Stochastic Geometry for the Analysis and Design of 5G Cellular Networks

Abstract: Future cellular systems are characterized by irregular and heterogeneous deployments with high densities of base stations. As a result, base stations and users are best modeled using stochastic point processes, which permit the application of the powerful tools of stochastic geometry for the network performance analysis.

In the first part, the tutorial provides a rigorous introduction to stochastic geometry, including the main models and the key results that enable closed-form calculations of distributions and spatial averages of network performance metrics, including transmission success probabilities, throughput, and delay. Spatial averaging is the process of averaging over the likely realizations of the network topology. It yields results that are valid for general classes of networks, rather than being restricted to a particular deployment of the nodes in a network.

In the second part, we focus on emerging single- and multi-tier cellular systems. The main metrics of interest are the distribution of the signal-to-interference-plus-noise ratio (SINR) and the per-user capacity. First focusing on a Poisson model for the base stations (BSs), we derive the complete SINR statistics for different cases of BS cooperation, including BS silencing, joint transmission, and interference cancellation, and we show the effects of network densification. Next, we turn our attention to more general network models that reflect the intra- and inter-tier dependencies that exist in heterogeneous cellular systems. Lastly, we present a novel and simple analytical framework based on the mean interference-to-signal ratio that yields simple expressions that provide very good approximations of the SINR distributions for many types of deployments and cooperation schemes.

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Martin Haenggi is a Professor of Electrical Engineering and a Concurrent Professor of Applied and Computational Mathematics and Statistics at the University of Notre Dame, Indiana, USA. He received the Dipl.Ing. (M.Sc.) and Dr.Sc.Techn. (Ph.D.) degrees in electrical engineering from the Swiss Federal Institute of Technology in Zurich (ETH) in 1995 and 1999, respectively. He is Fellow of the IEEE and a coauthor of the monograph *Interference in Large Wireless Networks* (NOW, 2008), the author of the textbook *Stochastic Geometry for Wireless Networks* (Cambridge University Press, 2012) and (co)author of more than 180 articles in refereed journals and conferences. He served on the Editorial Boards of the *Journal of Ad Hoc Networks*, the *IEEE Trans. on Mobile Computing*, *IEEE Journal on Selected Areas in Comm.*, *IEEE Trans. on Vehicular Technology*, and A*CM Trans. on Sensor Networks*. Currently he is the chair of the Executive Editorial Committee of the *IEEE Trans. Wireless Comm*. He was a Distinguished Lecturer for the IEEE Circuits and Systems Society in 2005-06 and the Keynote Speaker at the *2013 Workshop on Spatial Stochastic Models for Wireless Networks*. He received the ETH Medal for both his M.Sc. and Ph.D. theses, a CAREER award from the U.S. National Science Foundation in 2005, and the 2010 IEEE Communications Society Best Tutorial Paper award.