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An Improved Interference Mitigation Algorithm for D2D Communication in 5G Cellular Networks

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ABSTRACT

This research paper analyses an improved resource allocation algorithm for interference mitigation with improved QoS for cellular and Device-to-Device (D2D) communication. A heuristic allocation scheme was employed. The system was such that the CUEs were uniformly distributed, and the transmitter (DUE-Tx) and the receiver (DUE-Rx) of each D2D pair were also uniformly distributed in a cluster. Two important metrics namely access rate and D2D throughput gain were used to evaluate the performance and efficiency of the proposed resource allocation scheme. To validate the performance of the developed algorithm, the impact on the D2D throughput gain for different SINR requirement was compared to the result obtained by another research work. Simulations result showed that as the SINR requirement increased, the access rate and D2D throughput gain of the system was reduced. Although the two methods leveraged the greedy heuristic algorithm, the method used in this work increased the achievable throughput by introducing an additional threshold for minimum SINR requirement, such that the throughput was increased as the access rate increased. Comparisons showed that the developed method had a 5.3% improvement over the method by Celik et al (2017). Also, when the maximum distance between the DUE-Tx and DUE-Rx was 100m, the developed method showed about 60.9% improvement. In conclusion, an improved interference mitigation algorithm for d2d communication in 5g cellular networks was achieved.

KEYWORDS/PHRASE: Simulation, wireless network, allocation scheme, algorithm, interference.

I. INTRODUCTION

1.1 Background of Study

Several studies have been conducted to investigate the use of D2D in cellular networks. D2D enables proximate User Equipment (UE) to communicate with one another without passing through a base station by using various short-range wireless technologies such as Bluetooth, Wireless Fidelity (Wi-Fi/WLAN based on the IEEE 802.11 standard), and others as a medium to facilitate D2D communication. Despite the fact that the integration of D2D communication in cellular networks has enabled cellular offloading at the Base Station (BS) because UEs are free to choose mode of communication, the interference threat posed by D2D UEs to the cellular network remains a current research issue. The implementation of D2D communications in a multi-cellular network environment presents a number of technical challenges that must be addressed. This thesis develops an improved resource allocation algorithm for interference mitigation with improved QoS for cellular and Device-to-Device (D2D) communication.

II. LITERATURE REVIEW

2.1 Configuration of D2D Communication

D2D's communication configuration according to Demia (2018) includes:

Self-organized D2D Communication: It is the traditional ad-hoc networks where coordination between the radio interfaces is controlled by the users themselves and operates on the unlicensed spectrum. It is usually motivated by its limited signalling overhead and easy to deployment. This configuration finds its application where the cellular infrastructure is not operative. This creates instability due to lack of centralized control.

Network Controlled D2D: The base station (BS) assists the direct data-transmission between cellular users and D2D devices by means of control signalling resources management, and discovering/establishing the connection and cellular users. Due to centralized control by the BS, interference can be managed efficiently. One disadvantage of this coordination is that it might require high signalling overhead and complex centralized resource management.

2.2 Classification of D2D Communication based on Device's Access to Spectrum

According to Figure 1, the classification of D2D communication is based on its access to spectrum viz: Licensed Cellular Spectrum (In-band) or Unlicensed Spectrum (*Out-band).*

Unlicensed (Out-band) D2D: D2D communication takes explores unlicensed Industrial Scientific and medical band spectrum (ISM). It uses some wireless technologies such as Wi-Fi, ZigBee, or Bluetooth) in transmitting data. Unlicensed spectrum is further categorized into Autonomous and Controlled Out-band communication. In Controlled out-band, BS control the resources between DUEs. Again, in Autonomous (Out-band) Communication, devices are responsible for radio resources control. There is no interference issue between D2D and cellular communications unlike underlay. Nevertheless, the uncontrolled nature of unlicensed spectrum increases security risks and imposes constraints on QoS provisioning.

Licensed (In-band) D2D communication: In licensed communication, the cellular spectrum is shared by both D2D and cellular communications. It is further subcategorized into Underlay and Overlay in- band communication. Overlay (Dedicated Mode) provides a dedicated link for DUEs. As a result, the cross – tier interference problem is eliminated since devices are provided with separate spectral bands for their individual communication. The under-utilization of spectrum provided for D2D communication is a major drawback of this mode. In Underlay (Shared mode), D2D and cellular users reuse resources either in time or frequency. The eNB reuses either the uplink or downlink resource blocks for D2D communication. The spectrum efficiency is greatly enhanced due to resource sharing. However, this mode introduces severe interference problem between the D2D and cellular users since both users are simultaneously using the same physical resource blocks. The elimination of the interference problem requires complex interference management techniques.

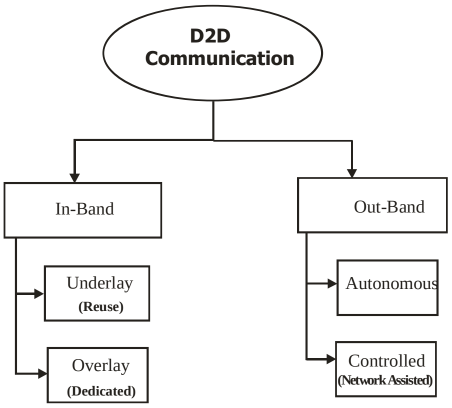

Figure 1: Classification of D2D communication

2.3 Device Proximity Discovery

Device proximity discovery can be explained to be a process whereby User Equipment (UE) sends a device discovery message to nearby devices before establishing a D2D link. It involves two main processes, Prose discovery and Prose communication of devices in close physical proximity (Athul et al, 2014). ProSe discovery is a procedure where the announcing UE sends a discovery signal to nearby devices (UEs) within its proximity. After both devices must have discovered each other, both devices exchange their identity. ProSe communication (Monitoring) follows suit. ProSe communication involves periodical listening of UE to ProSe announcing UEs; and in return the listening UE sends discovery response signal to an announcing UE. Both ProSe discovery and response messages contain ProSe UE identity and ProSe application layer identity. Regardless of its benefits, device discovery is still faced with energy consumption challenge encountered during ProSe transmission and monitoring procedure. Many D2D parameters are to be considered whenever a device discovery process is performed such as discovery range, discovery period, and the modulation and coding scheme of the discovery messages (Athul et al, 2014). According to Fodor et al (2011), peer discovery and device pairing has been a popular procedure (e.g. Bluetooth) where inquiry process allows a master node to identify devices within the range of its coverage area. Peer discovery from cellular network perspective has similar functionality as cell search in LTE. D2D user can sense the surrounding environment to obtain required channel state information (CSI), interference, mobility, and other information related to nearby wireless devices (Ahmed, (ND)).

Minjoong (2015) assumed that discovery processes need to be performed with a reasonably short discovery time and limited discovery resources, while large number of devices participate in a limited area, that is, the device density can be high. If the number of devices using the same resource block (RB) is large, the discovery range might be limited by the interference from other transmitting devices. However, if a certain discovery range needs to be maintained, there should be a corresponding carrier sensing threshold that can be used so as to satisfy the signal-to-interference ratio of the neighbour devices within the discovery range. But if no RB satisfies the carrier sensing threshold due to a high density of transmitting devices, the discovery period will then be increased so that more RBs can be included in a single period. The discovery period can either be adjusted centrally or distributed.

Similarly, a low modulation and coding scheme may increase the size of each RB, resulting in an increased discovery time as well. Therefore, the discovery range can be said to be a function of the device density, the discovery period, and the targeted Signal-to-noise Interference ratio of the discovery messages. Several works have focused on various issues regarding to discovery.

2.4 Review of Radio Resource Allocation (RRA) for D2D communication

Gu.J. et al. (2016) investigated the joint PF scheduling of both CUs and D2D pairs. Because the optimal PF algorithm for joint scheduling is computationally complex, the authors use a heuristic algorithm to reduce the computational complexity, but no rate constraints or QoS guarantees are considered for either the CUs or the D2D pairs. The interference caused by D2D transmitters during CU scheduling was largely ignored.

Yngve (2015) concentrated on radio resource allocation, using a case study in which out-of-coverage user equipments (UEs) communicate with a base station (BS) via a user equipment relay (UER) located within cell coverage. Two algorithms were created: one for adjusting various parameters to achieve higher performance in the developed system, and the other for battery management (including four-battery control allocation schemes). The first algorithm resulted in a performance that was less dependent on parameter configuration and more dependent on how spectrum is shared by different users. The second algorithm demonstrated that the performance of the studied network is heavily dependent on the battery level of the UE relays, implying that strict battery control policies are required to demonstrate the benefits of in-band D2D communications.

Although D2D communication can improve spectral efficiency and system capacity through spectrum sharing, it also causes interference to cellular network users. To achieve the target performance levels for both cellular and D2D users while maximizing spectrum utilization, methods for efficient interference management and coordination must be developed. Efficient resource allocation algorithms are critical in obtaining these benefits while minimizing negative effects on the performance of existing communications between users and base-stations (Isheden et al, 2015).

Koushik et al. (2018) examined different resource sharing methods based on mode selection and power control. A sum rate optimization algorithm (for cellular mode, dedicated mode, and frequency reuse mode) has been proposed. The simulation results showed that the D2D link provides acceptable SINR without disrupting the existing cellular link in the Intra-cell communication model.

Junquan et al. (2015) investigated an uplink power control D2D relaying enabled cellular network with a multi-user, multi-carrier, and multi-cell network to mitigate inter-cell interference and in-band emission interference. To enable D2D-relaying, the problems of relay selection, resource allocation, and power control must be solved. To address this, a joint optimization problem was proposed, as well as a simplified relay selection and resource allocation scheme. The simulation results show that D2D-relaying under power control significantly improves throughput performance for cell-edge users through proper resource scheduling.

Fareha.N. et al. (2019) proposed an efficient dynamic spectrum that uses licensed and unlicensed bands in such a way that it selects the optimum band for establishing D2D linkages in the network based on the distance between the D2D links. The suggested approach is based on the distance between the D2D link, and it selects the most efficient band that minimizes interference and maximizes network throughput. The simulation results suggest that the proposed technique, which employs dynamic spectrum, outperforms alternative static spectrums in terms of network performance.

III. METHODOLOGY

3.1 Methodology

This work proposes an improved Heuristic resource allocation method as a solution to the interference threat in the underlying cellular network's D2D communication. The method would consider a scenario in which the D2D and cellular users coexist.

MATLAB simulations would be carried out to simulate the test bed environment, as well as compare the results with an already existing work.

In this chapter, we consider a multi-cell network with inter-cell interference and assume D2D communications can be established between two devices located in the same cell or different cells. This work would formulate an optimization problem which aims at maximizing the overall network throughput while guaranteeing the QoS requirement for both CUEs and DUEs.

3.2 System Model and Problem Formulation

We consider a multi-cell system in which are neighbouring base stations communicate with mobile terminals over a coverage area. Figure 2 shows the two-cell system model used to describe multi-cell D2D communications underlying cellular networks as the basic concept. There are N subchannels in this network of OFDMA (Orthogonal Frequency Division Multiple Access), and M-DUEs coexist with N-CUEs in the serving eNB. We also assume that all eNBs in the network are identical and have the same bandwidth and that each eNB bandwidth is separated into multiple channels of equivalent bandwidth sizes. In addition, we assume that the cellular network is a fully loaded scenario in which the total quantity of channels allotted for uplink transmission is equal to the number of existed CUEs in each eNB. The transmitter of a D2D pair (D2D-Tx) and its receiver (D2D-Rx) are not required to be in the same cell that communicates directly under the control of the serving eNB. The network's frequency reuse is equivalent to one. Hence, the DUEs in serving eNB are victims of interference from CUEs in neighboring eNBs.

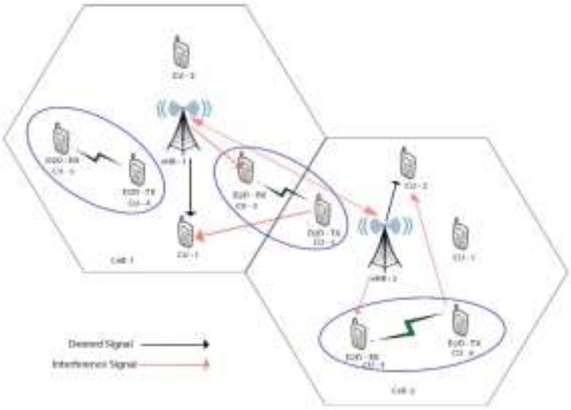

Figure 2: System Model of D2D Communication

When the CUEs and D2D pairs share downlink resources, co-channel interference occurs. Firstly, UE_1 (CU-1 cell 1) receives interference from UE_5 (D2D Tx cell 2). Secondly, D2D Rx (UE_5) receives interference from the Bs. The quantity of transmit power is not only dependent on the D2D transmitter but also on the channel gain between the D2D transmitter and the cellular users.

To obtain the maximum (achievable) rate at which data can be transmitted in the downlink channel, the Shannon's Capacity model is applied as expressed below:

$$C = Blog_2\left(1 + \frac{S}{N}\right) \qquad \ldots\ldots \quad (1)$$

Where

S/N = signal – to – noise ratio,

S = Received power in watt

N = Noise power in watt

B = Channel bandwidth in Hertz

C = Channel capacity in bit/seconds (bps)

$$SNR\left(\frac{S}{N}\right) = \frac{P_r}{N_o W} \qquad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

P_r = Received signal power

N_o = thermal noise power spectral density

$$C_{AWGN} = Blog_2\left(1 + \frac{P_r}{N_o W}\right) \qquad \ldots\ldots \quad (3)$$

Where

Received signal to noise ratio (SNR) known as Shannon-Hartley theorem for band limited channel = $\frac{P_r}{N_o W}$

If the d^{th} D2D pair shares downlink Resource Block (RB) as the CUE c, the received SINR of the CUE (UE_2) from UE_4 Rx can be calculated as:

$$SINR(\gamma_c^{DL}) \;=\; \frac{P_B G_{B2}}{N_o + \sum_d y_c^d \, P_d G_{42}} \qquad \ldots\ldots \quad (4)$$

Let

P_B be Base station transmit power

P_c is the CUE transmit power

P_d is the D2D transmit power.

G_{42} be the channel gain between the UE_4 Tx and the CUE2

G_{43} is the channel gain between the UE_4 Tx and UE_3 Rx (D2D pairs).

G_{B3} be the channel gain between the Bs and UE_3 Rx and $G_{B1,}$ the channel gain between the Bs and the CUE_1

Similarly, the received SINR at the dth D2D Rx (UE$_3$) is given by:

$$SINR(\gamma_d^{DL}) \quad = \frac{\sum_c y_c^d \, P_d G_{34}}{N_o + \sum_c y_c^d \, P_B G_{B3}} \qquad \dots\dots\dots \quad (5)$$

Where N$_o$ represents thermal noise power spectral density at the UE$_3$ Rx and the optimization variable, y_c^d, known as the indicator function is defined by:

$$y_c^d = \begin{cases} 1, & ifD2DpairsdreusesRBwithCUE \\ 0, & otherwise \end{cases}$$

Maximum achievable rate of CUE (M$_c$)

$$M_c = Wlog_2(1 + \gamma_c^{DL}) \qquad \dots\dots.. \ (6a)$$

$$M_c = Wlog_2\left(1 + \frac{P_B G_{B2}}{N_o \sum_d y_c^d P_{BG_{42}}}\right) \qquad \dots\dots\dots\dots \ (6b)$$

Similarly, Maximum achievable rate at the D2D Rx (M$_d$)

$$M_d = Wlog_2(1 + y_d^{DL}) \qquad \dots\dots\dots.. \quad (7)$$

$$M_d = Wlog_2\left(1 + \frac{\sum_c y_c^d \, P_d G_{43}}{N_o \sum_c y_c^d P_B G_{B3}}\right) \qquad \dots\dots\dots\dots \quad (8)$$

The sum rate of CUE and D2D UE is expressed as

$$R_{Sum}^{DL} = \ (M_c^{DL} + \ M_d^{DL}) \qquad \dots\dots\dots\dots \ (9)$$

For simplicity, we assume that one CUE shares RB with one D2D pair and vice versa. To formulate the sum rate of CUE and D2D UEs, a mixed Integer non-linear programming is formulated (MINLP).

$$Maximize \sum_c^C S_c M_c^{DL} + \sum_d^D \sum_c^C y_c^d S_c M_d^{DL} \quad \dots\dots\dots \ (10)$$

Subject to:

$$P_B G_{B2} \geq \gamma_{c,tgt}^{DL}\left(N_o + \sum_d y_c^d P_d G_{42}\right), \forall_c \in C \qquad \dots\dots\dots \ (11)$$

$$\sum_c y_c^d \, P_d G_{34} \geq \gamma_c^{DL}\left(N_o + \sum y_c^d P_B G_{B3}\right), \forall_c \in D \qquad \dots\dots \quad (12)$$

$$\sum_c y_c^d \leq 1; \ \forall_d \in D \qquad \dots\dots\dots\dots \ (13)$$

And

$$\sum_d y_c^d \leq 1; \ \forall_c \in C \qquad \dots\dots\dots\dots \ (14)$$

From equation (10), S$_c$ is the number of RB allocated to CUE c at each time slot during downlink. Also γ_c^{DL} and γ_d^{DL} denote minimum SINRs of CUE c and D2D pair respectively. Equations (13) and (14) ensure that D2D pair is assigned to at most one CUE's RB and one CUE can share its resources to at most one D2D pair respectively. Equations (11) and (12) maintain minimum rate requirements are for both CUE c and D2D pair d.

The optimization problems formulated above for the downlink scenario is a mixed integer non-linear programming (MINLP). Consequently, it makes it very hard to arrive at an optimal solution within a scheduling interval of one millisecond (1ms). This work proposes a Heuristic algorithm as an alternative resource block (RB) scheduling scheme for D2D Users. This work considers only downlink RB scheduling. Note that from equation 3.4, when the channel gain (G$_{42}$) between UE$_2$ and D2D Tx (UE$_4$) and G$_{B3}$ between UE$_3$ (D2D Rx) and Bs in equation (5) is reduced, the SINRs (γ_c^{DL}& γ_d^{DL}) would increase leading to increased system throughput. Thus, any CUE with high channel quality indicator (CQI) can share its resource blocks to a D2D transmitter with minimum interference.

3.3 Algorithm: Downlink D2D Resource Block Allocation Scheme

- *C*: Present list of CQIs for all DL UEs in decreasing order
- *D*: set of D2D pairs in the network
- G$_{42}$: Channel gain between CU c and CU d

- G_{43}: Channel gain between D2D pair d
- G_{B2}: Channel gain between Bs and CU c
- G_{B3}: 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

```
Start
c ← 1
while D ≠ ∅ or c = = C do
initialize target SINRs of CUE c and D2D pair
$\gamma_{c,thresh}^{DL} \leftarrow G_t$
If ($c^{th}$value = $c_{max}$) select c else Return
Find the D2D user d with minimum channel gain;
$\gamma_{c,tgt}^{DL} \leftarrow \frac{P_B G_{B1}}{N_o + \sum_d y_c^d P_d G_{41}}$;
$\gamma_{d,tgt}^{DL} \leftarrow \frac{\sum_c y_c^d P_d G_{43}}{N_o + \sum_c y_c^d P_B G_{B3}}$;
if $\gamma_c^{DL} \geq \gamma_{c,tgt}^{DL}$ and $\gamma_d^{DL} \geq \gamma_{d,tgt}^{DL}$ then
Allot all RBs of the UE c with D2D pair d;
D = D - {d};
else
if $\gamma_c^{DL} \geq \gamma_{c,thresh}^{DL}$ then
Share all RBs of the UE c with D2D pair d;
D = D - {d};
else
Do not assign RB to D2D pair d;
end if
c ←c + 1;
end
```

3.4 Flowchart of Downlink Interference Mitigation Algorithm

The Flowchart of Downlink Interference Mitigation Algorithm is as shown in figure 3.

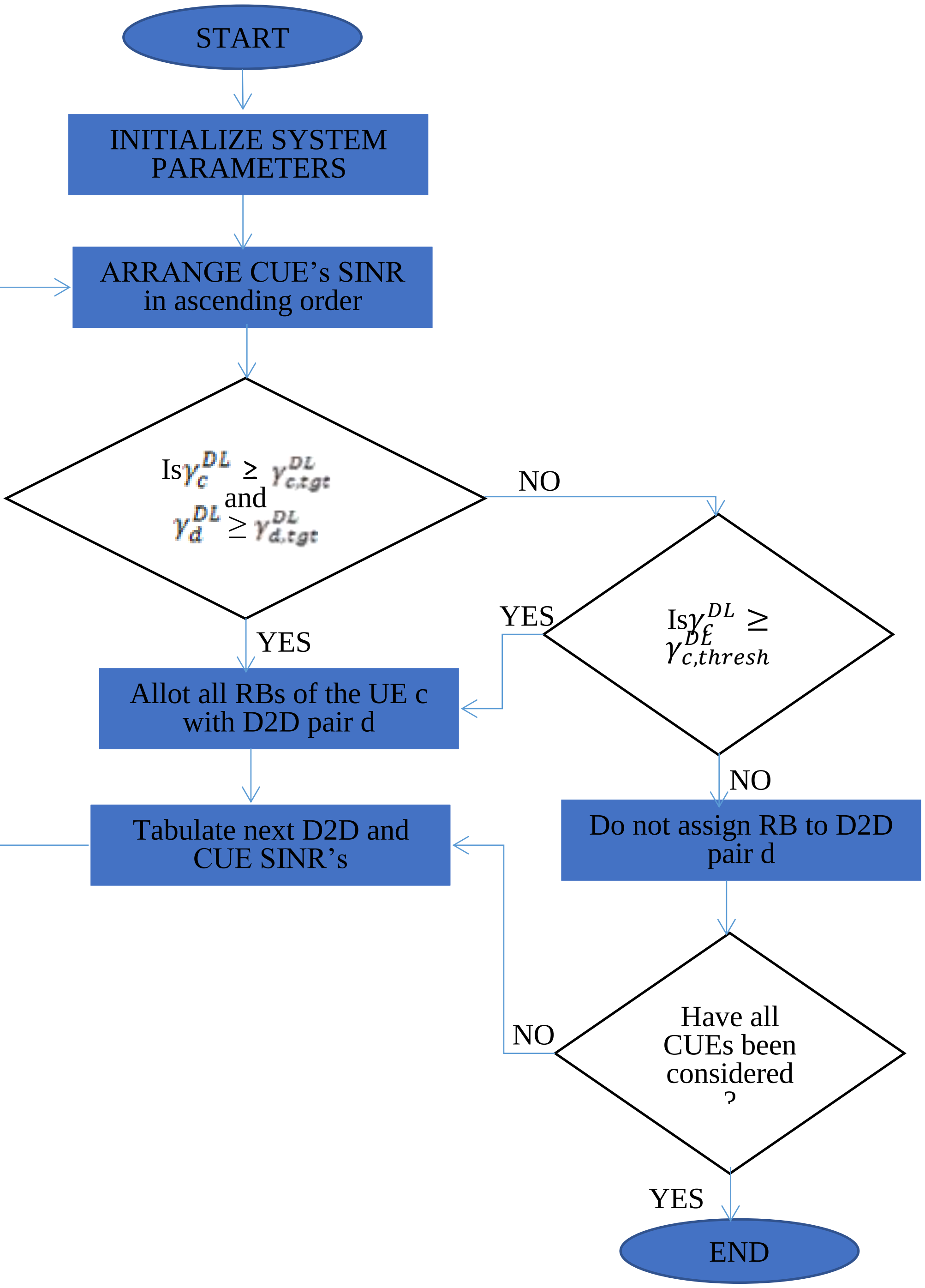

Figure 3: Flowchart of Downlink Interference Mitigation Algorithm

IV. RESULTS AND SIMULATION

4.1 Simulation Testbed

In this work the system model was validated using a MATLAB-based simulation. The simulation parameters used in the simulation for the D2D-enabled cellular HetNets is presented in table 1. The simulation codes are contained in appendix A. Three (3) neighbouring cells each of radius 500m were considered, where DUEs share uplink resources with CUEs. The CUEs are uniformly distributed in all cells. The clustered distribution model for D2D pairs is used, in which the transmitter (DUE-Tx) and the receiver (DUE-Rx) of each D2D pair are uniformly distributed in a cluster with radius r; and clusters are uniformly distributed in all cells so that the transmitter and the receiver of each pair may be situated in the same cell or different cells. A screenshot of the simulation scenario for distribution of CUEs and DUEs in the test bed is shown in Figure 4. The performance of the developed system was validated using an already existing design by Celik et al (2017).

Table 1: Simulation Parameters

PARAMETER	VALUE
Pathloss factor	3.4
Number of Cells	3
Cell radius	500m
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 Cellular UE’s number	50

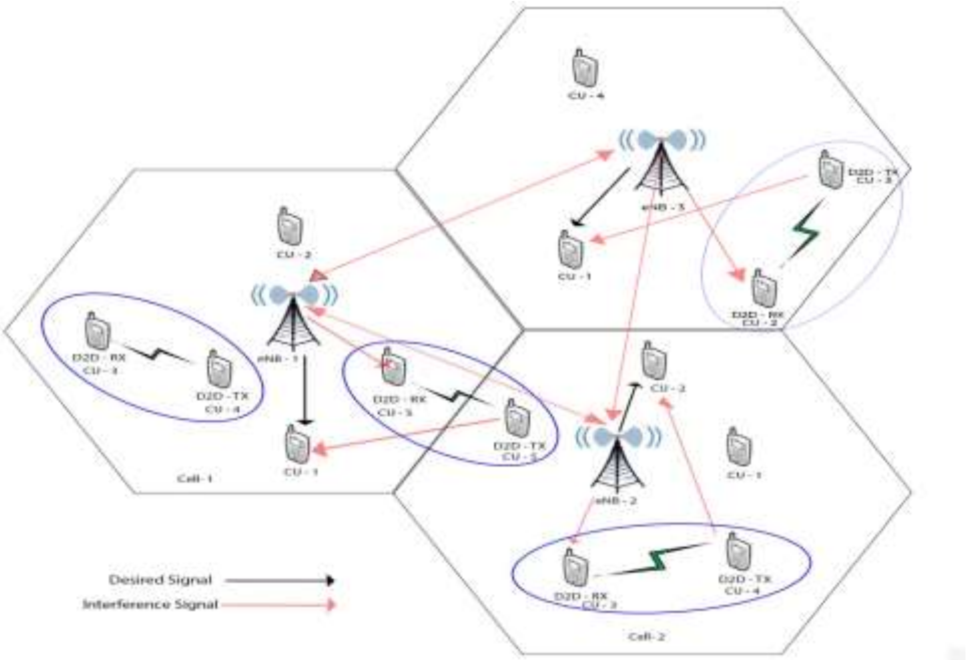

Figure 4: Screenshot of the Simulation Scenario

To evaluate the performance of the proposed system, two metrics which are being used to evaluate the efficiency of the resource allocation system were considered. These metrics are generally considered as the most important parameters that properly evaluates how effective the resource allocation scheme is (Amamer Saied, 2021). These metrics are D2D throughput gain and access rate.

The access rate indicates the ratio of the number of accessed DUE’s and the total number of DUE’s available. The D2D throughput shows the throughput of the network as a result of the accessed DUEs. The analysis done in this work is limited only to downlink scenario.

4.2 SIMULATION SCENARIO

- **Downlink Scenario**

When DUEs reuse downlink resources during D2D communication, the CUEs will receive interference from the D2D transmitters, causing the eNB to cause strong interference to the D2D receivers. The interference management scheme used in this work is centralized, with the central controller (eNB) performing interference management between CUE and DUE and collecting information from each user in the network about Channel State, Channel Quality, SNR, and interference level. By introducing a threshold value that is constrained on satisfying the minimum rate requirement for both CUE and D2D pairs, the developed algorithm aims to maximize the total achievable rate throughput. Figure 5 to figure 7 depict the access rate and D2D throughput gain at various minimum SINR levels.

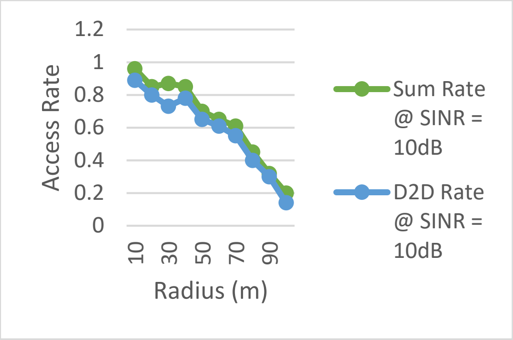

Figure 5: Access rate of system when the minimum SINR was 10dB with CUEs = 25 and DUEs = 15.

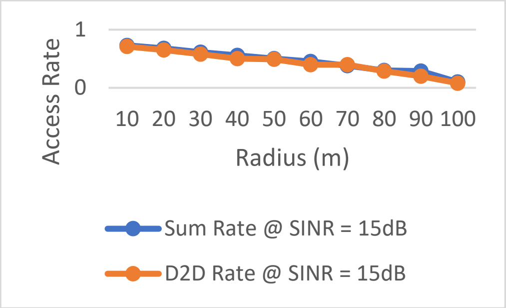

Figure 6: Access rate of system when the minimum SINR was 15dB with CUEs = 25 and DUEs = 15.

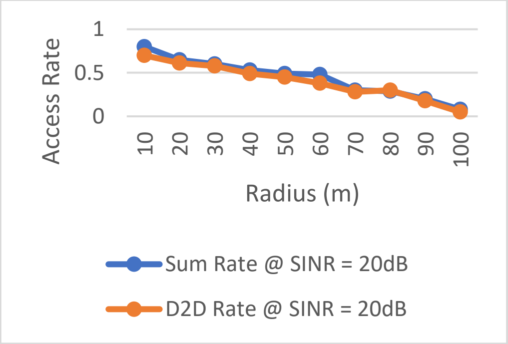

Figure 7: Access rate of system when the minimum SINR was 20dB with CUEs = 25 and DUEs = 15.

The results obtained from figures 5 to 7 showed that as the SINR requirement increased, the system's access rate decreased. In addition, when the SINR requirement was reduced, the system's access rate increased. This is because when the SINR requirements for users were reduced, the maximum allowable interference for CUEs increased. This enabled more DUEs to be admitted, which shared the same channels as CUEs, increasing the access rate and vice versa. The effects on D2D throughput gain are shown in figures 8 to 10.

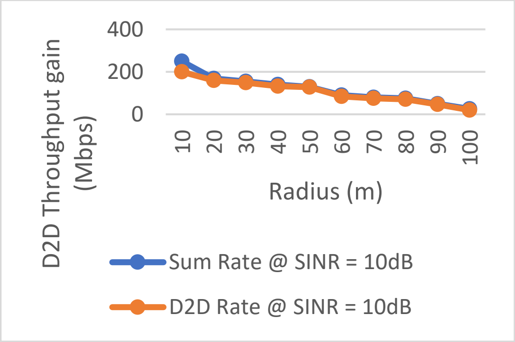

Figure 8: D2D Throughput gain of the system when the minimum SINR was 10dB with CUEs = 25 and DUEs = 15.

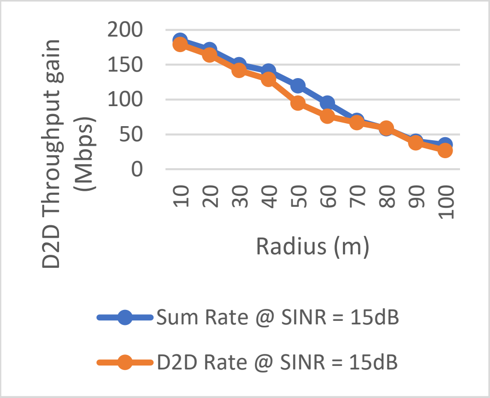

Figure 9: D2D Throughput gain of the system when the minimum SINR was 15dB with CUEs = 25 and DUEs = 15.

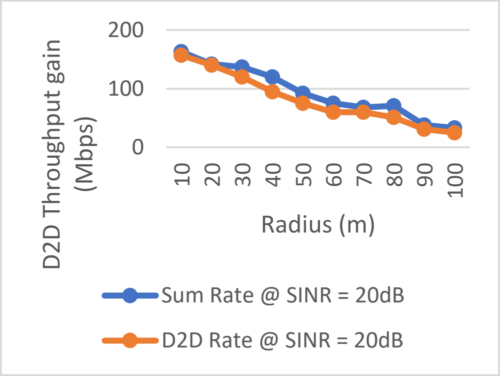

Figure 10: D2D Throughput gain of the system when the minimum SINR was 20dB with CUEs = 25 and DUEs = 15.

Figures 8 - 10 also show that as the SINR requirement increased, the D2D throughput of the system decreased. Furthermore, as the SINR requirement was reduced, the D2D throughput of the system increased. It should be noted that the reduction in user SINR requirements increased the maximum allowable interference for CUEs. This action allowed more DUEs into the system, resulting in a higher D2D throughput gain. To validate the performance of the developed algorithm, the impact on D2D throughput gain for different SINR requirements was compared to the result obtained by Celik et al (2017).

Furthermore, when the maximum distance between the DUE-Tx and DUE-Rx was 100m, the developed method demonstrated a throughput gain of 37Mbps, whereas Celik et al (2017) demonstrated a throughput of 19Mbps. This represents a 94.7 percent improvement over Celik et al (2017) method.

Power control is the process of adjusting the power levels of the eNB during DownLink (DL) transmissions and the UE during UpLink (UL) transmissions. The need to increase a device's transmission power exists because it can also increase link capacity. This, however, will cause incremental interference among devices that share the same resources. Figures 11 to 12 show the effects of varying maximum transmit power on the developed algorithm.

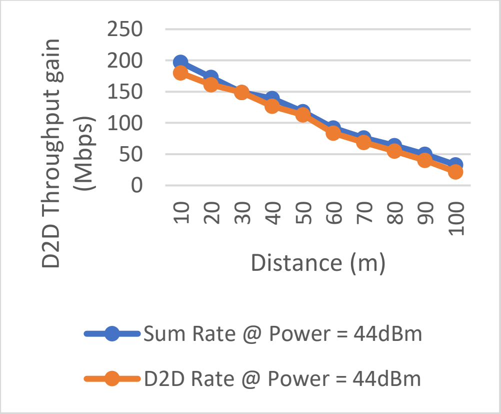

Figure 11: D2D throughput gain at a transmit power of 44dBm

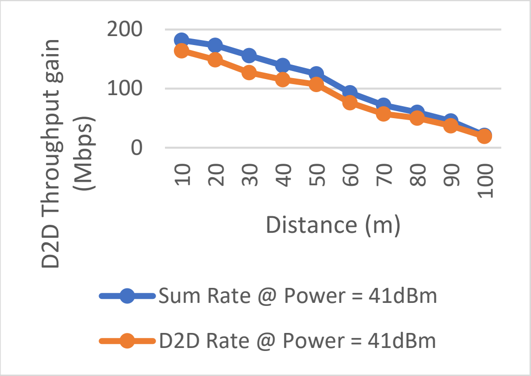

Figure 12: D2D throughput gain at a transmit power of 41dBm

Figures 11 and 12 show how the transmit power affects the developed algorithm. The system's performance dropped when the transmit power was reduced from 44dBm to 41dBm. It can also be seen that as the distance between the DUE-Tx and DUE-Rx increased, so did the degradation of throughput. It is important to note that the channel gain of the D2D link increases as the maximum distance between the DUE-Tx and DUE-Rx decreases. This makes it easier to meet the DUE's minimum SINR requirement, resulting in an increase in D2D throughput gain.

The effect of the transmit power over the developed algorithm was compared with the impact on the algorithm by Celik et al (2017).

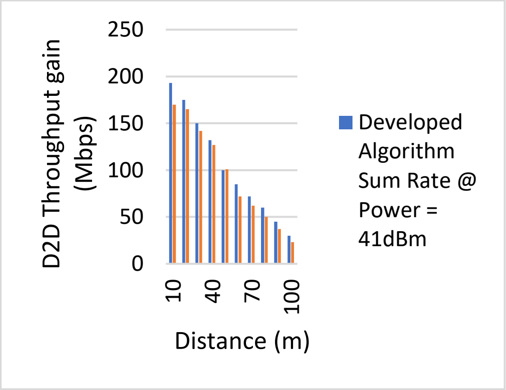

Figure 13: Compared D2D throughput gain at a transmit power of 41dBm

Figure 13 shows that when the transmit power was reduced from 44dBm to 41dBm, the system performance decreased. It can also be seen that as the distance between the DUE-Tx and DUE-Rx increased, so did the degradation of throughput with a decrease in transmit power. When compared to the algorithm developed by Celik et al (2017), the impact of transmit power reduction was lower in the developed algorithm. Figure 13 shows that when the maximum distance between the DUE-Tx and DUE-Rx was 30m, the reduction in transmit power had a 5.6 percent impact on the Celik et al (2017) algorithm when compared to the developed algorithm.

Lastly, the impact of increasing the number of CUEs was analyzed and is presented in figure 14.

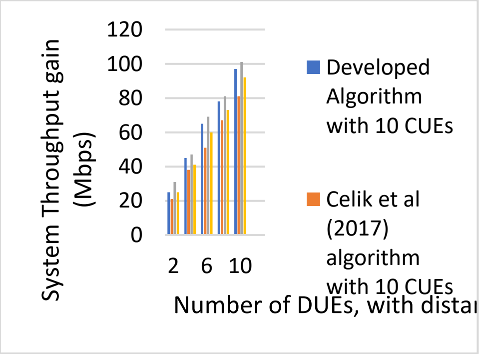

Figure 14: Compared system throughput gain at varying CUE and DUE number

The result shown in figure 14 shows that as the total number of DUEs and CUEs increases, so does the system performance of both algorithms. Nonetheless, the developed algorithm outperformed the algorithm developed by Celik et al (2017). Figure 14 shows that when the DUE was 10 and the CUE was 20, with a cluster radius of 50m, the system throughput gain was 101Mbps, compared to 92Mbps for Celik et al (2017).

V. CONCLUSION

To validate the performance of the developed algorithm, the impact on the D2D throughput gain for different SINR requirement was compared to the result obtained by other research works. The results obtained showed that the developed method outperformed the method by Celik et al (2017) for both instances. Although the two methods leveraged the greedy heuristic algorithm, the method used in this work increases the achievable throughput by introducing an additional threshold for minimum SINR requirement, such that the throughput is increased as the access rate is increased. For instance, in figure 4.8, when the number of DUEs was 10, the developed method showed a throughput gain of 180Mbps, while that of Celik et al (2017) showed a throughput of 165Mbps. This represents a 9.1% improvement over the method by Celik et al (2017). Also, when the maximum distance between the DUE-Tx and DUE-Rx was 100m, the developed method showed a throughput gain of 37Mbps, while that of Celik et al (2017) showed a throughput of 19Mbps. This represents a 94.7% improvement over the method by Celik et al (2017). The impact of the transmit power on both algorithms was also analyzed, and it was observed that the performance of the system declined with the reduction of the transmit power from 44dBm to 41dBm. It can also be observed that as the distance between the DUE-Tx and DUE-Rx increased, the degradation of the throughput increased with reduction in the transmit power. It is important to note that the channel gain of the D2D link increased with reduction in the maximum distance between the DUE-Tx and DUE-Rx. This makes it easy to meet the minimum SINR requirement of the DUE and thus results to an increase to the D2D throughput gain. The impact of the transmit power on both algorithms was also analysed, and it was observed that the performance of the system declined with the reduction of the transmit power from 44dBm to 41dBm.

In conclusion, the results obtained shows that the developed scheme can provide near-optimal performance and outperforms the compared algorithm in the literature in terms of achievable throughput and access rate.

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