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D2D Matching Techniques for Resource Allocation Management and Power Control Management in B5G/6G

Mai Elshreay[1,*], Eman Serag[2], Hussein M. Elattar[3], Hesham Elbadawy[2]

[1] Egypt University of Informatics (EUI), Cairo, Egypt
[2] National Telecommunications Institute (NTI), Cairo, Egypt
[3] Arab Academy for Science and Technology and Maritime Transport (AASTMT), Cairo, Egypt

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ABSTRACT

The upcoming 6G network is expected to have a great integration of Device-to-Device (D2D) technology. One of the key advantages of D2D technology is its potential to minimize the load on cellular base stations, which can help extend the lifespan of cellular network infrastructure. D2D multicast communication can meet the growing demand for multimedia content in local area services by maximizing energy efficiency and device lifespan by reusing the same resources for the cellular network. In this paper, we investigate an efficient resource allocation scheme by using the One-To-Many Gale Shapley pairing algorithm (GSA) for efficient allocation and power optimization. We propose a joint optimization approach for D2MD clusters that considers the Signal-to-Interference Noise ratio and energy levels of devices' batteries. The problem is optimized, so it is divided into two convex sub-problems. In the first sub-problem, power allocation is performed for each candidate cluster-head (CH)and cellular user to maximize energy efficiency using the Dinkelbach matching algorithm. In the second sub-problem, the One-to-Many Gale Shapley matching algorithm is used to optimize resource allocation and cluster-head selection to select the Cluster Nodes (CRns) to form the cluster. Numerous investigations show that the suggested technique maintains QoS and minimal battery power requirements while increasing cluster-head longevity and energy efficiency (EE) in D2D applications.

1. Introduction

The rapid evolution of wireless technologies has led to the deployment of 6th generation (6G) mobile networks and the ongoing exploration of beyond 5th generation (B5G) networks. B5G networks are envisioned to support a wide range of services and communication demands, including vehicle networking, the Internet of Things (IoT), device-to-device (D2D), and machine-to-machine (M2M) communications. These networks are characterized by ultra-dense architectures, aiming to meet the increasing tele-traffic demands and provide high-speed connectivity while guaranteeing Quality of Service (QoS) for all users (Su *et al.,*) [1]. B5G/6G radio deployment possibilities and

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[*] *Corresponding author.*
E-mail address: maielshreay@gmail.com

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preliminary planning for the implementation of B5G/6G New Radio (NR) technology in smart cities as in the administrative new capital, Knowledge City. The nature of dense urban areas and the need for high data rate applications that could be used in smart cities will be of particular concern and will be looked into. With the introduction of B5G/6G technology, smart cities may now be established with the connectivity required to enable the use of sensors, data processing, analytics, and other relevant resources (El-Badawy *et al.,*) [2]. So, Effective resource allocation and clustering techniques are essential for optimizing network performance, ensuring efficient utilization of network resources as conducted in [3] and managing the challenges posed by the dense and heterogeneous nature of B5G networks [4]. Resource allocation algorithms play a crucial role in distributing available resources among cellular and D2D users, while clustering techniques facilitate efficient communication and resource sharing within clusters [3-5].

The impact of resource allocation and clustering techniques on network scalability, robustness, and resilience as discussed in [6,7].

The potential of B5G and 6G networks in supporting advanced applications, improving QoS, and enabling emerging technologies [8]. Assigning resources according to timeslots is a technique which mentioned in previous research in (Nur Asfarina Idrus *et al.,*) [9] as Dynamic TDMA is used to assign timeslots based on QoS needs and data size. Traditional TDMA has synchronization problems that are resolved by using the Markov chain concept. Different Multiple access techniques in 6G have taken into consideration to enhance the allocation for the resources as mentioned in [10].The previous research papers argues as example in [11] has focused mainly on enhancing spectral efficiency and system capacity, rather than on transmitted power savings and resource allocation based on energy efficiency for D2D multicast clusters. The proposed scheme takes into account the physical distance of users, as well as their available stored energy, in its batteries when forming Device-to-Multi-Device (D2MD) clusters. The clusters reuse the uplink Resource blocks (RBs) of cellular users. The cluster-head selection, RB allocation, and power control are all carried out simultaneously to maximize the energy efficiency of the weakest user in each cluster and the cluster-head lifetime, while satisfying the minimum quality of service (QoS) requirements of cellular and D2D users and the maximum transmit power constraint.

We will explore the utilization of various algorithms and methodologies to optimize resource allocation and clustering in B5G networks discussed in [12,13]. By leveraging these techniques, the research aims to achieve efficient allocation of resources, minimize interference, enhance network performance, and ensure QoS for different communication requirements. It will explore the concept of network slicing, which involves partitioning the network into virtualized and customized slices to cater to specific communication needs [14]. The research will also emphasize the importance of collaboration between industry stakeholders, standardization bodies, and research communities to ensure the interoperability and compatibility of the proposed techniques.

Effective resource allocation (RA) algorithms play a crucial role in Ultra dense Networks (UDNs), as they enable the reusing of resources, reduce mutual interference, and facilitate spectrum sharing. One approach to improve network performance and cluster stability is through user clustering. Clustering divides network nodes with similar interests or behaviours into smaller group clusters. This technique has been extensively studied in access networks to accommodate mobile user equipment (UE) and assist in routing, throughput optimization, resource distribution fairness, load balancing, and the overall lifetime of a cluster or network as in previous research [9,10]. In [15-18], various clustering algorithms and resource allocation strategies have been proposed. For instance, some algorithms utilize graph theory concepts, such as graph colouring and matching models, to formulate clusters and allocate resources accordingly. Other approaches, like the Gale-Shapley pairing algorithm and Kuhn-Munkres (KM algorithm), optimize resource distribution and preference list generation for (D2D) links in a cellular network (Elshreay *et al.,*) [19]. These techniques aim to maximize system capacity, improve network throughput, minimize interference, and enhance user satisfaction. However, it is important to address the challenges of network heterogeneity and user preferences to achieve optimal results. Additionally, the evaluation and optimization of the clustering and resource allocation schemes are crucial to ensure their effectiveness in real-world scenarios.

In this paper, we propose a scheme to enhance the energy efficiency of underlay D2D multicast transmission. The proposed scheme involves three main parts: firstly: forming multicast clusters and selecting a cluster-head, secondly: allocating resource blocks (RBs), and finally: controlling transmitted power.

So that, the presented model will be analysed via a multi-objective optimization problem in order to enhance and optimize the energy efficiency as well as the lifetime for the cluster head but for such cases, the problem is complicated and can consume much computational power. In order to do that, the paper proposes a technique to convert the multi-objective problem of maximizing the energy efficiency and lifetime of the cluster-head into a single objective one via implementation into a two-step structure. In addition, the power control sub-problem will be solved via deployment of the parametric Dinkelbach method and the One-to-Many Gale Shapley pairing algorithms. Overall, the proposed scheme aims to maximize the energy efficiency of underlay D2D multicast transmission while ensuring reliable communication and maintaining the cluster-head battery lifetime.

The paper will be organized as follows: The system model and problem formulation are introduced in Section II. The methodology for cluster formation is described in Section III, which also includes the suggested approach for power control, cluster-head selection, and RB allocation. Numerical results &analysis results are shown and analysed in Section V. The study is finally concluded analysed in Section IV, which also offers some guidance for future work.

2. Proposed System Model

In this system, N smart devices are present in the coverage area of a Macrocell base Station (MBS). The smart devices can operate in either cellular mode (CM) or Device-to-Device (D2D) mode. In the CM, the smart devices communicate with others via the MBS links. However, in the D2D mode, the smart devices can communicate directly with other smart devices that are close to each other.

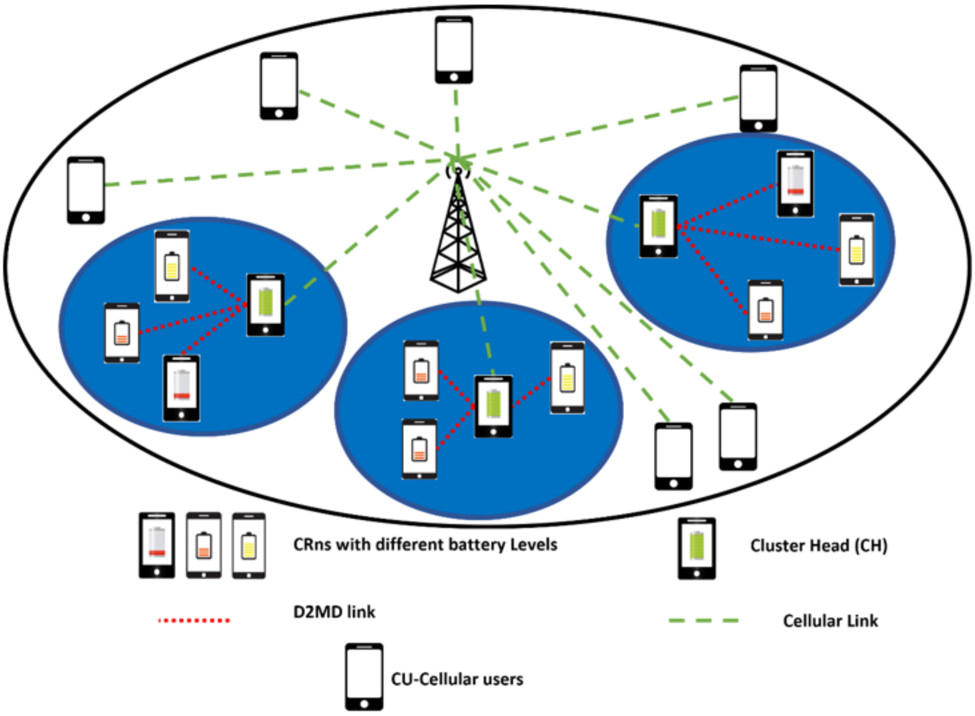

Fig. 1. System Model

The D2D communication mode supports multicast clusters where a group of D2D users can receive the same content. Each multicast cluster has a cluster-head that sends the desired content to the remaining users or receivers within the multicast cluster. The sets of N_c cellular users and N_d D2D clusters are respectively represented by $C= \{C_1,\ldots, C_{Nc}\}$ and $D = \{D_1,\ldots,D_{Nd}\}$. This suggests that the system has N_c cellular users and N_d D2D clusters, and each cluster includes a cluster-head and several receivers. Each D2D multicast cluster reuses a cellular user's uplink Resource Blocks (RBs), leading to two types of interference. The first interference occurs due to the transmission of the cluster-head to the cluster members, which interferes with the uplink signal transmitted by the cellular user and degrades the Quality of Service (QoS) at the MBS. The second interference occurs due to the uplink transmission of the cellular user to the MBS, which interferes with the cluster-head transmission and decreases the Signal-to-Interference plus Noise Ratio (SINR) of D2D receivers. Appropriate RB allocation and power control strategies are implemented to manage these interferences. The goal is to optimize the use of RBs and power resources to minimize interference and improve QoS. This could involve allocating separate RBs for D2D clusters to avoid interference with the uplink signals of cellular users. Additionally, power control can be implemented to adjust the transmission power of the D2D clusters to reduce interference with cellular users.

2.1 Clustering Interference Control

The interference caused by RB sharing between D2D clusters and cellular users in a wireless communication network. We assume that some users connect directly to the MBS (presumably via cellular links), while others (D2D users) connect to clusters via D2D links. The interference occurs because each D2D multicast cluster reuses the uplink RBs of a cellular user. There are two types of interference that result from this: The transmission of the cluster head to cluster members interferes with the uplink signal transmitted by the cellular user, degrading the QoS at the MBS. The uplink transmission of the cellular user to the MBS interferes with the cluster head transmission, decreasing the SINR (Signal-to-Interference-plus-Noise Ratio) of D2D receivers [20]. To manage these interferences, we propose appropriate RB allocation and power control techniques. These techniques aim to mitigate the effects of interference and ensure that both cellular users and D2D clusters can coexist and operate efficiently in the same spectrum.

2.2 Power Management for the Battery Lifetime of the Cluster-Head

The limited battery capacity of smart devices poses a challenge due to the increasing demand for multimedia and social applications in smartphones. In D2D multicast clusters (D2MD), the CH consumes more power than the receivers, affecting the lifetime of the elected cluster head [17]. To optimize the operation of the cluster head and cluster lifetime. In addition, residual energy should be considered during the cluster-head selection process.

2.4 Cluster Formation

The Gale-Shapley pairing algorithm (Abououf, Singh, *et al.,*) [21] also known as the Stable Marriage algorithm, is typically used for solving the problem of matching two sets of elements based on their preferences. In the context of D2D clustering, the algorithm can be used to match the devices or customers to the cluster heads. To apply the Gale-Shapley pairing algorithm to D2D clustering, we need to define the preferences of the devices and the cluster heads. Each device has a preference list of cluster heads, and each cluster head has a preference list of devices. For example, we could define the preferences of the devices based on the distance to the cluster head, the residual energy of the cluster head, or the quality of service provided by the cluster head. Similarly, we could define the preferences of the cluster heads based on the number of devices in the cluster, the total residual energy of the devices, or the total data rate of the devices.

Once the preference lists are defined, the Gale-Shapley pairing algorithm can be applied to find a stable matching between the devices and the cluster heads. The algorithm proceeds in rounds, where each device proposes to its most preferred cluster head that has not already rejected it, and each cluster head tentatively accepts the most preferred device that has been proposed to it. If a cluster head receives a proposal from a device that it prefers to its current tentative match, it replaces the tentative match with the new proposal. The algorithm terminates when no further proposals can be made.

Overall, the Gale-Shapley pairing algorithm can be a good alternative to the Chinese restaurant process (CRP) algorithm for D2D clustering and the comparison has been conducted in (Blei and Frazier) [22], as it allows us to take into account the preferences of both the devices and the cluster heads and find a stable and optimal matching between them.

3. Methodology

In this scenario, since the D2D cluster Dj reuses the uplink resource blocks of cellular user CM, it causes interference on CM ‘s transmission. The interference term I_c represents the cumulative effect of interference from all D2D devices in the cluster Dj using the same resource blocks. As mentioned, D2D clusters reuse the uplink RBs of cellular users. Suppose that cluster Dj reuses the same resource blocks of cellular user C_i. In this case, the SINR of cellular transmission at MBS is calculated as:

$$SINR^{C}_{r_i,x_j} = \frac{P_{x_j}\ H_{x_j,r_i}}{BN_0+P^{x_j}_{C_M}H^{x_j}_{C_{M,r_i}}} \tag{1}$$

Where P_{x_j} is the transmit power of the x_j(CH), $P_{C_M}^{x_j}$ is the transmit power of the normal Cellular user and this link will be reused by the CH to form D2D underlying Communication, N_0 the power spectral destiny of Additive White Gaussian Noise (AWGN), H_{x_j,r_i} is the channel power gain between the CH and CN. $H_{C_{M,r_i}}^{x_j}$ is the channel power gain between the normal cellular users' CM and the CN ri. The SINR of the user Ux of the cluster Dj:

$$SINR^{D}_{r_i,x_j,L} = \frac{P_{x_j}\ H^{D,D}_{r_{i,L}}}{N_0+P^{Cm}_{x_{j,}r_i}H^{Cm,D}_{x_{j,}r_{i,}L}} \tag{2}$$

So, the rate of the cellular users is calculated as:

$$R^{C}_{r_i,x_j} = BLog_2\left(1+\frac{P_{x_j}\ H_{x_j,r_i}}{N_0+P^{x_j}_{C_M}H^{x_j}_{C_{M,r_i}}}\right) \tag{3}$$

The rate of the D2D cluster that includes the user Ui:

$$R^{D}_{r_i,x_j,L} = BLog_2\left(1+\frac{P_{x_j}\ H^{D,D}_{r_{i,L}}}{N_0+P^{Cm}_{x_{j,}r_i}H^{Cm,D}_{x_{j,}r_{i,}L}}\right) \tag{4}$$

The energy efficiency in bits/J can be calculated as the ratio of the sum rates of cellular and D2D users to the total power consumption. Here, the sum rates refer to the combined data rates of all cellular users and D2D users. The total power consumption includes the power consumed by both cellular and D2D transmissions. The formula for energy efficiency η^{x_j,r_i}_{EE} will be determines as follows:

$$\eta^{x_j,r_i}_{EE} = \frac{R^{C}_{x_j,r_i}+\sum_{L=1,L\neq\omega_{X_{j,}r_i}}^{U_{D_{x_j}}} R^{D}_{x_j,r_i,L}}{P^{Cm}_{x_{j,}r_i}+P^{D}_{x_{j,}r_i}+\left(n_{x_j}+1\right)P_{circuit}} \tag{5}$$

Where n_{x_j} and $\omega_{X_{j,}r_i}$is the number of users that will be in the cluster Dj and $\omega_{X_{j,}r_i}$denotes the cluster-head of cluster Dj, and $P_{circuit}$ denotes the circuit power consumption of user equipment. The lifetime of the cluster-head is calculated as follows:

$$\gamma_{x_j,r_i} = \frac{E_0^{\omega_{X_{j,}r_i}}-E_{min}}{P^{D}_{x_{j,}r_i}} \tag{6}$$

Where γ_{x_j,r_i} *is* the lifetime of the cluster will indicate the cluster surviving through the system where $E_0^{\omega_{X_{j,}r_i}}$ is the energy will initially the cluster will start with where E_{min} is the minimum cluster head energy to make the cluster could survive so we can formulate the optimization problem to maximize the energy efficiency for the cluster so it will be as follows:

$$[P^*, X^*, \omega^*] = \underset{P,\omega,X}{\operatorname{argmax}}\, \eta_{EE} = \underset{P,\omega,X}{\operatorname{argmax}} \sum_{r_i=1}^{N_C}\sum_{x_j=1}^{N_D} J_{r_i,x_j}\, \eta^{r_i,x_j}_{EE} \tag{7}$$

In Eq. (9) defines the constraints collectively govern the transmission rates, power levels, RB allocation, and channel reuse in the system to optimize energy efficiency while satisfying minimum requirements for data rates and controlling interference between cellular users and D2D clusters. To improve the energy efficiency, we aim to maximize SINR, of the cluster. The minimum SINR can be obtained by considering the user with the lowest SINR, i.e., the weakest member of the cluster. Therefore, we have:

$$SINR^{D}_{x_j,r_i,L} = \min\ SINR^{D}_{x_j,r_i,L} \tag{10}$$

Where the minimum operation selects the smallest SINR among all users in cluster Dj. By improving SINR, we ensure that the required rate for the weakest member of the cluster is satisfied. Hence, the required rate of other members of the cluster will also be satisfied.

Furthermore, for the complexity of Solving the equation we can solve it as follows:

$$[P^{*}, \omega^{*}, X^{*}] = \underset{P,\omega,X}{argmax} \left(\eta_{EE}\, \gamma_{x_j,r_i}\right) \tag{11}$$

So, the maximization of the product of Eq. (7) and Eq. (8) for solving the optimization problem it is divided into two sub-problems first problem is to solve power allocation and the second problem is to solve Resource allocation and cluster head selection. To address this, several algorithms are employed: the parametric Dinkelbach algorithm, the concave-convex procedure (CCCP), and interior point algorithms. These methods are utilized to solve the difference-of-convex (DC) function with linear constraints. In the second phase of the solution, the optimal transmit powers obtained from the first phase are taken into consideration. The Hungarian algorithm, a combinatorial optimization algorithm, is employed to determine the binary variables of RB allocation and cluster-head. This algorithm explores all possible pairs of cluster-heads and RBs to maximize the life-energy. The proposed solution combines these algorithms and processes to tackle the complexity of the problem effectively. By utilizing the parametric Dinkelbach algorithm, CCCP, and interior point algorithms, the non-convex sub-problem is addressed. Then, with the Hungarian algorithm, the binary variables of RB allocation and cluster-head are determined to maximize the life-energy. This solution approach offers a detailed description of the methods employed to tackle the complexity of the problem and provide an efficient and effective solution.

3.1 Proposed Technique for Power Allocation

To address the power allocation sub-problem and decide on the cluster-head for each D2D cluster when reusing a cellular user's RB, the following approach is proposed. Firstly, we Explore all potential scenarios for RB reuse: Exhaustively examine all possible configurations of RB allocations between D2D clusters and cellular users. Evaluate whether each D2D cluster Dj can reuse the RB of a specific cellular user Cn. The Cluster-head determination When cluster Dj reuses the RB of cellular user Cn using the following scheme:

i. Assess the energy efficiency for each cluster member.
ii. Calculate the energy efficiency for each member in cluster Dj, considering the RB reuse. This involves evaluating SINR and transmission rates for each member with the selected RB allocation.

iii. Identify the member with the minimum energy efficiency: Determine the member in cluster Dj with the lowest energy efficiency, representing the weakest performer in terms of energy efficiency.
iv. Assign the member with the minimum energy efficiency as the cluster-head: Designate the member with the minimum energy efficiency as the cluster-head for Dj when it reuses the RB of cellular user Cn.

3.2 Nomination for Electing the CH

By considering all possible RB reuse cases and utilizing the proposed approach, the selection of the cluster-head for each D2D cluster is based on the member exhibiting the minimum energy efficiency. This methodology aims to optimize the energy efficiency of the D2D clusters while reusing RBs and ensuring reliable communication within the clusters, so we exhibit also the SINR $\aleph_{r_i,x_j,m}$between the CH and the CRNs after selection.

$$T_{x_j,r_i,m} = \underset{y\epsilon\mu_{x_j}|\{U\}}{argmin}\left(\gamma^{D}_{x_j,r_i,m}\right) \tag{12}$$

$$\aleph_{r_i,x_j,m} = \frac{P_{x_j}\ H^{D,D}_{r_{i,L}}}{N_0 + P^{C_m}_{x_{j,}r_i} H^{C_m,D}_{x_{j,}r_i,L}} \tag{13}$$

$$\omega_{r_i,x_j} = \underset{T_{x_j,r_i,m}}{\operatorname{argmin}} \aleph_{r_i,x_j,m} \tag{14}$$

The optimization problem for the power could be solved by the parametric Dinkelbach algorithm(Dinkelbach) [23] so the optimization problems will be as follows:

$$P^{*}_{r_i,x_j} = arg\max_{P}\left(\gamma_{x_j,r_i}\frac{R^{C}_{x_j,r_i}+R^{D}_{x_j,r_i}}{P^{C}_{x_j,r_i}+P^{D}_{x_j,r_i}+3P_{circuit}}\right) \tag{15}$$

$$\max\{\gamma_{x_j,r_i}\left(R^{C}_{x_j,r_i}+R^{D}_{x_j,r_i}\right) - \lambda^{*}\left(P^{C}_{x_j,r_i}+P^{D}_{x_j,r_i}+3P_{circuit}\right) = 0 \tag{16}$$

$$\lambda^{*} = max\eta^{x_j,r_i}_{\gamma EE} \tag{17}$$

The objective function has been changed and the convex constraints so the linear constraints and the DC function could be solved as:

$$\max\{\mathrm{f}_{\mathrm{cave}}(\mathrm{x}) + \mathrm{f}_{\mathrm{vex}}(\mathrm{x})\}. \tag{18}$$

$$P^{C}_{r_i,x_j}\ H^{C,B}_{r_i} - \left(2^{\gamma_{x_j,r_i}R^{C}_{min}} - 1\right)\left(P^{D}_{r_i,x_j}\ H^{D,B}_{r_i} + N_0\right) \geq 0 \tag{19}$$

$$P^{D}_{r_i,x_j}\ H^{D,D}_{r_i} - \left(2^{\gamma_{x_j,r_i}R^{D}_{min}} - 1\right)\left(P^{C}_{r_i,x_j}\ H^{C,D}_{r_i} + N_0\right) \geq 0 \tag{20}$$

$$\mathrm{f_{cave}}(\mathrm{x}) =\triangleq \log_2\left(P^{C}_{r_i,x_j}\, H^{D,B}_{r_i} + P^{D}_{r_i,x_j}\, H^{D,B}_{x_j} + N_0\right) + \log_2\left(P^{D}_{r_i,x_j}\, H^{D,D}_{x_j} + P^{C}_{r_i,x_j}\, H^{C,D}_{x_j} + N_0\right) \tag{21}$$

$$\mathrm{f_{vex}}(\mathrm{x}) \triangleq -\log_2\left(\, P^{D}_{r_i,x_j}\, H^{D,B}_{x_j} + N_0\,\right) - \log_2\left(P^{C}_{r_i,x_j}\, H^{C,D}_{x_j} + N_0\right) \tag{22}$$

3.3 Proposed Technique for Cluster Formation

After we mapped all the available RB for Cellular users and D2MD clusters as power allocation considers all the RBs we will simplify the optimization problem as follows:

$$[X^{*}, \omega^{*}] = \underset{\mathrm{X},\omega}{\operatorname{argmax}}\left(\eta_{\gamma EE}\left\{P^{C}_{x_j,r_i}, P^{D}_{x_j,r_i}\right\}\right) \tag{23}$$

To achieve optimal resource allocation in the B5G mobile network, it is essential to consider all possible mappings between the cellular users and the D2D clusters. This ensures that each resource block (RB) assigned to a cellular user is only reused by a single D2D cluster, minimizing interference, and maximizing system performance. Algorithms like the Hungarian algorithm can be employed to efficiently solve the assignment problem and find the best RB assignment for each D2D cluster. By exploring all possible mappings, the system can identify the most efficient allocation of RBs, leading to improved quality of service, network capacity, and overall performance. This approach enhances resource utilization and mitigates interference, ensuring optimal resource allocation in the B5G mobile network.

To achieve an optimal solution, we can use Gale Shapley Matching algorithms. By applying the Gale-Shapley pairing algorithm, cellular users and D2D clusters can form pairs based on their preferences, and resources can be allocated accordingly. The algorithm ensures that each cellular user is matched with a D2D cluster, and each D2D cluster is matched with a cellular user, creating a stable allocation of resources.

In the context of the matching game μ with two-sided players X and R, the results of the game are described using matching theory. The preference relations of the cluster-heads (CHs) and cluster nodes (CRns) are denoted,≻X={xj}xj∈ X and ≻R={ri}ri∈ R

Here, ≻X represents the preference relation of the CHs, where xj refers to an individual CH from the set X. This preference relation indicates the ranking or order of preference that CHs have for being matched with CRns. It captures the subjective preferences or priorities of the CHs regarding their desired matches.

Similarly, ≻R represents the preference relation of the CRns, where ri denotes an individual CRn from the set R. This preference relation reflects the ordering or preference of the CRns for being matched with CHs. It represents the individual preferences or priorities of the CRns in terms of their desired matches. These preference relations play a crucial role in determining the outcomes of the matching game μ. They influence the formation of stable matches between the CHs and CRns based on their respective preferences. The matching theory aims to find a matching that satisfies certain stability criteria, ensuring that no CH-CRn pair has an incentive to deviate from their assigned match. ∝ is the maximum number of Cluster nodes (CRns) that can enter a one cluster.

By considering the preference relations ≻X and ≻R, the matching theory provides a framework to analyse and understand the outcomes of the matching game μ. It allows for the examination of the compatibility and desirability of matches between CHs and CRns based on their preferences, leading to the establishment of stable and satisfactory matches.

Definition:

Given two disjoint finite sets of players X and R, a matching μ is denoted as a function where **Θ** is the set of X ∪ R, such that:

$$\begin{array}{l}\text{(i)}\forall x_j \in X, \mu\left(x_j\right) \in R \cup \{\emptyset\}\ and, \mu\left(x_j\right) \leq \propto, \\ \text{(ii)}\ \forall r_i \in R, \mu\left(r_i\right) \in X \cup \{\emptyset\}\ and, \mu\left(r_i\right) \in \{0,1\}, \\ \text{(iii)}\ \mu\left(r_i\right)=x_j \Leftrightarrow, \mu\left(x_j\right) = r_i\end{array} \tag{24}$$

User Grouping Clustering Algorithm Using One-to-Many Matching

```
Initialize the preference list of $r_i$, ∀ $r_i$ ∈ R,, and the set of CRns that are not matched to CHs as Θ= R.
repeat
    Each CH $x_j$ will select the best option from where ri ∈ Θ applies to its favorite in its preference list, and then removes $r_i$ from its preference list.
    Set Θ =∅.
    for $x_j$ ∈ X do
        if condition (i) in Definition 1 is satisfied, then
            Accept all current CRns.
        else
            Build its preference list based on (24).
            Accept the top ∝ CRns and reject the others.
        end if
    end for
    Update the matching result μ.
    Update Θ as the rejected $r_i$ → Θ.
until Θ =∅ or the preference list of $r_i$, ∀$r_i$ ∈ Θ, is empty.
```

4. Numerical Results & Analysis

We analysed the performance of the under varies numerical results and system parameters mentioned in Table 1 The selected system parameters are consistent with [15,18]and the simulation results were tested by the MATLAB simulation tool. In this section, we evaluate the performance of our proposed framework under various scenarios using MATLAB simulation Tool, with the system parameters listed in Table [1].

Table 1
System Parameters

Parameter	Value
System bandwidth	20 MHz
Centre frequency	5 GHz
PRB bandwidth	180 KHz
Noise Spectral density	−174 dBm/Hz
Macro Cell radius	1 Km
The power of Macro BS	50 dBm
Maximum distance of D2D user	10~25 m
D2D maximum transmit power	21 dBm
Circuit power	100 mW

In Figure 2 presents a comparison of our approach with different algorithms, including random allocation (RA) and the Many-to-One Gale-Shapley Matching Algorithm where the previous results discussed in [24,25]. The plot shows the system throughput as a function of the number of D2D users. As the density of UEs increases, we observe an improvement in system throughput across all solutions. However, our proposed technique outperforms existing algorithms in terms of mitigating inter-cell interference and enhancing system throughput. We adhere to the 3GPP recommendations [26] for setting the system parameters. This section aims to describe the performance of our proposed framework in diverse scenarios.

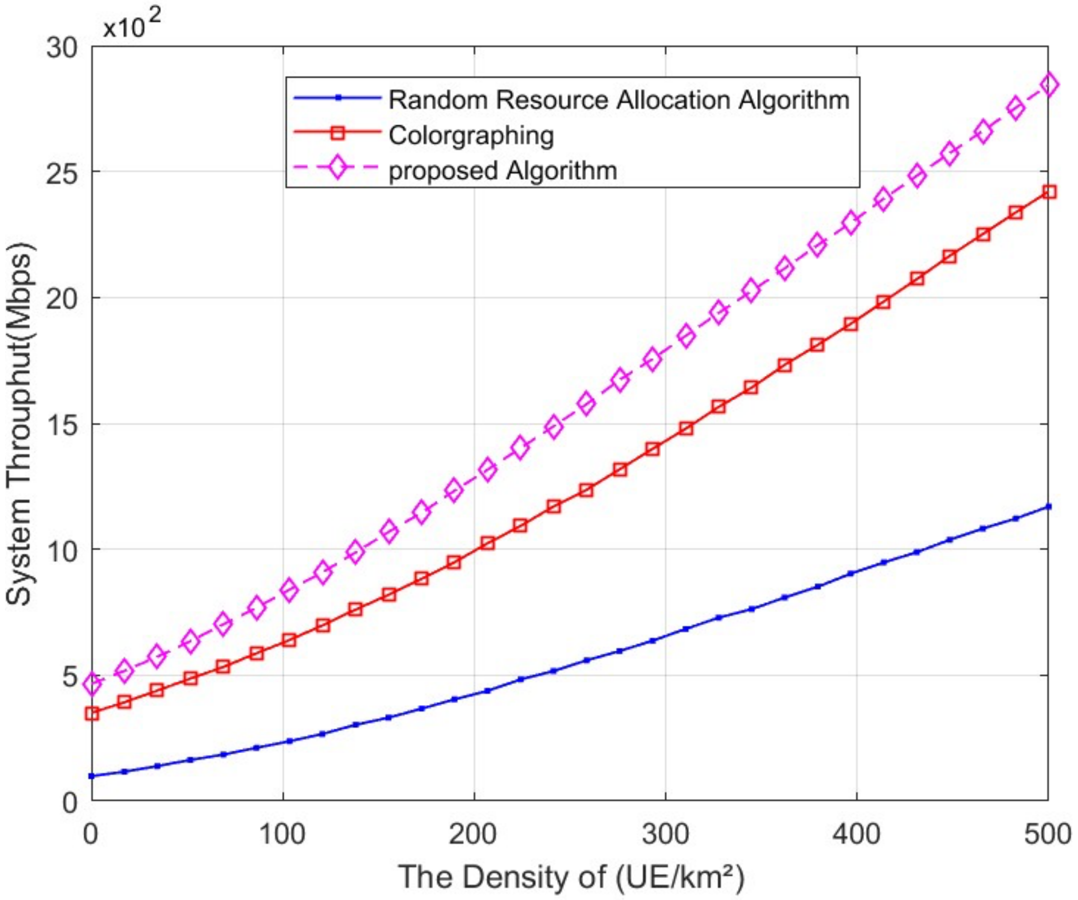

Fig. 2. System Throughput vs Density of users

In Figure 3 shows that the system throughput using our proposed algorithm One-To-Many Matching algorithms is higher than the other Algorithms, so our Algorithm has a better performance.

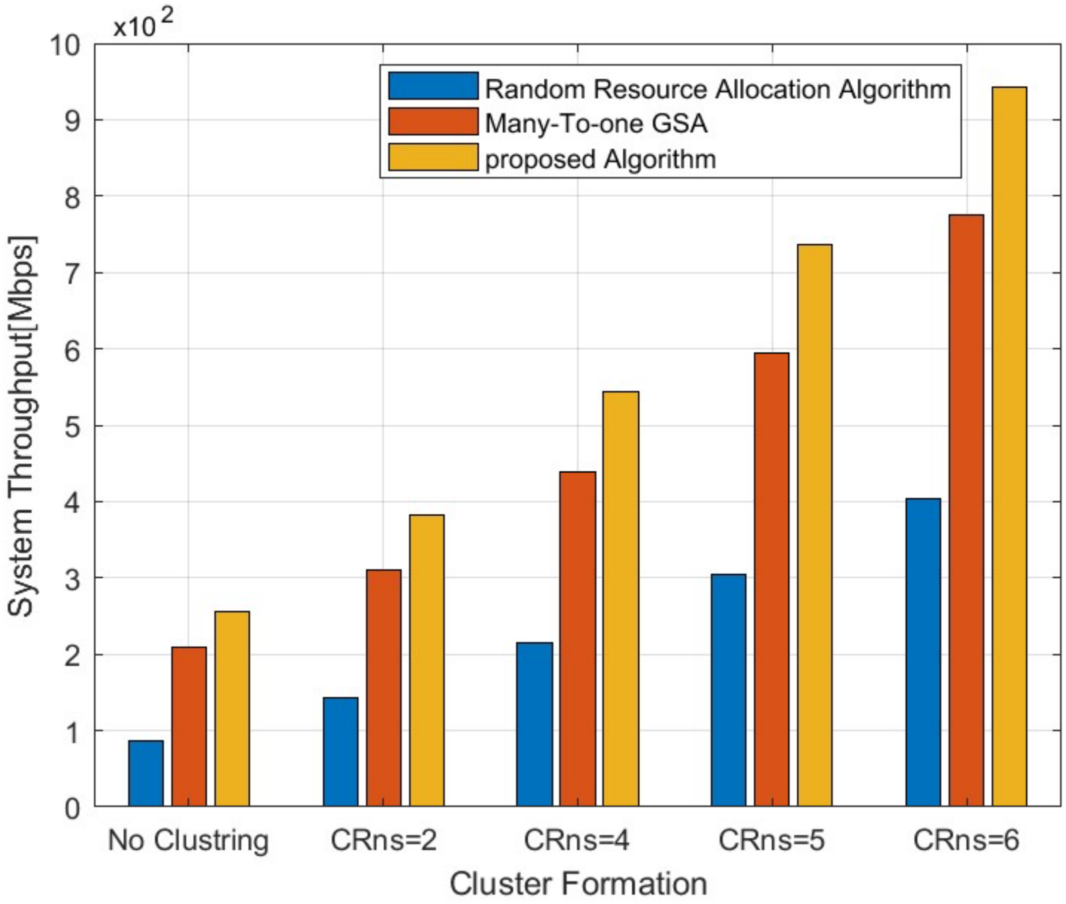

Fig. 3. Comparison between System Throughput through different algorithm and the proposed Matching Algorithm

In Figure 4 in essence, the higher values of D_{th} (Distance Threshold) in meter result in an amplification of the D2D multicast cluster head's transmission power, thereby extending its communication range. Nevertheless, this escalated broadcasting power leads to augmented interference over the MBS, the recipient of cellular users. Consequently, cellular users elevate their transmission power to counterbalance the interference and meet the MBS's minimal rate prerequisite. The amplified interference, in turn, diminishes the overall potential spectral efficiency for the multicast D2D receivers utilizing the same RBs. As the number of users surpasses 300 users, the system encounters restrictions, whereas stability is observed with 100 users.

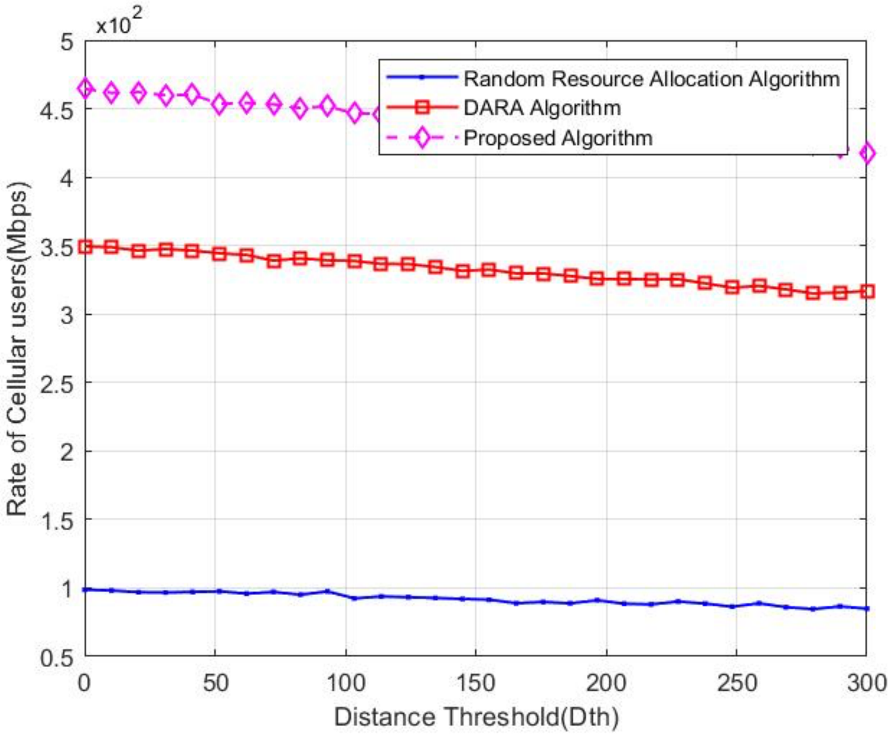

Fig. 4. rate of Cellular User according to the Dth in(meter)

In Figure 5 illustrates the impact of cluster Aggregated throughput on network performance. The cumulative number of allowed CRNs entering the clusters increases as the number of CRns joining the cluster increases until it reaches a stable state. This indicates that the likelihood of user collations assignment rises as α increases, initially improving the performance of the schemes. However, since the total number of users (N) is finite, there exists an optimal value of α that maximizes the effectiveness of each scheme. In other words, all schemes are bound to converge. Notably, the proposed system achieves stability at α=50, while previous systems do not stabilize until α=30 [27]. It should be noted that a larger α value introduces a significant signalling overhead within the cluster. In terms of reducing signalling overhead, the proposed method outperforms other matching schemes. The convergence of our power allocation scheme is validated through an analysis of system throughput evolution over iterations. So, it demonstrates the system throughput for different densities of UEs while maintaining a density of CRns. The results show an initial improvement in throughput as the UE density increases, followed by indicating system limitations beyond a certain threshold. Similarly, Figure 4 presents the system throughput for various densities of CRns with a fixed UE density of 500 users. The findings reveal an initial increase in throughput with a higher density of Cluster nodes per cluster, eventually reaching a point of stabilization. These observations confirm the convergence of our power allocation scheme and highlight the existence of limitations in the system as UE. These insights are crucial for optimizing wireless networks to achieve enhanced performance and efficiency.

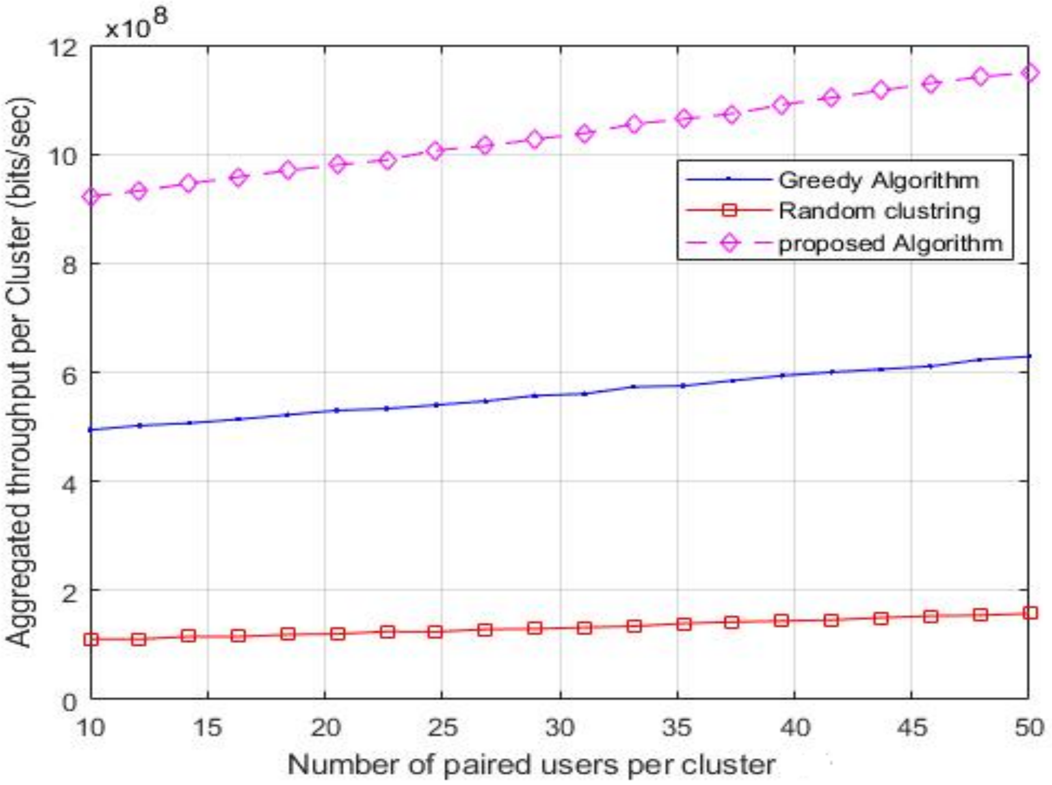

Fig. 5. Aggregated Throughput for Each Cluster vs. the number of D2D users per Cluster

5. Conclusion

The resource allocation approach based on the One-to-Many Matching paradigm presents a viable solution to address the challenge of resource distribution in diverse cellular network environments, particularly for Device-to-Device (D2D) users. This methodology effectively utilizes the channel resources of a single cellular user by allowing multiple D2D users to share them, thereby maximizing spectrum efficiency and ensuring superior communication services for both cellular and D2D users. The algorithm, employing the Gale-Shapley pairing algorithm, establishes a preference list for D2D users and channels through Cluster Head (CH) selection and the assignment of Cluster Resource Nodes (CRNs) to the cluster, aiming to optimize the overall throughput of the system. MATLAB simulations are performed to compare and evaluate the proposed algorithm against exhaustive search methods, random resource allocation techniques, and approaches allowing maximum permissible access for D2D users. The numerical results and analysis results demonstrate the superiority of the proposed algorithm in terms of its simplicity, faster convergence rate, and overall system throughput, outperforming state-of-the-art algorithms [27] and random resource distribution. Future research directions could explore the incorporation of mobility considerations in D2D scenarios to further enhance the performance and effectiveness of resource allocation strategies.

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