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Special Issue on Revolutionary Paradigms for Smart Connected Vehicles in the 6G Era

By jointly involving multiple challenging network requirements, such as ultra-high reliable and ultra-low latency communications, high efficiency and capacity, intelligent driving is one of the most ambitious and attractive applications of the 6G initiatives. To support driver assistance, self-driving, autonomous driving and a variety of smart safety and entertainment applications, each vehicle will be provided with communication, control, computing, caching (4C) resources and with multiple sensing capabilities. Moreover, Artificial Intelligent (AI) techniques will be the central pillar of 6G vehicular network intelligence.

6G vehicles will be complex systems able to generate and process terabytes of data per driving hour, while interacting with each other and heterogeneous entities like pedestrians, riders, road-side infrastructure, edge servers and remote Internet facilities. The complexity of the scenario requires the introduction of revolutionary communication and networking protocols and architectures that allow connected vehicles to meet extremely high data rates, to flexibility orchestrate 4C and sensing resources, to effectively enable vehicular cloud applications and services over vehicle-to-everything (V2X) channels, and to develop self-organizing and self-sustaining capabilities.

This special issue was organized to collect the prominent research advancements for connected vehicles that meet the expectations of the 6G era.

The first two papers provide the reader with an overview of the 6G vehicular network scenario, enabling paradigms and related state-of-the-art solutions. In particular, the work titled "*Vehicular intelligence in 6G: Networking, communications, and computing*" [1] reviews 6G vehicular applications and analyze the groundbreaking networking, communication and computing technologies that vehicular networks may use. The authors focus on the role of Software Defined Networking (SDN), Network Function Virtualization (NFV), quantum and mmWave communications, cloud, fog, and edge computing in 6G vehicular networks and conclude with a summary of challenges and research directions. The work titled "*Deep reinforcement learning techniques for vehicular networks: recent advances and future trends towards 6G*" [2], instead, reviews Reinforcement Learning (RL) approaches to address emerging issues in 6G vehicular networks. With focus on vehicular resource management, the authors review RL solutions for dynamic spectrum access, collision management, computing and caching services and energy efficient transmissions. With focus on vehicular infrastructure management, the authors review RL solutions for traffic management, e.g., traffic light control, and vehicle management, e.g., trajectory planning.

The paper titled "*Decentralized Federated Learning for Extended Sensing in 6G Connected Vehicles*" [3] leverages the ultra-low latency V2X links to support a novel fog-based Federated Learning (FL) scheme where Deep Machine Learning (DML) models are trained by mutually sharing parameters in a distributed manner via consensus. The proposed approach, called consensus-driven FL (C-FL), is suitable for PointNet compliant DML architectures and Lidar point cloud processing for the classification of road users and objects. Compared to vanilla FL, C-FL makes the distributed learning process faster, more scalable and fault resilient as the number of cooperating vehicles increases.

Two papers investigate strategies for implementing ultra-high reliable and ultra-low latency communications in vehicular networks. More specifically, the paper titled "*Improve the Reliability of 6G Vehicular Communication through Skip Network Coding*" [4] proposes a Skip Network Coding (SNC) multipath transmission scheme that copes against burst consecutive losses due to wireless channel fluctuation, while guaranteeing low-delay packet reordering. Conversely, the paper titled "*Fastening the Initial Access in 5G NR Sidelink for 6G V2X Networks*" [5] investigates an Initial Access (IA) technique to meet the extreme data rates of 6G. The authors considers beam-based millimeter Waves and sub-Terahertz communications and define a scheme to establish physical communication links between vehicles by selecting the the optimal beam to be used.

Finally, the paper titled "*B-IoMV: Blockchain-based Onion Routing Protocol for D2D Communication in an IoMV Environment beyond 5G*" [6] integrates the blockchain technology in the Internet of Military Vehicles (IoMV) to guarantee secure, trusted and anonymous vehicle-to-vehicle communications. By leveraging beyond 5G wireless channels, the proposal is also able to support ultra-low latency interactions compared to the traditional communication systems like 4G, LTE-A, and 5G.

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