Lagrange's multiplier based resource management for energy efficient D2D communication in 5G networks

Krishna Pandey[1] · Rajeev Arya[1] · Sandeep Kumar[2]

Abstract Device to device communication is the predominantly renowned trait for the 5G network and IoT applications. In the work, proposed novel joint low power/energy efficient resource allocation with mode selection for the D2D communication underlay in-band with transmit power, interference, data rate constraints are investigated with formulation of a novel problem which integrates the three major modules (resource management, mode selection, and power management) of D2D communication into one. To achieve the low power/energy efficient resource allocation with mode selection, we formulate novel optimization problem with objective of maximizing the energy efficiency using the subtractive form method to solve fractional objective function and form an iterative algorithm. The formulated fractional optimization problem is transformed into min–max problem and solved by the Lagrange dual function with low transmit power, interference, data rate constraints as a lagrange multipliers via an iterative process to achieve the optimal low power. Numerical analysis exemplifies and validates the optimal low power and the energy efficient characteristics of the novel proposed algorithm with all constraints to ensure the quality of the

communication for the D2D communication, 5G, and IoT applications with the industrial need of low power/energy efficient devices to promote the conservation of energy and green communication.

1 Introduction

To provide the large connectivity and applications like digital cities, smart agriculture, and intelligent healthcare, 5G becomes the integral part of the Internet of Things (IoT). To ensure the quality of service in the IoT applications the 5G acts as driving technology (Chettri and Bera 2020). In 5G and next generation cellular networks, the energy efficiency is a major factor which improves the overall performance. The device to device communication (D2D) ensures the energy efficiency in the wireless networks through different energy efficient algorithm and protocols. Due to its promising feature, the D2D communication becomes the subpart of 5G networks technologies (Hoyhtya et al. 2018).

In the present days, the numbers of IoT application are available in health sectors. In the pandemic COVID-19 situation, Indian government launched an Application named as Arogya Setu app to nurse the social distance by gathering the data of nearby surrounded persons. With keep in view of this problem, in the Arogya Setu app (an App by Indian government for gathering the information of and give awareness to the people during fight COVID-19), when we tried to use this application, the Bluetooth-ON prerequisite condition is imperative. But for these types of application,

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reliability and accessibility is exceedingly focal concern. Bluetooth requirement also drained the battery into some extent. To solve this problem, we have to provide a communication platform which ought to perform in licensed domain network and retain the power consumption. In our point of view device 2 device communication is probable solution for the above said problem.

We are highly motivated from this problem and try to give the solution through start working in the domain of D2D communication. As we studied that the energy efficient, low power device is always a concern for the purpose of communication, we work on the field of D2D communication and propose a novel Joint Low power and energy efficient resource management algorithm with mode selection for D2D communication in 5G and IoT application.

2 Related work

With the ingenious attribute and energy efficient spirit of D2D communication several underlay-in band cellular network models are optimized and analyzed to attain the resource allocation, mode selection, and power control strategies individually and jointly. For the mode selection the objective formulations are done based on maximization of quality of services (QoS) with the minimum transmit power (Shalmashi et al. 2014). A mode selection through the concept of guardzone is proposed for the D2D communication network (Ye and Zhang 2015). Load balancing technique is used in the optimal mode selection by proposing the distributed algorithm (Liu 2016). Using the bandit model for the mode selection is done for the small cell D2D communication (Maghsudi and Niyato 2017). The resource management with dynamic power control for D2D communication shown using the Lagrangian decomposition method for optimal power allocation is illustrated (Jiang et al. 2018). For the optimal power control, the reuse of the orthogonal pilots describes the concept of sharing of resources (Ghazanfari et al. 2018). A joint algorithm mode selection, channel allocation and power assignment is represented to minimize the power consumption with the data rate requirement (Gao et al. 2014). A joint admission control, mode selection and power management problem is proposed to enhance the throughput with QoS and interference constraint (Azam 2016). The maximization problem in D2D femtocell with considering the mode selection, resource allocation and power assignment is represented and solved by using the Lagrangian dual composition method (Wang et al. 2016). Maximization of the energy efficiency is a significant paradigm of the D2D communication.

After studying and analyzing the above mentioned and energy efficient articles (Fodor et al. 2016; Han et al. 2011, 2019; Feng et al. 2013; Gandotra et al. 2017; Wang et al. 2014, 2018; Sheng et al. 2016; Xu et al. 2016; Cai et al.

2019; Awan et al. 2020; Lee and Lee 2019; Huang et al. 2019), we conclude that the several authors already epitomize the concept of energy efficient algorithms for the mode selection, resource allocation and power control individually or jointly. In the above-mentioned glimpse of the literatures, Shalmashi et al. (2014), Ye and Zhang (2015), Liu (2016), Maghsudi and Niyato (2017) represent the study of different methods of mode selection, literature (Maghsudi and Niyato 2017; Jiang et al. 2018; Han et al. 2019) discuss about the resource allocation with optimized power. The Joint algorithm with mode selection and channel allocation was done with optimal power distribution in Gao et al. (2014), Azam (2016), Wang et al. (2016). The data rate (Gao et al. 2014) and interference (Azam 2016) are the widely and singly used constraint for achieving the optimal results, via using Lagrange dual decomposition method (Wang et al. 2016) and it has been observed after literature review that several authors discuss about the different power control methods to achieve the low power and energy efficiency separately to resolve the mode selection and resource management issues. There is no work for building a model which ensures the optimal low power requirement with energy efficiency by including all (data rate, interference, low transmit power) constraints together with performing the mode selection, and resource allocation for the D2D communication.

In this paper, we study the individual and joint association of resource allocation, mode selection and power allocation for the energy efficient D2D communication. We propose a novel Joint Low power and energy efficient resource management algorithm with mode selection. To create the proposed algorithm, we formulate the combinatorial fractional optimization problem for the energy efficient D2D communication to address the resource allocation, mode selection and power control issues jointly. Mode selection is done by using the basic algorithm using probabilistic approach. For the attaining the maximum energy efficient value, iterative approach is applied to fractional objective function which is represented in the subtracted form. In each iteration the optimal power value with resource allocation with mode selection is achieved to maximize the energy efficiency (EE) and further Lagrange dual function having Lagrange multipliers optimize the power with low transmit power rate, data rate, and interference constraints as a Min–Max problem.

To propose the Joint Low power energy efficient resource management algorithm with mode selection, we utilize the concept of energy efficiency and Min–Max approach (Jiang et al. 2016; Mensah et al. 2016). The footprint of our proposed algorithm after the profound literature survey is mentioned below.

1. Formulate the novel problem which integrates the three problems mode selection, resource allocation and optimal power into one.

2. Propose the novel mode selection method with theorem for the D2D communication.

3. Use the concept of maximizing the energy efficiency (Jiang et al. 2016; Dinkelbach 1967)

4. Add the low transmit power rate, data rate, and interference constraints to the formulated problem to transform into Min–Max problem.

5. With help of Lagrange dual function and Lagrange multipliers (Mensah et al. 2016) concept (adding interference constraint), we further obtain the optimal transmit power with low transmit power rate, data rate, and interference constraints.

6. Finally, we propose novel joint Low power and energy efficient resource management algorithm with mode selection.

7. By evaluating the numerical results, we finally attain a framework which reflects the improvement in the related work of energy efficient resource management algorithms (Jiang et al. 2016) by keeping the view of Low power devices and power conservation with maximum energy efficiency.

The paper is organized as follows. Section 2 describes the formulated problem with system model. In Sect. 3, the proposed Joint Low power and energy efficient resource management algorithm with mode selection is presented. The algorithm for the mode selection, iterative algorithm for the maximum energy efficiency and the iterative algorithm using Lagrange dual function with Lagrange multipliers are described here. The numerical results using system parameters evaluate the different performance parameters of the proposed algorithm in Sect. 4. And, Sect. 5 concludes the proposed work with improvement in the past analogous efforts.

3 System model and problem formulation

We assume the uplink resources of cellular user equipment (CUE) are shared by the D2D user pairs (DU) and there is a random distribution of DU and CUE in the cell. In the single cell we consider that

$A = \{1, 2, 3, \ldots A_{cue}\}$,
$B = \{1, 2, 3, \ldots, B\}$
$C = \{1, 2, 3, \ldots, t\}$
$D = \{1, 2, 3 \ldots t + A_{cue}\}$
must satisfy that $t \leq A_{cue} = B$ and $D = \{AUC\}$

where A, B, C denotes the set of CUE's and the resource blocks R_B and D2D users DU's respectively, we assume that 1 time frequency resource block consists of one-time slot and 4 frequency subcarriers and jth resource block allocated to

cellular user equipment are reused by the ithe mobile user MU with nth mode selection. Let us assume that G_{ij} is the transmit power of the transmitter of the ith mobile user MU on the jth resource block R_B and G_b denotes the base station transmission power. Let T_{DU} and T_{CUE} represent the data rate of DU and CUE respectively. By using the Shannon capacity formulae (Fan et al. 2017), we evaluate the mathematical formulae of T_{DU} and T_{CUE} (Fig. 1)

$$T_{CUE}(G_{ij}) = B \log_2\left(1 + \frac{G_b h d_b^{-\alpha}}{\sum_{i=0}^{t} G_{ij} g d_{ib}^{-\alpha} + N_0}\right) \qquad (1)$$

$$T_{DU}(G_{ij}) = B \log_2\left(1 + \frac{G_{ij} g d_{ii}^{-\alpha}}{G_b h d_{ib}^{-\alpha} + N_0}\right) \qquad (2)$$

$$T(G_{ij}) = T_{DU}(G_{ij}) \ when \ D2D \ user \ mode \ is \ active \qquad (3)$$

$$T(G_{ij}) = T_{CUE}(G_{ij}) \ when \ Cellular \ mode \ is \ active \qquad (4)$$

$T(G_{ij})$ denotes as data rate of the communication, and whereas B, N_0, d_{ii}, d_b, d_{ib}, α, t, h and g represents bandwidth, white gaussian noise, distance between the two user of ith D2D pair, separation between the base station and cellular user, distance between the ith D2D transmitter to base station, path loss exponent, number of D2D pair, shadow fading coefficient, and statistical distributed random effect of fading in the D2D pair environment respectively.

Mode selection plays a vital role in the D2D communication. In order to achieve the mode selection, we consider the channel quality and the interference level with all fading or wireless issues. In the work, we adopt data rate metric for the mode selection of the communication.

When

$$T_{CUE} > T_{DU}; represents \ that \ Cellular \ user \ Mode \ is \ active \ (m = 0) \qquad (5)$$

and

$$T_{DU} > T_{CUE}; represents \ tha \ D2D \ user \ Mode \ is \ active \ (m = 1) \qquad (6)$$
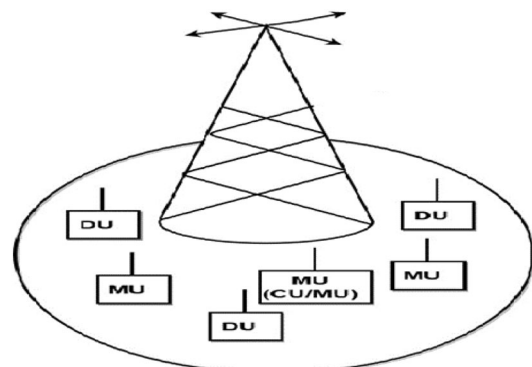

Fig. 1 Cellular architecture with different DU and MU

$$T(G_{ij}) = mT_{DU}(G_{ij}) + (1 - m)T_{CUE}(G_{ij}) \quad (7)$$

The total power during the communication is

$$P = \sum_{n=1}^{t+A_{cue}} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn}G_{ijn}m_{ijn} + P_{cd} + P_{cc} \quad (8)$$

whereas, $\sum \sum \sum y_{ijn}G_{ijn}m_{ijn}$, P_{cd} and P_{cc} denotes the total transmit power consumption, and the total circuit power consumption of DU and CUE respectively including battery backup

$$P_{cd} = 0; \text{ for } (m = 0) \quad (9)$$

$$\text{And } P_{cc} = 0; \text{ for } (m = 1) \quad (10)$$

In order to formulate the mathematical model of energy efficiency we use the Bit per joule metric and evaluate the optimal energy efficiency of the D2D communication after selecting the mode of the communication. The generalize formula of Energy efficiency is represented by η_{EE}

$$\eta_{EE} = \frac{\sum_{n=1}^{t+A_{cue}} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn}T(G_{ijn})m_{ijn}}{\sum_{n=1}^{t+A_{cue}} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn}G_{ijn}m_{ijn} + P_{cd} + P_{cc}} \quad (11)$$

Here, $T(G_{ij}) = mT_{DU}(G_{ij}) + (1 - m)T_{CUE}(G_{ij})$ (for the D2D communication mode the value of m should be one only), and

$y_{ijn} \in \{0, 1\}$ shows that jth resource block is allocated to the ith of the MU with nth selected mode.
$m_{ijn} \in \{0, 1\}$ shows n mode selection with jth resource block is allocated to the ith of the MU.

The D2D energy efficient optimization problem can mathematically represent as

$$\underset{y_{ijn}G_{ijn}m_{ijn}}{Max} \eta_{EE} \quad (12)$$

$$\text{Subject to. } m_{ijn} \in \{0, 1\}, \forall_i \in C, \forall_j = B, \forall_n = D \quad (13)$$

$$\sum m_{ijn} \geq 1, \forall_n \in C \quad (14)$$

$$\sum m_{ijn} < 1, \forall_n \in D \cap C \quad (15)$$

$$y_{ijn} \in \{0, 1\}, \forall_i \in C, \forall_j = B, \forall_n = D \quad (16)$$

$$\sum_{j=1}^{B} y_{ijn} = 1, \forall_i \in C, \forall_n \in C \quad (17)$$

$$\sum_{i=1}^{t} \sum_{n=1}^{t+A_{cue}} y_{ijn} \leq 1, \forall_j = B \quad (18)$$

$$T(G_{ijn}) = T_{DU}(G_{ijn}) \geq \beta, \forall y_{ijn} \in 1 \quad (19)$$

$$G_b h \, d_b^{-\alpha} \leq \bar{\lambda}, \forall y_{ijn} \in 1 \quad (20)$$

$$G^{min} < G_{ijn} \leq G^{max}, \forall y_{ijn} \in 1 \quad (21)$$

whereas G^{min} denotes the requirement of minimum transmit power of each DU for the purpose of the communication, G^{max} shows the maximum transmit power of each DU, and β denotes the minimum rate requirement of each DU, λ shows the threshold value of the allowed interference from CU when shared the same resources with corresponding DU.

4 Proposed joint low power energy efficient resource management algorithm with mode selection

Our proposed joint algorithm has two subsections. One is iterative algorithm for the energy efficiency named as Algorithm II and the second is iterative algorithm to attain the optimal low power with all constraints using the Lagrange dual function and multipliers named as Algorithm III. In the work, due to the self-realizing quality of the novel proposed formulated problem Eq. 11, the Algorithm I automatically recalled for getting the solution according to the selection of the D2D user and CUE.

In the Fig. 2, the logical flow process of the proposed Joint low power and energy efficient algorithm with resource management and mode selection is illustrated. The aim of the process is to provide a framework that reflects journey for achieving the low power and energy efficient system with the resource management and mode selection for the D2D communication. The process starts with the initialization of all the variables mentioned in the above Eqs. 1–21. After attaining all the variables for the D2D communication scenario, the Algorithms No. 2 comes into the picture. The analyzer can use the Algorithm No. 2 for the attaining the energy efficient resource management with mode selection including power control. Inhibit quality of the Algorithm no. 2 (Step number 4) enforce the use of Algorithm no. 1 for the mode selection purpose. If the D2D mode is active, the process goes into the next step by following the Algorithm No. 3 to attain the optimized low power with low transmit power rate, data rate, and interference constraints with the use of lagrange dual function and lagrange multipliers otherwise go back into the first block for initiating the variables. The process would be complete after attaining the desired output from the proposed Joint Low power and energy efficient algorithm with resource management and mode selection.

4.1 Mode selection

In the mode selection, the selection of the D2D user and CUE is defined. In this approach it is decided by using the probabilistic theory that the particular Mobile user is going for the D2D communication or not.
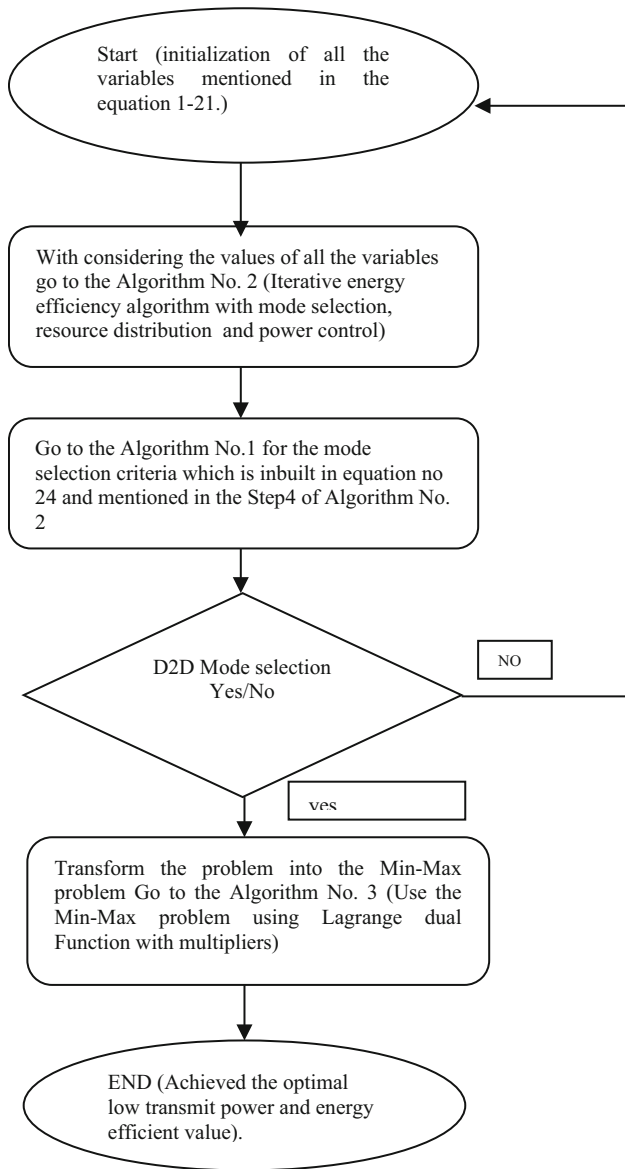
Fig. 2 Flow chart of proposed joint algorithm

Algorithm I. Mode selection

Algorithm-I	
Step 1	Calculate the total number of users that is $t+A_{cue.}$
Step 2	Set n=1;
Step 3	if ($T_{DU} > T_{CUE}$) and ($T_{DU} > \beta$), then move to step5
Step 4	else move to step 7
Step 5	if ($T_{DU} > \beta$) set the value $m_{ijn} = 1$;
Step 6	else set the value $m_{ijn} = 0$;
Step 7	set n=n+1; and Repeat step 2 to 7. until n= $t+A_{cue.}$

Theorem 1 *To prove*

$$T\left(G_{ijn}\right) = T_{DU}\left(G_{ijn}\right) \tag{22}$$

when D2D mode is selected or active.

Proof In this work the selection of mode depends upon the value of T_{DU} and T_{CUE}

$T_{CUE} > T_{DU}$; represents that Cellular user Mode is active (m = 0).

$T_{DU} > T_{CUE}$; represents that D2D user Mode is active (m = 1).

let assume that

$T_{DU} > T_{CUE}$ and $T_{DU} > \beta$

In this case the D2D user mode is active and value of m becomes one only.

From Eq. 7, we know that $T(G_{ijn}) = mT_{DU}(G_{ijn}) + (1 - m)T_{CUE}(G_{ijn})$.

By putting the value of m = 1

$$T\left(G_{ijn}\right) = 1T_{DU}\left(G_{ijn}\right) + (1 - 1)T_{CUE}\left(G_{ijn}\right)$$
$$T\left(G_{ijn}\right) = 1T_{DU}\left(G_{ijn}\right) + (0)T_{CUE}\left(G_{ijn}\right) \tag{23}$$
$$T\left(G_{ijn}\right) = T_{DU}\left(G_{ijn}\right)$$

Hence proved.   □

4.2 Iterative method for maximum energy efficiency

Our main objective is to maximize the η_{EE} with subject to Eqs. 13–21

Let k represents the maximum value of η_{EE}, £ represents the value of the constraints Eqs. 13–21. k may be defined as follows

$$k = \underset{y_{ijn}, G_{ijn}, m_{ijn} \in £}{Max} \left(\frac{\sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn} T(G_{ijn}) m_{ijn}}{\sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn} G_{ijn} m_{ijn} + P_{cd} + P_{cc}} \right). \tag{24}$$

Theorem 2 *For the D2D communication the maximum η_{EE} with joint mode selection is achieved if and only if*

$$\underset{y_{ijn}, G_{ijn}, m_{ijn} \in £}{Max} \left\{ \sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn} T(G_{ijn}) m_{ijn} \right.$$
$$\left. -k \left(\sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn} G_{ijn} m_{ijn} + P_{cd} + P_{cc} \right) \right\} = 0. \tag{25}$$

Proof In this case for the D2D communication, joint mode selection is done in Eq. 25. By considering the Eqs. 7, 10, and 25 we get

$$\underset{y_{ijn}, G_{ijn}, m_{ijn} \in £}{Max} \left\{ \sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn} T(G_{ijn}) m_{ijn} \right.$$
$$\left. -k \left(\sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn} G_{ijn} m_{ijn} + P_{cd} \right) \right\} = 0. \tag{26}$$

Now, the maximum η_{EE} is achieved if and if only Eq. 26 satisfies its conditions.   □

The proof of this statement is similar with the proof in Dinkelbach (1967). It can be observed from Eq. 26 and Dinkelbach (1967) that the fractional objective function represented in the subtractive form same as the case (Ye and Zhang 2015). To obtain the objective function which is in the fractional form is solve by analyzing its subtractive form. Similarly, we focus on the objective function in the subtractive form.

Let k_r denotes the temporary η_{EE} and γ_1 denotes the convergence threshold value for the iterative algorithm.

Algorithm II: Iterative algorithm for resource allocation and power control with mode selection

Algorithm-II	
Step 1	Set the number of iteration r =1 and k_r = 0;
Step 2	With present value of k_r solve the optimization problem to obtain new $y_{ij}@$ and $G_{ij}@$ $F(k_r) = \underset{y_{ijn},G_{ijn},m_{ijn} \in \mathcal{E}}{Max} \left\{ \sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn}T(G_{ijn})m_{ijn} - k \left(\sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn}G_{ijn}m_{ijn} + P_{cd} \right) \right\}$
Step 3	Set $k_r = \dfrac{\sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn}^@ T(G_{ijn})^@ m_{ijn}}{\sum_{n=1}^{t+Acue} \sum_{i=1}^{t} \sum_{j=1}^{B} y_{ijn}^@ G_{ijn}^@ m_{ijn} + P_{cd} + P_{cc}}$
Step 4	Go to the Algorithm I for getting the value of m_{ijn} and after attaining the value $T(G_{ijn})$ = $T_{DU}(G_{ijn})$ go to the Step 5.
Step 5	If $(|F(k_r)| \geq \gamma_1)$ {Set r = r +1; Repeat step 2,3, 4 and 5}
Step 6	else{end}.

4.3 Lagrange dual method use for optimum low power and energy efficient, resource allocation algorithm with mode selection

In this section we are using the Lagrange dual method for attaining the optimum minimum power for the above mentioned problem after following the (Algorithm I and II)

mode selection, resource and power allocation. By using the Eq. 24, with considering Eqs. 19–21, we can formulate the optimum power in Lagrangian form and can be written as follows:whereas u, v, w are the multipliers of transmission power constraint, data rate and allowed interference respectively. The Low Power optimization can be obtained by using Lagrange dual problem shown as

$$L\left(G_{ij},\ u,\ v,\ w\right) = T_{DU}\left(G_{ij}\right)$$
$$- k\left(G_{ij} + P_{cd}\right) - u\left(G_{ij} - G^{max}\right)$$
$$- v\left(\beta - T_{DU}\left(G_{ij}\right)\right) - w\left(\bar{\lambda} - \bar{\lambda}_{ij}\right)$$

$$\underset{u,v,w}{min}\ \underset{G_{ij}}{max}\ L(G_{ij},u,v,w); s.t.u,v,w \geq 0 \qquad (27)$$

By using the present Lagrange multipliers u, v, w, and Eqs. 1 and 22, we can find an optimal power allocation method shown as

$$G_{ij} = \left[\frac{(1+v)B}{(k+u)\ln 2} - \frac{(1+w)(G_b hd_b^{-\alpha} + N_0)}{gd_{ii}^{-\alpha}}\right]^+ \qquad (28)$$

where $[x]^+$ = max [0, x], for updating the lagrange multipliers we use gradient method

$$u(r + 1) = u(r) + \Omega_1\left(G_{max} - G_{ij}\right)$$
$$v(r + 1) = v(r) + \Omega_2\left(T_{DU}\left(G_{ij}\right) - \beta\right)$$
$$w(r + 1) = w(r) + \Omega_3\left(\bar{\lambda}_{ij} - \bar{\lambda}\right)$$

whereas $\Omega_1, \Omega_2, \Omega_3$ are the step sizes.

The proposed algorithm for the optimal low power allocation using Lagrange dual function is mentioned in the Algorithm III.

Let r_{max} is the maximum number of iterations and γ_2 denotes the maximum convergence threshold value for the iterative algorithm.

Algorithm III

Algorithm-III	
Step 1	After following the Algorithm-I and Algorithm-II go to the step2
Step 2	Set the initial value of u, v, w for r=0; $$G_{ij} = \left[\frac{(1+v(r))B}{(k+u(r))\ln 2} - \frac{(1+w(r))(G_b h d_b^{-\alpha} + N_0)}{g d_{ii}^{-\alpha}} \right]^+$$
Step 3	Find the value of G_{ij} by using equation number
Step 4	Update the Lagrangian multipliers $u(r+1) = [u(r) - \Omega_1 (G_{ij} - G^{max})]^+$ $v(r+1) = [v(r) - \Omega_2 (\beta - T_{DU}(G_{ij}))]^+$ $w(r+1) = [w(r) - \Omega_3 (\lambda - \lambda_{ij})]^+$

Step 5	if
	$$\|u(r+1) - u(r)\| + \|v(r+1) - v(r)\| + \|w(r+1) - w(r)\| \leq \gamma_2$$
	$\{$return $G_{ij}{}^* = G_{ij}\}$
	else
	set r = r+1;

Step 6	Repeat the step 2,3,4,5 until $$\|u(r+1) - u(r)\| + \|v(r+1) - v(r)\| + \|w(r+1) - w(r)\| > \gamma_2$$ or r = r$_{max}$.

By following the above mentioned proposed algorithms one can achieve the low power energy efficient resource allocation with mode selection.

5 Results and discussions

In this section we evaluate the performance analysis of our proposed algorithm for D2D communication. We consider the single cell having A_{cue}, t number of CUE and DU respectively within 200-m radius and the average power value of all D2D users are same. For the purpose of analysis, we considered the system parameters which are mentioned in Table 1.

By considering the above mentioned system parameters, first of all, the mode selection is achieved which ensures that the particular mobile user is working as a D2D user or not by using Algorithm 1 and by following the Algorithms 2 and 3, we get the performance evaluation of low power energy efficient resource allocation with mode selection. Figures 2, 3, and 4 are representations are the outcomes of the Algorithm 2, and Fig. 5 illustrates the final step of proposed work using the algorithm 3.

In Fig. 3, the EE versus number of iteration with t different number of D2D users (DU) is illustrated. It is observed that the Energy efficiency of the proposed algorithm increases with the number DU. As the number of

D2D user increases we achieved the higher value of EE (Jiang et al. 2016). It is also observed that only 2 iteration process requires gaining the maximum energy efficiency (EE) value. In our proposed algorithm no. 2, by adding the optimal power with low transmission rate, data rate, and interference constraints using the (min–max problem) Lagrange dual function with Lagrange multiplier (Mensah et al. 2016), we achieve better performance that is shown in the Fig. 6.

In Fig. 4, the energy efficiency versus distance between D2D users with different value of power value is represented. It is observed in the plot that the lower value of transmit power have the high energy efficiency and the energy efficiency is decreases as distance between the D2D user increases.

In Fig. 5, the data rate versus distance between D2D users with different value of power value is shown. Figure 5 shows the mutual relationship between the D2D distance and data rate. Higher power has high data rate and as the distance increases the data rate will decrease. As per Fig. 4 the low power object achieves the high energy efficiency and in the Fig. 5, it is shown that the high power attains the higher date rate, due to these behavioral representation of the Algorithm 2 requires the need of the importance to choose the optimal power value with including the data rate and all other constraints, which is further carried out by the Algorithm no 3. and Fig. 6 conclude the final representation of our proposed algorithm.

In Fig. 6, (EE) versus maximum transmitting power of D2D user is represented. Based on our proposed algorithm the resource allocation with mode selection, low power allocation strategies, and energy efficiency of the DU can be examined and is drawn in the figure. It is observed that higher value of maximum power threshold is required to achieve the greater energy efficiency to attain the optimal low power value G^{max}. After numerical analysis the threshold value 0.002 w is obtained and set as a threshold for the proposed algorithm. It is observed that the energy

Table 1 System parameter

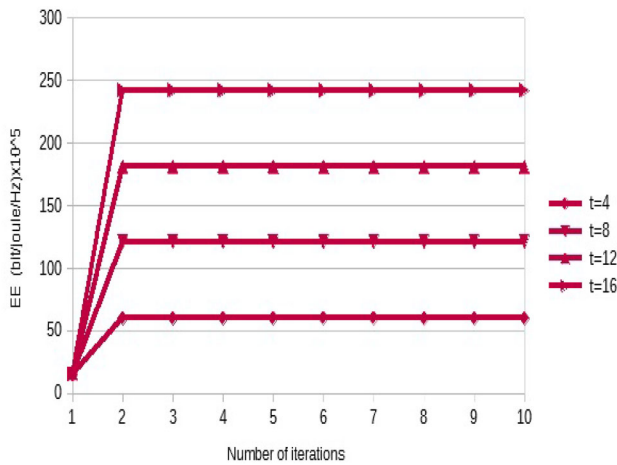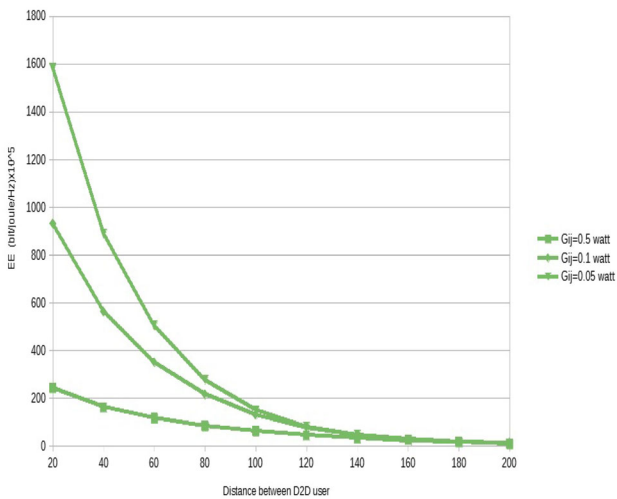|	
Cell radius	200 m
D2D distance	20 m
Noise	− 174 dbm/Hz
Path loss exponent	4
Shadow fading/random fading effect	8 db
G^{max}	0.5 W
Threshold	50 mW
Total circuit power consumption (P_{cd})	0.1 W
Base station transmission power (G_b)	1 W
Bandwidth (B)	1 MHz

Fig. 3 EE versus iterations number

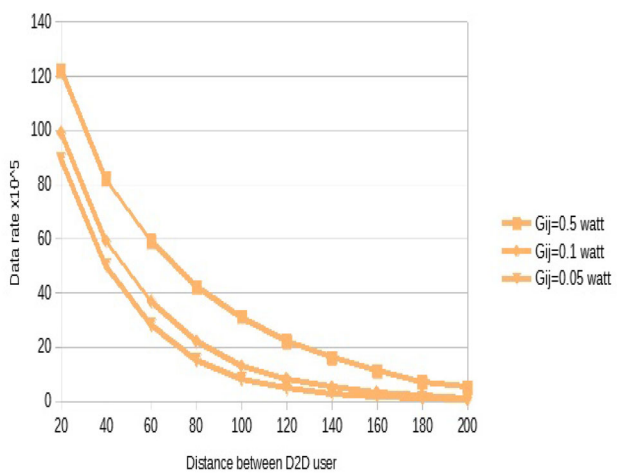Fig. 4 EE versus distance between D2D users
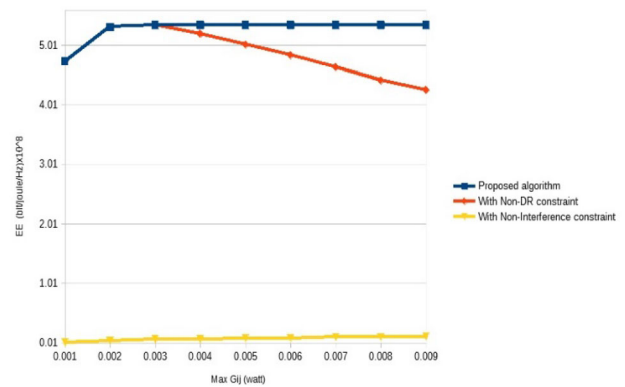

Fig. 5 Data rate versus distance between D2D users

Fig. 6 Illustrate that our proposed algorithm, provide better performance in the terms of low transmit power value and energy efficiency

efficiency increases with the increase of G^{max}. When the proposed algorithm reaches the threshold value, the energy efficiency provides a fixed value which doesn't varies with further raising the value of G^{max} and we can get optimal low power energy efficient value.

In the Fig. 6, we can compare the performance evaluation of mentioned three scenarios proposed algorithm, Non-DR constraint, and Non- Interference constraint respectively. It is clearly visualized that proposed algorithm provides better energy efficiency (max value 5.32×10^8 bit/J/Hz) with increase in the maximum transmit power value comparison to the Non-DR constraint, and Non- Interference constraint. It is analyzed that the addition of optimal power with low transmit rate, data rate, and interference constraints improves our algorithm performance in comparison to the Non-DR constraint, and Non-Interference constraint.

It is seen from the Table 2 and numerical results that our proposed algorithm achieve better results from the prevailed researches carrying resource allocation with power management.

6 Conclusion

In this paper, we proposed the novel low power energy efficient algorithm resource allocation algorithm with mode selection by formulating the optimal joint problem of mode selection, resource allocation, and power control using equivalent subtraction form of a fractional function problem to maximize the energy efficiency and further use the Lagrangian dual function with Lagrangian multipliers for attaining the optimal transmit power with low transmit power rate, data rate, and interference constraints. In the work, we conduct the numerical analysis for the validation of the algorithm, and the numerical result shows that with low power of 0.002 W we achieve the maximum energy

Table 2 Comparative table

Algorithm	References	Characteristic parameters	Improvement
Distributed algorithm	Liu (2016)	Optimal mode selection	Average throughput increases with transmit power
Bandit model	Maghsudi and Niyato (2017)	Mode selection	Improves transmission mode selection
Heuristic algorithm	Jiang et al. (2018)	Resource allocation and power control	Dynamic power control with resource allocation
SE algorithm with pilot allocation	Ghazanfari et al. (2018)	Power control	Optimize the power control with capacity
Iterative algorithm	Jiang et al. (2016)	Resource allocation and power control	Energy Efficiency with resource allocation and power control
Proposed algorithm		Mode selection, resource allocation, and power control	Energy efficiency with mode selection, resource allocation and power control
			Optimize the power with Interference, data rate, low transmit power constraints, using Lagrange method
			In the proposed work, the mode selection, resource allocation and power control done by using one mathematical function to obtain the Energy efficiency. Interference data rate, low transmit power constraints in the optimization provides an improvement in the results from the past researches (Liu 2016; Maghsudi and Niyato 2017; Jiang et al. 2016, 2018; Ghazanfari et al. 2018)

efficiency of 5.32×10^8 bit/J/Hz along with the mode selection and resource allocation, and we get the improvement in the energy efficient joint resource allocation and power control for D2D communication (Jiang et al. 2016) and related research domain of the optimal energy efficient resource management for the D2D communication with advancement in the terms of optimal low power with maintaining the effectiveness of the communication considering the Interference, data rate, low transmit power constraints, and achieve the low power energy efficient resource allocation algorithm with mode selection for the D2D communication underlay in-band cellular networks. Our novel proposed algorithm can be further used in the low power and energy efficient devices for the D2D communication as an Integral element of IoT applications and 5G.

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