A Noval Fast Resource Allocation Scheme for D2D-enabled Cellular Networks

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***Abstract*—In this paper, we investigate the resource allocation for device-to-device (D2D) communications with underlaying cellular networks. Specifically, in underlay mode, D2D communications optimize for maximizing the corresponding utility under cellular users' quality of service (QoS) requirement and transmit power constraints. To solve this challenging subchannel allocation problem, which is actually a nonconvex mixed-integer programming problem, we decompose the whole optimization problem into independent subproblems. Firstly, we find out the candidate D2D communications users who are permitted to share the same spectrum with cellular users in the admission control subproblem. Then, to solve the resource allocation subproblem, a novel fast and tradeoff subchannel allocation algorithm between utility and fairness is proposed with setting higher priority for unpopular D2D users. Simulation results validate our proposed novel fast allocation strategy achieves remarkable improvement with low complexity and fairness guaranteeing.**

Keywords— D2D communication; resource allocation; fast allocation; fairness guaranteeing

I. INTRODUCTION

Device to device (D2D) communications act as a proximity service (ProSe) scheme which was formally put forward by the 3rd Generation Partnership Project (3GPP) organization in LTE Release 12 in 2013. It was also shown that D2D underlaying cellular network are able to further improve the potential utility such as energy efficiency (EE) and spectrum efficiency (SE) with sophisticated resource allocation [1-2]. Although lots of works have been drown for D2D enabled networks, there also exist some shortcomings of the existing literatures, where most of works utilize exhaustive search such as Hungarian algorithm realize channel allocation. The weakness is obvious since the overhead complexity will occur when the number of users is large.

II. PROBLEM FORMULATIONS

In this paper, the users with local services form a D2D communications pair and underlay the uplink spectrum of cellular network. Moreover, we focus on the challenging of intra-cell co-channel interference and a single-cell scenario with multiple cellular users and D2D pairs is considered. we formulate the utility optimization question by **P1**, as follows

P1:
$$\underset{x_{m,k},P_{k,d},P_{m,c}}{\arg\max}\ U \tag{1}$$

$$\sum_{m\in M} x_{m,k} \le 1,\quad x_{m,k}\in\{0,1\},\ \forall k\in K \tag{1a}$$

$$\sum_{k\in K} x_{m,k} \le 1,\quad x_{m,k}\in\{0,1\},\ \forall m\in M \tag{1b}$$

$$\gamma_{m,c} \ge \gamma_{\min}^{c},\quad \forall x_{m,k}=1 \tag{1c}$$

$$\gamma_{k,d} \ge \gamma_{\min}^{d},\quad \forall x_{m,k}=1 \tag{1d}$$

$$0\le P_{m,c}\le P_{\max,c},\quad \forall m\in M \tag{1e}$$

$$0\le P_{k,d}\le P_{\max,d},\quad \forall k\in K \tag{1f}$$

where $\gamma_{\min}^{c}$ and $\gamma_{\min}^{d}$ denote the threshold of minimum SINR for guaranteeing the rate requirement of cellular users and D2D users respectively. In addition, $P_{\max,c}$ denotes the maximum transmit power of cellular users, and $P_{\max,d}$ denotes the maximum transmit power of transmitter users of each D2D pairs.

III. NOVEL FAST RESOURCE ALLOCATION ALGORITHM

Inspired by [3], we decompose the whole optimization problem into two independent subproblems. Firstly, we address the accessing rule of D2D pairs with finding out all the potential reusable cellular users for every single D2D user which constitutes the candidate reused partners. Secondly, we propose a novel fast resource allocation scheme differ from the global optimal solution, as the Hungarian. With insignificant utility loss, our proposed resource allocation scheme decreases the computational complexity and guarantee allocation fairness.

A. Access Control Strategy for D2D Communications

we check all the possible Cellular-D2D pairs and find out a feasible reused set for each D2D pairs as done in [2]. We decouple the channel allocation and power control questions, and focus on the remaining interference and transmit power restraints for D2D users and cellular users. It can be proved that the access control problem constitute a linear programming problem. The feasible and infeasible regions of power allocation for D2D users and cellular users are visually depicted similarly as [4].

B. Novel Fast Channel Allocation With Low Complexity

Firstly, the D2D users are sorted into the allocation queue with descending order of the number of channels that can be reused. Allocating channels for the D2D users with the least number of reusable channels with the highest utility. Then eliminating the D2D user and channel from allocation matrix. If there are several D2D users that have the same number of reusable channels, the KM algorithm is enforced to reduce the loss of utility performance. The detail of our spectrum allocation algorithm is described in Algorithm 1. It should be noted that our proposed CAFEE is very different from the inverse popularity pair order (IPPO) algorithm proposed in [5] in several key points. First, the IPPO assigns the least popular channel to a D2D user with the least number of reusable channels which can be called a poor-poor matching. Secondly, IPPO focus on reduction of computation complexity by fast pairing without iteration rather than fairness assurance. All of them make our proposed CAFEE distinguish from IPPO.

Algorithm 1 Compromised Algorithm Between Fairness And Energy Efficiency (CAFEE)

1: **For** $k = 1 : K$
2: Find the D2D users k_l with the least reusable channels
3: **if** $\|k_l\| = 1$
4: Choose the channel to maximize the utility of D2D users k_l , then remove the D2D user and the allocated channel.
5: **else**
KM or graph based algorithm is enforced to maximize the sum utility performance, then remove the D2D user and allocated channel.
end if
6: **end for**

C. Complexity Analysis

the channel allocation complexity (CAC) of KM algorithm is $O\left(\left(K+M\right)^3\right)$, and that of IPPO is $O\left(\left(K+M\right)\right)$. Whereas the CAC of our proposed CAFEE is $O\left(\left(K_i+M_j\right)^3\right)$ while $\sum_{i=1} K_i = K$ when $K \le M$.

IV. Numerical Results And Analysis

we study the effect of different channel allocation strategies on the sum utility such as EE of individual D2D communications. In this scenario, we compare the proposed CAFEE algorithm with the IPPO, Random and KM algorithm which is chosen as the utility upper bound. Fig. 1 illustrate that the CAFEE algorithm could achieve EE only second to the KM (upper bound) and make a significant improvement than IPPO and Random. Notice that, although the IPPO algorithm can reduce computational complexity, its improvement in overall system performance is almost negligible compared to the Random algorithm. However, our proposed CAFEE brings in a lower computational complexity when compared to the KM algorithm without significant overall system performance loss.

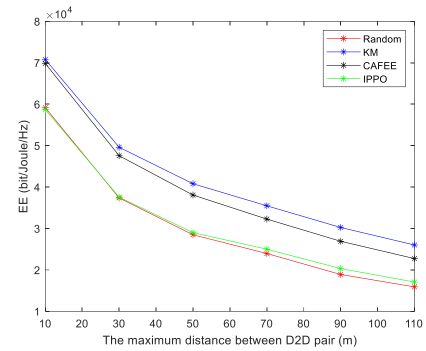

Fig. 1. EE versus channel allocation strategies, $K = 30$, M=30 , $\gamma^c_{\min}$=10 , $\gamma^d_{\min}$=10

V. Conclusions

A resource allocation algorithm with tradeoff between fairness and utility of D2D communications is proposed to solve the resource allocation problem. By setting higher priority for unpopular D2D users, the fairness is to be guaranteed and KM algorithm is applied to reduce the utility loss. Furthermore, numerical simulation has been done and demonstrate that our proposed resource optimization algorithm improve the performance of D2D-enabled network compared to the contrast algorithms.

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References

[1] K. Doppler, M. Rinne, C. Wijting, “Device-to-device communication as an underlay to LTE-advanced networks,” IEEE Commun. Mag. vol. 47 , pp.42–49, December 2009.

[2] X. Xu, Y. Li, A Multiscale Hierarchical Threshold-Based Completed Local Entropy Binary Pattern for Texture Classification, Cognitive Computation, doi.org/10.1007/s12559-019-09673-9

[3] S. Cicalò and V. Tralli, “QoS-aware admission control and resource allocation for D2D communications underlaying cellular networks,” IEEE Trans Wireless Commun, vol. 17, pp. 5256–5269, August 2018.

[4] L. Liang, J. B. Kim, S. C. Jha, K. Sivanesan and G.Y. Li, Spectrum and power allocation for vehicular communications with delayed CSI feedback, IEEE Wireless Commun Lett, vol. 6, pp. 458–461, April 2017.

[5] L. Wang and H. Wu, Fast pairing of device-to-device link underlay for spectrum sharing with cellular users, IEEE Commun Lett, vol. 18, pp. 1803-1806, October 2014.