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Case Report

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Future Rail line Flexible Correspondence Structure considering 5G and MNOs for Fundamental Rail Line Hailing Organizations

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Abstract

In order to demonstrate the viability of implementing 4G/5G systems based on mobile network operators (MNOs) to transmit signaling-critical data for railway systems as part of a potential solution for the Future Railway Mobile Communication System, this paper describes the prototype and tests conducted (FRMCS). The protocol-stack approach is used to develop this communication system, introducing KPIs for the physical layer, network layer, and application layer (RSRP, RSRQ, and SINR) (signalling communication timeout). In order to examine the data traffic behaviour in a communications lab, the analysis focuses on characterising signaling critical railway data. The study also confirms the method in a real-world railroad setting.

Keywords: Communications; Critical services; 5G; FRMCS; ITS; KPI;LTE; MNO; MTC; Railroad and signalling services

Introduction

Railway conversation structures are making ready for a big paradigm shift with the standardisation of the Future Radio Mobile Communication System (FRMCS) and the creation of 5G to the railway sector [1]. FRMCS opens using the cellular community to new programs which include signalling-crucial statistics, Mission Critical Push-To-Talk (MCPTT) or Operational Cyber security. On its face, 5G permits using cellular technology for extra offerings which include actual-time CCTV, far off tracking for maintenance works amongst others [2]. All of that is in a context in which GSM-R is the technology used nowadays, which gives voice and statistics solely for signalling offerings for teach-to-floor communications. The proposed device consists of new hyperlinks to attach any railway detail even as retaining the cutting-edge teach-to-floor conversation [3]. These hyperlinks are prolonged to machine-kind communications (MTC) for track-facet elements, teach-to-teach and IoT for maintenance, as a part of the brand new context of the Intelligent Transportation Systems (ITS) [4]. Nevertheless, this evolution implies a chain of demanding situations to conquer concerning the implementation criteria, standardisation, and spectrum law and legacy structures [5].

In the cutting-edge times, Mobile Network Operators (MNO) have all started to offer connectivity offerings to crucial offerings in different business sectors emergency bodies, nuclear strength plants, V2X or Industry 4.0 . However, withinside the railway sector, using MNO is handiest limited to transmitting non-crucial statistics (CCTV, rolling inventory logging series or passenger statistics offerings) [6].

In this context, MNOs can play a key position in introducing MTC for crucial offerings which include signalling structures, audio recording statistics series, or operational telephony. This opportunity answer is particularly thrilling for low railway site visitors lines, items and the mining industry, given the excessive prices that personal fibre optic deployment calls for nowadays. In addition, the proposed answer permits the modernisation of rural railway lines, permitting the set-up of current signalling structures and fending off the human thing in telephonic block tracks.

This paper assesses the feasibility of enforcing 4G/5G public networks to transmit crucial railway signalling offerings. The method is primarily based totally on measurements specifically to set up a sensible characterisation of the conversation parameters for railway signalling structures whilst introducing MNO networks. Particularly, the approach consists of 3 scenarios: first, an interlock (IXL) and an item controller (ObjC) are interconnected through an evolved prototype for this purpose; secondly, the ensuing signalling site visitors is simulated in a telecommunications laboratory; finally, area measurements are completed to evaluate the behaviour in an actual railway environment. The goal is to reap enough statistics to outline the radio and community Key Performance Indicators (KPIs) to offer good enough carrier to the railway signalling structures. In order to acquire this goal, the prototype has been evolved to accumulate statistics from the protocol stack perspective, being related to a signalling system mock-up.

This report is organised as follows: first, describes the method accompanied on this study; secondly, in, the size set-up explains the measuring technique accomplished collectively with the prototype built for this purpose; then, describes the measurements collected withinside the 3 scenarios; finally, affords the belief received from all this work [7].

Methodology and network design

This section presents the methodology followed in this study, including signaling system requirements and protocol stack perspectives.

Signalling system requirements

Conceptually, the trackside signaling system is located at a fixed location, most often in the technical rooms of major stations near cities. In these urban areas, MNOs are focused on deploying cellular networks.

They send messages to each other encapsulated in UDP/IP

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segments for transmission to the physical layer. Fiber optic cables are the most commonly used physical technology today. In this study, we present the results of replacing this widely used technology with his MNO-based cellular network [8].

Shows the communication requirements for this signaling system. Therefore, to analyze the feasibility of the proposals in this paper, we will verify how the MNO network affects bitrate, delay and jitter considering physical layer and application response times and timeouts. You need to measure a set of KPIs that Required layers for signal equipment.

Little information is available on the requirements to meet adequate communication performance of signaling systems. For this reason, a full characterization of communication is part of this study. Still, it is clear that signaling systems are limited by delay and time, and 4G and 5G can offer much higher data rates, so the required data rate will not be the bottleneck [9].

In particular, the timeout parameter for receiving messages indicates the maximum time allowed for order submission, execution, and reporting to IXL. This can be 1.8 seconds which can be caused by network round trip time. It is important to note that this parameter includes mechanical elements on the track as part of tasks such as: B. Move the turnout on the track. As for jitter, it is related to the time of message transmission period. Since this is a UDP communication protocol, any jitter greater than 300ms will cause a noticeable pause in the message and will be considered a lost message. Furthermore, the theoretical bit rate produced by communication between signaling devices is 4 kbps. Measurement setup and prototype this section describes the prototype hardware architecture, the developed software and the measurement setup proposed in this study [10].

Prototype architecture

Corporate interest in this area of research in the rail industry is just beginning to emerge. Therefore, there are no commercial tools for measuring and analyzing the overall behavior of signaling systems with 4G/5G mobile networks [11]. The main objective of this study was to develop a model between the IXL and the object controller with sufficient detail to define the radio and network parameters necessary to provide reliable service to the signaling system. It's about measuring traffic. For this reason, a prototype developed for this purpose is presented in this study. It measures and processes KPIs from a protocol stack perspective [12].

Architectural scheme of the prototype and the elements to which it is connected. The lowest layer represents the MNO network. The top represents the signaling technology as an application layer. In between, the prototype connects to MNOs and signaling equipment as an alternative to fiber optic networks acting as physical and network layers.

Signal Technology consists of a Real Object Controller and an IXL simulator. Both connect to two E-Lins H900fq-W-G devices with 4G/5G modems and routing capabilities. Connected to these components are non-invasive measuring elements based on specially developed traffic detectors and signal meters.

The types of MNO networks considered in these research scenarios are:

As a regular user, create a prototype based on commercially available equipment.

Prototype based on enterprise solution with guaranteed SLAs such as 80 ms maximum latency, 0.2% packet loss, monthly availability of 99.5 D44 software scheme.

A software scheme in which different functions are distributed into modules supported by different technologies. This software enables signal acquisition, acquisition, and post-processing at the physical, network, and application level.

Measurement Software: This area is divided into three modules for querying, retrieving and saving network parameters.

Radio and GNSS Parameter request module: Developed in Python. Every second he queries not only his GNSS parameters such as speed and geographic coordinates, but also radio and mobile communication parameters.

Data acquisition module: Using Wireshark. The wired interface collects network, transport and application data, while the Wifi interface collects wireless and GNSS data.

Measurement software control module: Batch programming developed in `.cmd` Responsible for synchronizing and storing data for the previous two modules.

Processing software: Divided into two modules whose purpose is to transform the data and check the quality of the network of signaling services.

Data processing module: Developed in Python, transforms files and filters the resulting files into other files that can be analyzed from the measurement software.

Analysis module: Developed in R and responsible for generating statistics to qualify data visualization and communication.

Scenario

In this section, we fully characterize the communication behavior of the proposed system in terms of protocol stacks and present various scenarios where investigations were conducted to reproduce this characterization in a realistic railway environment [13].

Railway Laboratory Test

The tests use models of real object controllers and his IXL simulator. The results show the correlation between application layer (signal response time and data rate) and network parameters (bit rate, delay, and jitter) according to the defined requirements of the signaling system [14].

Telecom Lab Test

This test compares LTE wireless networks with non-standalone (NSA) 5G. The aim is to analyze how the system will perform in areas where 5G is deployed and demonstrate its improvement compared to 4G networks. Similarly, in this scenario you can compare SLAs with regular users [15]. Long-term measurements, i.e. 672 periods of 15 minutes, are performed and the collected data allow finding correlations between radio parameters and delays according to signaling communication requirements based on UDP.

Result

This section describes the results of tests performed on the various scenarios presented. This analysis focuses on the characterization of the important signaling traffic and later analyzes the behavior of this traffic in a communications laboratory environment. Finally, field measurements evaluate behavior in a real low-density railway traffic environment.

Regarding jitter, the signaling system sends information over UDP every 318 milliseconds (communication heartbeat). Therefore, if the network jitter exceeds this value, the packets received by the signaling equipment may be corrupted, leading to degradation or failure of the communication process. This is because UDP does not provide congestion control or acknowledgments. In this case the prototype jitter he found to be less than 40ms 99% of the time. This indicates that the packet receive jitter can be 86.7% higher than the measured value.

In short, latency is the most limiting network parameter for establishing communication. This is because, as mentioned above, signaling equipment requires a message transmission period of less than 1.8 seconds for round-trip measurements.

4G and 5G Characterization

Comparison of 4G and 5G networks at physical and network levels. Each RSRP, RSRQ, and SINR metric and the network delay cumulative density function are described. The results allow us to determine KPIs that ensure proper functioning of critical services, taking into account the characteristics of the signaling data. These KPIs are summarized including latency which amounts to 99% of the measured time [16].

Conclusion

Signaling communication has been established over public communication networks via MNOs for railway signaling of critical data using 4G and 5G networks. The results show that the hypothesis is fulfilled because the communication between signaling devices based on the prototype can provide the required quality of service from the physical and network layer perspectives. In this study, we characterize 4G and 5G cellular networks and obtain nonlinear correlations between signal level parameters and delays provided by MNO cellular networks. At the KPI level, the study found that the prototype could achieve up to 150 ms at low radio levels of -109 dBm for 4G and -120 dBm for 5G networks, given the 500 ms latency threshold allowed for this service 99% of the time. . At the system level, we observe that this system spans the entire signal system "field element-IXL, OCC-IXL, etc." can be expanded.

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