

# Abstract

Heterogeneous networks have emerged as a popular solution for accommodating the growing number of connected devices and increasing traffic demands in cellular networks. While offering broader coverage, higher capacity, and lower latency, the escalating energy consumption poses sustainability challenges. Additionally, since macro and micro base stations operating at the same frequency are considerably close to each other, a non-optimized network in terms of resource allocation could lead not only to low quality of service from the users perspective (capacity, connection, latency, etc), but also high transmission power expenditures, making the technology not viable from an economic viewpoint. Therefore, this work proposes a joint optimization problem to minimize the transmission power of base stations in OFDMA heterogeneous networks, while respecting users' individual throughput constraints. The decision variables are the association between user equipment and base station, users' individual working bandwidth, and base stations transmission power. The technique is formulated in a format such that an initial highly non-convex problem is posed, after a power function approximation and change of variables followed by a logarithmic transformation, as a Geometric Program, which is known to be convex. The proposed approach is then evaluated in multiple realistic scenarios regarding a real-world neighbourhood from a large European city. With data provided by a leading mobile network operator (including the location of the transmitting base stations, their type, steering direction, transmission technology, etc) and information from Open Street Maps, we are able to reconstruct the environment into a ray tracing simulator allowing us to carefully emulate the electromagnetic waves propagation and estimate the channel gains between each user equipment and all base stations. The results are promising both

in terms of optimal value, considerably smaller when compared to literature approaches, and in terms of runtime to obtain the optimal solution. Finally, two work extensions are presented: first the channel gains are considered to be random variables due to motion of objects causing shadowing, and the resulting chance constrained optimization problem is then solved with a robust geometric program; subsequently MPC is applied to the network when one of the base stations is abruptly switched off to simulate a failure environment, so the transmission powers can be controlled while minimizing the users' throughput constraints violation.

Key-words: Heterogeneous networks, geometric program, joint optimization, transmission power, working bandwidth, channel gains, random.