Guest Editorial
Special Issue on IoT on the Move: Enabling Technologies and Driving Applications for Internet of Intelligent Vehicles (IoIV)

THE NEW era of the Internet of Things (IoT) is prompting the evolution of conventional vehicle ad-hoc networks (VANETs) into the Internet of Intelligent Vehicles (IoIV). Different from VANETs, where a vehicle is essentially considered as a node disseminating messages, the emerging IoIV paradigm is expected to regard each vehicle as a smart object equipped with a powerful multisensor platform, unprecedented communication capability, computing units, and Internet protocol (IP)-based connectivity. As such, the vehicles in IoIV are highly efficient in a broad array of vehicular and transportation applications. As a unique subset of general purpose IoT, IoIV can benefit from the existing research on VANET, which lays the foundation toward a more pervasive and ubiquitous communications and networking core that is essential for IoIV. Nevertheless, research in many aspects of IoIV, especially those that are application-driven and data-oriented ones, is still at its infancy.

In this Special Issue, we have received a large number of submissions, and after rounds of careful reviews, we chose 16 papers on diverse topics in IoIV, including channel modeling, physical layer techniques, MAC layer designs and networking, as well as applications. Among the accepted submissions, there are two survey papers.

The paper entitled "Toward Intelligent Vehicular Networks: A Machine Learning Framework" first identified the distinctive characteristics of high mobility vehicular networks and motivated the use of machine learning to address the resulting challenges. After a brief introduction of the main concepts of machine learning, the applications entailing the acquisition of the vehicular network dynamics and informed decision making to optimize the network performance were discussed. In particular, the application of reinforcement learning in managing network resources as an alternative to the prevalent optimization approach was discussed in detail. Finally, some open issues were highlighted.

The paper entitled "Wireless Toward the Era of Intelligent Vehicles" provided a comprehensive survey on IoIV. Specifically, it discussed the challenges, progresses, and perspectives of the vehicular wireless channels, wireless-vehicle combination, as well as the more demanding wireless-vehicle integration. For the channel modeling, the specific challenges and opportunities for high-mobility vehicular environment, as well as new wireless technologies, such as millimeter wave and massive multi-input multi-output (MIMO) were introduced. For the wireless-vehicle combination, both PHY and MAC layer challenges, and the corresponding state-of-the-art solutions, including interference carrier interference cancellation, new MIMO, congestion control, and resource sharing techniques were discussed in detail. In terms of the wireless-vehicle integration, some interesting topics surrounding the core vehicle functions were introduced and discussed.

As for channel modeling in IoIV, the paper entitled "5-GHz Obstructed Vehicle-to-Vehicle Channel Characterization for Internet of Intelligent Vehicles" characterized the obstructed V2V channels in the 5-GHz band through measurement-calibrated ray-tracing (RT) simulations. The objects in the physical world are divided into two groups: 1) the small-scale structures (e.g., lampposts and traffic signs) and 2) the large-scale structures (such as buildings and ground). Then, the radar cross sections of the small-scale structures were integrated into the provided RT simulator through a framework based on high frequency prediction techniques. For the large-scale structures, the electromagnetic and scattering parameters of the large-scale structures were calibrated through V2V channel measurements.

In terms of advanced physical layer techniques in IoIV, the paper entitled "Information-Guided Pilot Insertion for OFDM-Based Vehicular Communications Systems" proposed a novel pilot insertion technique to enhance the spectral efficiency, in which the pilot positions are selected according to some extra information bits. In other words, not only the pilots can be used for carrier phase tracking or channel estimation, their positions also carry additional information bits for communication purposes. Specifically, three different types of pilot position selection schemes, which result in equi-spaced, nonequi-spaced, and hybrid pilot placements, were studied. The corresponding pilot position detection methods were also designed.

The paper entitled "PHY-Layer Cover-Free Coding for Wireless Pilot Authentication in IoV Communications: Protocol Design and Ultrasecurity Proof" for multiantenna V2I OFDM communications, developed a PHY-layer cover-free coding theory to build a secure WPA protocol. The authors encoded and conveyed vehicle pilot signals into diversified

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subcarrier activation patterns (SAPs) in the time–frequency domain by employing cover-free coding. The decoding procedure was then redesigned using the signal independence feature such that those encoded SAPs, though camouflaged by malicious signals and superimposed onto each other in the wireless environment, could be separated, identified, and decoded into the original pilots securely. Thanks to this protocol, perfect pilot conveying and separation could both be guaranteed.

On the topic of MAC design and networking in IoIV, the paper entitled "Interference Hypergraph-Based Resource Allocation (IHG-RA) for NOMA-Integrated V2X Networks" proposed to introduce NOMA in device-to-device-enhanced vehicle-to-everything (V2X) networks, where resource sharing based on spatial reuse for different V2X communications is permitted via centralized resource management. Considering the complicated interference environment caused by NOMA and the spatial reuse-based resource sharing in the investigated NOMA-integrated V2X (NOMA-V2X) networks, an interference hypergraph was constructed to model the interference relationships among different communication groups. In addition, based on the constructed interference hypergraph, an interference hypergraph-based resource allocation scheme utilizing the cluster coloring algorithm was further proposed, which can lead to both effective and efficient resource block (RB) assignment with low computational complexity.

The paper entitled "A Power Allocation-Based Overlapping Transmission Scheme in Internet of Vehicles" presented a Polar code-based overlapping transmission scheme in which simultaneous transmissions from different nodes to the same receiving node are allowed to use the same time-frequency resource block. To effectively eliminate the multiple access interference introduced by the overlapped nonorthogonal transmissions, improved interference elimination decoding algorithm based on a successive cancellation list (SCL-based IIEDA) was proposed to retrieve the Polar encoded information. Numerical results confirm that the SCL-based IIEDA performs well on information recovery in the presented transmission scheme.

The paper entitled "Cooperative Temporal Data Dissemination in SDN-Based Heterogeneous Vehicular Networks" proposed a software-defined network-based architecture to facilitate unified management of heterogeneous network resources. Then, the cooperative temporal data dissemination (CTDD) problem was formulated by considering the property of the temporal data, the heterogeneity of wireless interfaces, and the delay constraints on service requests. The NP-hard problem of the CTDD was further proved by constructing a polynomial-time reduction from the well-known NP-hard classical Knapsack problem. On this basis, a heuristic algorithm termed as priority-based task assignment (PTA) was designed, which synthesizes the dynamic task assignment, broadcast efficiency, and service deadline into a priority design. Accordingly, PTA is able to adaptively distribute broadcast tasks of each request among multiple interfaces, so as to improve the overall system performance.

The paper entitled "Cost Optimization for On-Demand Content Streaming in IoV Networks with Two Service Tiers" proposed an integrated mobile streaming and caching scheme that jointly leverages two communication service tiers and the on-board caching resource for cost reduction. Algorithms were presented to achieve the optimal buffering at the session level and the optimal caching at the device level, respectively. An analytical framework was established to characterize the average cost as a function of the streaming rate in a large-scale network. Numerical results demonstrated how the "cost-streaming rate" function changes with the vehicle density, network congestion level, content length, and the average packet transmission time.

The paper entitled "iCast: Fine-Grained Wireless Video Streaming Over Internet of Intelligent Vehicles" proposed a fine-grained wireless video streaming strategy, namely iCast, that intelligently achieves the most appropriate data rate and frame protection for multimedia traffic in high-mobility vehicular environments. The insight of iCast is a simple joint source-channel rateless code. It reaps the benefits of the frequency diversity to provide fine-grained data rates for the channel in conjunction with suitable protection for the source. The conducted experiments showed that, by harnessing frequency diversity in mobile environments, iCast outperforms existing competitive wireless video delivery alternatives by up to 5-dB peak signal-to-noise ratio.

As to the applications in IoIV, the paper entitled "Optimal Resonate Beam Charging for Electronic Vehicles in Internet of Intelligent Vehicles" obtained the closed-form formula of the end-to-end power transmission efficiency after analyzing the modular model of the adaptive resonant beam charging (ARBC) system. According to the authors' proof, there exists a unique optimal power transmission efficiency. Moreover, the authors analyzed the relationships among the optimal power transmission efficiency, the source power, the output power, and the beam transmission efficiency, which provide the guidelines for the optimal ARBC system design and implementation. Hence, perpetual energy can be supplied to EVs in IoIV virtually.

The paper entitled "Distributed Routing and Charging Scheduling Optimization for Internet of Electric Vehicles" considered an Internet of Electric Vehicles (IoEV) powered by heterogeneous charging facilities in the transportation network. Each EV needs to decide on its path to take (i.e., the routing problem) and where and how much to charge/discharge its battery at the charging stations in the chosen path (i.e., the charging scheduling problem) such that its journey can be accomplished with the minimum monetary cost and time delay. From the system operator's perspective, a joint routing and charging scheduling optimization problem was formulated for an IoEV network. An approximate algorithm was proposed, which can achieve affordable computational complexity in large-size IoEV networks. The proposed algorithm allows the routing and charging solution to be calculated in a distributed manner by the system operator and EV users, which can effectively reduce the computational complexity at the system operator and protect the EV users' privacy and autonomy. Besides, a proximal method was introduced to improve the convergence rate of the proposed algorithm.

The paper entitled "Joint 3-D Shape Estimation and Landmark Localization from Monocular Cameras of Intelligent Vehicles" proposed a method to jointly estimate the global 3-D geometric structure of the vehicles and localize 2-D landmarks from a single viewpoint image. First, the 3-D shape was represented with a set of predefined shape bases, while parametrized by the coefficients of the linear combination of them. Second, a cascaded regression framework was adopted to regress the global shape encoded by the prior bases, by jointly minimizing the appearance and shape fitting differences. The position fitting item can help cope with the description ambiguity of local appearance and provide more information for the 3-D reconstruction. Experimental results demonstrated favorable improvements on pose estimation and shape prediction of the proposed method compared with some existing alternatives.

The paper entitled "Spike Coding for Dynamic Vision Sensor in Intelligent Driving" first analyzed the spike firing mechanism and the spatiotemporal characteristics of the spike data, then introduced a cube-based spike coding framework for DVS. In this framework, an octree-based structure was proposed to adaptively partition the spike stream into coding cubes in both spatial and temporal dimensions, then several prediction modes were designed to exploit the spatial and temporal characteristics of the spikes for compression, including the address-prior time-prior modes. To explore more flexibility, the intercube prediction was discussed extensively involving motion estimation and motion compensation.

The paper entitled "*Chimera:* An Energy-Efficient and Deadline-Aware Hybrid Edge Computing Framework for Vehicular Crowdsensing Applications" proposed a novel hybrid edge computing framework, termed as Chimera, integrated with the emerging edge cloud radio access network, to augment the network-wide vehicle resources for future large-scale vehicular crowdsensing applications, by leveraging a multitude of cooperative vehicles and the virtual machine (VM) pool in the edge cloud via the control of the application manager deployed in the edge cloud. A comprehensive framework model was presented and a novel multivehicle and multitask offloading problem was formulated, aiming at minimizing the energy consumption of network-wide recruited vehicles serving heterogeneous crowdsensing applications, and reconciling both the application deadline and the vehicle incentive at the same time. The Lyapunov optimization framework was invoked to design TaskSche, an online task scheduling algorithm, which only utilizes the current system information. As the core components of the algorithm, a task workload assignment policy based on graph transformation and a knapsack-based VM pool resource allocation policy were further proposed.

The paper entitled "Deployment and Dimensioning of Fog Computing-Based Internet of Vehicle Infrastructure for Autonomous Driving" investigated the problem of optimal deployment and dimensioning (ODD) of fog computing-based IoV infrastructure for autonomous driving. For the ODD problem, two diverse architecture modes were presented, that is, the coupling mode and the decoupling mode, and the ODD problem was formulated into two integer linear programming formulations with the objective of minimizing the deployment cost. A heuristic algorithm was also proposed to achieve the suboptimal deployment solution for large-scale fog computing-based IoV. Numerical results showed that the decoupling mode is more cost-effective and flexible than the coupling mode for deployment in practice.

To conclude, we are very grateful to all authors for their valuable contributions to this Special Issue, and to all reviewers for their timely and rigorous reviews. In addition, we would like to take this opportunity to thank the editorial team of this JOURNAL for their help throughout the publication process. We expect that this Special Issue can help both industry and academic research communities to better understand the recent advancements and potential research opportunities on the topic of "IoT on the Move: Enabling Technologies and Driving Applications for Internet of Intelligent Vehicles (IoIV)."

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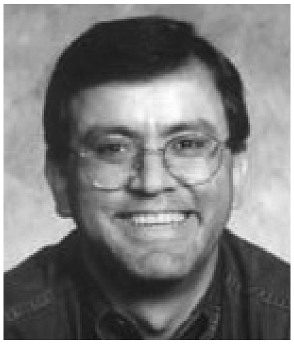

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