IEEE ACCESS SPECIAL SECTION EDITORIAL:
5G AND BEYOND MOBILE WIRELESS COMMUNICATIONS
ENABLING INTELLIGENT MOBILITY

Increasing urbanization is one major trend that shapes tomorrow’s society; by 2050, more than 85% of the developed world’s population will live in a comparatively small number of ever-growing cities. Within such cities and their commuter belts, reliable high-rate wireless communication will not only be required for (quasi-) static users but also for hosts of people moving in public and private transportation networks. Yet, wireless connectivity is not restricted to people; frictionless functioning of such a society in motion is supported by Intelligent Mobility, where each connected transportation vehicle (car, train, bus, ship, aircraft, motorcycle, and bicycle) is expected to be a smart object equipped with a powerful multi-sensor platform, communication capability, computing units, and Internet protocol (IP)-based connectivity, such as to be highly efficient in various vehicular and transportation applications. This vision requires a more pervasive and ubiquitous communications and networking core, which will not be only driven by the existing research on 5G but also enabled by future mobile wireless communications that employ new concepts, such as data analytics, artificial intelligence, machine learning, and cloud computing. Therefore, this IEEE Access Special Section focuses on various theoretical and experimental views on researching and developing the required technological enhancements of 5G and beyond mobile wireless communications, to efficiently support the vision of intelligent mobility, providing mobility as a service, and enabling dependable Internet services. Twenty-three high-quality contributions to this Special Section have been selected in a strict peer-review process supported by reputed international experts.

I. VEHICULAR COMMUNICATIONS FOR INTELLIGENT MOBILITY

The first group of articles deals with technical challenges for advanced vehicular communications. For instance, establishing and tracking beams in millimeter-wave (mmWave) vehicular communication is a challenging task. Large antenna arrays and narrow beams introduce significant system overhead for configuring the beams using exhaustive beam search. The invited article “MmWave vehicular beam selection with situational awareness using machine learning,” by Wang et al., proposed to learn the optimal beam pair index by exploiting the locations and types of the receiver vehicle and its neighboring vehicles (situational awareness) and leveraging machine learning classification and past beam training data. The numerical results show that situational awareness-assisted beam selection using machine learning can provide beam prediction with accuracy that increases with a more complete knowledge of the environment.

By considering the velocity variations of both terminals and moving scatterers, a general segment-based model for non-stationary vehicle-to-vehicle (V2V) channels was proposed in the article “A novel segment-based model for non-stationary vehicle-to-vehicle channels with velocity variations,” by Li et al. The time-evolving channel parameters, i.e., Doppler frequencies, angles of arrival and departure, path delays, and path powers, were analyzed and simplified by Taylor series expansions. The proposed model can be applied to realistic V2V communication environments and explicitly reveals the impact of velocity variations on the channels.

Vehicle-to-Pedestrian (V2P) communication is essential to enable a reliable collision avoidance system for vehicles and vulnerable road users (VRUs). In order to develop a dedicated channel model for V2P communication in critical scenarios, Rashdan et al., in “Large-scale fading characteristics and models for vehicle-to-pedestrian channel at 5-GHz,” conducted wideband channel sounding measurements considering a typical collision scenario between a vehicle and a pedestrian in line-of-sight (LoS) and non-LoS (NLoS) situations. The wideband measurement data are used to study the characteristics of large-scale or shadow fading, pathloss, and diffraction loss. The results show that the proposed diffraction model provides a good match to the measured pathloss.

Huang et al., in “Data dissemination of application service by using member-centric routing protocol in a platoon of Internet of Vehicle (IoV),” proposed routing protocols for transmission over a Vehicle ad hoc Network (VANET) in a platoon of vehicles that are driving together on the highway from the same starting point, with the same route, and going to the same destination. Based on the simulation results, the proposed member-centric routing protocols effectively improved the packet delivery ratio and throughput compared with other protocols in the VANET platoon scenario.
In the article “Efficient groupcast schemes for vehicle platooning in V2V network,” by Kim et al., the authors studied the problem of groupcast for vehicle platooning, where vehicles of a platoon moving in a single lane communicate with each other through V2V groupcast without network assistance. Two groupcast schemes were presented. The first groupcast scheme, called GC-BR, is a heuristic scheme that aims to maximize groupcast success rate. The second groupcast scheme, called GC-TC, is designed by formulating as a Markov decision process (MDP) to obtain a joint optimal strategy for retransmission vehicle user (R-VE) selection and time-domain resource allocation that can minimize total time consumption while maintaining a satisfactory groupcast success rate performance.

The services of enhanced mobile broadband (eMBB) and ultra-reliable low-latency communication (URLLC) enabled by 5G new radio (NR) are considered to be the essential prerequisites of future intelligent transportation systems. In particular, the eMBB service is designed to provide an extremely high data rate for content delivery and, thereby, can significantly enhance the quality of experience (QoE) of bandwidth-hungry in-vehicle entertainment applications. On the other hand, the URLLC is designed to tackle the stringent requirements on the latency and reliability of critical packet transmissions, and thereby can facilitate the autonomous driving of the connected vehicles. In the article “Performance analysis of one-way highway vehicular networks with dynamic multiplexing of eMBB and URLLC traffic,” by Song and Yuan, under the scenario of a one-way highway vehicular network, the authors address the issue of joint resource allocations of the eMBB and URLLC traffic types for the enhancement of network performance.

The following two articles deal with vehicular edge computing (VEC), an important innovation to address low latency communications, particularly suited to enhance vehicular traffic.

In the article “Short-term traffic prediction by two-level data driven model in 5G-enabled edge computing networks,” by Huang et al., a two-stage approach is followed to estimate vehicular traffic and finally predict it. First, a Deep Belief Network (DBN) is developed to extract the traffic characteristics between the road occupancy and road flow collected by the deployed detectors. The output of this DBN is fed as inputs to a Hidden Markov Model (HMM) to predict the future road speed of each road segment characterizing the statistical relationship between the traffic flow and road speed.

In the article “Joint optimization of computation offloading and task scheduling in vehicular edge computing networks,” by Sun et al., the off-loading algorithm that efficiently optimizes delay and computing resource consumption in multiuser, multi-server VEC scenarios is studied. The off-loading algorithm not only determines where the tasks are performed but also indicates the execution order of the tasks on the server. In order to reduce the complexity, a hybrid intelligent optimization algorithm based on the so-called Parthenon genetic algorithm and heuristic rules is proposed.

II. RAILWAY COMMUNICATIONS FOR INTELLIGENT MOBILITY

The second cluster of articles focuses on the challenges of railway communications. Providing seamless connectivity to mobile users onboard railway vehicles is quickly gaining ground as part of society in motion. Today, the main challenge for academia and industry investigating service quality improvements for smartphone users stems from a few tens of decibels of vehicle penetration loss at mobile communication frequencies. To deal with this, Berisha and Mecklenbräuker, in “Operational service quality assessment on-board railway vehicles,” demonstrate two designs to alleviate this: frequency selective surface- and amplify-and-forward repeater-aided railway vehicles.

Zhou et al., in “Simulation and analysis of propagation characteristics for tunnel train-ground communications at 1.4 and 40 GHz,” focus on the analysis of propagation characteristics for train-ground communication (TGC) systems in tunnel scenarios at both low-frequency and mmWave bands, based on ray-tracing (RT) simulation. A practical 3-D tunnel TGC environment considering the existence of train cars is established, which is further divided into three kinds of scenarios, involving the direct coverage, relay coverage, and in-train coverage scenarios. Both large-scale and small-scale propagation characteristics, such as path loss and root mean square delay spread, are analyzed for the three tunnel TGC scenarios. The obtained results can provide useful information for the design of future 5G tunnel TGC systems.

In “Experimental investigation of millimeter-wave MIMO channel characteristics in tunnel,” by Liu et al., a 28 GHz mmWave propagation measurement campaign was performed to predict the multiple-input multiple-output (MIMO) channel performance in a tunnel environment. The results indicated that the antenna array elements of horizontally polarized configuration have higher capacity than the vertically polarized for a constant signal-to-noise ratio (SNR).

Cloud radio access network (C-RAN) is considered a promising architecture for 5G, with advantages such as green energy and convenient resource allocation. In “Research on resource migration based on novel RRH-BBU mapping in cloud radio access network for HSR scenarios,” by Han et al., the authors explored the feasibility of C-RAN for high-speed railway (HSR) scenarios. A novel phenomenon of group handover is defined in the extensively and densely distributed railway network, and a resource migration cost with a closed-form expression was presented to depict the group handover.

III. AIRCRAFT COMMUNICATIONS FOR INTELLIGENT MOBILITY

The third theme is the link between air and ground. The 5G mobile communication system is attracting attention as one of the most suitable communication models for broadcasting and managing disaster situations, due to its large capacity and...
low latency. High-quality videos taken by a drone, which is an embedded internet of things (IoT) device for filming in a disaster environment, play an important role in managing the disaster. However, the 5G mmWave frequency band is susceptible to large attenuation by obstacles and has beam misalignment problems, which can sever the connection and greatly degrade TCP performance. To solve this problem, Na et al., in “DL-TCP: Deep learning-based transmission control protocol for disaster 5G mmWave networks,” propose a deep-learning-based TCP (DL-TCP) for a disaster 5G mmWave network.

Unmanned Aerial Vehicle (UAV) networks can be used as low-altitude BSs to flexibly and efficiently satisfy the communication demands of users. In “A two-step environment-learning-based method for optimal UAV deployment,” by Luo et al., the authors proposed an efficient two-step environment-learning-based method for optimal UAV deployment. The method has maximized the coverage performance under the premise of ensuring the connectivity and safety of the network. The simulation results have shown that the proposed deployment method has better adaptability to environmental changes and has higher coverage performance.

IV. EMERGING COMMUNICATIONS FOR INTELLIGENT MOBILITY

The last series of articles are all regarding various emerging communications that enable intelligent mobility. Wireless Big Data has gained extensive attention as enormous numbers of mobile devices have been developed and deployed for the upcoming 5G era. The context information of these devices is of importance for personalized services in a smart environment. Nevertheless, the constant change of scenes challenges the network operator. In the article by Zhang et al., “An ensemble learning scheme for indoor-outdoor classification based on KPIs of LTE network,” the authors propose an ensemble learning scheme for indoor-outdoor classification for a typical urban area, based on the cellular data captured in a commercial LTE network.

Reliable wireless data transmission in intelligent transportation systems (ITS) has drawn much interest in recent years. As an efficient wireless transmission technology, multicarrier modulation (MCM) finds its way into many applications. However, the high peak-to-average power ratio (PAPR) of the MCM signal degrades the system performance. To remedy this, the work by Hou et al., “Two-stage companding scheme to reduce peak-to-average power ratio for safety transportation scenarios,” introduced a novel two-stage distribution-based companding technique for the PAPR reduction of MCM transmission in transportation. The main principle of this technique is to transform the original MCM signal distribution into a desirable two-stage distribution, that is, compressing the large signals while maintaining the small signals.

The radio-frequency (RF) phase shifter with a finite number of quantization bits in analog beamforming (AB) structure forms quantization error (QE) and causes a performance loss of received signal to interference plus noise ratio (SINR) at the receiver. Li et al., in “Performance analysis of directional modulation with finite-quantized RF phase shifters in analog beamforming structure,” present an analysis of the effect of QE from finite-quantized phase shifters on the performance of a directional modulation (DM) system using an AB structure.

Zhang et al., in “Secure communications in SWIPT-enabled two-way relay networks,” investigated the secrecy performance of a wireless-powered two-way relay network in the presence of an eavesdropper. Based on adaptive time allocation (TA) and power splitting (PS), a novel secure relaying protocol was proposed. For secrecy capacity maximization, the optimal TA ratio and PS ratio, which are adaptively adjusted according to instantaneous channel state information, are derived in a high signal-to-noise ratio regime through a split-step iterative method.

Quadrature spatial modulation (QSM) is a novel index modulation technology, which extends the antenna index (AI) to two dimensions of both in-phase AI and quadrature AI. In order to further make full use of the idle transmit antennas (TAs) resource and to exploit the signal constellation domain, taking advantage of the spatial dimension of QSM, Huang et al., in “Quadrature index modulation with three-dimension constellation,” propose a new 3-D structure of quadrature index modulation (QIM), which is capable of not only transmitting directly a 3-D constellation symbol but also carrying more extra information bits, named as quadrature index modulation with a 3-D constellation (QIM-TDC).

Considering the frequent handover problem caused by network densification and the employment of mmWave in 5G heterogeneous networks (HetNets), Zhang et al., in “A seamless handover scheme with assisted eNB for 5G C/U plane split heterogeneous network,” presented a novel network framework for 5G control/user plane split (CUPS) network to perform seamless handover between two neighbor macro evolved nodeBs (M-eNBs). Simulation results show that the handover outage probability is lower than that of the traditional CUPS HetNets, and the handover success probability of inter M-eNB is almost 34.7% improved.

Cell-free (CF) massive MIMO systems have a large number of individually controllable antennas distributed over a wide area for simultaneously serving a small number of user equipments (UEs). This solution has been considered as a promising next-generation technology due to its ability to offer a similar quality of service to all UEs despite its low-complexity signal processing. In “Cell-free massive MIMO: A new next-generation paradigm,” by Zhang et al., the authors provided a comprehensive survey of CF massive MIMO systems.

The last two articles study propagation and wireless channels, which address the common challenges for all kinds of communications enabling intelligent mobility. Tian et al., in “Effect level based parameterization method for diffuse
scattering models at millimeter-wave frequencies,” proposed a multicoefficient estimation method for the dielectric parameters of rough materials, and an effect level-based parameterization method for diffuse scattering models to characterize and model the diffuse scattering propagation at mmWave frequencies. The investigations demonstrated that the proposed parameterization method is reliable and accurate for diffuse scattering models and can be applied for the determination of model parameters from extensive materials measurement data, especially for mmWave channel analysis and modeling.

In order to simulate mobile users or advanced beamforming strategies based on user location or angular information, it is crucial that spatial consistency is included in the applied channel models. Ademaj et al., in the article “A spatial consistency model for geometry-based stochastic channels,” introduced a novel model for spatial consistency that is applicable to all prevalent geometry-based stochastic channel models. The authors provided a detailed explanation of the model, analyzed its statistical properties, and showed its behavior when applied to the 3GPP 3-D channel model as an example.

The Guest Editors hope that this Special Section will benefit the scientific community and contribute to the knowledge base and would like to take this opportunity to applaud the contribution of the authors to this Special Section of IEEE Access. The efforts of the reviewers to enhance the quality of the manuscripts are also much appreciated. The Guest Editors also would like to acknowledge the guidance from the Editor-in-Chief, Prof. Derek Abbott, and staff members.

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