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# Energy Efficient Joint Scheduling For Underlay D2D Communications

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## Abstract

Energy-efficient downlink resource reuse strategies for device-to-device (D2D) communications underlaying cellular networks is being investigated. We aim to maximize the total energy efficiency of all D2D links while guaranteeing the quality of service (QoS) of cellular users (CUs) and the power requirements for both base station (BS) and D2D links. Based on the analysis of the characteristics of optimal joint power control and D2D-CU matching strategy, we propose an energy-efficient iterative algorithm for D2D communications. Simulation results show that the proposed energy-efficient downlink resource reuse strategy achieves higher energy efficiency of D2D communications than existing schemes.

***Index Terms***

**Device-to-device(D2D),Energy Efficiency, Downlink Resource Reuse, Quality of Service.**

## I. INTRODUCTION

In a traditional cellular network, all communications must go through the BS even if communicating parties are in range for proximity-based D2D communication. Communication through BS suits conventional low data rate mobile services such as voice call and text messaging in which users are seldom close enough for direct communication. However, mobile users in today's cellular networks use high data rate services in which they could potentially be in range for direct communications. Hence, D2D communications in such scenarios can greatly increase the spectral efficiency of the network. Future generation networks will accommodate a large amount of data traffic and lower latency. In order to meet these demands, it is essential to look over current spectral use or introduce new frequency bands. Introduction of new frequency bands requires a partial or complete change of already deployed infrastructure, which will have high operation expenditure and capital expenditure. It is more convenient to find other solutions by concentrating on device-related solutions. One of the solutions to achieve higher spectra efficiency is through device-to-device communication.

## II. SYSTEM MODEL

Consider a downlink hybrid macro-cell scenario where D2D links share downlink RBs with multiple CUs as illustrated in Fig. 1. In this network, there are D pairs of D2D users and K downlink CUs which occupy K orthogonal RBs.D2D shares downlink RBs with multiple CUs. Resource allocation for CUs is assumed to be predetermined ($i^{th}$ RB is allocated to $j^{th}$ CU).Assume, the downlink RB of each CU can be shared by at most one D2D link.

Assume that the downlink RBs of each CU can be shared by at most one D2D link, i.e.,

$\sum_{d=1}^{D} y_{d,i} \leq 1, \forall i.$  $y_{l,i}$

Let $y_{l,i} \in \{0, 1\}$(d = 1,…, D, i = 1,…, K) indicate whether the i-th RB is reused by the l-th D2D link.

$D \rightarrow$ Pairs of D2D users

$(i = 1,2,3 \ldots \ldots .. D)$

$C \rightarrow$ Downlink Cellular users

$(j = 1,2,3 \ldots \ldots .. C)$

We aim to maximize the total energy efficiency of all D2D pairs with the QoS constraints for CUs.

The energy efficiency is defined as the ratio of total sum bits to overall consumed power of all D2D pairs.

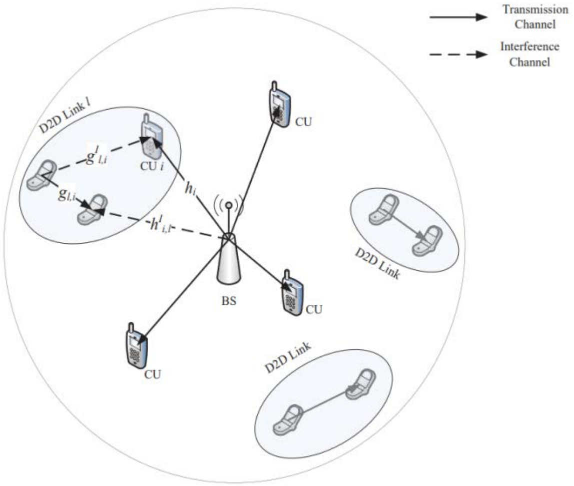

Fig 1. Scheme of D2D communication underlaying downlink network.

## III. METHODOLOGY USED

The Energy Efficiency(EE) of the system is found with the general formula for Energy Efficiency.

$$\text{Energy Efficiency} = \frac{\text{Rate}}{\text{Total Power of Transmitter}}$$

Where,

$$\text{Rate} = \log_2(1 + \text{SNR})$$

First the rate of the D2D user is found with the help of general equation of rate.

Rate of $i^{th}$d2d user using $j^{th}$ channel

$$r_{ij} = \log_2\left[1 + \frac{P_{d_{ij}}\, g_{d2d_{ij}}}{N_o + P_j g_{bdr_{ij}}}\right]$$

$P_{d_{ij}}$→Power of $i^{th}$d2d user on $j^{th}$ channel

$g_{d2d_{ij}}$→ Channel gain of $i^{th}$d2d user using $j^{th}$ channel

$P_j$ → Power of $j^{th}$ cellular user i.e., Power used for $j^{th}$ user from BS

$g_{bdr_{ij}}$→ Channel gain from BS to $i^{th}$d2d receiver through $j^{th}$ channel

Similarly, the rate of the Cellular user is found with the help of general equation of rate

Rate of cellular user,

$$R_j = \log_2\left[1 + \frac{P_j\, g_{bc_j}}{N_o + P_{d_{ij}} g_{dtc_{ij}}}\right]$$

$P_j$ → Power transmitted by BS to the $j^{th}$ Cellular User

$P_{d_{ij}}$→Power transmitted by $i^{th}$d2d user on $j^{th}$ Cellular User

$g_{bc_j}$→ Channel gain between the BS & $j^{th}$ Cellular User

$g_{dtc_{ij}}$→ Channel gain between $i^{th}$d2d transmitter & $j^{th}$ Cellular User

Actual rate of $i^{th}$ d2d user using any one channel ‘j’ ,

$$R_i = \sum_{j=1}^{C} \rho_{ij}\, r_{ij}$$

Where, $\rho_{ij}$ → Channel matrix ( $j^{th}$ CU’s resource block is used by $j^{th}$ d2d user)

$$R_i = \sum_{j=1}^{C} \rho_{ij}\ \log_2\left[1 + \frac{P_{d_{ij}} a_{ij}}{N_o e_{ij} + f_{ij} P_{d_{ij}}}\right]$$

Where,

$$a_{ij} = g_{d2d_{ij}}\, g_{bc_j}$$

$$e_{ij} = g_{bc_j} + \alpha g_{bdr_{ij}}$$

$$f_{ij} = g_{dtc_{ij}}\, g_{bdr_{ij}}$$

$$\alpha = 2^{R_j} - 1$$

**Optimization Problem (Dinkelbach)**

The energy efficiency $\eta_i$ can be updated by an iterative algorithm known as Dinkelbach method

$$\max_{\rho_{ij} R_{d_{ij}}} \sum_{i=1}^{D} \left[ \sum_{j=1}^{C} \rho_{ij} \log_2 \left[ 1 + \frac{P_{d_{ij}}\, a_{ij}}{N_0 e_{ij} + P_{d_{ij}} f_{ij}} \right] - \eta_i \left[ \varepsilon \sum_{j=1}^{C} \rho_{ij}\, P_{d_{ij}} + P_s \right] \right]$$

$$s.t \quad \textstyle\sum_{j=1}^{C} \rho_{ij} \le 1 \quad \forall i$$

$$\textstyle\sum_{j=1}^{C} \rho_{ij}\, P_{d_{ij}} \le P_i^{max} \quad \forall i$$

**Lagrangian function**

$$\mathcal{L}\left(\rho_{ij}, R_{d_{ij}}, \lambda_i, \mu_i\right) =$$

$$-\left[ \textstyle\sum_{i=1}^{D} \sum_{j=1}^{C} \rho_{ij} \log_2 \left[ 1 + \frac{P_{d_{ij}}\, a_{ij}}{N_0 e_{ij} + P_{d_{ij}} f_{ij}} \right] - \sum_{i=1}^{D} \eta_i \left[ \varepsilon \sum_{j=1}^{C} \rho_{ij}\, P_{d_{ij}} + P_s \right] \right] + \sum_{i=1}^{D} \lambda_i \left[ \sum_{j=1}^{C} \rho_{ij} - 1 \right] +$$

$$\textstyle\sum_{i=1}^{D} \mu_i \left[ \sum_{j=1}^{C} \rho_{ij}\, P_{d_{ij}} - P_i^{max} \right]$$

Where,

$\lambda_i, \mu_i$ are the Lagrangian constants.

## IV. RESULTS

The simulation results have been shown to evaluate the performance of our energy-efficient downlink resource reuse algorithm. In our simulations, the D2D links and CUs distribute randomly in a hybrid macro-cell network with a radius of 500m. The exponential path-loss channel model is adopted, in which the path-loss exponent is 3.5. The bandwidth of RB is 15 KHz and the thermal noise is -174 dBm/Hz. The maximum transmitting power of BS and D2D link are set to be 46 dBm and 20 dBm, respectively. The circuit power of each D2D link is 50 mW and the number of D2D links is 15.

Fig. 3 shows the total energy efficiency of D2D links as a function of the number of CUs. Since CU has a higher priority than D2D users, we choose the higher QoS of CUs, i.e., Rc=15 bits/s/Hz. The distance between D2D TX and RX is 10 meters. It can be seen that the total energy efficiency of D2D links of all the methods increases with the number of CUs. This is because the D2D links will have more RBs to reuse when the number of CUs increases.

As can be seen from Fig. 3, the total energy efficiency of all the methods decreases as the distance between D2D TX and RX increases. This is because the fading increases when the distance between D2D TX and RX increases, which has a great influence on EE of D2D links.

Fig. 4 presents the variation of the total energy efficiency of all D2D links versus different distances between D2D transmitter (TX) and receiver (RX) on the condition of different minimum data rate requirements of CUs. The distance of each D2D link is set from 10m to 100m with 10m interval identically. Therein, the number of CUs is 10.

It can be seen that the total energy efficiency of D2D links of all the methods increases with the number of CUs. This is because the D2D links will have more RBs to reuse when the number of CUs increases.

The total energy efficiency of D2D links even tends to decline for the random reuse algorithm. The reason is that the data rate of D2D links cannot always increase while they consume circuit power all the time.

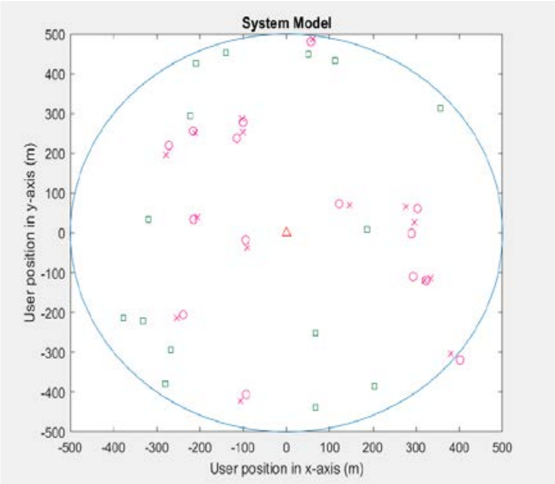

Fig 2. System model

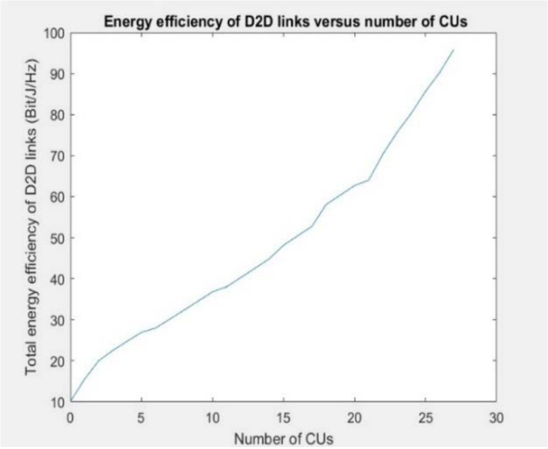

Fig 3. Energy efficiency of D2D links versus number of CUs.

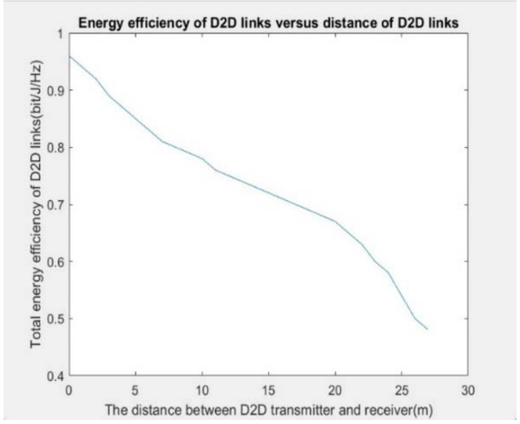

Fig 4. Energy efficiency of D2D links versus distance of D2D links

## V. CONCLUSION

The total energy efficiency maximization problem has been formulated for multiple D2D links considering joint power control and D2D-CU matching. Based on the theory of Dinkelbach and convex optimization algorithm, we have transformed the original non-convex problem into tractable form and proposed an iterative algorithm to solve the optimization problem. The effect of proposed scheme has been demonstrated by several simulation results.

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