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BEYOND FIFTH GENERATION (5G) NETWORKS AND BETTER PERFORMANCE EXPECTATIONS FOR CELLULAR WIRELESS NETWORKS

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ABSTRACT

Cellular wireless networks have greater speed, capacity and lower latency, as a result after the launch of 5G networks. device – to – device (D2D) communication technology and femtocell Networks have been introduced into cellular networks to form a three-layer heterogeneous network (HetNet). We are now working on creating networks that ensure the aggregation femtocell and D2D networks into heterogeneous networks. It has received significant attention due to the knowledge that it has the potential to increase the capacity of next generation networks as well as improve the spectral performance and energy efficiency of these networks. Utilization of cellular channels and improved network throughput are benefits that come as a result of the connection between the use of femtocells and D2D. This component is tasked with optimizing the network performance of CUE, DUE, and FUE, while also complying with the constraints imposed by quality of service (QoS) standards. This document presents a comprehensive solution to address the above problem, with a special focus on improving the overall data transfer rate of the cellular network system. The proposed approach includes several algorithms, including joint channel selection, energy regulation, and resource allocation. Together, these measures aim to improve the network's performance and improve its data transfer capabilities. Simulation results show that the proposed algorithm has the potential to minimize computational complexity while improving system throughput when compared to existing systems.

KEYWORDS: Cellular User Equipment (CUE), Device User Equipment (DUES), Femtocell User Equipment (FUE), Device-to-Device (D2D); resource allocation; spatial spectrum reuse; LTE-Advanced; ; Macro Base Station (MBS); Femto Base Station (FBS)

ما بعد شبكات الجيل الخامس (G5) وتوقعات أداء أفضل للشبكات اللاسلكية الخلوية

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الملخص

تتمتع الشبكات اللاسلكية الخلوية بسرعة وقدرة أكبر وزمن وصول أقل، ونتيجة لذلك بعد إطلاق شبكات الجيل الخامس. تم إدخال تكنولوجيا التواصل من جهاز إلى جهاز (D2D) والخلايا الصغيرة شبكات femtocell في الشبكات الخلوية لتشكيل ثلاث طبقات من الشبكة غير المتجانسة (HetNet). نعمل الآن على إنشاء شبكات تضمن تجميع شبكات femtocell وD2D في شبكات غير متجانسة. وقد حظيت باهتمام كبير نتيجة معرفة أن لديها القدرة على زيادة قدرة شبكات الجيل التالي بالإضافة

إلى تحسين الأداء الطيفي وكفاءة استخدام الطاقة لهذه الشبكات. يعد استخدام القنوات الخلوية وتحسين إنتاجية الشبكة من المزايا التي تأتي نتيجة للاتصال بين استخدام femtocells وD2D. تم تكليف هذا المكون بتحسين أداء الشبكة لمعدات المستخدم الخلوية (CUE)، ومعدات مستخدم الأجهزة (DUE)، ومعدات مستخدم (FUE) femtocell مع الامتثال أيضًا للقيود التي تفرضها معايير جودة الخدمة (جودة الخدمة). تقدم هذه الوثيقة حلاً شاملاً لمعالجة المشكلة المذكورة أعلاه، مع التركيز بشكل خاص على تحسين معدل نقل البيانات الإجمالي لنظام الشبكة الخلوية. ويتضمن النهج المقترح عدة خوارزميات ، بما في ذلك اختيار القنوات المشتركة، وتنظيم الطاقة، وتخصيص الموارد. وتهدف هذه الإجراءات مجتمعة إلى تحسين أداء الشبكة وتحسين قدراتها على نقل البيانات. تشير نتائج المحاكاة إلى أن التكنولوجيا المقترحة لديها القدرة على تقليل التعقيد الحسابي وتحسين إنتاجية النظام مقارنة بالأنظمة الحالية.

الكلمات الرئيسية: معدات المستخدم الخلوية (CUE)، معدات مستخدم الجهاز (DUES)، معدات مستخدم femtocell (FUE)، جهاز إلى جهاز(D2D) ، تخصيص الموارد؛ استخدام الطيف المكاني، LTE-متقدم، محطة قاعدة ماكرو (MBS) ، محطة قاعدة الفيمتو (FBS).

1. INTRODUCTION

In a 5G network, D2D communication allows for direct connection between devices without the need for an intermediate node. This improves cell coverage and radio frequency reuse. D2D communication is a key component of 5G vehicle − to − everything (V2X) connectivity, a crucial technology for autonomous driving. However, D2D communication in a 4G network poses security challenges such as impersonation, eavesdropping, privacy probing, and free-riding attacks. As IoT technology advances with 5G networks in Massive Machine-Type Communications (mMTC) and Ultra – Reliable and Low Latency Communications (URLLC) applications, security challenges become more critical and difficult to address due to the limited resources of IoT devices [1-4].

With the rapid growth of mobile combination software and the proliferation of mobile communications applications, the demand for spectrum capacity in system networks develops, as does traditional $D2D$ communications. This allows mobile devices to be close enough for direct communication without passing through a BS controlled by the cellular system, and is an essential learning for future wireless communications networks. It has a significant impact on reducing base station load, enhancing system throughput, improving bandwidth performance, and minimizing transmission delay. Furthermore, due to D2D communication's spatial limitations and channel link quality , sharing spectrum resources with cellular users can significantly improve D2D communication quality , minimize interference , and increase network throughput [5-7].

Cellular network design faces a number of challenges, including insufficient coverage for clients within the network's range, ineffective resource optimization, and low data rates. These issues would render the cellular network unable to meet the demands of mobile phone customers. Home base stations, or femtocells, are an efficient solution for interior coverage concerns because it allows mobile phone users to connect to the cellular network using femtocells. Moreover, as more mobile phone customers use femtocells, the spectrum efficiency improves. The connection between femtocells and the core network of mobile cellular users helps the cell enable lower power consumption, higher data rates, and less cross-talk to mobile consumers [8].

femtocells are home base stations designed to boost cellular network capacity by linking cellular users who live distant from MBS to the network's nearest FBS [9]. As a result, users of femtocells will see faster data rates and improved indoor coverage. However, because resources must be provided to both macro and femto users, femtocell integration into the macrocell network will alter the fundamentals of the cellular network configuration. Furthermore, in femto-macrocell designs, the two-tier network—the macro layer and the femto layer—causes significant interference since so many nodes operate in the same frequency band. In HetNets, resource allocation for D2D communications was investigated in [10–16].

Interference management for $D2D$ communications in HetNet was first proposed in [10] where the technique of adjusting the process of managing interference in the D2D communication channel while still meeting QoS standards is presented. To improve system throughput, [11] present an algorithm for heuristic resource allocation for HetNets, which consist of both D2D connections, macrocells, and microcells. [12] have proposed cooperative mode selection and power control in HetNets cellular networks with D2D enabled.

To ascertain each effective cellular user's interference-limited area, the authors conducted research [15] simulates femtocells as selfish nodes using a non-cooperative game and the Stackelberg game, where the MBS prices subchannels to defend itself. By using the same frequency, users of macrocells and femtocells should experience less disruption, according to the scientists.

To ascertain the strategic methods used for transmission by $D2D$ users and cellular users, who are followers who must access a private channel, cellular users who act as leaders own the channel. [17] propose models and algorithms for resource allocation in $D2D$ communications. In this study, we will examine how to use efficient resource allocation technology for $D2D$ communications and $femtocells$ and their presence in heterogeneous networks through cellular networks. Recommending the use of $D2D$ communications and $femtocells$ as they both hold promise for increasing the capacity of cellular infrastructure. We propose to create an $algorithm$ for efficient resource allocation so that $D2D$ connections and femtocells that underpin the networks are shared to achieve better use of cellular spectrum by reducing interference. Therefore, we recommend instituting incentives to motivate $D2D$ communications and femtocells to cooperate, along with a scenario in which $D2D$ communications and femtocells live side by side with heterogeneous networks ($HetNets$) to increase the overall cellular network throughput. This study describes a solution to the optimization problem while trying to maximize the total network throughput while maintaining the quality of service (QoS) required by $CUEs$, $DUEs$, and $FUEs$. We looked at both $D2D$ communications and the femtocell layer that aggregates uplink resources in the cellular network.

We propose a combination channel allocation, power control, and resource allocation technique for the D2D communications underlay in HetNets because the problem is non-convex mixed integer programming and difficult to solve directly. This is how the rest of the paper is structured. The related work are covered in section two. The system concept and problem formulation for a D2D underlay in HetNets are covered in Section three. The analysis of the suggested solution is done in Section three. Simulation results and comments are included in Section four. Section five Conclusion the article.

2. Related Work

In [19] of cellular networks researchers found that D2D communication through LTE-Advanced network improved network performance and reduced traffic pressure on BS. D2D communications enable spectral efficiency to be significantly improved by sharing radio resources with cellular user equipment (CUEs). However, the resulting mutual interference may overwhelm the benefit provided by D2D communications. The researchers in this study, in order to avoid interference, use a well-designed resource allocation strategy. The uplink resource allocation problem allows multiple D2D pairs to share a resource with a single CUE while satisfying the SINR requirement for both CUEs and admissible D2D pairs. An algorithm called Greedy Resource Allocation (GRA) is designed to optimize the number of D2D pairs allowed by carefully selecting a set of D2D pairs for each CUE. The simulation results show the effectiveness of the proposed approach.

In [20], D2D communications enabled the system to increase the spectrum efficiency of the mobile phone network system; But D2D resource allocation methods may not work effectively in this period with 5G mobile networks with many devices connected simultaneously. To overcome this problem, the researcher investigated the problem of allocating multiple resources for sharing, and from here he was able to enable any user's cellular device to share its radio resources with many D2D devices. The researcher formulates the multi-share resource allocation problem and shows its $\mathrm{NP}-\mathrm{hardness}$. Moreover, he created the Greedy Throughput Maximization Plus (GTM+) algorithm which reveals $\mathrm{GTM}+$ simulation results are better than existing algorithms in terms of throughput and allowed D2D pairs.

In [21] the researcher advances the study of D2D communication and small cell search techniques in heterogeneous cellular networks, leading to the creation of three-layer networks of heterogeneous networks (HetNet). Through this network, the researcher analyzed this problem by allocating resources to D2D users and small cell phone users (SCUEs), and he proposed a resource allocation technique that meets the call quality requirements of total cell phone users, D2D users, and small cell phone users. . To start, regional restrictions have been implemented for aggregate base stations and users to reduce computing complexity. After that, he proposed a mechanism for allocating resources that relies on interference management to enhance system productivity. The simulation results show that the proposed strategy reduced the computational complexity while increasing the overall throughput of the system.

3. System Model

Within the scope of this research, we investigate the upper layer (UL) of a multilevel SC-FDMA-based HetNet network. In this scenario, we are going to assume that a single large-cell wireless network is composed of many femtocell cells. As can be seen in figure (1), femtocell cells as well as a D2D are dispersed across the HetNet. Assume that there is a set of N cellular users CUE, a set of M pairings D2D DUE, and a set of K femtocells, each of which is supplied by the equations $C = \{i = 1,2, \ldots., n\}$, $D = \{j = 1,2,, \ldots.., m\}$ and $F = \{f = 1,2,,.., k\}$ respectively. C stands for the number of cellular users, while D stands for the number of pairings. When certain pairs of D2D and femtocell cells correspond to the uplink with the base station as described above. The shared channel contains a significant quantity of redundant information, and it is very uncommon for many DUEs or FBS to make use of the same channel. To prevent interference between CUEs operating on the same frequency inside the same cell, a method known as orthogonal frequency division multiple access (OFDMA) is utilized. It is possible to acquire channel status information (CSI) for each connection that is made to the base station.

Keeping in mind that there is also quick fading and slow fading owing to channel shading between two users because of multipath propagation, this is something to keep in mind. The profits of the linkages are denoted by the symbols $h_{j,B}$, $h_{I,j}$ and $h_{j,k}$ respectively. On the same channel, there are $h_{j,B}$ gain link lines that connect the CUE_I transmitter to the eNBB, $h_{I,j}$ link gain link lines that connect the CUE_i to the $D2D_j$ pair receiver, and $h_{j,k}$ link gain link lines that connect the DUE_j transmitter to the FUE_k. And there is a signal-to-noise loss ratio (SINR) for users on the channel who are CUE_i (ξ_i^c), $DUE_j\left(\xi_j^d\right)$ and FUE_k (ξ_k^f) which is supplied by:

$$\xi_i^c = \frac{P_i^c\, g_{i,B}}{\sum_{j\in D} \text{Я}_{i,j} P_j^d\, h_{j,B} + \sum_{k\in F} \text{Я}_{i,k} P_k^f\, h_{k,B} + \sigma_N^2} \qquad \text{Eq. (1)}$$

Subject to $\xi_i^c \geq \xi_{i,min}^c$

$$\xi_j^d = \frac{P_j^d g_{j,j}}{\sum_{m\in D} P_m^d h_{m.j} + \sum_{i\in c} \text{Я}_{i,j} P_i^c\, h_{i,j} + \sum_{k\in F} \text{Я}_{k,j} P_k^f h_{k,j} + \sigma_N^2} \qquad \text{Eq (2)}$$

$$\xi_k^f = \frac{P_k^f g_{k,F}}{\sum_{z\in F} P_z^f h_{z,F} + \sum_{i\in c} \text{Я}_{i,k} P_i^c\, h_{i,F} + \sum_{i\in D} \text{Я}_{j,k} P_j^d\, h_{j,F} + \sigma_N^2} \qquad \text{Eq. (3)}$$

There is a transmission power that is denoted by the letters P_i^c, P_j^d and P_k^f. These letters reflect the transfer power of CUE_i. , DUE_j and DUE_k in that order. The symbol $g_{i,B}$ denotes the channel power gain from the cellular user equipment (CUE)denoted as CUE_i to BS. Similarly, the symbol $g_{j,j}$ represents the channel power gain between the transmitter and receiver of the j D2D pair. Furthermore, the channel's power gain between the kth fixed user equipment (FUE) transmitter and the fixed base station (FBS) is represented by $g_{k,F}$. Lastly, σ_N^2 represents the power of the additive Gaussian white noise (AWGN).

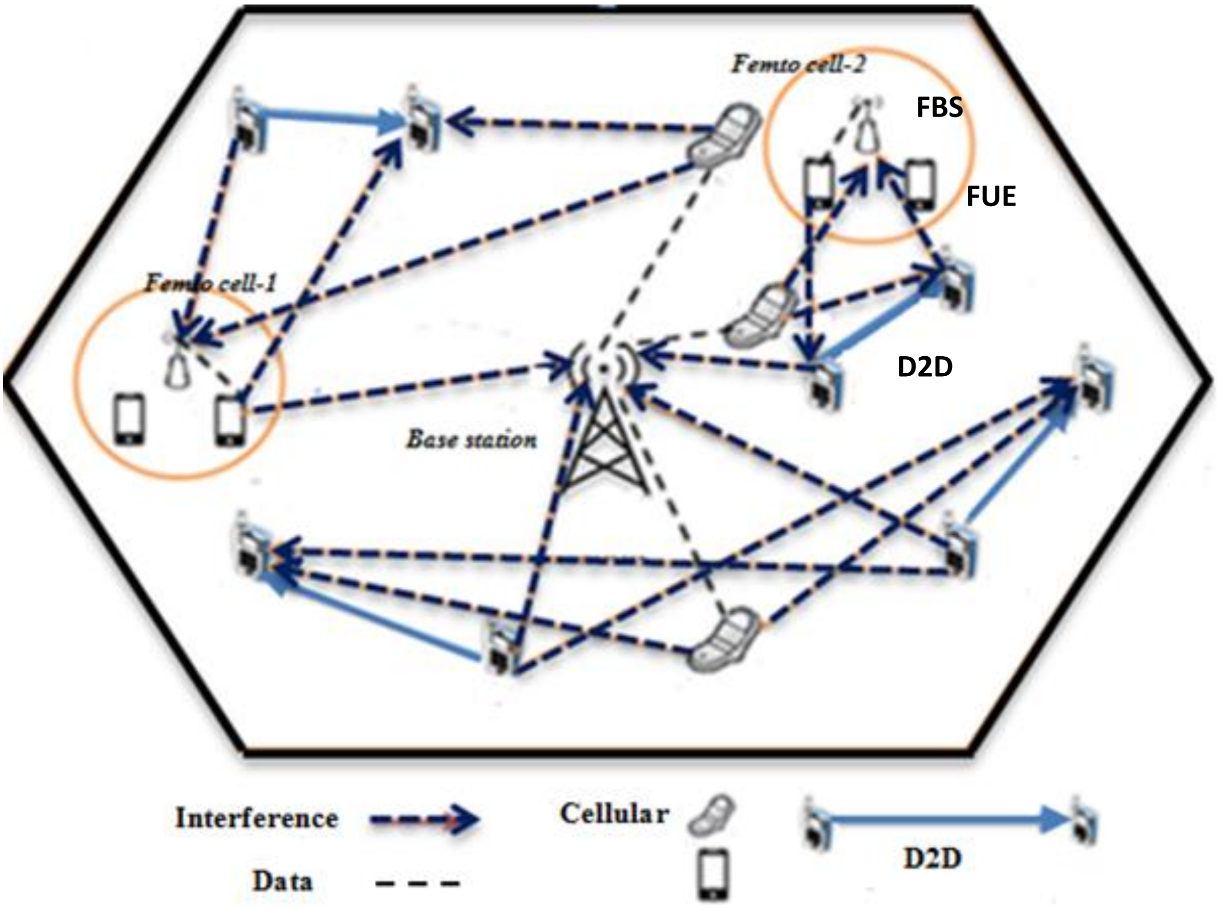


Fig.1: System ModelofD2DCommunicationsinHetNets

3.1. Problem Formulation

If the same CUE channel is utilized, there is the potential for reciprocal interference between numerous DUEs and multiple FUEs. Because of this, one of our primary objectives is to increase the entire system throughput while simultaneously having the highest possible transmission capacity and the lowest possible SINR limitations. It is feasible for DUEs or FUEs to reuse the resources of about one sub channel, depending on the type of device they are. The objective function and constraints of this optimization problem may be represented as follows, in accordance with the formula proposed by Shannon:

$$\max_{Я_{i,j},Я_{i,j},Я_{i,j},P_i^c,P_j^d,P_k^f} R_{overall} = \sum\nolimits_{i\in c}[\log_2\left(1+\xi_i^c\right) + \sum\nolimits_{i\in c}\log_2\left(1+\xi_i^c\right) + \sum\nolimits_{i\in c}\log_2\left(1+\xi_i^f\right)] \qquad \text{Eq, (4)}$$

Subject to

$$\xi_i^c \geq \xi_{i,min}^c$$
$$\xi_i^c \geq \xi_{i,min}^c$$
$$\xi_i^c \geq \xi_{i,min}^c$$
$$\sum_i Я_{i,j} \leq 1,\; Я_{i,j}\,\epsilon\{0,1\}, \qquad \forall\, j\,\epsilon\, D$$
$$\sum_i Я_{i,k} \leq 1,\; Я_{i,k}\,\epsilon\{0,1\}, \qquad \forall\, k\,\epsilon\, F$$
$$0 \leq P_i^c \leq P_{max}^c\,\forall\, i\,\epsilon\, C$$
$$0 \leq P_j^d \leq P_{max}^c\,\forall\, j\,\epsilon\, D$$
$$0 \leq P_k^f \leq P_{max}^c\,\forall\, k\,\epsilon\, F$$

Wherever $Я_{\mathrm{i,j}}$ (or $Я_{\mathrm{i,k}}$) represents the channel reuse event for CUE_i and DUE_j, $Я_{\mathrm{i,j}} = 1$ (or $Я_{\mathrm{i,k}} = 1$) indicates that DUE_j reuses the CUE_i channel (or that the In the event that this is not the case, Wherever $Я_{\mathrm{i,j}} = Я_{\mathrm{i,k}} = 0$ will be the result The requirements for the level of service quality that are imposed by $SINR$ of all CUE_i, DUE_j and FUE_k are illustrated by the restrictions of the SINR is greater than the minimum SINR requirements of both DUE_j, respectively.

Both constraint $Я_{\mathrm{i,j}}$ and $Я_{\mathrm{i,k}}$constraint ensure that a DUEs or FUEs may only employ a single resource that is already available in the CUE. This is the case since both constraints are mutually exclusive. The limitations constraints $\mathrm{P_i^c}$, $\mathrm{P_j^d}$, and $\mathrm{P_k^f}$ respectively, ensure that the transmission powers of CUE_i, $\mathrm{DUE_j}$ and FUE_k are consistently maintained at levels that are substantially below the maximum limits.

3.2. Proposed Solution

Consequently, the co-optimization issue in Equation (4) This difficult NP combinatorial problem, which is part of the class of problems known as convex optimization problems Mixed-integer nonlinear programming ($MINLP$), is unsolvable. As the problem gets bigger, the computations required to answer it will get harder and harder. Choosing the right channel and managing the power and resource distribution techniques are the first two steps in addressing this problem, which can be divided into two phases to achieve a compromise between complexity and usability. Subheadings that go into greater detail are found below.

As a result, the problem of co-optimization found in Equation (4) This is a challenging NP combinatorial problem that does not have any viable solutions and belongs to the class of issues known as convex optimization problems mixed-integer nonlinear programming (MINLP). The difficulty of the computations necessary to solve the problem will increase exponentially as its size grows. It is possible to tackle this issue by breaking it down into two steps, the first of which involves selecting the channel, and the second of which involves controlling the power and resource distribution mechanisms in order to strike a healthy balance between ease of use and level of complexity. The following subsections feature topics that are more in depth.

3.3. Channels Selection

The CUE_i subchannel is allocated to increase the overall uplink throughput of the network and this is the main goal, we choose a sub-channel that provides CUE_i, DUE_j, and FUE_k the largest possible data rate of the system [22]. This sub channel is comprised of CUE_i, DUE_j and FUE_k. A greater signal-to-interference ratio is needed to improve the efficiency of cellular and D2D users. Allow $\mathrm{x}_\mathrm{j}^\mathrm{i}$, $\mathrm{y}_\mathrm{k}^\mathrm{i}$ to determine the permutations and variations of the joint channel gain element for DUE_j and FUE_k on the i^{th} channel [18, 23, 24]. These combinations are correspondingly stated as follows:

$$\mathrm{x}_\mathrm{j}^\mathrm{i} = \frac{h_{i,B} * h_{j,j}}{h_{i,j} * h_{j,B}} \quad \forall\ i\ \in \mathrm{C}\ \&\ \forall\ j\ \in \mathrm{D} \qquad \text{Eq. (5)}$$

$$\mathrm{y}_\mathrm{k}^\mathrm{i} = \frac{h_{i,B} * h_{k.F}}{h_{i,F} * h_{k,B}} \quad \forall\, i\ \in \mathrm{C}\ \&\ \forall\ k\ \in \mathrm{F} \qquad \text{Eq. (6)}$$

The upper limit of interference for a CUE_i at BS can be calculated by taking into account the fixed SINR constraint, the known channel $\mathrm{g}_{\mathrm{i,B}}$ and the permissible transmit powers $\mathrm{P}_\mathrm{j}^\mathrm{d}$. Because of the set SINR limitation, and in conjunction with the known channel $\mathrm{g}_{\mathrm{i,B}}$, and abilities of forgiveness in transmission $\mathrm{P}_\mathrm{j}^\mathrm{d}$, the interference threshold that can be reached for a CUE_i at BS B may also be interpreted as:

$$I_{\mathrm{max,B}}^{(\mathrm{i})} = \frac{\mathrm{p}_\mathrm{i}^\mathrm{c} \mathrm{g}_{\mathrm{i,B}}}{\xi_{\mathrm{i,min}}^\mathrm{c}} - \sigma_\mathrm{N}^2 \qquad \text{Eq. (7)}$$

Fig.2.b. Illustration of the useful path loss links represented by the nbroken line (g1 and g2) and the broken line represent interference path loss links (g3 and g4) in a cell that form the inputs of the heuristic MS algorithm under study.

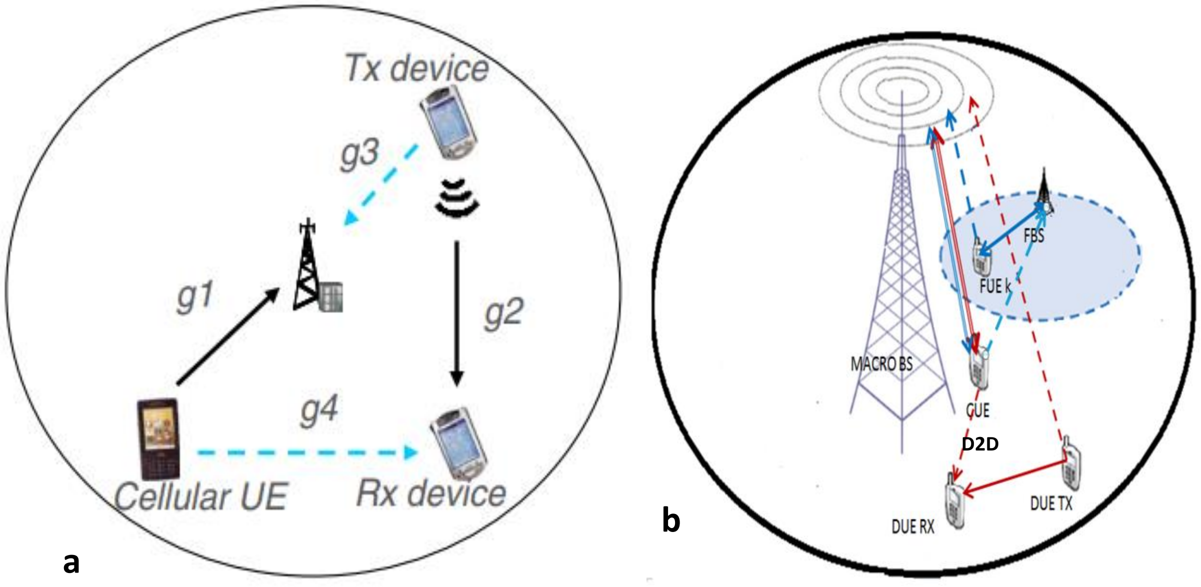


Fig.2.a. System Model for the Distributed CSI-based Mode Selection [22]

3.4. Optimal Power Allocation

The channel selection technique for specified DUE transmission powers, which was discussed previously. A power control strategy is required in order to meet the minimal SINR limits imposed on CUEs and DUEs, as well as to allow for the bundling of additional D2D pairs inside each subchannel. The best distribution of power would look something like this:

$$P_j^{d*} = \min\left[P_{max}^d , \frac{\xi_{j,min}^d}{\xi_j^d} * P_j^d\right] \qquad \text{Eq. (8)}$$

As can be seen in equation (8), the power of the D2D transmission is capped by P_{max}^d, CUEs, on the other hand, transmit at a constant power level without taking part in power control..

3.5. Joint Resource and Power Allocation

The proposed solution is executed using a two-phase algorithm. The algorithm's initial phase identifies a probable set of channels that each DUE and FUE can reuse. In the suggested algorithm's integrated power control and resource allocation phase, we offered a method for assigning and allocating power resources to each DUE on each channel. We maximize the resource coupling relationship between CUEs, DUEs, and FUEs by assuming all constraints are satisfied. The first phase of the algorithm covers the procedure for selecting candidate channels. A proposed approach is used to choose a candidate set of CUE channels that both DUE and FUE can use initially. This can be accomplished by generating a candidate set of CUE channels.

In the first stage of the proposed algorithm, the interference from the DUE units to the BS $I_{j,B}^{(i)}$ is evaluated, and the interference from the FUE units to BS $I_{k,B}^{(i)}$ where the maximum interference limits for each digital channel are at BS $I_{max,B}^{(i)}$ and the interference from DUE units j^{th} with FUE units k^{th} in case they share the same channel number $h_{j,k}^{(i)}$. An algorithm is utilized to choose the candidate set of CUEs that both DUE and FUE can employ. The algorithm needs interference assessments from DUEs to BS $I_{j,B}^{(i)}$, interference values from FUEs to the BS $I_{j,B}^{(i)}$, and interference thresholds for each channel with the BS $\mathrm{I}_{\mathrm{max,B}}^{(\mathrm{i})}$, and interference between DUE_j and FUE_k using the same channel i^{th} for both devices is $\mathrm{h}_{\mathrm{j,k}}^{(\mathrm{i})}$.

first phase algorithm channel selection

```
input: $C$; the set of active CUEs,
       $D$; the set of DUEs, and
       $F$; the set of FBSs
Output $\xi_{j,k}^{i}$, $\mathcal{D}_r^{(i)}$, $\mathcal{F}_r^{(i)}$ from first phase andinput to second phase
1:  Initialization: $\begin{cases} \xi_{j,k}^{i} = \emptyset,\ \mathcal{D}_r^{(i)} = \emptyset,\ \mathcal{F}_r^{(i)} = \emptyset \quad \forall_i \in C \\ \mathrm{I}_{max,B}^{(i)} \end{cases}$
2:  for all $i \in C$ do
3:    for all $j \in D$ do & $k \in F$
4:      calculate $\{x_j^i\}$ from eq. 5
5:      calculate $\{y_k^i\}$ from eq. 6
6:      while $x \neq \emptyset$ & $y \neq \emptyset$ do
7:        select $j^{th}$ DUE that the highest $x_j^i$ in $x$
8:        select $k^{th}$ FBS that the highest $y_k^i$ in $y$
9:        If $(\sum_{j \in D} \gamma_{j,B}^{(i)} \leq \gamma_{max,B}^{(i)}$ then $\mathcal{D}_r^{(i)} \leftarrow j$
          //$\gamma_{max,B}^{(i)}$ max interference threshold that can be reached for $CUE_i$ at BS//
          // where $\gamma_{j,B}^{(i)}$ interference gain from $DUE_j$ on channel i to BS B
10:       end if
11:       If $(\sum_{k \in D} \gamma_{j,B}^{(i)} \leq I_{max,B}^{(i)}$ then $\mathcal{F}_r^{(i)} \leftarrow k$
          //where $\gamma_{k,B}^{(i)}$ interference gain from $FUE_k$ on channel i to BS//
12:       end if
13:         $x \leftarrow x \setminus x_j^i$,  // remove the $x_j^i$ from the vector x //
14:       $y \leftarrow y \setminus y_k^i$,  // remove the $y_j^i$ from the vector y //
15:     end while
16:   end for
17: for $j \in \mathcal{D}_r^{(i)}$ & $k \in \mathcal{F}_r^{(i)}$ do
18:     calculate $h_{j,k}^{(i)}$ by using
19:     if $\left(h_{j,k}^{(i)} < h_{th}^{(i)}\right)$ then set $\xi_{j,k}^{i} = \xi_{j,k}^{i} \cup i$
20:       else
21:         $\mathcal{D}_r^{(i)} \leftarrow \mathcal{D}_r^{(i)} \setminus j$, / remove $j^{th}$ DUE from the set $\mathcal{D}_r^{(i)}$/
22:         $\mathcal{F}_r^{(i)} \leftarrow \mathcal{F}_r^{(i)} \setminus k$, /remove $k^{th}$ FUE from the set $\mathcal{F}_r^{(i)}$/
23:         end if
24:     end for step 21
25: end for
```

Second phase : *Joint Resource and Power Allocation*

Input $\xi_{j,k}^{i}$, $\mathcal{D}_r^{(i)}$, $\mathcal{F}_r^{(i)}$ *from first phase and input to second phase*

```
output $Я_{i,j}, Я_{i,k}, Я_{j,k}$
  constraints for show staisfying the users $CUE_i$ ($\xi_i^c$), $DUE_j$($\xi_j^d$) and $FUE_k$ ($\xi_k^f$)//
Initialization $\xi_{i,min}^c, \xi_{j,min}^d \& \xi_{k,min}^f$
  //(SINR) for users on the channel who are $CUE_i$ ($\xi_i^c$), $DUE_j$($\xi_j^d$) and $FUE_k$ ($\xi_k^f$)//
for $\forall DUE_j \in D$ do
    calculate $(P_j^{d*})$ using eq.(16)
end for
for $\forall CUE_i \in$ do
  for $\forall DUE_j \in \mathcal{D}_r^{(i)}$ and $\forall FUE_k \in \mathcal{F}_r^{(i)}$ do
  calculate $\xi_i^c, \xi_j^d \& \xi_k^f$ according to formula 1, 2 & 3
      if ( $\xi_i^c \geq \xi_{j,min}^c$)&( $\xi_j^d \geq \xi_{j,\min}^d$)then set $Я_{i,j=}1$
        else if ( $\xi_i^c \geq \xi_{i,min}^c$)&( $\xi_k^f \geq \xi_{k,\min}^f$)then set set $Я_{i,k=}1$
          else if ( $\xi_j^d \geq \xi_{j,min}^d$)&( $\xi_k^f \geq \xi_{k,\min}^f$)then set $Я_{j,k=} Я_{k,j=}1$
    end if
  end for
 end for
$\forall DUE_j$ has $Я_{i,j} = 1$, and $\forall FUE_k$ has $Я_{i,k} = 1$will reuse $i^{th}$ channel
```

4. Simulation Parameter & Results

Our simulation parameters are illustrated in Table1.

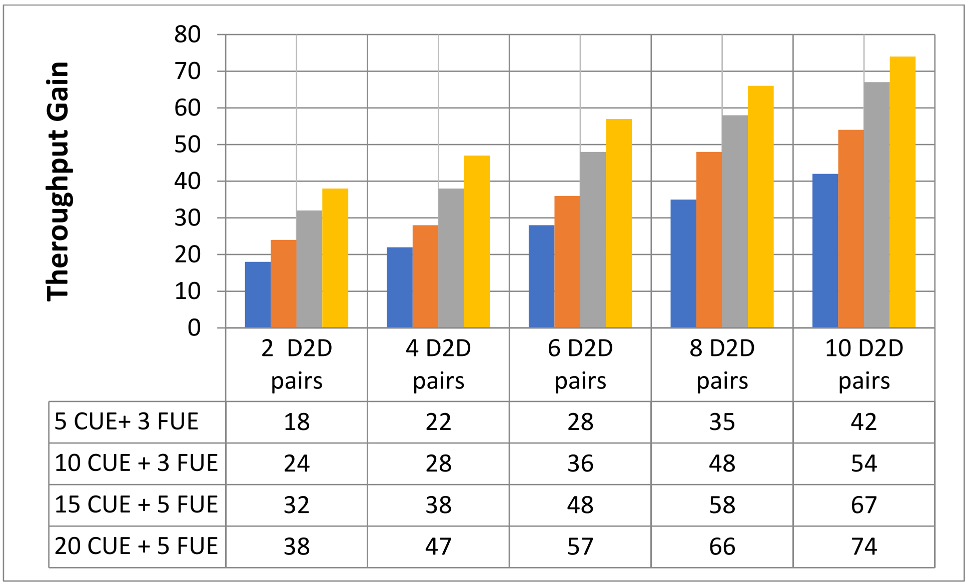
Table 1 Simulation Parameters

Parameter	***Value***
Bandwidth	5 *MHz*
Channel bandwidth	180 *kHz*
Macro cell radius	500 *m*
Femto cell radius	50 *m*
D2D cluster radius	20 − 120 *m*
Noise power	−114 *dBm*
Power of transmission max, for CUE	24 *dBm*
Power of transmission max. for DUE	24 *dBm*
Power of transmission max. for FUE	10 *dBm*
SINR req. for CUEs DUEs, FUEs	0 − 20 *dB*
Path Loss Exponent ρ	4
Simulation type	MATLAB

4.1. Simulation Results

Fig.3 shows the increase in the total number of $DUEs$ versus the increase of $CUEs$ and small cell $FUEs$ when the radius between $D2D$ cell pairs is about $60\ m$. The graph unambiguously shows that the performance of this proposed solution is better when the number of DUE pairs and

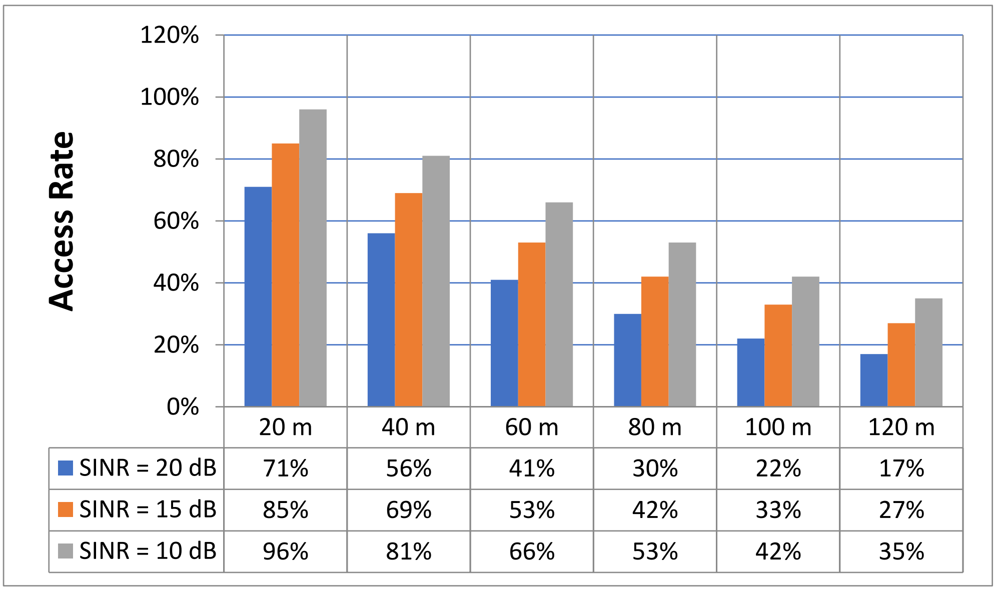
$CUEs$ is increased, because the result is increased system throughput. This is due to the extensive reuse of spectrum resources in our proposed technique.



	2 D2D pairs	4 D2D pairs	6 D2D pairs	8 D2D pairs	10 D2D pairs
5 CUE+ 3 FUE	18	22	28	35	42
10 CUE + 3 FUE	24	28	36	48	54
15 CUE + 5 FUE	32	38	48	58	67
20 CUE + 5 FUE	38	47	57	66	74

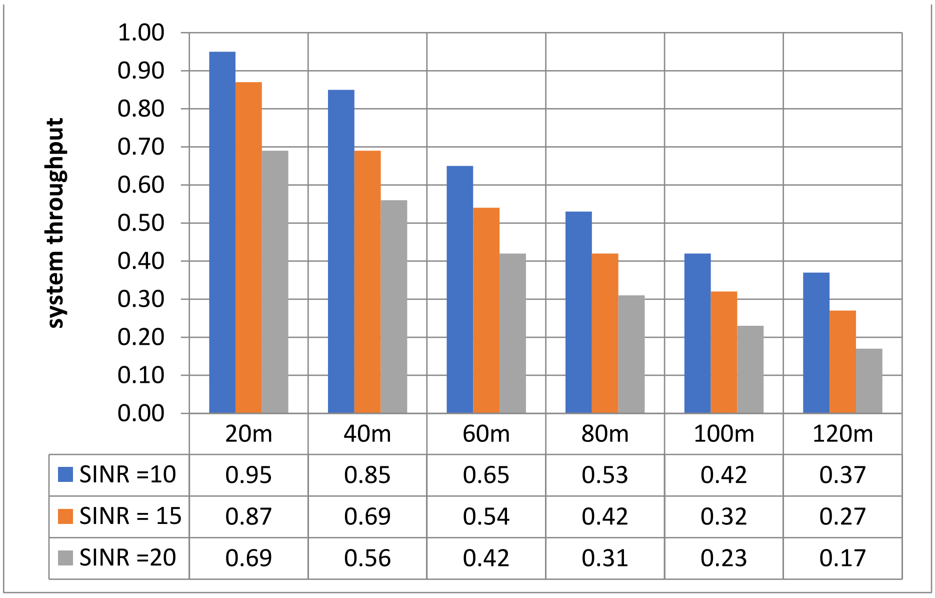
Fig. 3 depicts the relationship between system throughput and the number of D2D and number of CUEs

The performance of the proposed algorithm for CUEs and DUEs under different minimum SINR requirements is shown in Figs. 4 and 5, which leads to higher access rate and system throughput with lower SINR requirements. This is due to decreased SINR requirements for users, which increases the maximum permitted interference for CUEs. As a result, more DUEs and FUEs will be accepted and share channels with CUEs, increasing the access rate and D2D throughput.



	20 m	40 m	60 m	80 m	100 m	120 m
🟦 SINR = 20 dB	71%	56%	41%	30%	22%	17%
🟧 SINR = 15 dB	85%	69%	53%	42%	33%	27%
⬜ SINR = 10 dB	96%	81%	66%	53%	42%	35%

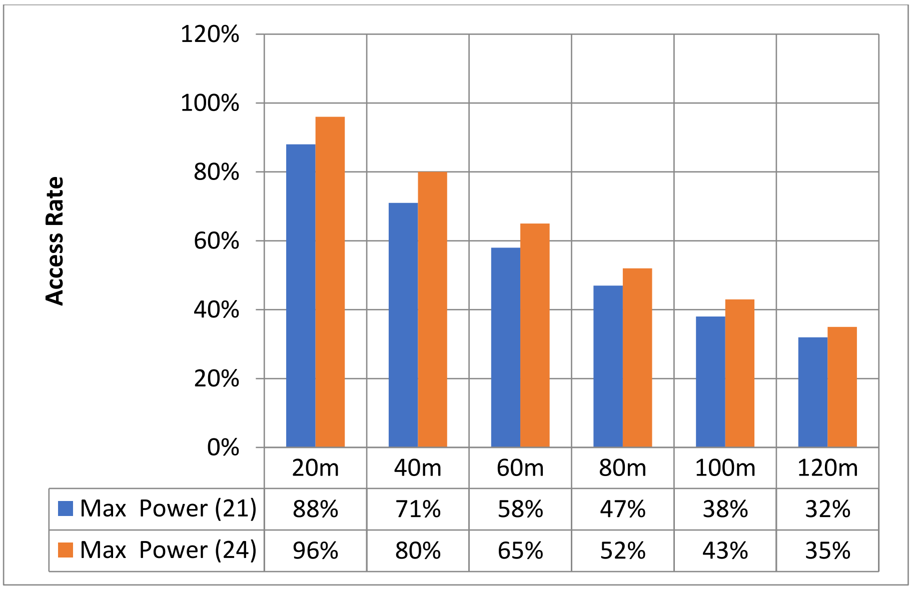
Fig. 4: Access rate in comparison to D2D radius whenever the SINR criteria are altered



	20m	40m	60m	80m	100m	120m
🟦 SINR =10	0.95	0.85	0.65	0.53	0.42	0.37
🟧 SINR = 15	0.87	0.69	0.54	0.42	0.32	0.27
⬜ SINR =20	0.69	0.56	0.42	0.31	0.23	0.17

Fig. 5: Changing the SINR parameters changes the relationship between the system throughput gain and the D2D radius

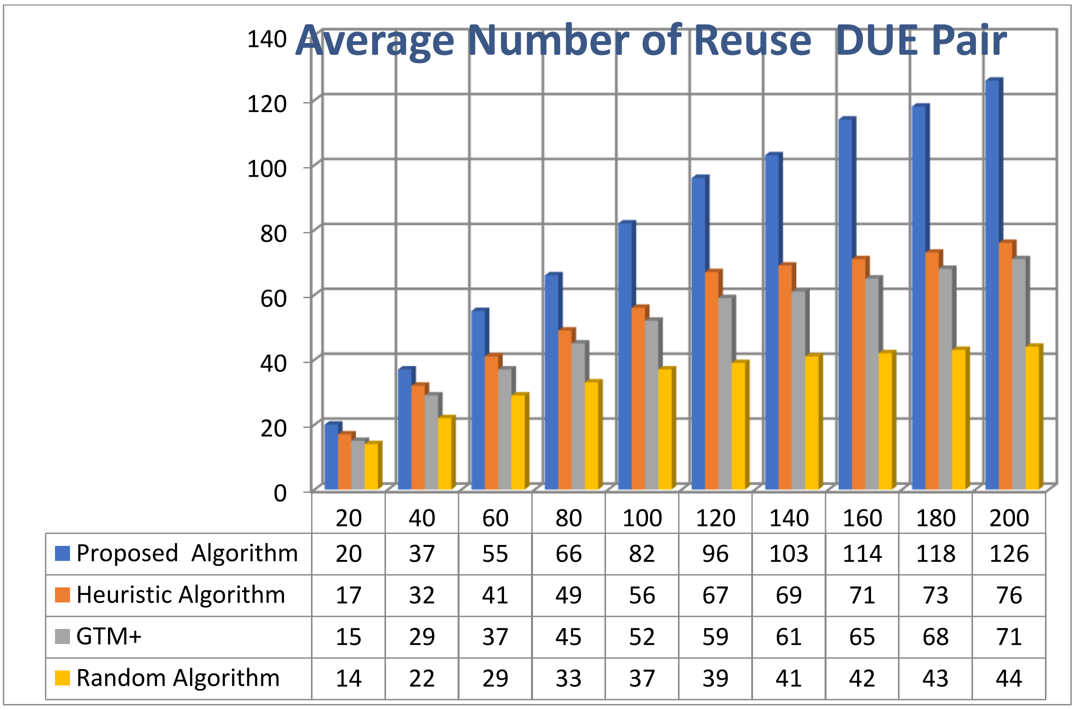
Fig. 6 depicts the system throughput increase for varied D2D group radius versus maximum transmit power. It has been noticed that as maximum transmit power falls, so does total throughput performance. In fact, as P_{max}^{c} & P_{max}^{d} increase, The system throughput gradually increases as the achievable rate of CUEs and DUEs increases, resulting in an overall improvement in system throughput, and if the distance between both $DUE - TX$ and $DUE - RX$ increases, the degradation becomes rapid until it reaches the maximum distance.



	20m	40m	60m	80m	100m	120m
🟦 Max Power (21)	88%	71%	58%	47%	38%	32%
🟧 Max Power (24)	96%	80%	65%	52%	43%	35%

Fig. 6 Access rate in comparison to $D2D$ radius whenever Max Power 21dBm and 24 dBm

The effectiveness of the proposed method was evaluated and then compared with the heuristic algorithm that was previously presented in [21], as well as the (GTM+) algorithm that was previously presented in [20], as well as the. random search method regarding the increase in the total amount of productivity produced by the system. This is the number of DUE pairs accepted for RB reuse. The distance between the transmitter and the DUE receiver is fixed at a specific value where $\mathrm{d}_{\mathrm{TR,RX}} = 30$ m for all DUE pairs. Related to this, DUEs and CUEs were randomly placed in the cell. The number of CUE/RB is set to 10 while the number of DUE pairs is initially set to 20 with an increment step of 20 DUE pairs up to 200 DUE pairs.



	20	40	60	80	100	120	140	160	180	200
🟦 Proposed Algorithm	20	37	55	66	82	96	103	114	118	126
🟧 Heuristic Algorithm	17	32	41	49	56	67	69	71	73	76
■ GTM+	15	29	37	45	52	59	61	65	68	71
🟨 Random Algorithm	14	22	29	33	37	39	41	42	43	44

Fig. 7 depicts the relationship between system throughput gain and D2D radius when the SINR =10 dB, 20 CUEs 20, 10 DUEs, and5 FBSs .

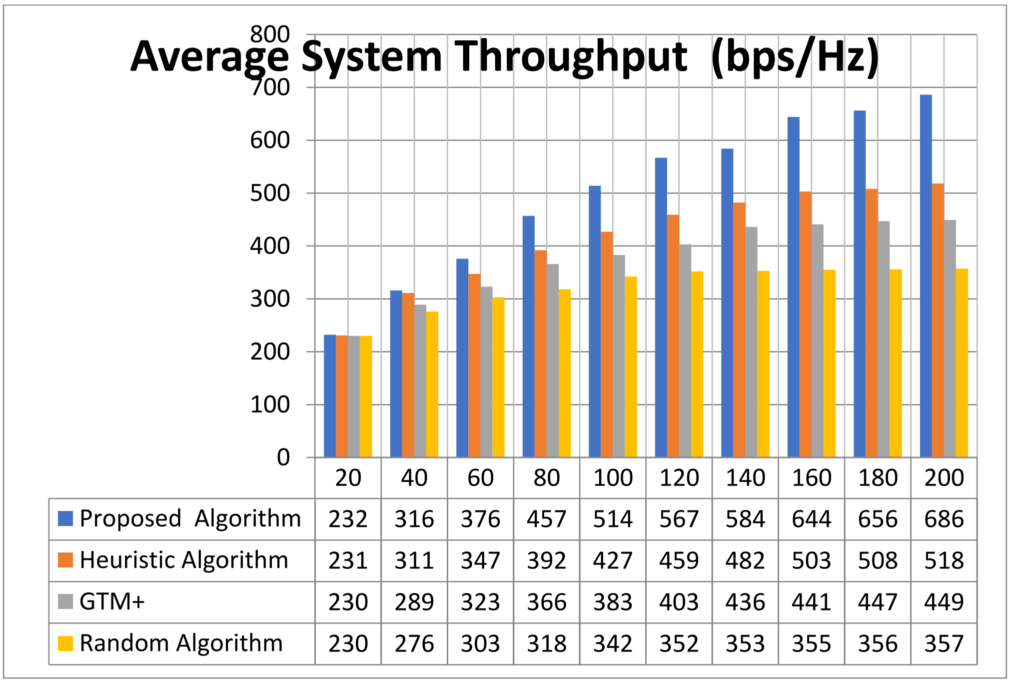
To ensure fairness, during this simulation phase, the transmission power of each DUE is set to 10 dBm for algorithms that do not require power regulation, such as Heuristic and GTM+ algorithms. The proposed technique, which includes power management, enables DUEs to send power ranging from $(0-23, \mathrm{Pmax} = 23\ \mathrm{dBm})$, with the actual transmit power regulated by power control. The SINR objectives for DUEs and CUEs were set to $\gamma_{\mathrm{d}}^{\mathrm{tgt}} = 12$ dB and $\gamma_{\mathrm{c}}^{\mathrm{tgt}} = 15$ dB. To demonstrate the true average performance, as in the previous simulation phase, this simulation was run and the average results plotted, as shown in Figs. 7,8,9.

Figure 7 shows the average number of DUE pairs accepted for cellular RB reuse versus the total number of DUE pairs in the proposed, heuristic and $GTM+$ network. As shown, the proposed algorithm had the highest number of DUE pairs among the three algorithms, followed by the heuristic algorithm and the $GTM+$ algorithm. The heuristic approach achieved its peak of 40 DUE pairs allowed very early, when the total number of DUE pairs was 120. It also achieved an acceptance threshold of 70 $DUE\ pairs$ when the network had 160 total DUE pairs. On the other hand, the values of the proposed algorithm increased when the total number of DUE pairs exceeded 200. In the case of the proposed algorithm, the total number of DUE pairs allowed to be reused with 10 $CUEs$ reached 125 out of 200 in the network.

Figure 8 displays the overall average throughput of the system achieved with different numbers of DUE pairs for the network of the proposed algorithm, the heuristic algorithm, and the GTM+ algorithm. According to the figure, we find that the proposed algorithm has the highest performance in productivity, followed by the Heuristic algorithm and then the $GTM+$ algorithm. As the system throughput of the $GTM+$ algorithm approaches its maximum at $N = 120$, it achieved a throughput of about 400 bps/Hz. At $N = 160$ the heuristic algorithm also reached a limit of about $500\ bps/Hz$. The overall system throughput in the proposed algorithm reached 680 bits/Hz at N = 200.

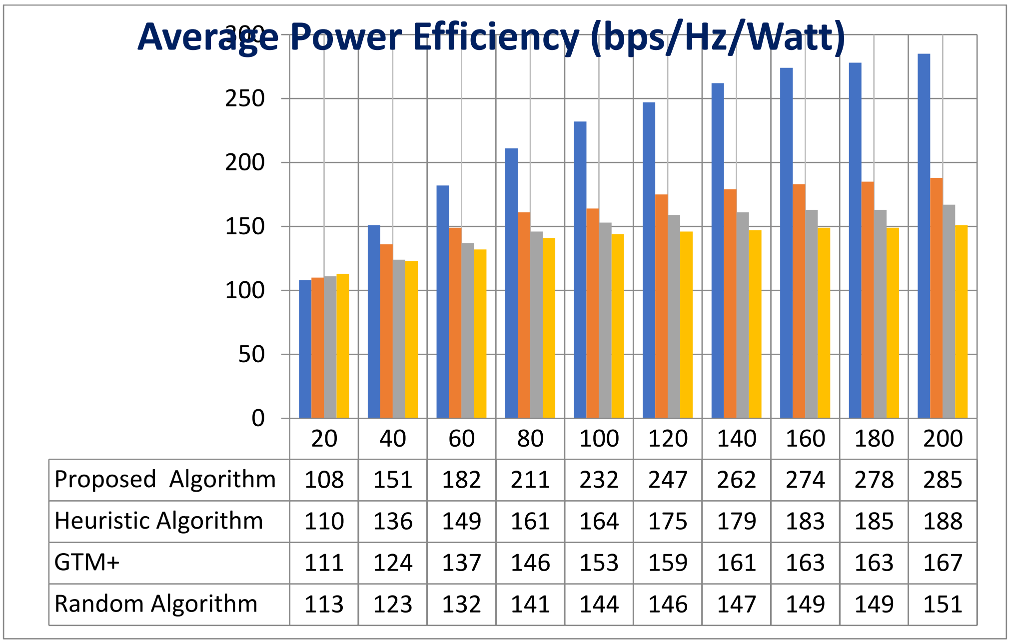
Figure 9 shows the average energy efficiency versus the total number of DUE pairs in the network using the proposed, heuristic, and $GTM+$ algorithms. Whereas, the energy efficiency values in Heuristic and $GTM+$ reached their limits when the total number of DUE pairs in the network reached 120 and 160, respectively, while in the case of the proposed algorithm it continues to increase.

In conclusion, based on the three performance criteria mentioned above, the Proposed algorithm outperforms the Heuristic and GTM + algorithms, with GTM + providing the poorest performance of the three. The proposed method is considered the best in performance due to finding distinct methods that can control power. Accordingly, the proposed algorithm was able to accept a relatively large number of DUE pairs out of the total number of the network. Power control methods have been used to reduce the interference imposed on the CUE by $DUEs$ sharing an RB so as to reduce mutual interference between $DUEs$ sharing the same RB in group reuse. As a result, the proposed algorithm produced higher throughput while utilizing less transmit power, yielding a more power-efficient network than competing techniques.



	20	40	60	80	100	120	140	160	180	200
🟦 Proposed Algorithm	232	316	376	457	514	567	584	644	656	686
🟧 Heuristic Algorithm	231	311	347	392	427	459	482	503	508	518
◼ GTM+	230	289	323	366	383	403	436	441	447	449
🟨 Random Algorithm	230	276	303	318	342	352	353	355	356	357

Fig. 8. System Throughput



	20	40	60	80	100	120	140	160	180	200
Proposed Algorithm	108	151	182	211	232	247	262	274	278	285
Heuristic Algorithm	110	136	149	161	164	175	179	183	185	188
GTM+	111	124	137	146	153	159	161	163	163	167
Random Algorithm	113	123	132	141	144	146	147	149	149	151

Fig. 9. Power Efficiency

5. Conclusion

This research investigates the optimal resource allocation problem with QoS restrictions in order to maximize and obtain the highest total throughput of cellular networks. We formulate the problem so that we can improve the overall productivity, since it is usually a challenge to find the optimal solution directly for a non – convex problem. We present the algorithm for dividing the shared channel between them and how to control the power, taking into account the allocation of communication resources with D2D devices in addition to other small cells known femtocell represented by HetNet . Numerical simulation findings show that the suggested approach outperforms traditional techniques in terms of throughput.

References

[1]panelAbderahman Rejeb, Karim Rejeb, Horst Treiblmaier, Salem Alghamdi, Yaser Alhasawi, Mohammad Iranmanesh, “The Internet of Things (IoT) in healthcare: Taking stock and moving forward”, ScienceDirect, ELSEVIER, Internet of Things, Volume 22, July 2023, 100721

[2] Chandra, S.; Arya, R.; Verma, A.K., “Reliability and age of information analysis of 5G IoT for intelligent communication. Comput. Electr. Eng.”, 2022,.

[3] Azari, A.; Masoudi, M. “Interference management for coexisting Internet of Things networks over unlicensed spectrum.”, Ad Hoc Networks, Volume 120, 1 September 2021, 102539

[4] Del Valle Soto, Carolina. "Utilization of 5G technologies in IoT applications: current limitations by interference and network optimization difficulties—a review." Repositorio Scripta; Repositorio Nacional Conacy; Openaire (2023).

[5] Ali Sufyan , Khan Bahadar Khan , Osama A. Khashan, Talha Mir and Usama Mir “From 5G to beyond 5G: A Comprehensive Survey of Wireless Network Evolution, Challenges, and Promising Technology” , Electronics 2023, 12(10), 2200;

[6] S. Sesia,I.Toufik,andM.Baker, LTE the UMTS longterm evolution: from theory to practice. John Wiley & Sons, 2011.

[7] S. M. Alamouti and A.R.Sharafat, “Resource allocation for energy- efficient device-to-device communication in 4g networks, ”in 7’th International Symposiumon Telecommunications (IST’2014), pp.1058–1063, IEEE,2014.

[8] muayad k. Murtadha, “adaptive d2d communication with integrated in-band and out-band spectrum by employing channel quality”, journal of engineering science and technology vol. 17, no. 1 (2022) 0491 - 0507

[9] F.Jameel,Z.Hamid,F.Jabeen,S.Zeadally,andM.A.Javed,“A survey of device-to-device communications: Research issues and challenges, ” IEEE Communications Surveys & Tutorials, vol. 20, no.3, pp.2133–2168, 2018.

[10] K. Doppler, M.P.Rinne, P.Janis,C. Ribeiro, and K.Hugl,“Device-to-device communications; functional prospects for LTE advanced networks, ” in 2009 IEEE International Conference on Communications Work shops, pp.1–6,IEEE, 2009.108

[11] P.Janis, V.Koivunen, C.Ribeiro,J. Korhonen,K. Doppler, and K.Hugl, “Interference- aware resource allocation for device-to-device radio underlaying cellular networks,” in VTC Spring 2009-IEEE 69th Vehicular Technology Conference, pp.1–5,IEEE, 2009.

[12] K. Doppler, M.Rinne, C.Wijting, C.B.Ribeiro, and K.Hugl, “Device-to-device communication as an underlay to LTE-advanced networks, ” IEEE Communications Magazine, vol.47,no.12,pp.42–49,2009.

[13] A. Asad i,Q. Wang,and V.Mancuso, “A survey on device-to-device communication in cellular networks,” IEEE Communications Surveys & Tutorials, vol.16,no.4, pp. 1801–1819,2014.

[14] Malik, P.K., Wadhwa, D.S. & Khinda, J.S. A Survey of Device to Device and Cooperative Communication for the Future Cellular Networks. Int J Wireless Inf Networks 27, 411–432 (2020). https://doi.org/10.1007/s10776-020-00482-8

[15] P.Mach, Z.Becvar, and T.Vanek, “In-band device-to-device communication in Of dma cellular networks: A survey and challenges,” IEEE Communications Surveys & Tutorials, vol. 17,no.4,pp.1885–1922,2015.

[16] D.Verenzuela and G.Miao,“Scalable d2d communications for frequency reuse in 5g” IEEE, vol. 16, no.6, 2017.

[17] Yali Chen, Bo Ai, Senior Member, IEEE, Yong Niu, Ruisi He, Zhangdui Zhong, Senior Member, IEEE, and Zhu Han, Fellow, IEEE, “Resource allocation for device-to-device communications in multi-cell multi-band heterogeneous cellular networks, ” IEEE Transactions on Vehicular Technology, 2019.

[18] A. M. Waswa, S. Mwanje, J. Mueckenheim, and A. Mitschele-Thiel, “Opportunistic and Partial Random Resource Reuse for Multiple D2D Communication in Cellular Networks,” in IEEE 10th International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT 2018), November 2018, pp. 1–7, Moscow, Russia .

[19] Sun, Hongguang, et al. "Resource allocation for maximizing the device-to-device communications underlaying LTE-Advanced networks." 2013 IEEE/CIC International Conference on Communications in China-Workshops (CIC/ICCC). IEEE, 2013.

[20] Ciou, Si-An, et al. "Multi-sharing resource allocation for device-to-device communication underlaying 5G mobile networks." 2015 IEEE 26th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC). IEEE, 2015.

[21] Wen, Kai, Yongli Chen, and Yunhan Hu. "A resource allocation method for D2D and small cellular users in HetNet." 2017 3rd IEEE International Conference on Computer and Communications (ICCC). IEEE, 2017.

[22] Reider, Norbert, and Gabor Fodor. "A distributed power control and mode selection algorithm for D2D communications." EURASIP Journal on Wireless Communications and Networking 2012.1 (2012): 1-25.

[23] Mohamed Mahmoud Abd El-Hamid1, Mohamed Fared Zaghloul2, Ahmed Rashad Khalifa3 “Efficient Mode Selection and Resource Allocation Algorithm for D2D Underlying 5G Cellular Networks”, AL-AZHAR ENGINEERING FIFTEENTH INTERNATIONAL CONFERENCE The Triumph Luxury Hotel, 5th Settlement, Cairo, Egypt, Saturday to Monday 13-15 March, 2021, Code/Reference Number: SCE01#184

[24] Mohamed Mahmoud Abd El-Hamid1, Mohamed Fared Zaghloul2, Ahmed Rashad Khalifa3 ““Peer Discovery and Device to Device Pairs Selection in Outage Area”, AL-AZHAR ENGINEERING FIFTEENTH INTERNATIONAL CONFERENCE The Triumph Luxury Hotel, 5th Settlement, Cairo, Egypt, Saturday to Monday 13-15 March, 2021, Code/Reference Number: SCE01#185