NEWSLETTER

5GRail

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO 951725.

PUBLISHED IN NOVEMBER 2023

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO 951725.

List of Abbrevations

Abbreviation	Description
3GPP	3rd Generation Partnership Project
5GRAIL	5G for future RAILway mobile communication system
API	Application Programmable Interface
ATO	Automatic Train Operation
CCS	Control Command and Signalling
CCTV	Closed Circuit TeleVision
CR	Change Request
CU	Centralized Unit
DG MOVE	Directorate-General for mobility and transport
DU	Distributed Unit
EC	European Commission
ERTMS	European Railway Traffic Management System
ETCS	European Train Control System
ETSI	European Telecommunications Standards Institute
EU	European Union
FRMCS	Future Railway Mobile Communication System
GSM-R	Global System for Mobile Communications – Railway
GW	GateWay
H2020	Horizon 2020 framework program
IP	Internet Protocol
IWF	Inter Working Function
MC	Mission Critical
MCX	Mission Critical, with X=PTT (Push-To-Talk for Voice) or X=Video or X=Data
OBapp	On-Board Application (e.g. ETCS on-board, ATO on-board)
PIS	Passenger Information System
PLMN	Public Land Mobile Network
QoS	Quality of Service
RAN	Radio Access Network
REC	Railway Emergency Communication
RMR	Regional Mobile Radio
SA	StandAlone
TCMS	Train Control Management System
TDD	Time Division Duplex
TOBA	Telecom On-Board Architecture
TS	Track Side
TSI	Technical Specification for Interoperability
UE	User Equipment
VPN	Virtual Private Network
WP	Work Package

01 Foreword

Dear Reader,

In this final newsletter before the completion of 5GRAIL (5G for future RAILway mobile communication system), you will get an overview of what the project has achieved now that it has reached its final month of activities.

The project partners have achieved a lot, building the first FRMCS prototypes, obtaining FRMCS 1900 MHz chipsets, testing them in lab and then in field, in real trains.

5GRAIL has also received innovation recognition from the EC for the following items:

- **FRMCS tailor-made 5G module (1900 – 1910 MHz TDD);**
- **5G FRMCS – GSM-R interworking;**
- **Cyber Security architecture for the MC over 5G ATO application.**

You will find the information on all these achievements in this newsletter directly from the Work Package (WP) leaders.

To find out more about 5GRAIL and its objectives, to access the public deliverables and to get a closer look at the project partners, please visit our website at http://www.5grail.eu

Enjoy the read!

02 Project Scope & Structure

The Future Railway Mobile Communication System (FRMCS), that will be materially proven by 5GRAIL against the V1 specifications, is seen by the railway sector not only as the GSM-R successor, but also as the enabler of train digitalisation, and consequently as one, if not the one, of the major "Game Changers" of DG MOVE's strategy for railway Command-Control System evolution.

The deployment of 5G FRMCS will open the possibility for railway operators to implement in addition to existing critical services supported by GSM-R which are the Voice applications and the ETCS (European Train Control system), of an extensive list of new applications permitting to optimise train operations and maintenance on one side, and to increase the quality of service to passengers (security, availability, punctuality and information) on the other side, such as for instance:

- **Automated trains: this major evolution of railway transport, for both freight and passengers, cannot be achieved without FRMCS;**
- **Remote monitoring and surveillance of vehicle elements (TCMS applications) will be made possible only with FRMCS deployment;**
- **Video.**

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. It will replace GSM-R, which represents around 130,000 km of coverage of tracks in Europe, announced obsolete by around 2030, due to its current 2G based technology. 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, included in the European regulation.

The work on the FRMCS functional & system requirements specifications, including for the on-board, interfaces, standardisation in 3GPP and ETSI as well as regarding harmonised spectrum solutions is currently led by UIC, in cooperation with the whole railway sector.

The major challenge to update the Technical Specification for Interoperability of Control Command and Signalling (CCS TSI) has been reached, with the inclusion of the FRMCS and its version 1 specifications in the 2023 CCS TSI. 5GRAIL, a DG Connect co-financed project, has helped within the build of 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, including for border crossing. 5GRAIL will also be key for the preparation of the next step, which is the European Trial, which is planned to start in June 2024.

Regarding on-board, 5GRAIL aims to reduce specific equipment costs and installation engineering time by combining all train-to-ground communications, with an on-board setup based on standardised interfaces and including mainstream 5G components, called TOBA (Telecom On-Board Architecture), in alignment with the sector's technical vision.

Prototypes have been tested in simulated and real environments, with pilots in labs and in the field that were rolled out in various European sites (France, Hungary and Germany), in order to ensure compliances and validation for the FRMCS version 1 specifications, and consequently significantly support the time to market for FRMCS products, planned for the end of 2025 as per the European timeline.

FRMCS is a 3GPP 5G Stand Alone Mission Critical system. The 5GRail architecture took this into account, where the MCX service layer had the first installation and test both as equipment and applications.

5GRAIL spans a period of 38 months and is divided into 8 Work Packages (WPs), which are detailed in the figure on the left.

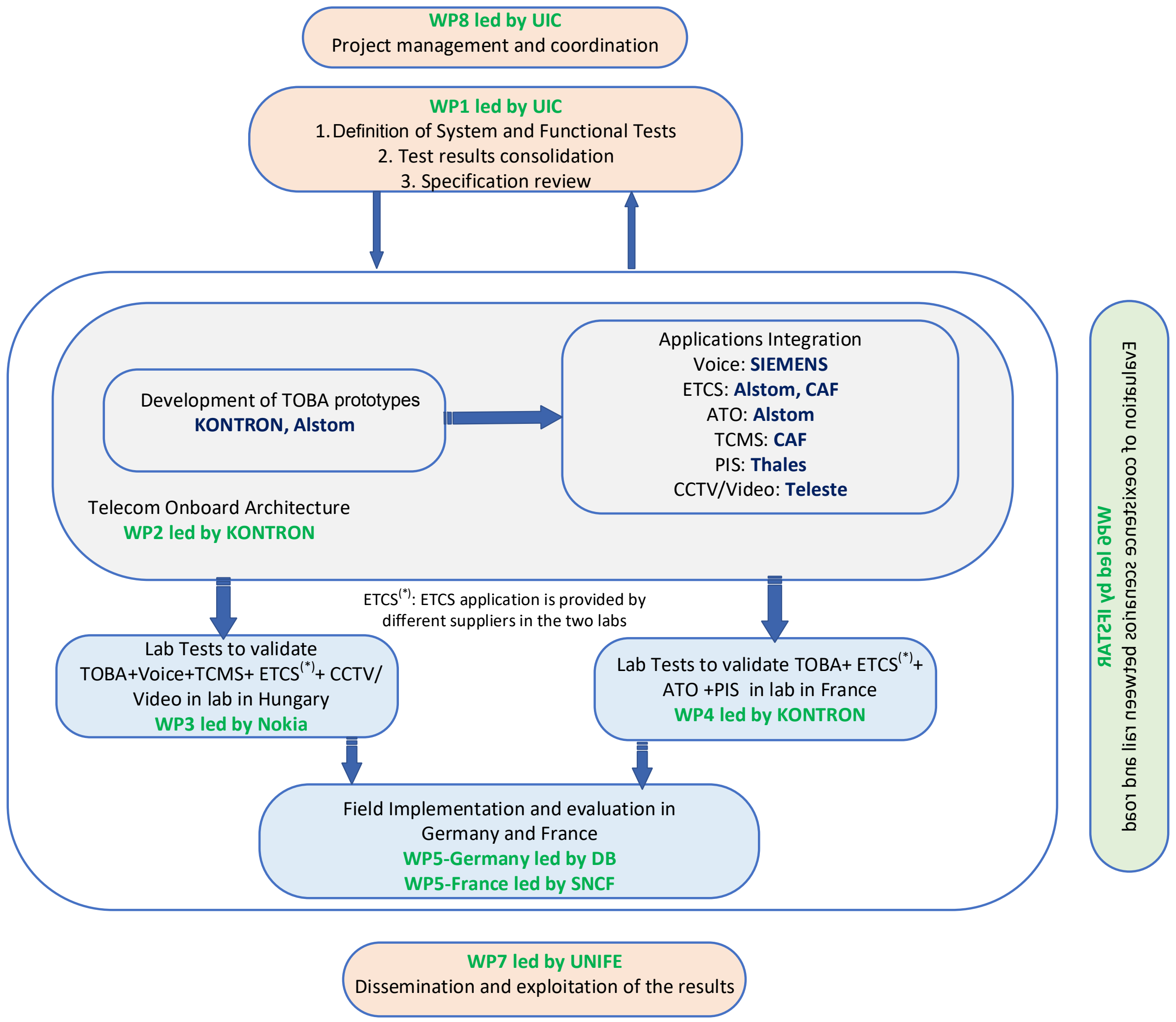


FIGURE 1 5GRAIL PROJECT STRUCTURE

03 FRMCS tests definition, tests results and specification review

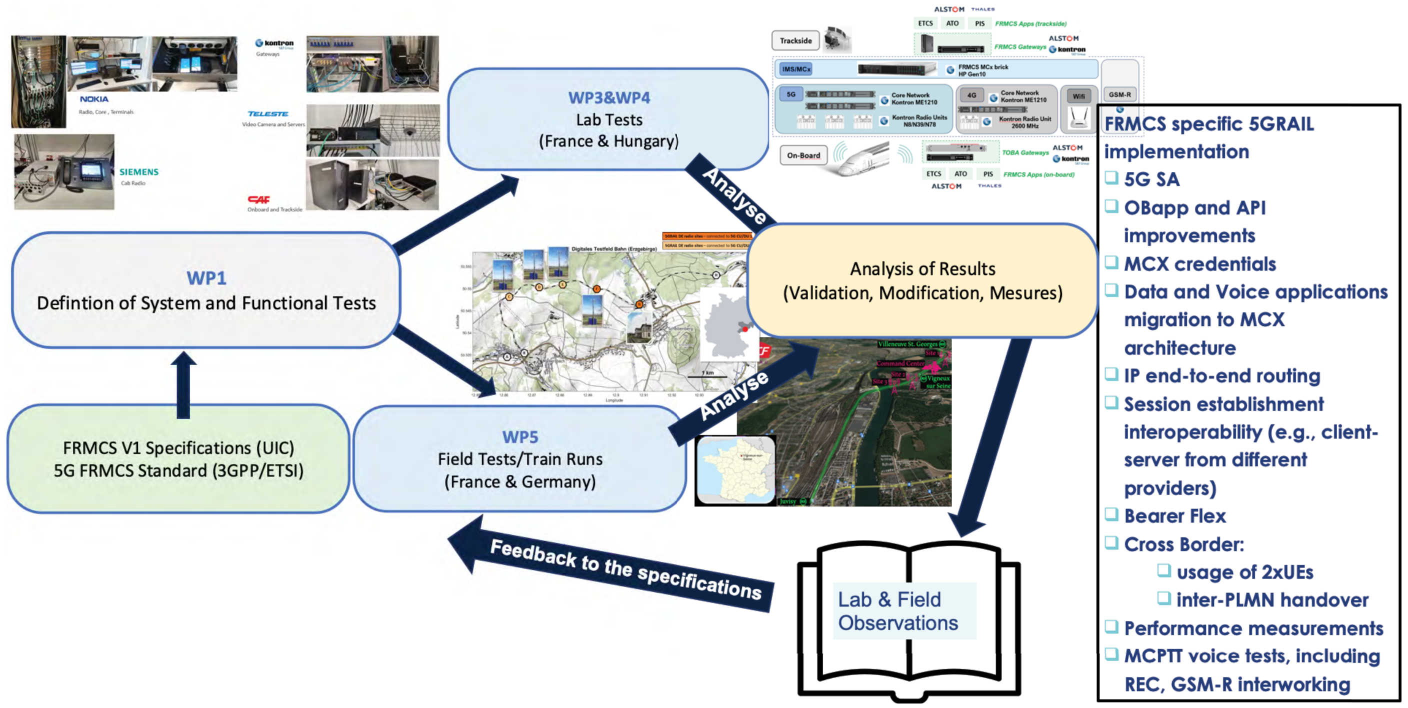


FIGURE 2 WP1 SCOPE - TESTS DEFINITION, OBSERVATIONS ON LAB AND FIELD CAMPAIGNS, LOOPBACK TO THE SPECIFICATIONS

WP1 has a key position in the 5GRAIL project by exchanging inputs with all the other WPs and partners during the whole lifecycle of the project:

- **It is a major contributor of the lab and field activities by selecting the FRMCS features and principles to be validated through a succinct test plan.**
- **The test plan has been successfully executed during the lab campains led by Nokia and Kontron in the framework of WP3 and WP4 respectively but also in field testbeds of Germany and France, led by DB and SNCF respectively.**
- **As part of the test activities, preliminary performance tests have been performed based mainly on applications KPIs (Key Performance Indicators) both in lab and field. Consequently, a performance methodology per application presented in D1.3 deliverable provides interesting ideas for the railway's stakeholders, preparing the 5G FRMCS operational deployment in Europe.**
- **A valuable feedback was provided to the standardization organizations for improvements in the UIC-FRMCS specifications, 3GPP specifications through proposals of CRs (Change request) and ETSI Working items.**

As a conclusion, the testing experience will contribute to the preparation of FRMCS V2 test specifications and the FRMCS European trial, planned to start in June 2024.

04 TOBA Prototypes Development

TOBA (Telecom on-board Architecture) is the FRMCS entry point for the On-Board and Track-Side applications. As shown in Figure below, FRMCS TOBA is based on 3 key design paradigms:

- **Decoupling of Applications and Communication Services/Transport;**
- **Bearer Flexibility (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).**

To enable the lab and field trials, there are two types of prototypes that have been developed:

- The Applications, already rolled out in GSM-R which need to be ported over the new FRMCS systems. Main evolution implemented is the compliancy with the new FRMCS standardised reference points OBapp for the on-board part and TSapp for the trackside part.
- The TOBA system that is declined into the two FRMCS gateways for on-board and trackside. These prototypes have been developed from scratch being new nodes of FRMCS.

At the end of the 5GRAIL project journey, the main achievements for WP2 are:

- TOBA 5G/FRMCS Architecture and the new interface with Application (OBapp/Tsapp) have been finalised and specified in the Architecture report (deliverable D2.1);
- New 5G/FRMCS radio module has been specified and prototyped. For that, Qualcomm has released a new firmware supporting 5G 1900MHz band;
- TOBA prototypes have been developed from scratch integrating the 5G modem supporting both 5G/FRMCS 1900MHz band and the 5G public bands;
- TOBA prototype units and the associated Applications have been delivered and integrated in 5G lab for WP3 in Hungary and for WP4 in France and later on handed over for 5G field test for WP5 in France and Germany.

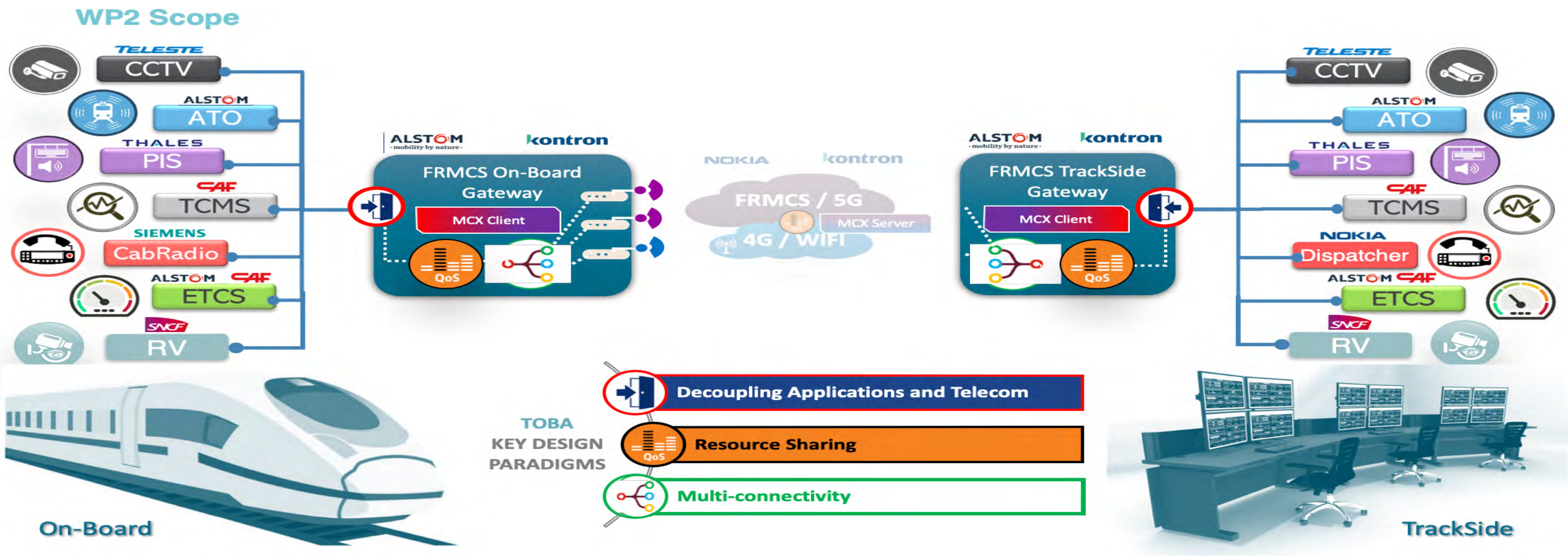


FIGURE 3 TOBA PROTOTYPES AND DESIGN PARADIGMS

05 Validation of ETCS, Voice, TCMS and CCTV/Video within TOBA

Laboratory tests

WP3 provided the first 5G reference lab environment situated at Nokia premises in Hungary/Budapest. The activities of this lab are focused on voice applications, ETCS, TCMCS, CCTV and Video.

With a strong focus on voice also pre standard solutions for Railway Emergency Call and GSM-R Interworking have been tested. Thus beside a complete 5G SA network consisting on Radio, Core, MCX, Dispatcher, Gateways and applications, and additional GSM-R network setup was installed. All scenarios as defined in WP1 were addressed with the partners and applications as shown below:

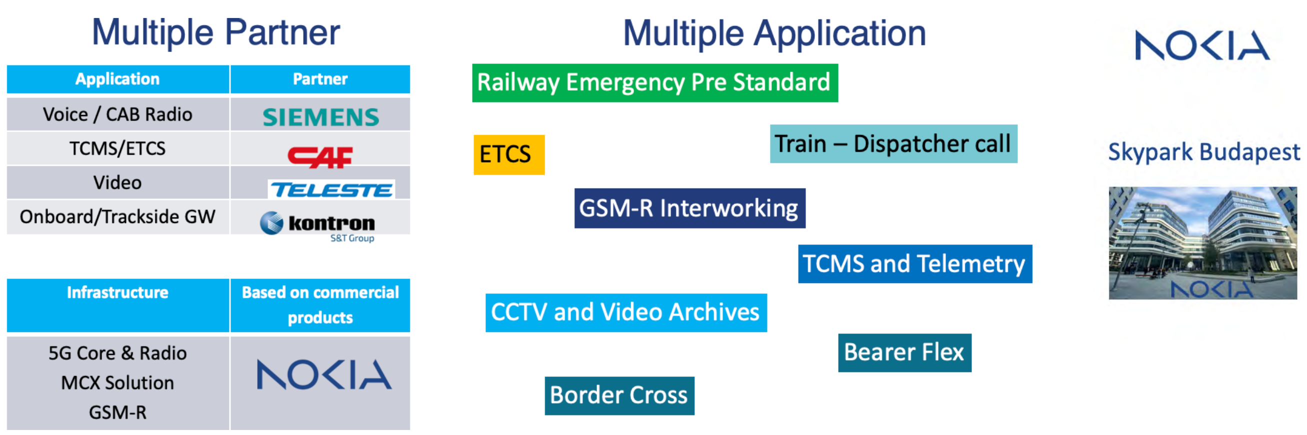
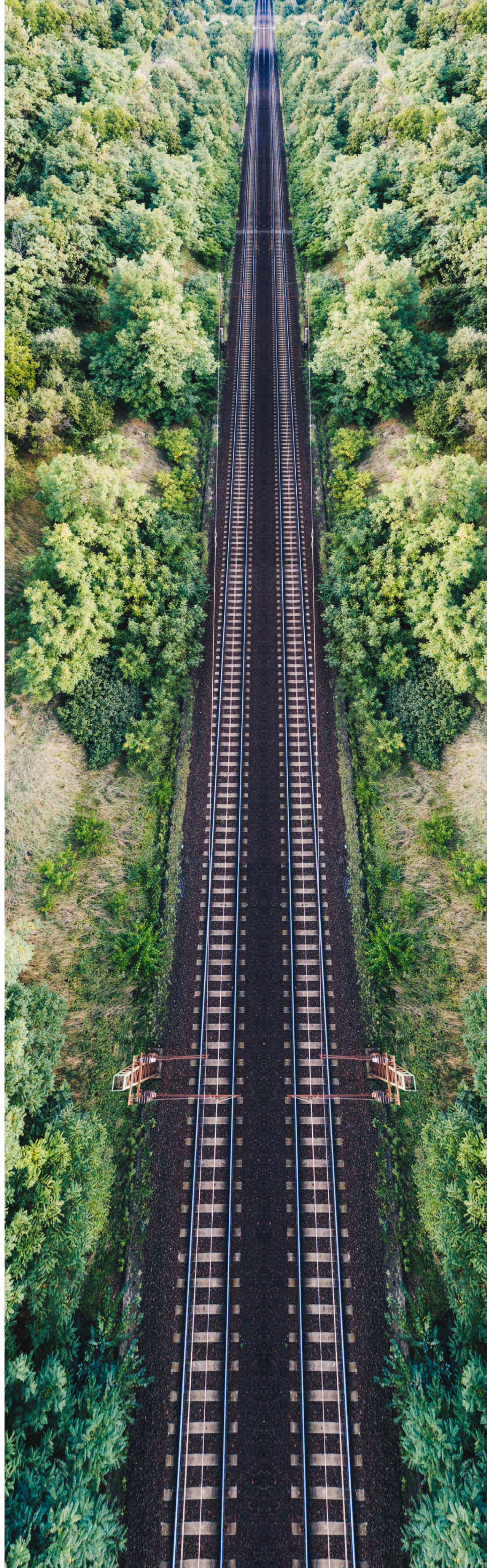


FIGURE 4 WP3 APPLICATION AND PARTNER OVERVIEW AT NOKIA BUDAPEST LAB

As specifications have not been finalised during the project, assumptions or innovations have been provided, e.g. on the GSM-R IWF, the solution to solve requirements for bearer flexibility and border crossing or QoS treatment.

One of the main challenges was to find solutions for testing based on the restrictions still existing in 5G SA technology in the market, ecosystem and products, leading to limited maturity of aspects related to Roaming, Handover or Interconnection. For example, an existing 5G SA solution was enhanced to achieve some of the important aspects of smooth border crossing scenarios (Inter core Handover), MCPTT solutions related to Railway Emergency call have been provided as interim step towards final standardisation.

The impact of Covid and the successful mitigation by implementing secure and stable remote cooperation and work was a main success factor to be able to execute WP3 tasks – a lesson learnt also for future projects to come.



The setup of WP3 supporting WP5 with remote connectivity of the lab with the field radio deployment caused on the one hand additional effort, but provided also a lot of benefits executing tasks and tests of lab and field in parallel – again some lessons learnt to be considered for future projects. While the integration mainly took place in 2022 (described in deliverable D3.2), the test activities took place in 2023, as shown below:

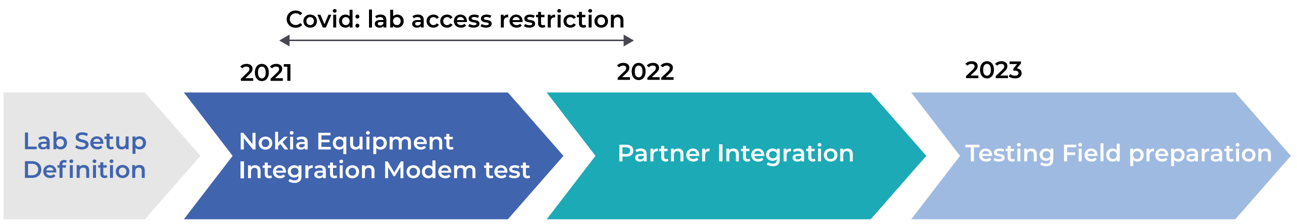


FIGURE 5 WP3 TIMELINE

The figure below depicts the lab installation of network and application devices, documented in WP3 deliverables D3.1 and D3.2, published in September 2021 and February 2022.

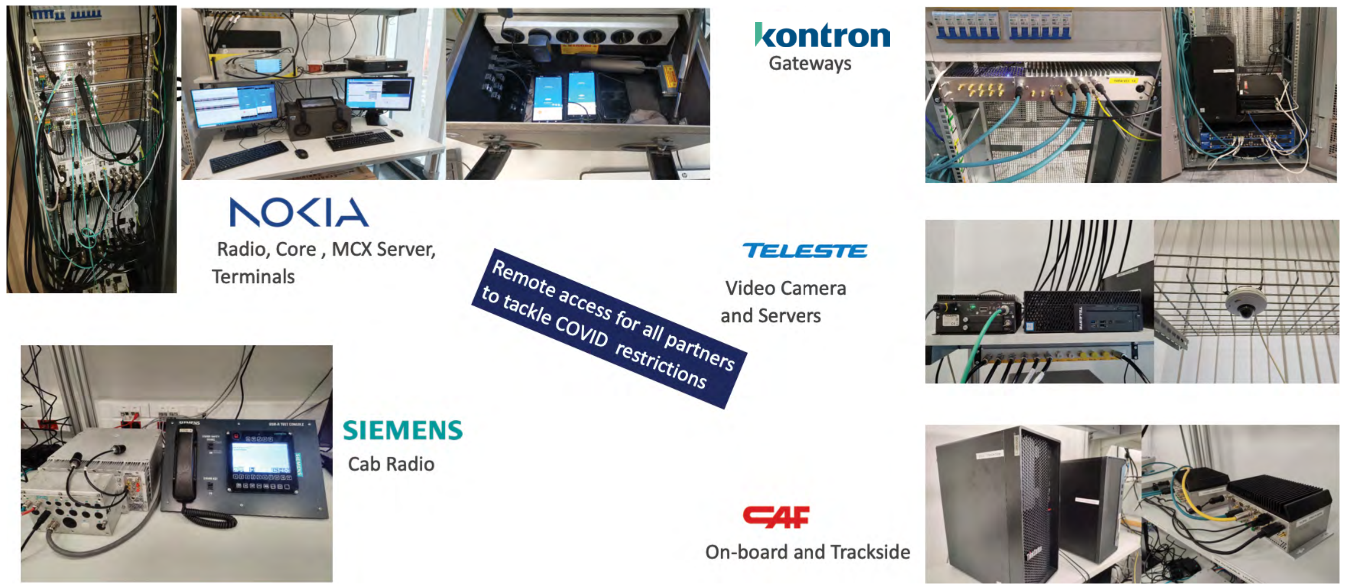


FIGURE 6 WP3 LAB IMPRESSIONS

The following tests were successfully addressed in WP3 and have been described in detail in deliverable D3.3 (revised document published in September 2023):

- **First successful FRMCS Voice and with CAB radio, smartphones and dispatcher;**
- **Railway Emergency Calls with innovative new dynamic group affiliation based on train position;**
- **GSM-R Interworking and network transition, which received the award by the EU as a key innovation (Innovation Radar > Discover great EU-funded innovations (europa.eu));**
- **Evaluation and testing of QoS mechanism to control different application requirements.**

06 Validation of Data, ETCS, ATO and Cybersecurity within TOBA

Laboratory tests

As per WP3, WP4 was responsible for building a test lab in order to integrate FRMCS components coming from WP2, then running the tests defined in the WP1 test plan (deliverable D1.1). However, whereas WP3 mainly focused on voice applications, the main target of WP4 was to test some data railway applications, especially ETCS and ATO, provided by Alstom, and PIS application provided by Thales. As regards FRMCS gateways, WP4 lab received two flavors: On-Board and Trackside Gateways from Kontron (TOBA-K, TrGW-K) and Alstom (TOBA-A, TrGW-A).

Thus, the first task of WP4 consisted in building a lab in which a 5G network would play a major role. Kontron hosted this lab in its heardquarters in Montigny, near Paris, France, and provided the project with a complete MCx/SIP Core system on top of a 5G SA network. Partners either sent their own equipments or used VPNs in order to complete the lab-setup. Remote connections then proved to be very convenient for testings during restrictive pandemic times.

FIGURE 7 WP4 LAB WAS SET-UP IN FRENCH MONTIGNY'S KONTRON OFFICE

By the end of 2021, the lab, described in deliverable D4.1, was fully operational and started to receive FRMCS deliveries coming from the WP2 team. This integration task lasted until the end of 2022. During that period, the WP4 team tested FRMCS gateways and applications, helping WP2 to fine-tune protocols and behaviours. This was also an important period linked to the very first usage of the RMR band n39 (1900 MHz) with tailor made modems provided by Thales. All these efforts are captured in the WP4 integration report, deliverable D4.2.

FIGURE 8 WP4 TESTS PHASE WAS AN INTENSE COLLABORATIVE WORK BETWEEN PARTNERS

Having all parts of the puzzle, including the WP1 test plan, the last task could then start with executions of many FRMCS related scenarios dealing with FRMCS, ATO, ETCS and PIS applications in normal tests conditions, and with variants (emulating speed effects, attenuation, concurrent applications and 5G QoS enforcement benefits, handovers). Specific focus was also given on the border crossing scenario; yet, having no 5G SA Home Routing neither Local Break Out features available at that time, WP4 chose to study solutions where 2 5G UEs are used in TOBA. Thanks, to the efforts of Kontron and Alstom teams, two different approaches could then be evaluated during that period. Based either on primary/secondary link or multiconnectivity approach (both modems being simultaneously active), interesting tests could be performed in that area too. Also to be mentioned are the numerous tests that were performed optionally (MCPTT voice tests, interconnection with GSM-R with IWF prototype usage, cybersecurity devices…) or executed in order to derisk WP5 field activities.

All these actions are described in a test report, deliverable D4.3. WP4 lab was then partially dismantled in Q2 2023 in order to support WP5 in France: some parts were sent on-site (5G RAN and Core Networks), keeping a VPN link to Montigny in order to connect to the whole FRMCS trackside part. Globally, the WP managed to achieve its goals and showed a very good collaboration among all its partners.

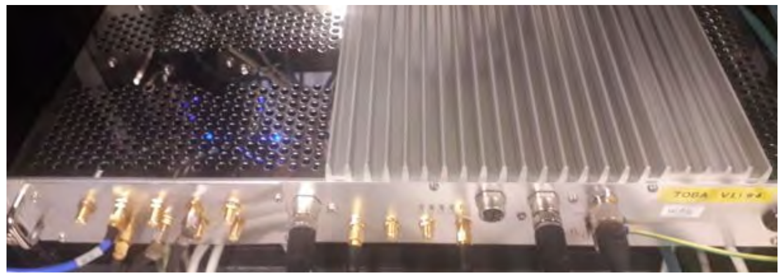


FIGURE 9 KONTRON TOBA-K N39 WAS TESTED AND INTEGRATED WITHIN WP4 LAB IN SEP.2022

07 Field Implementation and Evaluation

The objectives of the field trials were to provide a 5G railway field test environment to evaluate technical solutions and prototypes developed as part of this innovative 5GRAIL project. The prototypes developed and lab-tested have been integrated into real railways environment, i.e., rolling stock running on rail tracks with dedicated 5G radio coverage, which allow evaluation of their functionalities and performances. Field tests demonstrate the usability of 5G to answer railway needs using railway applications and application simulators. The summarised objectives are as follows:

- **Real-world 5G testing of essential functional requirements for the railways;**
- **Evaluation of End-to-End functionality and connectivity;**
- **Integration of Voice applications via 3GPP's mission-critical push-to-talk (MCPTT) functionalities, such as point-to-point calls, group calls and railway emergency calls (REC);**
- **Integration of Data applications via 3GPP's mission-critical data (MCDATA) functionalities, such as simulations of ETCS, ATO and TCMS traffic as well as real-time Video for remote vision and CCTV;**
- **Emulation of FRMCS bearer flexibility and border-crossing scenarios.**

Testing is performed in two test-fields (France and Germany), each having different characteristics. In SNCF's testbed in France, the test sites consist of a portion of commercial line in sub-urban environments in the Paris South-East region. 5G RAN is deployed as a test network at TDD band n39 (1.9 GHz, using 10 MHz bandwidth) in three sites called: Bourbonnais, Marin and Rive, with reuse of existing GSM-R/GPRS basic infrastructure setup. The CU/DUs and 5G Core are deployed at a local command centre close to the test sites. Train speed is limited to a maximum of 70 Km/h.

In DB's testbed in Germany, 5G RAN is deployed as a test network at TDD band n78 (3.7 GHz, using 20 MHz bandwidth) in 8 sites in the Erzgebirge region. The 5G Core is operated remotely from a control centre located at Nokia's lab premises in Hungary via a leased line. Trains run with a speed of 50-80 Km/h. The Figure below depicts the two setups.

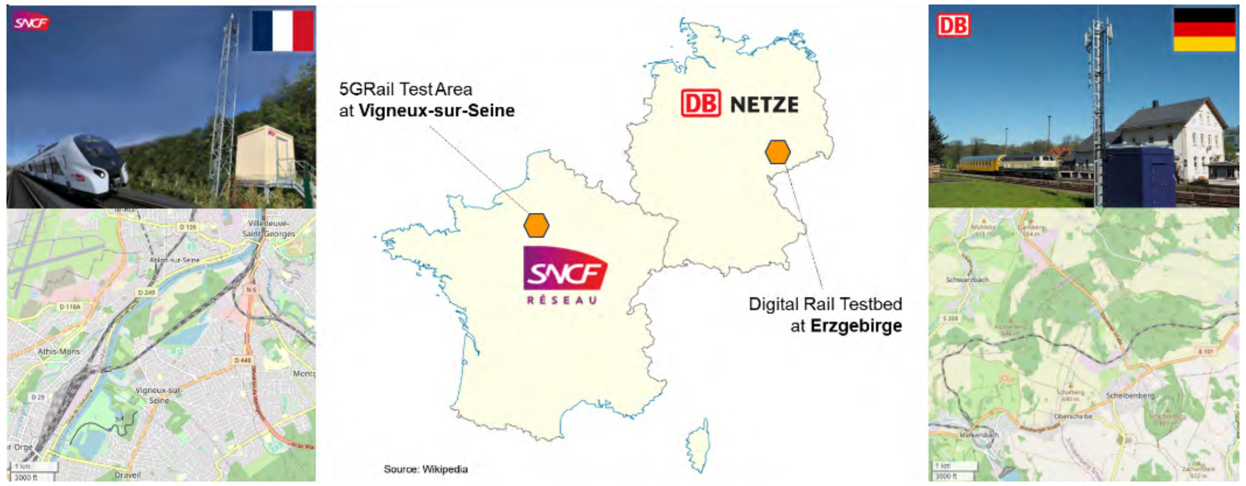


FIGURE 10 LOCATION OF 5GRAIL TESTBEDS IN FRANCE AND GERMANY

The testing is conducted in parallel in the two fields with different scopes. Some similar initial end-to-end connectivity tests are executed in both test fields to compare the results in different deployment conditions.

Both in France and Germany, there have been a total of 6 weeks of drive test campaigns with rolling stock. Voice, data, and video calls as well as combined use of heterogeneous applications have been successfully completed. For the data applications with rather small bitrates, achieved latencies in the 5G-based FRMCS test networks have been generally low without impact on QoS of the application. This was also true for combined data application scenarios. The figure below summarizes the 5GRAIL achievements in the fields.

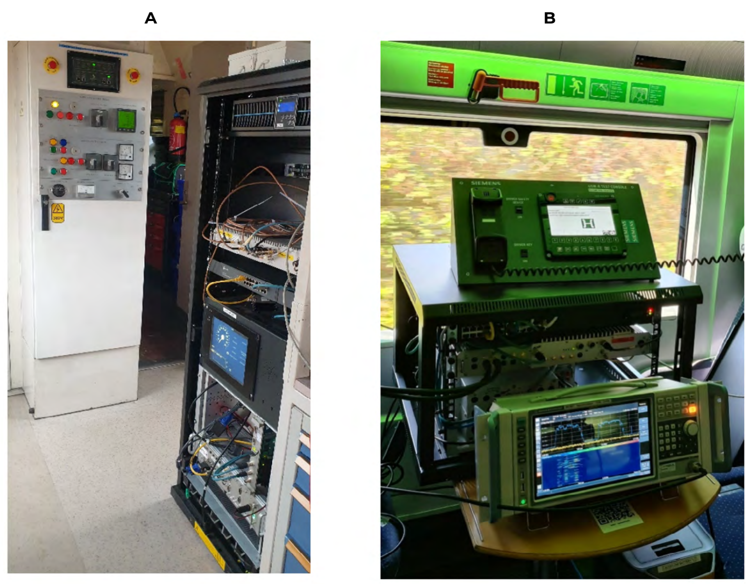


FIGURE 11 5GRAIL FIELD TEST EQUIPMENT A) 5GRAIL ONBOARD EQUIPMENT IN THE FRENCH FIELD TRIALS, B) 5GRAIL ONBOARD EQUIPMENT IN THE GERMAN FIELD TRIALS.

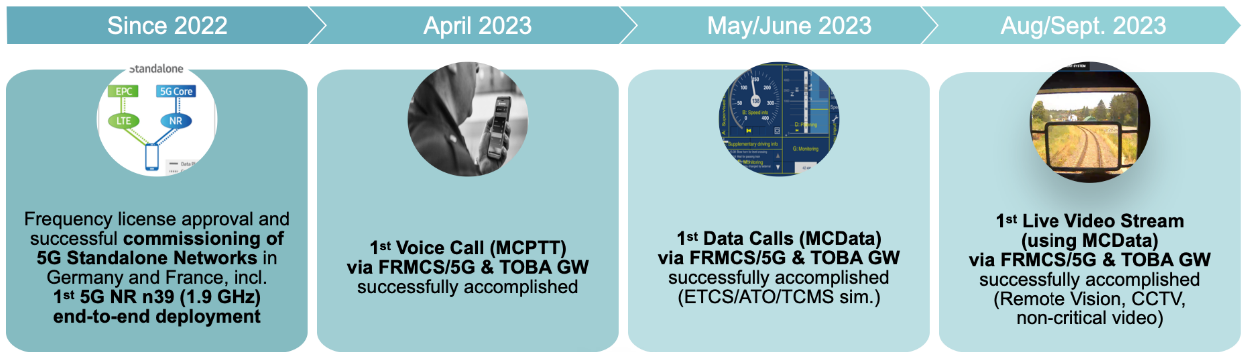


FIGURE 12 ACHIEVEMENTS OF THE 5GRAIL FIELD STUDY

08 Rail and Road communication systems coexistence

Given the unavoidable coexistence of rail and road environments, and the development of efficient communication systems in both contexts, the WP6 focused on Rail and Road communication systems coexistence. Three initial objectives were identified. First, the definition/identification of various scenarios (including level crossing but not only) of rail/road systems interaction in present operation, when future autonomous trains and cars are implied, and where a level of autonomy is used by automotive and another by railway (Task 6.1). Then, the implementation of a set of specific scenarios of coexistence with discreet event simulators able to reproduce the mobility, communications and services of different terminals. Finally, simulations/emulations and conclusions regarding coexistence of these communication systems based on simulation/emulation results (Task 6.3).

In this context, the work carried out in WP6 has produced three main achievements:

- From a theoretical point of view, the identification of various parameters to characterise the coexistence of rail and road environments. First, coexistence scenarios from an infrastructure point: tracks parallel to road, tracks crossing road (the level crossing and the tramways cases are differentiated) and the case of tunnels and bridges. Then, the identification of scenarios from an application perspective depending on the type of automation considered in each environment (i.e. common emergency service for level crossing management). Finally, the coexistence from a network perspective considering different kind of scenarios: shared core network, shared radio access network, shared access points, etc. All these conclusions and scenarios were published and provide a relevant basis for analysing coexistence scenarios.
- From the point of view of experimentation, the implementation of an emulation platform reproducing the operation of the 5G architecture developed in the framework of the 5GRAIL project (cf. Figure 13). This open source platform called Emu5GNet enables vehicles' mobility emulation (trains, cars), data processing architectures' deployment (i.e. edge computing), 5G Core and Radio Access Deployment and real railway applications' deployment (services considered in the 5GRAIL project). Numerous tools have been interconnected to enable the implementation of this platform: UERANSIM, Open5GS, SONATA, SUMA, Mininet, etc. Emu5GNet is available online, and can be used in a wide range of coexistence contexts, from rail and road communications to new environments such as drones;
- From the point of view of experimentation/evaluation, based on Emu5GNet, the implementation of new information transmission protocols (including SDN technology) have been proposed in order to measure their impact. Various deployment scenarios for rail and road applications were then considered. To this end, the possibility of dynamically deploying and managing these services using Edge Computing servers was proposed. The main idea is to offer a solution capable of efficiently adapting to the mobility of trains and cars. Thirdly, the common emergency scenario management application for level crossings was implemented at network and application level. These solutions can be 1) integrated into the FRMCS environment and 2) integrated into the 5G architecture to meet the needs of both cars and trains. Finally, a first cross-border handover management service has been integrated into the Emu5GNet tool. Based on a Home Routing approach, the aim is to show that this tool could prove relevant for the evaluation of new handover solutions in a rapidly changing environment.

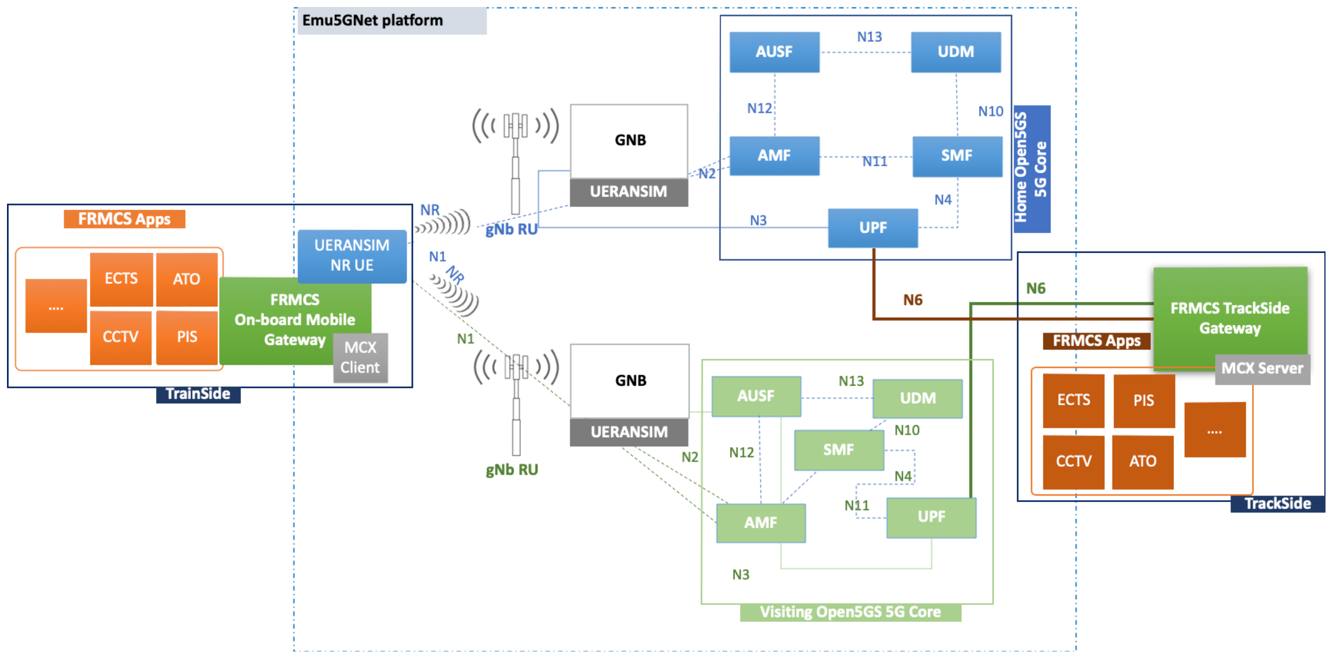


FIGURE 13 ARCHITECTURE IMPLEMENTED IN THE EMU5GNET PROJECT

09 Final 5GRAIL Demo

One of the project's main milestones was achieved through the successful field demonstration on the 20th September 2023, on-board DB's Lab ICE "advanced TrainLab" which performed a demo run on the 5GRAIL testbed in Annaberg, Germany.

The 5GRAIL demo was one of the project's key moments for showcasing several railway operational and performance applications like:

- **Voice calls including Group Calls;**
- **Railway Emergency Calls (in FRMCS, GSM-R, coexistence FRMCS and GSM-R and transition from FRMCS to GSM-R modes);**
- **Uplink Video Streaming and multiple applications over the same TOBA – Video and Voice Call simultaneously.**
- **This was performed via the 5GRail FRMCS network (3GPP 5G Stand Alone, Mission Critical).**

FIGURE 14 PICTURES FROM THE 5GRAIL DEMO RUN ON THE 5GRAIL TESTBED IN ANNABERG, GERMANY

STARTING DATE
01/11/2020

BUDGET
13.3 M€

CALL IDENTIFIER
H2020-ICT-2019-3

DURATION
38 MONTHS

TOPIC
ICT-53-2020, 5G PPP
5G FOR CAM

GRANT AGREEMENT
NUMBER 951725

Dan Mandoc
Project Coordinator

mandoc@uic.org

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION`S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO: 951725