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Robust Distributed Power Control with Resource Allocation in D2D Communication Network for 5G-IoT Communication System

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Abstract: In the domain of communication technologies, the Device-to-Device (D2D) communication becomes a predominant technology for the implementation of 5G communication system and Internet of Things (IoT) applications. In D2D communication Network, resource allocation and power management are the key areas of interest with ensuring the Quality of Services (QoS). Firstly, we propose the power control problem which is a non-convex problem. By using the log transformation approach, the non-convex problem converts into the convex optimization problem. Robust distributed power control method is further utilized for the power optimization at both ends (base station and D2D user) for underlay Inband D2D communication, where the cellular user and D2D user both use the cellular spectrum. After the power control, resource allocation is done to maximize the energy efficiency by 66.67% for the D2D system. Our proposed work provides new insight to power control techniques in D2D communication. Numerical analysis of the proposed algorithm reflects the impact of robust distributed power control for maintaining the quality of services and enhancing the energy efficiency of the system.

Index Terms: Device to Device (D2D), Robust distributed power control (RDPC), Quality of Service (QoS), Energy efficiency, Resource allocation, Internet of Things (IoT).

1. Introduction

D2D communication is the integral part of 5G technologies specially for the usage of IoT (Internet of Things) applications with the concern of communication reliability. In India, the technologist is looking for the 5G communication system advancement with their implementation and at the same time in the year 2020, the whole world is facing the challenges due to the different variant of COVID-19. Every country suffers from health and financial related crisis. Several researchers quote the importance of 5G communication system with IoT applications in Pandemic situations to overcome the effect of health and financial crisis. Presently Omicron variant high spreading rate is a major concern declared by WHO (World Health Organization). In this situation real time data generation and analysis is required which can be feasible by IoT application. The need of the IoT application with D2D communication provides the reliability and spectrum utilization under the aegis of 5G communication technologies [1].

In D2D communication sharing of license bands between the cellular user and D2D user provides communication spectrum utilization with maintaining the communication reliability. To keep in mind of present situation (pandemic and its solution by technology), there is a need to explore the D2D communication. For fulfilling the concern of demand, the detailed analysis of D2D communication, with power management and resource allocation mechanism [2] is required in D2D communication for IoT applications.

2. Related Work

Orthogonal Frequency Division Multiple Access (OFDMA) based technique is used with multi-objective optimization problems to increase the value of energy efficiency and power distribution is done on the basis of channel information among D2D devices [3]. Distributed power control (DPC) method is discussed [4] with considering the interference produced by different D2D users to achieve novel power control methods. Optimal admission control is done using the low power transmission and interference coordination [5] method to increase the spectral efficiency [6]. Transmission power allocation is done using the genetic algorithm to ensure the increased spectral efficiency [7]. In [8] increasing the sum rate with minimizing rate requirement is done to formulate the power control problem. CNN based optimization of power control problem is illustrated to increase the performance [9]. Generalized Benders Decomposition (GBD) method is utilized to solve the MINLP problem and disjoint scheme ensures the power allocation [10]. A DPC method [11] is used for the power control and stochastic framework to solve coverage probability with enhancing the D2D sum rate [12]. Power control evolves as an optimization problem to ensure the maximization of sum rate and QoS [13]. Location based autonomous power control mechanism is used in [14] with deep learning techniques to minimize the decision making time for power allocation. In [15] the SWIPT model is proposed for optimizing the power and resource distribution based on the NON-EH framework. Factor graph method is used for the power management with max-min message passing approach to increase the sum rate [16]. In [17] power constraint is used as an NP hard problem for the ADC based algorithm to maximize the sum rate. Deep reinforcement learning based optimization method is utilized for the power control to maximize the energy efficiency [18]. Transmit power and energy harvesting optimization problems are solved with the help of KKT method [19]. To solve MINLP power allocation problems, maximization optimization is utilized to attain a high value of sum rate [20]. Spectral efficiency is achieved by using the distributed power control (DPC) strategies [21]. In [22] DPC method is utilized with KKT optimization problem with proposed price factor,

By studying the above-mentioned literature [3-22], there is no discussion of the robust distributed power control method with resource allocation for D2D communication and reliable framework for the power optimization in D2D communication. By keeping the view of the above discussed literature gap, the following mentioned work is done.

- First of all, we present the literature review of recent power control related concerns in the D2D communication and propose the problem formulation as a function of minimum power usage.
- Utilized the Robust distributed power control technique to propose the Algorithm No. 1 and Algorithm No. 2 to get optimal low power for the D2D user and base station respectively.
- After getting the optimum power, resource allocation is done by using an iterative algorithm for maximizing the Energy Efficiency of the D2D system.

Section-2 elaborates the system modeling and problem formulation. Proposed model for Robust distributed power control with resource allocation in D2D communication for the IoT application is discussed in section-3. Section-4 elaborates the numerical analysis of proposed algorithm using system parameters. Conclusion and future work will be discussed in Section-5.

3. System Model and Problem Formulation

In this section, we will discuss on modeling of D2D communication for 5G communication system with deployment of users in a cell and we will formulate the problem. Random Distribution of (Base station), cellular user device (CUD) and D2D users is present in a hexagonal cell and we assume that downlink resources of n^{th} CUD are shared by the m^{th} D2D user using the p^{th} Resource block (RB) of time division duplex (TDD) system.

In a cell, we consider that the cellular user devices, D2D users, resource blocks are randomly distributed. It is shown in Fig. 1. We have

$$\mathrm{C} = \{1, 2, 3, \ldots.., n\},$$

$$\mathrm{R} = \{1, 2, 3, \ldots.., p\}$$

$$\mathrm{D} = \{1, 2, 3, \ldots\ldots., m\}$$

It must satisfy the condition that $m \le n$ and $\mathrm{D} = \{\mathrm{CUR}\}$

Where $\mathrm{C, R, D}$ represents the set of CUD's and the resource blocks RB and D2D users DU's respectively.

The received power for each Device-to-Device user can be represented as

$$P = M_T C \tag{1}$$

where, M_T is the transmitted power of the user

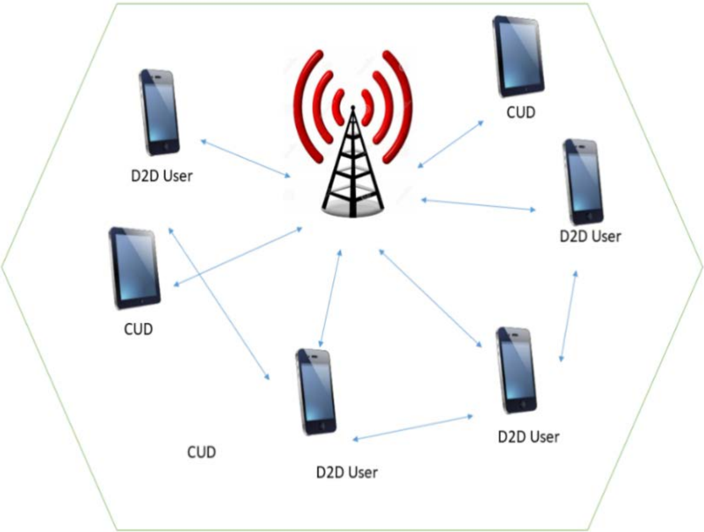

Fig.1. Random distribution of CUD and D2D user.

$$C = \left(A + B\log_{10}\left(d_{TR}\right)\right)^{-1} F \tag{2}$$

C = Channel Gain
d_{TR} = distance between the transmitter and receiver
F = Fast fading effect

According to the Shannon's Capacity theorem [23], the downlink capacity of the D2D user can be written as

$$H = X \log_2\left(1+\mu\right) \tag{3}$$

whereas, X is Bandwidth and μ is received SINR (Signal to Interference Noise Ratio) by D2D user.

$$\mu = \frac{\sum_{i=1}^{n} k_i P_d C_{dd}}{\xi^2 + \sum_{j=1}^{n} k_j P_B C_{Bd}} \tag{4}$$

whereas, $k_i \in \left(0,1\right)$ depends upon the RB (resource block) use by D2D user.

Energy efficiency can be defined as [24]:

$$\Phi = \frac{H}{P_B + P_{ic}} \tag{5}$$

P1:

$$\min \sum P_d + \beta\left(\theta\right) \tag{6}$$

Subject to-

$$\mu_i\left(P_d\right) \geq \alpha_i\left(1+\theta\right) \quad \text{for } \forall i$$

With variables θ, P_d.

Whereas, α_i shows the threshold function of μ_i (SINR), θ is optimization variable and $\beta\left(\theta\right)$ is decreasing convex cost function, P_d is power value of D2D users. The power control problem is a non-convex problem. It can be solved by converting non-convex into convex optimization problem by using the log transformation approach. We will discuss the conversion of non-convex problem into convex optimization problem in the next section.

4. Proposed Model for Robust Distributed Power Control and Resource Allocation

In this section, the proposed power control problem will be not solved directly because it is a non-convex problem. With the help log transformation approach, we will convert non-convex into convex problem. And also, the proposed model for robust distributed power control (RDPC) and resource allocation is used to solve the convex problem.

Lemma 1. For feasibility of P and θ in equation the following function must hold.

$$(1+\theta)\upsilon D(\alpha)F < 1 \tag{7}$$

Proof: Problem is non convex problem similar to [25].

Optimization problem P1 given in equation (6) is not a convex optimization problem, for a function $\beta(\theta)$. It is converted into non-convex to convex optimization problem, by applying the log transformation in the equation (6). By applying the log transformation in equation (6), we get

P2:

$$\min \sum e^{P_d'} + \beta\left(e^{\theta'}\right) \tag{8}$$

Subject to-

$$\log \mu_i \left(\frac{P_d'}{\alpha_i}\right) \geq \log\left(1+e^{\theta'}\right) \quad \text{for } \forall\, i$$

With variables $\theta' = \log\theta$ and $P_d' = \log P_d$

Whereas α_i shows the threshold function of μ_i (SINR), θ is optimization variable and $\beta(\theta)$ is decreasing convex cost function.

Optimization problem P2 mentioned in equation (8) is convex if

$$\frac{\frac{\partial^2 \beta(z)}{\partial z^2}}{\frac{\partial \beta(z)}{\partial z}} \geq -\frac{1}{z^2} \text{ for } z > 0 \tag{9}$$

Algorithm No. 1: RDPC for i^{th} users

1. The base station initiates $\theta = 0$; and new user power value is very small i.e., $P_d(0) = \omega''$
   if $\mu_i(t) \geq \alpha_i$ **then**
2. Update $P_d(t+1) = \frac{\alpha_i(1+\theta(t))}{\mu_i} P_d(t)$
   else
3. $P_d(t+1) = \alpha_i(1+\theta(t))$
4. **end;**

Fig. 2 represents the flow chart of proposed model. With considering the system model and problem formulation, the initiation of equation no. (1) to (8) is completed to run the Algorithm No. 1. We proposed RDPC model to solve the convex problem P2 with the help of log transformation approach used in P1 given in equation (6). Non-convex problem P1 given in equation (6) is transformed into convex problem P2 given in equation (8). Optimum power value for different D2D users can be attained from Algorithm No. 1. If the threshold SINR condition is satisfied to get the optimal power value for D2D users means D2D power gets updated by maintaining the QoS constraint of D2D user. Otherwise, power value gets updated without QoS constraint which is not an optimal D2D power. After that, updated optimal D2D power is used in Algorithm No. 2 to achieve the optimum power value for base station. Variables used for optimizing the power at base station gets calculated with the help of D2D parameter, updated optimal D2D power and equation (9) must be satisfied. With considering the optimum results from Algorithm No. 1 and Algorithm No. 2, the resource allocation is done by the Algorithm No. 3 to achieve the RDPC with Resource allocation in D2D communication (Proposed model). We set the maximum and minimum threshold power value based on the Algorithm No. 1 and 2. If the condition for maximum and minimum threshold power of D2D user is satisfied, then calculate energy efficiency of the devices and repeat the initialization process of all the values from the equation (1) to (6) till achieves improve energy efficiency. Otherwise, repeat the Algorithm No. 1 and 2 to achieve optimal power.

With considering all the parameters mentioned in equation (1)-(8), we propose the Algorithm No. 1 for the robust distributed power control in D2D users.

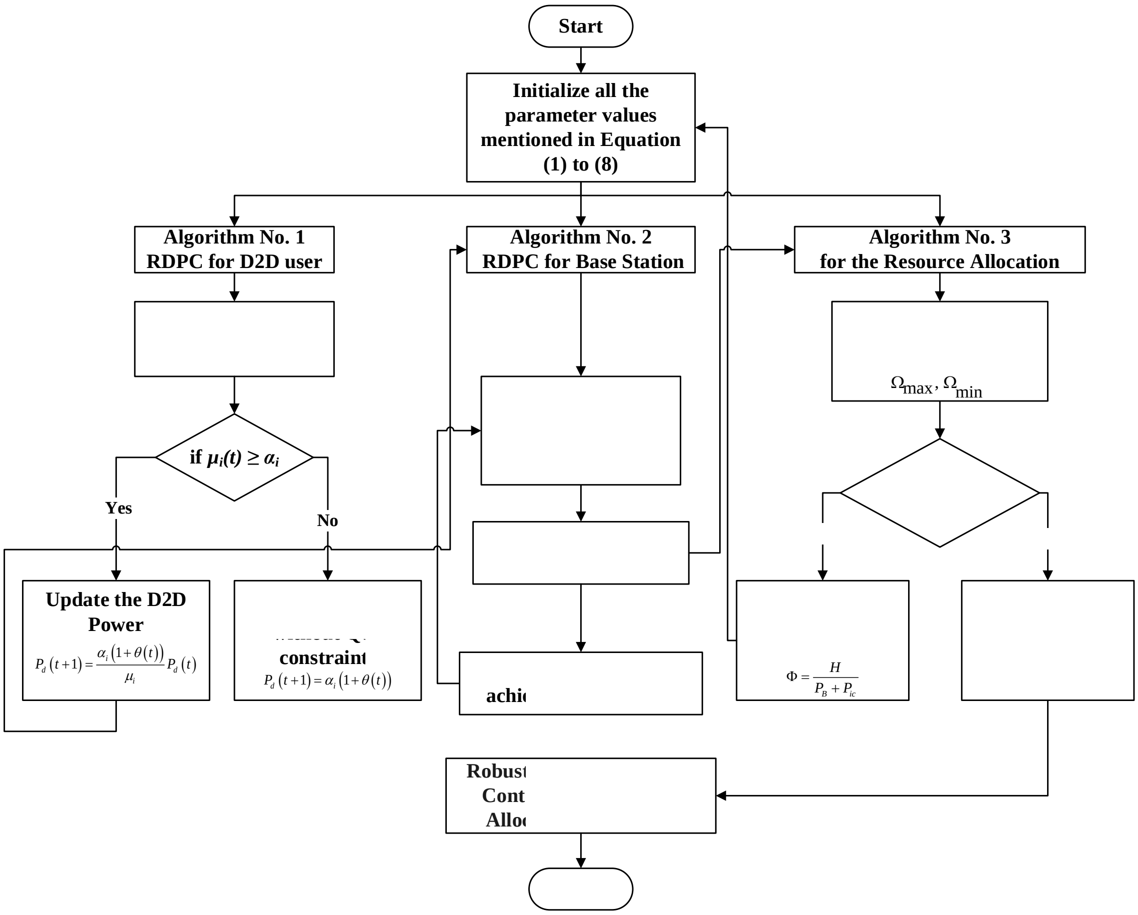

Fig.2. Flow chart of Proposed Model.

Algorithm No. 1 provides the optimize power value for different D2D users. After running the Algorithm No. 1, we further go for the algorithm No. 2, which optimize the power value for the base station.

Algorithm No. 2: RDPC for Base station

1. Initiate all the equation (1) to (8)
2. Start iteration (at t=0) to get updated value of $y(t)^*, L(t)^*, \theta(t)^*$
3. Get $y(t)^* = y(t+1)$ by using
   $$y(t+1) = (1+\theta(t))(D(\alpha)F)^{\mathrm{T}}\, y(t)+1$$
4. Get $L(t)^* = L(t+1)$ by using
   $$L(t+1) = y(t+1)P_d(t+1)$$
5. Get $\theta(t)^* = \theta(t+1)$ by solving
   $$\frac{\partial\beta(\theta)}{\partial\theta} = L(t+1) \text{ at } \theta=\theta(t+1)$$
6. Repeat Step 2, 3, 4, 5 till the convergence achieve.
7. **end;**

After the getting the optimized power value of Base station (36W) and D2D user (201mW). Further Algorithm No. 3 comes into the picture to perform the resource allocation for D2D communication system.

Algorithm No. 3: Iterative Resource allocation algorithm

1. Initialize all the values of equation (1) to (6) and Go to Algorithm No. 1 and Algorithm No. 2
2. Set the max and min threshold Power value based on the Algorithm No. 1 and 2 named as Ω_{max}, Ω_{min} respectively.
3. **if** $\Omega_{max} > P_d > \Omega_{min}$ **then**
   {Give the value of Φ and go to step no.1}
4. **else**
   {**end;**}

After doing the analysis of above-mentioned algorithms, the robust distributed power control with resource allocation is achieved.

5. Results and Discussion

In this section, numerical analysis and result discussion of proposed work is done. Here, we consider the Inband underlay D2D network for 5G-IoT communication system with carrier frequency equal to 2 GHz. After the initiating the parameters mentioned in equation from (1) to (8) with system parameters are listed in Table 1. The cellular user devices (CUDs) and D2D users (DUs) are uniformly distributed whereas the path-loss of the users follows the model defined in [26]. We do step wise mathematical analysis of Algorithm No. 1, 2 and 3 to obtain the optimum power values and resource allocation. The simulation results of the proposed algorithm based on the robust distributed power control (RDPC) model in comparison with a baseline scheme which employs our proposed algorithm, DPC [21,22] and DPC/ALP algorithms. The energy efficiency (EE) is analyzed with respect to some key parameters, including the number of D2D users, distance between D2D links, and the D2D transmitted power.

Table 1. System Simulation Parameters

Simulation Parameters	Values
Cell radius	500 m
Carrier frequency	2 GHz
D2D distance	25-500 m
Standard deviation for shadowing effect	4dB
Noise power	-174dBm/Hz
Path loss D2D to cellular user [26]	33.65+23.47log10(d)
Path loss between D2D users	36.67+19.54log10(d)

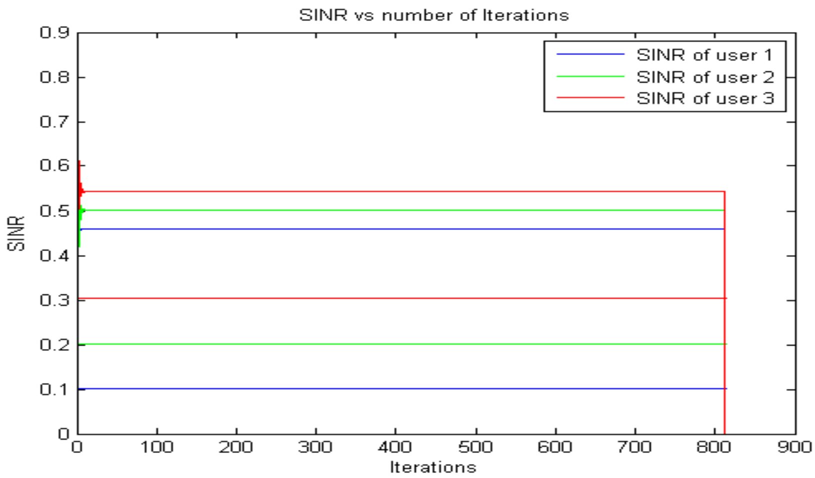

Fig.3. SINR versus number of Iteration

In the Fig. 3, the SINR versus number of Iteration is represented for our proposed algorithm. Here, we consider three users' user 1, user 2, user 3 enters for the purpose of communication having different threshold values of SINR 0.1, 0.2, 0.3 respectively. Our proposed algorithm achieves the constant SINR value which is more than threshold value for respective users up-to 800 iterations reflects the effectiveness of proposed algorithm.

Fig. 4 represents the performance of RDPC algorithm with comparison with DPC [21,22] and DPC/ALP algorithms. Here we assume three users are active in communication using the resource allocation method with the help of (CDMA codes) resource blocks. Here, we assume till time frame 200, only two users are active, third user enters at after time frame 200. And after communication, two users left at time frame 1000. We can analyze here, that DPC/ALP requires more power value that is 500mW, and DPC overburden just after time frame 200 and having low power values that is 190mW. RDPC provides balance and reliability than the DPC/ALP, and DPC with 60% and 5.26% change.

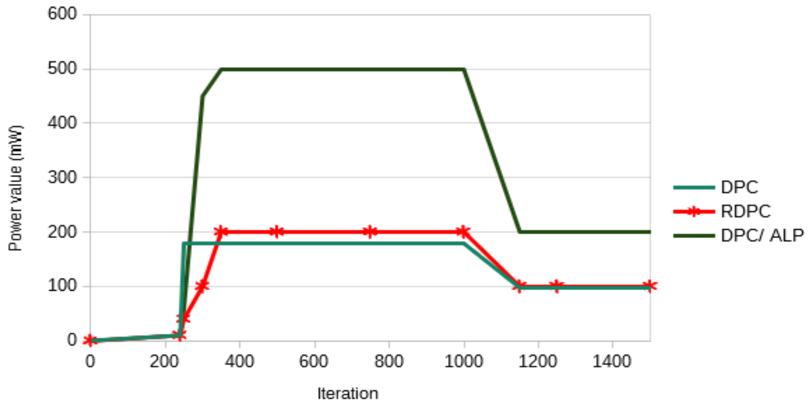

Fig.4. Performance of DPC, DPC with Active link protection (ALP), RDPC

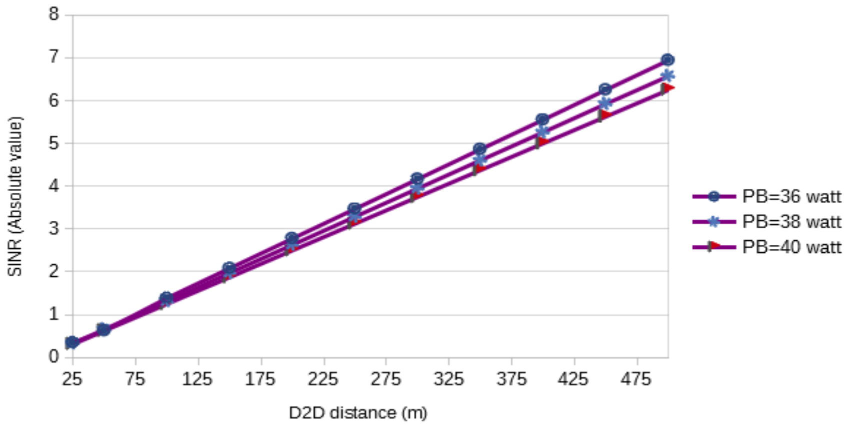

Fig.5. SINR versus D2D distance

Fig. 5 represents the relationship between the SINR with distance between D2D user and base station. We can analyze the impact of different power values (36W, 38W, 40W) of base station with the SINR corresponding to the distance between the D2D user. We can conclude from Fig. 5, that minimum power value of base station (36W) achieves better SINR with increasing the D2D distance by 6.06% and 9.38%.

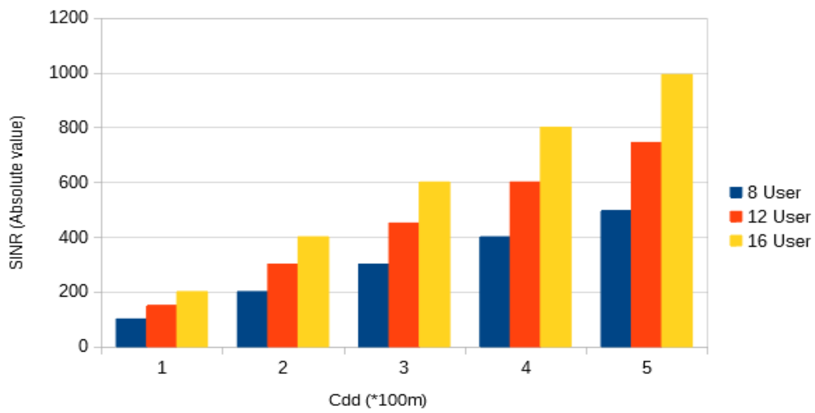

Fig.6. SINR versus No. of D2D users.

Fig. 6 shows the analytical representation of Number of D2D users versus SINR. As the number of D2D user increases the SINR is increases. Impact of the distance of different D2D users is also drawn in the above figure. SINR is the most important parameters which provides the strength of the communication link. Improvement in SINR by decreasing the interference means throughput gets improved with controlled transmission power of D2D users.

In the Fig. 7, the energy efficiency of our proposed work is represented. Energy Efficiency with different D2D user optimized power value is plotted to find out the effectiveness of proposed algorithm. Fig.7 illustrate that RDPC algorithm (proposed work) achieves greater energy efficiency by 66.67% and 50.9% in comparison to Non-RDPC algorithms when power is 0.1 watt and 0.6 watt.

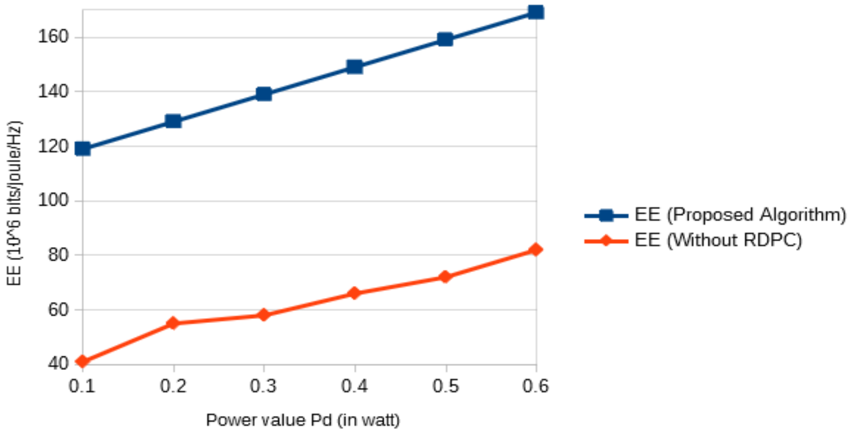

Fig.7. EE versus D2D user power value.

6. Conclusions

Our proposed work provides the reliable and balance solution in comparison to DPC algorithms for D2D system. By utilizing the RDPC method with resource allocation, we achieve a new framework in the D2D communication for 5G communication system and IoT application. Analysis of parameters with different aspects i.e., SINR, base station power, D2D optimum power, and energy efficient devices have been performed. Numerical analysis and results represent the effectiveness our proposed model (RDPC) compares with baseline approaches that is conventional DPC method and DPC/ALP algorithms for D2D communication. RDPC algorithm provides reliability and stability with optimal D2D power by 5.26% and 60% change compared to DPC and DPC/ALP algorithms. Also, RDPC algorithm improves energy efficiency by 66.67% compared to non-RDPC algorithms. The proposed model will contribute towards improving the communication part using the D2D communication for IoT Healthcare applications. Importance of D2D in 5G-IoT communication system during Pandemic situation is that COVID-19 warriors can be able to communicate with doctors/families even from remote location.

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