Guest Editorial
Introduction to the Special Issue on Cognitive Networking for Intelligent Transportation Systems

COGNITIVE networking is expected to analyze and utilize the various information for improving the intelligence of transportation systems. For example, through the Vehicle-to-Vehicle (V2V), Infrastructure-to-Vehicle, and Vehicular-to-Infrastructure (V2I) communications, which are the foundation and key support technologies determining the overall performance of advanced Intelligent Transportation Systems (ITS), road safety and traffic efficiency are significantly improved.

To address the advanced demands of ITS which cannot be met by the traditional technologies, such as high throughput, high mobility, low latency, heterogeneity, and scalability, etc., innovative cognitive networking technologies have been applied to ITS for raising the user experience through providing high-performance communications between the vehicular network nodes, reconstructing the vehicular network structure, and optimizing the networking coverage, system security, communication latency, etc. Especially, novel ITS assisted by cognitive computing, data mining, machine learning, and other advanced techniques are available to support entertainment, navigation, location-based services, etc., and even significantly improve the user experience, and even effectively guarantee traffic safety. For example, through cognitive vehicular networks, it is available to monitor the driver's physiological and psychological state for avoiding traffic accidents caused by fatigued driving and mood swings. In this direction, the integration of different body sensors and enhanced computer vision tools can provide useful information to detect driver's stress conditions promptly reacting.

For the record, our open call for papers of special issue had seen a recent explosion of interest. These papers were rigorously evaluated according to the normal reviewing process of the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS. In all, a total of 16 submissions were accepted from the all submitted articles.

In [A1], Han et al. propose an efficient collaborative anomaly detection methodology to protect the lane-following mechanism of Autonomous Driving Systems (ADSs), which is equipped with a novel transformer-based one-class classification model to identify time series anomalies (GPS spoofing threat) and adversarial image examples (traffic sign and lane recognition attacks). Besides, Autonomous Vehicles (AVs) inside the Cooperative Intelligent Transportation System (C-ITS) form a cognitive network, enabling to apply the federated learning technology to the anomaly detection method, where the vehicles in the C-ITS jointly update the detection model with higher model generalization and data privacy. Experiments on Baidu Apollo and two public datasets (GTSRB and Tumsimple) indicate that the method can not only detect sensor anomalies effectively and efficiently but also outperform state-of-the-art anomaly detection methods.

In [A2], Aswin et al. develop a deep learning-based scheme to detect microsleep in drivers using a single channel Electroencephalogram (EEG) input. It is noteworthy that it would be impractical and inconvenient for a driver to wear a multiple-channel EEG device during driving (e.g., a 14-channel/ 24-channel EEG kit). However, several portable single-channel EEG kits are now commercially available which are more user-friendly/ convenient to wear. The work deals with how to process the single-channel EEG data that are acquired to accurately detect micro-sleep patterns which can be further used for appropriate actions (e.g., playing an alert message to wake up the driver/intimating concerned authorities etc.).

In [A3], Sun et al. propose an efficient bit-level image encryption algorithm based on rearrangement Arnold cat map to protect the privacy of sensitive images. Experiments show that the correlation coefficients of the proposed algorithm are obviously weaker than that of the original image. And the proposed algorithm has stronger ability to resist different attacks compared with other solutions. Especially, the lower time complexity and only one round permutation make it particularly suitable to be used in the time-limited scenarios.

In [A4], Wang et al. propose a graph-optimized data offloading algorithm leveraging a Crowd-Artificial Intelligence (Crowd-AI) hybrid method to minimize the data offloading cost and ensure the reliable urban tracking result. The method first formulates a Crowd-AI hybrid urban tracking scenario, and prove the proposed data offloading problem in this scenario is NP-hard. Then, the method decomposes the problem into two parts, i.e., trajectory prediction and task allocation. The trajectory prediction algorithm, leveraging the state graph, computes possible tracking areas of the target object, and the task allocation algorithm, using the dependency graph, chooses the optimal set of crowds and cameras to cover the tracking area while minimizing the data offloading cost.

In [A5], Lin et al. introduce a novel collaborative decision-making architecture with cognitive networking to support dynamic perception in vehicle-road-cloud collaborative decision-making for Intelligent Transportation Systems (ITS). In order to strengthen the knowledge discovery ability of fuzzy information, a multi-task parallel multi-granularity learning model and a collaborative decision-making algorithm based on deep Q-learning is proposed to realize precise decision-making through the integration of local training within each layer and iteration between layers. The simulation

Digital Object Identifier 10.1109/TITS.2022.3226340

results show that the proposed algorithm optimally performs the parallel decision-making with cognitive networking for ITS, effectively reduces the decision-making time and is more suitable for accurate decision-making in fuzzy data environments.

In [A6], Shabir et al. consider a multiple Intelligent Reflecting Surfaces (IRSs) assisted multi-vehicle Multiple-Input Multiple-Output (MIMO) communication system and optimize transmit beamforming vectors at the transmitter and reflect beamforming (phase shifts) at each IRS to achieve max–min Quality of Service (QoS) in the form of weighted Signal-to-Interference-Plus-Noise Ratio (SINR). The optimization problem is divided into two Semidefinite Relaxation (SDR) sub-problems and iteratively solved using the alternate optimization technique. The simulation results show that the proposed technique significantly increases the sum-rate and SINR of the vehicular network.

In [A7], Zhao et al. present Newt, an enhanced Federated Learning (FL) approach. It includes a new client selection utility that explores the tradeoff between accuracy performance in each round and system progress. Besides, it highlights a feedback control on the selector. Specifically, the method implements a control on the selection frequency as a new dimension of client selection method design.

In [A8], Zhang et al. consider a hybrid scheme, combining the Priority Dynamic Access Class Barring (PDACB) scheme and back-off (BO) scheme. The Internet-of-Vehicles (IoV) devices are classified depending on different delay characteristics, where the delay-sensitive devices are classified as high priority. The target is to maximize the successful transmission of packets with the success rate constraint by adjusting various Access Class Barring (ACB) factors. A Proximal Policy Optimization (PPO) algorithm as a unique Deep Reinforcement Learning (DRL) method is utilized, which can obtain continuous action space and solve for the optimal ACB factors without estimating backlog of nodes. A quick convergence is achieved by designing sensible state space, action space and reward. The access capability of the PDACB traffic control scheme is verified by simulations.

In [A9], Yang et al. propose a Multi-Feature Fusion Network (MFFNet) to improve detection precision for 3-D point cloud data by combining the global features from 3-D voxel convolutions with the local features from the point learning network. The algorithm is an end-to-end detection framework that contains a voxel convolutional module, a local point feature module and a detection head. Significantly, MFFNet constructs the local point feature set with point learning and sampling and the global feature map through 3-D voxel convolution from raw point clouds. The detection head can use the obtained fusion feature to predict the position and category of the examined 3-D object, so the method can obtain higher precision than existing approaches. An experimental evaluation on the KITTI 3-D object detection dataset obtain 97% MAP (Mean Average Precision) and Waymo Open dataset obtain 80% MAP, which proves the efficiency of the developed feature fusion representation method for 3-D objects, and it can achieve satisfactory location accuracy.

In [A10], Mirzadeh et al. propose a trust-aware cognitive framework to give vehicles spatial intelligence and provide them with a mechanism to evaluate the trustworthiness of received data on their own. This framework exploits the redundancies in the exchanged Decentralized Environmental Notification Message (DENM) and Cooperative Awareness Message (CAM) packets as well as spatial information to filter malicious messages. This approach outperforms its competitors and achieves an accuracy of over 90% in decision-making even when 50% of network participants are malicious. A novel centralized supplementary mechanism is also presented that applies subjective logic on the pieces of information collected from all vehicles to detect and isolate malicious entities.

In [A11], Muhammad and Hossain propose lightweight Convolutional Neural Network (CNN) models for cognitive connectivity in automated vehicle systems. Two CNN models are used, one with 1-D convolution and the other with a tree-like topology. While the deep tree CNN model analyzes image data from automotive camera sensors, the 1-D CNN model is used to process 1-D temporal data such as the driver's body temperature and electrocardiogram (ECG) data to detect emotion. Different edge controllers should quickly handle the data from the automobile sensors since the driver's cognitive state might constantly vary based on the scenario and where the car is. Less computing is required to perform the tree-based deep-learning model that may be branched and processed separately in the edge devices. This lessens the workload and the duration of the model's execution.

In [A12], Tang et al. propose a 6G Semantic Communication Scheme based on Intelligent Fabric (6GSCS-IF) in transportation in-cabin scenarios, which empowers the senseless ubiquity and intelligence of intelligent fabrics to traditional communication and enhances the communication experience of users' smart interaction. Then, a Deep-Learning-based Semantic Communication Model for Time-series data (DL-SCMT) is proposed, which provides a semantic communication solution for the time-series data sensed by intelligent fabrics in 6GSCS-IF. Finally, experiments show that the proposed DL-SCMT model is far superior to traditional communication models in terms of signal reconstruction and high-order service effects, and has good robustness to communication noise.

In [A13], Xu et al. propose a personalized location privacy protection scheme based on differential privacy to protect the privacy of location-based services in vehicular networks. First, a normalized decision matrix is proposed to describe the efficiency and the privacy effect of navigation recommendations. A utility model integrated with users' privacy preferences is established to compute the effective driving route. Second, for different service request locations in the driving route, sensitivity distance as an index is defined to quantify their privacy requirements. The privacy budget will be added to the service request location to generate a false location. Moreover, due to the limitation of road range in the driving route, if the privacy budget value allocated is small enough, the false location generated by the Plane Laplace will be deviated. As a result, the attacker can deduce users' real request locations. Consequently, considering the factors of trajectory leakage, attack strategy, and QoS, a multi-objective optimization model is established to optimize the false location. Based on the real dataset, a series of comparison simulations is conducted to evaluate the performance of the proposed scheme. The experimental results demonstrate that the scheme can satisfy users' personalized services needs and provide an optimal solution to privacy and QoS.

In [A14], Zhu et al. propose a spectrum access algorithm based on Federated Deep Reinforcement Learning (FDRL) to maximize the QoS reward function with considering the hybrid benefits of delay, transmission power, and utility of Second Users (SUs) in intelligent transportation systems. To guarantee the utility of SUs, the warranty contract is designed for SUs to obtain compensation for data transmission failure, which promotes SUs to compete for more spectrum resources. To meet the real-time requirements and improve QoS in ITS, a spectrum access model is proposed based on federated Deep Q-Network (DQN), which adopts the Asynchronous Federated Weighted Learning Algorithm (AFWLA) to share and update the weights of DQN in multiple agents to decrease time cost and accelerate the convergence.

In [A15], Xia et al. propose a short-term traffic flow prediction model that combines community detection-based federated learning with a Graph Convolutional Network (GCN) to alleviate the time-consuming training, higher communication costs, and data privacy risks of global GCNs as the amount of data increases. The numerical results demonstrate the utility of the proposed model.

In [A16], Li et al. divide the related factors into three dimensions by the work methods. After that, a new dimension indefensible factor is obtained by filter operation to eliminate the correlation between external factors and internal factors, which is used to capture the degree that the internal abnormal operational behavior can be explained by the external environment. Inspired by the multichannel information of pictures, the work regard the driving information of four dimensions as the four channels of driving behaviors and extract the channel information through CNN. The efficiency of the proposed method is demonstrated based on experimental results.

In [A17], Ju et al. propose a novel model-inspired fusion network, called IVF-Net, for infrared and visible image fusion (IVF) problem. To enhance the detailed texture information and salient objects, a novel enhancement-oriented IVF model (IVFM) is proposed. We optimize the proposed IVFM with proximal gradient strategy and then unfold the optimization solution into a deep network with learnable parameters, which is expected to draw on the strengths of the model-based methods and deep learning-based techniques, and thus ensure the better fusion performance. In addition, we also design a multiple task-driven loss function to train the unfolded network. Owing to being motivated by IVFM, each layer of our IVF-Net enjoys a semantic interpretability and a clear mission, thereby leading to a significantly enhanced fusion effect.

YIN ZHANG, *Corresponding Guest Editor*
School of Information and
Communication Engineering
University of Electronic Science
and Technology of China
Chengdu 610056, China
e-mail: yin.zhang.cn@ieee.org

ALA AL-FUQAHA, *Guest Editor*
Department of Computer Science
Western Michigan University
Kalamazoo, MI 49008 USA
e-mail: ala@ieee.org

HUA WANG, *Guest Editor*
Institute for Sustainable Industries
and Liveable Cities
Victoria University
Melbourne, VIC 8001, Australia
e-mail: hua.wang@vu.edu.au

JIA LIU, *Guest Editor*
Department of Mathematics and Statistics
The University of West Florida
Pensacola, FL 32514 USA
e-mail: jliu@uwf.edu

APPENDIX: RELATED ARTICLES

[A1] X. Han et al., "ADS-lead: Lifelong anomaly detection in autonomous driving systems," *IEEE Trans. Intell. Transp. Syst.*, early access, Feb. 15, 2022, doi: 10.1109/TITS.2021.3122906.

[A2] A. Balaji, U. Tripathi, V. Chamola, A. Benslimane, and M. Guizani, "Towards safer vehicular transit: Implementing deep learning on single channel EEG systems for microsleep detection," *IEEE Trans. Intell. Transp. Syst.*, early access, Nov. 12, 2021, doi: 10.1109/TITS.2021.3125126.

[A3] Y. Sun, K. Yu, A. K. Bashir, and X. Liao, "Bl-IEA: A bit-level image encryption algorithm for cognitive services in intelligent transportation systems," *IEEE Trans. Intell. Transp. Syst.*, early access, Nov. 30, 2021, doi: 10.1109/TITS.2021.3129598.

[A4] P. Wang et al., "Graph optimized data offloading for crowd-AI hybrid urban tracking in intelligent transportation systems," *IEEE Trans. Intell. Transp. Syst.*, early access, Jan. 19, 2022, doi: 10.1109/TITS.2022.3141885.

[A5] K. Lin, J. Gao, Y. Li, C. Savaglio, and G. Fortino, "Multi-granularity collaborative decision with cognitive networking in intelligent transportation system," *IEEE Trans. Intell. Transp. Syst.*, early access, Mar. 9, 2022, doi: 10.1109/TITS.2022.3151754.

[A6] M. W. Shabir, T. N. Nguyen, J. Mirza, B. Ali, and M. A. Javed, "Transmit and reflect beamforming for max-min SINR in IRS aided MIMO vehicular networks," *IEEE Trans. Intell. Transp. Syst.*, early access, Mar. 1, 2022, doi: 10.1109/TITS.2022.3151135.

[A7] J. Zhao, X. Chang, Y. Feng, C. H. Liu, and N. Liu, "Participant selection for federated learning with heterogeneous data in intelligent transport system," *IEEE Trans. Intell. Transp. Syst.*, early access, Feb. 16, 2022, doi: 10.1109/TITS.2022.3149753.

[A8] H. Zhang, M. Jiang, X. Liu, X. Wen, N. Wang, and K. Long, "PPO-based PDACB traffic control scheme for massive IoV communications," *IEEE Trans. Intell. Transp. Syst.*, early access, Apr. 5, 2022, doi: 10.1109/TITS.2022.3160757.

[A9] S. Yang, H. Lu, and J. Li, "Multifeature fusion-based object detection for intelligent transportation systems," *IEEE Trans. Intell. Transp. Syst.*, early access, Apr. 27, 2022, doi: 10.1109/TITS.2022.3155488.

[A10] I. Mirzadeh, M. S. Haghighi, and A. Jolfaei, "Filtering malicious messages by trust-aware cognitive routing in vehicular ad hoc networks," *IEEE Trans. Intell. Transp. Syst.*, early access, Aug. 9, 2022, doi: 10.1109/TITS.2022.3191634.

[A11] G. Muhammad and M. S. Hossain, "Light deep models for cognitive computing in intelligent transportation systems," *IEEE Trans. Intell. Transp. Syst.*, early access, May 11, 2022, doi: 10.1109/TITS.2022.3171913.

[A12] Y. Tang et al., "Intelligent fabric enabled 6G semantic communication system for transportation in-cabin scenarios," *IEEE Trans. Intell. Transp. Syst.*, early access, Jun. 3, 2022, doi: 10.1109/TITS.2022.3174704.

[A13] C. Xu, L. Luo, Y. Ding, G. Zhao, and S. Yu, "Personalized location privacy protection for location-based services in vehicular networks," *IEEE Trans. Intell. Transp. Syst.*, early access, Jul. 25, 2022, doi: 10.1109/TITS.2022.3182019.

[A14] R. Zhu, M. Li, H. Liu, L. Liu, and M. Ma, "Federated deep reinforcement learning-based spectrum access algorithm with warranty contract in intelligent transportation systems," *IEEE Trans. Intell. Transp. Syst.*, early access, Jun. 20, 2022, doi: 10.1109/TITS.2022.3179442.

[A15] M. Xia, D. Jin, and J. Chen, "Short-term traffic flow prediction based on graph convolutional networks and federated learning," *IEEE Trans. Intell. Transp. Syst.*, early access, Jun. 10, 2022, doi: 10.1109/TITS.2022.3179391.

[A16] D. Li, Y. Wang, and W. Xu, "A deep multichannel network model for driving behavior risk classification," *IEEE Trans. Intell. Transp. Syst.*, early access, Sep. 2, 2022, doi: 10.1109/TITS.2022.3201378.

[A17] M. Ju, C. He, J. Liu, B. Kang, J. Su, and D. Zhang, "IVF-Net: An infrared and visible data fusion deep network for traffic object enhancement in intelligent transportation systems," *IEEE Trans. Intell. Transp. Syst.*, early access, 2022.