Resource Allocation for Underlay D2D with Partial Channel State Information

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Device-to-device (D2D) communications is a key technology for next generation 5G wireless standards. In it, two nearby users communicate with each other directly instead of communicating through the base station (BS). This reduces transmission delay, saves power, and reduces the traffic load on the BS. In underlay D2D, the spectrum allocated to cellular users (CUs) is reused by D2D users, thereby improving spectral efficiency. However, the CUs and the D2D users interfere with each other, which degrades their transmission rates. Therefore, it is critical to develop algorithms for a BS to allocate subchannels to the D2D users in an interference-aware manner that maximize spectral efficiency while also ensuring a minimum quality-of-service for the CUs.

Resource allocation for such D2D systems is challenging to implement in practice because the BS does not a priori know the channel gains of the CU to D2D user links and the links between the D2D transmitter and receiver pairs. These gains have to be fed back to the BS, which incurs significant overhead. To address this challenge, we focus on a partial channel state information feedback scheme in which a D2D receiver sends just 1-bit feedback about the SINR of the D2D link. This model differs from the literature, which makes the practically unrealistic assumption that the BS has full channel state information of all the links in the system.

First, we consider the case in which multiple D2D pairs can share a subchannel. Our goal is to maximize D2D sum throughput subject to a minimum rate guarantee constraint for the CUs and the constraint that a D2D pair can transmit on at most one subchannel. In this case, resource allocation is a binary integer programming problem that is NP-hard. Hence, we propose two sub-optimal resource allocation algorithms, namely, locally greedy algorithm and relaxation-pruning algorithm. They are polynomial time algorithms that provably achieve at least one-third and half of the optimal D2D sum throughput. We also propose a rate upgradation step that exploits the asymmetry in the channel state information available at the D2D users and the BS, which arises due to the partial feedback model and is unique to our problem, to further improve the data rates of the scheduled D2D users.

We then extend the model to the multi-cell scenario with co-channel interference between neighboring cells. We present extensions of the above two algorithms that maximize the average D2D throughput with stochastic guarantees for the minimum rate of each CU when the BS has only statistical knowledge of the inter-cell interference. In the process, we also develop a statistical model for the interference from the CUs in the neighboring cells.

Our numerical results show that even with one bit of feedback about each D2D link, both algorithms achieve a sum throughput that is close to that of the optimal brute-force scheme in which the BS has full channel state information and searches over all possible combinations. We observe the same trends in the multi-cell scenario also.

Future work involves extending the system model to the practically motivated case in which the base station has imperfect channel state information.