The World’s First LTE R for 250km/h High Speed Railway in Republic of Korea

2018. 6.

Deputy General Manager,
Electronic communication Division
Radio Communication System Department
KRNA(Korea Rail Network Authority)
Tel : +82-42-607-3576 | Mobile : +82-10-6485-9701
Korea Rail Network Authority is a state owned agency established in January 2004 for construction and management of railways including high speed, conventional and urban rail infrastructures.

Business Area

- **Railway Construction**
  High speed railways, conventional railways, intercity railways, privately invested railways, trans-Korean railway
  Fields of communication, civil, trackbed, electric power, signaling and rolling stock.

- **Railway Facilities & Standard Management**
  Maintenance and repair of high speed railways and conventional railways, facilities improvement, standardization

- **Railway Assets Management**
  Development of railway station spheres and station complexes, lease of railway assets, public housing projects

- **Overseas Railway Projects**
  Project management, design and construction supervision, technical consultation, privately invested projects
CONTENTS

1. LTE-R for 250km/h High-Speed Railway in Republic of Korea

2. LTE-R Project on Wonju-Gangneung HSR

3. LTE-R Optimization & Validation Result

4. Future Plan
CONTENTS

1. LTE-R for 250km/h High-Speed Railway in Republic of Korea
   A. Background
   B. LTE-R Major Performance Factors
   C. Standardization
   D. System Improvement

2. LTE-R Project on Wonju-Gangneung HSR

3. LTE-R Optimization Test Result

4. Future Plan
A. Background

Establishment of Integrated Public Network (2014)

- Sewol Ferry Disaster (2014)

Need for Public Safety Network

- LTE-R (LTE-Railway)
- PS-LTE (Public Safety LTE)

Frequency Allocation of 700 MHz Band (UL 718–728 MHz, DL 773–783 MHz)
A. Background

Legacy Railway Wireless Communication System

<table>
<thead>
<tr>
<th>Railway Line</th>
<th>Wireless Communication System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Rail</td>
<td>VHF (150MHz band) TRS ASTRO TRS TETRA</td>
</tr>
<tr>
<td>Gyeongbu High-speed Rail</td>
<td></td>
</tr>
<tr>
<td>Phase 1 Seoul~Dongdaegu</td>
<td>○</td>
</tr>
<tr>
<td>Phase 2 Dongdaegu~Busan</td>
<td>△</td>
</tr>
<tr>
<td>Honam High-speed Rail</td>
<td>Oson~Gwangju</td>
</tr>
<tr>
<td>Seoul Metropolitan High-speed Rail</td>
<td>Suseo~Pyeongtaek</td>
</tr>
</tbody>
</table>

※ Gyeongbu line train has an on-board equipment and each train crew carries three different mobile devices.

Evolution of Wireless Communication System

LTE-R (700MHz band)

- A railway wireless communication system for train operation and maintenance
- Supports railway specific wireless services (voice, video, large data) between trains and stations based on 4G technology LTE
- The first LTE-R for high-speed railway is implemented on Wonju~Gangneung Line

1. LTE-R for 250km/h High-Speed Railway in Republic of Korea

The World’s First LTE-R for 250km/h High-speed Railway
A. Background

Plan for implementation of Intelligent Railway System (IRIS) (MOLIT)
Application of LTE-R technology for high-tech railway services from Seoul to Pyeongchang

Introduction Plan of LTE-R System (KRNA → MOLIT)
Proposal of LTE-R Project on Wonju~Gangneung Line based on IRIS (MOLIT) & frequency reallocation (MSIT) plans
→ ’15.11 Announcement of Processing Plan for LTE-R system (MOLIT → KRNA)

Report of Data Verification & 3 Domestic Standards for LTE-R Introduction (KRNA → MOLIT)
Verification of 23 test items at Test-Bed on KTX Honam Line (34km, Iksan~Jeongeup) / Standardization of three LTE-R standards for conventional and high-speed rail service with TTA

Introduction Plan of LTE-R Project on Wonju~Gangneung (MOLIT → KRNA)

Conclusion of Contract for LTE-R Project on Wonju~Gangneung HSR

Amendments to Enforcement Decree of the Radio Waves Act & Notification of Telecommunication Numbering (MSIT)
Insertion of new service factor for reduction of spectrum use fee for LTE-R / Amendments of telecommunication, signaling point and mobile telephone number related rules

Opening of Wonju–Gangneung HSR (High-Speed Railway)

Nationwide Extension (To be completed in 2027)

*MOLIT: Ministry of Land, Infrastructure and Transport / KRNA: Korea Rail Network Authority / MSIT: Ministry of Science and ICT
B. LTE-R Major Performance Factors

LTE-R Performance Test & Verification Data Preparation

National R&D Project “Building Ground Infrastructure for LTE Based Railway Wireless Communication Network (LTE-R)”

Iksan~Jeongeup (34.3km) on Honam high-speed line (including Noryeong Tunnel 4.3km)
### B. LTE-R Major Performance Factors

#### Verification Data & Test Result (23 items)

<table>
<thead>
<tr>
<th>Verification Data</th>
<th>Test Result</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Propriety of LTE-R network architecture</td>
<td>Based on 3GPP LTE standards, design effective network with the minimum equipment. ※ Ref.: 3GPP TS23.228 &quot;IP multimedia subsystem(IMS)&quot;; 3GPP TS23.401 &quot;GPRS for E-UTRAN Access&quot;.</td>
<td></td>
</tr>
<tr>
<td>2. Redundancy of major equipment</td>
<td>EPC/DU/RRU coverage redundancy for LTE-R network stability.</td>
<td></td>
</tr>
<tr>
<td>3. RRU distance (Tunnel, Open area)</td>
<td>Tunnel: 1km, Open area: 1km</td>
<td>Coverage redundancy</td>
</tr>
<tr>
<td>4. DU handover</td>
<td>PASS (100%) ≥ 99% (※ 2T8R)</td>
<td></td>
</tr>
<tr>
<td>5. RRU handover</td>
<td>PASS (100%) ≥ 99% (※ 2T8R)</td>
<td></td>
</tr>
<tr>
<td>6. Field strength (RRU output)</td>
<td>PASS (46.62dBm) 46dBm</td>
<td></td>
</tr>
<tr>
<td>7. Coverage</td>
<td>PASS (98.8%) ≥ 98% (≥ RSRP –110dBm)</td>
<td></td>
</tr>
<tr>
<td>8. Call setup time</td>
<td>PASS (100%) PASS (100%) PASS (100%)</td>
<td>Emergency: ≤ 2sec 100% Group: ≤ 2.5sec 100% Others: ≤ 5sec 100% ※ Others: Voice/Video calls except emergency/group calls, external PSTN is not considered</td>
</tr>
<tr>
<td>9. Handover success rate</td>
<td>PASS (100%) PASS (100%)</td>
<td>Open area: ≥ 99% Tunnel: ≥ 99%</td>
</tr>
<tr>
<td>10. Call connection success rate</td>
<td>PASS (100%)</td>
<td>≥ 99%</td>
</tr>
<tr>
<td>11. Long call drop rate</td>
<td>PASS (none)</td>
<td>≤ 0.01 times/hour</td>
</tr>
<tr>
<td>12. Data transmission success rate</td>
<td>PASS (100%)</td>
<td>≥ 99%</td>
</tr>
<tr>
<td>13. Data transmission delay</td>
<td>PASS (28ms)</td>
<td>≤ 600ms</td>
</tr>
<tr>
<td>14. Continuous packet loss rate</td>
<td>PASS (0s)</td>
<td>≤ 5s</td>
</tr>
<tr>
<td>15. On-board device requirements</td>
<td>Device mobility, call quality, private/group/emergency calls, device locating, voice calls, ambience listening , etc.</td>
<td></td>
</tr>
<tr>
<td>16. On-board device prototype</td>
<td>Prototype manufacture completed</td>
<td></td>
</tr>
<tr>
<td>17. On-board device call quality</td>
<td>PASS (DAQ 4.0) ≥ DAQ 4.0</td>
<td></td>
</tr>
<tr>
<td>18. Mobile device requirements</td>
<td>Call setup time, call connection success rate, long call drop rate, private/group/emergency calls, device location, call quality, video calls, etc.</td>
<td></td>
</tr>
<tr>
<td>19. Mobile device Prototype</td>
<td>Prototype manufacture completed</td>
<td></td>
</tr>
<tr>
<td>20. Mobile device call quality</td>
<td>PASS (DAQ 4.0) ≥ DAQ 4.0</td>
<td></td>
</tr>
<tr>
<td>22. QoS control prototype</td>
<td>Prototype manufacture completed ( ※ LTE-R: PCRF and eNB supports QoS control)</td>
<td></td>
</tr>
<tr>
<td>23. LTE-R Network attach time</td>
<td>PASS (414ms) ≤ 500ms</td>
<td></td>
</tr>
</tbody>
</table>

※ Criteria Source:
- No.4, 5, 8, 9, 10, 11, 12, 20 : TTAK.KO-06.0369 "Functional requirements for LTE based railway communication", TTAK.KO-06.0370 "User requirements for LTE based railway communication".
- No.6 : 3GPP TS36.101 "E-UTRA; User Equipment (UE) radio transmission and reception".
- No.7 : 3GPP TS36.304 "E-UTRA; User Equipment procedures in idle mode".
- No.13, 14, 20, 23 : LTE-R national R&D project, Stage 1 Final report on standardization and performance test of radio-based train control system.
- No.17 : Honam high-speed rail railway wireless system standard DAQ 4.0.
C. Standardization

+ TTA Domestic Standards for LTE based Railway Communication System
  - TTAKKO-06.0369, Functional Requirements (14.10.13)
  - TTAKKO-06.0370, User Requirements (14.10.13)
  - TTAKKO-06.0437, System Requirements (16.12.27)
  - TTAKKO-06.0438, System Architecture (16.12.27)
  - TTAKKO-06.0458, Performance Test Specification (17.12.13)

+ Vitalize of Railway Business
  - Plan for nationwide LTE-R projects
  - Amendment to [Railway design regulation] for LTE-R
    (Notification No. 2017-460 of the MOLIT, 2017.7.4)

+ 3GPP International Standardization
  - MCPTT Rel.13 & IMS based LTE-R Standardization

The World’s First LTE-R for 250km/h High-speed Railway
D. System Improvement

+ Solution for Frequency Interference

Co-use of 700MHz frequency band for Integrated Public Network (LTE-R, PS-LTE, LTE-M)

**Problem**
Frequency Interference between LTE-R, PS-LTE and LTE-M
- Frequency Interference between Integrated Public Networks using 700 MHz bandwidth.

**Solution**
SOP (Standard Operating Procedure) for interference optimization
- Related institutes (MOLIT, MOIS, MOF) established **SOP**
- Applying **RAN Sharing** between Integrated Public Networks
- Setting up **resource allocation rules** and **standard interworking procedure**

**Diagram**

- **KRNA (MOLIT)**: Ministry of Land, Infrastructure and Transport
- **MOIS**: Ministry of the Interior and Safety
- **MOF**: Ministry of Oceans and Fisheries

The World’s First LTE-R for 250km/h High-speed Railway
### D. System Improvement

#### Technical Regulation of Radio Equipment for Integrated Public Network Frequency

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Class</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Condition</strong></td>
<td>Communication mode</td>
<td>OFDMA</td>
</tr>
<tr>
<td></td>
<td>– mobile station direction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Communication mode</td>
<td>SC-FDMA</td>
</tr>
<tr>
<td></td>
<td>– base station direction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Occupied bandwidth</td>
<td>≤ 10 MHz</td>
</tr>
<tr>
<td></td>
<td>Radio wave type</td>
<td>one out of G7D, D7D, D7W, G7W, W7W (※ LTE-R: G7W, D7W)</td>
</tr>
<tr>
<td><strong>Base Station Transmitting</strong></td>
<td>Antenna power</td>
<td>below 80W</td>
</tr>
<tr>
<td></td>
<td>Frequency tolerance</td>
<td>± (designated frequency×5×10⁻⁸−12Hz)</td>
</tr>
<tr>
<td></td>
<td>Unwanted emission</td>
<td>mean power of resolution bandwidth depends on frequency difference</td>
</tr>
<tr>
<td></td>
<td>Adjacent channel leakage power</td>
<td>≤ 44.2 dB than the average power of the fundamental frequency</td>
</tr>
<tr>
<td><strong>Base Station Receiving</strong></td>
<td>Spurious emission</td>
<td>≤ -57 dBm</td>
</tr>
<tr>
<td></td>
<td>Adjacent channel selectivity</td>
<td>≥ 76 dB from 698 MHz to 710 MHz</td>
</tr>
<tr>
<td><strong>Mobile Station Transmitting</strong></td>
<td>Antenna power</td>
<td>≤ 2W (≤ 200mW for mobile device)</td>
</tr>
<tr>
<td></td>
<td>Frequency tolerance</td>
<td>±(designated frequency×10⁻⁷−15Hz)</td>
</tr>
<tr>
<td></td>
<td>Unwanted emission</td>
<td>mean power of resolution bandwidth depends on frequency difference</td>
</tr>
<tr>
<td></td>
<td>Adjacent channel leakage power</td>
<td>≤ 29.2dB than the average power of the fundamental frequency</td>
</tr>
<tr>
<td><strong>Mobile Station Receiving</strong></td>
<td>Spurious emission</td>
<td>≤ -57 dBm</td>
</tr>
<tr>
<td></td>
<td>Adjacent channel selectivity</td>
<td>≥ 53 dB from 753 MHz to 771 MHz</td>
</tr>
</tbody>
</table>
Amendment to Detailed Rules on Management of Telecommunication Number

(Notification No. 2017-12 of the MSIT, 2017.02.06)

**PLMN ID**

PLMN (Public Land Mobile Network) ID

= Mobile Country Code + Mobile Network Code

- **LTE-R** (Railway) : 5033

- **LTE-R** (Subway) : 5070

**Phone Number**

Phone number

= Network ID No. + Dialing Code + Subscriber No.

- **LTE-R** (Railway) : 135700

---

**Allocation of Telecommunication Network Identification Number**

<table>
<thead>
<tr>
<th>Mobile Country Code (MCC)</th>
<th>Mobile Network Code (MNC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>PS-LTE</td>
</tr>
<tr>
<td>31</td>
<td>LTE-R (Subway)</td>
</tr>
<tr>
<td>32</td>
<td>LTE-M</td>
</tr>
<tr>
<td>33</td>
<td>LTE-R (Railway)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification Number (013Y)</th>
<th>Dialing Code</th>
<th>Service</th>
<th>Number of Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>013</td>
<td>5</td>
<td>PS-LTE</td>
<td>2 Millions</td>
</tr>
<tr>
<td>200 ~ 399</td>
<td>500 ~ 599</td>
<td>LTE-M(Maritime)</td>
<td>1 Million</td>
</tr>
<tr>
<td>700 ~ 799</td>
<td>800 ~ 899</td>
<td>LTE-R</td>
<td>Railway 1 Million</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Subway 1 Million</td>
</tr>
</tbody>
</table>

The World’s First LTE-R for 250km/h High-speed Railway
1. LTE-R for 250km/h High-Speed Railway in Republic of Korea

2. LTE-R Project on Wonju–Gangneung HSR
   A. Project Overview
   B. System Diagram
   C. System Requirements

3. LTE-R Optimization & Validation Result

4. Future Plan
A. Project Overview

Title: LTE-R Project on Wonju~Gangneung Line

Period: 2016.08.01 ~ 2018.03.31 (20 months)

Cost: About ₩ 39 billion (VAT included) $ 36 million

Contractor: [KT Consortium]

Contract: 2016
Detail design: 2016
Manufacturing & delivery: 2017
Installation & S/W development: 2017
Demonstration: 2017
End-to-end test & Trial run: 2018
Education & Training: 2018
Standardization: 2018
Completion: 2018

Content:
- Equipment redundancy and dualization at Railway Traffic Control Center(Guro) & Sub-control Center(Daejeon)
- Wonju ~ Gangneung 120km (Tunnel 68%, Bridge, Earthwork), 7 stations and 234 access equipment
- 545 mobile devices (smartphone type + PTT type)
## A. Project Overview

### Major Manufacturers

<table>
<thead>
<tr>
<th>EPC</th>
<th>MME, SAE-GW, PCRF, HSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MME</td>
<td>Samsung Electronics</td>
</tr>
<tr>
<td>SAE-GW</td>
<td></td>
</tr>
<tr>
<td>PCRF</td>
<td></td>
</tr>
<tr>
<td>HSS</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IMS</th>
<th>CSCF, AS, MCPTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGCF</td>
<td></td>
</tr>
<tr>
<td>MGW</td>
<td></td>
</tr>
<tr>
<td>MRF</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IBCF, TrGW</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Command Server
- Samsung Electronics

### Dispatcher
- COVADA

### Access Equipment (DU, RRU)
- Samsung Electronics
- NOKIA

### Mobile Device (Smartphone/PTT type)
- Samsung Electronics
- AMTelecom

### On-board Unit
- Hoimyung ICT
B. System Diagram

2. LTE-R Project on Wonju-Gangneung HSR

The World’s First LTE-R for 250km/h High-speed Railway
C. System Requirements

1. Coverage

Mobile device coverage (≥ RSRP - 110dBm 98%)

On-board device coverage (≥ RSRP - 95dBm 95%)

2. Throughput

**LTE-R Capacity Requirements**

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downlink Traffic</td>
<td>4,132 kbps</td>
</tr>
<tr>
<td>Uplink Traffic</td>
<td>10,142 kbps</td>
</tr>
</tbody>
</table>

- **Data transmission delay**: less than or equal to **300ms**
- **Data transmission success rate**: greater than or equal to **99%**

Considering data service demand of LTE-R, capacity on the left should be satisfied.

3. MIMO

**3 Types of Antenna adapted for LTE-R**

- **Sector Antenna (65°, 35°)**
  - Open Area

- **Yagi Antenna**
  - Tunnel inside/entrance/exit

- **Omni Antenna**
  - In-building area

*Final Report on Radio-Based Train Control System Standardization and Performance Test (2014, KAIA) *

*KIAA: Korea Agency for Infrastructure Technology Advancement*
C. System Requirements

4. Redundancy

Core & eNB Redundancy

+ Location Dualization

- Node dualization switch condition. Redundancy failure of core equipment
- Switch procedure by Fault Level

<table>
<thead>
<tr>
<th>Fault Level</th>
<th>Equipment (Redundancy Failure)</th>
<th>Service Impact</th>
<th>Switch Procedure (Node Dualization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical</td>
<td>MME, HSS, MCPTT, CSCF, SAE-GW</td>
<td>VoLTE, MCPTT available</td>
<td>Immediate switch</td>
</tr>
<tr>
<td>Major</td>
<td>AS, MRF, PCRF</td>
<td>VoLTE, MCPTT available (Supplementary service not available)</td>
<td>Idle hour switch (after service decision)</td>
</tr>
<tr>
<td>Minor</td>
<td>IBCF/TrGW, MGCF, MGW</td>
<td>VoLTE, MCPTT available (PS-LTE &amp; internal calls not available)</td>
<td>No switching (Equipment recovery)</td>
</tr>
</tbody>
</table>

- Switch Plan: When critical fault occurs, follow switch procedure after monitoring LTE-R NMS
- Control center–Sub–control Center runs in Active–Standby mode (Hot Site), control center is operating in service

Equipment Redundancy

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Redundancy</th>
<th>Switch Test Result</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPC</td>
<td>MME, S-GW, P-GW, HSS, PCRF</td>
<td>Redundancy (Active/Standby)</td>
<td>Auto-switch (in seconds)</td>
</tr>
</tbody>
</table>

DU #1

DU Redundancy

- Active-Standy DU 1.1 Redundancy
- Active-Standy DU are managed as one eNB

Auto switch (Samsung: 30secs / Nokia: 7~13mins)

The World’s First LTE-R for 250km/h High-speed Railway
CONTENTS

1. LTE-R for 250km/h High-speed Railway in Republic of Korea

2. LTE-R Project on Wonju-Gangneung HSR

3. LTE-R Optimization & Validation Result
   A. LTE-R Specific Functions & Performances
   B. LTE-R Cell Configuration Test
   C. LTE-R Performance Validation in Wonju-Gangneung

4. Future Plan
A. LTE-R Specific Functions & Performances

Point 1

Flexibility in High-speed Moving Environment (≥250km/h)
- LTE-R for Wonju-Gangneung High-Speed Railway (Max. speed : 250km/h)
  → Assurance of 98% service coverage, Average data throughput DL 40Mbps, UL 20Mbps
- Supports wireless services for IoT, unmanned technology, etc. (following 3GPP international standards)

Point 2

Comparison of GSM-R and LTE-R

<table>
<thead>
<tr>
<th>Category</th>
<th>GSM-R</th>
<th>LTE-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>• Global (Europe, China, etc.)</td>
<td>• Republic of Korea (World’s first LTE-R for high-speed railway on Wonju-Gangneung line)</td>
</tr>
<tr>
<td>Throughput</td>
<td>• Max. 172Kbps(DL), 172Kbps(UL)</td>
<td>• Avg. DL 40Mbps, UL 20Mbps ※ 10MHz bandwidth</td>
</tr>
<tr>
<td>Service</td>
<td>• Voice &amp; Low-rate data (ETCS/ERTMS Level II  Voice PTT, Nonstandard)</td>
<td>• Voice, Video, High-rate data (Video+Voice PTT, MCPTT Standard, MCPTT QC169/Signaling, 65/Voice, 70/File applied)</td>
</tr>
</tbody>
</table>

Point 3

Railway Specific Advantages of LTE-R System

<table>
<thead>
<tr>
<th>Openness &amp; Availability</th>
<th>Railway Environment</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 3GPP satisfied equipment</td>
<td>• Redundancy/Dualization for seamless railway services</td>
<td>• Improved maintenance with LTE-R NMS</td>
</tr>
<tr>
<td>• DU receives 12 RRU Max.</td>
<td>• Stable operation in ~30°C (DU, RRU)</td>
<td>• Supports remote antenna tilting</td>
</tr>
<tr>
<td>• Max. 75Mbps of data throughput</td>
<td>• Optimal handover at high-speed(250km/h) using virtual technologies(2T2R)</td>
<td>• Antenna, RRU, UPS, earthquake/salt attack/vibration/water/dust-proof certification</td>
</tr>
</tbody>
</table>
A. LTE-R Specific Functions & Performances

**Point 4**

**Functional & Location Dependent Addressing** (TTAK.KO-06.0369 / TTAK.KO-06.0370)

**Functional Addressing**

Ex) If control center calls Train#1, call connects to on-board unit or drive of Train#1

**Location Dependent Addressing**

Ex) If Train#1 calls controller, call connects to controller A or B depends on location of Train#1
Seamless Coverage & eNB Redundancy (250km/h)

Point 5

1. RRU alternation for cell coverage redundancy
2. Takes 66sec from RRU2-1 to RRU2-3 for train
3. RRU2-3 is in service after about 30sec of switch time

Switching time:
- DU (Samsung): 30 sec
- MTTR: 4 hours

Point 6

Infrastructure with IP-MPLS

1. 1G capacity IP MPLS applied
2. Equipment redundancy
3. DWDM interface

Traffic flow of backhaul architecture:
- 1G capacity IP MPLS
- L3(IP MPLS) x 2Ring

The World’s First LTE-R for 250km/h High-speed Railway
According to characteristics of each site, different cell configuration is applied

- Open Area : 2T2R
- Station and Tunnel Area : 2T4R

**LTE-R Cell Configuration (2T2R/2T4R) Test for Optimization**

<table>
<thead>
<tr>
<th>Cell Config.</th>
<th>Result</th>
<th>RSRP</th>
<th>SINR</th>
<th>DL (Mbps)</th>
<th>UL (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2T2R</td>
<td>Avg.</td>
<td>-71.7</td>
<td>18.2</td>
<td>33.2</td>
<td>10.2</td>
</tr>
<tr>
<td>2T4R</td>
<td>Avg.</td>
<td>-70.1</td>
<td>23.6</td>
<td>42.6</td>
<td>14.4</td>
</tr>
</tbody>
</table>

With 2T4R (copy cell), number of handover reduced

Improvement of SINR and other qualities
C. LTE-R Performance Validation in Wonju-Gangneung

Test Goals
Validation of Coverage and Quality of Wonju-Gangneung LTE-R
- Measurement of coverage for mobile devices with RSRP -110 dBm or more
- Measurement of handover success rate at speed of 250 km/h
- Validation of LTE-R quality such as call success rate, data throughput and data transmission success rate

Result

Coverage (Total 120 km)

<table>
<thead>
<tr>
<th>Mobile Device</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage</td>
<td>99.717%</td>
</tr>
<tr>
<td></td>
<td>-110dBm, over 98%</td>
</tr>
</tbody>
</table>

Data Throughput

<table>
<thead>
<tr>
<th>Avg. Data Throughput</th>
<th>Railroad</th>
<th>Station</th>
<th>Major Facilities (Control station, Depot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL (Mbps)</td>
<td>35.950</td>
<td>53.154</td>
<td>61.125</td>
</tr>
<tr>
<td>UL (Mbps)</td>
<td>15.304</td>
<td>19.755</td>
<td>20.419</td>
</tr>
</tbody>
</table>

Handover Success Rate

<table>
<thead>
<tr>
<th>Handover success rate</th>
<th>Mobile Device</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>DU</td>
<td>99.880%</td>
<td></td>
</tr>
<tr>
<td>RRU</td>
<td>99.895%</td>
<td>Over 98%</td>
</tr>
</tbody>
</table>

Voice Call Success Rate

<table>
<thead>
<tr>
<th></th>
<th>Railroad</th>
<th>Station</th>
<th>Major Facilities (Control station, Depot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call success rate</td>
<td>99.10%</td>
<td>99.63%</td>
<td>99.51%</td>
</tr>
</tbody>
</table>

Data Transmission Success Rate

<table>
<thead>
<tr>
<th>Transmission success rate</th>
<th>Railroad</th>
<th>Station</th>
<th>Major Facilities (Control station, Depot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL</td>
<td>99.27%</td>
<td>99.98%</td>
<td>100.0%</td>
</tr>
<tr>
<td>UL</td>
<td>99.15%</td>
<td>99.96%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
CONTENTS

1. LTE-R for 250km/h High-speed Railway in Republic of Korea

2. LTE-R Project on Wonju-Gangneung HSR

3. LTE-R Optimization & Validation Result

4. Future Plan
   A. Plan for LTE-R Extension
   B. Study on Railway Specific Services using LTE-R
   C. Interoperability Test with KRTCS
      (Korean Radio-based Train Control System)
Phased Replacement of VHF/TRS with LTE-R until 2027

LTE-R replacement plan on existing lines (Conventional/High-Speed Railway)
B. Study on Railway Specific Services using LTE-R

**Data Service Acceptance of LTE-R**

- Traffic capacity of LTE-R on Wonju ~ Gangneung: Average UL 20Mbps, DL 40Mbps
  (VoLTE Voice 45Kbps, Video 1Mbps / MCPTT Voice 60Kbps, Video 1Mbps)

<table>
<thead>
<tr>
<th>Data Path</th>
<th>Traffic capacity (avg.)</th>
<th>Capacity used (Estimate*)</th>
<th>Free capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL</td>
<td>20Mbps</td>
<td>10.6Mbps</td>
<td>47%</td>
</tr>
<tr>
<td>DL</td>
<td>40Mbps</td>
<td>4.8Mbps</td>
<td>88%</td>
</tr>
</tbody>
</table>

※ Final report on standard system implementation and performance test of radio-based train control system (2014, KAIA)

**Applications**

- ICT-based smart service system,
- AI-based air conditioning management system,
- Integrated energy management system, etc.

**Future Plan**

"Research on Linking Plan for Industry 4.0 Using LTE-R" (2017.8 ~ 2018.7)

eMBMS (evolved Multimedia Broadcast Multicast Service) based application services
Future Intelligent Railway Services (Examples)

- Monitoring infrastructure status
  - Railway asset management
- Image information
  - Cab and coach CCTV real time transmission
- Train control
  - GIS location-based Central Traffic Control

- Wire–wireless integration
  - Wired & wireless integrated system
    - (Inside) WIFI ↔ (Outdoor) LTE-R
- Maintenance technical support
  - Emergency recovery support including image transmission

- Logistics information
  - Provide real-time logistics information (Cargo information)
C. Interoperability Test with KRTCS

K.R.T.C.S

Korean Radio-based Train Control System

1. Radio-based signal system development (*14.12 ~ *17.12 / 33.5 billion)

2. With 4G LTE technology, advanced passenger service & video service are available
   (Voice & data services are also available)

3. Development of on-board & ground equipment
   (Core parts: onboard computer, wireless transmission module, wireless signal control device)

Validation for Practical Use

~2020

Stability Certification
Performance Validation
Field Validation
User Validation
Certification Support

Plan for Practical Use

Replacement of entire signal system with KRTCS_2 (~2029)
- Based on validation result on Wonju~Gangneung line
- Example application on Jeolla High-speed Railway (2018~)
- New and upgrading lines first
The world’s first LTE-R opens a new chapter of railway wireless communication!

Thank you