KOREA RAIL NETWORK AUTHORITY

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

ABOUT

KOREA RAIL NETWORK AUTHORITY

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

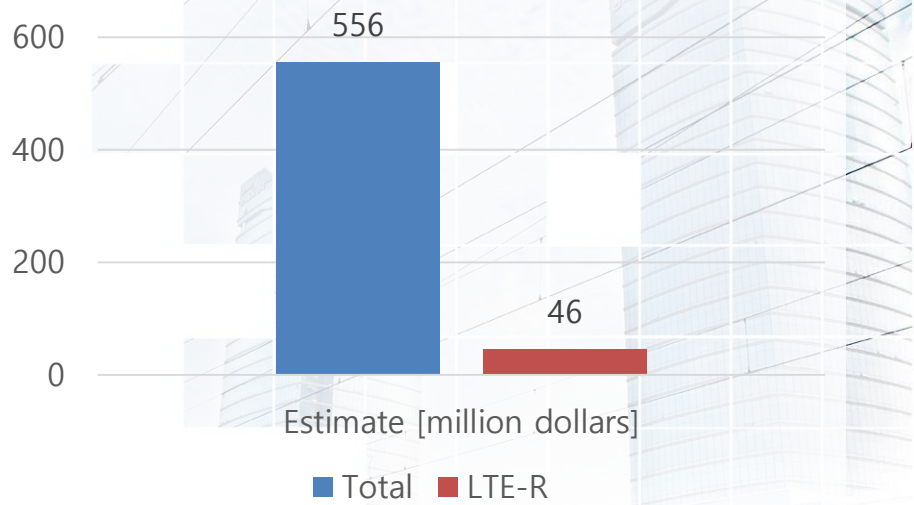
- Railway Assets Management

  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

Annual Budget



CONTENTS

CONTENTS

Establishment of Integrated Public Network (2014)

Different Radio Communication System

CONFUSION

Need for Public Safety Network

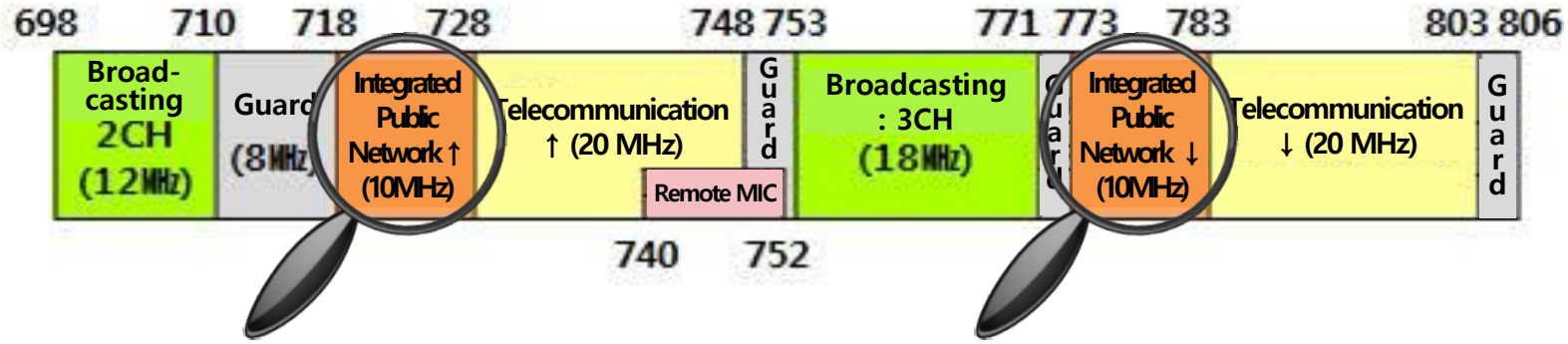
Ministry of Science and ICT

Integrated Public Network

- Sewol Ferry Disaster (2014)
- Daegu Subway Fire (2003)

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

Frequency Allocation of 700 MHz Band (UL 718-728 MHz, DL 773-783 MHz)



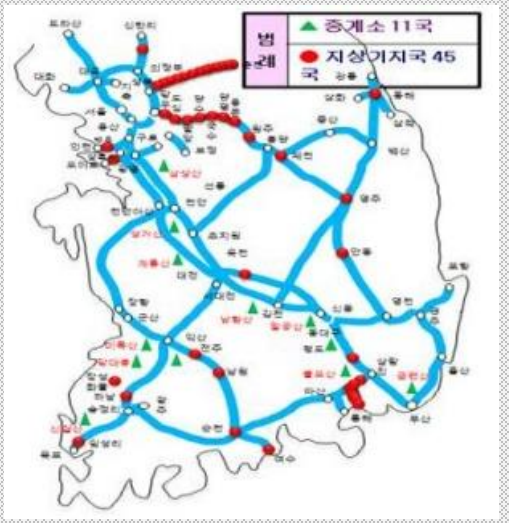
Legacy Railway Wireless Communication System

VHF(150MHz band) & TRS(800MHz band)

Railway Line			Wireless Communication System		
			VHF	TRS-ASTRO	TRS-TETRA
Conventional Rail	Entire route		◎		
Gyeongbu High-speed Rail	Phase1	Seoul~Dongdaegu	◎	□	
	Phase2	Dongdaegu~Busan			△
Honam High-speed Rail	Osong~Gwangju				△
Seoul Metropolitan High-speed Rail	Suseo~Pyeongtaek				△

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

▣ VHF (Conventional Line)



Evolution of Wireless Communication System

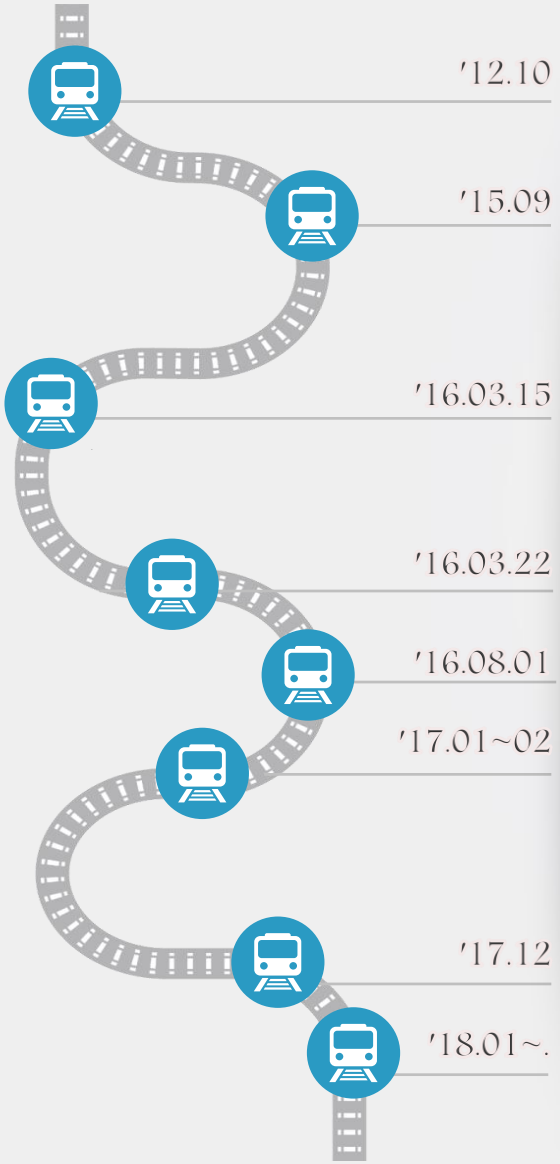
LTE-R(700MHz band)

- 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

	1G.	2G	3G	4G
Railway Wireless Communication System	VHF Voice	TRS Voice Small DATA(below 200 kbps)	N/A	LTE-R Voice Large DATA(below 75Mbps) Video

▣ TRS (High-speed Line)

A. Background



'12.10 Plan for implementation of Intelligent Railway System(IRIS) (MOLIT)

Application of LTE-R technology for high-tech railway services from Seoul to Pyeongchang

'15.09 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)

'16.03.15 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

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

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

'17.01~02 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

'17.12 Opening of Wonju-Gangneung HSR (High-Speed Railway)

'18.01~. 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

Project Title

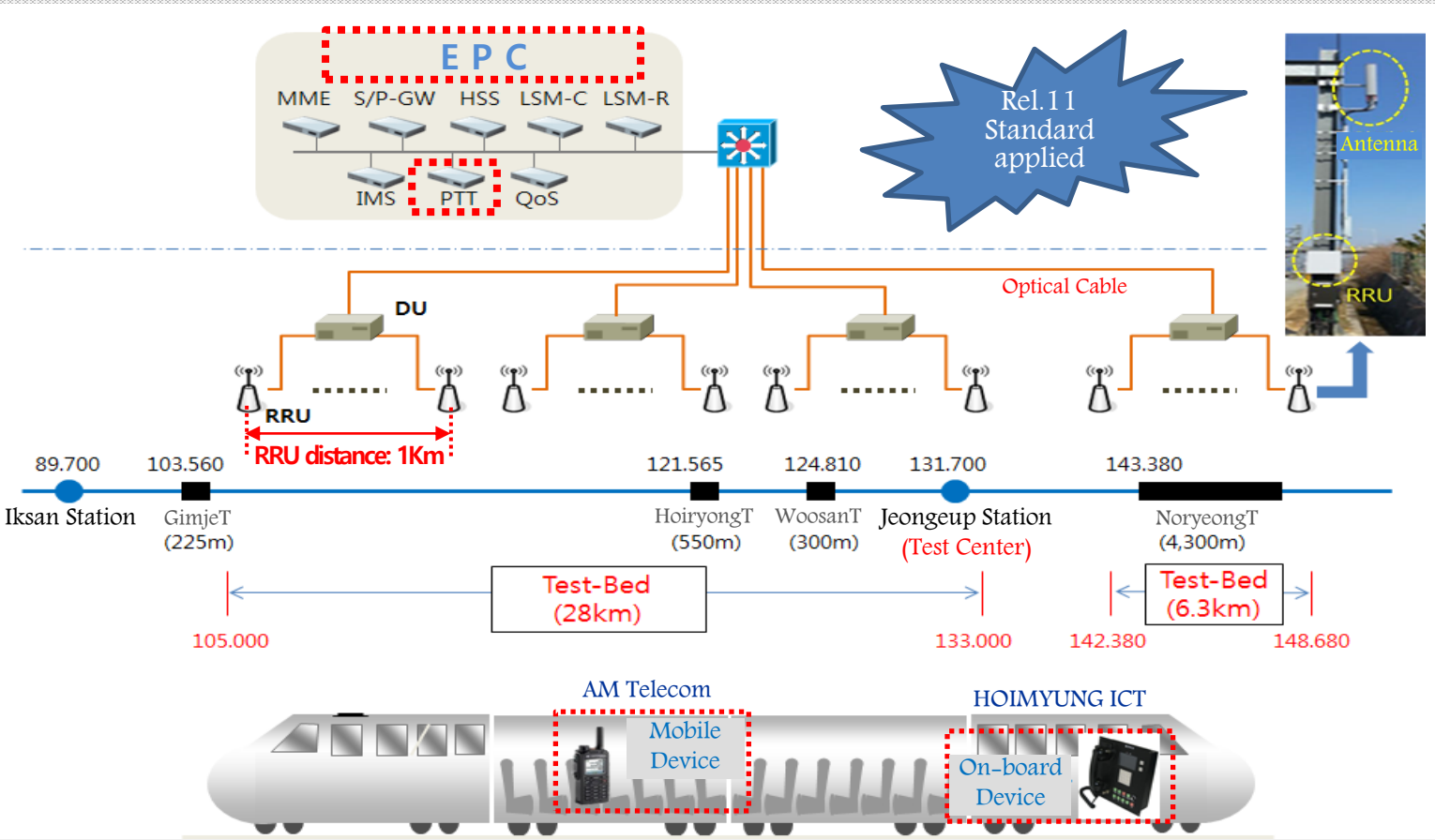
LTE-R Performance Test & Verification Data Preparation

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

Test Area

Iksan~Jeongeup (34.3km) on Honam high-speed line (including Noryeong Tunnel 4.3km)

Test-Bed Configuration



B. LTE-R Major Performance Factors

Result

Verification Data & Test Result (23 items)

	Verification Data	Test Result	Criteria
1	Propriety of LTE-R network architecture	Based on 3GPP LTE standards, design effective network with the minimum equipment ※ Ref. : 3GPP TS23.228 "IP multimedia subsystem(IMS)", 3GPP TS23.401 "GPRS for E-UTRAN Access"	
2	Redundancy of major equipment	EPC/DU/RRU coverage redundancy for LTE-R network stability	
3	RRU distance (Tunnel, Open area)	Tunnel: 1km Open area: 1km	Coverage redundancy
4	DU handover	PASS (100%)	≥ 99% (※ 2T8R)
5	RRU handover	PASS (100%)	≥ 99% (※ 2T8R)
6	Field strength (RRU output)	PASS (46.62dBm)	46dBm
7	Coverage	PASS (98.8%)	≥ 98% (≥ RSRP –110dBm)
8	Call setup time	PASS (100%) PASS (100%) PASS (100%)	Emergency : ≤ 2sec 100% Group : ≤ 2.5sec 100% Others[1] : ≤ 5sec 100% ※ Others : Voice/Video calls except emergency/group calls, external PSTN is not considered
9	Handover success rate	PASS (100%) PASS (100%)	Open area: ≥ 99% Tunnel: ≥ 99%
10	Call connection success rate	PASS (100%)	≥ 99%
11	Long call drop rate	PASS (none)	≤ 0.01 times/hour
12	Data transmission success rate	PASS (100%)	≥ 99%

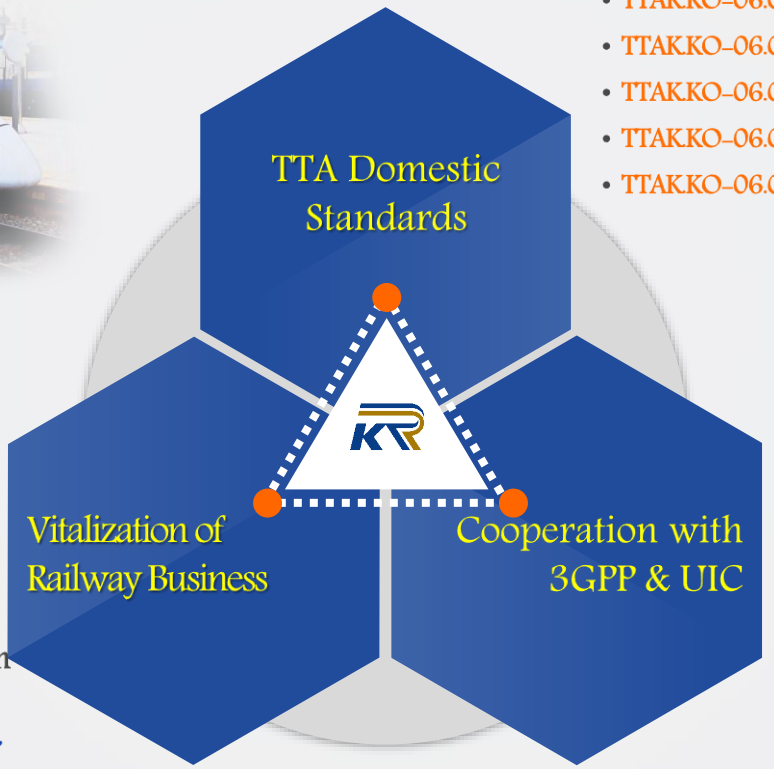
	Verification Data	Test Result	Criteria
13	Data transmission delay	PASS (28ms)	≤ 600ms
14	Continuous packet loss rate	PASS (0s)	≤ 5s
15	On-board device requirements	Device mobility, call quality, private/group/emergency calls, device locating, voice calls, ambience listening , etc.	
16	On-board device prototype	Prototype manufacture completed	
17	On-board device call quality	PASS (DAQ 4.0)	≥ DAQ 4.0
18	Mobile device requirements	Call setup time, call connection success rate, long call drop rate, private/group/emergency calls, device location, call quality, video calls , etc.	
19	Mobile device Prototype	Prototype manufacture completed	
20	Mobile device call quality	PASS (DAQ 4.0)	≥ DAQ 4.0
21	QoS control requirements	Common standards : 3GPP TS 23.107, TS 23.203, TS 23.207 Gx interface standard : 3GPP TS 29.210 Rx interface standard : 3GPP TS 29.214	
22	QoS control prototype	Prototype manufacture completed (※ LTE-R : PCRF and eNB supports QoS control)	
23	LTE-R Network attach time	PASS (414ms)	≤ 500ms

※ 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

- TTAK.KO-06.0369 : Functional Requirements ('14.10.13)
- TTAK.KO-06.0370 : User Requirements ('14.10.13)
- TTAK.KO-06.0437 : System Requirements ('16.12.27)
- TTAK.KO-06.0438 : System Architecture ('16.12.27)
- TTAK.KO-06.0458 : Performance Test Specification ('17.12.13)



+ Vitalization 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

+ Solution for Frequency Interference

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

Problem

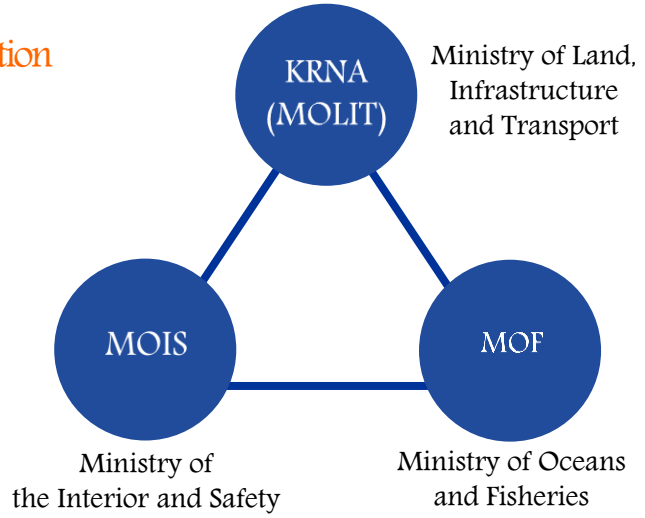
Frequency Interference between LTE-R, PS-LTE and LTE-M

- 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**



Amendment Technical Regulation of Radio Equipment for Integrated Public Network Frequency

Equipment	Class	Condition
Common Condition	Communication mode – mobile station direction	OFDMA
	Communication mode – base station direction	SC-FDMA
	Occupied bandwidth	≤ 10 ㎒
	Radio wave type	one out of G7D, D7D, D7W, G7W, W7W (※ LTE-R : G7W, D7W)
Base Station Transmitting	Antenna power	below 80W
	Frequency tolerance	± (designated frequency×5×10-8+12㎐)
	Unwanted emission	mean power of resolution bandwidth depends on frequency difference
	Adjacent channel leakage power	≤ 44.2 dB than the average power of the fundamental frequency
Base Station Receiving	Spurious emission	≤ -57 dBm
	Adjacent channel selectivity	≥ 76 dB from 698 ㎒ to 710 ㎒
Mobile Station Transmitting	Antenna power	≤ 2W (≤ 200mW for mobile device)
	Frequency tolerance	±(designated frequencyX10-7+15㎐)
	Unwanted emission	mean power of resolution bandwidth depends on frequency difference
	Adjacent channel leakage power	≤ 29.2dB than the average power of the fundamental frequency
Mobile Station Receiving	Spurious emission	≤ -57 dBm
	Adjacent channel selectivity	≥ 53 dB from 753 ㎒ to 771 ㎒

+ Amendment to Detailed Rules on Management of Telecommunication Number

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

LTE-R Number Allocation

PLMN ID — Allocation of Telecommunication Network Identification Number

- PLMN (Public Land Mobile Network) ID

  = Mobile Country Code + Mobile Network Code

EX. LTE-R (Railway) : 450 33

Republic of Korea — LTE-R (Railway)

Mobile Country Code (MCC)	Mobile Network Code (MNC)	
450 (Republic of Korea)	30	PS-LTE
	31	LTE-R (Subway)
	32	LTE-M
	33	LTE-R (Railway)

Phone Number — Allocation of Identification Number & Dialing Code

- Phone number

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

EX. LTE-R (Railway) : 13-57 0-***

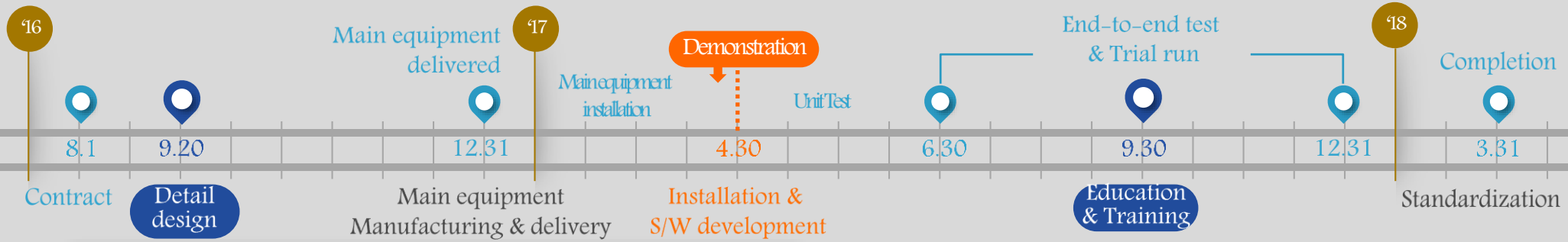
Integrated Public Network — LTE-R (Railway) — Subscriber No.

Identification Number (013Y)		Dialing Code	Service		Number of Resources
013	5	200 ~ 399	PS-LTE		2 Millions
		500 ~ 599	LTE-M(Maritime)		1 Million
		700 ~ 799	LTE-R	Railway	1 Million
		800 ~ 899		Subway	1 Million

CONTENTS

A. Project Overview

Title	Period	Cost	Contractor
LTE-R Project on Wonju~Gangneung Line	2016.08.01 ~ 2018.03.31 (20months)	About ₩39 billion (VAT included) $ 36 million	kt Consortium: 한국전파기지국주식회사 KRTnet Corporation, 현대정보기술, 쌍용정보통신 / Vendor: SAMSUNG, NOKIA, AM telecom

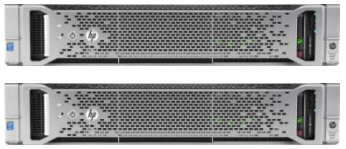


Content

- 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

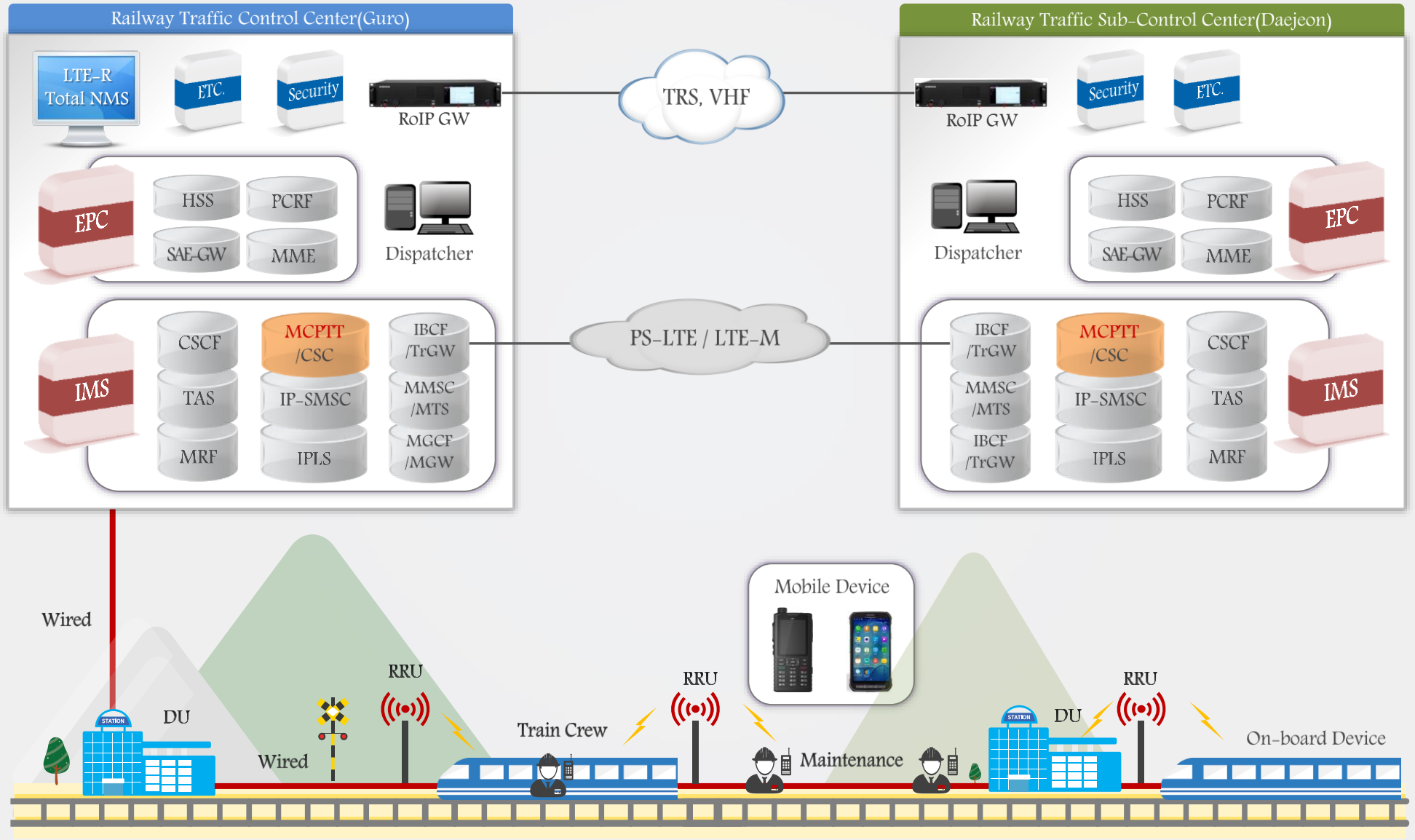
+ Major Manufacturers

EPC	MME, SAE-GW, PCRF, HSS		Samsung Electronics
IMS	CSCF, AS, MCPTT		
	MGCF		IPAGEON
	MGW		
	MRF		ELUON
	IBCF, TrGW		

Command Server		COVADA
Dispatcher		
Access Equipment (DU, RRU)	   	Samsung Electronics NOKIA
Mobile Device (Smartphone/ PTT type)	 	Samsung Electronics AMTelecom
On-board Unit	 	HOIMYUNG ICT

* DU : Digital Unit / RRU : Remote Radio Unit

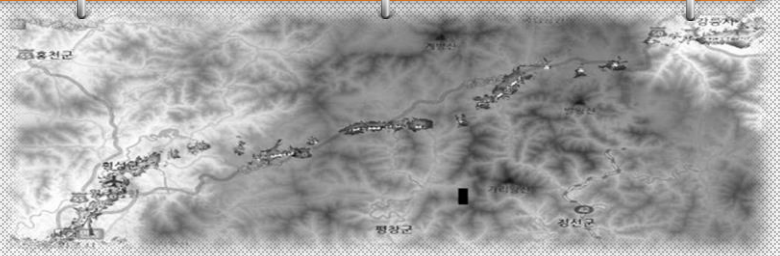
B. System Diagram



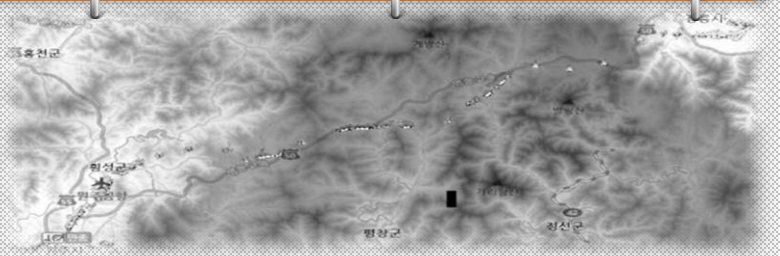
C. System Requirements

1. Coverage

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



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



2. Throughput

LTE-R Capacity Requirements

「Final Report on Radio-based Train Control System Standardization and Performance Test (2014, KAIA)」
*KAIA: Korea Agency for Infrastructure Technology Advancement

Downlink Traffic	4,132 kbps
Uplink Traffic	10,142 kbps

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

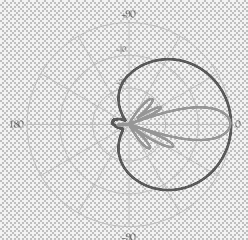
▸▸ Data transmission delay
: less than or equal to 300ms

▸▸ Data transmission success rate
: greater than or equal to 99%

3. MIMO

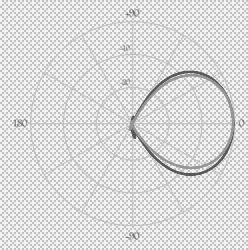
3 Types of Antenna adapted for LTE-R

▸▸ Sector Antenna (65°, 35°)



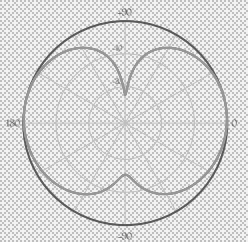
Open Area

▸▸ Yagi Antenna



Tunnel inside/entrance/exit

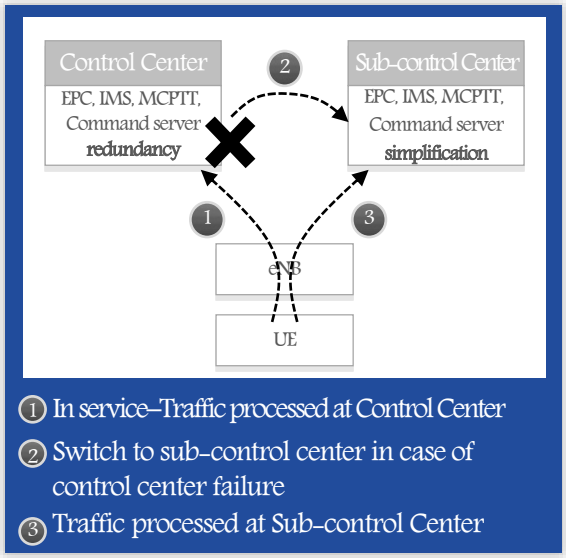
▸▸ Omni Antenna



In-building area

4. Redundancy — Core & eNB Redundancy

+ Location Dualization



① In service-Traffic processed at Control Center
② Switch to sub-control center in case of control center failure
③ Traffic processed at Sub-control Center

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

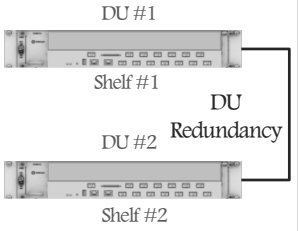
Fault Level	Equipment (Redundancy Failure)	Service Impact	Switch Procedure (Node Dualization)
Critical	MME, HSS, MCPTT, CSCF, SAE-GW	VoLTE, MCPTT available	Immediate switch
Major	AS, MRF, PCRF	VoLTE, MCPTT available Supplementary service not available (Call forwarding, etc.)	Idle hour switch (after service decision)
Minor	IBCF/TrGW, MGCF, MGW	VoLTE, MCPTT available PS-LTE & internal calls not uvailable	No switching (Equipment recovery)

- 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

Equipment		Redundancy	Switch Test Result	Note
EPC	MME	Server/Port/Power/SW Redundancy (Active/Standby)	Auto switch (in seconds)	Integration server
	S-GW			
	P-GW			
	HSS			
	PCRF			

Equipment		Redundancy	Switch Test Result	Note
IMS	CSCF/BGCF	Same as EPC	Auto switch (in seconds)	Integration server
	AS			
	MRF	Server Redundancy		Single server
	MGCF			
	IBCF/TrGW			
	MGW			

Equipment		Redundancy	Switch Test Result
DU		▪ Active-Standby DU 1:1 Redundancy ▪ Active-Standby DU are managed as one eNB	Auto switch (Samsung: 30secs /Nokia: 7~13mins)

CONTENTS

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

Category	GSM-R	LTE-R
Range	• Global (Europe, China, etc.)	• Republic of Korea (World's first LTE-R for high-speed railway on Wonju~Gangneung line)
Throughput	• Max. 172Kbps(DL), 172Kbps(UL)	• Avg. DL 40Mbps, UL 20Mbps ※ 10MHz bandwidth
Service	• Voice & Low-rate data (ETCS/ERTMS Level II Voice PTT, Nonstandard)	• Voice, Video, High-rate data (Video+Voice PTT, MCPTT Standard, MCPTT QCI69/Signaling, 65/Voice, 70/File applied) • Functional & Location dependent addressing

Point 3

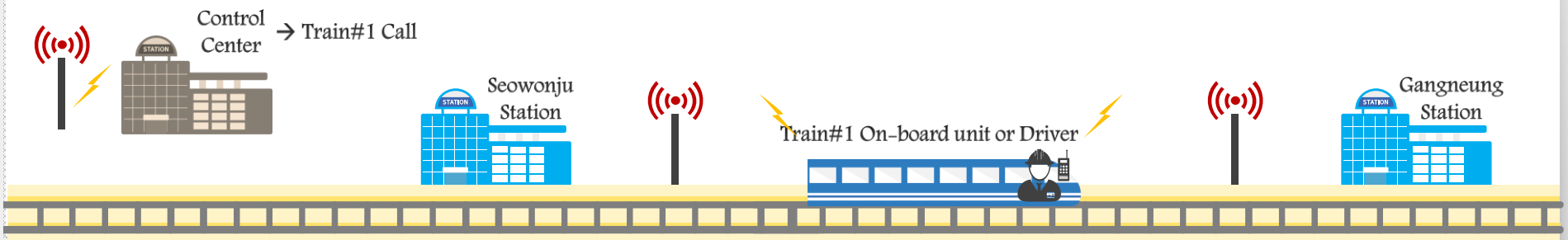
Railway Specific Advantages of LTE-R System

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

Point 4 Functional & Location Dependent Addressing (TTAK.KO-06.0369 / TTAK.KO-06.0370)

+ Functional Addressing

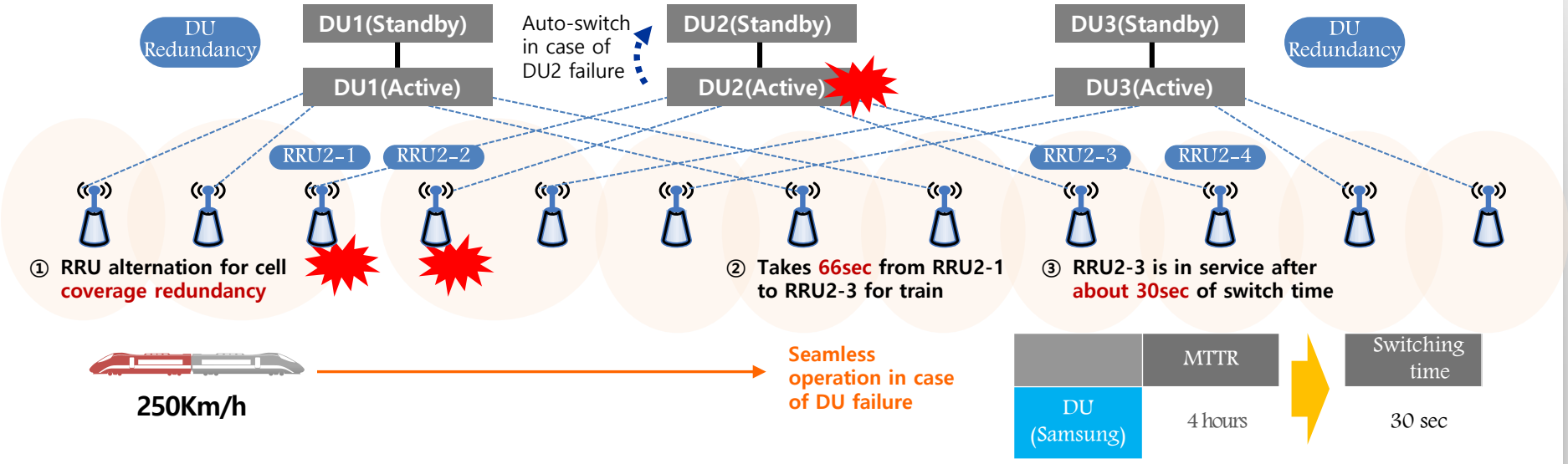
Ex) If control center calls Train#1, call connects to on-board unit or drive of Train#1



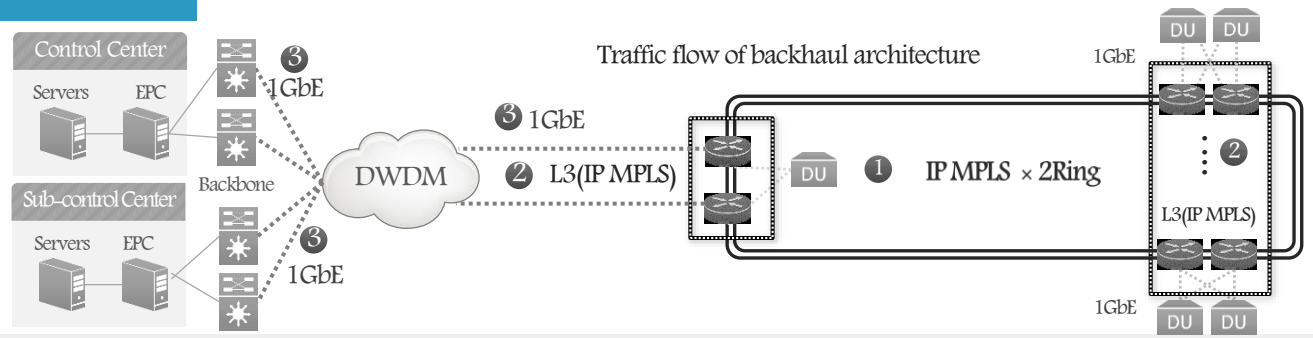
+ Location Dependent Addressing

Ex) If Train#1 calls controller, call connects to controller A or B depends on location of Train#1

Point 5 Seamless Coverage & eNB Redundancy (250km/h)



Point 6 Infrastructure with IP-MPLS



① 1G capacity IP MPLS applied

② Equipment redundancy

③ DWDM interface

B. LTE-R Cell Configuration Test

Title

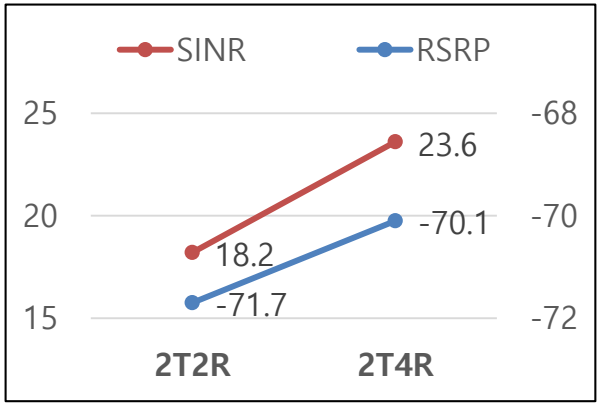
LTE-R Cell Configuration(2T2R/2T4R) Test for Optimization

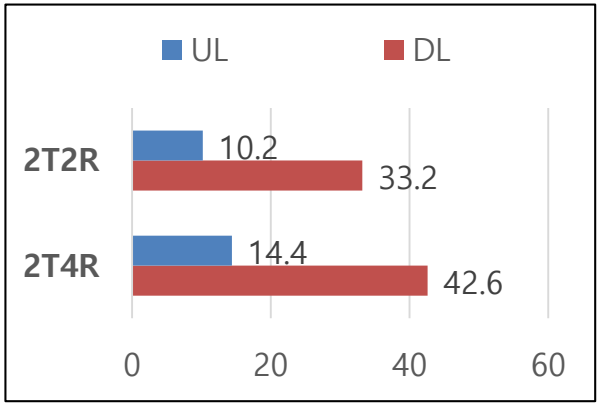
Period & Area

2017.08.01 ~ 08.31, From Manjong Station to Gangneung Station

Result

Cell Config.	Result	RSRP	SINR	DL (Mbps)	UL (Mbps)
2T2R	Avg.	-71.7	18.2	33.2	10.2
2T4R	Avg.	-70.1	23.6	42.6	14.4





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

Improvement of
SINR and other qualities

According to characteristics of each site, different cell configuration is applied

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

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)

	Mobile Device	Criteria
Coverage	99.717%	-110dBm, over 98%

Voice Call Success Rate

	Railroad	Station	Major Facilities (Control station, Depot)
Call success rate	99.10%	99.63%	99.51%

Data Throughput

Avg. Data Throughput	Railroad	Station	Major Facilities (Control station, Depot)
DL (Mbps)	35.950	53.154	61.125
UL (Mbps)	15.304	19.755	20.419

Data Transmission Success Rate

Transmission success rate	Railroad	Station	Major Facilities (Control station, Depot)
DL	99.27%	99.98%	100.0%
UL	99.15%	99.96%	100.0%

Handover Success Rate

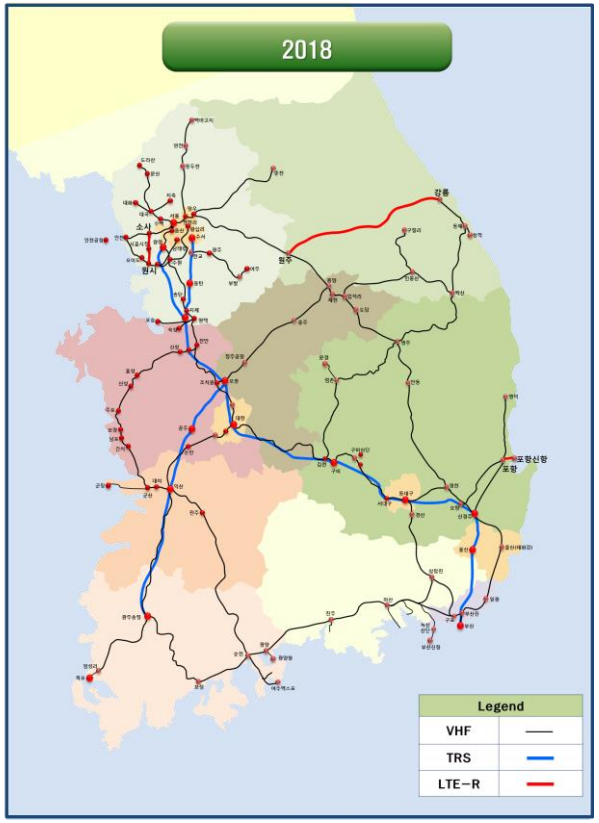
Handover success rate	Mobile Device	Criteria
DU	99.880%	Over 98%
RRU	99.895%	

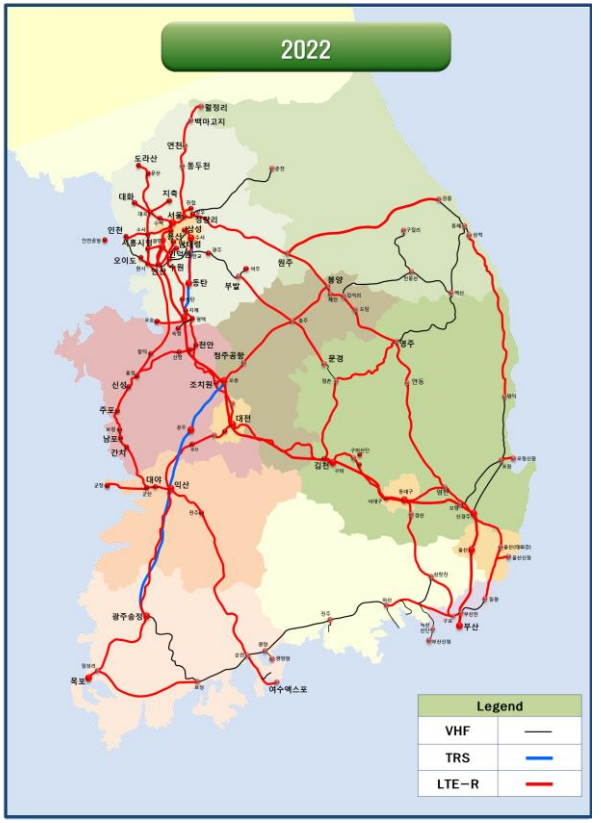
CONTENTS

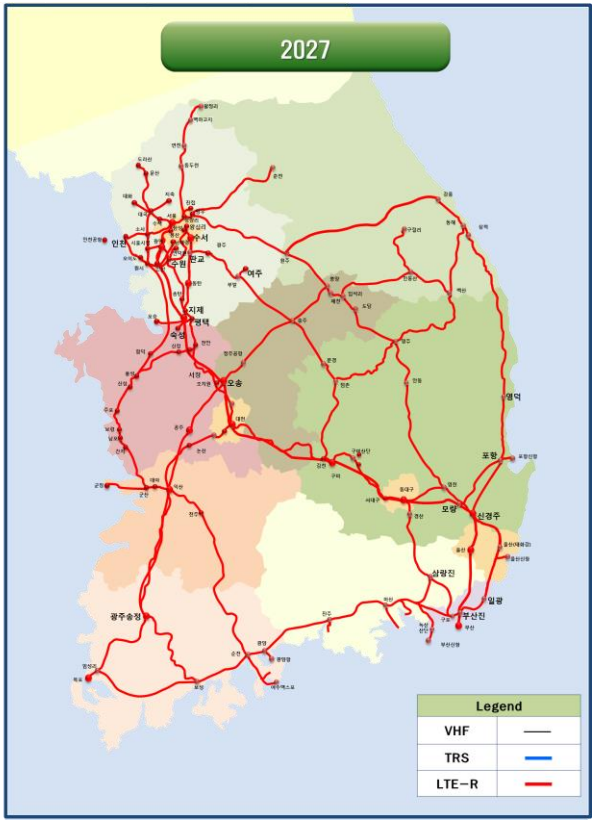
A. Plan for LTE-R Extension

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

Status

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)

Data Path	Traffic capacity (avg.)	Capacity used (Estimate※)	Free capacity
UL	20Mbps	10.6Mbps	47%
DL	40Mbps	4.8Mbps	88%

※ 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.

- Earthquake early response system,
- Railway structures & ground monitoring system,
- Track condition monitoring system,
- Accident site video transmission 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

Railway Safety

Maintenance Enhancement

Customer Service

- 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

KRTCS 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

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

한국철도시설공단
KOREA RAIL NETWORK AUTHORITY