ABSTRACT

With rapid advancement of mobile devices, data rate requirement of various mobile applications are also increasing. Advanced cellular networks such as LTE-A, 5G, and beyond 5G, use various add-on technologies to boost network performance. ***Device-to-Device*** (D2D) communication is one of the popular techniques used in cellular networks for improving network performance in various aspects such as throughput, energy efficiency, coverage range, spectral efficiency, load balancing, and quality of user experience. Device discovery mechanism, mode selection, efficient power allocation, sophisticated resource sharing mechanism, security, multi-hop relaying, etc., are the challenges in implementing such a scheme. In this thesis we discuss several issues and challenges faced by D2D communications underlaying advanced cellular networks. We provide efficient solutions to resource allocation problems for throughput maximization, user-centric energy-efficient multimedia transmissions, intercell D2D communications, and UAV (Unmanned Aerial Vehicle)-assisted multi-hop D2D communications.

First, we study the resource allocation problem of cellular and D2D users (CUs and DUs) to provide relay-assistance to the deeply-faded CUs using D2D communications. An optimization problem has been formulated to minimize the difference between *rate demand* and *rate achieved* of the cellular users, subject to power and resource constraints. We solve the formulated problem step-wise using a Heuristic Greedy Search method with reduced complexity.

The next-generation cellular networks are expected to support rich multimedia streaming to heterogeneous users. This leads to more power consumption at the base stations (BSs) and the users. Therefore, energy-efficient data transmission is a key research area for upcoming cellular networks. In our subsequent work, we present a scheme, named D2D-assisted Multimedia Streaming (DAMS) for streaming multimedia content to low-battery CUs with the help of D2D communications. The proposed method also minimizes the transmission power of the BSs by sending data through D2D relay nodes (DRNs). We use the maximum weight bipartite matching and transmission power allocation algorithm for allocating optimal transmission power at the BS.

As the wireless channels are prone to fading and shadowing, the achievable data rate of a user varies with time. Adaptive video streaming is an effective solution to cope up with channel variability. Next, we study the performance of user-centric adaptive multimedia transmissions over D2D-assisted cellular networks. D2D-assisted communication helps in extending the battery energy of the low-battery users. At each scheduling interval, four user-centric utility functions,

namely, quality utility, power consumption utility, packet loss ratio utility, and remaining battery utility are used for the adaptation purpose. Here, we formulate an optimization problem and solve it efficiently using the Hungarian algorithm.

So far we have considered a single cell cellular network; however, D2D transmitters and receivers located in different cells may end up leading to a more complex design for resource allocation. Therefore, our next work investigates the resource sharing problem between intercell D2D pairs and CUs in a multi-cell cellular network. We have used *Repeated Game Theory* for solving the problem of dynamic resource blocks (RBs) sharing between the CUs and DUs. A penalty is imposed for the deviating selfish player to return to the cooperative mode quickly. In addition, we also compute the number of RBs initially allotted optimally.

Lastly, we have studied two major applications of 5G D2D relayed communication in *Wireless Sensor Networks* (WSNs) and UAV networks. We propose a D2D-based data forwarding procedure from sensor cluster heads to base stations that solves the problem of frequent disconnection of multi-hop sensor links in WSNs. Further, we have developed a UAV-assisted multi-hop D2D communication technique using a Machine Learning approach in 5G cellular networks. In this work the trajectories of such UAVs are found with the help of active user prediction using Neural Networks.

We evaluate the performance of the proposed solutions and compare them with well-known existing techniques. Both analytical and simulation results show that our proposed schemes achieve good performance gain in terms of system throughput, energy efficiency, churn rate, and quality of experience.

Keywords: Device-to-Device Communication, Maximizing Throughput, D2D Relay Node, Cellular User, D2D User, Resource Allocation