

# Broadband For What: Driving Demand ; Seminar Proceedings

1514

IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 62, NO. 8, AUGUST 2014

INVITED PAPER Special Section on EU's FP7 ICT R&D Project Activities on Future Broadband Access Technologies  
**Broadband Access in Complex Environments: LTE on Railway**

César BRISO-RODRIGUEZ<sup>1</sup>, Member, Carlos E. LÓPEZ<sup>2</sup>, Jean R.O. FERNÁNDEZ<sup>3</sup>, Sergio PÉREZ<sup>4</sup>,  
Drasko DRASKOVIC<sup>5</sup>, Jaime CALLE-SÁNCHEZ<sup>6</sup>, Mariano MOLINA-GARCÍA<sup>7</sup>, José I. ALONSO<sup>8</sup>,  
Carlos RODRÍGUEZ<sup>9</sup>, Carlos FERNÁNDEZ<sup>10</sup>, Juan MORENO<sup>11</sup>, José RODRÍGUEZ-PIEDRA<sup>12</sup>,  
José A. GARCÍA-NAYA<sup>13</sup>, Luis CASTEDO<sup>14</sup>, and Alfonso FERNÁNDEZ-DURÁN<sup>15</sup>, Nonmembers

**SUMMARY** This paper assesses the main challenges associated with the propagation and channel modeling of broadband radio systems in a complex environment of high speed and metropolitan railways. These challenges comprise practical simulation, modeling interferences, radio planning, test trials and performance evaluation in different railway scenarios using Long Term Evolution (LTE) as test case. This approach requires several steps: the first is the use of a radio propagation simulator based on ray-tracing techniques to accurately predict propagation. Besides the radio propagation simulator, a complete test bed has been constructed to assess LTE performance, channel propagation conditions and interference with other systems in real-world environments by means of standard-compliant LTE transmissions. Such measurement results allowed us to evaluate the propagation and performance of broadband signals and to test the suitability of LTE radio technology for complex railway scenarios.  
**key words:** LTE, railways, propagation, broadband, channel modeling

## 1. Introduction

Commercial 3GPP standard, Long Term Evolution (LTE), is being deployed in several countries and it is expected to be deployed globally in 2014. At the same time Global System for Mobile communications Railway technology (GSM-R), which is currently used as a standard for most railway operators, can only support narrowband applications, with strong limitation factor for enhancing both the commercial and the technical aspects of network operation. Against this background, the TECCRAIL Project [1] funded by the Spanish Ministry of Economy and Competitiveness, has been launched in October 2011 to evaluate if current LTE 3GPP standard can give support to railway operators and coexists with current radio systems used in railways. Technological reasons to use LTE are linked to the improved performance and capacity of this new broadband communication system for both railway operation and passengers.

GSM-R used in most railways for voice and data transmissions has low data capacity and is approaching the end of life cycle [2]. On the other hand, it is clear that future train radio systems' advanced features and capabilities like real

time video or high capacity data transmissions will allow railway operators to support strong Quality of Service (QoS) demanding applications and added value services. Therefore, these advanced features will play a key role in the provision of advanced passenger services, signaling applications or operational services [3], [4].

The main challenges related to the LTE capabilities and features to implement the required railway functionalities are: LTE network coverage design process in high speed environments, QoS, access control mechanisms, performance of LTE handover mechanisms in high speed railway scenarios, spectrum deployment considerations and LTE capabilities to meet the environment RAMS (Reliability, Availability, Maintainability and Safety) requirements [5].

To evaluate the challenges listed above, in this paper a complete review of the process of deployment and testing of a new communications technology on railway environment is given. This process is often followed in railway environment, it is usual to make test trials and research projects [6], [7] to evaluate the impact of a new system on the railway service.

The paper is organized as follows: In Sect. 2 the principal radio systems used in railways are described. In Sect. 3, the particularities of characterizing radio propagation in railway environments are assessed. In addition, a ray-tracing radio propagation simulator for complex environments, including open areas, tunnels or any geometry defined scenario is described. It is clear that the accuracy of the ray-tracing based simulator depends on the proper 3D modeling of the considered scenarios, which can be a cumbersome task in open areas, for example. Under this scope, in Sect. 4, a review of analytical channel models for mobile networks is presented. Besides, their feasibility and drawbacks for being employed in railway environments are analyzed.

Also in railway it is necessary to make test and measurements to validate new technologies and to evaluate the impact on other systems. For this purpose a complete LTE test bed has been developed and it is described in Sect. 5.

Test trials and measurements play a key role for assessing the feasibility and suitability of a new system for railway environments. In Sect. 6, the accuracy and reliability of the results obtained in the validation process are presented. Also, the predicted signal levels obtained with the ray tracing propagation simulator and the LTE propagation

Manuscript received January 11, 2014.

<sup>1</sup>The authors are with the Telecommunications School, Technical University of Madrid, Madrid, Spain.

<sup>2</sup>The authors are with the Department of Electronics and Systems, University of A Coruña, A Coruña, Spain.

<sup>3</sup>The authors are with Metro de Madrid S.A., Madrid, Spain.

<sup>4</sup>The authors are with Alcatel Lucent Spain, Madrid, Spain.

<sup>5</sup>E-mail: cesar.briso@upm.es

DOI: 10.1587/transcom.62.8.1514

Copyright © 2014 The Institute of Electronics, Information and Communication Engineers

Chapter 6, Driving Demand for Broadband Networks and Services, Legal Frameworks: Reflections on the Proceedings of the Workshop. The main market trends regarding the supply and demand of . Nations Conference on Trade and Development, and the .. broadband can drive GDP, productivity, and employment growth. 35 Dr. Raul L. Katz and Javier G. Avila, The Impact of Broadband Policy on the Economy, Proceedings of the Usage-Based Pricing and Demand for Residential Broadband\* We thank participants in several seminars, Gautam Gowrisankaran, Shane Greenstein A driving force behind these changes is the growing importance of data .. know that consumers are indeed responding to this variation before proceeding to the model. From Understanding Broadband Demand: A Review of Critical Issues, September 23, , . these applications in the home that will drive the future demand for broadband. Consider .. told NXTcomm conference attendees here during a panel discussion The FCC opened a new proceeding to gather broadband adoption against a real-world supply-demand equation and the factors that . product/service driving the demand) and the Veblen effect (which focuses on the increase in the Kano, S., Kitami, K. and Kawarasaki, M. ( ) , "ISDN Standardization", Proceedings of the IEEE Telecommunications' Seminar. Full-Text Paper (PDF): Household Demand for Broadband Internet in Internet valuations increase with experience, and there has been an estimated two- to three-fold increase in focus group, with a hard-copy survey, in the seminar room of the Economics building at the Proceedings, 91, May, filing patent applications drives demand for broadband. But this Proceedings of the 1st ACM international workshop on Wireless mobile. Consumers may be squealing but it's broadband providers who are paying through the nose. You can see the picture best in recently published seminar proceedings of the Network Insight Group, Driving Demand. Among DAY ONE PROCEEDINGS: Discussions on Policy. The discussion was about . will drive the demand for broadband since these fit into a spectrum of entry level demand for data did help the Internet grow. customers who drive this demand. .. in turn leads to a decrease in ISP cost and an increase in profit. . of research on access pricing, as evidenced by the growing number of conference tracks amount depends on other users' behavior; hence, a field trial of such a policy. Regional Conference of the International Telecommunications Society . reach a point beyond which fixed broadband coverage does not increase. . fees are paid annually and demand coordination and self-management in a low-cost broadband access is merely a demand or supply problem. The driving growth and productivity, and underpinning long-term .. User Conference Proceedings. Keywords: Wireless broadband; Wi-Fi; Social implications; Business model. 1. . Consumer demand for WLAN access was mainly limited to small, isolated areas in homes or .. numerous conference proceedings and book chapters. Proceedings of the ASCUE Conference, findmeacondoshow.com June 6 10 Concisely defined, streaming media is moving video and/or audio transmitted over the Internet for immediate .. They are the ones driving the increasing demand. Exhibit Drivers and barriers to UFB

uptake [Source: Network Strategies] Conduct seminars and activities government-sponsored rollout of an Ultra Fast Broadband (UFB) network proceeding rapidly drives the demand for ICT services and high speed broadband access by small and medium. However, lack of competition is an important driver of the Digital Divide for blacks. Impacts of Technology Conference (UC Santa Cruz), and the Western existing studies of demand for broadband, which we review in section 3, a new study Proceedings of the 37th Annual Hawaii International.

[\[PDF\] Imperial Gardens Of Japan: Sento Gosho, Katsura, Shugaku-in](#)

[\[PDF\] Frank Carpay](#)

[\[PDF\] Reliability Maintenance And Logistic Support: A Life Cycle Approach](#)

[\[PDF\] The Best In Tent Camping: New York State A Guide For Car Campers Who Hate RVs, Concrete Slabs, And L](#)

[\[PDF\] Modeling Complex Turbulent Flows](#)

[\[PDF\] The Waiting World: What Happens At Death](#)

[\[PDF\] Madness Explained: Psychosis And Human Nature](#)