# Distance Based Power Control for D2D Communication in LTE-Advanced Networks

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***Abstract*:** Device to device communication systems places a very important role in handling both voice and data services efficiently in LTE-A networks. Power control techniques that we adopt for efficient D2D communication becomes a challenging issue. D2D and cellular signals under the same network may result in In-band Emission Interference (IEI). This degrades discovery range which result in loss of energy efficiency, throughput and hence increases the power requirement in both uplink and downlink transmissions. In this paper, a power control algorithm is introduced which greatly helps in saving power in LTE-Advanced networks for D2D communication. Power calculation mechanisms for D2D users and cellular users are shown separately. Based on mode selection, transmit and receive power requirements are evaluated to obtain the preset Quality of Service (QoS) parameters. The simulation results presented in the proposed method demonstrates the effectiveness of power consumption in LTE-Advanced networks for device to device communication.

***Keywords*:** D2D users, Interference, QoS, SINR, LTE-A**.**

## 1. Introduction

Device-to-device (D2D) communication permits two mobile user equipments to communicate directly which are closely located. Reducing the power of UEs and base stations enhances the spectrum/Energy efficiency. In the existing cellular communication system call setup between two user equipments takes place through base stations and mobile switching centers irrespective of the distance between the user equipments. In this mechanism power consumption is high in both uplink and downlink transmissions [17]. This paper gives a proposed power control mechanism based on the distance between the user equipments. To reduce interference, co-channel interference problems while device to device users reuse uplink and downlink resources are explored in [7]. Quality-of-service (QoS) constraints to increase sum rate with the cellular users and D2D pairs are presented in [4]. Authors of [8] proposed techniques to maximize the network throughput considering the QoS requirements for both CUs and DUs. Signal transmission through the base station (BS) consumes large power, which leads to interference between the DUs. Optimization of the device to device and cellular users matching for power control in uplink resource sharing is considered in [3]. The QoS requirements to share the cellular spectrum for both CUs and DUs and to increase the overall throughput and maximizing the spectrum efficiency are explored in [9].

The peak data rates of LTE-A networks for downlink and uplink transmissions are approximately around 1 Gbps and 500 Mbps, with a bandwidth scalability of 100 MHz [2]. In LTE-A networks due to high speed internet and data rate batteries discharges rapidly. Hence this major issue of sudden battery discharge in the user equipments is considered as a challenging issue in this paper. In the present approaches irrespective of the distance between the mobile terminals, the call setup takes place through base stations. The increased uplink power in mobiles for high speed and data rate allows interference problems [1]. Due to this the cell edge user equipments are not able to connect to the eNBs.

The two main types of power control mechanisms are centralized and distributed. The centralized approach computes power levels of the mobile stations. In the distributed mechanism, the transmit power of base station is determined and power calculations are to be carried within the user equipments [5]. The distributed power control technique is advantageous than the centralized power control for reducing delay and complexity. To overcome the complexity in reducing the power at D2D and cellular user terminals, the proposed system allow each cell to calculate the transmission power requirement independently. The transmission power level parameters like traffic load and smart discontinues transmission (DTX) are considered in which for the UE distribution in neighboring cells [19]. A power control algorithm is introduced which limits uplink and downlink power in LTE-Advanced networks. The transmit power calculation is based on the UEs distance measurement and the network capacity [18].

The contribution of this paper is as follows:

- The proposed method calculates the power requirement for base stations and D2D users to communicate based on the D2D distance.
- If the D2D distance is less i.e. the users are closely located, the UEs communicate directly without using BS power.
- BS power is utilized when the D2D distance increases.
- A power control algorithm is proposed to find the optimal power level allocated to each user in LTE-A networks.

The organization of the paper is as follows:

Section II describes the related work. Section III describes the power control mechanism with the proposed algorithm. Simulation results described in Section IV and last section concludes the paper.

## 2. Related Work

In this paper, the cellular network considered for D2D communications is a LTE-A network which enables the services by a D2D radio. Figure 1 illustrates the communication between the cellular users and D2D pairs in a single cell. It is assumed that the uplink resources of cellular users are reused by D2D user equipments. The cellular users and the D2D user are randomly distributed in the cell [12]. A centralized and dynamic power control mechanism proposed by the authors of [16] is analyzed to mitigate the interference observed due to D2D communications of LTE-A network in downlink. The algorithm has two stages. In the first stage, BS allocates the same resources for D2D pairs and cellular users [14]. Then, the power control technique is to be applied to decrease the interference for device to device communication. The uplink resources for D2D transmitter based on the distance between the cellular and D2D pairs are illustrated in [10].

Consider a system with a single base station and multiple device to device users as shown in Figure 1. There are two different users: D2D users communicate directly without BS and cellular users require BS to communicate with the other cellular/D2D users. The users in the D2D mode to transmit/receive calls should satisfy the distance constraint. If the user equipments distance is in the region of proximity, the UEs communicate directly without using BS power and these UEs are called D2D pairs. If the D2D distance is not in the region of proximity, then these UEs use BS to communicate and these are called cellular users (CU).

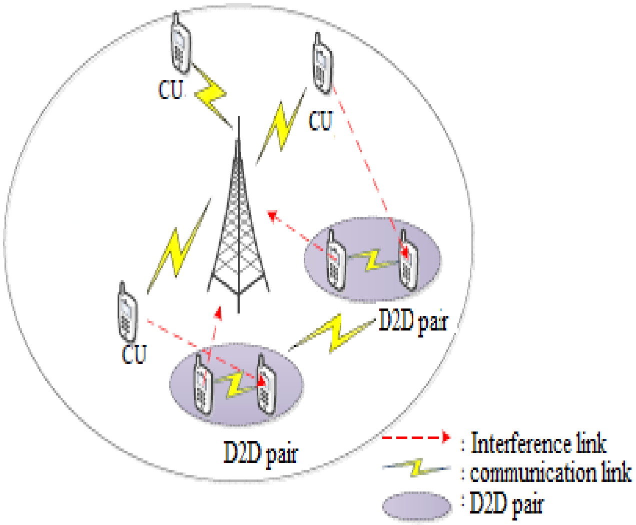


**Figure 1.** A single base station with multiple device to device and cellular users

The system model of the proposed work is shown in Figure 1. The cellular users communicate with the other users through the base station and D2D users communicate directly without the involvement of BS based on the distance constraint between the called and calling parties. The interference minimization using uplink resources to perform D2D communication are presented in [11]. Since the interference effect between the cellular and D2D users is very small and is neglected in the proposed work.

Figure 2 shows the interference probabilities between the D2D users at different conditions. Let Q1, Q2,…Qn are the queues at which the D2D users waiting for D2D communication at time intervals T1, T2,….Tn to communicate with D2D receivers R1, R2,…Rn.

When a D2D transmitter T1 is in conversation with D2D receiver R1and during that time if D2D transmitter T2 also tries to connect with D2D receiver R1, interference affects the communication process. Interference effect can also be observed when cellular user connects call with the D2D user. The solutions for these kinds of interference problems are explained in the proposed technique. The proposed method reduces the interference effect based on the distance between the users.

The resources distribution for D2D communication is as follows: the CUs and device to device users share same resources if any D2D pairs are close to each other. When the distance increases the base station automatically allocates resources in such a way that the cellular users collect resources from BS and allow D2D pairs to communicate with the use of cellular users through BS. We assume that there are K CUs and M pairs of D2D users, whose sets are denoted as Cs = {1, 2,…..,K} and Ds = {K +1,K +2,…..,K +M} respectively. Let the $i_{th}$ CU has already chosen the $i_{th}$ radio base station in the LTE-A system with transmission power pi. The transmit power of CUs is denoted as Pc = {p1, p2,…., pK}. The transmit power of D2D users is denoted as Pd = {pK+1, pK+2,….,pK+M}. Let hij be the channel gain from user equipment i to user equipment j.

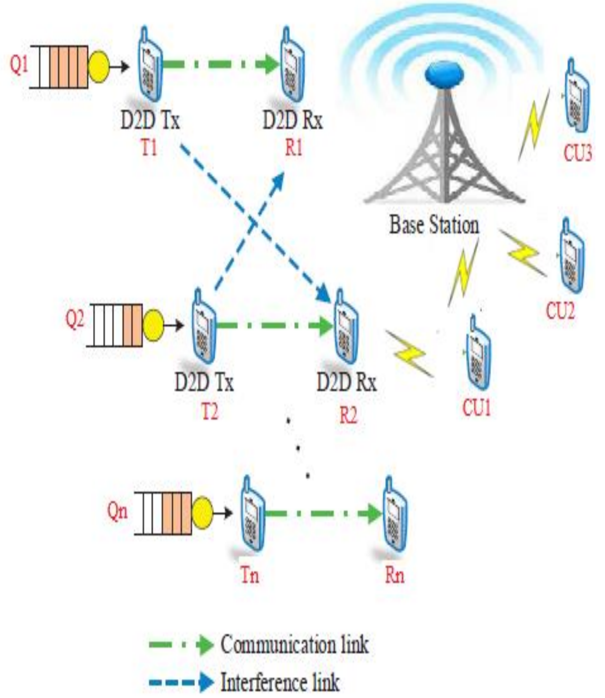


**Figure 2.** Interference in Device to Device communication

For downlink transmissions, the D2D receivers are synchronized with their closest D2D transmitters [13]. D2D transmitters use path-loss inversion power control techniques to transmit data in a cell. The devices are classified into primary and secondary nodes based on the distance and the algorithm derives the required transmit power for communication.

The power control scheme established makes the D2D transmitters to sense the average received power levels of receivers. The distance between the devices and receiver sensitivity determines the transmission power requirement. The guard zones are placed around the primary receivers and transmitters [20].

## 3. Proposed Power Control Mechanism

The power control algorithms given in [8] are analyzed to reduce the power consumption in the devices based on the distance. In the centralized approach, the base station handles the transmit power requirement of D2D and cellular users. The distributed approach gives permission to the D2D users and cellular users to handle the power requirements. In our proposed approach each transmitter decides individually whether to directly transmit to the other user or not based on the distance of the receiver.

It is assumed that the base station is covered by three cellular users and two pairs of D2D users. When the distance between the D2D users of D2D pairs and distance between the two D2D pairs are in the region of proximity, they are allowed to communicate directly without the involvement of base station [15]. If the distance increases these D2D pairs use BS to transmit/receive data. During channel resource sharing, interference is observed when a base station receives from the D2D transmitter and a D2D receiver receives from the cellular user. This signal to interference noise ratio (SINR) is a important factor to meet the quality of service requirements.

Let each user equipment is covered by an $m^{th}$ base station (eNB) with N users for transmitting information with a power level of $P_{nm}$ and data rate of $\gamma_{nm}$ in the LTE-A network. σ is the Gaussian noise variance and δ is the path loss exponent with channels are modeled at a distance of $l_{nm}$ meters. $h_{nm}$ is the frequency flat Rayleigh fading function. The Signal to Interference Noise Ratio at $n^{th}$ user $\gamma_{nm}$ [1] is expressed as

$$\gamma_{nm} = \frac{P_{nm} l_{nm}^{-\delta} h_{nm}^2}{\sigma^2} \tag{1}$$

where: $P_{nm}$ = Power level of the eNB for transmitting information

$\gamma_{nm}$ = Signal to Interference Noise Ratio of $n^{th}$ user at the $m^{th}$ base station

$h_{nm}$ = Frequency flat Rayleigh fading function

σ = Gaussian noise variance

δ = the path loss exponent

The D2D user Signal to Interference Noise Ratio $SINR_{DUE}^k$ from [3] is expressed as

$$SINR_{DUE}^K = \frac{P_{DUE}^K \left|h_{DUE}^K\right|^2}{IEI^K + \sigma^2} \tag{2}$$

The data transmission rate between the $n^{th}$ D2D user and $m^{th}$ eNB is $r_{nm}$ and is given by

$$r_{nm} = \gamma_{nm} \alpha_{nm} \tag{3}$$

where: $\alpha_{nm}$ = the power gain between $n^{th}$ D2D user and $m^{th}$ eNB

The power gain of the D2D user from [3] is given by

$$\alpha_{nm} = \frac{P_{DUE}^K \left|h_{DUE}^K\right|^2 / IEI^K + \sigma^2}{P_{nm}} \tag{4}$$

where: $P_{DUE}^k$ = the D2D power of the $k^{th}$ user

$\left|h_{DUE}^k\right|^2$ = the D2D user equipment channel gain of the $k^{th}$ user

$IEI^k$ = the D2D interference from the $k^{th}$ user

The utility function of $n^{th}$ D2D user and $m^{th}$ eNB is $U_{nm}$ ($P_{nm}$) [9] and is given by

$$U_{nm} = r_{nm} - \beta_{nm} P_{nm} - \phi_{nm} P_{nm} \tag{5}$$

where: $\beta_{nm}$ = pricing parameter of the utility function for uplink transmission

$\phi_{nm}$ = pricing parameter of the utility function for downlink transmission

The details of these pricing parameters [6] are shown in Table 1.

**Table 1.** Parameters of utility function

| Parameter | Number of D2D users (n) | | | | |
|---|---|---|---|---|---|
| βnm | n= 1 | n= 5 | n= 10 | n= 15 | n= 20 |
| m=1 | 0.2 | 0.5 | 0.8 | 1.1 | 1.4 |
| m=2 | 0.3 | 0.36 | 0.42 | 0.48 | 0.54 |
| ϕnm | n= 1 | n= 5 | n= 10 | n= 15 | n= 20 |
| m=1 | 0.75 | 0.78 | 0.82 | 0.85 | 0.88 |
| m=2 | 0.72 | 0.77 | 0.81 | 0.84 | 0.88 |

The D2D optimal power $P_{nm}^*$ required for each user is given by

$$P_{nm}^* = [C_m / \{(\beta_{nm} + \phi_{nm}) \ln 2 \textstyle\sum_{n\varepsilon N} (\alpha_{nm} / (\beta_{nm} + \phi_{nm}) \ln 2\}] - (1/\alpha_{nm}) \tag{6}$$

where: $C_m$ = the total capacity of $m^{th}$ eNB

The the total capacity of $m^{th}$ base station from [13] is given by

$$C_m = (1 - \lambda_{nm}) \textstyle\sum_{n\varepsilon N} \{\alpha_{nm} / (\beta_{nm} + \phi_{nm}) \ln 2\} \tag{7}$$

where: $\lambda_{nm}$ = wavelength of $n^{th}$ D2D user at the $m^{th}$ eNB

The proposed algorithm for power control is as follows.

**Algorithm: Proposed algorithm for power control**

**1** Initialize $P_{DUE}^k, \left|h_{DUE}^k\right|$, $IEI^k$ and σ
**2** Find SINR = $\gamma_{nm}$ using equation (2)
**3** Obtain $\alpha_{nm}$using equation (3)
**4** Calculate the total capacity of $m^{th}$ base station $C_m$ using equation (7)
**5** The D2D optimal power $P_{nm}^*$ required for each user is calculated using equation (6)

The distributed power control mechanism [16] is used by D2D users for maximum transmit power constraint. This power control mechanism compensates path-loss to maintain the average signal power at a certain threshold level.

## 4. Simulation Results

This section gives the simulation results of the proposed power control mechanism for an LTE-Advanced network with a cell consisting of base station covered by cellular users and D2D pairs. It is seen that the proposed scheme saves considerably large power than the iterative transmission scheme. In this simulation, we considered the number of mobile users to be 5 to calculate the optimal power level. The D2D users and cellular users position are iteratively altered to obtain the average value of N.

We performed the simulation under LabVIEW platform. A plot of optimal power levels versus number of mobile users for the proposed and conventional methods is shown in Figure 3 and Figure 4.

Results in Figure 3 show that the proposed algorithm efficiently saves power by calculating optimal power levels required for the transceivers based on the distance. The results of the proposed and conventional methods are compared. It is found that the performance of the proposed system greatly enhances power levels of both D2D and cellular users. The initial power level of each user in the base station is assumed to be 14mW.

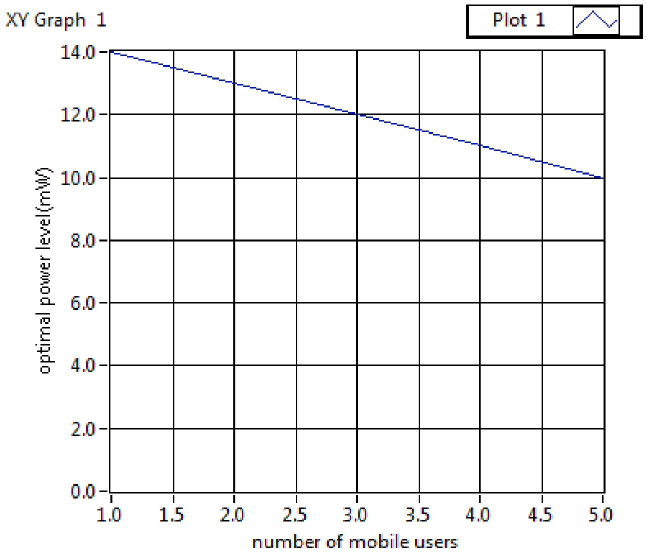


**Figure 3.** Optimal power level calculation for the proposed technique

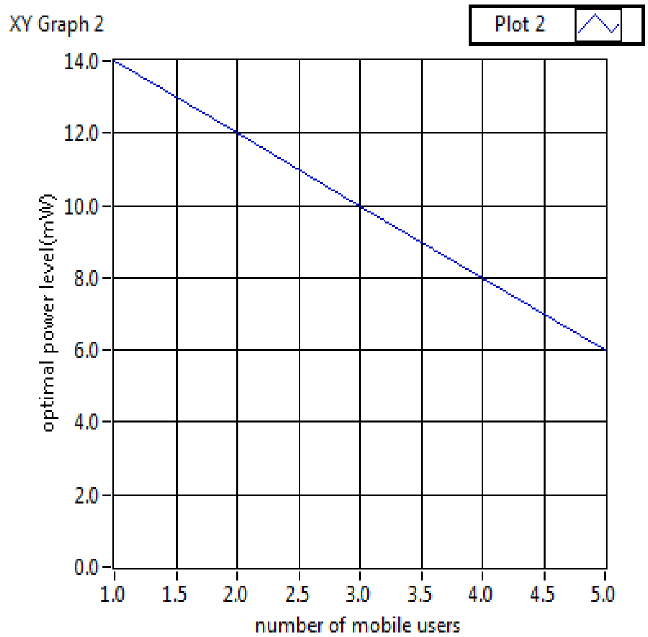


**Figure 4.** Optimal power level calculation of the conventional technique

For the simulation, 5 mobile terminals considered. Simulation results show that the optimal power level that can be allocated for each user is 10mW for the proposed system and it is 6mW for the iterative method.

Hence we can allocate 4mW extra power for each user as compared to the conventional method. Thus the proposed technique can be efficiently used to save power in LTE-Advanced networks for device to device communication.

The time switching fraction to calculate the outage SINR threshold in [20] is considered with a constant value of 0.5. But in our proposed approach it varies from 0.5 to 0.7 according to the distance between D2D users. Using statistical model the uplink and downlink network performances are evaluated under different scenarios.

Figure 5 shows the transmission delay of D2D users for the proposed and Dinkelbach methods. The results show that the data transmission delay can be further reduced by using the proposed technique.

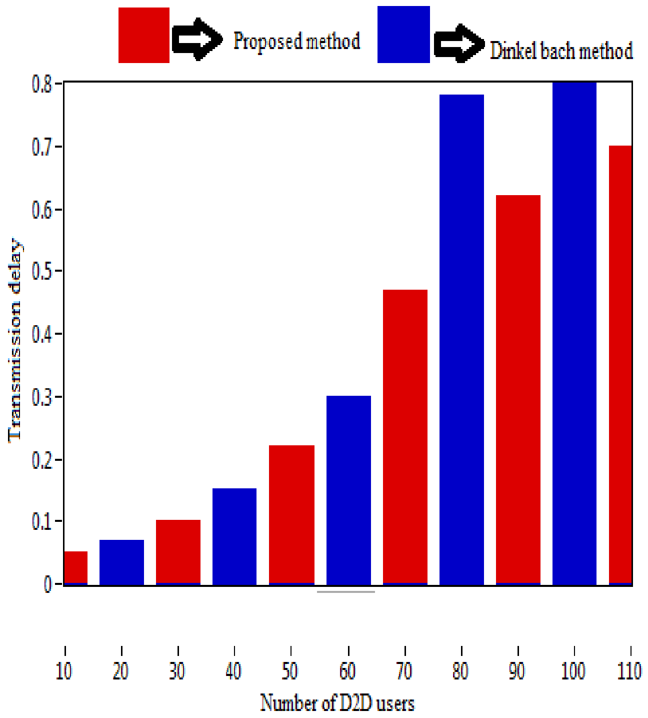


**Figure 5.** Data transmission delay of D2D users

From the Dinkelbach method it is also observed that there is a rapid increase in the data transmission delay with the increase in the number of D2D users. But this can be greatly reduced by using the proposed method.

To meet the QoS requirements of D2D users for given number of CUs a plot of feasible number of D2D users versus the number of CUs is shown in Figure 6.

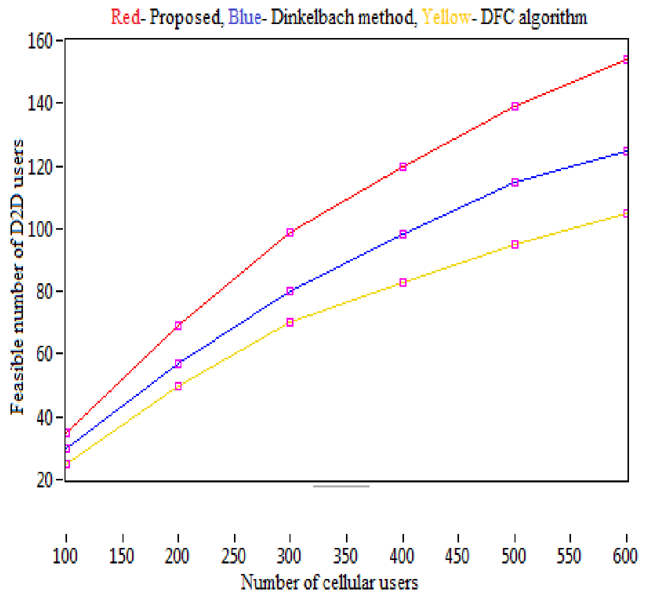


**Figure 6.** Feasible number of D2D users versus CUs

Since a large number of cellular areas can be reused by D2D users, the feasible number of D2D users number increases with the increase in number of cellular users. But the ratio of the number of feasible device to device users to the number of cellular users decreases with the increase in number of cellular users. Hence the number of feasible D2D users increases slowly compared to cellular users. From the figure it is observed that the proposed method allows more number of feasible device to device users compared to Dinkelbach method and DFC algorithm.

The network parameters considered for simulation are listed in the Table 2.

**Table 2.** Network parameters for simulation

| Parameter | Values |
|---|---|
| Total number of eNBs (M) | 1 |
| Total number of D2D Users (N) | 5 |
| D2D Users in a single Cell | 4 |
| Path Loss exponent δ | 0.8 |
| Additive white Gaussian noise Power | -83DBM |
| Adjacent Cell Power | -10.3 DBM |
| Total capacity M Cells | $10^5$ BPS |

The power dissipation is assumed constant for all the D2D and cellular users throughout the simulation, but in reality this varies depending on the distance between the D2D users. At minimum power levels maximum time switching coefficients observed during simulation.

## 5. Conclusion

The proposed work helps to save power of the eNBs and UEs for Device to Device communication system in LTE-Advanced networks. Simulation results proved that the proposed power control algorithm effectively reduces power requirements at both the base stations and user equipments with lower complexity. In this paper we examined the performance of the work considering a single cell consisting of a base station, covered by cellular and D2D users. This work can be further enhanced by considering more cells with effective interference mitigation approaches.

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