Guest Editorial: Special Section on Embracing Artificial Intelligence for Network and Service Management

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I. Introduction

Artificial Intelligence (AI) has the potential to leverage the immense amount of operational data of clouds, services, and social and communication networks. AI techniques have been adopted by telcoms to develop virtual assistants based on advances in natural language processing (NLP) for interaction with customers and machine learning (ML) to enhance the customer experience by improving customer flow. Machine learning has been applied to finding fraud patterns which enables operators to focus on dealing with the activity as opposed to the previous focus on detecting fraud.

These successes have fuelled a strong interest in more efficiently managing network operations and computing resources using AI techniques. However, many applications of AI for network management and prediction are at a conceptual stage or lack maturity For example, rule-based systems can be used for fault diagnostics but there is still a high percentage of faults that cannot be diagnosed by rule-based systems. Research is needed to understand and improve the potential and suitability of artificial intelligence in the context of services, systems and network management. There are opportunities to define novel platforms and algorithms that can harness the vast operational data and advanced artificial intelligence algorithms to drive management decisions in networks, data centers, and clouds. This will provide deeper understanding and better decision making based on available operational and service data. It will also present opportunities for improving artificial intelligence algorithms on aspects such as reliability, dependability and scalability, as well as demonstrate the benefits of these methods in management and control systems.

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The special section of IEEE Transactions on Network and AND SERVICE MANAGEMENT presents novel research tackling important challenges. It is the sixth special issue in this area to appear in this series [1]–[5]. The collection of papers illustrates recent trends, novel solutions and approaches to leveraging AI 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. This special issue consists of 19 papers out of 93 papers submitted to the call for novel contributions addressing the underlying challenges of embracing AI for network and service management.

II. Special Issue Overview

The special section papers span four central areas: distributed edge learning, resource management, general network and systems management, and security.

A. Distributed Edge Learning

Three papers in this special issue focus on challenges with federated learning using multiple distributed edge nodes.

In "DeepEdge: A New QoE-based Resource Allocation Framework Using Deep Reinforcement Learning for Future Heterogeneous Edge-IoT Applications" AlQerm et al [1 in Appendix] uses deep reinforcement learning to allocate resources to heterogeneous Internet of Things (IoT) applications running on the edge based on the mapping of the Quality of Service (QoS) requirements to Quality of Experience (QoE) scores.

In "Predictive UAV Base Station Deployment and Service Offloading with Distributed Edge Learning" Zhao et al [2 in Appendix] presents a framework for distributed learning using Multi-Access Edge Computing (MEC) for predicting user mobility that can be used by Unmanned Aerial Vehicles (UAVs) to provide download capacity to support usage demands.

In "Joint Optimization With DNN Partitioning and Resource Allocation in Mobile Edge Computing" Wen et al [3 in the Appendix] presents a framework that jointly allocates computing resources on IoT devices and edge nodes to support deep neural networks (DNN) inferencing based on Lyapunov Optimization.

B. Artificial Intelligence for Resource Management

Six papers in this special issue focus on artificial intelligence for resource management.

In "DQN Dynamic Pricing and Revenue Driven Service Federation Strategy" Martin-Perez et al [4 in Appendix] developed several reinforcement learning algorithms to support a federated resource management strategy based on dynamic pricing to be used when a service provide needs to lease services and/or resources from another service provider based on established agreements.

In "Real-time Multiple-Workflow Scheduling in Cloud Environments" Ma et al [5 in Appendix] addresses challenges with real-time scheduling of multiple workflows composed of tasks from these different applications. The problem is formulated as an optimization problem that relies on accurate predictions of finishing times for tasks.

In "Adaptive Feature Selection and Construction for Day-ahead Load Forecasting Use Deep Learning Method" Wang et al [6 in Appendix] uses a long short-term memory (LSTM) for load forcecasting of a smart power grid to be used for power dispatching. The forecasting takes into account external factors unique to each season.

In "AI-based Communication Virtualization for Network Management in Society 5.0" Misra et al [7 in Appendix] manages network services and increases data transmission efficiency. To reduce transmission and energy consumption while transmitting the data from end devices requires that each edge device performs concurrent data transmission by associating with a virtual access point which is determined through fuzzy c-means clustering.

"Embracing Complexity: Agent-based Modeling for HetNets Design and Optimization via Concurrent Reinforcement Learning Algorithm" Ibrahim et al [8 in Appendix] focusses on wireless heterogeneous networks (HetNets) with an emphasis on different aspects of spectrum management. This requires optimizing certain paramters. Based own their investigation of drawbacks of previously used techniques that have been previously used they developed an agent-based model model that uses rules for determining actions. ML can be used to adapt rules.

"Harnessing UAVs for Fair 5G Bandwidth Allocation in Vehicular Communication via Deep Reinforcement Learning" Yuan et al [9 in Appendix] uses distributed reinforcement learning for dynamic UAV placement with a focus on netework resource allocation fairness.

C. Artificial Intelligence for General Network Management

In "VNE-HRL: A Proactive Virtual Network Embedding Algorithm Based on Hierarchical Reinforcement Learning" Cheng et al [10 in Appendix] uses hierarchical reinforcement learning for the embedding of virtual networks into a substrate network. This is a significant improvement over previous heuristics that provide feasible embedding solutions with low execution time but often produce a solution at a local optimum that may be far away from the global optimum.

In "Motion-Aware Optimizations for Downlink MU-MIMO in 802.11ax Networks" Su et al [11 in appendix] developed an algorithm that uses network client density and spatial streaming for optimization purposes. They developed a throughput model related to client motion based on a regression model.

In "Deep Learning and Traffic Classification: Lessons learned from a commercial-grade dataset with hundreds of encrypted and zero-day applications" Yang et al [12 in Appendix] uses a commercial grade dataset comprising of tens of millions of flows and thousands of application labels. This represents a data set that is larger than that typically found in many research papers. This is used to evaluate the state of the art machine learning and deep learning methods for traffic data. They then developed a variation of deep learning for traffic classification.

In "Log Sequence Anomaly Detection Based on Local Information Extraction and Globally Sparse Transformer Model" Zhang et al [13 in Appendix]focusses on log sequence anomaly detection. Log files record information on system operations. A log sequence represents logs organized by their creation. Past work based on rules are not alway successful since patterns are difficult to predict. This work presents a log sequence anomaly detector using unsupervised learning.

In "Multi-Objective Deep Reinforcement Learning Assisted Service Function Chains Placement" Bi et al [14 in Appendix] proposes and evaluates a deep reinforcement learning algorithm, Chebyshev-assisted Actor-Critic Algorithm, that considers multiple objectives in the placement of Service Function Chains (SFCs) and addresses the limitations of the previous work was not scalable.

In "A Packet Loss Monitoring System for In-band Network Telemetry: Detection, Localization, Diagnosis and Recovery" Tan et tal [15 in Appendix] proposes LossLight that includes detecting packet loss, deducing the time and location of loss, diagnosing the cause of loss and recovering lost information. The evaluation shows that LossSight has excellent performance and low overhead. LossSight uses a generative adversarial network to recover lost telemetry information.

In "Predicting traffic overflows on private peering" Rapaport et al [16 in Appendix] describes their use of an ensemble of deep learning models trained over a short enough time period so that action can be taken to handle the excess traffic.

In "Neural and Attentional Factorization Machine Based Web API Recommendation for Mashup Development" Kang et al [17 in Appendix] addresses limitations with service selection with a new hybrid factorization machine model based on the integration deep neural network and attention mechananism to capture the importance of feature interactions to support service recommendation.

D. Artificial Intelligence for Security Management

In "Network Abnormal Traffic Detection Model Based on Semi-Supervised Deep Reinforcement Learning" Dong et al [18 in Appendix] focusses on improving ML-based detection methods by reducing the reliance on manual extraction of traffic features. Their goal is real-time detection. The paper proposes a method that is implemented by combining two unsupervised learning algorithms: Auto Encoder and K-Means.

In "Abnormal Behavior Detection Based on Traffic Pattern Categorization in Mobile Cellular Networks" DeAlmeida et al [19 in Appendix] uses the unsupervised learning algorithm, energy-based flow classifier, to detect abnormal behaviour in

mobile cellular networks. The evaluation used a real dataset provided by an Italian operator and includes a comparison with state of art solutions. The proposal approach showed an improvement of 35%.

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APPENDIX

1) Ismail AlQerm and Jianli Pan, "DeepEdge: A New QoE-based Resource Allocation Framework Using Deep Reinforcement Learning for Future Heterogeneous Edge-IoT Applications", IEEE Trans. Netw. Service Manag., vol. 18, no. 4,
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16) Elad Rapaport, Ingmar Poese, Polina Zilberman, Oliver Holschke, and Rami Puzis "Predicting traffic overflows on private peering", IEEE Trans. Netw. Service Manag., vol. 18, no. 4,
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18) Shi Dong, Yuanjun Xia, Tao Pen "Network Abnormal Traffic Detection Model Based on Semi-Supervised Deep Reinforcement Learning" IEEE Trans. Netw. Service Manag., vol. 18, no. 4,
19) Jonathan M. DeAlmeida, Camila Pontes, Luiz A. DaSilva, Chrstiano Both Bonato, Joo Gondim, Clia Ralha, Marcelo Marotta "Abnormal Behavior Detection Based on Traffic Pattern Categorization in Mobile Cellular Networks" IEEE Trans. Netw. Service Manag., vol. 18, no. 4,

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