DTU Library

Train-to-Ground communications of a Train Control and Monitoring Systems: A simulation platform modelling approach

Bouaziz, Maha; Yan, Ying; Kassab, Mohamed; Soler, José; Berbineau, Marion

Train-to-Ground communications of a Train Control and Monitoring Systems: A simulation platform modelling approach

Maha Bouaziz[1], Ying Yan[2], Mohamed Kassab[1], José Soler[2], Marion Berbineau[1]

[1]Univ Lille Nord de France, IFSTTAR, COSYS, F-59650 Villeneuve d'Ascq
[2]Technical University of Denmark, 2800 Kgs.Lyngby, Denmark

Abstract

Under the SAFE4RAIL project, we are developing a simulation platform based on a discrete-events network simulator. This platform models the Train-to-Ground (T2G) link in the framework of a system-level simulation of Train Control Management System (TCMS). The modelled T2G link is based on existing wireless technologies, e.g. Wi-Fi and LTE. Different T2G scenarios are defined in order to evaluate the performances of the Mobile Communication Gateway (managing train communications) and Quality of Services (QoS) offered to TCMS applications in the context of various environments (regular train lines, train stations, shunting zones, *etc*.) while varying the number of communicating trains, train's speed, radio channel characteristics (delay spread, channel attenuation, *etc*.). This paper focusses on the design and validation of the TCMS transmission over Wi-Fi/LTE via an approach based on simulation. This simulation platform aims to be also used to test actual TCMS equipment's, *i.e*. Mobile Communication Gateway and Ground Communication Gateway, connected to it through Hardware-In-the-Loop facilities of the chosen discrete-events network simulator.

Keywords: SAFE4RAIL, TCMS, Train-to-Ground simulation, Wi-Fi/LTE, discrete-events network simulator, Hardware-In-the-Loop.

Nomenclature

ANS	Access Network Simulator
ED	End Device
EPC	Evolved Packet Core
GCG	Ground Communication Gateway
HITL	Hardware In The Loop
LAN	Local Area Networks
LTE	Long-Term Evolution
MCG	Mobile Communication Gateway
NIC	Network Interface Card
OAI	Open Air Interface
QoS	Quality-of-services
SITL	System In The Loop
TE	Test Environment
TCMS	Train Control & Monitoring System
Wi-Fi	Wireless Fidelity

1. Introduction

The project SAFE4RAIL (SAFE architecture for Robust distributed Application Integration in roLling stock) from the Shift2Rail Joint Undertaking will provide a holistic architectural approach for building the next generation of Train Control and Monitoring Systems called TCMS (SAFE4RAIL, 2016) . This implies a possible radical change in the rolling stock architecture and embedded platforms, taking into account all significant railway subsystems, the integration/coexistence with the upcoming IEC61375 Ethernet-based systems, as well as their complex inter-actions and lifecycle processes. Under the Innovation Programme 1 (IP1) of Shift2Rail, SAFE4RAIL develops technology feasibility studies and concepts supporting the development of next generation integrated TCMS and safe by-wire control for brakes.

One part of this project focuses on designing and developing a platform to model the Train to Ground link in the framework of a system-level simulation of the TCMS. The goal is to validate the T2G communications by evaluating performances of the Mobile Communication Gateway (MCG) that manages train communications and assessing Quality of Services (QoS) provided to TCMS applications in the context of various environments (regular train lines, train stations, shunting zones, etc.) while varying number of communicating trains, train's speed, channel characteristics (delay spread, channel attenuation, *etc.*). For this purpose, different T2G scenarios are defined in order to be applied for the T2G communications. In particular, an heterogeneous radio deployments where trains have the ability to communicate through different radio technologies is considered. These deployments will improve QoS performances provided to TCMS applications. In addition, The Train-to-Ground link will eventually be validated and evaluated based on a discrete-events network simulator.

In this paper, we focus on the design of the T2G Test Environment and the validation of the TCMS transmission over Wi-Fi/LTE technologies via an approach based on simulation and hardware/software co-simulation. Wi-Fi and LTE have been considered as two alternative solutions for the future non-critical railway communications. Besides, they are both well-proved and existing telecommunication standards. We aim in this project to investigate and evaluate their communication network architectures and functionalities in a railway environment, as a contribution for the railway systems. Various network parameters will be evaluated regarding to their impacts on the railway communication services, for example, the capacity, the signal coverage, the latency and the outage probability. The key QoS features of both Wi-Fi and LTE network concerns the analysis of their performance for realistic railway applications and under different railway traffic conditions. The simulation platform will be used to test actual TCMS equipment's, i.e. Mobile Communication Gateway and Ground Communication Gateway, connected to it through Hardware-In-the-Loop facilities of the discrete-events network simulator.

The remainder of this paper is organized as follows. Section 2 presents the Train Control and Management System. Then, section 3 focuses on the platform models proposed for the Train-to-Ground interface, in which, we highlight two Test Environments. Section 4 describes the considered frameworks and libraries, while the validation of the T2G Test Environment is discussed in section 5. Finally, section 6 concludes the paper and present the future works.

2. Train Control & Management System: components and functions

Train Control & Management System (TCMS) (Railengineer, 2015) is the distributed control system of the train. It consists of some computer devices and software, human-machine interfaces, input/output capabilities and data

networks to connect all these together in a secure and fault-resistant manner. TCMS refers to the brain of train, because of its central role in the train control and monitoring. In fact, it is the central point of control over train sub-systems such as brakes, doors, as well as HVAC, lighting or communication. This system aims to execute a set of functions and provide some data communicated to other train systems for the safety of the railway (TCMS, 2009).

The collection of data is provided thanks to a number of sensors, which perform data aggregation and then send them to the TCMS Supervisor, in order to provide operation indications to drivers in a fully automatic mode. In addition, some additional data traffic may be added to the TCMS infrastructure such as the video among others. TCMS architecture varies depending on the operational requirements and market segment, but the purpose and benefits of the TCMS are common across all architectures.

3. Platform models for the simulations of Train-to-Ground interface

Train-to-Ground communication is defined in IEC standard 61375-2-6 (IEC, 2017). It concerns interconnection and data exchange between the train devices and the ground equipments. The design of the T2G is extracted from the CONNECTA requirements (EU. CONNECTA. 2017) and from extra requirements for the T2G test environment defined in S4R deliverable D3.6 (EU. Safe4RAIL, 2017). This section presents the architecture models with the different options for test environments defined based on the Access Network Simulator (ANS) that will be implemented in the Safe4RAIL project. Three architecture models are proposed. We describe the internal interactions between the modules of the discrete-events simulator, as well as the LTE's eNode emulator system and the internal interactions between users and network simulator.
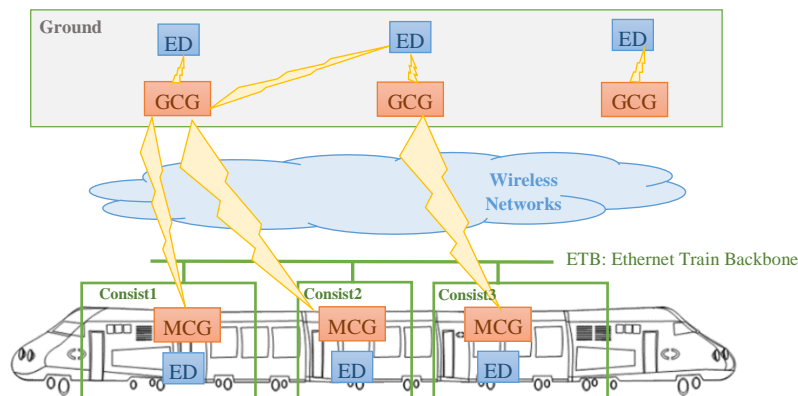
3.1. Introduction: why simulations?

Fig. 1 Train-to-Ground Communication

As illustrated in Fig. 1, the train-to-ground architecture consists of two entities types:

- o The Mobile Communication Gateway (MCG): train-side system that provides board-to-ground services to the on-board end devices.

- o The Ground Communication Gateway (GCG): For each train fleet, a GCG is defined and initiated to manage fleet train-to-ground communication. From ground side, the GCG is used as an IP gateway to communicate with any consists (A sequence of railroad carriages or cars that form a unit).

Both entities (MCG and GCG) are connected to End Devices (EDs) on their sides to collect communicated data. In addition, they interconnect and exchange data traffic between each other through wireless communication networks LTE (Long-Term Evolution) and Wi-Fi following the required condition. LTE technology provides a high-speed and low-latency communications, while the Wi-Fi is used for Local Area Networks (LANs) like the urban environment case. Using these two technologies allows sharing communications in order to avoid congestion and data loss when the communication number exceeds capacity.
The Test Environment simulation will provide means for validation of the MCG and GCG communication entities implementation with respect to the defined T2G protocol.

3.2. Test environment Setup A: Pure simulation

The setup A is a pure simulation test environment without interaction with real equipments (MCGs and GCGs), as illustrated in Fig. 2. The goal of this setup is to enable the evaluation of the effect of network configuration,

traffic load and mobility on data exchange performances. Regarding evaluation context, Setup A focuses on the Low-speed train scenario for urban environment, a railway station, where the deployment of the two communication technologies (LTE/Wi-Fi) is required in order to share communication and avoid link overload following the available capacities. This TE will allow us testing the communication behavior of MCG during mobility, which moves across the two technologies. Thus, an optimized handover management mechanism (fast vertical handover) among technologies is required in order to provide continuous connectivity of the MCG, when limited capacities are encountered (EU. Safe4RAIL, 2017). Moreover, the handover triggering between the two accesses technologies is based on usual parameters such as radio conditions (SNR and BER) and user preferences.
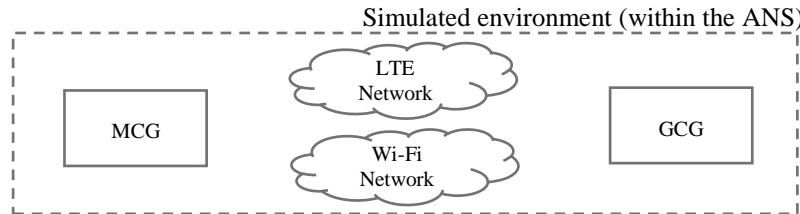

Fig. 2 Train-to-Ground communication link – Setup A

This TE will enable the scalability studies of the proposed network architecture, regarding number of communicating MCG and GCG and amount of exchanged data.

3.3. Test environment Setup B: Hardware-In-The-Loop Techniques using discrete-events network simulator and eNodeB emulator

The setup B proposes a test environment that combines the use of a discrete-event network simulator and a LTE eNodeB emulator. The goal is to evaluate the behaviors of actual MCG and GCG equipments in realistic network architecture configurations. This TE presents an in-lab mobile network demonstration. In this configuration, this TE combines virtual models with real networks. It includes one MCG equipment, one CGC equipment, one emulated LTE eNodeB and a discrete-event network simulator. The discrete-event network simulator is used to simulate the core LTE network and the interconnection network to CGC. The LTE eNodeB emulator emulates the LTE wireless link to attach MCGs. The MCG and GCG equipments generates data traffic to be exchanged through the network. As show in Fig. 3, the network simulator machine connects the GCG equipment and the LTE NodeB emulator using Hardware in the Loop features, via the Ethernet interfaces. The LTE modem of the MCG equipment is connected to the LTE NodeB emulator via an Ethernet connection.
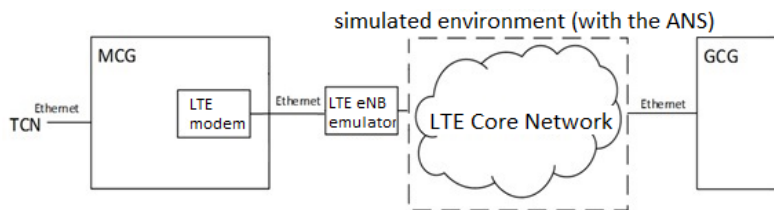
Fig. 3 Train-to-Ground communication link – Setup B

The overall setup as realization of the proposed emulation is depicted in Fig. 4. It is a real-simulation-real implementation. An application (e.g. data transfer or video streaming) running on a mobile device is connected via a real mobile link to an emulated eNodeB device. The LTE core (EPC) is simulated by discrete-event network simulator, while, the connection to the eNodeB and the application servers uses Ethernet in real environment. To be noticed, the signaling between the eNodeB and LTE MME/HSS need to be configured under the emulation system.

Fig. 4 The real-sim-real experimental setup

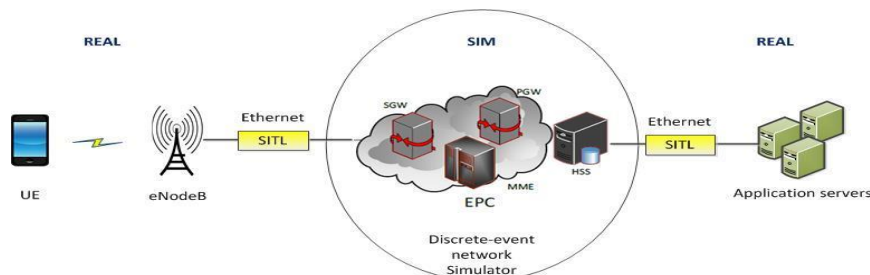Regarding evaluation context, Setup B focuses on the high-speed train scenario for rural environment and considers the standard LTE network for the T2G communication in Safe4RAIL. In this setup, the hardware measurements and software simulation environment are connected. This scenario aims to setup LTE communication between the Mobile Communication Gateway (MCG) equipment and the LTE eNodeB under realistic conditions. For example, the radio channel environment and the transmission power are changed due to the signal interference. The LTE backhaul network that interconnects base stations to the Internet is implemented under the simulated environment, while the railway services are further delivered to the Ground Communication Gateway (GCG) in order to view the realistic performances. Results reflect measurements from real networks. In this scenario, we evaluate railway services running on a real mobile device (to mimic the MCG equipment). Communication is established between the user equipment to the eNodeB with consideration of effects of the radio access. On the other hand, the LTE backhaul, which consists of a large amount of equipment in reality, is simulated to simplify the setup.

This test environment is extended to the HITL method based on the simulator SITL interface and the LTE eNodeB and EPC emulator. The OAI subsystem is dedicated to the LTE eNodeB functions and signaling functions implementation, while, the discrete-events network simulator contains the real-sim and sim-real interfaces via the SITL gateways and the LTE core network functionalities via the LTE EPC module. This architecture enables the evaluation of the effect of network configuration on data exchange performances of a Real MCG but not the traffic load and the mobility effects. The co-simulation network framework consists of three devices:

o USRP B210: The USRP B210 provides a fully integrated, single-board, Universal Software Radio Peripheral (USRP™) platform with continuous frequency coverage from 70 MHz – 6 GHz. This device is used to transmit and receive LTE signal from the LTE UE.

o LTE NodeB emulator: provides a base station that allows the connection of the MCGs and transforms the LTE frame into an Ethernet frame and vice versa.

o Central PC: provides the LTE EPC functionalities for data communication between the MCGs and GCGs. The simulator's SITL interface is used to translate packets between the real and simulated environment.

4. Frameworks and libraries

The network simulator used for the test environment of the train to ground is the Riverbed Modeler (formerly OPNET Modeler® V.18.6.0 (Release Oct 31, 2016). This simulator is a discrete-events simulation tool used for network modelling and evaluation. It supports various network types and technologies allowing the design and study communication networks, devices, protocols, and applications. In addition, this simulator can provide a test environment allowing the interaction between the MCGs, the GCGs and different configuration of the T2G network. Besides, this simulator is able to provide statistics about performances perceived by data exchanges through the T2G network regarding latency, jitter, throughput, message errors and link. Thus, it allows testing the MCGs and GCGs behaviors under different network architectures and loads.
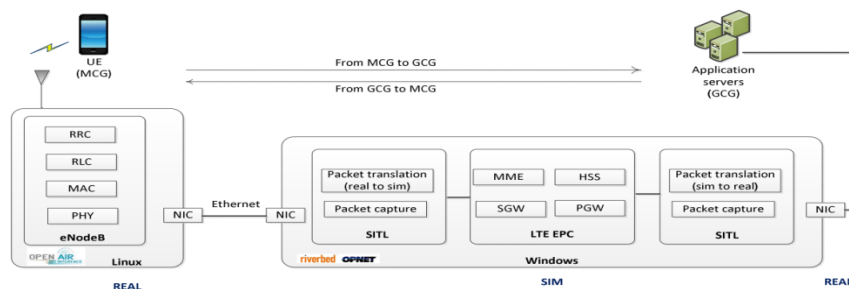

Fig. 5 Co-simulation software modeling architecture

Concerning the hardware/software co-simulation, it is based on the OpenAirInterface (OAI) wireless network emulator and System In The Loop (SITL) interfaces in the discrete-events simulator (Riverbed modeler, 2017). This co-simulation aims to combine the simulated network for the LTE core network with the real LTE traffic. In fact, the co-simulation software modules capture the real LTE traffic from an LTE base station in hardware, processes the traffic in the simulation environment and forward the traffic to the application servers in the real environment. As illustrated in Fig. 5, there are three main components in the developed framework:

o LTE eNodeB: the protocol stack of 3GPP standard in E-UTRAN in the OAI LTE base station.

o   Traffic capture and interpretation: the packet translation function between the realistic and simulated environment in the simulator SITL gateway.

o   LTE EPC: the basic features in the LTE core network (EPC) in the simulator based on 3GPP Release 8 and Release 9.

4.1. LTE access network communication via OpenAirInterface (OAI)

OpenAirInterface (OAI) (OpenAirInterface, 2017) is an open-source hardware and software initiative created by the Mobile Communications Department at EURECOM. OAI is a Software Defined Radio (SDR) based solution and provides a complete software implementation of all elements of the 4G LTE system architecture. It includes the entire protocol stack from the physical to the networking layer, including standard compliant (Rel 8 and a subset of Rel-10) implementations of Physical (PHY), Medium-access Control (MAC), Radio Link Control (RLC), Packet Data Convergence Protocol (PDCP) and Radio Resource Control (RRC), for both eNodeB and UE and in both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) (OpenAirInterface, 2017). Regarding the core network, the standard compliant (Rel 9 and Rel 10) implementations of a subset of 3GPP LTE EPC components are supported by OAI.

The methodology deployed in the OAI platform (OpenAirInterface, 2017) is to use the real stack to perform more realistic and reliable simulations. Regarding the configurations for an in-lab radio network experiment, the OAI installs the software platform on the host computer and runs the full protocol stack in the emulation mode. The proposed eNodeB experimental testbed consists of two elements: RF hardware as the radio part and a computer as the baseband unit. The transceiver functionality is realized using a software defined radio card connected to a host computer for processing. The OAI software is written in C language and will be preferably run on a low latency Linux kernel. This project plans to use the USRP B210 SDR card from Ettus Research as the radio part. The hardware platform for the USRP-B210 based OAI eNodeB installation is a computer equipped with an Intel Xeon Processor with four cores and using Linux on Ubuntu 16.04. An LTE-enabled mobile phone equipped with a test-SIM will be used as UE. Alternatively, a laptop can be used and connected via USB to the mobile phone as a modem.

4.2. Real-sim-real communication via the simulator's SITL module

The simulator System-in-the-loop (SITL) module provides an interface between a simulated network running in Riverbed Modeler and a real hardware platform. With SITL, a simulation environment can connect and interact with the external physical hardware in real-time. In the chosen simulator, the SITL interface is implemented as a process model, which allows applications to send real IP packets across the simulation environment. Packet translation and conversion are key functions in the SITL process, because the packet formats are different for real communication and simulation. As shown in Fig. 6, packets are exchanged and converted between the simulated packet and the real packet via an Ethernet link.

A SITL gateway is used as the interface module, which is developed secondarily based on WinPcap (Winpcap, 2017). Therefore, this SITL interface module can capture data from the Ethernet card on the workstation hosting the simulation software. A SITL component routes the packets intended for the SITL simulation directly from the network adapter to the simulation. At the beginning of the simulation, SITL initializes the packet translation function and registers all translation pairs. Upon receiving a packet, SITL attempts to determine the packet format and then calls the translation function to convert the packet. The packet translation process includes a set of built-in translation functions. There are three basic network configurations for Riverbed SITL simulations: real-sim, real-sim-real and sim-real-sim. The latter two configurations require multiple gateways to connect to the different external physical ports.
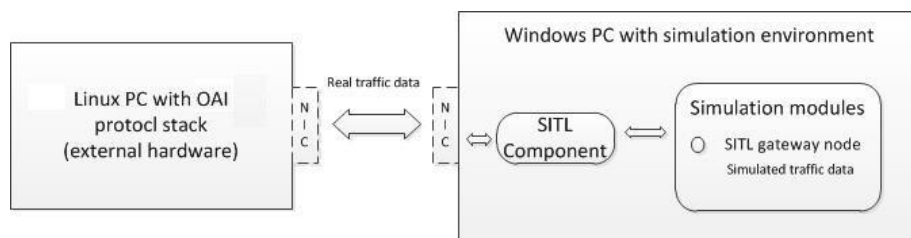

Fig. 6 Packet pathway in the SITL simulation

In order to run the simulation correctly and efficiently, the simulator and the SITL gateway node need to be pre-configured. For example, the real-time execution ratio property should be set, so that the simulation time in the simulator is ensured to be consistent with the real time. The SITL gateway node is assigned with the right network card. In addition, the rule for packet filtering is set appropriately in order to reduce the amount of processed data.

4.3. Discrete-events simulator Modules

The different Riverbed modules that we are using for this simulation framework are:

o   Simulation runtime module.

o   Wireless module: to create a radio network with the radio link and the mobile node.

o   LTE specialized model; to create an LTE network with LTE UE node, eNodeB node and EPC nodes as well as LTE network attribute module.

o   IPV6 module: to support the Internet Protocol version 6 in the simulation.

o   System-In-the-Loop module: to convert data packets from the real to the simulated environment or from the simulated to the real environment.

4.4. Third party libraries

The software components of the co-simulation simulator are based on a series of third party libraries:

o   OAI LTE eNodeB: The access network software is freely distributed by the OAI under the terms stipulated by a new open source license, the OAI Public License. The license caters to the intellectual property agreements used in 3GPP and allows contributions from 3GPP members holding patents on key procedures used in the standard (OpenAirInterface, 2017).

o   Real-sim-real interface:

   o   Riverbed Modeler (Release 18.5 or later)

   o   2 SITL licenses (independent SITL license for real-sim and sim-real interfaces)

   o   WinPcap/LibPcap: each network interface card used for a SITL interface must be compatible with the Pcap library that SITL uses to capture and send packets. The WinPcap library is based on Windows, while the LibPcap is based on Linux.

o   Riverbed LTE:

   o   Requires a license for the Riverbed LTE module

5. T2G Test Environment Validation and acceptance criteria

As the T2G Test Environment is a new system to be developed, the T2G communication through the wireless access needs to be studied and validated. Thus, it is confirmed that the TE implementation fulfils the defined requirements and is in accordance with the design.

5.1. Test Equipment

o   Network Simulator Central PC: PC running the network simulator with two Ethernet interfaces.

o   OpenAirInterface system.

o   1 MCG with 2 Ethernet interfaces.

o   1 MCG with LTE interface.

o   1 GCG with 1 Ethernet interface.

5.2. Test scenarios

Fig. 7 shows an LTE based mobile network. In Safe4RAIL, the user equipment will be the MCG. The eNodeB is a base station providing radio coverage, managing radio resources and scheduling packets. The Evolved Packet

Core (EPC) is the backbone of LTE network, which consists of Packet Data Gateway (P-GW), Serving Gateway (S-GW), Home Subscriber Register (HSS) and Mobility Management Entity (MME).
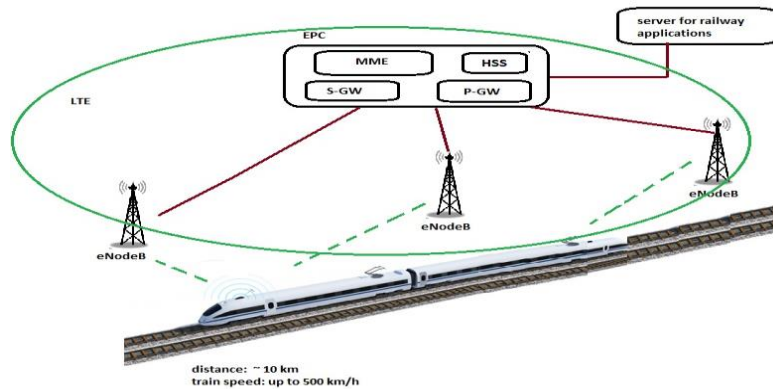

Fig. 7 High speed train communication based on LTE technology

For the test of the TCMS interface to the ground wireless systems, we refer two cases:

5.2.1.   Test Scenario (Setup A): Low speed scenario cases for urban environment

In urban environments, trains generally move with low and various speeds. Some parameters have an impact on the performance provided for the train connectivity:

a.   Ability to use the two different communication technologies LTE and Wi-Fi, according to usual parameters such as radio conditions (e.g. Signal-to-Noise Ratio (SNR) and Bit Error Rate (BER)) and user preferences. Hence, trains have to perform the two kinds of handover: 1) A vertical handover is triggered to change the radio access technologies (RAT), when it is necessary to improve performance, 2) a horizontal handover is required to only change the attachment point (eNodeB for the LTE or AP for the Wi-Fi), keeping connected to the same RAT.

b.   Use of Micro and Macro cells, according to the environment characteristics. In fact, the topology deployment can use various coverage areas provided by each eNodeB for the LTE technology. It aims to provide connectivity in the entire railway domain with the minimum number of eNodeB.

c.   Use of various speeds. In the urban environment, trains are limited to use a high speed. However, they are required to modify their speeds following the travelling zones and stations. These different speeds may impact on the railway application communication, for this reason it is necessary to evaluate performance with different speeds.

d.   Change of the traffic load and types. Using the LTE for the railway application allows us to introduce a more critical communicating data based on the IP level. Thus, for the purpose to fulfill the required performance and succeed the railway application, it is interesting to study the change of the traffic load and types.

Some performances are required for the railway application. It is crucial to evaluate these performances, when trains move through their defined trajectory and change their communicating technologies in the urban environment:

a.   Transfer delay: refers to the necessary delay of data transmission between the train and its corresponding server.

b.   Data integrity: refers to the succeeded delivering data between the two communicating entities.

c.   Handover delay: refers to the required delay to perform handovers and attachment point change, for the vertical and horizontal handover.

d.   Priority consideration: because of the different traffic used by the railway application. It is necessary to assign some priorities for the critical real time data.

5.2.2.   Test Scenario (Setup B): High speed scenario cases for rural environment

Capabilities and performance of the mobile communication systems affect railway operations. By improving the communication reliability and reducing the information delay, the wireless transmission system becomes higher efficient and more robust (Sniady, A., 2015):

o   The communication network must support trains among the other users. Trains can travel up to 500 km/h (Project EIRENE, 2010). For a high-speed train line, the rolling stocks normally run over a long distance and pass uninterrupted without frequent intermediate stops. The highest speed limit on this type of railway line varies from country to country, for example 180 km/h (e.g. the Snoghoej-Odense line in Denmark) and 300 km/h (e.g. the Lille-Paris line in France) (European Commission, 2010).

o   Various railway services and applications delivered by the standard mobile communication network have different priorities and different impacts on the operation. There is a need to differentiate between these services and to provide them with various processing (e.g. routing and scheduling strategies) in the network in order to guarantee the performance requirements such as delay and throughput. The case of the high-speed communication aims to evaluate the performances of the applied railway applications with respect to the LTE network deployment, mobility, and the traffic load (Sniady, A., 2015).

a.   LTE network deployment

If we consider a standard LTE network for the T2G communication in Safe4RAIL, the handover could be a critical event, especially for high speed. The LTE network is not deployed specifically for the railway. Therefore, a key parameter is the network planning and deployment, for example the number of base stations used for providing the necessary radio coverage. It may be decided to deploy relatively few base stations (eNodeBs), which would transmit at a high power. This setup would cover a railway line with just a few large radio cells. Alternatively, the same railway line may be covered with more base stations, which transmit at a lower power. Thus, the coverage would be provided by many—relatively small—radio cells. The chosen deployment strategy has an impact on the capacity, relative traffic load per cell, interference and handover frequency. Therefore, the deployment may have an impact on the performance of railway applications.

b.   Train speed

According to the requirements established by the 3GPP, LTE is supposed to support user speed up to 500 km/h. Despite that, the LTE transmission in a high-speed scenario is the worst compared to static or slow-speed scenarios. There are multiple factors (e.g. multipath, handover) that degrade LTE transmission performance in a high-speed environment. For the purpose of analyzing train speed impact on railway application transmission, this high-speed test case will examine the transfer delay and data loss with varying the train speed.

c.   Traffic load

The problem of insufficient capacity occurs in GSM-R in the areas with high-density of railway traffic, such as big train stations and junctions, due to the availability of channels. GSM-R is a circuit-switched network, where data is transmitted over virtual circuits. The drawback is that the network resources can not be assigned based on the actual demand. Therefore, LTE is expected to significantly increase the network capacity and to solve the communication bottleneck, since it is a packet-based technology. The goal of the high-speed scenarios will analyze the impact of the traffic load on the application transmission performance in terms of delay and data integrity, also in the event of the horizontal handovers.

6.   Conclusion and perspectives

For the safety of the railway domain and under the SAFE4RAIL project, we focus on evaluating performance of the communication Train-to-Ground. For this purpose, two scenarios, currently under development, are proposed and considered in this paper. The first one consists in a Low-speed scenario for urban environment, in which the test environment can use the two communication technologies (LTE and Wi-Fi). Thus, vertical handover are allowed for trains following conditions. This may enhance the provided QoS, mainly when a congestion and overloaded link are presented. In this scenario, the interface communication Train-to-Ground is assessed through a pure simulation. The second one consists in a High-speed scenario for rural environment, in which the test environment focuses only on the LTE communication technology. This scenario is interested to evaluate railway services running on a real Mobile devices using actual equipment. Thus, to achieve this goal, the LTE UE and eNodeB hardware devices are proposed to be integrated in a co-simulation with the discrete-events simulator for performance evaluation. In this method, the real data traffic needs to be routed into the simulation environment form the real communication environment.

This paper focusses on presenting the testing framework as a system-level simulation/co-simulation for components of a Train Control Management System (TCMS). Our aims consist in evaluating various non-critical train services when these links are provided by LTE and WiFi networks. At the time of writing integration efforts are on the way to complete the experimental setups and qualitative and performance evaluation results are expected within the first three months of 2018.

Acknowledgements

References

European Commission, 2010. High-speed Europe, a sustainable link between citizens, Publications Office of the European Union, 2010, ISBN 978-92-79-13620-7 doi: 10.2768/17821.

EU. CONNECTA. 2017. CONTRIBUTING TO SHIFT2RAIL'S NEXT GENERATION OF HIGH CAPABLE AND SAFE TCMS AND BRAKES : D2.1 – Requirements and Specification for the T2G System. CONNECTA, 9.6.2017.

EU. Safe4RAIL. 2017. D3.6 Draft : Report on final requirements. Safe4RAIL, 23.6.2017.

IEC. 2017. 9/2185/CDV : IEC 61375-2-6: ELECTRONIC RAILWAY EQUIPMENT TRAIN COMMUNICA-TION NETWORK (TCN) : Part 2-6: On-board to Ground Communication. IEC, 19.8.2016.

Kassab, M., Bonnin, J.M.et Belghith, A., 2010. Technology integration framework for fast and low cost handovers: case study: Wi-Fi-WiMAX network. Journal of computer systems, networks, and communications, 2010, vol. 2010, p. 9.

Navid N., Mahesh K.M., Saravana M., Dawson, A., Knopp, R. and Bonnet, C., 2014. OpenAirInterface: A Flexible Platform for 5G Research. SIGCOMM Comput. Commun, Rev. 44, 5, 33-38, October 2014.

OpenAirInterface, 2017. www.openairinterface.org

Project EIRENE, 2010. System Requirements Specification, Ref: P0011D010, v. 15.1, International Union of Railways (UIC), June 2010. ISBN 2-7461- 1832-4.

Railengineer, 2015. https://www.railengineer.uk

Riverbed modeler, 2017. www.riverbed.com

SAFE4RAIL, 2016. DoA-Part B H2020-S2R-OC-IP1-02-2016.

Sniady , A. et Soler, J., 2013. Impact of the traffic load on performance of an alternative LTE railway communication network. In : ITS Telecommunications (ITST), 2013 13th International Conference on. IEEE, 2013. p. 396-401.

Sniady , Aleksander et Soler, Jose, 2014. LTE for railways: Impact on performance of ETCS railway signaling. IEEE Vehicular Technology Magazine, 2014, vol. 9, no 2, p. 69-77.

Sniady , A., Soler , J. , and Dittmann, L. 2015. Communication Technologies Support to Railway Infrastructure and Operations. Ph.D. thesis, DTU Fotonik, 2015, DOI: 10.11581/DTU:00000010.

TCMS, 2009.Traffic Control Management System, poster elaborated under the Solari udine.

Winpcap , 2017. https://www.winpcap.org/