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Heuristic Resource Allocation Method as a Solution to Interference Threat in Cellular Network's D2D Communication

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***Abstract* - Many 5G solutions have been proposed, with the goal of either increasing the efficiency of existing resources or providing new radio resources or infrastructure. Device-to-Device (D2D) communications are regarded as a promising technique that allows mobile devices to communicate directly with one another without the use of access points or BSs. The implementation of D2D communications in a multi-cellular network environment presents a number of technical challenges that must be addressed. This work focused on interference management, which stands out as a critical and complex issue that must be addressed. In this work, an improved resource allocation algorithm for interference mitigation with improved QoS for cellular and Device-to-Device (D2D) communication was developed. Aheuristic 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.**

Keywords: Cellular network, algorithm, device-to-device, throughput, communication.

I. INTRODUCTION

1.1 Background of Study

Device-to-device (D2D) communications are regarded as a promising technique that allows mobile devices to communicate directly with one another without the use of access points or BSs Haus et al (2017). D2D communication in cellular networks will result in significant performance gains in data offload (due to direct communications), improved spectrum efficiency (due to cellular resource reuse), coverage extension (by improving connectivity among UEs), and content sharing/dissemination.

Several studies have been conducted to investigate the use of D2D in cellular networks. D2D enables proximate User Equipments (UEs) 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 Concept of Device – to - Device (D2D) Communication

With the unprecedented demand of mobile traffic due to increased number of UEs, 5G of mobile networks are anticipated to support 1000 times more data traffic (Zabestian et al, 2019). This exponential growth in usage causes caused inadequate spectrum resources and increase in power consumed by UEs. 5G has been proposed to address the

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current challenges especially in the area of high data and power consumed by devices. The 5G heterogeneous architecture which composed of small cells that overlay macro cells is supported by new and enhanced technologies (e.g., massive MIMO, mm Waves, Full Duplex, Visible light communication (VLC), and device-to-device communication [D2D]). The architectural nature of cellular network allows UEs to send data to BS using uplink (UL) resources and the BS redirecting the data to a corresponding UE receiver using downlink (DL) resources.

Currently, a shift in cellular network allows node -to-node (D2D) communication as to decongest traffic at the BS. Indranil, (2016) defined D2D communication is a direct communication between two or more devices without passing through a base station (BS). This mode of communication contradicts traditional cellular network where communication between CUEs compulsorily transverse the Base station. In an unlicensed industrial and medical (ISM) band, devices communicate via Bluetooth, Wifi etc. In cellular network, D2D communication is done under licensed spectrum and share spectrum with other cellular devices. The Fig. 1 below shows that CUE1 and CUE2 are communicating with the BS using uplink while CUE3 downlink resources. DUE's communicate directly in overlay or underlay mode. The cellular infrastructure (eNB) may however assist with tasks such as peer discovery and synchronization (Fodor G et al, 2012). By sharing the radio resources and avoiding data routing through the BS, D2D communication can improve the SE and offload some traffics from the cellular network (Lin X. et al, 2014) According to Ibrahim, (2019) main features of D2D as examined by 3GPP include: Proximity Service (ProSe) management, device discovery, device synchronization, and direct communication etc. By this D2D communication can be said to be an enabler of proximity-based services which provides higher data rate, improved spectral efficiency and energy efficiency with low power consumption and latency. Fig. 1 describes a D2D Communication Integrated in Cellular network.

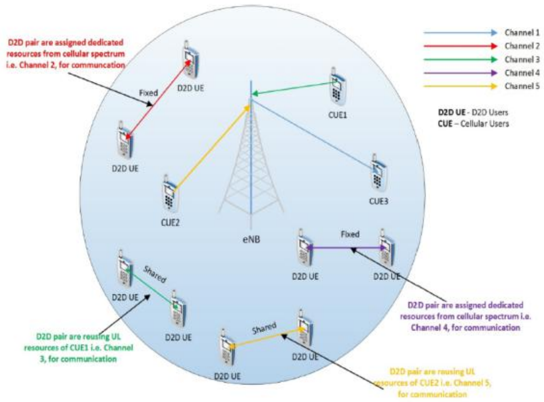

Figure 1: D2D Communication Integrated in Cellular network

D2D communication can provide four types of gains (Xue Chen, 2016):

i. **Proximity gain:** Short range communication provided in D2D link which enables high bit rates, low delays, and lower power consumption.
ii. **Hop gain:** D2D uses uplink (UL) or a downlink (DL) rather than two hops (uplink and downlink) when communicating through eNB.
iii. **Reuse gain:** D2D and CUE can simultaneously share radio resource during communication.
iv. **Pairing gain:** This enables a UE to communicate in cellular mode and D2D communication mode.

2.2 Configuration of D2D Communication

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

- **Self-organized D2D Communication** 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.

Table 1 shows the comparative analysis of D2D communication classifications.

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Table 1: Comparative Analysis of D2D Communication Classifications

Criteria	In-band		Out-band	
	Overlay	Underlay	Network-assisted	Autonomous
Spectral efficiency	Medium	Very high	Low	Low
Interference between cellular and D2D user	Very low	High	Negligible	Negligible
Interference among D2D user	Medium	Medium	High	High
Controlled interference environment	Yes	Yes	No	No
Implementation complexity	Medium	Low	High	High
Extra signalling overhead to network	Medium	High	High	Very Low
Inter platform coordination	No	No	Yes	Yes
Network controlled	Full/Hybrid	Full/Hybrid	Full	Loose
Cell Coverage	In coverage/ Partial coverage	In coverage/ Partial coverage	In coverage/	In coverage/Out of coverage
Simultaneous D2D and Cellular transmission	No	No	Yes	Yes
Energy efficiency	High	High	Low	Low

2.3 Overview of Radio Resource Management for D2D Communication

Radio resource management (RRM) in D2D communications consists of mode selection, power control, resource allocation and interference management (FodorG. et al, 2012).

2.3.1 Mode Selection

The introduction of D2D communication in cellular network brought in another challenge called Mode Selection. Mode selection is a process whereby User Equipments (UEs) in cellular network make decision on the transmission path before transmitting data. This decision of selecting the best mode for DUEs is between transmitting UE to UE receiver via a base station or through a dedicated link. According to Demia (2018) the choice of this mode may be influenced by: (i) The amount of energy that will be consumed (ii) Path with lesser loss (Link quality) (iii) The load at the Bs and interference level.

Neeta (2017) & Mahda et al (2018) highlighted and explained three different communication modes through which UE can communicate with each other:

- Reuse (Underlay) Mode: CUE and DUE share the same downlink and uplink resources with the existing cellular user Equipment (CUE) causing interference to each other.
- Cellular Mode: D2D users communicate with each other through the BS just like CUE does.
- Dedicated (Underlay) Mode: Here D2D UE uses dedicated resources that are orthogonal or without BS but they cannot reuse the spectrum resources. This mode is preferred when the signal quality is required to be very high with no interference.

Furqan et al (2018) classified device discovery scheme into centralized discovery and distributed discovery. In Centralized discovery, a central infrastructure (BS) helps devices discover each other. The BS first, initiates the message for exchange between two devices so as to obtain essential information such as channel conditions, interference and power control policies based on the network requirements. Devices are not permitted by the BS to initiate device discovery process rather they only listen to the messages transmitted by the BS. But in a case where the BS is partially involved in discovery process, devices send discovery messages to each other without obtaining prior permission from BS. However, they simply involve BS to communicate path gains and signal-to-interference noise ratio (SINR) level of each device. In distributed discovery approach devices are allowed to locate each other and transmit control messages periodically to locate nearby devices without involving BS in the process. However, issues of synchronization, interference and power frequently affect this mode. In Fig. 3, the Centralized discovery of (a) explains the complete involvement of BS; while (b) explains partial involvement of BS.

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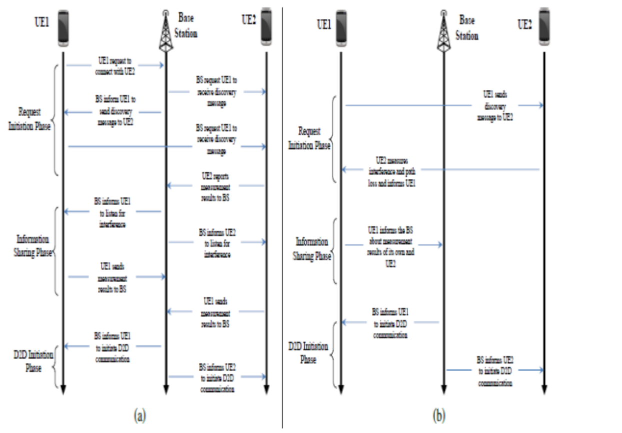

Figure 3: Centralized discovery (a) Explains complete involvement of BS (b) Explains partial involvement of BS

As one of key techniques in the fifth generation (5G) mobile communications, device-to-device (D2D) communication has attracted great attention in both academia and industry. However, D2D communication may bring about interference to the cellular links especially when it shares resource with cellular links.

The integration of D2D users in cellular networks has make the issue of interference between devices more complex (Chou et al, 2016 & Wen et al, 2012). Proper allocation of spectrum resources is very critical in maintaining the required level of QoS in the network. D2D communication shares resources uplink and downlink directions. Each of these can result in interference. When downlink resources are being reused by DUEs, CUEs will receive interference from D2D transmitters, and the BS may cause strong interference to the D2D receivers. For applications that require high data rates, downlink direction can become more congested compared to the uplink (Dahat et al, 2014). On the other hand, when uplink resources are reused by the DUEs in the cell, the BS becomes a victim and receives interference from the D2D transmitters. Similarly, the D2D receivers will receive interference signal from the nearby CUEs. Uplink resources are more favourable because they are usually less utilized compared to downlink resources. By reusing uplink resources, interference can be minimized as the interference can be better handled by the BS (Lin. X. et al, 2014).With this integration, cellular architecture has evolved into a two-tier cellular system: a Macro cell tier and a Device tier. Macro cell tier involves cellular communications from base station to cellular users while device tier involves D2D communications. Two types of interference can occur in this two-tier scenario: Co-tier and Cross-tier (Noura et al, 2016). In Co-tier, interference occurs between a DUE and another DUE which must be in close proximity while cross tier occurs between DUE and BS or CUE and DUE. In OFDMA systems, the co – tier interference arises when the same set of resource blocks are allocated to multiple DUEs. In this regard, the interference is always generated from the D2D transmitter to the D2D receiver in a D2D pairs which are assigned the same cellular resources regardless of the resources reuse direction (UL/DL).Fig.4 shows the types of interference in a two tier D2D enabled cellular network.

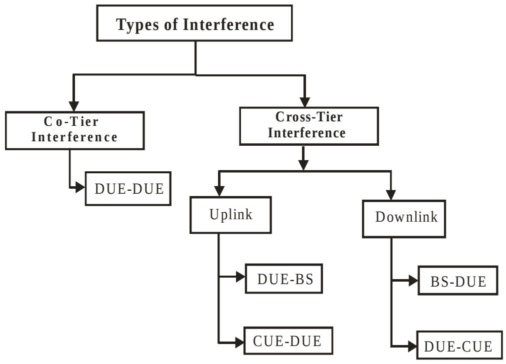

Figure 4: Types of Interference in a Two Tier D2D Enabled Cellular Network

Conversely, Cross-tier interference exists between two devices belonging to different tiers for example: interference existing between (i) DUE and CUE (ii) A CUE and multiple DUEs. In this situation, there is always an aggressor (the source of interference) and the victim (depending on the reuse direction (UL/DL). If cellular users and D2D users share the same channel resources in the UL communication then the source of interference is the D2D transmitter and the victim is the cellular base station. In the same situation, interference exists between the CUE (the source of interference) and the D2D user becomes the victim. In the case of DL communication, the base station causes interference to D2D receivers and D2D transmitters interfere with DL CUE receiver. The Fig.5 demonstrates interference scenario of D2D and cellular links under downlink resource reuse.

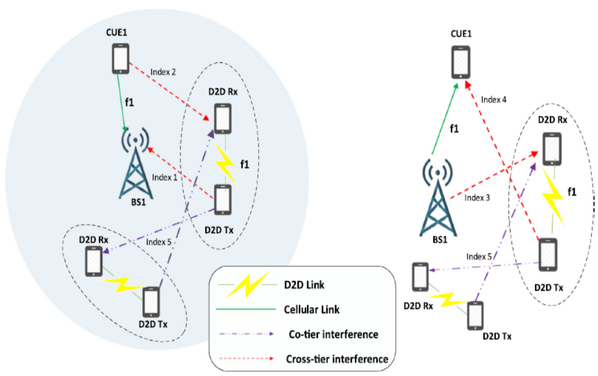

Figure 5: Interference Scenario of D2D and Cellular Links under Downlink Resource Reuse

Different Classification of Resource Sharing Modes is shown in table 2.

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Table 2: Different Classification of Resource Sharing Modes

Transmission Mode	Aggressor	Victim	Type of Interference
Uplink/Downlink	D2D Tx	D2D Rx	Co-tier
Uplink	D2D Tx	BS	Cross tier
Uplink	CUE	D2D Rx	Cross tier
Downlink	BS	D2D Rx	Cross tier
Downlink	D2D Tx	CUE	Cross tier

Different Interference management scheme in the literature can be categorized into centralized, distributed and semi distributed approaches depending on the algorithm operation (Noura et al, 2016).

In centralized approach, the central controller (eNB) performs interference management between CUE and DUE and collects information regarding Channel State, Channel quality, SNR and interference level from each user in the network. The BS (central controller) is responsible for allocating resources to DUE and CUE based on the information collected. The main challenge faced by this scheme relates to complex signalling overhead required for exchanging CSI and feedback which results to wastage of resources. Also, the interference management complexity increases as the number of users in the network increases. As a result, this scheme is only suitable for small sized D2D network. In distributed scheme, a central entity is not required for management of interference rather interference management is managed by DUEs themselves. Each node carries out some measurements and calculations that are enough to reach the decision or should be shared among its neighbours to take the decision. This way the scheme reduces the control and computational overhead due to limited CSI and feedback unlike in centralized approach. This scheme is recommended for large sized D2D network. Thus, distributed approaches present more robust communications. For Semi-distributed interference management scheme, it combines the advantages of centralized and distributed scheme to take care of their limitation. The scheme is suitable for moderating large networks.

Most of the interference management techniques for D2D enabled cellular network in the literature discussed about networking coding, spectrum splitting, MIMO. Here we shall be looking into Radio Resource Allocation (RRM), and Power control (PC) technique.

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

In wireless communication systems, radio resource management (RRM) is the system-level control of co-channel interference and other radio transmission characteristics. It entails strategies and algorithms for controlling parameters such as transmit power, channel allocation, handover criteria, modulation scheme, error coding scheme, and so on, with the goal of maximizing the use of limited radio spectrum resources and radio network infrastructure (Sukhpreet Kauret al, 2014). That is, radio resource allocation (RRA) primarily addresses research issues concerning how to optimally assign frequency resources to a group or all D2D pairs. Using one of the RRM schemes to manage resources efficiently can significantly reduce interference, conserve power, and maximize throughput.

Arashi (2014) conducted a thorough survey of D2D communications in cellular networks, categorizing the available literature as in band or out band. According to the literature, the main issue in underlay D2D communication is power control and interference management between D2D and cellular users, whereas overlay D2D communication does not have this problem because D2D and cellular resources do not overlap. Despite the fact that this approach dedicates cellular resources to D2D users and has lower spectral efficiency than underlay. However, because the interference level of the unlicensed spectrum is uncontrollable, ensuring QoS in highly saturated wireless areas is a difficult task.

Giovanni.G. (2017) investigated the underlay mode, in which Cellular User Equipments (CUEs) and Device to Device User Equipments (DUEs) can transmit on the same sub-channels within a cell, causing interference. To improve cell capacity while ensuring low outage probability, a Heuristic resource management scheme (combining a scheduler and a pairing strategy) was proposed. The scheme uses a proportional fairness (PF) scheduler for both CUEs and D2Ds and modifies D2D allocations if they cause outages for CUEs. With a low outage probability, total cell capacity was maximized. However, the work lacked a shadowing effect and power control.

Ibrahim.R. (2017) created a collision reduction algorithm for estimating local Channel State Information (CSI), in which the base station requires some signalling exchange to obtain this information. Based on D2D users' knowledge of the local CSI, energy efficient scheduling framework was provided that demonstrates how a distributed approach outperforms a centralized one.

Amila et al. (2015) investigated how to use device-to-device (D2D) communication to improve the performance of a converged network made up of an LTE-Advanced (LTE-A) cellular network and IEEE 802.11n wireless local area

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networks (WLANs). As three major technical challenges complicating resource allocation, the author cited allocation of resources capturing diverse radio access technologies of the networks, selection of users' communication modes for multiple networks to maximize hop and reuse gains, and interference management. To address these issues, the author proposed a semi-distributed scheme for mode selection, WLAN resource allocation, and LTE-A network resource allocation across three-time scales.

Ramona.T. et al. (2012) provided a thorough survey of current research on game theory approaches to network selection solutions. These theories have been classified, compared, and analyzed, but the issue of computational complexity remains a challenge.

III. 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 section, 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.

3.1 System Model and Problem Formulation

We consider a multi-cell system in which the neighbouring base stations communicate with mobile terminals over a coverage area. Figure 6 shows the two-cell system model used to describe multi-cell D2D communications underlying cellular networks as the basic concept. There are N sub channels 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.

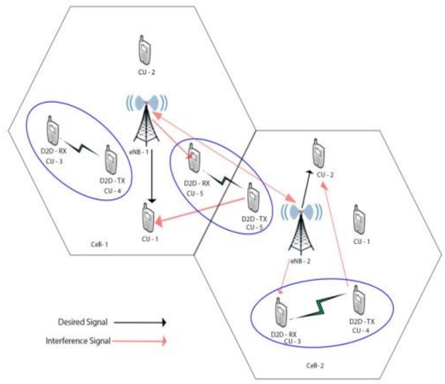

Figure 6: System Model of D2D Communication

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:

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

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)

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

P_r = Received signal power
N_o = thermal noise power spectral density

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

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:

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

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 d[th] D2D Rx (UE_3) is given by:

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

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

$$y_c^d = \begin{cases} 1, & if D2D pairs d reuses RB with CUE \\ 0, & otherwise \end{cases}$$

Maximum achievable rate of CUE (M_c)

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

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

Similarly, Maximum achievable rate at the D2D Rx (M_d)

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

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

The sum rate of CUE and D2D UE is expressed as

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

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).

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

Subject to:

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

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

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

And

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

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 (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. Similarly, in uplink scenario equation (15) & (16) has to keep G_{24} and G_{3B} at minimal value for an improved system throughput.

3.2 Algorithm: Downlink D2D Resource Block Allocation Scheme

1. *C*: Present list of CQIs for all DL UEs in decreasing order
2. *D*: set of D2D pairs in the network
3. G_{42}: Channel gain between CU c and CU d
4. G_{43}: Channel gain between D2D pair d
5. G_{B2}: Channel gain between Bs and CU c
6. G_{B3}: Channel gain between Bs and D2D pair d
7. Pc: Transmit power of CU c
8. Pd: Transmit power of D2D transmitter d
9. Pb: Transmit power of Bs
10. R_c: Number of resource blocks allocated to CU c

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```
Start
c ← 1
while D ≠ ∅ or c = = C do
initialize target SINRs of CUE c and D2D pair
γ^DL_c,thresh ← G_t
If (c^th value = c_max), select c else Return
Find the D2D user d with minimum channel gain;
γ^DL_c,tgt ← P_B G_B1 / (N_o + Σ_d y_c^d P_d G_41);
γ^DL_d,tgt ← Σ_c y_c^d P_d G_43 / (N_o + Σ_c y_c^d P_B G_B3);
if γ^DL_c ≥ γ^DL_c,tgt and γ^DL_d ≥ γ^DL_d,tgt then
Allot all RBs of the UE c with D2D pair d;
D = D - {d};
else
if γ^DL_c ≥ γ^DL_c,thresh 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
```

IV. RESULTS AND SIMULATION

4.1 Simulation Test bed

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 3. Three (3) neighboring 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 Fig.7. The performance of the developed system was validated using an already existing design by Celik et al (2017).

Table 3: 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

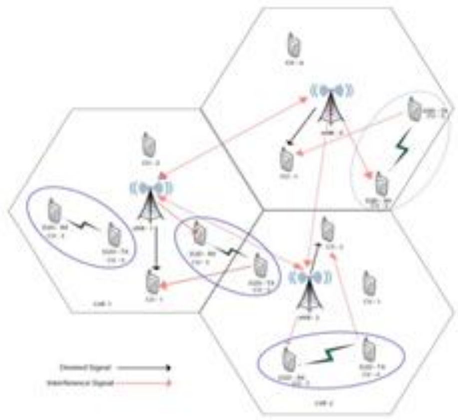

Figure 7: Screenshot of the Simulation Scenario

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. Fig. 8 to fig. 10 depicts the access rate and D2D throughput gain at various minimum SINR levels.

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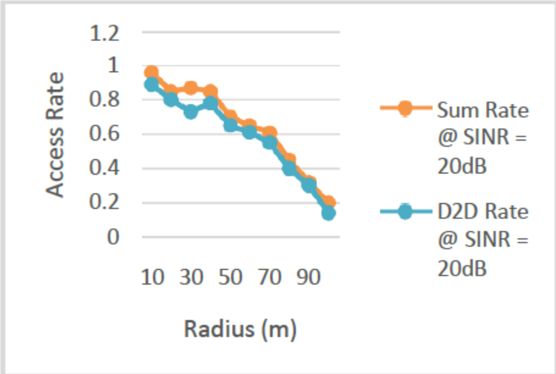

Figure 8: Access rate of system when the minimum SINR was 20dB with CUEs = 25 and DUEs = 15

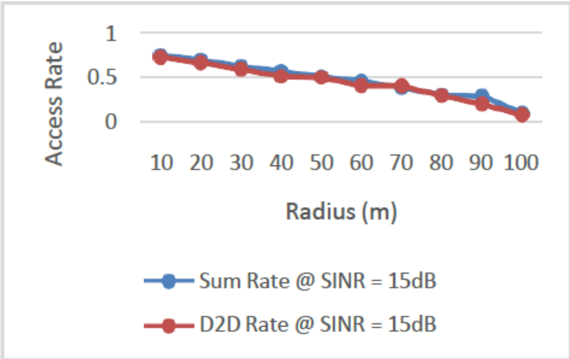

Figure 9: Access rate of system when the minimum SINR was 15dB with CUEs = 25 and DUEs = 15

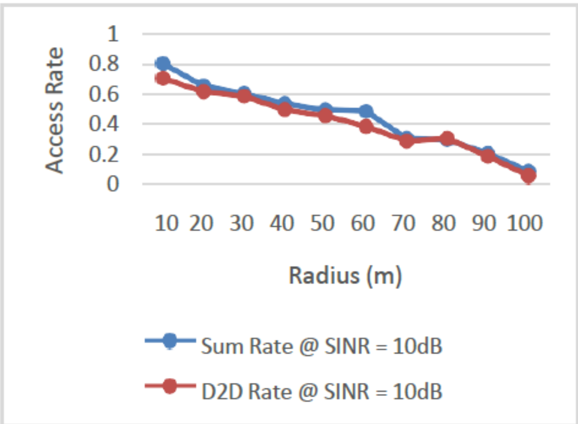

Figure 10: Access rate of system when the minimum SINR was 10dB with CUEs = 25 and DUEs = 15

The results obtained from figures 8 to 10 showed that as the SINR requirement increased, the system's access rate increased. In addition, when the SINR requirement was reduced, the system's access rate decreased. The effect on D2D throughput gain is shown in figures 11 to 13.

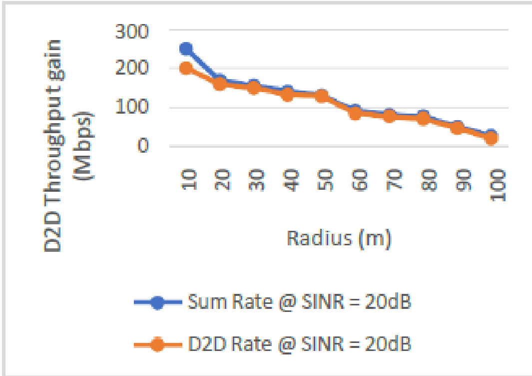

Figure 11: D2D Throughput gain of the system when the minimum SINR was 20dB with CUEs = 25 and DUEs = 15

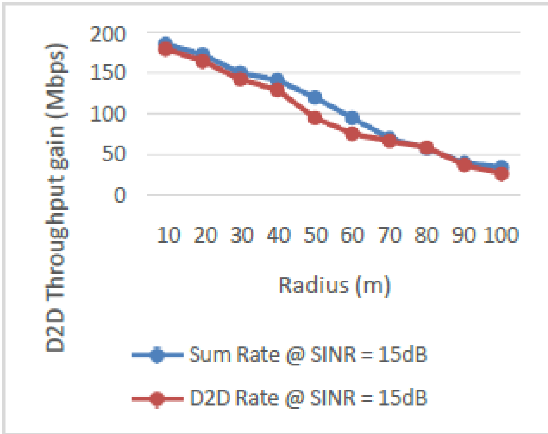

Figure 12: D2D Throughput gain of the system when the minimum SINR was 15dB with CUEs = 25 and DUEs = 15

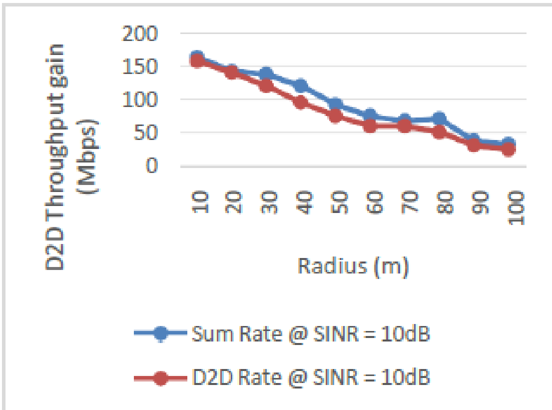

Figure 13: D2D Throughput gain of the system when the minimum SINR was 10dB with CUEs = 25 and DUEs = 15

Figures 11 through 13 also show that as the SINR requirement increased, the system's D2D throughput increased. Furthermore, as the SINR requirement was reduced, the D2D throughput of the system decreased. It should be noted that the increment in SINR requirements increased the maximum allowable interference for CUEs. This action allowed more DUEs into the system, resulting in a higher D2D throughput gain.

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V. CONCLUSION

5.1 Conclusion

There are many challenges that should be tackled in order to successfully execute D2D communication technology. Specifically, D2D communications require complex resource management techniques, efficient device discovery mechanisms, intelligent mode selection algorithms, robust security protocols, and mobility management procedures. There have been many research studies in D2D communications that aimed to improve spectral efficiency and interference management. Nevertheless, extensive reviews of comprehensive studies that examine various aspects of D2D communications, including the requirements and challenges, are largely missing. This work focuses on interference management, which stands out as a critical and complex issue that must be addressed. 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.

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. Three (3) neighboring 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. The performance of the developed system was validated using an already existing design by Celik et al (2017). From the results obtained, it was observed that as the SINR requirement increased, the access rate of the system was reduced. Also, when the SINR requirement was reduced, the access rate of the system increased. This is because when the SINR requirements for users were reduced, it led to an increase in the maximum allowable interference for CUEs.

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