Spatiotemporal Stochastic Models for 5G and Beyond

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Abstract

With the proliferation of the Internet of things (IoT), the next evolutions of cellular networks (5G and beyond) are envisioned to support massive numbers of heterogeneous devices. To realize the foreseen 5G evolution, the way cellular networks are operated and designed should be revolutionized. Recent studies indicate that cellular networks are evolving towards a blend of infrastructure based and ad-hoc based networking that allows direct device-to-device (D2D) and machine-to-machine (M2M) communications on top of the legacy device-to-BS communication. Furthermore, denser BSs deployment is expected along with aggressive spatial frequency reuse among the BSs as well as among the D2D and M2M links. This will change the interference behaviour, which leads to an interference limited operation, and brings more sources of uncertainties to the network. Consequently, new mathematical models that account for such 5G network characteristics and uncertainness are required.

Using stochastic geometry and queueing theory, spatiotemporal mathematical models are developed to account for both the spatial and temporal uncertainties. Hence, enabling rigorous proof of concepts and efficient design for new technologies/services in large-scale setup. This presentation introduces spatiotemporal stochastic models in the context of 5G networks and beyond and discusses/assesses several emerging technologies that are proposed to fulfill the ambitious 5G performance requirements.

Tutorial Outline

Part I: Introduction and Motivation

1. Introduction to 5G and beyond networks
2. The Internet of things
3. Challenges and research problems
4. Motivation for using spatiotemporal stochastic models

Part II: Theory

5. Stochastic geometry preliminaries
    a. Point processes
    b. Fading models
    c. Propagation models
    d. Useful results
6. Exact interference and performance characterization
7. Viable simplifying approximations and their subsequent effects
8. Temporal performance correlation
9. Queueing theory preliminaries
    a. Continuous time and discrete time Markov chains
    b. Quasi birth death models
    c. Matrix analytic method

Part III: Applications

10. Emerging Technologies
    a. Full-duplex communication in cellular networks
    b. Device-to-device communication
    c. IoT scalability and stability analysis
    d. Ultra-densification and handover management

Part IV: Future Research

11. Conclusions
12. Open Problem
13. Future research Directions

Biographies of the Speakers:

Hesham ElSawy (S'11, M'14) joined the Computer, Electrical, and Mathematical Sciences and Engineering (CEMSE) Division, of the King Abdullah University of Science and technology (KAUST), as a postdoctoral fellow in April 2014. He also has an adjunct affiliation to the school of Computer Science and Engineering, York University, Canada. Dr. ElSawy obtained his Ph.D. degree in Electrical Engineering from the University of Manitoba, Winnipeg, MB Canada, in 2014. During his PhD studies, he worked with TRTech in Winnipeg, as Student Researcher. For his academic excellence, he has received several academic awards, including the Canadian Natural Sciences and Engineering Research Council Industrial Postgraduate Scholarship (NSERC-IPS). He is also distinguished by the IEEE transactions on communication as an exemplary reviewer in 2015 & 2016 and won the best paper award in *ICC 2015 small cells and 5G networks workshop*. His research interests include statistical modeling of wireless networks, stochastic geometry, and queueing analysis for wireless communication networks.

Mohamed-Slim Alouini (S'94, M'98, SM'03, F09) Dr. Alouini was born in Tunis, Tunisia. He received the Diplome d'Ingenieur from the École Nationale Supérieure des Télécommunications (TELECOM Paris Tech) and the Diplome d'Etudes Approfondies (D.E.A.) in Electronics with Highest Honors from the Université Pierre et Marie Curie in Paris, both in 1993. He received the M.S.E.E. degree from the Georgia Institute of Technology (Georgia Tech) in 1995, and a PhD in Electrical Engineering from California Institute of Technology (Caltech) in 1998. He also received the Habilitation degree from the Université Pierre et Marie Curie in 2003.

Dr. Alouini served as a faculty member in the University of Minnesota, Minneapolis, MN, USA, then in the Texas A&M University at Qatar, Education City, Doha, Qatar before joining King Abdullah University of Science and Technology (KAUST), Thuwal, Makkah Province, Saudi Arabia as a Professor of Electrical Engineering in 2009. His current research interests include design and performance analysis of diversity combining techniques, MIMO techniques, multi-hop/cooperative communications systems, optical wireless communication systems, cognitive radio systems, and multi-resolution, hierarchical and adaptive modulation schemes.

Dr. Alouini has published several papers on the above subjects, and he is co-author of the textbook Digital Communication over Fading Channels published by Wiley Interscience. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), a member of the Thomson ISI Web of Knowledge list of Highly Cited Researchers as well as the list of Most Cited Researchers Developed for Shanghai Ranking's Global Ranking of Academic Subjects 2016 by Elsevier, an IEEE Distinguished Lecturer for the IEEE Communication Society, and a co-recipient of best paper awards in ten IEEE conferences (including ICC, GLOBECOM, VTC, PIMRC, and DySPAN).