5GRAIL paves the way to the Future Railway Mobile Communication System (FRMCS)

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Abstract

Future Railway Mobile Communication System (FRMCS) will be the 5G worldwide standard for railway operational communications, conforming to European regulation as well as responding to the needs and obligations of rail organisations outside of Europe. UIC (International Union of Railways) is leading the design of this telecommunication system, in close cooperation with the railways stakeholders. FRMCS is the successor of GSM-R, representing around ~150,000 km of coverage of tracks in Europe. GSM-R is announced obsolete by around 2030, due to its current radio technology based on 2G. Moreover, GSM-R is one of the components of the European Railway Traffic Management System (ERTMS), which is the European unified system for Control-Command and signalling, fully specified and included in the European regulation (CCS TSI, Control-Command System Technical Specification for Interoperability). 5G technology is the catalyst for railways digitalisation, with increasing demand of data while keeping at the same time the high quality of service for critical railways applications in an interoperability context. Within FRMCS framework, 5GRAIL is consequently an innovative project, aiming to prove the technology readiness of the future railway standard. 5GRAIL's goal is to validate the first set of FRMCS specifications (also called FRMCS V1) by developing and testing prototypes of the FRMCS ecosystem, for both trackside infrastructure and on-board. Regarding on-board, 5GRAIL aims to reduce specific equipment costs and installation engineering time by combining all train-to-ground communications, by enabling a modular on-board setup based on standardised interfaces and including mainstream 5G components, called FRMCS On-Board System (also known as TOBA), in alignment with the sector's technical vision. Moreover, 5GRAIL includes the design of ad-hoc modems aligned with the future FRMCS railway harmonized bands in Europe. [1]
For more information about our project and the partners, visit: 5GRAIL – 5G for future RAILway mobile communication system

Keywords: FRMCS, 5G, MCX, Specifications, TOBA.

1. Introduction

The European railway sector concluded these last years to the necessity to evolve the European Railway Traffic Management System (ERTMS) due to the announced obsolescence around 2030 of GSM-R and the necessity to study the migration conditions. This evolution is based on the introduction of "ERTMS Game Changers", namely ATO (Automatic Train Operation), optimised braking curves, ETCS Level 3 (reducing the trackside components of ETCS), enhanced positioning of trains, cybersecurity measures and FRMCS, the later one being the enabler of all the others. FRMCS is designed to support mission-critical rail applications not only already supported by GSM-R, such as the European Train Control System (ETCS) level 2 signalling system and other sophisticated communication functions, such as the Railway Emergency Call (REC). Also, additional ones such as train automation and self-driving trains, ETCS Level 3, remote control and monitoring of on-board equipment (TCMS), Internet of Things (IoT), use of video for safety, predictive remote maintenance, real-time passenger information, and many more shall be supported. This is why FRMCS, specified and implemented as a standard, combining 5G transport means with MCX features, is considered as a major trigger for the wide-ranging digitalisation of the rail sector. To support such mission-critical rail applications, FRMCS shall rely on underlying telecom building blocks. These are the transport services provided by wireless networks based primarily on 3rd Generation Partnership Project (3GPP) technology (5G Core and Access networks supporting at least Railway Mobile Radio harmonised spectrum for Europe, ensuring the relevant performance requirements per railway application) and the service layer leveraging the functionalities of the 3GPP Mission Critical Services. 5GRAIL is consequently a fundamental element of this overall program, supported also by DG Connect, clearly dedicated to the specifications verification and first ecosystem prototyping. It is worth mentioning that the emphasis of the 5GRAIL project is on Mission Critical Services and 5G capabilities relevant for Mission-Critical communications, necessary to support mission-critical rail applications to be developed and tested in the context of 5GRAIL. Therefore, Mission Critical Services standardised as part of 3GPP Release 15, Release 16 and pre-release 17 to support FRMCS Applications, will be part of 5GRAIL prototypes development and testing. This paper summarizes in the following sections the scope of work of 5GRAIL, as per objectives, architecture system principles, functionalities and lastly methodology. 5GRAIL outcomes are considered by the railway sector as a key milestone in the global plan leading to FRMCS market readiness for railways in Europe, planned for 2025.

2. Objectives

2.1 Focus on 3GPP advanced features

As mentioned above, the FRMCS ecosystem relies on 5G Core and Access Networks, next generation of 5G modems and Mission Critical Services. With regards to 5G advanced features developed and tested in the context of 5GRAIL, the following list recalls some of them:

- 5G Standalone Core (5G SA Core) ;
- 5G QoS (Quality of Service) characteristics and optimized signalling relevant for mission-critical communications;
- 5G unicast IP based PDU (Protocol Data Unit) session;
- Session continuity over 5G Systems for cross-border use cases (emulation);
- 5G User Equipment supporting 5G NR bands relevant for FRMCS.

Below is a list of some 3GPP Release 15 onwards Mission Critical Services (MCx) used to support FRMCS applications, as part of the 5GRAIl prototypes:

- Mission Critical Push-to-Talk (MCPTT) Service;
- Mission Critical Data (MCData) Service;
- Functional alias;
- Multi-talker control;
- Mission Critical Services/GSM-R Interworking;
- Mission Critical Services Systems interconnections for emulation of cross-border use cases.

2.2 5GRAIL prototypes

As shown in “Figure 1: 5GRAIL prototypes/components in FRMCS ecosystem”, the prototypes of the FRMCS ecosystem are applications and Gateways:

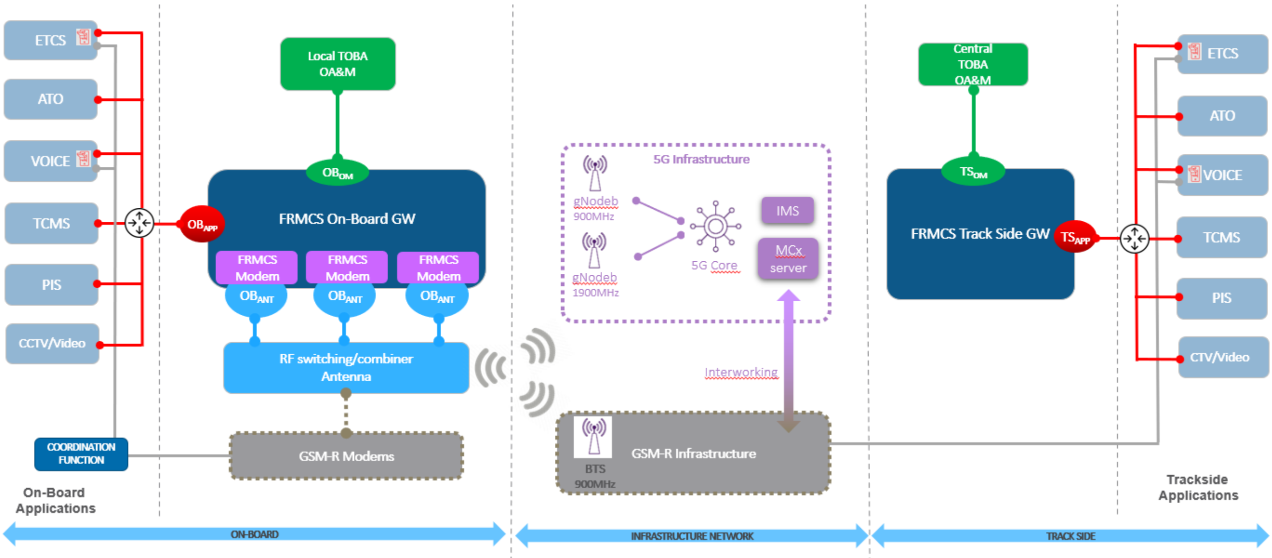

Figure 1: 5GRAIL prototypes/components in FRMCS ecosystem [7]

- The Applications, already rolled out in GSM-R which need to be ported over the new FRMCS system. Main evolution is the compliancy with the new FRMCS standardized reference points OBapp for the onboard part and TSapp for the trackside part and the underlying 5G infrastructure.

- A complete set of new applications which will be tested in the future 5G FRMCS railway environment, such as ATO, TCMS (Train Control and Management System) applications or video applications.
- The two FRMCS gateways for on-board and trackside, which are completely new prototypes specifically developed for FRMCS.

The key design principles expected to be fulfilled by the FRMCS gateways prototypes are:

- Decoupling of Applications and Communication Services/Transport.
- Ensuring improved performance and service availability (i.e., variety of bearers or Radio Access Technologies simultaneously).
- Resource Sharing (e.g., providing transport services for multiple applications of any category using the same FRMCS on-board system considering the individual QoS requirements of the application and possibly priorities among applications).

3. Architecture System Principles and Functionalities [2],[3],[4],[5],[6],[7]

This chapter summarizes the main characteristics of the prototypes, as per their architecture concept in 5GRAIL. As shown in figure 1, the applications are implemented in two parts:

- One part on the on-board side.
- One part on the trackside.

Connections between the on-board and the trackside parts of each application go through two gateways, located on both sides of the 5G infrastructure, as described below:

- The FRMCS on board gateway (OB_GTW), connected to the applications through OBapp interface and to the 5G Radio Access Network, through a set of FRMCS modems.
- The FRMCS trackside gateway (TS_GTW), connected to the applications through TSapp interface and to the 5G Core Network.

As the number of antennas on the roof of a train is limited by the available space, a "radio frequencies combining/switching" function will be inserted between antenna outputs of the modems and the antennas.
Both gateways (OB_GTW and TS_GTW) are managed through a dedicated interface, respectively named OBom (On-Board Operation and Maintenance reference point/interface) and TSom (Trackside Operation and Maintenance reference point/interface).
As a complementary information, the following table presents the main functionalities and the impact on the FRMCS components, in the scope of 5GRAIL:

COMPONENT	ARCHITECTURE SYSTEM FUNCTIONALITIES													
	FRMCS Service Stratum	Loose vs Tight	QoS	Session Mngt Adressing	BearerFlex	GSM-R Interworking	Positionning	Timestamping Synchro	Availability Redundancy Resilience	Cynbersecurity	FRMCS OB & TS GW interfaces	Auxiliary Function	RF switching Combining	FRMCS Roaming Capability
GATEWAYS														
FRMCS OB GTW	x	x	x	x	x	x	x	x	x	x	x	x	x	x
FRMCS TS GTW	x	x	x	x	x			x	x	x	x			
APPLICATIONS														
ETCS		x	x			x			x	x	x	x		
ATO		x	x			x			x	x	x	x		
VOICE	x	x	x	x		x	x		x	x	x	x		
CCTV		x	x						x	x	x	x		
TCMS		x	x						x	x	x	x		
PIS		x	x						x	x	x	x		

Table 1: System functionalities mapped to the 5GRAIL components [7]

The fundamental principle of the decoupling between railway application stratum and transport, so that the transport layer can evolve (to support a new radio technology, for example) without impacting the application layer, implies that:

- Both gateways (on-board and trackside) are in charge of service and transport strata.

- All applications in the railway application stratum must interface with the FRMCS system.
- Applications will only use facilities exposed by FRMCS Services.
- All FRMCS modems will be part of the transport stratum, on the on-board gateway.
- FRMCS services will be in charge of processing application requests using the facilities offered by the transport layer.

The implementation of FRMCS services is based on one MCx server, located in the infrastructure, and MCx clients, on each side of the FRMCS infrastructure. These MCx server and MCx clients are used to interconnect both parts of an application and it is a key principle of the FRMCS System architecture.
Although MCx clients are still a part of the service, two integration options are possible:

- either the MCx client is embedded in the application; defined as **tight coupling mode**
- or the MCx client is embedded in the gateways, defined as **loose coupling mode**.

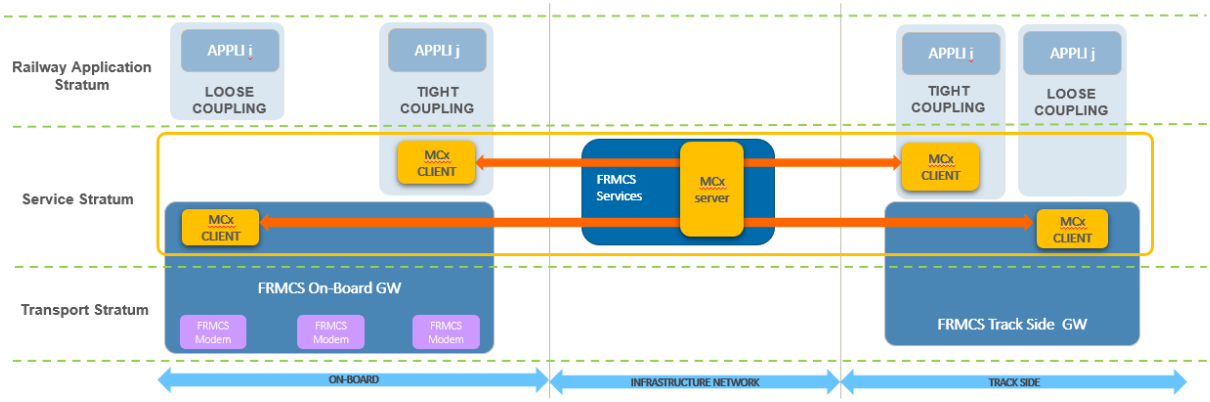

Figure 2: FRMCS Service Stratum – MCx Server and MCx Clients for loose and tight coupling applications [7]

Railway applications exhibit different characteristics in terms of performance, e.g., latency, reliability and priority. On the other hand, the FRMCS System offers communication services with different characteristics. The main purpose of the QoS mechanism is to specify the list of attributes applicable to the FRMCS bearer service to fulfil the application requirements.

Application categories describe the data transfer characteristics to be achieved by a communication service. In order to reach the performance applicable for each application category, priority levels are also required to differentiate among the communication urgency. Priority handling of communication service encompasses the assignment of a priority to a communication and involves the seizing of resources, but also the interruption of a lower priority in favour of a higher priority incoming communication.

Bearer flexibility aims at improving service availability and performance, enabling either data connectivity using multiple transport paths over separate UEs (User Equipment) or the use of multiple radio access technologies on a single UE and a single (FRMCS) Transport Domain. [2] In the context of 5GRAIL, bearer flexibility is managed by two gateways (OB GW and TS GW) to support multiple transport paths.

During the migration period, the coexistence of GSM-R and FRMCS systems will be managed at application level through the coordinating function, allowing the switching from FRMCS to GSM-R, as presented in figure 1.
All of the aforementioned are considered as part of the fundamental principles but more details about other principles and functionalities can be retrieved in the deliverables of the 5GRAIL project.

4. Methodology [1]

After a first phase of test definition and development of prototypes, a campaign of pilot tests (in labs & in the fields) will be rolled out in Europe to demonstrate how these technical solutions can be integrated, to validate their feasibility and to evaluate their performance. Most of the developments of the project will be tested and improved under a combination of environmental conditions in various test-sites in France and in Hungary and in-field sites in Germany and France).

The test activities, in-lab and in-field, will aim to:

- Test and fine-tune the prototypes for infrastructure and on-board.
- Perform the end-to-end evaluation of the functions and performance of the prototypes, applications and FRMCS-On-board Gateway, under simulated and real-world conditions, within a 5G reference environment
- Check, validate and amend, when necessary, the FRMCS specifications and standards.

In parallel of the main FRMCS activities, various scenarios of coexistence between the rail and the automotive telecommunication worlds will be assessed.

The figure below illustrates more precisely the organisation of the 5GRAIL project:

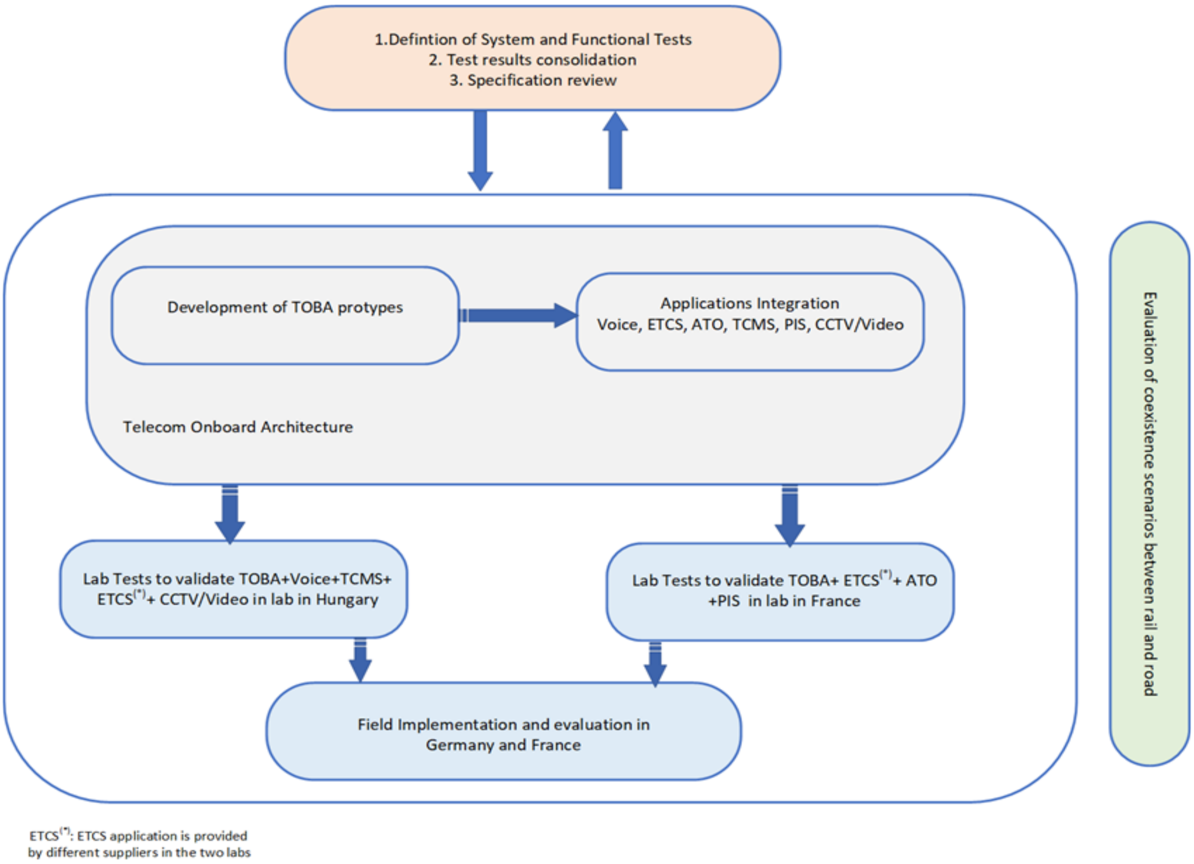

Figure 3: Structure of 5GRAIL project

5. Conclusion

FRMCS, which will be materially proven by 5GRAIL as an intermediate step, is seen by the railway sector as the enabler of train digitalisation, and consequently as one of the main factors for DG MOVE's strategy for railway Command-Control System evolution. The global outcome of 5GRAIL will be the validation of the 1st set of specifications for railway operational communications (FRMCS V1), that will specify the railway operational communications for the next decades, and for all European countries, due to the existing ERTMS regulation and its next update.

Industrial prototypes will be developed in the framework of 5GRAIL, such as the new On-Board System, which will be in the future the major component for managing railway operational communications between the train and the ground systems, and furthermore adapted versions of ETCS and ATO vital computers to manage IP connections within the 5G scheme.

For the first time, a complete set of new applications compared to GSM-R, will be tested making use of the new FRMCS services and standards, being also implemented for the first time in 5G infrastructure solutions by key players of the railway telecom industry.

Acknowledgment

The work described herein has been carried out within the project “5G for future RAILway mobile communication system” (5GRAIL). This project has received funding from the European Union’s Horizon 2020 research and innovation program, under grant agreement No 951725.

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