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THROUGHPUT OPTIMIZATION FOR DEVICE TO DEVICE COMMUNICATION OVER RAYLEIGH FADING CHANNEL USING COALITION GAME APPROACH

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Abstract —
In this paper, we explore the sum rate maximization in a Device-to-Device (D2D) underlying network, where the uplink resources are shared among numerous D2D pairs and the cellular users (CUs). We demonstrate system sum rate maximization expression as an MILP (mixed integer non-linear programming), which is NP-hard. We approach this problem by applying the optimization decomposition: 1) In the given Resource Allocation policy, we aim to derive the ideal Signal to Interference plus Noise Ratio (SINR) threshold to increase the system sum rate 2) We at this point propose a coalition game approach to additionally upgrade the resource allocation approach, and show the proposed coalition game approach to converge to the Nash-stable partition in limited time with a unit probability. The results come about to demonstrate that: a) The execution of the coalition game is close to the exhaustive search; however it has a substantially shorter run-time than the exhaustive research b) As compared to other resource allocation policies, the coalition game has the potential to accomplish a change in the sum rate of 13%-173%, and clearly, proves to possess the best resource sharing and also the most reasonable one.

Keywords
Device-to-Device, resource allocation, SINR optimization, Rayleigh fading channel.

I. INTRODUCTION

The portable information movement is developing quickly these days. To satisfy such fast developing interest for versatile information, we adhere to the idea of Device-to-Device (D2D) communication, which enables the gadgets to convey specifically without navigating through the base station (BS). It has been proposed to further increase the limit of the cell organization [1][2]. Most of them deal with D2D correspondence underlying cell arrangement (alluded to as D2D communication) , and have been centered around how to boost the framework throughput [**3]– [5]. In [3], [4],** Yu and Wang et al. upgraded the throughput of a D2D coordinate with a solitary D2D match while satisfying organized cell benefit limitations. In **[5],** Feng et al. considered an asset designation issue to expand the general system throughput in the case that one CU imparts its asset to just a single D2D match. The vitality productive plan of D2D organize is examined in**.** Notwithstanding, **[3] - [5]** considering the basic case that the channel pick up is consistent. Recently, two papers [8] and [12] analyzed the problem with the time-varying channels. In [8], Peng et al. inferred the success likelihood, spatial average rate, and zone spectral efficiency performances for the D2D networks under Rician Fading Channels without considering the asset distribution issue. In [12], Shen et al. examined the power minimization of D2D organize under Rayleigh Fading Channels. Be that as it may, they do not consider the advancement of the Signal to Interference plus Noise Ratio
(SINR) threshold .In this paper, we have tried to optimize the sum rate of the considerable number of CUs and D2D pairs in a network of D2D, where the uplink resources of the CUs are shared by the D2D pairs. The Rayleigh fading channel is used, under which the computation of the sum rate is substantially complex. Moreover, since the determination of the SINR threshold is basic to every transmission, optimization of the SINR threshold is limited to each transmission, along with the resource allocation. The fundamental contributions of this paper are compressed are as follows:

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1) Formulation of the closed-form sum-rate expression of the
D2D network with numerous CUs and D2D pairs for Rayleigh fading channel. We prove that the maximization problem of the system sum-rate can be expressed as a mixed integer non
linear programming problem.

2) An optimal SINR thresholds that maximizes the average rate of each transmission, is derived. This can further be used to calculate the maximum system sum-rate when the resource
allocation policy is given.

3) We propose a coalition game approach to further optimize the resource allocation policy. The coalition game approach
is guaranteed to be feasible, albeit not necessarily optimal. Moreover, we prove that the coalition game approach converges to the Nash-stable partition in finite time with probability 1. Simulation results show that the performance of the coalition game approach is close to the optimal solution and can achieve an average sum-rate enhancement of 13%-173% without sacrificing the resource sharing fairness compared with several other resource allocation policies.

The remaining part of the paper goes about as given hereafter. The network model is presented in Section II. Section III gives the formulation of the system sum-rate and its maximization problem. The derivation of the optimal SINR thresholds is made in section IV and the average rate of each transmission is maximized. The coalition game approach is proposed to improve the resource allocation policy even more; the convergence and stability is analyzed. In section IV, we present the performance evaluation. The paper is concluded by Section V.

II. SYSTEM DESCRIPTION

We are considering the case of a D2D underlaying cellular network, which consists of a base station (BS), several CUs and D2D pairs. D2D pairs are supposed to share the uplink resource of the CUs. So to facilitate this, we are implementing Rayleigh fading channel model in this system. The channel gain g varies exponentially or in other words we can say that it's distribution is exponential in nature. Ideally, the channel gain should not vary during the transmission of a particular packet. To take care of this situation, block fading model is adopted. We aim to maximize the sum-rate performance of the CUs and D2D pairs by proper allocation of resources and selection of SINR threshold.

II. PROBLEM FORMULATION

We will define the sets of CUs and D2D pairs, given $C = \{c_1, c_2, \ldots\ldots c_{|C|}\}$ and $D = \{d_1, d_2, \ldots\ldots d_{|D|}\}$. Now we will estimate the range of values of $y_{i,j}^{cd} \epsilon \{0,1\}$, which is also an indication that a pair of CU shares it's uplink resources with the D2D pair otherwise $y_{i,j}^{cd} = 0$. We are assuming that each D2D pair is permitted to share the resource with only one CU. Further, we will find out the average rates of CU and D2D pairs.

A. Average rate of CU:

During the calculation of average rate of a CU, we consider the interference and channel gain from one device to another. Let $\Upsilon^{u,v}$, P_{tr}^{u}, N_0 W be the SINR, power transmitted, spectral power density and bandwidth respectively.

The average transmission rate from CU to base station equals

$$x_{avg}^{c_i,BS}\left(I_{all}^{c_i,BS}\right) = W \log(1+\gamma_0^{c_i,BS}) e^{-\frac{\gamma_0^{c_i,BS}((N_0 W + \Sigma_{dj \epsilon D}\ (y_{i,j}^{cd} I_{d_j}^{BS} 1))}{T}}$$

$$T = P_{tr}^{c_i} E[g_{c_i}^{BS}] \qquad (1)$$

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When all the interferences to BS while c_i transmits, are independent, average transmission rate of c_i equals

$$x_{avg}^{ci} = \int \dots \int_0^{+\infty} \mathrm{x}_{\mathrm{avg}}^{\mathrm{ci,BS}} \left(I_{all}^{ci,BS} \right) \prod_{dj \in D} (h(I_{d_j^1}^{BS}) d(I_{d_j^1}^{BS}) \quad (2)$$

B. Average rate of D2D pair

During the process of transmission from a D2D pair, the interference occurring due to concurrent transmission of D2D and CU is taken into account, along with the channel gain.

Considering the interferences are independent in nature, the average transmission rate equals

$$x_{avg}^{dj} = \int \dots \int_0^{+\infty} \mathrm{x}_{\mathrm{avg}}^{\mathrm{d_j^1,d_j^2}} \left(I_{all}^{d_j^1, d_j^2} \right) . \prod_{c_i \in C} (h(I_{c_i}^{d_j^2}) dI_{c_i}^{d_j^2}) \prod_{d_j' \in D / \{dj\}} (h(I_{d_{j'}^1}^{d_j^2}) dI_{d_{j'}^1}^{d_j^2}) \quad (3)$$

C. Sum-Rate Maximization

After calculating the average rate of CU and D2D pair, the system sum rate, which is the summation of average transmission rate of CU and D2D pairs.

The sum-rate expression is given by:

$$R_{sum} = \sum_{c_i \epsilon C} \left(x_{avg}^{c_i} + \sum_{d_{j\epsilon}} y_{i,j}^{cd} \, x_{avg}^{d_j} \right) \quad (4)$$

From the expression, we can clearly find out that the D2D pairs are summed up separately and then added to the average rate of transmission from CU to base station.

There are certain criterion, which should be met for an effective sum-rate. The minimum and maximum threshold values of SINR are used as the range in the sum-rate expression.

System Sum-Rate Maximization can be calculated as follows:

$$Maximize\ R_{sum} = \begin{cases} \sum_{c_i \epsilon C} y_{i,j}^{cd} = 1, \forall d_j \epsilon D, \\ \gamma_0^{min} \leq \gamma_0^{c_i, BS} \leq \gamma_0^{max}, \forall c_i \epsilon C, \\ \gamma_0^{min} \leq \gamma_0^{d_j{}^1, d_j{}^2} \leq \gamma_0^{max}, \forall d_j \epsilon D, \\ y_{i,j}^{cd} \epsilon \{0,1\}, \forall c_i \epsilon C, \forall d_j \epsilon D. \end{cases} \quad (5)$$

Here minimum and maximum values of SINR threshold are given by $\Upsilon_0^{\min}$ and $\Upsilon_0^{\max}$ respectively. Hence equation (5) becomes a non linear problem and therefore we have to adopt decomposition optimization method.

III. DECOMPOSITION METHOD

In this segment, we break down the sum-rate maximization equation into two sub-equations :

1) Given $y^{c,d_{i,j}}, \forall ci \in \mathcal{C}, \forall dj \in \mathcal{D}$ we calculate the ideal SINR limit for every transmission that augments the system sum-rate rate.

2) We at that point propose a coalition game algorithm to deal with additionally enhanced $ycd\ i,j$.

A. The optimization of SINR thresholds given $ycd\ i,j$

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We realize that when $y^{c,d_{i,j}}$ is given, the system sum-rate is augmented when $x^{ci,avg}$ and $x^{dj,avg}$ are individually amplified, which is given in the accompanying hypothesis.
Hypothesis 1 - The average rate $x^{ci,avg}$ is maximized when,

$$\gamma_0^{c_i,BS} = \begin{cases} \gamma_0^{min}, & \gamma_0^*(c_i, BS) < \gamma_0^{min} \\ \gamma_0^*(c_i, BS), & \gamma_0^{min} \le \gamma_0^*(c_i, BS) \le \gamma_0^{max} \\ \gamma_0^{max}, & \gamma_0^*(c_i, BS) > \gamma_0^{max} \end{cases} \quad (6)$$

where $\gamma^*_0(ci,BS)$ is the value of $\gamma(ci,BS)$ at the base station.
Hypothesis 2 - The average rate $xdj\ avg$ is maximized when

$$\gamma_0^{d_j^1,d_j^2} = \begin{cases} \gamma_0^{min}, & \gamma_0^*(d_j^1,d_j^2) < \gamma_0^{min} \\ \gamma_0^*(d_j^1,d_j^2), & \gamma_0^{min} \le \gamma_0^*(d_j^1,d_j^2) \le \gamma_0^{max} \\ \gamma_0^{max}, & \gamma_0^*(d_j^1,d_j^2) > \gamma_0^{max} \end{cases} \quad (7)$$

$xciavg$ first increases and then decreases as $\gamma ci,BS\ 0$ increases. It reaches the maximum value when $\gamma ci,BS\ 0 = \gamma*\ 0\ (ci,BS)$. Considering that $\gamma^{*(ci,BS)}$ is not always in the range
$[\gamma^{min}, \gamma^{max}]$, we have that $x^{ci,avg}$ is maximized when $\gamma^{ci,BS} = \gamma^{min}$ if $\gamma*\ 0\ (ci,BS) < \gamma min\ 0$, and when $\gamma ci,BS\ 0 = \gamma max\ 0$ if $\gamma*\ 0\ (ci,BS) > \gamma max\ 0$

B. The Coalition game Algorithm –

In the coalition game algorithm, the players frame coalitions to augment the system utility. For the considered issue, the D2D sets are dealt with as players. They are divided into |C| coalitions Ƭ = {Ƭ1,Ƭ2...Ƭ?...Ƭ|C|} to separately share the assets of various CUs. That is, CU ci shares its resources with the D2D pair(s) in Ƭi. IfƬi is ∅, Ci does not impart its asset to any D2D combination. Clearly, we have Ƭ? ∩Ƭ ?′ = ∅ for any i not equal to i'. The aggregate rate of the CU Ci and its sharing D2D matches in Ƭi, RƬi, can be expressed as follows:

$$R_{\mathcal{L}_i} = x_{avg}^{ci} + \sum_{d_j \in \mathcal{L}_i} x_{avg}^{dj} \quad (8)$$

Accordingly, the transferable utility of the coalition Ƭi can be defined by the highest estimation of RLi given by R_{Li}^{max}, which can be acquired from Section III-A. The coalition game contains two sub-forms: the underlying procedure and the modifying procedure, as appeared in Algorithm 1.
In the underlying procedure, the coalition game produces an irregular coalition partition $Ƭ_{ini}$ to such an extent that for every beneficiary, the average received power is greater than any interference power. In the modifying procedure, the coalition game tries to move a D2D match from a coalition to another coalition. The details of the same are as per the following. At each progression, the coalition game haphazardly chooses a D2D match (i.e. d_j) in a coalition (i.e. $Ƭ_i$) and moves it to another arbitrarily chosen coalition (i.e. $Ƭ_{i'}$). In the event that for every receiver, the average received power is bigger than any interference power, and

$$R_{\mathcal{L}_i}^{max} + R_{\mathcal{L}_{i'}}^{max} < R_{\mathcal{L}_i \setminus \{d_j\}}^{max} + R_{\mathcal{L}_{i'} \cup \{d_j\}}^{max} \quad (9)$$

at that point, the movement is executed; else, the movement is pulled back. After a set number of movements, the coalition segment meets to the final Nash-stable segment $Ƭ_{final}$.

Algorithm:
The Algorithm of Coalition game

1) Initialization : Generate a random coalition partition $Ƭ_{ini}$ such that for each receiver, the average received power is bigger than any interference power;

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2) Set the current partition Υcur as Υini;
3) repeat
4) Randomly select a D2D pair (i.e. dj) in a coalition (i.e. Υi);
5) Randomly select a coalition $\Upsilon i' \in \Upsilon cur \backslash \{\Upsilon i\}$
6) **if** for each receiver, the average received power is bigger than any interference power, and
7) $R\max \Upsilon i + R\max \Upsilon i' < R\max \Upsilon i \backslash \{dj\} + R\max \Upsilon i' \cup \{dj\}$ then,
7) Move D2D pair dj from Υi to $\Upsilon i'$;
8) Update the current partition set as follows:
$(\Upsilon cur \backslash \{\Upsilon i, \Upsilon i'\}) \cup \{\Upsilon i \backslash \{dj\}, \Upsilon i' \cup \{dj\}\} \rightarrow \Upsilon cur$
9) **end if**
10) **until** the coalition partition converges to the final Nash-stable partition $\Upsilon final$.

IV. Simulation Results

Through simulation we arrive at certain results using the channel parameters, coalition game algorithm, sum-rate maximization expression and capacity channel matrix. The results are in accordance with the standard values of noise power density of $20dBm$ and a channel bandwidth of 2GHz.

The results obtained from the simulation are as follows:

1)The result shown in Fig 1.1 is of the channel capacity matrix, and it depicts the points of interferences occurring in the channel:

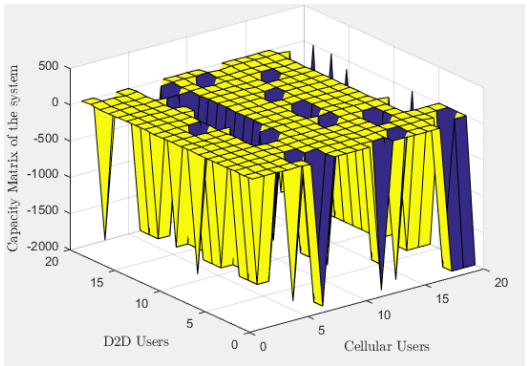

Fig 1.1 Capacity matrix of the system

2) The result shown in Fig. 1.2 shows the generated network, which includes the number of clusters of D2D pairs and also the present CUs.

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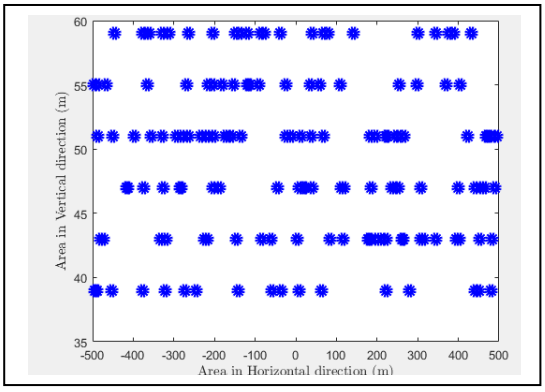

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3) The result in figure 1.3 shows the comparison between the Running time of Exhaustive search (ES) and Coalition Game algorithm (CG)

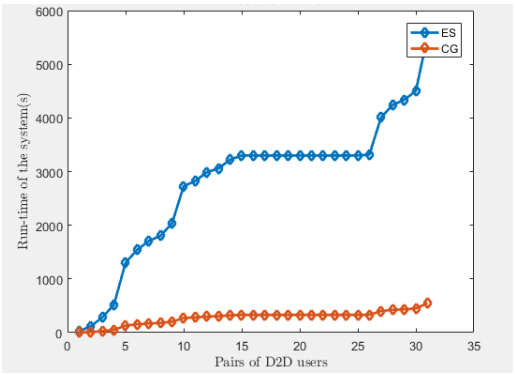

Fig. 1.3 Comparison of Running time

4) The result obtained in figure 1.4 depicts the System Sum-Rate when using the Exhaustive search technique and the using the Coalition game approach.

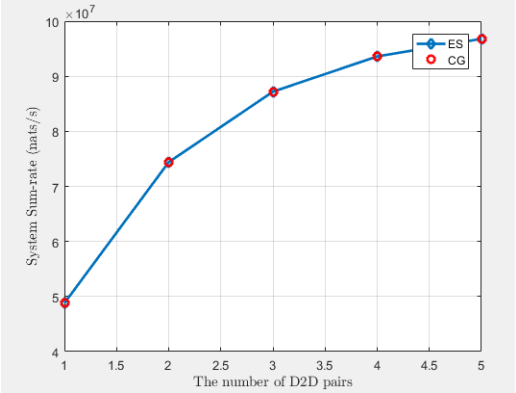

Fig. 1.4 System Sum-rate comparison

The paper presented here focuses on enhancing the system sum-rate of a D2D underlaying cellular network which works on the principles of Rayleigh Fading channel. The format of the system sum-rate equations came out in the form of mixed-integer non linear programming problem which is complex and takes time to give results. This to improve the time complexity, a decomposition method was given that simultaneously optimizes the SINR threshold and the resource allocation policy. The sum-rate was improved and to improve the run-time, we proposed a Coalition game algorithm. Thus, the proposed method achieves close-to-optimal solution and a much better run-time performance. Also, the resource sharing fairness was better as compared to other resource allocation techniques.

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VI .FUTURE ENHANCEMENTS

On the basis of our observations, we find that although the system sum-rate if fairly equal in both Exhaustive search and Coalition game approach, there is a significant improvement in run-time for the latter. Further, a Time-Division Scheduling (TDS) algorithm can be used in which the scheduling period of a base station is divided into a set of timeslots and the D2D pairs in the system are assigned to different timeslots for communication in a balanced manner in order to accommodate more D2D users in the system. This can significantly improve the system throughput. Thus, both run-time and throughput can be enhanced by using the combination of the two algorithms namely Coalition game and Time Division Scheduling.

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