Spatiotemporal Modeling in Wireless Networks: Analysis and Applications

Abstract:

The fifth-generation wireless network is coming into reality. Along with the rapid progress of wireless industry, conventional macro base stations are now overlaid by another tier consists of access points that are small size, low power, and densely deployed. Such heterogeneous network architecture reduces the distance between transmitters and receivers, and, with an upgraded transmission scheme, e.g., the millimeter wave communication, at the base stations, will greatly boost up data rate, enlarge capacity, and reduce transmission delay. As a result, a number of new techniques are emerging, including the Internet-of-Things (IoT), autonomous vehicles, and Unmanned Aerial Vehicles (UAVs). In addition to the increasing volume of the connected devices, the content flowing through the network is also largely switching from the traditional text/voice messages to multimedia-oriented applications. These new trends not just flourish the blossom of wireless industry, but also impose many challenges for the network operators, e.g., how to connect a vast amount of devices while still guarantee the delay to be within certain range across the network, especially when there are high degrees of fluctuations in both spatial and temporal domain.

Before any adequate response can be given, the primary requirement for network operators will be to attain a full understanding of the joint effect from two fundamental aspects of wireless network, i.e., the spatial locations of base stations and the temporal dynamic of traffic, because the former determines the deployment strategy and the latter affects the employed transmission technology. Conventionally, the impacts related to topological aspect in wireless network has been well investigated by leveraging tools from stochastic geometry, and the temporal traffic dynamics are thoroughly explored via the models based on queuing theory. However, neither of these tools allows one to take into account the effect from the other domain, and hence they lack a complete treatment in the modeling purpose. On the other hand, with the dense deployment of access points, temporal dynamic of different transmitters are highly coupled, i.e., the activation or silence of one base station can affect the queueing status of base station located in proximity to it, which in turns will change the related delay. As such, purely understanding the impact from one single dimension of the network, either it is spatial or temporal, is not sufficient, and both the academic and industry are calling for a model that is able to simultaneously capture the impact from both spatial and temporal aspects. In this tutorial, we will first provide the background about basic models for wireless networks in spatial and temporal domain. Based upon these models, we will elaborate in details on several advanced improvements that end up in useful spatiotemporal network models. We will also introduce different applications of the spatiotemporal model, that facilitates the design of various wireless technologies.

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Tony Q. S. Quek (S'98-M'08-SM'12-F'18) received the B.E. and M.E. degrees in Electrical and Electronics Engineering from Tokyo Institute of Technology, Tokyo, Japan, respectively. At Massachusetts Institute of Technology (MIT), Cambridge, MA, he earned the Ph.D. in Electrical Engineering and Computer Science. Currently, he is a tenured Associate Professor with the Singapore University of Technology and Design (SUTD). He also serves as the Associate Head of ISTD Pillar and the Deputy Director of SUTD-ZJU IDEA. His current research topics include wireless communications and networking, security, big data processing, network intelligence, and IoT.

Dr. Quek has been actively involved in organizing and chairing sessions, and has served as a TPC member in numerous international conferences. He is currently an elected member of the IEEE Signal Processing Society SPCOM Technical Committee. He was an Executive Editorial Committee Member of the IEEE Transactions on Wireless Communications, an Editor of the IEEE Transactions on Communications, and an Editor of the IEEE Wireless Communications Letters. He is a co-author of the book "Small Cell Networks: Deployment, PHY Techniques, and Resource Allocation" published by Cambridge University Press in 2013 and the book "Cloud Radio Access Networks: Principles, Technologies, and Applications" by Cambridge University Press in 2016. Dr. Quek received the 2008 Philip Yeo Prize for Outstanding Achievement in Research, the IEEE Globecom 2010 Best Paper Award, the 2012 IEEE William R. Bennett Prize, the 2016 IEEE Signal Processing Society Young Author Best Paper Award, 2017 CTTC Early Achievement Award, 2017 IEEE ComSoc AP Outstanding Paper Award, and 2017 Clarivate Analytics Highly Cited Researcher. He is a Distinguished Lecturer of the IEEE Communications Society and a Fellow of IEEE

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