MODERN RAILWAYS: COMMUNICATIONS SYSTEMS AND TECHNOLOGIES


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This Feature Topic focuses on the connection between railways and wireless communications and contains many interesting contributions to the most relevant research topics in this field. Besides the "connected car," the "connected train" is one of the most relevant use cases for modern communications systems and technologies posing unique challenges. High data rates to communicate with trains running at 300 km/h, Internet access to massive transit systems with up to 1000 people in 100 m long metro trains, ultra-dense sensor networks to know the condition of all the subsystems within the train, and vehicle-to-vehicle mission-critical services to move trains safely and reliably imply many challenges in the communications field that could be solved with novel wireless communication technologies. In particular, the fifth generation (5G) mobile communication system is perceived in both the railway and the communications industries as a potential enabler of many disruptive use cases for railways, including remote driving, virtual coupling of trains, massive sensing, and so on. Many of these disruptive and safety-relevant services require ultra-reliable low-latency communication capability. This means that railways are ready to embrace massive transformation that will allow an evolution to a more efficient, greener, and safer public service.

The first article, "Reasoning Functional Requirements for Virtually-Coupled Train Sets: Communication," written by Parise *et al.*, focuses on the description of functional requirements with respect to sensors, control, and communication for virtually coupled trains. Furthermore, the article assesses some current and future communication systems (i.e., terrestrial trunked radio [TETRA], IEEE 802.11p, LTE, 5G) regarding this novel and challenging use case. This article is a fascinating example of connecting pure railway use cases with radio communications systems in a novel way.

The next article, "Delivering Gigabit Capacities to Passenger Trains: Tales from an Operator on the Road to 5G," authored by Jamaly *et al.*, explains different challenges train operators face when providing efficient, high-capacity connectivity to onboard users. The road ahead to 5G is envisaged as well. In contrast to normally relaying the radio signals through technology-dependent onboard equipment into trains, the authors propose RF transparent windows together with RF corridors and reflective panels to deliver gigabit data rates inside trains.

Talvitie *et al.,* in their article "Positioning and Location-Aware Communications for Modern Railways with 5G New Radio," focus on the opportunities that 5G NR technology can accurately locate high-speed trains and location-aware communications offer. Nowadays, trains use old-fashioned, expensive, but very safe location methods like track circuits. Hence, this new proposal could be interesting for both industry and operators to gain efficiency and reduce costs.

The next article, written by Soliman *et al.*, on "Automatic Train Coupling: Challenges and Key Enablers" introduces an ultra-reliable and low-latency millimeter-wave (mmWave) wireless communication system to directly communicate between trains. The aim of this system is to provide more flexibility and efficiency in the composition of trains, which is one of the current bottlenecks in the day-to-day operations of many railway lines.

The fifth article, "Train Communication Systems: Status and Prospect," written by Lüdicke *et al.*, presents for the first time in scientific literature an overview of the onboard communications networks for trains: the train communication network (TCN). TCN is a key technology for modern trains in all the service domains available onboard: safety-related; train control and management; and multimedia and passenger-oriented. Further, the authors describe possible evolution paths to wireless TCN enabling new uses cases such as virtual coupling of trains with TETRA, IEEE 802.1p, LTE, 5G, and mmWave communication technologies.

The next two articles focus on channel measurements and channel modeling. First, in "Train-to-Infrastructure Channel Modeling and Simulation in mmWave Band" He *et al.* explain both the state of the art and the future trends of channel modeling for the train-to-ground communication in the mmWave band. The authors provide an overview on channel measurement and ray-tracing-based mmWave radio propagation modeling for time-variant railway scenarios. Then, in "Recent Developments and Future Challenges in Channel Measurements and Models for 5G and Beyond High-Speed Train Communication Systems," Liu *et al.* extend the discussion on channel measurements and channel modeling from mmWave to 5G technology features such as massive MIMO, coordinated multipoint, and mobile relaying.

In the eighth article, "Large-Scale Hybrid Antenna Array for Millimeter-Wave/Terahertz High-Speed Railway Communication," Wu *et al.* introduce the challenges and opportunities and show solutions for beamforming-based techniques of both mmWave and terahertz communications systems in high-speed railways.

Finally, "Zero on Site Testing Strategies for Wireless TCMS" by Bouaziz *et al.* describes simulation- and emulation-based techniques focused on saving costs of validating wireless communications systems for onboard applications like train control and management systems (TCMSs). These cost figures represent an important bottleneck for train manufacturers in order to roll out state-of-the-art wireless communication technology in a fast and efficient way in new trains.

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BIOGRAPHIES

JUAN MORENO [SM'19] received his Ph.D. from Universidad Politécnica de Madrid in 2015 and works as a rolling stock engineer in the Engineering and Research Department of Metro de Madrid, where he has led many projects on railway communications. He is also a part-time professor at the Universidad Politécnica de Madrid. He has been working in railways since 2007, first in high-speed and then in subways. He has participated in many railway-related research projects like Roll2Rail and Tecrail, and has authored more than 40 papers on railway communications. His research interests are channel measurement and modeling, railway communications systems and software-defined radio.

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