

# Guest Editorial: Special Section on Networks, Systems, and Services Operations and Management Through Intelligence

## I. INTRODUCTION

**M**ACHINE Learning (ML) and Artificial Intelligence (AI) can harness the immense amount of operational data from clouds to services, to social and communication networks. In the era of data science and connected devices of all varieties, Intelligence have found ways to improve operations and management of next generation networks, systems, and services. Further research is therefore needed to understand and improve the potential and suitability of ML/AI in the context of network, system, and service operations and 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 ML/AI 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 ML/AI algorithms to drive management decisions in open and highly programmable networks, clouds, and data centers.

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 focuses on recent, emerging approaches and technical models that exploits intelligence in network and service management solutions. It is the seventh special section to appear in this series, after in [A1], [A2], [A3], [A4], [A5], [A6], [A7], [A8]. The collection of works we present illustrates recent trends, novel solutions and

approaches to leverage intelligence in Network and Service operations and management, as well as to extract insights from data that can guide system operators and managers in their daily activities. In this most recent special section presented here, we have accepted 18 papers out of 98 papers submitted to the open call for novel contributions addressing the underlying opportunities and challenges of *Networks, Systems and Services Operations and Management through Intelligence*.

## II. SPECIAL ISSUE SECTION OVERVIEW

The special section papers span several 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 General Operations and Management, (iii) ML/AI for Managing Security, and (iv) ML/AI for Managing Performance.

### A. ML/AI for Managing Resources

In [A9], Emu et al. focusses on data management for Metaverse requirements. The Stochastic Integer Programming (SIP) model is used for optimizing resource allocation by leveraging Quantum Neural Networks (QNN).

In [A10], Tian et al. proposes a novel self-adaptive network slicing (SNS) modeling scheme that considers heterogeneous QoS requirements.

In [A11], Tian et al. describes a new structured federated learning method for spatial-temporal data modeling under data decentralized due to privacy issues by using a split of a complete model into several pieces which can subsequently be deployed on several machines separately and trained individually.

### B. ML/AI for General Operations and Management

In [A12], Liu et al. provides algorithms for analysis of multi-source log inputs. In [A13], Yaacoub et al. aims to reduce energy and memory consumption of executing AI/ML models for adapting the configuration of mobile network systems. In [A14], Carmel and Keslassy presents the Dragonfly system that classifies the congestion control algorithm of any flow that crosses a given router. In [A15], Gioacchini et al. enables network providers and their customers to share AI-based models that describe traffic in their networks. This paper show that knowledge can be transferred across networks.

### C. ML/AI for Managing Security

In [A16], Diallo and Patras provides a novel approach to malicious traffic classification that can be used for deployment at the network edge. In [A17], Malekghaini et al. describes the AutoML4ETC tool that automatically designs an efficient and high-performing neural network architectures for a target dataset. In [A18], Chen et al. focusses on greedy behavior detection methods using machine learning algorithm to classify and fight against channel access. In [A19], Li et al. proposes a Schmitt-based four-dimensional space-based data multi-embedding mechanism to protect data in the network.

### D. ML/AI for Managing Performance

In [A21], Seufert et al. focusses on anomaly detection techniques that includes a framework that uses machine learning (ML) models to monitor traffic flows and map them to critical events. In [A22], Portela et al. developed a forecasting model (T-For) that adjusts the time series of throughput measurements using a set of statistical analyses. In [A23], Collet et al. presents a forecasting model learn the loss function based on the management objective. In [A24], Seufert and Orsolich highlights that assessing the quality of user experience is difficult when there is encrypted traffic and the previous work developed models on limited set of network scenarios. The paper addresses this by having QoE/KPI estimation models trained on 4 separate datasets. In [A25], Bagora et al. presents a suite based active learning framework for automated labeling of cloud metrics data with the corresponding cloud system state while accounting for emerging fault patterns and data or concept drifts.

### ACKNOWLEDGMENT

We sincerely thank the authors for contributing their papers and the reviewers for their thorough assessment and their work to improve the quality and presentation of each paper. We are very grateful to the Editor-in-Chief Hanan Lutfiyya for her continuous support throughout the process and to Janine Bruttin for her help with the administrative tasks associated to this special section.

### APPENDIX: RELATED ARTICLES

- [A1] G. Casale, Y. Diao, H. Lutfiyya, P. Owezarski, and D. Raz, "Guest editors' introduction: Special issue on big data analytics for management," *IEEE Trans. Netw. Service Manag.*, vol. 13, no. 3, pp. 578–580, Sep. 2016, doi: [10.1109/TNSM.2016.2598093](https://doi.org/10.1109/TNSM.2016.2598093).
- [A2] G. Casale, Y. Diao, M. Mellia, R. Ranjan, and N. Zincir-Heywood, "Guest editorial: Special section on advances in big data analytics for management," *IEEE Trans. Netw. Service Manag.*, vol. 15, no. 1, pp. 10–12, Mar. 2018, doi: [10.1109/TNSM.2018.2806897](https://doi.org/10.1109/TNSM.2018.2806897).
- [A3] D. Carrera, G. Casale, T. Inoue, H. Lutfiyya, J. Wang, and N. Zincir-Heywood, "Guest editorial: Special section on novel techniques in big data analytics for management," *IEEE Trans. Netw. Service Manag.*, vol. 16, no. 3, pp. 797–799, Sep. 2019, doi: [10.1109/TNSM.2019.2934363](https://doi.org/10.1109/TNSM.2019.2934363).
- [A4] N. Zincir-Heywood et al., "Guest editorial: Special section on data analytics and machine learning for network and service management—Part I," *IEEE Trans. Netw. Service Manag.*, vol. 17, no. 4, pp. 1971–1974, Dec. 2020, doi: [10.1109/TNSM.2020.3038736](https://doi.org/10.1109/TNSM.2020.3038736).
- [A5] N. Zincir-Heywood et al., "Guest editorial: Special issue on data analytics and machine learning for network and service management—Part II," *IEEE Trans. Netw. Service Manag.*, vol. 18, no. 1, pp. 775–779, Mar. 2021, doi: [10.1109/TNSM.2021.3058742](https://doi.org/10.1109/TNSM.2021.3058742).
- [A6] H. Lutfiyya et al., "Guest editorial: Special section on embracing artificial intelligence for network and service management," *IEEE Trans. Netw. Service Manag.*, vol. 18, no. 4, pp. 3936–3941, Dec. 2021, doi: [10.1109/TNSM.2021.3127543](https://doi.org/10.1109/TNSM.2021.3127543).
- [A7] N. Zincir-Heywood et al., "Guest editorial: Special issue on machine learning and artificial intelligence for managing networks, systems, and services—Part I," *IEEE Trans. Netw. Service Manag.*, vol. 19, no. 4, pp. 3988–3994, Dec. 2022, doi: [10.1109/TNSM.2022.3227775](https://doi.org/10.1109/TNSM.2022.3227775).
- [A8] N. Zincir-Heywood et al., "Guest editorial: Special section on machine learning and artificial intelligence for managing networks, systems, and services—Part II," *IEEE Trans. Netw. Service Manag.*, vol. 20, no. 2, pp. 882–889, Jun. 2023, doi: [10.1109/TNSM.2023.3280230](https://doi.org/10.1109/TNSM.2023.3280230).
- [A9] M. Emu, S. Choudhury, and K. Salomaa, "Stochastic resource optimization for metaverse data marketplace by leveraging quantum neural networks," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2608–2612, Jun. 2024, doi: [10.1109/TNSM.2024.3389048](https://doi.org/10.1109/TNSM.2024.3389048).
- [A10] C. Tian, H. Cao, J. Xie, S. Garg, M. Alrashoud, and P. Tiwari, "Community detection-empowered self-adaptive network slicing in multi-tier edge-cloud system," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2624–2636, Jun. 2024, doi: [10.1109/TNSM.2023.3332509](https://doi.org/10.1109/TNSM.2023.3332509).
- [A11] Y. Tian et al., "Towards robust and generalizable federated graph neural networks for decentralized spatial-temporal data modeling," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2637–2650, Jun. 2024, doi: [10.1109/TNSM.2024.3386740](https://doi.org/10.1109/TNSM.2024.3386740).
- [A12] Y. Liu, S. Tao, W. Meng, J. Wang, H. Yang, and Y. Jiang, "Multi-source log parsing with pre-trained domain classifier," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2651–2663, Jun. 2024, doi: [10.1109/TNSM.2023.3329144](https://doi.org/10.1109/TNSM.2023.3329144).
- [A13] K. E. Yaacoub, O. Stenhammar, S. Ickin, and K. Vandikas, "Continual learning with Siamese neural networks for sustainable network management," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2664–2674, Jun. 2024, doi: [10.1109/TNSM.2024.3368928](https://doi.org/10.1109/TNSM.2024.3368928).
- [A14] D. Carmel and I. Keslassy, "Dragonfly: In-flight CCA identification," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2675–2685, Jun. 2024, doi: [10.1109/TNSM.2024.3380417](https://doi.org/10.1109/TNSM.2024.3380417).
- [A15] L. Gioacchini et al., "Cross-network embeddings transfer for traffic analysis," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2686–2699, Jun. 2024, doi: [10.1109/TNSM.2023.3329442](https://doi.org/10.1109/TNSM.2023.3329442).
- [A16] A. F. Diallo and P. Patras, "Cluster and conquer: Malicious traffic classification at the edge," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2700–2714, Jun. 2024, doi: [10.1109/TNSM.2023.3342716](https://doi.org/10.1109/TNSM.2023.3342716).
- [A17] N. Malekghaini et al., "AutoML4ETC: Automated neural architecture search for real-world encrypted traffic classification," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2715–2730, Jun. 2024, doi: [10.1109/TNSM.2023.3324936](https://doi.org/10.1109/TNSM.2023.3324936).
- [A18] M. Chen, J. Ben-Othman, and L. Mokdad, "Greedy behavior detection with machine learning for LoRaWAN network," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2731–2740, Jun. 2024, doi: [10.1109/TNSM.2024.3351313](https://doi.org/10.1109/TNSM.2024.3351313).
- [A19] M. Li, H. Cui, C. Liu, C. Shan, X. Du, and M. Guizani, "A four-dimensional space-based data multi-embedding mechanism for network services," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2741–2750, Jun. 2024, doi: [10.1109/TNSM.2023.3339674](https://doi.org/10.1109/TNSM.2023.3339674).
- [A20] N. Alhussien, A. Aleroud, A. Melhem, and S. Y. Khamaiseh, "Constraining adversarial attacks on network intrusion detection systems: Transferability and defense analysis," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2751–2772, Jun. 2024, doi: [10.1109/TNSM.2024.3357316](https://doi.org/10.1109/TNSM.2024.3357316).
- [A21] M. Seufert et al., "Marina: Realizing ML-driven real-time network traffic monitoring at terabit scale," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2773–2790, Jun. 2024, doi: [10.1109/TNSM.2024.3382393](https://doi.org/10.1109/TNSM.2024.3382393).
- [A22] A. L. C. Portela, S. E. S. B. Ribeiro, R. A. Menezes, T. de Araujo, and R. L. Gomes, "T-For: An adaptable forecasting model for throughput performance," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2791–2801, Jun. 2024, doi: [10.1109/TNSM.2024.3349701](https://doi.org/10.1109/TNSM.2024.3349701).
- [A23] A. Collet, A. Bazco-Nogueras, A. Banchs, and M. Fiore, "Explorable and transferable loss meta-learning for zero-touch anticipatory network management," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2802–2823, Jun. 2024, doi: [10.1109/TNSM.2024.3377442](https://doi.org/10.1109/TNSM.2024.3377442).
- [A24] M. Seufert and I. Orsolich, "Improving the transfer of machine learning-based video QoE estimation across diverse networks," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2824–2836, Jun. 2024, doi: [10.1109/TNSM.2023.3326664](https://doi.org/10.1109/TNSM.2023.3326664).

- [A25] P. Bagora, A. Ebrahimzadeh, F. Wuhib, and R. H. Glitho, "Labeling cloud metrics data for fault detection in cloud using active learning with test suite," *IEEE Trans. Netw. Service Manag.*, vol. 21, no. 3, pp. 2837–2853, Jun. 2024, doi: [10.1109/TNSM.2024.3355310](https://doi.org/10.1109/TNSM.2024.3355310).

NUR ZINCIR-HEYWOOD  
Faculty of Computer Science  
Dalhousie University  
Halifax, NS B3H 4R2, Canada

ROBERT BIRKE  
Department of Computer Science  
University of Turin  
10124 Turin, Italy

ELIAS BOU-HARB  
College of Business  
The University of Texas at San Antonio  
San Antonio, TX 78249 USA

TAKERU INOUE  
NTT Corporation  
NTT Network Innovation Laboratories  
Yokosuka 239, Yokoham, Japan

NEERAJ KUMAR  
Department of Computer Science and Engineering  
Thapar Institute of Engineering and Technology  
Patiala 147004, India

HANAN LUTFIYYA  
Department of Computer Science  
Western University  
London, ON N6A 3K7, Canada

DEEPAK PUTHAL  
School of Computing  
Newcastle University  
NE1 7RU Newcastle upon Tyne, U.K.

ABDALLAH SHAMI  
Electrical and Computer Engineering  
Western University  
London, ON N6A 3K7, Canada

NATALIA STAKHANOVA  
Department of Computer Science  
University of Saskatchewan  
Saskatoon, SK S7N 5A2, Canada



**Nur Zincir-Heywood** (Member, IEEE) is a Dalhousie Distinguished Research Professor and an Associate Deans Research of Computer Science with Dalhousie University, Canada. She is the Co-Editor of the books *Communication Networks and Service Management in the Era of Artificial Intelligence and Machine Learning* (Wiley/IEEE), and *Recent Advances in Computational Intelligence in Defense and Security* (Springer) as well as the coauthor of the book *Nature-Inspired Cyber Security and Resiliency: Fundamentals, Techniques, and Applications* (IET). Her research interests include machine learning and artificial intelligence for cyber security, network, systems, and information analysis, topics on which she has published over 200 fully reviewed papers. She is a recipient of several best paper awards as well as the Supervisor for the recipient of the IFIP/IEEE IM 2013 Best Ph.D. Dissertation Award in Network Management. She is an Associate Editor of the IEEE TRANSACTIONS ON NETWORK AND SERVICE MANAGEMENT, *International Journal of Network Management* (Wiley), and a Guest Editor on *Journal of Network and Systems Management* (Springer).



**Robert Birke** (Senior Member, IEEE) received the Ph.D. degree in electronics and communications engineering from the Politecnico di Torino, Italy, in 2009. He is a tenured Assistant Professor with the University of Turin, Italy. He has been a Visiting Researcher with IBM Research Zurich, Switzerland, and a Principal Scientist with ABB Corporate Research, Switzerland. He has published more than 90 papers at venues related to communication, system performance and machine learning, e.g., SIGCOMM, SIGMETRICS, FAST, INFOCOM, ACML, and JSAC. His research interests are in the broad area of virtual resource management, including network design, workload characterization, and AI and big-data application optimization.



**Elias Bou-Harb** (Senior Member, IEEE) received the Ph.D. degree in computer science from Concordia University, Montreal, Canada, which was executed in collaboration with Public Safety Canada, Industry Canada, and NCFTA Canada. He is currently the Director of the Cyber Center For Security and Analytics, UTSA, where he leads, directs and organizes university-wide innovative cyber security research, development and training initiatives. He is also a tenured Associate Professor with the Department of Information Systems and Cyber Security specializing in operational cyber security and data science as applicable to national security challenges. Previously, he was a Senior Research Scientist with Carnegie Mellon University, where he contributed to federally-funded projects related to critical infrastructure security and worked closely with the Software Engineering Institute. He has authored more than 130 refereed publications in leading security and data science venues, has acquired significant state and federal cyber security research grants. His research and development activities and interests focus on operational cyber security, attacks' detection and characterization, malware investigation, cyber security for critical infrastructure, and big data analytics. He is the recipient of five Best Research Paper Awards, including the prestigious ACM's Best Digital Forensics Research Paper.



**Takeru Inoue** (Member, IEEE) received the B.E. and M.E. degrees in engineering science and the Ph.D. degree in information science from Kyoto University, Japan, in 1998, 2000, and 2006, respectively. He joined Nippon Telegraph and Telephone Corporation Laboratories in 2000, where he is currently a Distinguished Researcher. He was an ERATO Researcher with Japan Science and Technology Agency from 2011 to 2013, where his research focused on algorithms and data structures. His research interests widely cover algorithmic approaches in communication networks. He is an Associate Editor of the IEEE TRANSACTIONS ON NETWORK AND SERVICE MANAGEMENT. He is a member of the Institute of Electronics, Information, and Communication Engineers.



**Neeraj Kumar** (Member, IEEE) is working as a Full Professor with the Department of Computer Science and Engineering, Thapar Institute of Engineering and Technology (Deemed to be University), Patiala, India. He is also adjunct professor at various organizations in India and abroad. He has published more than 400 technical research papers in top-cited journals and conferences which are cited more than 31500 times from well-known researchers across the globe with current H-index of 97. He is highly cited researcher in the list released by the Web of Science in 2019, 2020, and 2021. He has guided many research scholars leading to Ph.D. (14) and M.E./M.Tech. (24). His research is supported by funding from various competitive agencies across the globe. He has also edited/authored ten books with International/National Publishers like IET, Springer, Elsevier, and CRC titled *Security and Privacy of Electronic Healthcare Records: Concepts, Paradigms and Solutions* in (ISBN-13: 978-1-78561-898-7), *Machine Learning for Cognitive IoT* (CRC Press), *Blockchain, Big Data and Machine learning* (CRC Press), *Blockchain Technologies Across Industrial Vertical* (Elsevier), *Multimedia Big Data Computing for IoT Applications: Concepts, Paradigms and Solutions* (ISBN: 978-981-13-8759-3), *Proceedings of First International Conference on Computing, Communications, and Cyber-Security* in 2019 (978-981-15-3369-3), *Probabilistic Data Structures for Blockchain-Based IoT Applications* (CRC Press). One of the edited text-book titled, *Multimedia Big Data Computing for IoT Applications: Concepts, Paradigms, and Solutions* published in (Springer, 2019), is having 3.5 million downloads till 6 June 2020. It attracts attention of the researchers across the globe. His broad research areas are green computing and network management, IoT, big data analytics, deep learning and cyber-security. He has won the Best Papers Award from IEEE Systems Journal and IEEE ICC 2018, Kansas-City in 2018. He won the Best Researcher Award from TIET, Patiala, India, every year from last eight consecutive years. He is serving as an Editor of *ACM Computing Survey*, IEEE TRANSACTIONS ON SUSTAINABLE COMPUTING, IEEE TRANSACTIONS ON NETWORK AND SERVICE MANAGEMENT, *IEEE Network Magazine*, *IEEE Communication Magazine*, *Journal of Networks and Computer Applications* (Elsevier), *Computer Communication* (Elsevier), and *International Journal of Communication Systems* (Wiley). Also, he has organized various special issues of journals of repute from IEEE, Elsevier, and Springer. He has been the Workshop Chair at IEEE Globecom 2018, IEEE Infocom 2020, and IEEE ICC 2020, and the Track Chair of Security and Privacy of IEEE MSN 2020. He is also the TPC Chair and a member for various International conferences, such as IEEE MASS 2020 and IEEE MSN2020.



**Hanan Lutfiyya** (Senior Member, IEEE) is a Professor with the Department of Computer Science, Western University, Canada. Her research interests include Internet of Things, software engineering, self-adaptive and self-managing systems, autonomic computing, monitoring and diagnostics, mobile systems, policies, and clouds. She was a recipient of the UWO Faculty Scholar Award in 2006. She is currently an Associate Editor of the IEEE TRANSACTIONS ON NETWORK AND SERVICE MANAGEMENT, and has recently served as the General Co-Chair for the IEEE International Conference on Network and Service Management. She is currently on the board of Directors for CS-CanInfo-Can. She is a past member of the Natural Science and Engineering Research Council of Canada (NSERC) Discovery Grant Committee, and a past member and the Chair of an NSERC Strategic Grants Committee. She was a member of the Computer Science Accreditation Council.



**Deepak Puthal** (Member, IEEE) is a Lecturer (Assistant Professor) with the School of Computing, Newcastle University, U.K. Prior to this position, he was a Lecturer with the University of Technology Sydney, Australia, an Associate Researcher with Commonwealth Scientific and Industrial Research Organization (CSIRO Data61), Australia, and a Research Associate with Qatar Mobility Innovations Center, Qatar. His research spans several areas in cyber security, blockchain, Internet of Things, and edge/fog computing. He has received several recognitions and best paper awards from IEEE. He serves on the editorial boards of top quality international journals, including IEEE TRANSACTIONS ON BIG DATA, *IEEE Consumer Electronics Magazine*, *Computers and Electrical Engineering* (Elsevier), *International Journal of Communication Systems* (Wiley), and *Internet Technology Letters* (Wiley).



**Abdallah Shami** (Senior Member, IEEE) received the B.E. degree in electrical and computer engineering from Lebanese University, Beirut, Lebanon, in 1997, and the Ph.D. degree in electrical engineering from the Graduate School and University Center, The City University of New York, New York, NY, USA, in 2003. He is currently a Professor with the Electrical and Computer Engineering Department and the Acting Associate Dean (Research) of the Faculty of Engineering, Western University, London, ON, Canada, where he is also the Director of the Optimized Computing and Communications Laboratory. He has chaired key symposia for the IEEE GLOBECOM, IEEE International Conference on Communications, and IEEE International Conference on Computing, Networking and Communications. He is currently an Associate Editor of the IEEE TRANSACTIONS ON MOBILE COMPUTING, IEEE NETWORK, and IEEE COMMUNICATIONS SURVEYS AND TUTORIALS. He was the Elected Chair for the IEEE Communications Society Technical Committee on Communications Software from 2016 to 2017

and the IEEE London Ontario Section Chair from 2016 to 2018.



**Natalia Stakhanova** is the Canada Research Chair of Security and Privacy, and an Associate Professor with the University of Saskatchewan, Canada. She is a former NB Innovation Research Chair of Cybersecurity with the University of New Brunswick. Her work focuses on software security. She has published over 60 publications in the areas of mobile security, software protection, and code attribution. Working closely with the industry on a variety of research and development projects, she developed a number of technologies that resulted in four patents in the field of computer security and have been adopted by high-tech companies. She is the recipient of numerous recognitions and awards including the top 20 Women in Cybersecurity, the CyberNB Recognition Award, and the McCain Young Scholar Award and the Anita Borg Institute Faculty Award.