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Uplink Resource Allocation Scheme for Improved Interference Mitigation for Device -to – Device Communication Underlay Cellular Network

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Abstract

The exponential rise in data traffic is driving the telecommunication industry towards developing cutting edge technology that would support such demands in an efficient and effective manner. Device-to-device (D2D) communication in cellular networks is viewed as a prospective solution, which provides the opportunity for users located in close proximity, to communicate directly without traversing data traffic through the eNB (evolved NodeB). Research has equally shown that this technology results to improved throughput, energy gain, hop gain, and reuse gain. Regardless of the benefits that come with D2D communication, it still poses a great challenge to the cellular system, since it introduces certain technical challenges that act as bottleneck to its adoption. Among the notable issues is interference which forms a major problem. In this work, an improved resource allocation algorithm for interference mitigation with improved QoS for cellular and Device-to-Device (D2D) communication was developed. A greedy heuristic allocation scheme was employed while considering a single cell system. The performance and efficiency of the developed resource allocation scheme was measured in terms of access rate and D2D throughput gain. To The impact on the D2D throughput gain and access rate for different SINR requirement was validated by comparing it to other results obtained by other research works in downlink (DL) scenario. Simulation results showed that as the SINR requirement increases, the access rate and D2D throughput gain of the system decreases. Also, as the distance between DUE Tx and DUE Rx increases, The D2D throughput gain and access rate decreases. When validated with the results in the literature, comparisons showed that the developed algorithm had a throughput gain of 160Mbps, while that of Çelik .A. et al (2017) had a throughput of 152Mbps. This represented a 5.3% improvement over the method by Çelik .A. et al (2017). Also, when the maximum distance between the Device to Device User Equipment Transmitter (DUE-Tx) and Device User Equipment receiver (DUE-Rx) was 100m, the developed algorithm showed a throughput gain of 37Mbps, while that of Çelik .A. et al (2017) showed a throughput of 23Mbps. This represented a 60.9% improvement over the method by Çelik et al (2017). These results indicated that the developed scheme offers near-optimal performance and outperformed the compared algorithm both in achievable throughput and access rate of DUEs.

***Keywords:* Uplink, throughput, access rate, SINR, interference**

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I. INTRODUCTION

Recently, cellular network has experienced an explosion in growth of mobile devices. The emergence of Internet of things (IoT), increased access to social media applications and improved cellular technology standards has been pointed to be major factors responsible for the outburst of cellular devices and mobile users. Due to this, base stations (Bs) are faced with huge traffic which increases as the number of Cellular Users (CU) increases. The effect of his has resulted to poor user experience, poor condition of link and poor user experience. To improve cellular network performance, the scarce resource must be efficiently allocated so as to measure up with the increased number of User Equipments (UEs); since the spectrum resources are essential commodity, decongestion of the volume of traffic were suggested to increase network capacity. Paper [1] noted that heterogeneous networks improve wireless link quality since the BS(s) are now much closer to the mobile devices. Although, [2] grouped ways of increasing system capacity to include: (i) Increasing the radio spectrum (ii) Improving the link efficiency via multi-antenna transmissions (MIMO) (iii) Densification of the network by deploying more base stations and reducing the cell size. The latter is usually impractical due to high cost involved in procuring good number of Bs, limited space and low utilization ratio [3]. Again, deployment of small cells as an integral part of heterogeneous networks improves wireless link quality [4, 5]. Apart from the above solution; Device to Device (D2D) communication has been reported to improve the network capacity of fifth generation (5G) of systems [6]. It has the capacity of offloading traffic effectively from the network core.

Indeed, D2D communication provided a new paradigm in cellular networks due to improved link quality and throughput by allowing direct communication between two or more proximate devices without passing through base station (BS) [7]. This mode of communication contradicts the traditional way of traversing information through the Base station when communication is initiated between two CUEs. According to [8] D2D communication commences with; first, a DUE sending a device discovery message to proximate devices. Then, the eNodeB checks if the receiver is in the same proximity. If some conditions such as the distance between the D2D pairs, the interference level (signal to interference noise ration) and the channel quality are met; then eNodeB triggers a direct D2D link between the transmitter and the receiver in overlay or underlay mode. In an unlicensed spectrum, UEs at close proximity communicate with one another through various short range wireless technologies like Bluetooth, Wireless Fidelity (Wi-Fi/WLAN based on IEEE 802.11 standard) etc. This mode is devoid of interference but underutilizes spectrum resources; although the energy efficiency is improved due to the communicating distance between D2D pair. In a Licensed spectrum, D2D can operate in underlay or overlay mode. This work considered underlay cellular network since the CUE shares its link with DUE. This increases spectral efficiency, although interference poses a challenge. In effect, the sum throughput has to be maximized and the quality of the link improved. To achieve this, an efficient interference mitigation algorithm is needed so that DUE can communicate effectively without hampering the primary users (CUEs). Research shows that several efforts and achievements have been recorded in the area of spectrum allocation in centralized or distributed mode. Centralized approaches determine the channel state information (CSI) of the link. It relies on several tools as: stochastic geometry [9, 10, 11], centralized graph theoretic approaches [12, 13], and mixed-integer programming [14] to enhance the network capacity. The author of [15] investigated the underlay modewhere CUEs and DUEs can transmit on the samesub-channels inside a cell thus interfering each other. A Heuristic resource management scheme which combines a scheduler and a pairing strategy was proposed by [16] to improve cell capacity while guaranteeing low outage probability was used. Paper [17–18] investigated centralized full-duplex resource allocation to manage the co-tier/cross-tier interference.In [21] a three-step scheme was proposed to address resource allocation problem. First is admission control and power allocation to each admissible D2D pair and its potential CU partners. Secondly is development of a maximum weight bipartite matching based scheme to select a suitable CU partner for each admissible D2D pair to maximize the overall network throughput. Ref [22] deployed a non co operative game theory in tackling the issue of resource allocation and interference mitigation in cluster based D2D communication. The proposed scheme increases SINR and spectral efficiency. In [21-22], the uplink RB assignment between cellular and DUEs is performed based on a Q-learning solution. Nevertheless, the full potentials of D2D communication cannot be complete until it is integrated in cellular network. Apart from improvement of spectral efficiency, other advantages of D2D communication include: offloading of traffic, improved energy efficiency, network throughput, link quality, extended coverage, delay reduction and latency. The main contributions in this work are but not limited to:

(i) Development of an improved interference mitigation algorithm
(ii) Maximization of spectrum reuse in uplink subcarriers using the developed algorithm.
(iii) Improve the throughput gain and access rate of DUEs
(iv) Simulate the developed using Matlab
(v) Validate the developed system with the previous work in the literature

II. SYSTEM MODEL

2.0. Introduction

This section presents a Greedy Heuristic resource allocation algorithm as a solution to and CUE is assumed to reuse downlink radio resources. The D2D UE known as the secondary user must not interfere with CUE in trying to coexist with CUE. Nevertheless, the problem of resource allocation was Optimized interference menace in D2D communication underlying cellular network. The choice of Greedy Heuristic algorithm is because it provides an optimal solution at each step in selecting a reuse path for CUE and DUE and/or a path with minimum SINR so as to maintain QoS in each sub frame. A scenario where a cell situated at the centre having the UEs (consisting of the CUEs and D2D UEs) round the Bs where considered. The DUE using mixed integer non linear programming (MINLP). Later, a suboptimal solution which exploits the relative channel gains between the BS and user equipments (CUE and DUE) and that between the CUE and DUE were proposed so that resource blocks (RB) can be greedily allocated to D2D users without hampering the CUE.

2.1. Problem Formulation

Here, a single cell system comprising of one BS with an omni directional single antenna located at the cell center with a circular coverage area of radius R was considered. The scheduling of CUE's resource is done by the Bs by some existing online and offline scheduling algorithm in each sub frame n. The CUEs (CUE1 and CUE2) which communicate directly to the BS in both downlink and uplink are considered as primary users, while

DUEs (UE_3R_x and UE_4T_x) are the secondary user and as such, communicate in direct mode. In the system model, R is considered as the number of available resource blocks for the uplink. The number of RBs is the same with the number of cellular user and only one RB can be assigned to each cellular user at any given time. Again, we considered central resource allocation coordination for both the cellular users and the D2D pairs. This model assumed a perfect CSI at the receiver and as such all the channel gains between BS and CUEs, the interfering links between the BS and D2D transmitter as well as the link between the CUE to the D2D receiver are known to the BS before scheduling decisions are taken. Let the Bs serves as a set $C = \{1, \ldots, N_c\}$ of cellular users and a set $D = \{1, \ldots, N_D\}$ of D2D pairs respectively. Assuming that $N_C \geq N_D$, we can then formulate the problem of assigning appropriate RBs for underlying D2D communication as an optimization problem that achieves higher throughput without interfering with the existing primary users.

2.2. Uplink Resource Allocation System Model and Analysis

In an Uplink scenario, the Bs suffers interference due to transmission from UE_4 Tx (D2D Tx), while UE_3 (D2D Rx) receives interference due to transmission from CUE_2 as shown in Figure 1 below.

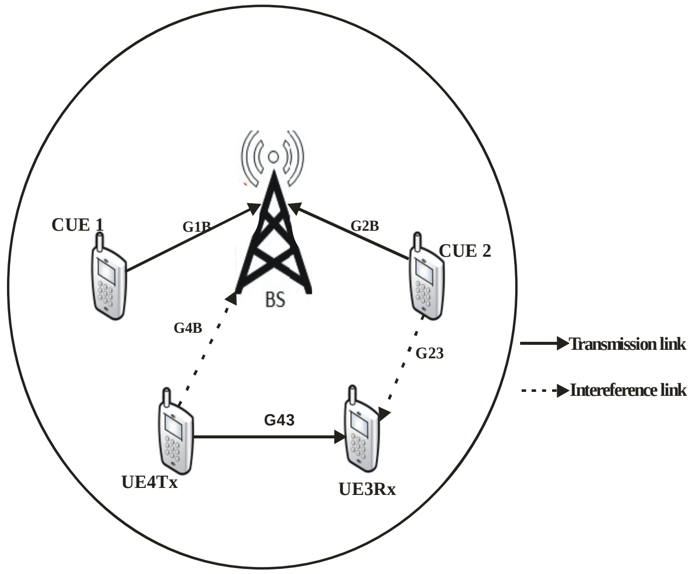

Fig 1: Uplink Resource Allocation System Model

Let P_B, P_c, P_d represents Base station transit power, CUE transit power and D2D transit power respectively. Also, G_{43}, G_{4B}, G_{2B}, $G_{23,}$ G_{1B} represent the channel gain between the D2D pairs (UE_3& UE_4), channel gain between UE_3 (D2D Tx) and Bs, channel gain between UE_2 (CUE_2) and Bs, channel gain between CUE_2 and UE_3 (D2D Rx), and channel gain between CUE_1 and Bs respectively.

Therefore, the received SINR of the link between the Bs and UE_4 (D2D Tx) can be calculated as follows:

Received SINR at Bs (γ_{Bs}^{UL})

$$\gamma_{Bs}^{UL} = \frac{P_c G_{2B}}{N_o + \sum_d x_c^d P_d G_{4B}} \qquad (2.1)$$

Similarly, the CU causes the interference to the D2D pair. The SINR of the D2D pair is calculated as calculated:

$$\gamma_d^{UL} = \frac{\sum_c x_c^d P_d G_{43}}{N_o + \sum_c x_c^d P_c G_{23}} \qquad (2.2)$$

Where

Optimization variable, $x_c^d$is an indicator function is defined as $x_c^d = \begin{cases} 1, & if\ D2D\ pairs\ d\ reuses\ RB\ with\ CUE\ c \\ 0, & otherwise \end{cases}$

The maximum achievable rate at the Base station: M_{Bs}^{UL} and at D2D Rx, (M_d^{UL}) are calculated as using Shannon model capacity as follows:

Maximum achievable rate at Bs:

$$M_{Bs}^{UL} = Wlog_2(1 + \gamma_{BS}^{UL}) \qquad (2.3)$$

Maximum achievable rate at D2D Rx,

$$M_d^{UL} = W\log_2(1 + \gamma_d^{UL}) \qquad (2.4)$$

The total system sum rate R_{sum}^{UL} is expressed as:

$$R_{Sum}^{UL} = (M_{Bs}^{UL} + M_d^{UL}) \qquad (2.5)$$

Since the aim is to maximize total achievable rate throughput which is constrained on satisfying minimum rate requirement for both CUE and D2D pairs, a mixed Integer non-linear programming is formulated (MINLP).

$$Maximize \quad \sum_{c}^{C} R_c M_{Bs}^{UL} \sum_{d}^{D} \sum_{c}^{C} \sum_{c} x_c^d R_c M_d^{UL} \qquad (2.6)$$

$$P_c G_{2B} \geq \gamma_{Bs,tgt}^{UL} \left(N_o + \sum_{d} x_c^d P_d G_{4B} \right) \forall_c \in C \qquad (2.7)$$

$$\sum_{c} x_c^d P_d G_{43} \geq \gamma_d^{UL} \left(N_o + \sum_{c} x_c^d P_c G_{23} \right), \forall_c D \qquad (2.8)$$

$$\textstyle\sum_c x_c^d \leq 1, \forall_d \in D \qquad (2.9)$$

And

$$\sum_{d} x_c^d \leq 1, \forall_c \in C \qquad (2.10)$$

Here, R_c, stands for the number of uplink resource block allocated to CUE at each time slot during uplink period. Again, γ_c^{UL} and γ_d^{UL}represent minimum SINR of CUE and D2D pair which must be maintained by increasing the G_{4B} and G_{23}. Equations 2.7 and 2.8 set a threshold to ensure minimum rate requirements for CUE c and D2D pair d. For equations 2.9 and 2.10, one D2D pair can be allocated to at most one CUE resource and one CUE shares its resource to at most one D2D pair respectively. However, solutions based on optimization formulation leads to a better system performance but they are often not practical due to their complexity and signal overhead.

III. GREEDY HEURISTIC RESOURCE BLOCK SELECTION ALGORITHM FOR D2D USERS

We did state earlier that the optimization problems formulated above for the uplink scenario is a mixed integer non-linear programming (MINLP). Due to its complexity, is very hard to arrive at an optimal solution within a scheduling interval of one millisecond (1ms). Therefore, we propose a Greedy Heuristic algorithm as an alternative resource block (RB) scheduling scheme for D2D Users. First, we assume that the resource block scheduling for CUEs is already taken care at the Bs.This same link is proposed to be reused be D2D pair without altering the QoS signal of the CUEs.For downlink RB scheduling, observe carefully from equation 2.4, that if the channel gain (G_{41}) between CUE_2 and D2D Tx (UE_3) and G_{B3} between DUE_3 (D2D Rx) and Bs in equation 2.5 is reduced, the SINRs (γ_c^{UL}& γ_d^{UL}) would increase. This will impact negatively on the system performance. Meaning that, any CUE with high channel quality indicator (CQI) can share its resource blocks to a D2D

Algorithm: Uplink D2D Resource Block (RB) Allocation Scheme

```
C: Sorted list of CQIs for all UL UEs in decreasing order
D: set of D2D pairs in the network
$G_{24}$: Channel gain between CU c and CU d
$G_{43}$: Channel gain between D2D pair d
$G_{2B}$: Channel gain between CU c and Bs
$G_{4B}$: Channel gain between Bs and D2D pair d
Pc: Transmit power of CU c
Pd: Transmit power of D2D transmitter d
Pb: Transmit power of Bs
$R_c$: Number of resource blocks allocated to CU c
Begin
c ←1
while D ≠ null or c == C do
initialize target SINRs of CUE c and D2D pair
```

```
    $\gamma_{BS,thresh}^{UL} \leftarrow G_{thresh}$
    if ($c^{th}_{value} = c_{max}$) select c else Return
        Find the D2D transmitter d with minimum channel gain;
        $\gamma_{BS}^{UL} \leftarrow \frac{P_c G_{2B}}{N_0 + \sum_d x_c^d P_d G_{4B}}$;
        $\gamma_d^{UL} \leftarrow \frac{\sum_c x_c^d P_d G_{43}}{N_0 + \sum_c x_c^d P_c G_{24}}$;
        if $\gamma_c^{UL} \geq \gamma_{c,tgt}^{UL}$ and $\gamma_d^{UL} \geq \gamma_{d,tgt}^{UL}$ then
            Share all RB of CU c withD2D pair d;
            D = D - {d};
        else
            if $\gamma_{BS}^{UL} \geq \gamma_{BS,thresh}^{UL}$ then
                Share all RBs of the CU c with D2D pair d;
                D = D - {d};
            else
                Do not assign RB to D2D pair d;
            end if
        c ← c + 1;
end while
```

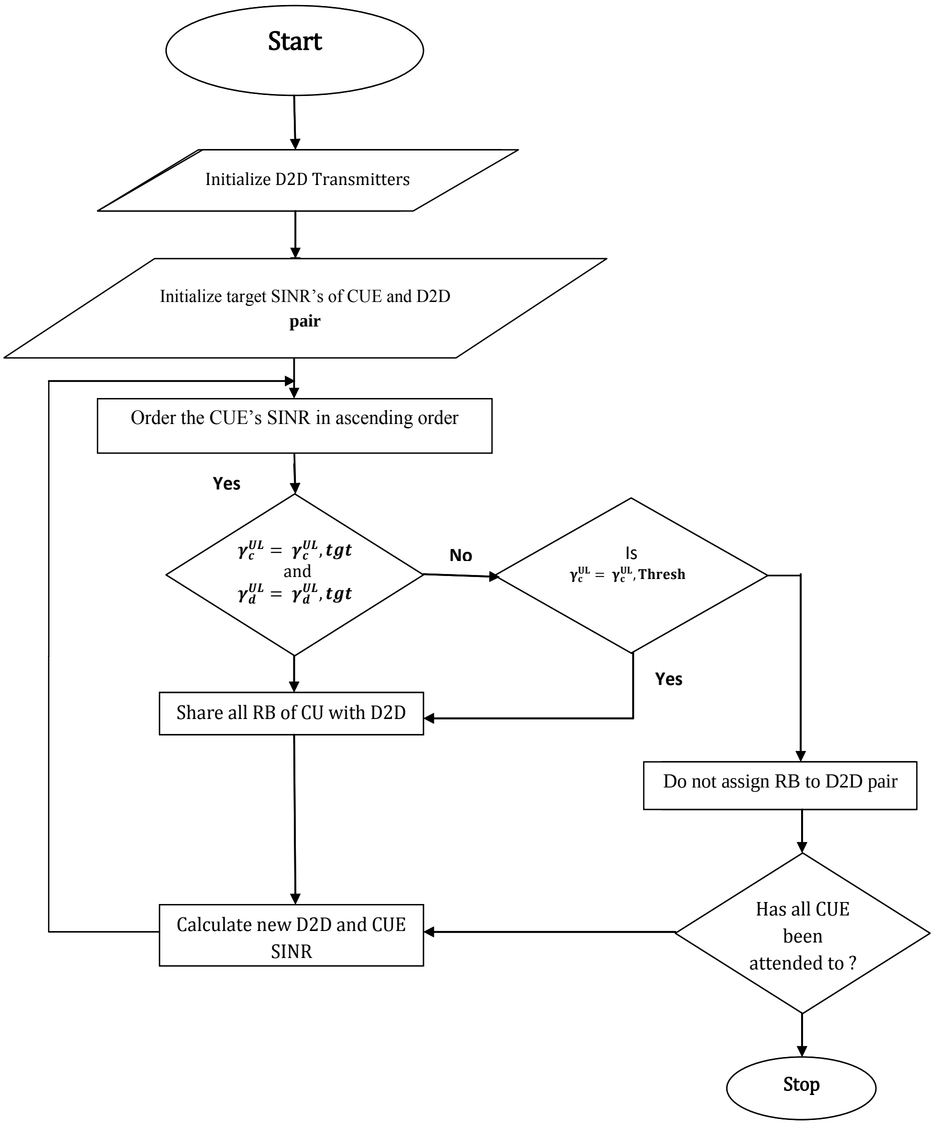

Fig 2: Flow chart of uplink interference mitigation algorithm.

IV. NUMERICAL RESULTS AND ANALYSIS

In this work, the simulation was conducted using MATLAB software. The testbed was designed and simulated to emulate real life scenarios. The performance of the developed system was validated using an already existing design by Celik et al (2017). The system is such that the CUEs are uniformly distributed, and the transmitter (DUE-Tx) and the receiver (DUE-Rx) of each D2D pair are also uniformly distributed in a cluster. The simulation parameters are shown in Table I.

Table I: Simulation Parameters

PARAMETER	VALUE
Pathloss factor	3.2
Cell radius	1000m
Channel Bandwidth	250kHz
Noise Power	-109dBm
Maximum distance between DUE-Tx and DUE-Rx	10, 20, 30, 40, 50, 60, 70, 80, 90, 100m
Maximum transmit power for CUE	24dBm, 21dBm
Maximum transmit power for DUE-TX	24dBm, 21dBm
Maximum transmit power of eNB	44dBm,41dBm
Maximum Cellular UE’s number	50
Simulation type	MATLAB

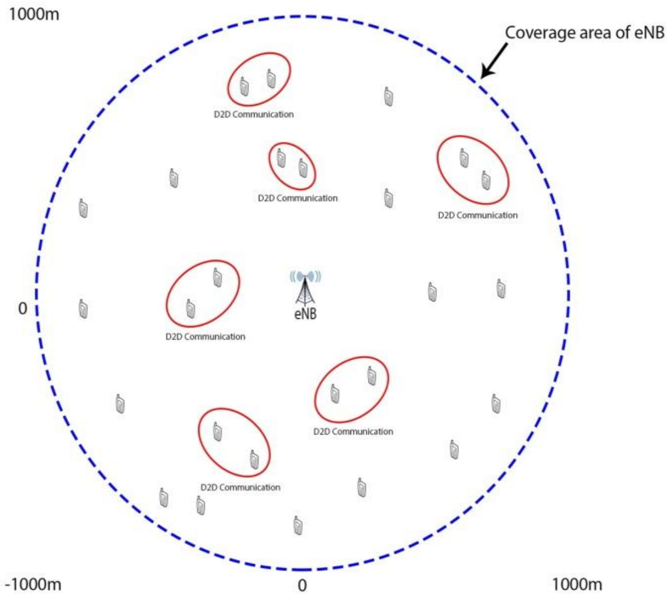

Figure 3: Image of D2D network topology and user placement

In this work, two important metrics were used to evaluate the performance and efficiency of the proposed resource allocation scheme. The metrics considered are access rate and the D2D throughput gain.The access rate explains the rate at which DUE can access resources with CUEs. At the other hand, D2D throughput shows the throughput of the network as a result of the accessed DUEs.

4.1. Uplink Resource Allocation Scenario

In this scenario, when the uplink resources are being reused by the DUEs in the cell, the eNB receives interference from the D2D transmitters. Also, the D2D receiver would also receive interference signal from the nearby CUEs. By reusing uplink resources, interference can be minimized as the interference can be better handled by the eNB.The performance of the DUEs in terms of access rate and D2D throughput gain at various minimum value of SINR for the uplink scenario will be evaluated using Matlab. The results of the simulation are shown from figure 4 to figure 6 below.

4.2. Evaluation of Access Rate and Distance between D2D pair with varying Minimum SINR

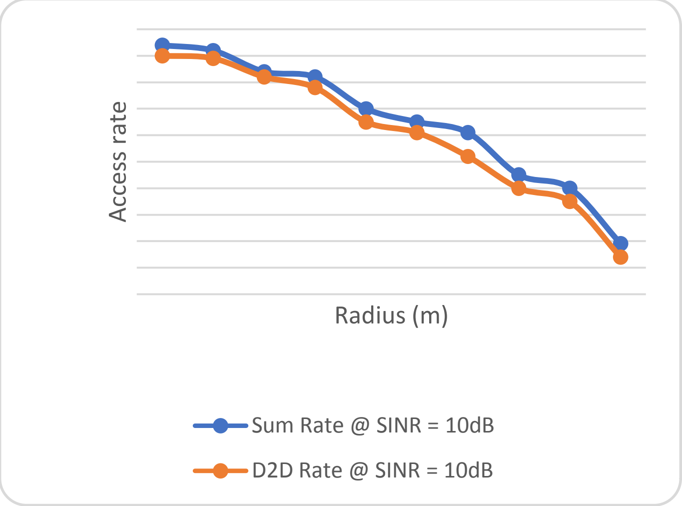

Figure 4: Access rate when the minimum SINR was 10dB with CUEs = 25 and DUEs = 15 for uplink scenario.

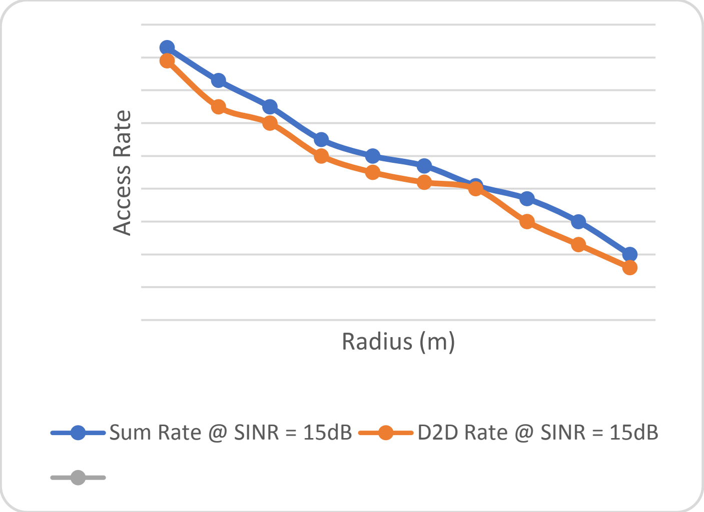

Figure 5: Access rate when the minimum SINR was 15dB with CUEs = 25 and DUEs = 15 for uplink.

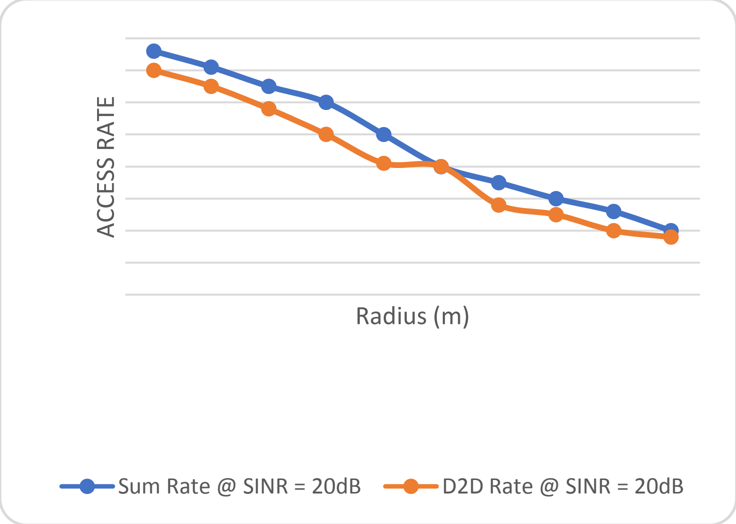

Figure 6: Access rate when the minimum SINR was 20dB with CUEs = 25 and DUEs = 15 for uplink

From figure 4 to figure 6, it was observed that in the uplink scenario, as the SINR requirement increased, the access rate of the system was reduced. This action allowed more DUEs to be admitted, which would share the same channels with CUEs, and consequently increasing the access rate and vice versa. The impact on the D2D throughput gain is as shown from figure 7 to 9.

4.3. Evaluation of D2D Throughput gain and Distance between D2D pair with varying SINR

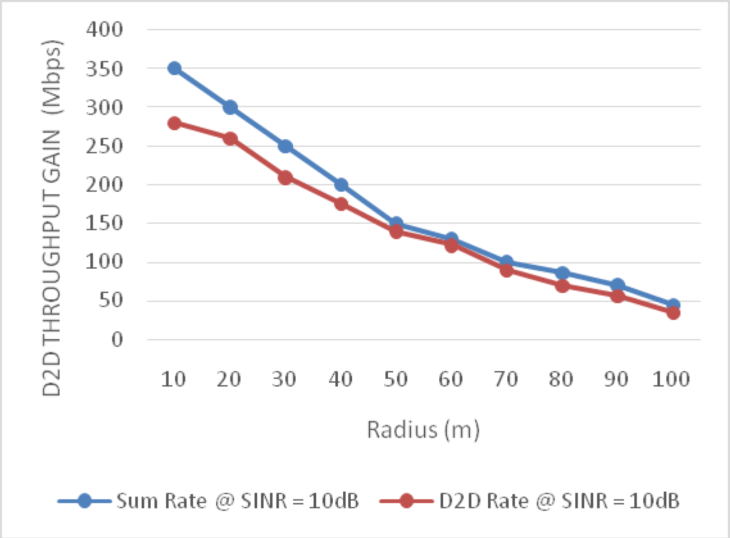

Figure 7: D2D Throughput gain of the system when the minimum SINR was 10dB with CUEs = 25 and DUEs = 15 for uplink.

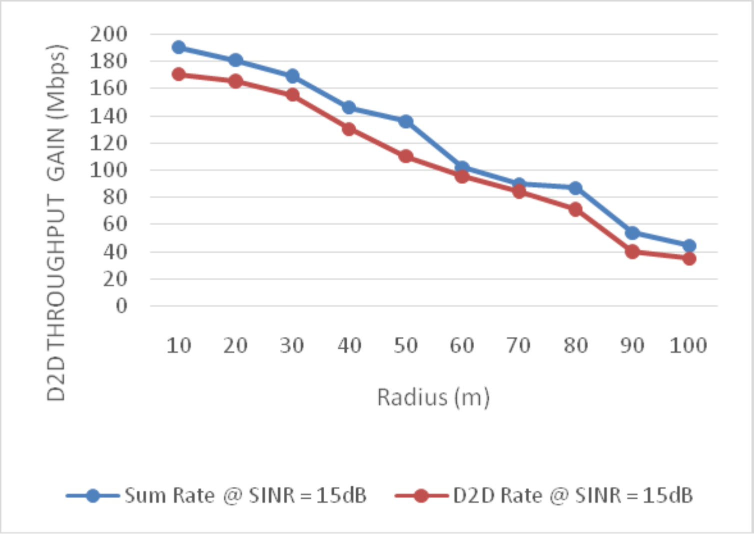

Figure 8: D2D Throughput gain of the system when the minimum SINR was 15dB with CUEs = 25 and DUEs = 15 for uplink.

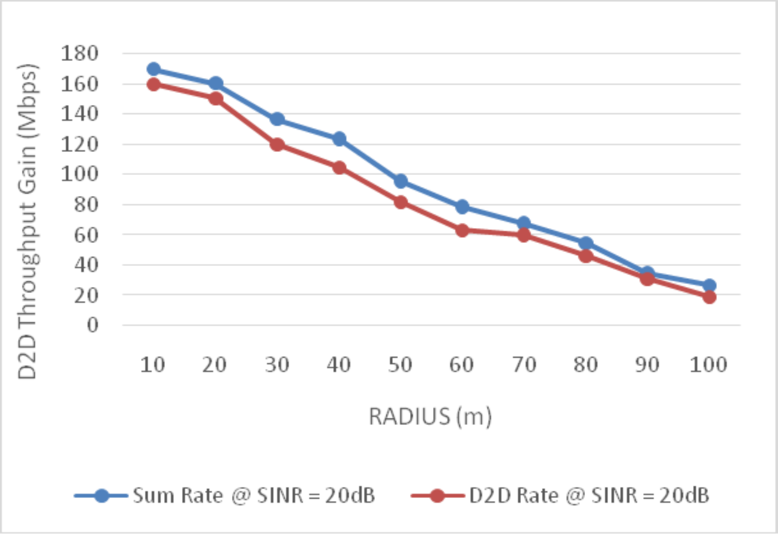

Figure 9: D2D Throughput gain of the system when the minimum SINR was 20dB with CUEs = 25 and DUEs = 15.

The results obtained from figure 7 to figure 9 also shows that as the SINR requirement increased, the D2D throughput of the system was reduced for uplink scenario. Also, when the SINR requirement was reduced, the D2D throughput of the system increased. Note that the reduction in the SINR requirements for users led to an increase in the maximum allowable interference for the eNBs. This action allowed more DUEs to be admitted into the system, thus increasing the D2D throughput gain.

V. CONCLUSION

Device to Device communication has provided a prospective solution to the implementation of the next generation of network, which has the capability of providing improved coverage, high data rate, improved spectral efficiency etc. This paper has presented an improved interference mitigation algorithm that enables DUEs sharing uplink resources with CUEs in order to maximize the overall throughput while ensuring QoS requirement for both devices. The system model presented an optimization model first as a Mixed Integer Non – Linear Programming (MINLP), but due to its computational complexity a Greedy Heuristic algorithm which provides an alternative solution for resource allocation by setting a certain SINR threshold for CUEs and DUEs in maintaining the link minimum SINR. In this way improve the network overall throughput and increase DUEs access to the network without hampering CUEs.

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4.2.4 LAB Average wt. % fraction Yield

The calculated LABs percentage Yield from the average LAB weight fraction is as shown in Table 4.3
The calculated percentage yield of average LAB wt. % fraction indicated a higher percentage yield at the top and bottom stream temperature of 280°C. At this temperature the obtained yield of top and bottom streams are 92.2% and 95.3 %. Table 5 and Figure

Table 5: LAB Average wt. % fraction Percentage Yield

Operating *Temperatures (^{0}C)	Percentage Yield of Average LAB wt.% at various Top Stream operating condition	Percentage Yield of Average LAB wt.% at various Bottom Stream operating condition
280	92.2	95.3
300	87.6	94.8
320	87.5	94.2
340	87.6	93.8
360	87.5	93.3

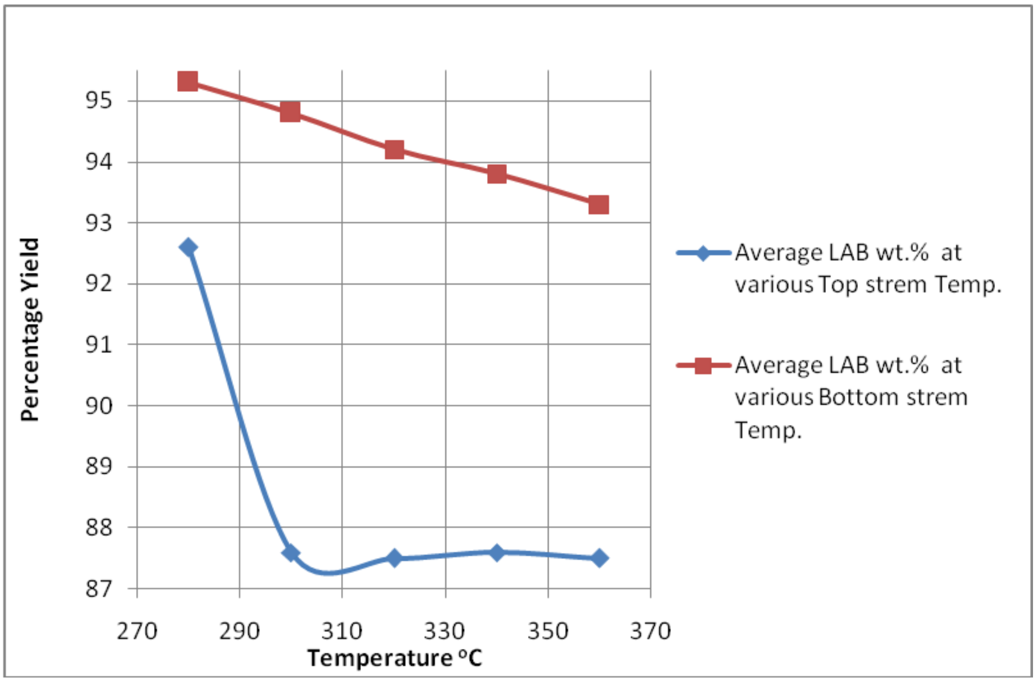

Figure 5:LAB Average wt. % fraction Percentage Yield

5 Percentage Yield of LAB in the distillate at T_{Bottom}= 280 ^{0}C.

- The bottom stream operating temperature of 280 ^{0}C has the highest average percentage yield of linear alkylbenzenes (LABs). The percentage yield of the linear alkylbenzene was calculated by keeping the operating temperature at 280 ^{0}C and varying the operating pressure at 17Kpa, 42Kpa, 67Kpa, 92Kpa and 115Kpa. The highest yield obtained is 99.4% which is at 115Kpa. This is as shown in Table 6. And figure 6

Table 6: Percentage Yield of LAB in the distillate.

Pressure Kpa	Percentage Yield Of LAB in the Distillate
17	89.1%
42	95.4%
67	97.9%
92	98.97%
115	99.4%

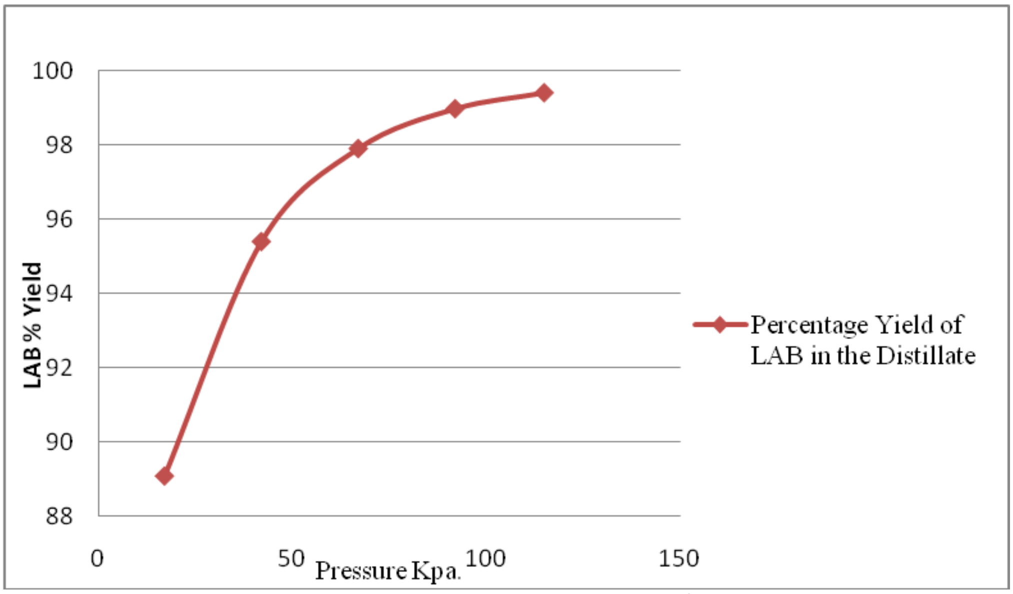

Fig.6:LAB % Yield at T_{Bottom}= 280^{o}C.

VI. CONCLUSION

It was observed that the rerun column bottom stream temperature has greater effect on the linear alkylbenzene yield than the temperature variation of the top stream. At higher temperature of both streams , lower percentage yield of average wt. % of linear alkylbenzene was obtained with that of the top stream being the lowest at 87.5% as against 93.3% for the bottom stream. The highest linear alkylbenzene yield of 99.4%was recorded at bottom stream temperature of 280^{o}C and pressure of 115Kpa.

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