Editorial:

Theory and techniques for “intellicise” wireless networks

Ping ZHANG¹, Mugen PENG^{‡1}, Shuguang CUI², Zhaoyang ZHANG³,
 Guoqiang MAO⁴, Zhi QUAN⁵, Tony Q. S. QUEK⁶, Bo RONG⁷

¹State Key Laboratory of Networking and Switching Technology,

Beijing University of Posts and Telecommunications, Beijing 100876, China

²School of Science and Engineering, The Chinese University of Hong Kong (Shenzhen), Shenzhen 518172, China

³College of Information Science and Electronic Engineering, Zhejiang University, Hangzhou 310027, China

⁴Research Institute of Smart Transportation, Xidian University, Xi'an 710071, China

⁵College of Electronics and Information Engineering, Shenzhen University, Shenzhen 518060, China

⁶Department of Information Systems Technology and Design, Singapore University of Technology and Design, Singapore 487372, Singapore

⁷Communications Research Centre Canada, Ottawa, Ontario K2K 2Y7, Canada

E-mail: pzhang@bupt.edu.cn; pmg@bupt.edu.cn; shuguangcui@cuhk.edu.cn; ning_ming@zju.edu.cn;
 g.mao@ieee.org; zquan@szu.edu.cn; tonyquek@sutd.edu.sg; bo.rong@canada.ca

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With the acceleration of a new round of global scientific, technological, and industrial revolution, the next generation of information and communication technology, i.e., 6G, will inject new momentum into industry transformation and upgrading, as well as into economic innovation and development. This will subsequently promote a global industrial integration. Wireless communication will be ubiquitous in all areas of future society, supporting novel applications with various performance requirements, such as immersive- or interactive-experience applications requiring a large bandwidth, autonomous driving and vehicle-to-everything applications requiring ultra-high reliability and ultra-low latency, and applications for industrial Internet requiring massive machine-type connectivity. Facing the challenges of the post-Moore and post-pandemic era, wireless communication needs breakthroughs in network architecture to improve the intelligence, security, robustness, bandwidth, and heterogeneity. With this background, several important tendencies have emerged in the development of 6G wireless communications:

1. Future wireless networks will evolve from “human-to-human” communications into intelligent “human-to-machine” communications.

In addition to enabling communications among humans, future wireless networks will be able to support close connections among humans and machines. The behavior and intent of humans will be sensed and communicated to machines that will accordingly adjust their operations. Typical scenarios include smart building, intelligent transportation, mixed reality (MR), and others.

2. Network nodes will evolve from carrying out only traditional communications to carrying out communication, sensing, computation, management, and caching in an integrated manner.

To meet the diverse service requirements of mobile MR, intelligent transportation, industrial Internet of Things, and other areas, future networks will possess multiple functionalities. For example, by sensing human head position, pre-caching necessary content, and rendering high-quality images, network nodes can provide fully immersive MR experiences. In addition, with artificial intelligence (AI), network nodes can manage multi-dimensional resources in an on-demand fashion, where intent-driven network

[‡] Corresponding author

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management and control can be realized.

3. Network architecture will focus on collaborations between the cloud and the network edge, which will become more heterogeneous.

To shorten latency and alleviate the backhaul/fronthaul burden, the network edge must collaborate with the cloud. The first method of collaboration is that the cloud finishes AI model training and then deploys AI models into the network edge, which supports the so-called edge intelligence. In the second method, users demanding high throughput are served via a cloud radio access mode, while users requiring ultra-low latency can benefit from edge computation and caching. As for architecture heterogeneity, future networks are envisioned to incorporate unmanned aerial vehicle (UAV) networks, satellite communication networks, and dense cellular networks, bringing three-dimensional and hierarchical network coverage.

In short, the evolution of existing 5G technologies and the development of 6G need to address more stringent and diverse application scenarios, a more strict energy constraint, and the orchestration of multi-dimensional resources. These challenges call for an *intellicise* wireless network operation paradigm, where “*intellicise*” is a new adjective that we coin, standing for intelligence-endogenous and primitive-concise. Built upon the integration of AI and next-generation networking technologies, an *intellicise* wireless network continually explores and exploits new intelligent primitives, e.g., semantic base (Seb) in semantic communications, proactively takes systematic entropy reduction as the global optimization objective, adaptively reshapes the core models of information systems, and ultimately endows itself with endogenous intelligence and primitive conciseness.

In this context, the journal *Frontiers of Information Technology & Electronic Engineering* has organized a special feature on the theory and techniques for *intellicise* wireless networks. This special feature covers information theory, architecture design, and *intellicise* wireless networks for achieving air-space-ground-sea integration, resource management, hardware testbeds and platforms, as well as related applications. In addition, this feature is intended to provide a review of advancements and future research directions in the research field of *intellicise* wireless networks. After a rigorous review process, six papers have been selected for this feature, including one review article and five research articles.

Yaohua SUN and his collaborators undertook a comprehensive literature review in terms of the architectures, key techniques, and experimental platforms of intelligent wireless networks. Specifically, they first introduced an intent-driven wireless network, an autonomous driving network, an O-RAN reference architecture, and other elements. Then, they presented a deep discussion on AI-driven network slicing, intent perception, intelligent operation and maintenance, AI-based cloud-edge collaborative networking, and intelligent, multi-dimensional resource allocation. To fill the gap between theoretical study and practical implementation, they further surveyed recent progress in developing experimental platforms to demonstrate the benefits of network AI.

Intellicise Internet-of-Things (IoT) networks can provide ultra-low-power communication connecting numerous miniaturized devices, for which, however, traditional software-defined radio (SDR) platforms are insufficient, making fast algorithm implementation and evaluation difficult. Fei XIAO and her collaborators provided an ultra-low-power SDR design to meet ultra-low-power or even battery-free requirements. The core idea is to use μW -level backscatter in the design instead of power-hungry active RF chains. An evaluation was conducted with different modulation schemes, and a data rate of 100 kb/s was reported with less than 200 μW of power consumption.

Equipped with a large number of reflection elements, intelligent reflecting surfaces (IRSs) can generate desired reflection beams and create favorable propagation conditions, a promising technique for *intellicise* networks. Yu ZHANG and his collaborators proposed to integrate IRSs into cloud radio access networks to further enhance capacity and coverage. They investigated a scenario with multiple IRSs deployed between the users and remote radio heads, and developed a successive convex approximation approach to handle the non-convexity of an uplink sum-rate maximization problem under fronthaul capacity constraints. Via the proper design of user transmit beamformers, IRS passive beamformers, and compression noise covariance matrices, the cloud radio access network (C-RAN) uplink rate can be significantly improved.

Edge AI plays a vital role in enabling *intellicise* networks to support complex and dynamic tasks in an industrial wireless environment. Chi XU and his collaborators adopted multi-agent deep reinforcement learning (DRL) to orchestrate the computation and

communication resources of both industrial devices and edge servers with each device being seen as a self-learning agent. Compared to a traditional DRL approach, their proposal was shown to achieve better adaptation to the computation capacity of edge servers, data size, computation resources required, and the number of industrial devices.

The coverage of intellicise networks can be greatly extended with UAVs. However, interference between terrestrial links and UAV-ground links can degrade the performance of the whole network. To address this, Jing GUO and her collaborators used the coordinated multipoint (CoMP) technology to mitigate the interference in a three-dimensional, multi-layer UAV-terrestrial heterogeneous network (Het-Net). A rigorous analytical study was conducted using stochastic geometry theory, resulting in a tractable mathematical framework for coverage probability evaluation. Its accuracy was further validated via numerical results.

To better support applications with stringent requirements, such as virtual reality (VR), multi-dimensional resource management is essential. In this field, Chenxi LIU and his collaborators presented a mobile, VR delivery framework where both uplink and downlink transmissions were considered. They characterized the round-trip latency of the VR service and revealed its dependence on communication, caching, and computation resource allocation. Then, they proposed a simple yet efficient optimization algorithm to minimize round-trip latency, while satisfying practical constraints on caching, computation capability, and transmission capability in the uplink and downlink. Numerical evaluations illustrated that the proposed algorithm can effectively reduce the round-trip latency compared with various benchmarks.

Overall, a broad spectrum of current research topics relevant to the theory and techniques of intellicise wireless networks is covered in this special feature, from software-defined-radio hardware and beamformer design, to AI-driven resource orchestration, network coverage performance analysis, multi-dimensional resource management, and others. We hope that this collection of diverse but interconnected topics will be beneficial to those with an interest in intellicise networks or in related areas.

Finally, we would like to express our special gratitude to the authors and reviewers for their support and valuable contributions to this special feature, the editorial staff, and the Editors-in-Chief Profs. Yunhe PAN and Xicheng LU.

Prof. Ping ZHANG received his PhD degree from Beijing University of Posts and Telecommunications (BUPT), Beijing, China, in 1990. He is an academician of the Chinese Academy of Engineering. He is currently a professor and director of the State Key Laboratory of Networking and Switching Technology at BUPT. His research interests focus on mobile communications. He is a Fellow of the IEEE. He is currently the Editor-in-Chief of *J Commun* (in Chinese) and an Associate Editor-in-Chief of *Front Inform Technol Electron Eng*.

Prof. Mugen PENG received his PhD degree in communication and information systems from BUPT, Beijing, China, in 2005. Following this, he joined BUPT, where he has been a full professor with the School of Information and Communication Engineering since 2012. In 2014 he was also an academic visiting fellow at Princeton University, USA. He has authored or co-authored over 100 refereed IEEE journal papers and over 300 conference papers. His research interests include wireless communication theory, radio signal processing, cooperative communication, self-organization networking, heterogeneous networking, cloud communication, and the Internet of Things. He is a Fellow of the IEEE. He is the recipient of the 2018 Heinrich Hertz Prize Paper Award, the 2014 IEEE ComSoc AP Outstanding Young Researcher Award, and the Best Paper Award in ICC 2020, JCN 2016, IEEE WCNC 2015, IEEE GameNets 2014, IEEE CIT 2014, ICCTA 2011, IC-BNMT 2010, and IET CCWMC 2009. He currently is or has been on the editorial board of *IEEE Commun Mag*, *IEEE Int Things J*, *IEEE Trans Veh Technol*, *IEEE Trans Netw Sci Eng*, *Intell Conv Netw*, *Dig Commun Netw*, and *IEEE Netw*.

Prof. Shuguang CUI received his PhD degree in electrical engineering from Stanford University, California, USA, in 2005. He has been working as an assistant, associate, full, and chair professor in electrical and computer engineering at the University of Arizona, Texas A&M University, UC Davis, and CUHK at Shenzhen, respectively. He has also served as the executive dean for the School of Science and Engineering at CUHK, Shenzhen, and the executive vice director at Shenzhen Research Institute of Big Data. His current research interests include data-driven large-scale system control and resource management, large data-set analysis, IoT system design, energy-harvesting-based communication system design, and cognitive network optimization. He was selected as the Thomson Reuters Highly Cited Researcher and listed in the World's Most Influential Scientific Minds by *Science Watch* in 2014. He is the recipient of the IEEE Signal Processing Society 2012 Best Paper Award. He has served as the general co-chair and TPC co-chair for many IEEE conferences. He has also been serving as an area

editor for *IEEE Signal Process Mag*, and an associate editor for *IEEE Trans Big Data*, *IEEE Trans Signal Process*, *IEEE JSAC Ser Green Commun Netw*, and *IEEE Trans Wirel Commun*. He was the elected member for the IEEE Signal Processing Society SPCOM Technical Committee (2009–2014) and the elected Chair for IEEE ComSoc Wireless Technical Committee (2017–2018). He is a member of the Steering Committee for *IEEE Trans Big Data* and the chair of the Steering Committee for *IEEE Trans Cogn Commun Netw*. He was also a member of the IEEE ComSoc Emerging Technology Committee. He was elected as a Fellow of the IEEE in 2013, an IEEE ComSoc Distinguished Lecturer in 2014, and an IEEE VT Society Distinguished Lecturer in 2019. He has won the IEEE ICC Best Paper Award, ICIP Best Paper Finalist, and the IEEE Globecom Best Paper Award all in 2020.

Prof. Zhaoyang ZHANG received his PhD degree from Zhejiang University, Hangzhou, China, in 1998. Since then, he has been with Zhejiang University. He is currently a Qiusi Distinguished Professor. His research interests include next-generation wireless communications, network intelligence, and synergetic sensing computation and communication. He has served as the general chair, TPC co-chair, or symposium co-chair for WCSP 2013/2018, the GLOBECOM 2014 Wireless Communications Symposium, and the VTC-Spring 2017 Workshop HMWC. He is currently serving as an editor for *IEEE Trans Wirel Commun*, *IEEE Trans Commun*, *IET Commun*, and *Front Inform Technol Electron Eng*.

Prof. Guoqiang MAO is currently a distinguished professor and the dean of the Research Institute of Smart Transportation, Xidian University, Xi'an, China. Before this, he was with the University of Technology Sydney, Ultimo, NSW, Australia and with the University of Sydney, Camperdown, NSW, Australia. He has authored or co-authored more than 200 papers in international conferences and journals, which have been cited more than 9000 times. His research interests include intelligent transport systems, applied graph theory and its applications in telecommunications, the Internet of Things, wireless sensor networks, wireless localization techniques, and network modeling and performance analysis. Since 2018, he has been an editor of *IEEE Trans Intell Transp Syst*. From 2014 to 2019, he was an editor of *IEEE Trans Wirel Commun*. Since 2010, he has been an editor of *IEEE Trans Veh Technol*. He was the co-chair of the IEEE Intelligent Transport Systems Society Technical Committee on Communication Networks. He was the chair, co-chair, or TPC member in a number of international conferences. He is a Fellow of the IEEE and a Fellow of the IET. He was the recipient of the Top Editor Award for outstanding contributions to *IEEE Trans Veh Technol*, in 2011, 2014, and 2015.

Prof. Zhi QUAN received his PhD degree in electrical engineering from UCLA, USA, in 2009. He was a visiting scholar with the Department of Electrical Engineering, Princeton University, USA, from 2007 to 2008. He worked as a senior system engineer with the Research and Development Department, Qualcomm Inc., USA, from 2008 to 2012, and a senior RF system engineer and an architect at Apple Inc., USA, from 2012 to 2015. He is currently a distinguished professor with the College of Electronics and Information Engineering, Shenzhen University, China. His current research interests include next-generation wireless communication systems, RF system calibration and measurement, industrial IoT, edge computing, data-driven signal processing, and embedded machine learning. He was the recipient of the UCLA Outstanding PhD Award in 2009 and the IEEE Signal Processing Society Best Paper Award in 2012. He was supported by the National Natural Science Foundation of China for Distinguished Young Scholars in 2016.

Prof. Tony Q. S. QUEK received his PhD degree in electrical engineering and computer science from MIT, USA, in 2008. Currently, he is the Cheng Tsang Man Chair Professor with Singapore University of Technology and Design (SUTD). He also serves as director of the Future Communications R&D Program, head of ISTD Pillar, and deputy director of SUTD-ZJU IDEA. His current research interests include wireless communications and networking, network intelligence, IoT, ultra-reliable and low-latency communications, and big data processing. He is a Fellow of the IEEE. He has been actively involved in organizing and chairing sessions and has served as a member of the TPC and symposium chair in a number of international conferences. He is currently serving as an editor for *IEEE Trans Wirel Commun* and an elected member of the IEEE Signal Processing Society SPCOM Technical Committee. He was an executive editorial committee member for *IEEE Trans Wirel Commun* and an editor for *IEEE Trans Commun* and *IEEE Wirel Commun Lett*.

Dr. Bo RONG is a research scientist with the Communications Research Centre Canada. He has authored or co-authored over 100 technical papers in major journals and conferences on the topic of wireless networking and communications. His research interests include space-air-ground integrated networks, deep machine learning, intelligent radio resource management in 5G/6G, and smart IoT. He is a member of the IEEE Communications Society and the IEEE Broadcasting Society. He serves as an associate editor for *IEEE Netw*, and a guest editor of special issues in *IEEE Commun Mag*, *IEEE Wirel Commun Mag*, and *IEEE Int Things J*.