Guest Editorial: Special Section on Machine Learning and Artificial Intelligence for Managing Networks, Systems, and Services—Part II

I. Introduction

MACHINE learning and artificial intelligence can harness the immense stream of operational data from clouds, to services, to social and communication networks. In the era of big data and connected devices of all varieties, machine learning and artificial intelligence have found ways to improve operations and management of information technology and communications.

Further research is therefore needed to understand and improve the potential and suitability of machine learning and artificial intelligence in the context of network, system and service management. This will provide deeper understanding and better decision making based on largely collected and available operational and management data. It will also present opportunities for improving machine learning and artificial intelligence algorithms on aspects such as reliability, dependability, and scalability, as well as demonstrate the benefits of these methods in control and management systems. Moreover, there is an opportunity to define novel platforms that can harness the vast operational data and advance machine learning and artificial intelligence algorithms to drive management decisions in open and highly programmable networks, clouds, and data centers.

This special section of IEEE TRANSACTIONS ON NETWORK AND SERVICE MANAGEMENT presents novel research in tackling the above challenges. It is the sixth special section to appear in this series, after issue published in [1], [2], [3], [4], [5], [6]. The collection of works we present illustrates recent trends, novel solutions and approaches to leverage Machine Learning and Artificial Intelligence in Network and Service management, as well as to extract insights from data that can guide system operators and network managers in their daily activities.

The most recent special section consists of two parts. In the Part II of the special section, presented here, we have accepted 39 papers out of 141 papers submitted to the open call for novel contributions addressing the underlying challenges of *Machine Learning and Artificial Intelligence for Managing Networks, Systems and Services*. The Part I of the special section was published in December 2022 [7].

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II. Special Section Overview

The Part II of the special section papers span five central areas of *Machine Learning (ML) and Artificial Intelligence (AI) for Management of Networks, Systems, and Services*: (i) ML/AI for Managing Resources, (ii) ML/AI for Managing Services, (iii) ML/AI for Managing Performance, (iv) ML/AI for Managing Security, and (v) ML/AI for General Operations and Management.

A. ML/AI for Managing Resources

Nine papers in this special section focus on opportunities and challenges related to the ML/AI for resource management in networks, systems, and services.

In [A1], Sulaiman et al. propose to use multi-agent deep reinforcement learning to jointly solve the problems of network slicing and slice Admission Control. The proposed approach along with reward shaping is a promising choice, which is well-suited to resource management problems where multiple distinct tasks have to be performed optimally.

In [A2], Gorla et al. present a framework using federated learning and distributed machine learning for mobile edge based resource provisioning for user equipments.

In [A3], Abdellatif et al. investigate an optimized, intelligent network slicing framework to maintain a high performance of network operations by supporting diverse and heterogeneous services, while meeting KPIs such as reliability, energy consumption, and data quality.

In [A4], Nagib et al. discuss the results from an exhaustive experiment to examine the efficiency of using transfer learning to accelerate the convergence of reinforcement learning based radio access network slicing. They introduce a predictive approach to enhance their solution.

In [A5], Ndikumana et al. explore two closed loops for managing radio access network slice resources for cars. Their goal is to address resoruce under or over provisioning problems that can cause quality of service violations.

In [A6], Mendoza et al. present a forecasting framework based on the use of automatic feature selection techniques in both spatial and temporal dimensions. Their goal is to take a proactive appraoch to address the requirements of 5G new services.

In [A7], Li et al. propose a meta-reinforcement learning task offloading algorithm, GASTO, based on graph neural networks and seq2seq networks for the generalization and robustness of offloading algorithms in mobile edge computing.

In [A8], Zhao et al. present MM, a multivariate KPI anomaly detection framework to address the systems' reliability issues. MM follows the multi-task learning using the proposed dynamic balancing loss function to adaptively balance the tasks' weights.

In [A9], Lou et al. jointly consider assignment and migration for mixed duration tasks and introduce a bew energy-efficient task scheduling algorithm. the goal is to address the energy-efficient task scheduling problem where the task execution times are mixed and hard to estimate.

B. ML/AI for Managing Services

Six papers in this special section focus on opportunities and challenges related to the ML/AI for service management in networks, systems, and services.

In [A10], Ho et al. address 5G service provisioning in an automated warehouse scenario, where swarm robotics is controlled by an industrial controller that provides routing and job instructions over the 5G network.

In [A11], Zhou et al. investigate a spatial context-aware time series forecasting framework to predict quality of service by considering both the temporal and the spatial context of users and services.

In [A12], Cao et al. introduce a Web service recommendation system via combining bilinear graph attention representation and eXtreme deep factorization machine quality prediction. It is based on content and structure-oriented service function classification.

In [A13], Tan et al. present a neural network framework, named neural attention recommendation, for auxiliary data based collaborative filtering. The goal is to alleviate the data sparsity by using auxiliary data available via Web services to improve the recommendation performance.

In [A14], Raza et al. introduce a framework that uses Bayesian optimization to find the optimal resource configuration and placement for functions in a serverless application. They use statistical learning techniques to collect samples and predict the cost and execution time of a serverless function.

In [A15], Yang et al. explore a root cause indicator location algorithm named ProphetKdeRCL. They use time series indicators and kernel density estimations. Their goal is to analyse abnormal monitoring indicators of online servcies in order to determine the root cause indicators.

C. ML/AI for Managing Performance

Eight papers in this special section focus on opportunities and challenges related to the ML/AI for performance management in networks, systems, and services.

In [A16], Deka et al. propose a semi-supervised dynamic density-based detection rule that uses the reconstruction error vectors in order to detect anomalies in cloud key performance indicators. Detecting anomalies is a critical step towards building for high availability, reliability, and high performance cloud systems.

In [A17], Qi et al. investigate LogEncoder, a framework of log sequence encoding for semi-supervised anomaly detection. Their goal is to separate normal and abnormal log event sequences for improving the performance and quality of service monitoring.

In [A18], Banerjee et al. present and evaluate their CoDeRa method that neutralizes manipulative function behavior in cognitive autonomous networks. Furthermore, they propose an alternate network management architecture to handle error propagation in function coordination caused by corrupted network data.

In [A19], Gijón et al. introduce a comprehensive analysis tackling cell and slice throughput estimation in the downlink of radio access sliced networks through supervised learning. The work is based on information collected in the operations support system.

In [A20], Garg et al. follow an implicitly coordinated and scalable self-organizing architecture. The goal is to locally optimize a global balance between the network coverage and capacity on each radio access network node using a multi-objective utility function.

In [A21], Qi et al. investigate a flexible reconstruction strategy to avoid severe performance loss in mobile and dynamic topology of satellite terrestrial integrated networks. The proposed approach uses a deep Q-learning model to optimize the node classification results and determine the range of network reconstruction.

In [A22], Qu et al. explore an environmentally-aware and energy-efficient multi-drone coordination and networking scheme to improve situational awareness in disaster response management. The scheme features a reinforcement learning based location prediction algorithm coupled with a packet forwarding algorithm for drone-to-ground network establishment.

In [A23], Lindner et al. aim to reduce the bit index explicit replication inefficiencies when its implementation requires packet recirculation to iteratively serve one next-hop after another using the P4 programming language. They use Spectral Clustering, an unsupervised machine learning technique, to configure static multicast groups on P4 switches so that traffic can be sent to all next-hops without recirculation.

D. ML/AI for Managing Security

Eight papers in this special section focus on opportunities and challenges related to the ML/AI for secuirty management in networks, systems, and services.

In [A24], Lunardi et al. present an unsupervised anomaly-based deep learning system called ARCADE (Adversarially Regularized Convolutional Autoencoder for unsupervised network anomaly DEtection). ARCADE could automatically build a profile of the normal traffic using a subset of raw bytes of a few initial packets of network flows.

In [A25], de Neira et al. present COOPRED DDoS, a cooperative system for predicting distributed denial of service attacks based on early warning signals extracted during the preparation of such attacks. Its goal lies in preventing an attacker from launching it.

In [A26], de Oliveira et al. introduce a machine learning approach to place security virtual network functions based on performance to mitigate distributed denial of service attacks on industrial Internet of Things networks.

In [A27], Vergütz et al. propose IoTReGuard, an Internet of Things based method to reveal and guard Internet of Things network traffic features. The goal is to explore network traffic features to identify the most relevant ones and hide them to protect users' privacy.

In [A28], Liu et al. investigate a non-intrusive solution of digital forensic service for smart homes. They leverage side-channel analysis on sniffed network traffic to monitor commands, actions, and states of Internet of Things devices. Then, they introduce provenance graphs for smart home modeling to provide a holistic approach.

In [A29], Ali et al. explore a multitask deep learning model for detecting malware on Internet of Things devices. They propose a Long Short-Term Memory based model for two tasks: (i) determination of whether the provided traffic is benign or malicious, and (ii) determination of the malware type for identifying malicious network traffic.

In [A30], Sagar et al. discuss an artificial neural network-based trust framework, Trust–SIoT. this framework has been envisaged for identifying the complex non-linear relationships to classify trustworthy objects in the amalgamation of the social networking concepts with the Internet of Things.

In [A31], Nowroozi et al. focus on extracting a set of lexical and Web-scrapped features and employing machine learning techniques for malicious URL detection.

E. ML/AI for General Operations and Management

Eight papers in this special section focus on opportunities and challenges related to the ML/AI for general operations and management on networks, systems, and services.

In [A32], Nascita et al. investigate interpretability via explainable artificial intelligence techniques to understand and improve the behavior of state-of-the-art multimodal and multitask deep learning based traffic classifiers. They explore and characterize the considered classifiers providing global interpretations of the data used.

In [A33], Fawaz et al. present the use of multi-agent deep learning for a set of classified network flows. The goal is to learn to cooperate principles to meet strict service level agreements in terms of throughput and end-to-end delay.

In [A34], Saha et al. explore multi-step forecasting for Internet Traffic due to its volatile and random nature. Several deep sequence models are evaluated including Recurrent Neural Network, Long Short-Term Memory and Gated Recurrent Unit with the proposed Long Short-Term Memory Encoder-Decoder model for single-step and multi-step forecast analysis.

In [A35], Zang et al. propose an encryption-independent approach from a network-side perspective by analyzing the communication behavior of the IP traffic. They identify similar service behavior clusters by employing service influence metrics, and then aim to infer the intended service.

In [A36], Huoh et al. introduce geometric deep learning that takes into account packet raw bytes, metadata and packet relations for classifying encrypted network traffic. Their goal is to leverage chronological and temporal relations for identifying encrypted network flows.

In [A37], Islam et al. explore a communication link failure prediction scheme based on the long short term memory autoencoder that considers the spatial-temporal correlation between radio communication and weather forecast. Their goal is to mitigate such service interruption on radio communications.

In [A38], Han et al. investigate the challenges of fault diagnosis in industrial control networks, where the samples of the target and source domains might not share the same fault mode label spaces. They develop a transferability-measured adversarial adaptation network to identify unknown labels without prior knowledge.

In [A39], He et al. propose a cross-lingual multi-modal misinformation detection framework for e-commerce management. The goal is to deploy the framework in an international e-commerce platform for misinformation detection.

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APPENDIX: RELATED ARTICLES

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