INVESTIGATION OF LTE/LTE-R FUNCTIONALITIES IN TRAIN RADIO

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Abstract - **High-speed railways (HSRs) improve the quality of rail services, yield and help to create socioeconomically balanced societies. To handle increasing traffic, ensure passenger safety, and provide real-time multimedia information, a new communication system for HSR as well as for conventional rail (CR) is required. In the last decade, public networks have been evolving from Global System for Mobile Communications (GSM) with limited capabilities, to third (3G) and fourth-generation (4G) broad-band systems that offer higher data rates e.g., long-term evolution (LTE). This requires development for the railways of upgraded or new train dispatchers and drivers terminals with LTE/LTE-R functionalities. In this paper, the necessary functionalities in broadband wireless access for train radio have been discussed.**

Keywords - **LTE, LTE-R, Dual radio, GSM-R, Functionality, Cab Radio**

I. INTRODUCTION

For high-speed railway (HSR) and conventional rail (CR) to evolve the current Global System for Mobile Communications (GSM) - railway (GSM-R) technology with the next-generation railway-dedicated communication system providing improved capacity and capability is now in EU an upcoming task. [1] A reliable broadband communications system is essential for different HSR and CR components, such as train control and safety-related communications. Since 2014, a project of the International Union of Railways (UIC), known as the Future Railway Mobile Communication System (FRMCS), has started to assess and shape the future of HSR mobile communications and to identify suitable candidate technologies to use once the currently used GSM-R has become obsolete. HSR applications have strict requirements for quality-of-service (QoS) measures, such as data rate, transmission delay, and bit error rate (BER). Due to these factors as well as a desire to use mature and low-cost technology, HSR communications generally use off-the-shelf technologies and add applications to meet specific services and demands.

GSM-R [2] is a successful example, based on the GSM standard and used on over 70,000 km of railway lines (including over 22,000 km of HSR lines) all over the world [3]. The GSM communications systems are being decommissioned as the public communication market is evolving toward the Third Generation Partnership Project (3GPP) long-term evolution (LTE) [4]. A new system is thus required to fulfill HSR operational needs, with the capability of being consistent with LTE, offering new services but still coexisting with GSM-R for a long period. The selection of a suitable wireless communication system for HSRs needs to consider such issues as performance, service attributes, frequency band, and industrial support. Compared with third-generation (3G) systems, fourth-generation (4G)f LTE has a simple flat architecture, high data rate, and low latency, making it an acknowledged acceptable bearer for real-time HSR applications. Fifth-generation (5G) systems, although currently discussed in 3GPP, will be available only after 2020 and, therefore, are not suitable for the HSR time frame [5]. In view of the performance and level of maturity of LTE, LTE - railway (LTE-R) will likely be the next generation of HSR communication systems [6], [7], and the future vision for HSR and CR wireless technologies will thus rely on it.

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II. GSM-R SYSTEM

GSM-R is essentially the same system as the GSM but with railway-specific functionalities. It uses a specific frequency band around 800/900 MHz, as illustrated [8].

In addition, the frequency bands 873 – 876 MHz (uplink) and 918–921 MHz (downlink) are used as extension bands for GSM-R on a national basis, under the name Extended GSM-R (E-GSM-R). GSM-R is typically implemented using dedicated base stations (BSS) close to the rail track. The distance between two neighboring BSS is 7–15 km but in China it is 3–5 km because redundancy coverage is used to ensure higher availability and reliability. GSM-R has to fulfill tight availability and performance requirements of the HSR radio services.

III. GSM-R SERVICES

The GSM-R network serves as a data carrier for the European Train Control System (ETCS), which is the signaling system used for railway control. The ETCS has three levels of operation and uses the GSM-R radio network to send and receive information from trains. On the first level, ETCS-1, the GSM-R is used only for voice communications. On the other two levels, ETCS-2 and ETCS-3, the GSM-R system is used mainly for data transmissions. The GSM-R is very relevant to ETCS-2 and ETCS-3, where the train travels at a speed up to 350 km/h, and it is thus necessary to guarantee a continuous supervision of train position and speed. When the call is lost, the train has to automatically reduce the speed to 300 km/h (ETCS-1) or lower [9].

In Fig.1 [10] is summarized the future possible services provided by LTE-R, which is based on UIC technical reports of China Railway and ERA. It is noteworthy that broad-band wireless access for passengers inside high-speed trains is not provided by LTE-R because of its limited bandwidth.

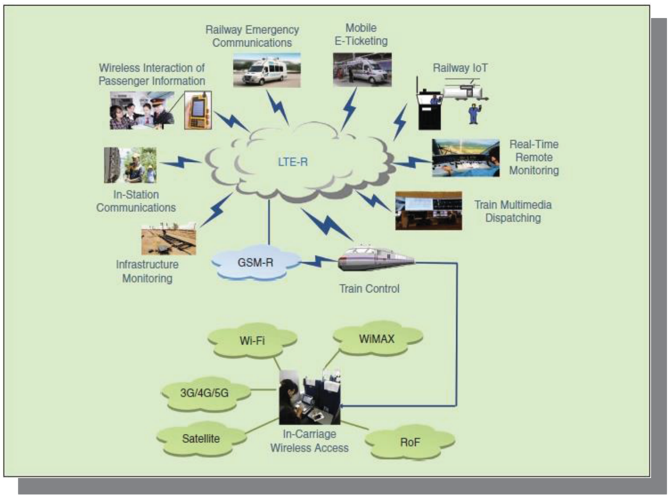

Fig.1 The LTE-R services

IV. LTE-R CHALENGES

➢ **There are several challenges associated with LTE/R.**

1) HSR-specific scenarios: In the LTE standard of [11], a channel model for HSR is resented that only includes two scenarios, open space and tunnel, and uses a nonfading channel model in both scenarios.
2) High mobility: High-speed trains usually run at a speed of 350 km/h, and LTE-R is designed to support 500 km/h. The high velocity leads to a series of problems. First, high velocity results in a non-stationary channel because, in a short time segment, the train travels over a large region, where the field strength change significantly.
3) Delay spread: Delay dispersion leads to a loss of orthogonality between the OFDM sub-carriers, and a special type of guard interval, called the cyclic prefix (CP), should be employed. The delay dispersion determines the required length of LTE CP supports both short (4.76 ms) and long (16.67 ms) CP schemes.
4) Linear coverage: In HSRs, linear coverage with directional antennas along the rail track is used, where the directional BS antennas orientate their main lobe along the rail track so that it is power efficient. The linear coverage brings some benefits, e.g. with the known location of a train, it is possible to design distance/ time-based beam forming algorithms with good performance.

V. THE FUTURE CAB RADIO INCLUDED IN LTE-R

The Future Cab Radio generations will be based on a packet oriented data transmission system, using or derived from current available commercial networks. Based on its long years of experience, in Funkwerk, they has been developed a LTE based Cab Radio system providing 2G/3G/4G telephony and data services as well as VoLTE1 and IP-based data-services (Fig.2)[12]. It operates on an Android based system. Due to the implementation of this market leading operating system the sage of this device is nearly self-explanatory. The dispatching radio is designed for use in Rail vehicles. In the vehicle there are two directional antennas supporting the MIMO technology which is applied in LTE for speed increases of download and upload data stream. The equipment was tested in Huawei's lab successfully in 2014. On this base a dual-mode GSM-R/LTE Cab Radio is based on Funkwerk's well-known GSM-R Cab Radio family "MESA".

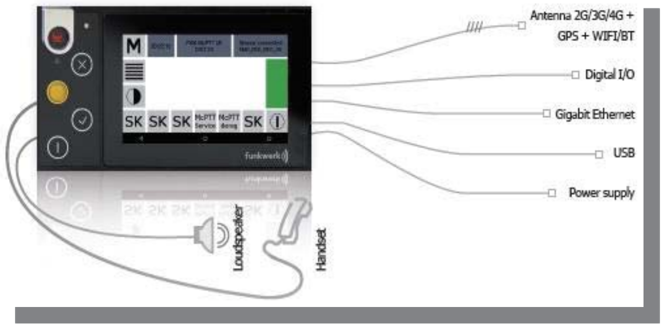

Fig.2 LTR Cab radio

It can be operated using public available SIM cards and is an all-in-one unit for fixed installation in vehicles. Besides the interfaces for 2G/3G/4G network "access further interfaces like Gigabit Ethernet, WIFI, Bluetooth", as well as a handset, a loudspeaker and generic I/O connection, are available. The installation of 3rd party applications is possible and therefore it can be smoothly integrated into an existing or new infrastructure of systems supporting Funkwerk McPTT (Mission critical Push to Talk) application. Customer specific applications or adjustments can be provided by Funkwerk or by 3rd parties too. The system is designed for the support of upcoming LTE releases and will be adapted to future services like group communication services.

VI. LTE FEATURES FOR SUPPORTING REQUIRED RAILWAY FUNCTIONALITIES

Railway services demands specific functionalities to train radio systems. For instance, GSM standard was enhanced with the Advanced Speech Call Items (ASCI) functionalities. Proposed LTE features and mechanisms to implement the railway functionalities are shown in Table 1.

TABLE I

PROPOSED LTE FEATURES TO SUPPORT GSM-R RAILWAY FUNCTIONALITIES

GSM-R Functionality	LTE Feature
Voice Group Call Service (VGCS)	**LTE** IMS based **VoIP (VoLTE)** + IMS based **Push to talk Over Cellular (PoC)** + **Enhanced Multimedia Broadcast Multicast Service (eMBMS**
Voice Broadcast Calls (VBS)	**VoLTE** + **PoC** and/or **eMBMS**: IP multicast of voice and video services
Priority and Pre-emption (eMLPP)	**Access Class Barring** mechanisms + **Policy Control Rules** + **QoS** mechanisms **(ARP)**.
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 Calls Set-up	IMS based **PoC** + **Access Class Barring**
Data Exchange (SMS, Shunting)	IMS based **SMS Service**

The IP Multimedia Subsystem (IMS) is enhanced-services architecture for delivering any service, reaching any customer regardless of how they connect to the network [13]. The main drawback is the fact that it is far from ready for deployment. The Session Initiation Protocol (SIP) is a protocol that facilitates the formation, modification and execution of communication sessions between individual or multiple participants. Locating call recipients and talking with them on their different user agents is accomplished using a SIP address [14]. The Push to Talk Over Celular (PoC) deployed into an IMS Service Delivery Platform can be an efficient way to provide the VGCS functionality in LTE standard while fulfilling railway services delay requirements. However, Voice Group Call Services (VGCS) is radio cell based in contradiction to PoC functionalities (Mandoc [15]).

VII. TOP CHALLENGES OF LTE

In this section, main technical challenges of LTE for supporting railway functionalities with their specific QoS requirements are described:

➢ **Voice service provision over IP LTE networks**

GSM-R functionality for delivering voice services is considered a key core functionality for railway operation. The voice service provision in the LTE standard is a major challenge that must be carefully assessed and analyzed. Regarding the technological solutions for delivering voice over LTE, the solutions based on using the IP Multimedia Subsystem (IMS), the hybrid voice over LTE via Generic Access (VoLGA) solution and the CSFB solution are the most promising ones [16].

➢ **Handover in LTE**

LTE standard support hard handover mechanisms, which reduces the complexity of the LTE network architecture. However, the hard-handover (HHO) mechanism does not guarantee any data packet losing in handover process. LTE HHO must fulfill the railway service QoS and RAMS requirements, especially in high speed scenarios. It is necessary that the HHO mechanisms supported in LTE, lossless and seamless, minimize the packet loss or avoid it completely with fast connection and re-association time.

➢ **Quality of service mechanisms and access control in LTE networks**

Service prioritization, the ability to preempt users, and Quality of Service are all crucial to a future railway communication system. In railway environments, LTE must assure the delivery of data and voice packets while meeting a combination of delay, jitter, dropped call rate or data error rate, handover interruption time, maximum call setup time and maximum/guaranteed bit rate requirements.

➢ **Network performance in high speed environments**

The impact of high speed in LTE performance and capacity should be assessed carefully. The most important issues that should be evaluated are:

– *The Doppler shift effect in LTE downlink and uplink channel performance.*
– *The effect of high speed in resource scheduling.*
– *Handover mechanisms in LTE.*

➢ **Service RAMS requirements**

The described in [17] RAMS requirements Availability (interval availability), Regular Maintenance, Down Time, Corrective Maintenance, Preventive Maintenance, Maintenance Window, Mean Time to Restore (MTTR), Preventive Maintenance, RAM Program, Service Failure, System Lifecycle and Up Time has to be defined before implementation of LTE-R cap radio into HSR networks.

VIII. DUAL-MODE GSM-R/LTE CAB RADIO

The dual mode cab radio (Fig.3) is not limited to provide video / voice communication over LTE, it also supports voice communication between GSM-R network and LTE network. Since the bandwidth demands are increasing in the transport fields the dual mode cab radio will be one better choice for all Railway and Public Transport operators in the future.

➢ **APPLICATION SCENARIOS:**

- Real-Time Video communication over LTE between train driver and the dispatcher terminals, and maintenance staffs with handhelds.
- Voice communication over LTE between train driver and the dispatcher terminals, and maintenance staffs with handhelds.
- Voice communication between GSM-R network and LTE network

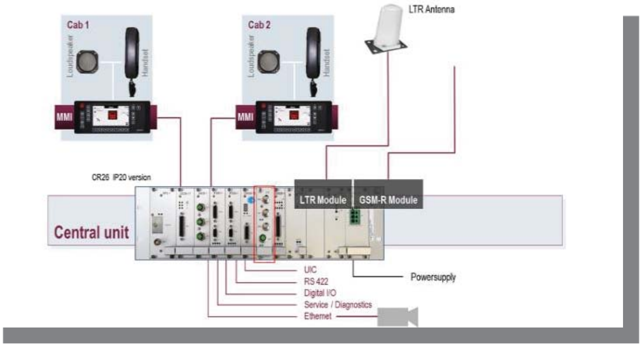

Fig.3 Dual-mode GSM-R/LTE Cab Radio Overview

IX. CONCLUSION

In this paper, the top challenges for the LTE system to become the future railway communication system are identified and discussed. These are related to the LTE mechanisms and features to implement the required railway functionalities, LTE technical requirements, the convergence to an all IP network, spectrum harmonization, network deployment considerations and LTE capabilities to meet the service RAMS requirements.

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