Abstract:

This research thesis aims to provide conclusive statements towards effective resource utilization for 5G (5th Generation) mobile networks and applications using game theory. In this context, we investigate two key scenarios pertaining to mobile communications and smart grids. A pivotal design driver for the upcoming era of mobile communications is energy efficiency, with particular emphasis on the mobile side where battery technology is still limited. Related works have shown that cooperation can be a useful engineering paradigm to take a step towards solving the energy deficit. However, we go beyond by envisaging cooperation and mobile users as a game of rational players, that can act on strategies and utilities in order to choose the most appropriate relay for energy saving. This interpretation lends itself to the application of game theory, and we look at coalitional games to settle conflicts of interest among cooperating user equipments, and employ Linear Programming (LP) to solve the relay selection problem and to derive the core solution of the game. Simulations results reveal that adopting the proposed coalitional relaying game can potentially double battery lifetime, in an era where the next wave of next generation handsets will be more energy demanding supporting sophisticated services and applications. The second scenario investigates demand response in smart grid applications, which is also gaining momentum under the umbrella of 5G, which is a promising approach urging end-users to consume electricity more evenly during non-peak hours of the day. Again, we resort to game theory and picture the strategic interactions between the electric utility company and the potential end-users as an extensive form game. Two real-time demand response programmes are addressed, namely Day-Ahead Pricing (DAP) and convex pricing tariffs. The response of price-aware residential consumers to these programmes is formulated as Mixed Integer Linear Programming (MILP) or Quadratic Programming (QP) problem, which optimally schedule their smart home appliances so as to minimise their daily electricity expenses while satisfying their daily energy needs and comfort levels. Simulations results demonstrate that implementing the DAP programme can reduce the Peak-to-Average Ratio (PAR) of demand by up to 56% and cut smart households bill by 32%. Moreover, applying real-time convex pricing tariffs can push these performance metrics even further, achieving 62% PAR reduction and more than 50% saving on the household electricity bill.

How my research is having impact:

Firstly, it has already warned by some researchers and experts of mobile communications that without new approaches for battery saving, there is a significant threat that the future mobile users will be searching for power outlets rather than network access, and becoming once again bound to a single location. To this end, our proposed coalitional relay-selection game can be readily implemented in mobile networks to help mobile users extend their scarce battery lifetimes by up to twice. This can enable them to enjoy truly ubiquitous connectivity, without worrying about their battery power. Secondly, demand response programmes can help release a considerable amount of
(virtual) capacity in smart grids, by flattening the users' consumption profiles. This can help avoid deploying additional peaking plants, which are normally both cost and environmentally inefficient. Our proposed demand response games can enhance the social welfare, benefiting both utility companies and the end users. It can cut the cost of electricity for consumers by half, while avoiding additional capital expenditures for the utilities to deploy new generation units. Above all, these games-theoretic solutions can reduce the carbon footprint of mobile and electricity networks.