IEEE Access
The journal for rapid open access publishing

Date of current version January 14, 2016.

Digital Object Identifier 10.1109/ACCESS.2015.2507798

EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: ARTIFICIAL INTELLIGENCE ENABLED NETWORKING

With today's computer networks becoming increasingly dynamic, heterogeneous, and complex, there is great interest in deploying artificial intelligence (AI) based techniques for optimization and management of computer networks. AI techniques—that subsume multidisciplinary techniques from machine learning, optimization theory, game theory, control theory, and meta-heuristics—have long been applied to optimize computer networks in many diverse settings. Such an approach is gaining increased traction with the emergence of novel networking paradigms that promise to simplify network management (e.g., cloud computing, network functions virtualization, and software-defined networking) and provide intelligent services (e.g., future 5G mobile networks). Looking ahead, greater integration of AI into networking architectures can help develop a future vision of cognitive networks that will show network-wide intelligent behavior to solve problems of network heterogeneity, performance, and quality of service (QoS).

IEEE ACCESS is the new multidisciplinary, flagship open-access journal of IEEE that is committed to presenting the results of high-quality research across all of the IEEE's fields of interest. The objective of this Special Section on Artificial Intelligence Enabled Networking in IEEE ACCESS is to document the state of the art in this fast-developing exciting area of networking research. The topic of this Special Section lies at the intersection of a number of complementary specializations such as machine learning/AI, cognitive sciences, big data, etc. This is reflected in the diversity of techniques and networking configurations that we observe in the papers accepted in this Special Section.

Overall seven high-quality papers have been accepted from leading groups around the world after a rigorous peer-review process. The accepted papers include comprehensive survey/tutorial and position papers from leading experts as well as original research on new and emerging topics. The accepted papers focus on a number of distinct network configurations such as Internet of Things (IoT); 4G and 5G networks such as long-term evolution (LTE) and heterogeneous networks (HetNets); cognitive networks; and vehicular ad-hoc networks. These papers propose a wide spectrum of techniques such as reinforcement learning (RL), deep neural networks (DNN), and tensor voting.

We start by discussing the two survey papers, and the position paper, that have been accepted in this Special Section.

In the article "*Artificial intelligence based techniques for emerging heterogeneous networks: State of the arts, opportunities and challenges*", Xiaofei Wang et al. provide a detailed survey of how AI-based techniques apply to emerging heterogeneous networks. The use of AI-based techniques for mobile cellular networks is becoming increasingly important as mobile networks are becoming more complex. The authors describe how AI can be used to surmount the myriad challenges related to management, optimization, and maintenance of mobile networks that crop up due to the fast developing mobile communication industry. The use of AI techniques can be use to enable HetNets in becoming intelligent, self-organizing, and autonomously-evolving networks. The authors provide a detailed taxonomy of AI-related techniques from a wide variety of fields (including machine-learning, bio-inspired algorithms, fuzzy neural networks).

In the article "*Neighbour discovery for opportunistic networking in Internet of Things scenarios: A survey*", Pozza et al. have provided a survey of neighbor discovery techniques for opportunistic networking in Internet of Things (IoT) scenarios. The problem of neighbor discovery is becoming increasingly important with the emergence of opportunistic networking in IoT scenarios (such as smart cities)—in such scenarios, acquiring and predicting patterns of node encounters becomes fundamentally important since the success of communication relies on exploiting the availability of fleetingly-available dynamic end-to-end paths. AI techniques can be leveraged in such settings to learn and thereafter exploit knowledge of the mobility patterns of users and devices. In this survey paper, the authors presented a detailed taxonomy through which mobility-aware and mobility-agnostic neighbor discover approaches were introduced. It was shown that mobility-aware neighbor discovery approaches can can profit significantly by optimizing from their knowledge of mobility.

Michele Zorzi et al. presents a detailed position paper titled "*Cognition-based networks: A new perspective on network optimization using learning and distributed intelligence*"

that provides a deeply interdisciplinary look into the systematic application of advanced machine learning techniques to system-wide learning, modeling, optimization, and data representation. In particular, a blueprint of a new class of cognition-based networks (dubbed COBANETs) that will incorporate advanced machine learning—particularly, unsupervised deep learning and probabilistic generative models using techniques such as generative deep neural networks (GDNN)—in a setup that exploits recent network-architectural advances such as network virtualization and software-defined networking. Such a networking vision is compelling and can break new ground in developing better ways to manage and optimize telecommunication networks. Preliminary investigation has been conducted to train the GDNNs using the size of the encoded data frames in order to improve the estimation of the quality-rate characteristics of video flows, an important function in quality-of-experience (QoE)-aware resource management schemes. Various research challenges that need to be addressed in GDNNs are presented.

Other than the two survey papers and the position paper discussed above, we have accepted four research papers that have proposed original AI-based solutions for networking problems. We briefly introduce these papers next.

In the article "*Resource management and inter-cell-interference coordination in LTE uplink system using random neural network and optimization*", Adeel Ahsan et al. present an AI-based framework based on random neural networks (RNN) and genetic algorithms (GA) for resource management and inter-cell interference (ICI) coordination in LTE uplink system. The presence of inter-cell interference, caused by collisions between resource blocks, can limit the coverage and capacity of the uplink system in LTE. The author propose their power-control-based ICI solution based on RNN and GA which significantly improves the state-of-the-art solutions based on traditional artificial neural network (ANN) models.

Reinforcement learning (RL) is an AI-based approach that enables a decision maker to observe, learn, and take actions in its operating environment in order to increase its accumulated reward. RL promises to play a major role in AI-enabled cognitive networks of the future. In this special section, we have two papers that have proposed RL-based solutions. In the work by Morozs Nil et al. ("*Heuristically accelerated reinforcement learning for dynamic secondary spectrum sharing*"), an enhanced RL approach called heuristically accelerated reinforcement learning (HARL) is applied to the problem of dynamic spectrum sharing in LTE cellular networks. HARL utilizes external information, specifically radio environment map (REM), to guide, and hence speed up, the learning process. Compared to the traditional RL approach and a heuristic LTE solution, HARL has been shown to reduce the secondary systems' interference to the primary systems, as well as the probability of retransmission, while achieving higher system throughput compared to the state-of-the-art reinforcement learning or purely heuristic LTE solutions. In the work by Celimuge Wu et al. ("*Packet size-aware broadcasting in VANETs with fuzzy logic and RL-based parameter adaptation*"), a fuzzy logic-based algorithm consists of fuzzy membership functions is applied to a broadcast protocol to select the best relay node by taking into account multiple metrics including link quality, inter-vehicle distance and vehicle mobility. RL is applied to tune the fuzzy membership functions according to the network environment so that the fuzzy logic-based algorithm can adapt to various network scenarios. Both real-world experiments and computer simulations have been shown to increase packet forwarding ratio and reduce number of required transmissions in multi-hop broadcasting.

In the article "*Tensor voting techniques and applications in mobile trace inference*", Erte Pan et al. have proposed the use of tensor voting techniques to address the tracking problem of inferring human mobility traces. While the use of tensor mathematics is common in maths and physics, very little work has focused on the use of tensor techniques—that have significant applications for the AI task of automatic inference and perceptual grouping—in wireless networks. The human-tracking mobile trace inference problem is becoming increasingly important with the emergence of location-based networking services in modern life where smartphones are becoming the hub of interpersonal communication. The authors consider the mobile trace inference problem when the recorded location information is noisy and missing data and propose a tensor voting based approach that uses a sparse tensor voting algorithm. The authors have evaluated their proposed solution on real human mobility traces with the results demonstrating the ability of the proposed solution to effectively recover human mobility trace from incomplete and noisy data.

While the topic of AI-enabled networking is vast, we are happy with the technical depth and the range of topics covered in this special section. In the future, we anticipate that machine learning and artificial intelligence will be applied to more and more facets of communications and networking. We hope that the networking community benefits from the insights presented in this paper and that it provides a balanced snapshot of the range and breadth of AI-enabled networking. We sincerely thank all the authors and reviewers for their help and efforts in helping us curate a high-quality special section on an important topic. We will also like to thank the staff members and the Editor-in-Chief of IEEE ACCESS for their guidance and help.

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