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Exploiting Heterogeneity in the Development of the Next Generation 5G Mobile Networks

par

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Abstract

Exploiting the dense heterogeneity in terms of multiple radio access technologies (LTE/LTEA, WiMax, HSDPA, Wi-Fi, ...etc.), as well as different cell sizes (macro, micro, metro, pico, and femto cells) is a promising way to achieve the main goals of the fifth generation (5G) of cellular mobile networks. However, the deployment of new network architectures based on this dense heterogeneity faces many big technical challenges to be overcome. This PhD thesis addresses some major technical challenges related to vertical handoff management, interference management, QoS management, backhauling, energy efficiency, as well as load balancing that need huge efforts for the deployment of 5G networks in the near future of 2020.

In this PhD thesis, we address some major technical challenges linked to the development of 5G heterogeneous networks. Furthermore, we propose four contributions based on recent mathematical tools, methodologies and technologies that are seen by both industrial and academic research communities as golden key solutions for the success of the deployment of 5G heterogeneous networks.

In the first contribution, we address the problem of network congestion in 5G multi-RAT heterogeneous networks. This problem eventually occurred in group mobility scenarios due to the vertical handoff decisions done nearly at the same time by a number of mobile users moving together inside a car or a bus not equipped with a mobile base station. Therefore, to resolve the problem of network congestion in this situation known as a group vertical handoff (GVHO), we model our problem as a symmetric congestion game using game theory. Then, we propose two fully decentralized learning algorithms to reach the nash equilibrium that represents a fair and efficient solution ensuring load balancing in 5G multi-RAT heterogeneous networks. In addition, to adapt our solution for high mobility scenarios, we propose a heuristic method dubbed DSSSA (Decreasing Step Size-Simulated Annealing) incorporated in a hybrid reinforcement learning algorithm to speed up the convergence time to the nash equilibrium solution.

In the second contribution we deal with the challenges related to downlink interference management, downlink QoS management and backhauling in the hyper-dense LTE HetNets architectures. Then, we provide a solution based on a self-organizing network (SON) algorithm combined with the multi-homing capabilities of macro cellular users, to improve the overall downlink throughput system, as well as to satisfy the QoS throughput requirements of both home and macro cellular users. Moreover, our solution permits to reduce the huge overhead signaling induced by centralized scheme solutions in hyper-dense HetNets. Instead of the downlink channel studied in the previous work, in the contributions 3 and 4, we focus our study on the uplink channel due to the assumed decoupling uplink downlink (DUD) access. In the third contribution we propose the same solution as in the second contribution for the uplink channel to improve the energy efficiency of cellular mobile users. However, due to the technical limitations to deploy many homogeneous LTE interfaces in mobile devices, in the fourth contribution we consider mobile devices with single LTE interface, then we formulate the same problem as a many to one matching game using matching theory, where the two sided of players are respectively macro indoor cellular users and small base stations (SBSs). Then, based on the preference list of players, we provide the deferred acceptance algorithm to reach the optimal stable matching consisting of assigning each macro indoor user to the most suitable SBS and vice versa.

Finally, the proposed solutions are evaluated through extensive numerical simulations and the numerical results are presented to provide a comparison with the related works found in the literature.

Keywords: Fifth generation (5G), Heterogeneous networks, Energy Efficiency, Load balancing, Handover, LTE/LTE-A, Multi-RAT, HetNets, Small cells, Small base Stations (SBSs), Decoupling Uplink Downlink (DUD), Multi-homing.