Tutorial T-20: Distributed Resource Allocation for 5G Communications and Networks

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Tutorial Overview

Modern wireless cellular networks have been witnessed an unprecedented evolution from classical, centralized and homogenous architectures to a mix of heterogeneous technologies, in which the network devices are densely and randomly deployed in a decentralized architecture. This shift in network architecture requires network devices to become more autonomous, which causes non-cooperative behaviors. To cooperate with one another, the need for smart and autonomic network designs has become a central research issue in a variety of applications and scenarios. There are examples such as next-generation heterogeneous dense cell networks, LTE-Unlicensed networks or device-to-device communication networks in which the mobile devices must be able to interact, co-exist, meet stringent QoS requirements, and self-adapt to uncertainties and time-varying environments. Incorporating self-organizing capabilities in heterogeneous wireless systems motivates the development of innovative analytical techniques, such as game theory, which is expected to play a critical role towards deploying intelligent, distributed, and flexible networked systems in which devices can make independent and rational strategic decisions, smartly adapting to their environment.

In this tutorial, we will concentrate on the use of resource allocation tools (such as optimization and game theory) to analyze and design the next generation wireless networks. This tutorial will take a comprehensive and coordinated approach in presenting the ways of performance enhancement. There are three main objectives of presenting this tutorial:

- The first objective is to provide a general introduction to 5G wireless communication and networking including the requirements for 5G communication, and the key evolutionary techniques from physical to MAC and network layer issues, and,
- The second objective is to illustrate how such 5G paradigm will affect the design of other layers for radio resource management with distributed solutions in the before mentioned representative scenarios.
- The third objective is to present other state-of-the-art applications under the umbrella of 5G networking schemes. This will include classifications of the different schemes and the technical details in each scheme, such as various M2M systems, wireless network virtualization, etc.

Outline of the tutorial

- **Basic of 5G Communication** – presents the basics and recent progress in 5G communication systems.
    1) Background
    2) Key Technologies such as Ultra Dense Cells, mmWaves, Massive MIMO, NOMA, D2D, Full-duplex, Mobile Relay, Smart Networks, etc.
    3) Working and application scenarios

- **Resource Allocation** – discusses the use of optimization and distributed resource allocation such as game theory to analyze and design 5G communication networks.
    1) Game theory basics
    2) Non-cooperative game for D2D networks
    3) Matching theory for full-duplex networks
    4) Contact theory for LTE-U
    5) Auction game for NOMA
    6) Cooperative game for ultra dense cells
- **Other Related Applications** – apply the game theoretic tools into possible applications beyond 5G communications and networks.
    1) Dynamic spectrum access and sharing in M2M networks
    2) Physical-layer security for D2D and relay networks
    3) Scheduling and resource allocation for wireless network virtualization

Presenter Biographies

Lingyang Song received his PhD from the University of York, UK, in 2007, where he received the K. M. Stott Prize for excellent research. He worked as a postdoctoral research fellow at the University of Oslo, Norway, and Harvard University, until rejoining Philips Research UK in March 2008. In May 2009, he joined the School of Electronics Engineering and Computer Science, Peking University, China, as a full professor. His main research interests include cooperative and cognitive communications, physical layer security, and wireless ad hoc/sensor networks.

He published extensively, wrote 6 text books, and is co-inventor of a number of patents (standard contributions). He received eight paper awards in IEEE international conferences including IEEE WCNC 2012, ICC 2014, Globecom 2014, and ICC 2015. He is currently on the Editorial Board of IEEE Transactions on Wireless Communications and Journal of Network and Computer Applications. He served as the TPC co-chairs for the International Conference on Ubiquitous and Future Networks (ICUFN2011/2012), symposium co-chairs in the International Wireless Communications and Mobile Computing Conference (IWCMC 2009/2010), IEEE International Conference on Communication Technology (ICCT 2011), and IEEE International Conference on Communications (ICC 2014, 2015).He is the recipient of 2012 IEEE Asia Pacific (AP) Young Researcher Award. Dr. Song is a senior member of IEEE, and IEEE ComSoc distinguished lecturer since 2015.

Zhu Han (S'01–M'04-SM'09-F'14) received the B.S. degree in electronic engineering from Tsinghua University, in 1997, and the M.S. and Ph.D. degrees in electrical engineering from the University of Maryland, College Park, in 1999 and 2003, respectively. From 2000 to 2002, he was an R&D Engineer of JDSU, Germantown, Maryland. From 2003 to 2006, he was a Research Associate at the University of Maryland. From 2006 to 2008, he was an assistant professor in Boise State University, Idaho. Currently, he is a Professor in Electrical and Computer Engineering Department as well as Computer Science Department at the University of Houston, Texas. His research interests include wireless resource

allocation and management, wireless communications and networking, game theory, wireless multimedia, security, and smart grid communication. Dr. Han received an NSF Career Award in 2010, the Fred W. Ellersick Prize of the IEEE Communication Society in 2011, the EURASIP Best Paper Award for the Journal on Advances in Signal Processing in 2015, several best paper awards in IEEE conferences, and is currently an IEEE Communications Society Distinguished Lecturer.