chain are growing.
  - Selecting LTE conforms to the national policy for technologies.
  - Railway mobile communications systems evolve towards LTE.

- **Successful tests on the pilot segment**
  - The pilot segment from Xiao Jiao to Xi Bai Po was successfully deployed and passed the strict acceptance test by RITT. The researches and construction on the pilot segment provide technical guarantee and equipment support for LTE application on the entire Shuo-Huang railway.

**Conclusion: feasible**
Reason: fulfillment of Shuo-Hang Railway’s requirements, conformity with national policy for technologies, technical guarantee, and equipment support
Challenges of LTE Application on Heavy-Haul Railways

Security
- **Network**: how to ensure that network faults do not affect security services
- **Service**: How to ensure normal operation of all services under limited spectrum resources, especially high reliability of important services such as synchronized operations on locomotives, train-tail control, and emergency calls.

Service Requirement
- **Security service**: How to meet the low-latency requirement of security services and dispatching voice service requirements in the IP architecture
- **Non-security service**: How to fully utilize high LTE bandwidths to carry more train-to-ground information, increasing efficiency and security of heavy-haul transportation

Interoperability
- **With new systems**: How to interwork with new systems, for example, for synchronized operations on locomotives, train-tail control, and cab radio
- **With existing systems**: How to interwork with existing systems, including FAS and CTC
LTE Meeting Network Security Requirements of Heavy-Haul Railways

- High network resource efficiency
- Zero interruption in heavy-haul services
- Preferential guarantee of important services
- High reliability of 99.999%
- Reasonable bandwidth allocation
- Innovative dual-layer network design
- Multi-priority service quality guarantee
- All-NE redundancy
LTE Meeting Service Requirements of Heavy-Haul Transportation

Meeting Service Requirements

● Security service
  • Optimize procedure and algorithm (for example, direct data transfer for vehicle-mounted devices) to achieve low end to end latency (50 ms), which is much lower than the latency in GSM-R (500 ms).
  • Develop IP address servers to bind terminal IP addresses with engine numbers in compliance with railway regulations.

● Non-security service
  • Develop LTE handset for railways to meet railway operation requirements.
  • Develop trunking servers to implement group calls and voice services on railways in all-IP architecture and support interworking with the existing FAS.
  • Speech coding algorithm optimization reduces the voice terminal bandwidth to 30 kbit/s or less, saving network resources.
  • The terminal chips developed based on uplink-downlink data volumes, fully utilize limited radio network resources.
Seamless Interworking Between LTE and Other Systems

**Interworking**

- **With new systems**
  - **Standardization**: Huawei, CREEC, and CARS jointly made technical solutions and standardized interfaces and implementation principles, addressing interoperability and interworking issues.
  - **Joint development**: equipment vendor (Huawei), cab radio vendor (CARS), vendor of the system for synchronized operations on locomotives (CSR Zhuzhou Electric Locomotive Research Institute Co. Ltd, Changsha Nanrui Rail Transp Electrical Equipment Co. Ltd, and Central South University) and vendor of the system for train-tail control (Chengdu ChangTong Locomotive&Vehicle Technology Exploitation Co., Ltd).
  - **Thorough tests**: both tests in laboratories and site

- **With existing systems**
  - **Interoperability with PSTN**: unified wired and wireless voice communication
  - **Interworking with wired dispatching system FAS**: coordinated dispatching in FAS and LTE systems
LTE System Design for Shuo-Hang Railway

- **LTE network design**
  - **EPC**: two EPCs deployed for redundancy at Suning North Station
  - **E-UTRAN**: co-siting dual-network scheme using distributed base stations (BBU+RRU); leaky coaxial cables in tunnels
  - **Frequency planning**: intra-frequency network; one 5 MHz frequency for each layer of the network

- **Service application systems**
  - Wireless reconnection information transfer system
  - Train-to-ground common data transfer system
  - Trunking voice system for dispatching
  - Video surveillance (reserved)
  - Communication-based train control (reserved)
Third-Party Test Results from RITT

Radio network performance test
- Field strength is satisfactory in the pilot segment.
- User-plane latency, handover delay, single-UE peak throughput, and cell throughput meet expectations.

Network quality test
- The connection setup success rate for data services, paging success rate, handover success rate, voice call completion rate, and service drop rate are better than expectations.
- However, the latency of voice services is larger than expected, and voice quality requires improvement.

Priority test
The LTE system provides differentiated services based on service priorities. High-priority services can preempt low-priority services so that the QoS requirements of high-priority services are preferentially fulfilled.
# Third-Party Test Report from RITT (Extract)

<table>
<thead>
<tr>
<th>SN</th>
<th>Item</th>
<th>Target</th>
<th>Test Result</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Network coverage</td>
<td>RSRP &gt; -105 dBm</td>
<td>RSRP &gt; -95 dBm</td>
<td>The test result is better than the designed target.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RS-SINR ≥ 0 dB (&gt; 95%)</td>
<td>RS-SINR ≥ 5 dB (&gt; 97%)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Delay in registration with the network</td>
<td>≤ 8 s (95%)</td>
<td>Not tested</td>
<td>The testing system is under development, so this item has not been tested yet. This item should be better than the designed target according to human estimation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤ 10 s (100%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Delay in mobile-originated connection setup</td>
<td>&lt; 200 ms (95%)</td>
<td>184 ms on average</td>
<td>The test result is better than the designed target.</td>
</tr>
<tr>
<td>4</td>
<td>Connection setup failure rate</td>
<td>&lt; 1%</td>
<td>0.33%</td>
<td>The test result is better than the designed target.</td>
</tr>
<tr>
<td>5</td>
<td>Maximum end-to-end transmission latency</td>
<td>&lt; 100 ms (99%)</td>
<td>&lt; 85 ms (99%)</td>
<td>The test result is better than the designed target.</td>
</tr>
<tr>
<td>6</td>
<td>Connection loss rate</td>
<td>≤ 10⁻²/h</td>
<td>No connection loss during the test</td>
<td>The test result is better than the designed target.</td>
</tr>
<tr>
<td>7</td>
<td>Inter-cell handover success rate</td>
<td>≥ 99.5%</td>
<td>No connection loss during the test</td>
<td>The test result is better than the designed target.</td>
</tr>
<tr>
<td>8</td>
<td>Throughput</td>
<td>Peak: ≥ 15 Mbit/s (uplink+downlink)</td>
<td>Downlink peak rate: 14.0 Mbit/s</td>
<td>The test result is better than the designed target.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average: ≥ 5 Mbit/s (uplink+downlink)</td>
<td>Uplink peak rate: 3.9 Mbit/s</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Packet loss rate</td>
<td>Security services: 0.001</td>
<td>0.0007</td>
<td>The test result is better than the designed target.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other services: 0.01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The test result shows that LTE application in the pilot segment meets network design requirements.
Results of Second Field Test on Pilot Segment in Apr to May, 2013

Radio network performance test

- After the co-siting active/standby scheme was changed to co-siting load balancing, network performance indicators almost remain unchanged.
- The network capacity is nearly doubled.

Network quality test

- There is a great improvement in performance and reliability of wireless reconnection services, compared with those in phase I. After locomotives are assembled, performance of data transmission for synchronized operations on locomotives is stable.
- The LTE system supports dispatching. Call functions and performance noticeably improve.

Service tests in abnormal cases

- If faults occur, various security measures (for example, dual-network load balancing and QoS control) ensure that synchronized operations on locomotives and train-tail control are not interrupted.
- In live networks and overload scenarios, high-priority services such as operations on locomotives and train-tail control work properly.
Test Result: LTE Better Than GSM-R on Heavy-Haul Railways

Better Performance
- Lower latency due to direct communication between vehicle-mounted terminals, more prompt synchronization between locomotives, and less vehicle wear-out
- Important services guaranteed using enhanced anti-interference techniques
- Safer transportation due to real-time backhaul of vehicle-mounted video surveillance data

Advanced Technology
- Flat architecture, fewer network elements, low latency, and easy maintenance
- LTE being the only 4G technology, towards which various mobile communications technologies will evolve

Scalable Services
- High spectral efficiency, higher bandwidth, and larger capacity of train-to-ground data services
- All-IP platform, standardized interfaces, and interoperability with future railway application systems
Contents

- Application Requirement Analysis
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Characteristics and Difficulties in Applying LTE Technologies to Shuo-Huang Railway

- **High security and reliability requirements**: With limited frequency resources, the normal running of all services, especially key services such as synchronized operations on multiple locomotives, train-tail control, and emergency calls, requires a high reliable and secure system.

- **Multi-system interworking**: To realize the interworking among multiple systems (LTE system, synchronized operation system, and existing dispatching system), it has a high requirement for equipment interconnection and collaboration of involved construction departments.

- **Integrated carrying of multiple services**: Secure and non-secure services are distinguished and the multi-service QoS guarantee mechanism of the LTE system is used. Therefore, multiple services, such as, synchronized operations, group calls, video surveillance, can be carried on one network.

- **Adequate verification on the early stage**: By sufficient technology verification, lab tests, and onsite tests in test segments, LTE networks are proved that they are able to support wireless connection, train-tail control, voice communication for dispatching, train number verification, dispatching order transmission, and video surveillance services for twenty-thousand-tonnage heavy-haul trains.
Analysis on Project Risks and Solutions

- **Frequency resource insufficiency:** The frequency resources are limited and the network redundancy is required. In this case, *load sharing is used to improve the double the resource usage.*
- **First trial:** This project involves design institute, network equipment suppliers, manufacturers providing devices to carry services, and railway operators with abundant heavy-haul railway experiences and technology strengths. *They all take part in the research and ensure the completely interconnection among devices.*
- **Prevention of "technology silos":** The application of LTE in railways has no existing standards to comply with. To avoid technology silos in the project, *Shuohuang summaries and compiles the technology standards and design specifications for applying LTE in heavy-haul railways,* which leads the global development trends of mobile broadband communication system for heavy-haul railways.
- **Secure service carrying of heavy-haul railways:** To apply LTE in railways, the features like high-priority services, railway voice dispatching, and UL/DL data transmission in heavy-haul railways must be guaranteed. *By multiple onsite tests in test segments, LTE is proved that it is able to support services of heavy-haul railways.*
Innovation of LTE application on Shuo-Huang Railway – Heavy-Haul Railway Services

Load sharing between two networks
The primary and secondary vehicle-mounted terminals for performing synchronized locomotive operations can be controlled to camp on two different networks (A and B). Other terminals can camp on either network A or B by preferential selection. This ensures no interruption in synchronized locomotive operations and fully utilization of resources in networks A and B, improving the bandwidth of wireless frequency resources.

Security mechanism
Service security is ensured by LTE network redundancy, application service system redundancy, and service tolerance mechanism.

Multi-service priority guarantee
Priority policies in accordance with requirements of Shuo-Huang heavy-haul railway services are made so that high-priority services, such as, heavy-haul railway services, have a precedence to use transmission resources when the resources are insufficient.

Direct communication between heavy-haul segments via IP networks
The dependency on the service coupling and processing capability of servers is reduced, the service delay is decreased, and the network reliability is improved.
Innovation of LTE application on Shuo-Huang Railway – Voice Dispatching Services

UL/DL timeslot ratio 0
The UL and DL timeslots on both terminals and base stations must be in the ratio of 3 to 1. UL and DL frequency resources are fairly used so that the balance of service traffic can be achieved and uplink throughput is improved, satisfying customers’ more service running requirements.

Railway emergency calls
Dispatching voice services are prior to other voice services and are able to preempt resources of other services except for synchronized locomotive operation services when resources are insufficient. All parties involved in a dispatching voice call cannot hang up the call before the call is ended. When a railway emergency call is completed, all involved parties are recorded. Push-to-talk (PTT) can be enabled for railway emergency calls by pressing a special button on a terminal.

Railway-characterized group call services, inheriting from GSM-R voice features
The system provides the functions of railway-dedicated functional numbers, cell-based routing, and call access matrix. A mature solution has existed and been verified in railway scenarios.

Optimized handheld terminals
The followings are supported: 1. Dedicated PPT button and emergency call button; 2. Protection class of IP67; 3. Numeric key-set keyboard operations.
Innovation of LTE application on Shuo-Huang Railway – Interconnection Capabilities

The interconnection between the LTE system and application devices or existing systems must be stable and compatible:

- The interconnection tests between the LTE system and the following national railway devices have been completed:
  - Vehicle-mounted stations for synchronized locomotive operations
  - Locomotive CIRs
  - Mainstream train-tail control devices

- The group voice system can work with existing FAS to achieve the centralized wireless and wired dispatching and also can interconnect with the existing railway PSTN.

- LTE communication module cards are integrated on the vehicle-mounted modules for heavy-haul railways, which is strictly verified and successfully completes the interconnection tests.
Forecast of LTE Application in Urban Metro Transportation (1)

The successful experiences of applying LTE in Shuo-Huang Railway can be used in urban metro transportation.

- Similarity in rail transportation: Both the urban metro transportation and heavy-haul railways belong to the rail transportation system and have multiple similar or even same services.
- Broadband loading capability: Both the urban metro transportation and heavy-haul railways have to carry train control, voice, and video services.
- Complete QoS guarantee capability: Key services must be preferentially guaranteed when multiple services are running.
- Secure service carrying capability: Synchronized locomotive operation services are significant, which is similar to that in the CBTC.

The analysis shows that the LTE system is able to carry mobile communication services of urban metro transportation.
Forecast of LTE Application in Urban Metro Transportation (2)

LTE model for urban metro transportation
谢谢！
THANK YOU！