Guest Editorial
Special Issue on AI Enabled Cognitive Communication and Networking for IoT

As we enter the Internet of Things (IoT) era in which the communication network is becoming increasingly dynamic, heterogeneous, and complex, it is desirable to have cognitive communication systems and networks that possess multiple interacting capabilities for situation assessment, resource management, online/distributed learning, big-data processing, and intelligent decision making. AI techniques, such as deep learning, probabilistic graph model, and reinforcement learning, aided with big data and IoT, provide a wide variety of tools and solutions to many new problems encountered in the design, operation, and optimization of cognitive communication systems and networking, including resource management, situation assessment, channel identification, anomaly detection, root cause analysis, and online/distributed learning.

This Special Issue has received a total of 63 submissions around the world in response to the Calls for Papers. After rounds of rigorous review process, 17 papers were finally selected for publication, thanks to the great support from this Journal's Editor-in-Chief Prof. Sherman Shen and the dedicated work of numerous Reviewers.

In the paper "IoT Enabled Machine Learning for an Algorithmic Spectrum Decision Process," the authors propose a data-based approach for future regulatory spectrum management. Here, spectrum sensing data are collected by a spectrum environment awareness system built on a cloud-based service of IoT, and these data are used to characterize channel behaviors and establish a sharing predictor model which enables a set of efficient machine learning algorithms for automated spectrum sharing decision making. It is shown that by identifying and selecting candidate sharing channels based on occupancy models and performance labels generated from spectrum sensing data, the spectrum sharing assignment improves the usage efficiency of the spectrum resource.

In the paper "IoT-Fog-Based Healthcare Framework to Identify and Control Hypertension Attack," an IoT-Fog-based healthcare system is proposed for continuous monitoring and analysis of blood pressure statistics to diagnose the stage of hypertension in real time. Following a two-step approach, it first identifies the stage of hypertension on the basis of user's health parameters collected using IoT sensors at fog layer, and then predicts the risk level of hypertension attack using artificial neural networks at a remote site. Finally, analysis results and compiled medical information of each user are stored on cloud storage for sharing with domain experts, such as clinicians, doctors, and personal caregivers.

In the paper, "A Feature-Based Learning System for Internet of Things Applications," the authors proposed a new feature-based learning system for IoT applications, which can effectively classify data and detect anomaly events by employing an RBF-BP hybrid neural network. In addition, based on the theory of distributed compression, the sparsity and relativity of the data are exploited to obtain the classification features, which can reduce the computation overhead and energy consumption.

"Distributive Dynamic Spectrum Access Through Deep Reinforcement Learning: A Reservoir Computing-Based Approach," the authors apply deep reinforcement learning to distributed dynamic spectrum access (DSA) network to investigate intelligent resource allocation strategies under sensing errors. Reservoir computing, a special class of recurrent neural network, is utilized to realize deep reinforcement learning by taking advantage of the underlying temporal correlation of the distributed DSA network. Extensive experiments are conducted to demonstrate the efficiency and effectiveness of the introduced deep reinforcement learning-based resource allocation strategies for distributed DSA networks.

In the paper "MSML: A Novel Multi-Level Semi-Supervised Machine Learning Framework for Intrusion Detection System," the authors propose "MSML," a multi-level intrusion detection framework to address two issues affecting the performance of learning models: 1) imbalance of network traffic in different categories and 2) distribution mismatch between training data and test data. The proposed framework can effectively distinguish known pattern samples and unknown pattern samples from the whole dataset, which eventually yields excellent performance.

In "Deep Reinforcement Learning-Based Mode Selection and Resource Management for Green Fog Radio Access Networks," the authors present a study on AI-enabled fog radio access networks (F-RANs) to support emerging IoT services by leveraging edge caching and edge computing. With deep reinforcement learning (DRL), the network controller makes intelligent decisions on UE communication modes and processors' on-off states, as well as UEs' precoding in the C-RAN mode, aiming at minimizing long-term system power consumption. Transfer learning is integrated with DRL to

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accelerate learning process. The performance of the proposed approach is validated with simulations.

Services generated by various IoT devices are in heterogeneous contexts, causing interoperability problems. The transformation of heterogeneous device information to user-acceptable formats is addressed in the paper "Tabdoc Approach: An Information Fusion Method to Implement Semantic Interoperability Between IoT Devices and Users." It proposes a user-device interoperability framework, called the Tabdoc approach, to implement semantic interoperability between IoT devices and users. Following a divide-and-conquer strategy it provides a means to automatically integrate and process large amounts of information without human intervention.

In the paper "Artificial Intelligence Inspired Transmission Scheduling in Cognitive Vehicular Communications and Networks," the authors investigate the problem of data transmission in cognitive radio (CR)-enabled vehicular network. The performance of CR-based vehicular communication is analyzed via a Markov decision process, where the characteristics of the CR channels in different road regions, the mobility of vehicles as well as the QoS requirements of data transmission are taken into account. In order to minimize transmission costs subject to data delay constraints, a deep-Q learning approach is also proposed, which exploits various spectrum resources and the benefits from proper transmission mode selection.

In the paper "Secure Phrase Search for Intelligent Processing of Encrypted Data in Cloud-Based IoT," the authors propose an efficient privacy-preserving phrase search scheme for intelligent encrypted data processing in cloud-based IoT, with which phrase queries can be securely performed over sensitive IoT data outsourced to.

Energy harvesting is a promising technique to fulfill the long-term and self-sustainable operations for IoT systems. In "Reinforcement Learning-Based Multiaccess Control and Battery Prediction With Energy Harvesting in IoT Systems," the authors study the joint access control and battery prediction problems in a small-cell IoT system including multiple energy harvesting equipments. To maximize the uplink transmission sum rate, a scheduling algorithm based on reinforcement learning with deep Q-network enhancement was proposed. Furthermore, to predict battery status, a reinforcement learning-based algorithm was developed to minimize the prediction loss.

Artificial intelligence and big data analytics enable autonomous vehicles (AVs) to dramatically change future intelligent transportation in smart cities. In the paper "Big Data Analytics and Network Calculus Enabling Intelligent Management of Autonomous Vehicles in a Smart City," the authors extended the network calculus to model the queueing problem, and machine learning techniques were applied to capture the microscopic vehicle traffic patterns. Based on them, an online AV fleet management scheme with congestion control was developed. Simulation results show that the proposed solution enables efficient transportation, while achieves substantial energy saving.

The deeply penetrated WiFi signals can enable cognitive sensing ability in many applications, such as human activity recognition. Given the complexity of wireless environment with dead zones, how to ensure the accuracy of wireless sensing is a challenge issue. In the paper "On Spatial Diversity in WiFi-Based Human Activity Recognition: A Deep Learning-Based Approach," the authors closely examined spatial diversity in WiFi-based human activity recognition and identified the dead zones and their key influential factors. Accordingly, WiFi-based Spatial Diversity-aware device-free Activity Recognition (WiSDAR) system was designed and implemented. WiSDAR employs an advanced deep learning model to analyze their patterns through supervised learning, leading to superior performance.

To achieve energy-efficient decentralized computing among IoT devices with limited energy constraints, in "Walk Proximal Gradient: An Energy-Efficient Algorithm for Consensus Optimization," the authors develop a first-order algorithm for energy-efficient decentralized consensus optimization. The proposed algorithm, called walk proximal gradient (WPG), passes a token through a walk in the network and updates the information of the visited agents. The authors analyze WPG with repeated Hamiltonian cycle and show that the token has a faster convergence rate to the consensual solution (in terms of energy consumption) than existing gradient-based decentralized methods. Numerical experiments are presented to validate the energy efficiency claims.

Fog computing and caching has emerged as a promising paradigm for IoT to provide proximity services, and thus reduce service latency and save back-haul bandwidth. In the paper "Joint Optimization of Caching, Computing, and Radio Resources for Fog-Enabled IoT Using Natural Actor–Critic Deep Reinforcement Learning," the authors addressed the joint optimization of content caching, computation offloading, and radio resource allocation, for the fog-enabled IoT. The actor–critic reinforcement learning framework was used to solve the joint decision-making problem with the objective of minimizing the average end-to-end delay. The deep neural network was employed to estimate the value functions given the large state and action space of the problem. Another deep neural network was used to represent a parameterized stochastic policy, and the natural policy gradient method was adopted to avoid convergence to the local maximum.

In the paper "Caching Transient Data for Internet of Things: A Deep Reinforcement Learning Approach," the authors present a novel edge caching approach for transient IoT data, which strikes a balance between the data freshness and the communication cost. By leveraging the deep reinforcement learning (DRL) technique, the proposed approach can determine a proper caching policy without knowing IoT data popularity and user request pattern. Simulation studies verify that the proposed approach outperforms other baseline approaches and is superb for handling transient IoT data.

To enable better cognitive interactivity between brain signals and IoT objects, in "Internet of Things Meets Brain–Computer Interface: A Unified Deep Learning Framework for Enabling Human-Thing Cognitive Interactivity," the authors propose a unified deep learning framework to bridge brain computer interface and IoT objects. Their framework extracts inter-dimensional dependency among the input signal of the human brain activities via a reinforcement learning-based selective attention mechanism and a modified long short-term memory network. Real-world experiments are conducted to evaluate the proposed framework and the numerical clearly demonstrate the advantages of the proposed method.

With the rapid growth in services and applications, software defined IoT is vulnerable to possible attacks and face severe security challenges. In the paper "AI-Based Two-Stage Intrusion Detection for Software Defined IoT Networks," an AI-based two-stage intrusion detection empowered by software defined technology is proposed. It first selects features using the Bat algorithm, a metaheuristic algorithm for achieving global optimization, with swarm division and binary differential mutation, and then classify flows using the Random Forest algorithm with the weighted voting mechanism. Implementation of this approach in a real network for traffic classification is envisioned as a future work.

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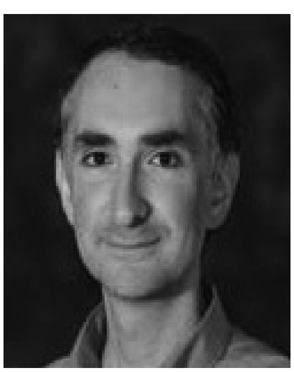

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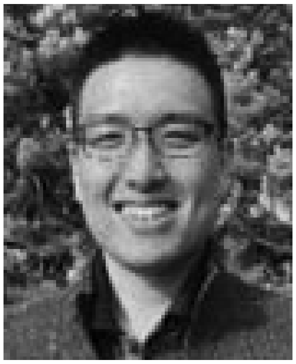

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