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Artificial Intelligence based Future Mobile Networks

Presented by

Haijun Zhang, University of Science and Technology Beijing, China
Yansha Deng, King's College London (KCL), U.K
Arumugam Nallanathan, Queen Mary University of London (QMUL), U.K

Abstract

This tutorial will identify and discuss technical challenges and recent results related to the Artificial Intelligence (AI) based future wireless networks. The tutorial is mainly divided into five parts. In the first part, we will introduce future wireless networks and AI, discuss about the future wireless networks architecture, and provide some main technical challenges in AI based future wireless networks. In the second part, we will focus on the issue of AI based resource management in future wireless networks and provide different recent research findings that help us to develop engineering insights. In the third part, we will address the signal processing and PHY layer design of AI based future wireless networks and address some key research problems. In the fourth part, we will present the AI enabled dynamic optimization for IoT. In the last part, we will summarize by providing a future outlook of AI based future wireless networks.

Brief Description

Nowadays, the mobile network no longer just connects people but is evolving into billions of devices, such as sensors, controllers, machines, autonomous vehicles, drones, people and things with each other and then achieves information and Intelligence. From a planning and optimization perspective on the mobile network, this means that we also need a lot more flexibility to address these future needs.

Next-generation (B5G/6G) mobile networks are characterized by three key features: heterogeneity, in terms of technology and services, dynamics, in terms of rapidly varying environments and uncertainty, and size, in terms of number of users, nodes, and services. The need for smart, secure, and autonomic network design has become a central research issue in a variety of applications and scenarios. Intelligence (AI) and future mobile networks have attracted intense interest from both academia and industry to potentially improve spatial reuse and coverage, thus allowing cellular systems to achieve higher data rates, while retaining the seamless connectivity and mobility of cellular networks. However, considering the severe inter-tier interference and limited cooperative gains resulting from the constrained and non-ideal transmissions between adjacent base stations, a new paradigm for improving both spectral efficiency and energy efficiency through suppressing inter-tier interference and enhancing the cooperative processing capabilities is needed in the practical evolution of AI based future mobile networks.

This tutorial will identify and discuss technical challenges and recent results related to the AI based future mobile networks. The tutorial will introduce future mobile networks and AI, discuss about the future mobile networks architecture, AI based resource management, PHY layer design with AI and providing a future outlook of AI based future mobile networks.

Outline

Part I: Overview of Future Mobile Networks and AI
- RAN Evolutions: Brief introduction of UDN, SON, Fog RAN, and their potential evolution.
- Introduction of AI based Future Mobile Networks: Features, definitions, challenges, and state of the art.
- System architecture: Fronthaul, Fog/cloud computing, heterogeneous networks, performance metrics

Part II: AI based Resource Management in Future Mobile Networks
- Intelligent Resource allocation with heterogeneous services
- Resource allocation: A cooperative bargaining game theoretic approach
- NOMA based resource allocation in future mobile networks
- Cross layer optimization in AI based future mobile networks
- User association and power allocation using deep learning

Part III: AI based Interference Management in Future Mobile Networks
- Learning based interference mitigation
- AI based interference mitigation and handover management
- Coexistence of Wi-Fi and UDN with LTE-U
- Incomplete CSI based resource optimization in SWIPT

Part IV: AI enabled dynamic optimization in IoT
- Deep reinforcement learning in NB-IoT

Part V: Outlook of AI based Future Mobile Networks
- Evolution of AI based Future Mobile Networks: Future research challenges

Potential Participants

The half-day tutorial is intended for the generally knowledgeable individual working in the field of wireless communications and networking with some background in convex optimization, game theory and AI. It is also suitable for students and researchers who are interested to learn about AI, UDN, Heterogeneous Networks, Small Cells, LTE-U, C-RAN, SWIPT, and 5G/6G.

Short CV of speakers

Haijun Zhang (M'13, SM'17) is currently a Full Professor in University of Science and Technology Beijing, China. He was a Postdoctoral Research Fellow in Department of Electrical and Computer Engineering, the University of British Columbia (UBC), Vancouver Campus, Canada. He visited KCL from 2011 to 2012. He serves as Editor of IEEE Transactions on Communications, IEEE Transactions on Green Communications and Networking, IEEE Communications Letters, and IEEE Future Networks Tech Focus.

He serves/served as General Co-Chair of GameNets'16 and 5GWN'19, Symposium Chair of Globecom'19, TPC Co-Chair of INFOCOM'18/19 Workshop IECCO, General Co-Chair of ICC'18/ICC'17/Globecom'17 Workshop on UDN, and General Co-Chair of Globecom'17 Workshop on LTE-U. He received the IEEE CSIM Technical Committee Best Journal Paper Award in 2018 and IEEE ComSoc Young Author Best Paper Award in 2017.

Yansha Deng (S'13–M'18) received the Ph.D. degree in electrical engineering from the Queen Mary University of London, U.K., in 2015. From 2015 to 2017, she was a Post-Doctoral Research Fellow with
King's College London, U.K, where she is currently a Lecturer (Assistant Professor) with the Department of Informatics. Her research interests include molecular communication, Internet of Things, and 5G wireless networks. She has served as a TPC member for many IEEE conferences, such as IEEE GLOBECOM and ICC. She was a recipient of the Best Paper Awards from ICC 2016 and GLOBECOM 2017 as the first author. She also received the Exemplary Reviewer Award for the IEEE TRANSACTIONS ON COMMUNICATIONS in 2016 and 2017. She is currently an Editor of the IEEE TRANSACTIONS ON COMMUNICATIONS and the IEEE COMMUNICATION LETTERS.

Arumugam Nallanathan (F'17) is Professor of Wireless Communications and the Head of Communication Systems Research (CSR) Group in the School of Electronic Engineering and Computer Science at Queen Mary University of London (QMUL) from September 2017. He was with the Department of Informatics at King's College London from December 2007 to August 2017, where he was Professor of Wireless Communications from April 2013 to August 2017. He was an Assistant Professor in the Department of Electrical and Computer Engineering, National University of Singapore from August 2000 to December 2007. He published nearly 300 technical papers in scientific journals and international conferences. He is a co-recipient of the Best Paper Award presented at the IEEE International Conference on Communications 2016 (ICC'2016) and IEEE International Conference on Ultra-Wideband 2007
(ICUWB' 2007). He is an IEEE Distinguished Lecturer. He has been selected as a 'Thomson Reuters Highly Cited Researcher' in 2016. He is an Editor for IEEE Transactions on Communications and IEEE Transactions on Vehicular Technology. He was an Editor for IEEE Transactions on Wireless Communications (2006-2011), IEEE Wireless Communications Letters and IEEE Signal Processing Letters.

He served as the Chair for the Signal Processing and Communication Electronics Technical Committee of IEEE Communications Society. He received the IEEE Communications

Society SPCE outstanding service award 2012 and IEEE Communications Society RCC outstanding service award 2014.

Prior History of Tutorial

1. **Haijun Zhang**, et al, "Ultra Dense Networks: Principles and Technologies," IEEE International Conference on Communications (**ICC 2018**), Kansas City, MO, USA, 2018.
2. **Haijun Zhang** "Ultra Dense Networks," **WiOpt 2018**, Shanghai, China, 2018.
3. **Haijun Zhang** "Ultra Dense Networks: Principles and Technologies," IEEE International Conference on Hot Topics in Information-centric Networking (IEEE **HotICN 2018**), Shenzhen, China, Aug 15th-17th, 2018.
4. **Haijun Zhang**, David Lopez-Perez, and Ming Ding, "Ultra Dense Networks: Principles and Technologies," **PIMRC 2017**, Montreal, QC, Canada, 08-13 Oct. 2017.
5. **Haijun Zhang** "Heterogeneous Ultra Dense Networks: Principles and Technologies," IEEE/CIC International Conference on Communications in China (**ICCC 2017**), Qingdao, China, Oct. 2017.
6. **Haijun Zhang**, et al, "Ultra Dense Heterogeneous Small Cell Networks in 5G: Principles and

   Technologies", The 19th International Symposium on Wireless Personal Multi-media Communications (**WPMC 2016**), Shenzhen, China, Nov. 16, 2016.
7. **Yansha Deng**, et al, " Molecular Communication: Methods, Simulations, and Experiments", IEEE Global Telecommunications Conference' 2018 (GLOBECOM 2018), Abu Dhabi, December, 2018.
8. **Arumugam Nallanathan**, et al, " Invoking Emerging Analytical Tools for NOMA: Matching Theory, Stochastic Geometry and Machine Learning", IEEE ICCC'2018, China, July 2018.

Lecture Experience of Tutorial Speaker

Prof. Haijun Zhang has given a series of invited talks and short courses on ultra dense networks and heterogeneous networks at several universities, public and private research institutions in Asia and North America. In addition, they have been delivering courses and lectures on wireless communications and networking at UBC, USTB, and overseas universities on a regularly basis. Dr. Yansha Deng has given tutorials on Molecular Communications. Professor Arumugam Nallanathan have tutorials on NOMA.

Selected Publications of the speakers related to the tutorial

1. J. Wang, C. Jiang, H. Zhang, V. Leung and L. Hanzo, "Learning-Aided Network Association for Hybrid Indoor LiFi-WiFi Systems," IEEE Transactions on Vehicular Technology, 2017.
2. C. Jiang, H. Zhang, Y. Ren, Z. Han, K. C. Chen, and L. Hanzo, "Machine Learning Paradigms for Next-Generation Wireless Networks," IEEE Wireless Communications, vol. 24, no. 2, pp. 98-105, Apr. 2017.

3. Q. Zheng, K. Zheng, H. Zhang, and V. C. M. Leung, "Delay-Optimal Virtualized Radio Resource Scheduling in Software-Defined Vehicular Networks via Stochastic Learning," IEEE Transactions on Vehicular Technology, vol. 65, no. 10, pp. 7857-7867, Oct. 2016.
4. K. Lei, Y. Li, X. Piao and H. Zhang, "NDN Producer Mobility Management based on Echo State Network: a Lightweight Machine Learning Approach," *Proceedings of the 24th International Conference on Parallel and Distributed Systems (ICPADS)*, Singapore, Dec. 11-13, 2018.
5. H. Zhang, S. Huang, C. Jiang, K. Long, V. C. M. Leung, and H. Vincent Poor, ``Energy Efficient User Association and Power Allocation in Millimeter Wave Based Ultra Dense Networks with Energy Harvesting Base Stations," IEEE Journal on Selected Areas in Communications, 2017.
6. H. Zhang, Y. Dong, J. Cheng, and V. C.M. Leung, "Fronthauling for 5G LTE-U Ultra Dense
Cloud Small Cell Networks", IEEE Wireless Communications, 2016.
7. H. Zhang, X. Chu, W. Guo, and S. Wang, "Coexistence of Wi-Fi and Heterogeneous Small Cell Networks Sharing Unlicensed Spectrum", IEEE Communications Magazine, vol. 53, no. 3, pp. 158-164, March 2015.
8. H. Zhang, C. Jiang, N. Beaulieu, X. Chu, X. Wang, and T. Quek, "Resource Allocation for Cognitive Small Cell Networks: A Cooperative Bargaining Game Theoretic Approach", IEEE Transactions on Wireless Communications, vol. 14, no. 6, pp. 3481-3493, June 2015.
9. H. Zhang, C. Jiang, R. Hu and Y. Qian, "Self-Organization in Disaster Resilient Heterogeneous Small Cell Networks", IEEE Network, vol. 30, no. 2, pp. 116-121, March-April 2016.
10. H. Zhang, Y. Qiu, X. Chu, K. Long, and V. C. M. Leung, ``Fog Radio Access Networks: Mobility Management, Interference Mitigation and Resource Optimization," Accepted on June 14, 2017 for publication in IEEE Wireless Communications.
11. N. Jiang, Y. Deng, M. Condoluci, W. Guo and A. Nallanathan, "RACH Preamble Repetition in NB-IoT Network", IEEE Communications Letters, Vol. 22, No. 6, pp. 1244-1247, June 2018
12. N. Jiang, Y. Deng, O. Simeone and A. Nallanathan, 'Cooperative Deep Reinforcement leanring for Multi Groups NB-IoT Networks Optimization", Proc. of IEEE ICASSP'19, Brighton, U.K, May 2019. (invited paper)
13. N. Jiang, Y. Deng, A. Nallanathan and J.A Chambers, '' Deep Reinforcement Learning for Real-Time Optimization in NB-IoT Networks", to appear in IEEE Journal on Selected Areas in Communications, 2019 (minor revision)

Conferences/Workshops Organized related to future mobile networks

1. ICC 2019 Workshop Co-Chair (Haijun Zhang): Workshop on User-Centric Cell-Free Ultra-Dense Massive MIMO Networks, 20-24 May 2019, Shanghai, China.
2. IEEE INFOCOM 2019 IECCO Workshop Co-Chair

3. ICC 2018 Workshop Co-Chair (Haijun Zhang): Workshop on 5G Ultra Dense Networks.
4. Globecom 2017 Workshop Co-Chair (Haijun Zhang): Workshop on 5G Ultra Dense Networks.
5. ICC 2017 Workshop Co-Chair (Haijun Zhang): Workshop on 5G Ultra Dense Networks.
6. Globecom 2019 Symposium Chair (Haijun Zhang)
7. General Chair (Haijun Zhang) of 6th International Conference on Game Theory for Networks (GameNets) 2016, May 10-12, 2016, Kelowna, Canada.