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LTE as the Future Railway Communication System: Benefits and Challenges

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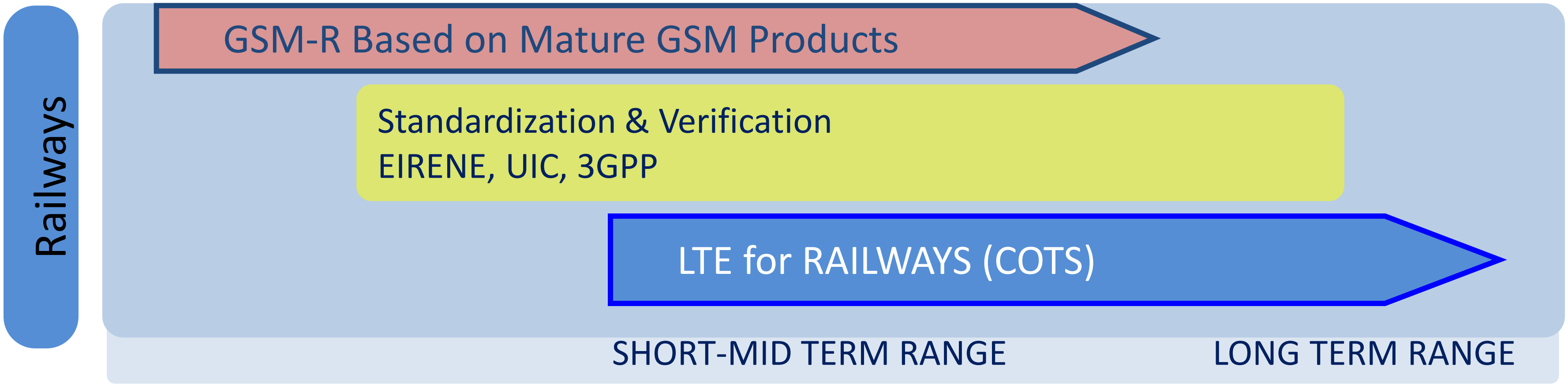
OUTLINE

- Introduction
- Railway Services & Applications.
- GSM-R Migration Process.
- LTE Features for Supporting Railway Services.
- LTE PHY & MAC Performance Assessment in HSR Environments.
- LTE & GSM-R Coexistence Challenges.
- Conclusions.

INTRODUCTION

Migration of current GSM-R train radio system

- Maintenance Cost Reduction: **GSM-R** Support and Maintenance outdated and expensive → **OBSOLESCENCE**
- Reduce OPEX and increase ROI:
  - GSM-R supports only Narrowband Services.
  - **Future Broadband System**: New added value services.



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RAILWAY SERVICES & APPLICATIONS

On board Advanced Passenger Services

Real Time Traveller Information
Digital Signage

INCREASE REVENUES

ENSURE SECURITY

IMPROVE EFFICIENCY / REDUCE COSTS

High Definition Video Surveillance On-Board
Level Crossing Look Ahead
Driver Video

Emergency Voice Calls

Tele-Diagnosis
Fleet & Trackside Maintenance
Localization Services

Automatic Train Operation

Operational Voice Services

LTE

GSM-R

Critical Core Services Main Constraints

- RAMS Requirements.
- Traffic Prioritzation
- Strong QoS Requirements: Delay, Drop Call Rates, etc.

Additional Communication Services Main Constraints

- Coverage
- Network Capacity
- Costs Requirements

RAILWAY SERVICES & APPLICATIONS

PASSENGER EXPERIENCE SERVICES

- Traveller information: Timetables, route planners, delays, etc.
- E- Ticketing.
- High-speed internet access.
- Personal on-board multimedia entertainment.
- Digital signage.

BUSSINESS PROCESS SUPPORT SERVICES

- Real Time crew communication with Station Staff.
- High speed communications in depots and stations between operators staff.
- Tele-diagnosis and fleet maintenance.
- Localization Services

OPERATIONAL DATA & VOICE SERVICES

- Telemetry
- Remote and driverless operation: Real time video and data information.
- Real time traffic managment
- Safety Services: Onboard CCTV, look ahead from driver video.
- Communication based train control or signalling
- Legacy services: Operational voice services.

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GSM-R MIGRATION PROCESS

Which factors drive the Migration towards Broadband Networks?

RAILWAY APPLICATIONS

- Increasing use of bandwidth hungry - data applications and new operational services require efficient networks.
- NEW APPLICATIONS/SERVICES ➡ INCREASE ROI & DECREASE OPEX
- LTE is simple, high efficient, high capacity, low delay and cost, and meanwhile provides security voice and data communications.

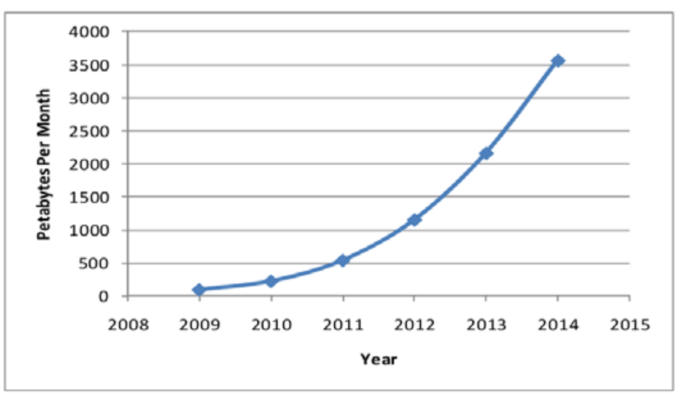
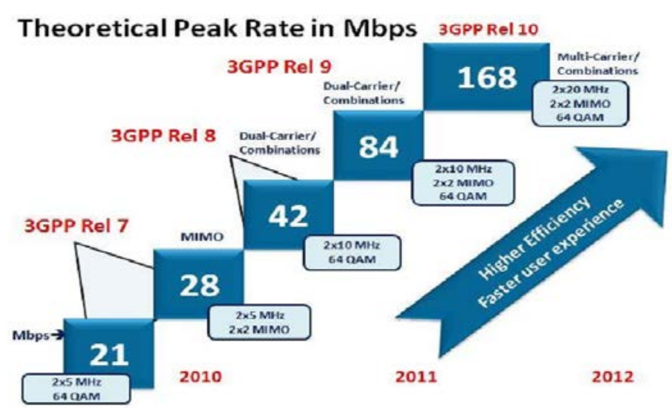


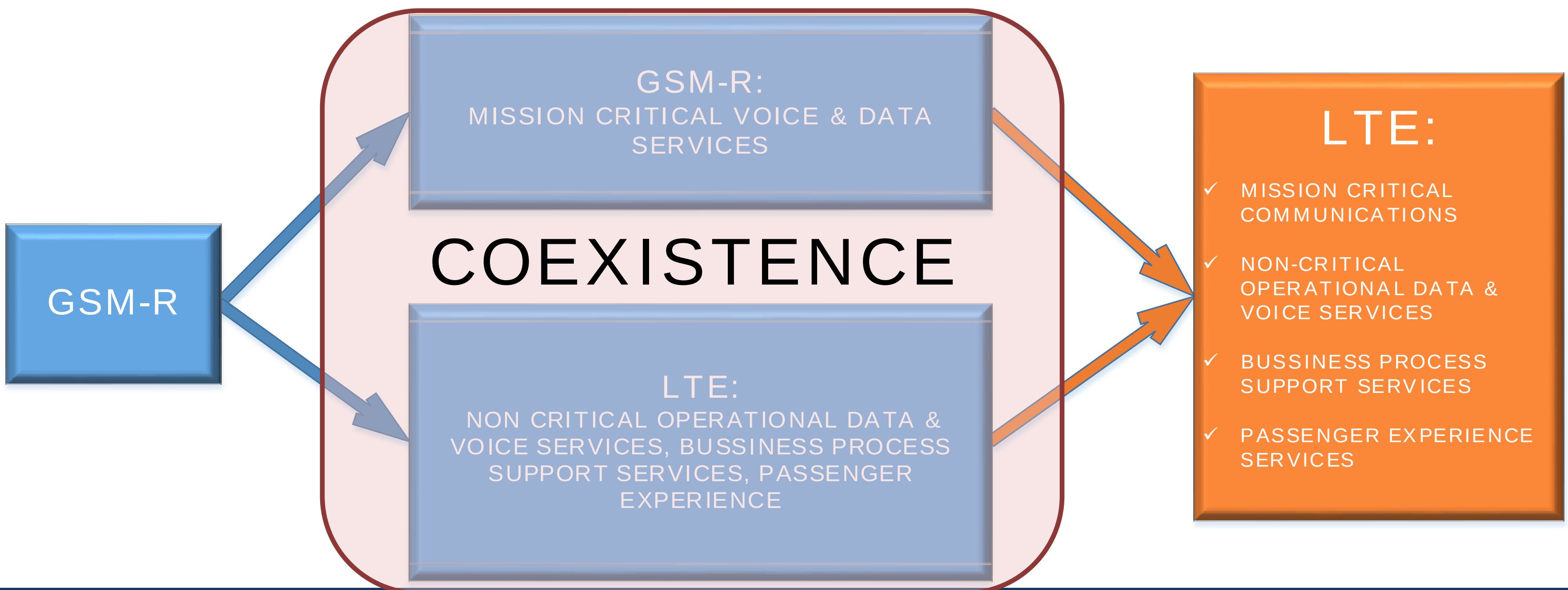
Figure 4.1. Global Mobile Data Growth.[25]



GSM-R MIGRATION PROCESS

Proposed Migration Process

- Integrated and Standardized System: **Solution COTS.**
- Avoid Operating Parallel Heterogeneous Systems: **Cost Reduction.**



GSM-R MIGRATION PROCESS

LTE Main Challenges in High Speed Railways

- *LTE Features for supporting Railway Specific Services ⟶ VOICE SERVICES*
- *LTE PHY & MAC Layer Interface Performance in High Speed Railway Environments.*
- *LTE Coexistence with GSM-R and other Mobile Communication Systems: Interference Issues.*
- **Convergence to an all-IP Transport Network System.**
- **LTE Core Network Architecture and Functionalities for Railways.**

LTE FEATURES FOR SUPPORTING RAILWAY SERVICES

GSM-R FUNCTIONALITY	PROPOSED POSSIBLE LTE SOLUTION
VOICE GROUP CALL SERVICE (VGCS)	LTE IMS based VoIP (VoLTE) + IMS based Push to talk Over Cellular (PoC) (note, this will be enhanced with the 3GPP Release 12 GCSE_LTE)
VOICE BROADCAST CALLS (VBS)	VoLTE + PoC: IP multicast of voice and video services (note, this will be enhanced with the 3GPP Release 12 GCSE_LTE)
PRIORITY AND PRE-EMPTION (EMLPP)	Access Class Barring mechanisms + Policy Control Rules + QoS mechanisms.
FUNCTIONAL ADDRESSING (FN)	Session Initiation Protocol (SIP) Addressing
LOCATION DEPENDING ADDRESSING (LDA, ELDA)	Localization Services in LTE (Release 10)
RAILWAY EMERGENCY CALLS (REC, E-REC)	Emergency and critical safety voice services over IMS in LTE.
FAST CALL SET-UP	Very low latency of LTE to support fast exchange of signaling (e.g. IMS based PoC) + Access Class Barring
DATA EXCHANGE (SMS, SHUNTING)	IMS based SMS Service Use SGs Interface between MME and MSC Server. MME based SMS service

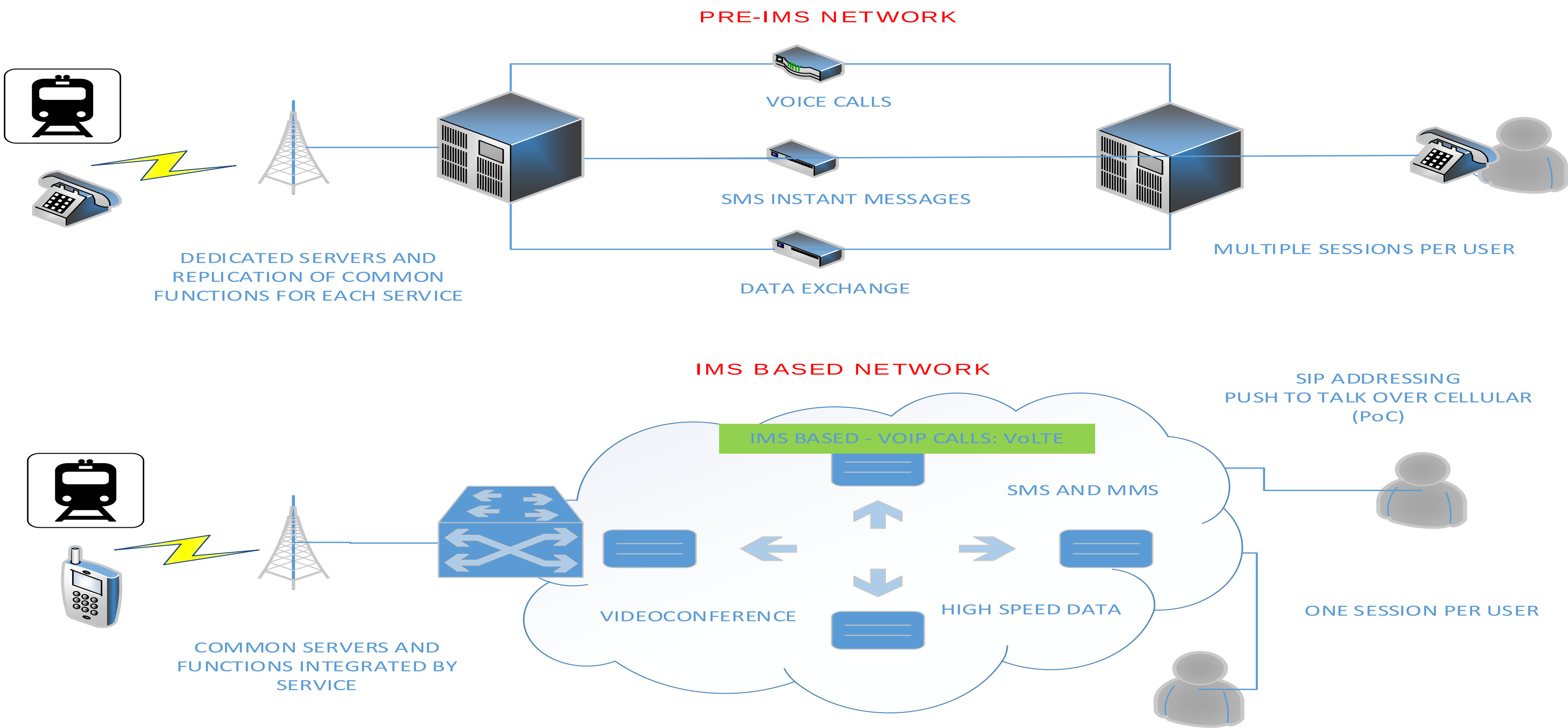
LTE FEATURES FOR SUPPORTING RAILWAY SERVICES

Voice Service Provision in LTE Networks

VoLTE (IMS)	VoLGA	CSFB
• Simultaneous Data and Voice over LTE. • Low Latency and Reduced Call Setup times. • Support LTE QoS Mechanisms. • High initial CAPEX	• Simultaneous Data and Voice over LTE. • Reduced Call Setup Times. • No MSC Upgrades. • Limited operators support. • Not Standarized yet.	• No IMS infrastructure. • Low initial CAPEX. • Additional call setup latency up to 8 sg. • Fall Back to legacy 2G/3G will suspend/reduce data transmission.

LTE FEATURES FOR SUPPORTING RAILWAY SERVICES

Voice Service Provision in LTE Networks



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LTE PHY & MAC Performance Assessment in HSR Environments.

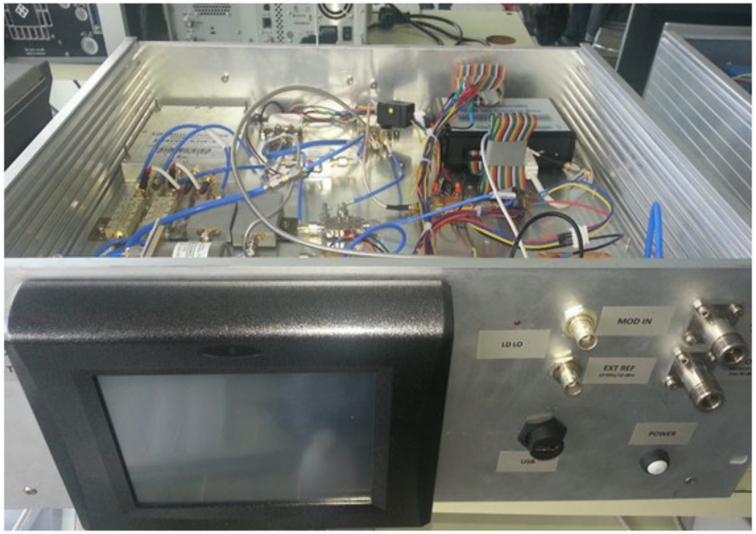
- **The Doppler shift and Delay Spread Effect in LTE Downlink and Uplink Channel Performance.**
  - Cyclix Prefix (CP) length & Doppler Shift (DS) effect in HSR ⟹ Interference InterSymbol (ISI)
  - Doppler Spread ⟹ InterCarrier Interference (ICI).
  - DEVELOPMENT OF LTE DEMOSTRATOR ⟹ Measurement of the LTE field performance in complex and high speed railway environments.
- **The performance of Dynamic LTE schedulers and related MAC Processes in High Speed Railway Environments.**
  - DEVELOPMENT OF LTE SYSTEM LEVEL SIMULATOR ⟹ Evaluate the performance of dynamic LTE schedulers and MAC Processes in HSR environments.
  - Makes use of LTE DL & UL Channel Performance measurements & theoretical developed propagation models
  - The software simulator tool will be a valuable help for assessing the LTE functionalities, reducing the complexity of the evaluation process and providing accurate and reliable results.

LTE PHY PERFORMANCE ASSESSMENT IN HSR ENVIRONMENTS

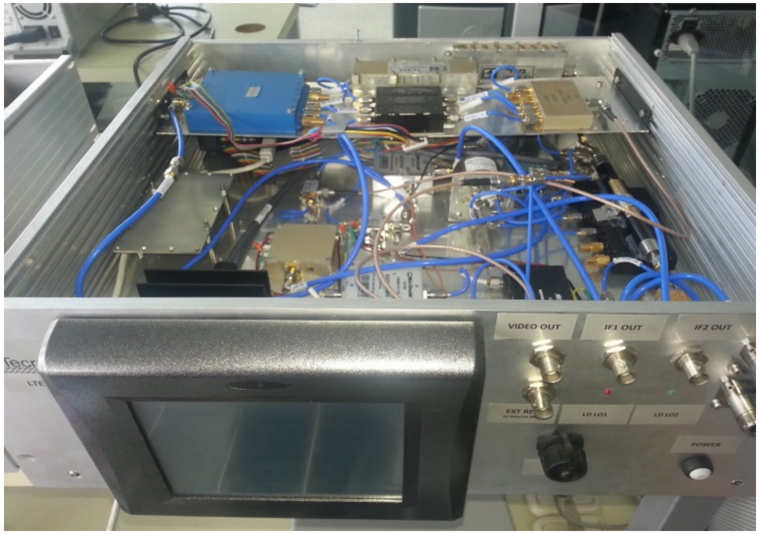
Development of LTE Transmitter and Receiver Demonstrator.

Up to 100 MHz bandwidth channel sounder for channel propagation modeling: Broadband and narrowband characterization of radio-propagation channel. Frequency Margin: 700 MHz – 5.80 GHz.

LTE Transmitter



LTE Receiver



LTE PHY PERFORMANCE ASSESSMENT IN HSR ENVIRONMENTS

LTE Transmitter and Receiver Demonstrator.

TECHNICAL SPECIFICATIONS:	
LTE RF Transmitter Front End	LTE Receiver Front End.
Frequency margin: 0,7–5,800 GHz	
Intermediate Frequency (IF) – ADC: 0,820–1,050 GHz	
Local Oscillators Frequency (OLF): 2,268–4,750 GHz	
Image Response Rejection Ratio (IRRR) ≥ 20 dBc)	Image Response Rejection Ratio (IRRR) ≥ 60 dBc
Spurious Rejection (No Armonics): > 50 dBc	Spurious Rejection (No Armonics) > 50 dBc
Maximum Transmitted Power: 29,5 dBm. TTC SubSystem S-band (Diplexor output): 37 dBm	Noise Figure (NF) : ≤ 10 dB TTC Subsystem S-Band (Diplexor Input)NF ≤ 5,5 d
	Sensibility: 30 dBm TTC Subsystem S-Band (Diplexor Input): 128 dBm
	Dynamic Margin 15 dB

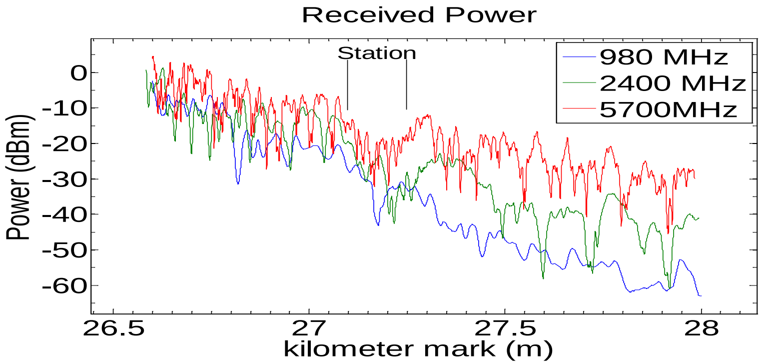
Channel Sounding Measurements ⟹ Characterization of LTE Channel Propagation in Complex and HSR Environments & EVALUATION OF LTE SUITABILITY FOR SUPPORTING CRITICAL RAILWAY COMMUNICATION SERVICES & Results Further Employed in the Development of LTE Radio Planning and Dimensioning Tool for HSR.

LTE PHY PERFORMANCE ASSESSMENT IN HSR ENVIRONMENTS

Radio Propagation Characterization:

Broadband and narrowband propagation channel model for tunnels and open space railway environments: Validation of Theoretical Model.

- Frequencies: 700 /900 /2450 /5750 MHz
- Several types of tunnels measured.
- High resolution measurements
- Narrow band and broadband measurements
- Complete channel model for LTE



Transmitter

Train and antenna

On-Board Receiver

LTE MAC Layer Performance Assessment in HSR Environments

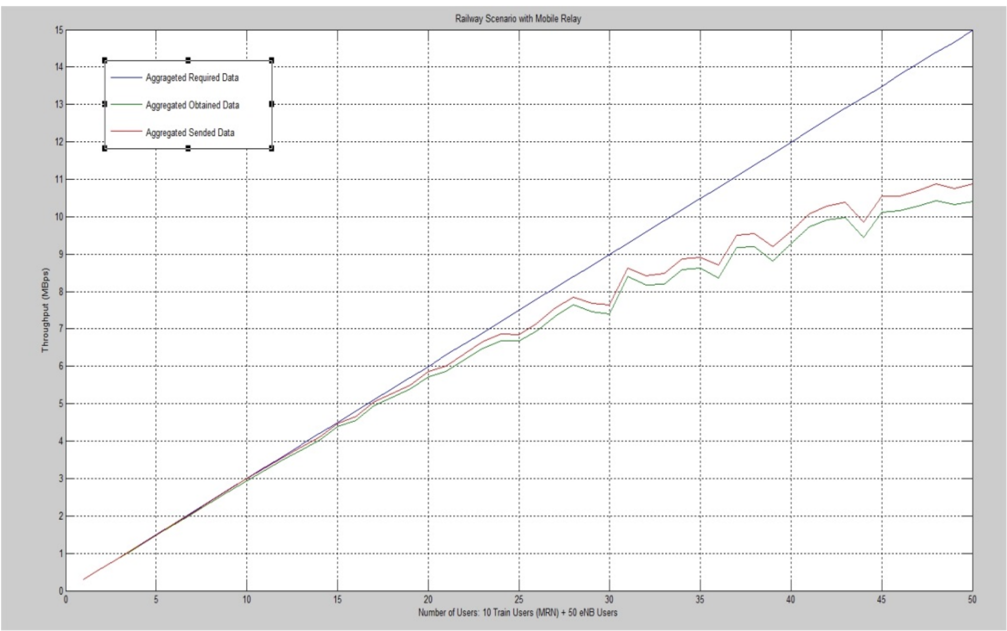
LTE System Level Simulator.

- Several LTE functionalities must be evaluated in HSR:
  - Optimal opportunistic dynamic scheduler performance with mobile relays
  - The HARQ retransmission protocols
  - The Channel Quality Indicator (CQI) feedback mechanisms
- Makes use of Measurements collected with the LTE demonstrator (Link to System model): Used in the system level simulator.
- Simulation results:
  - Determine the most suitable LTE system level configuration
  - Determine the LTE radio access interface dimensioning and planning in high speed railway environments.

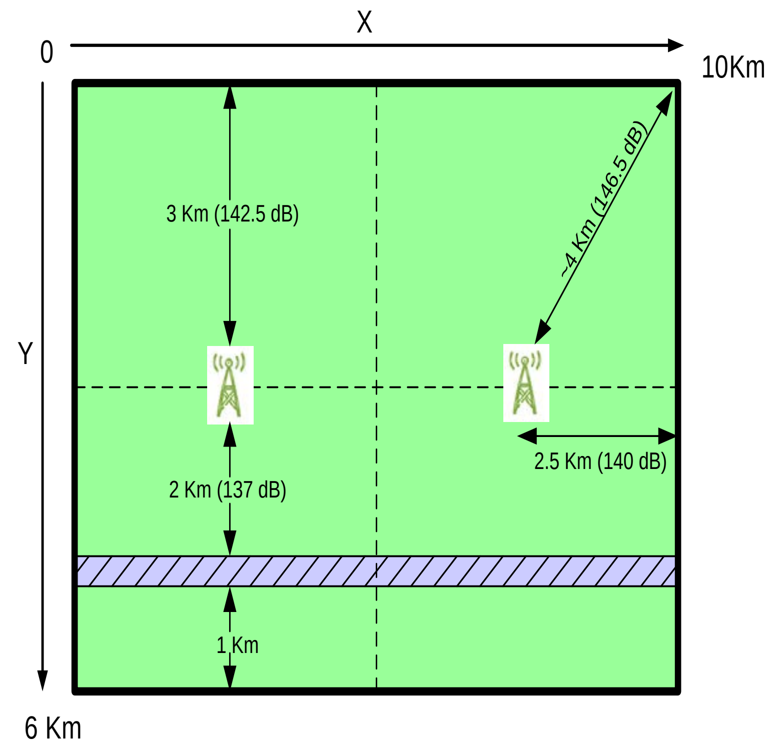
LTE MAC Layer Performance Assessment in HSR Environments

LTE System Level Simulator.

- Case Study: Scenario Simulated



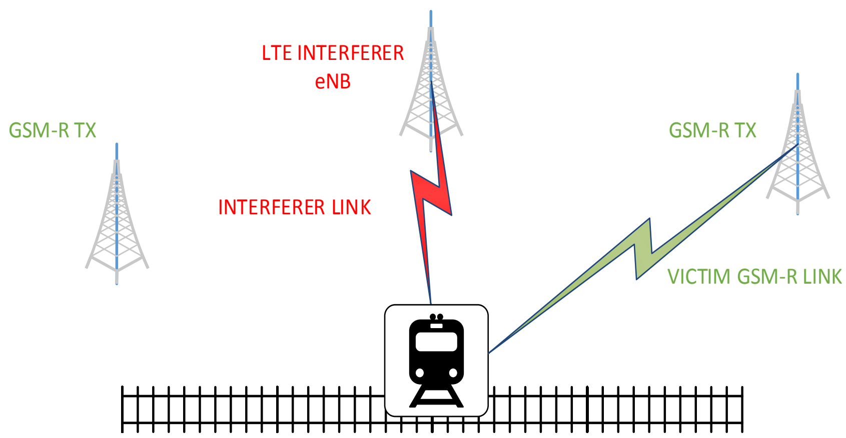
Railway Scenario with Mobile Relay



LTE & GSM-R COEXISTENCE CHALLENGES

Interference Assessment Between LTE & GSM-R

➢ Coexistence between LTE system for non-critical Railway Services and current GSM-R system. Case Study:



Development of a Novel Software Tool for the evaluation of Interferences between commercial cellular communication systems and railway communication systems.

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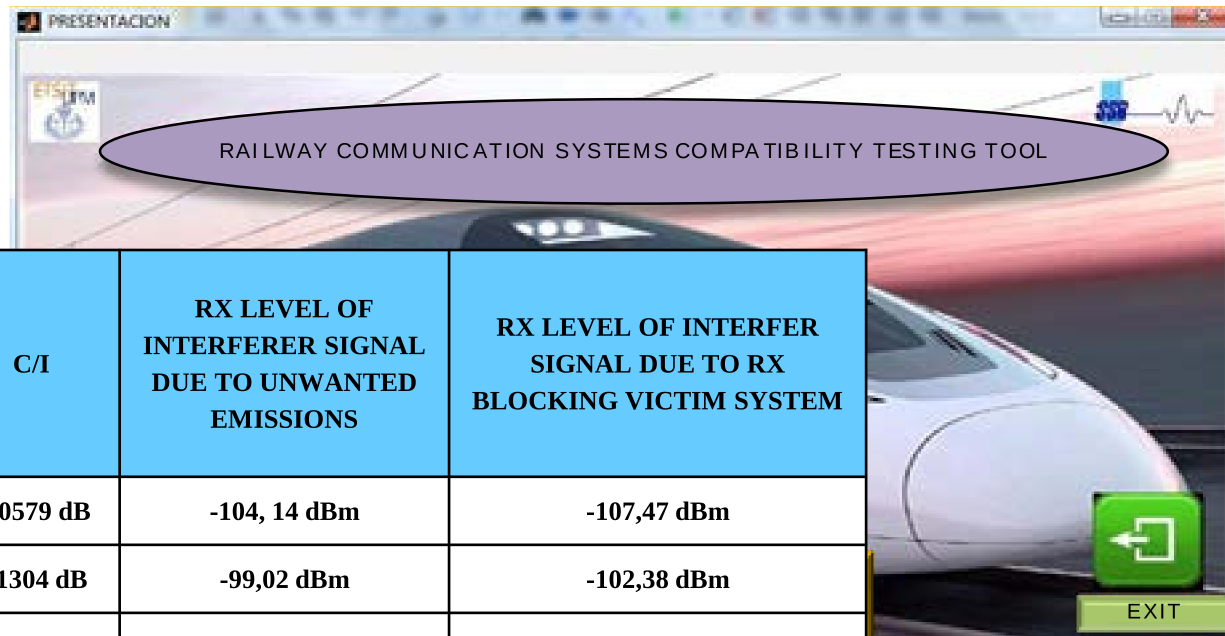
LTE & GSM-R COEXISTENCE CHALLENGES

Software Tool for Interference Assessment: Obtained Results.



INTERFERER LTE SYSTEM BW	MINIMUM SEPARATION BETWEEN LTE eNB TX and GSM-R TRAIN MOUNTED RECEIVER	C/I	RX LEVEL OF INTERFERER SIGNAL DUE TO UNWANTED EMISSIONS	RX LEVEL OF INTERFER SIGNAL DUE TO RX BLOCKING VICTIM SYSTEM
3 MHz	40 m.	9, 0579 dB	-104, 14 dBm	-107,47 dBm
5 MHz	20 m.	9,1304 dB	-99,02 dBm	-102,38 dBm
10 MHz	20 m.	9,5112 dB	-94,79 dBm	-97,79 dBm
20 MHz	13 m.	9,0684 dB	- 79,10 dBm	- 81,43 dBm

CONCLUSIONS

The migration of GSM-R system to a broadband communication system (LTE) for railways has been discussed. Some of the migration constraints have been analyzed:

1. The Voice over IP Service Provision & Convergence to an All-IP Network.
2. LTE Features for Supporting Railway Specific Service Requirements.
3. LTE PHY & MAC performance in High Speed Railways (HSR) environment.
4. LTE Coexistence with current GSM-R System.

Under this scope, several actions have been taken to evaluate these constraints:

- ✓ Development of a LTE demonstrator for assessing the LTE radio performance in railway environments.
- ✓ This demonstrator will allow for practical testing of LTE radio capabilities and performance in real field trials, as well as for the radio propagation characterization in complex and HSR environments.
- ✓ Development of a LTE system level simulator for dimensioning and planning LTE radio access.
- ✓ Development of a new software tool for the evaluation of interferences between commercial cellular and railways communications systems.

LTE AS THE FUTURE RAILWAY COMMUNICATION SYSTEM: BENEFITS AND CHALLENGES

THANKS FOR YOUR ATTENTION.
QUESTIONS?

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