Stochastic Geometry-Based Analysis and Optimization of 5G Full-Duplex Cellular Networks

Context and Problem Formulation

The field of stochastic geometry [1] provides a rich set of mathematical tools to model and analyze cellular networks with different types of cells (e.g., macro, micro, pico, or femto) with different characteristics, in terms of several key performance indicators (KPIs) such as coverage probability, and link or network capacities.

Nowadays, stochastic geometry models and tools provide tractable and accurate performance bounds for cellular wireless networks, including multi-tier HetNets, cognitive cellular networks, underlay device-to-device (D2D) communications, and full-duplex (FD) communications; which are all seen as enabling technologies for the evolving fifth generation (5G) cellular networks [2]. In addition, unmanned vehicular networks (UAVs) rise and adoption for commercial and large scale deployment is an increasingly attractive context where 3D stochastic geometry models are being developed and evaluated [3].

The objective of the thesis is to offer a new and insightful understanding of the analysis and optimization of the next-generation cellular networks from an operator's point of view. It should result in the definition of an efficient planning and optimization procedure, with analytical and simulation tools ready to use by 5G cellular network planners and operators.

The first phase of the thesis will provide an extensive overview of the stochastic geometry modeling approaches, the state-of-the-art research on this topic, as well as a comprehensive survey on the literature related to stochastic geometry models for single-tier, multi-tier, cognitive cellular networks, underlay D2D, and UAV communications. This should yield a clear taxonomy of the stochastic geometry modeling approaches based on the target network model, the point process used, and the performance evaluation metrics.

The rest of the thesis will be dedicated to highlighting the key design and optimization parameters, and deriving new analytical expressions for the performance metrics taking into consideration the new 5G context. These results will be exploited to derive optimal network configurations and resource allocations in many scenarios (HetNets, cognitive, D2D, UAVs), and to define adapted KPIs for future deployments.

Finally, the obtained results may be extended by considering the full-duplex mode, and evaluating its impact on the design and optimization procedure, as well as the constraints and limitations it may have on the overall system performance and operations [4].

All analytical results will be assessed through the development of a simulation environment, that may be used also to extend the analysis and include other system-level parameters, upper-layers, and cross-layer considerations [5].

Keywords

5G, D2D, Full-Duplex, Optimization, Performance Analysis, Simulation, Stochastic Geometry, UAV, Wireless Communications.

Background

- Strong background: wireless communications, maths and probability, optimization.
- Simulation and numerical environments: Matlab, Mathematica, C/C++, ...

References

[1] H. ElSawy, E. Hossain, and M. Haenggi, "Stochastic Geometry for Modeling, Analysis, and Design of Multi-Tier and Cognitive Cellular Wireless Networks: A Survey," *IEEE Communications Surveys & Tutorials*, vol. 15, no. 3, pp. 996–1019, Third Quarter 2013.

[2] J. G. Andrews *et al.*, "What Will 5G Be?," *IEEE Journal on Selected Areas in Communications*, vol. 32, no. 6, pp. 1065–1082, June 2014.

[3] R. Irem Bor Yaliniz, A. El-Keyi, and H. Yanikomeroglu, "Efficient 3-D Placement of an Aerial Base Station in Next Generation Cellular Networks," in *Proc. IEEE International Conference on Communications (ICC)*, Kuala Lumpur, Malaysia, May 22-27, 2016.

[4] A. AlAmmouri, H. ElSawy, and M.-S. Alouini, "Harvesting Full-Duplex Rate Gains in Cellular Networks with Half-Duplex User Terminals," in *Proc. IEEE International Conference on Communications (ICC)*, Kuala Lumpur, Malaysia, May 22-27, 2016.

[5] Y. Wang, J. Xu, and L. Jiang, "Challenges of System-Level Simulations and Performance Evaluation for 5G Wireless Networks," *IEEE Access*, vol. 2, pp. 1553-1561, 2014

Supervisor

Prof. Mustapha Benjillali
INPT
Rabat, Morocco

benjillali@ieee.org
sites.google.com/site/benjillali