Interference aware D2D Multicasting using Modified Hungarian Method

Poulomi Mukherjee
Department of Computer Science & Engineering
National Institute of Technology
Durgapur 713 209, West Bengal, India
Email: pm.20cs1105@phd.nitdgp.ac.in

Tanmay De
Department of Computer Science & Engineering
National Institute of Technology
Durgapur 713 209, West Bengal, India
Email: tanmay.de@cse.nitdgp.ac.in

2023 OITS International Conference on Information Technology (OCIT) | 979-8-3503-5823-0/23/$31.00 ©2023 IEEE | DOI: 10.1109/OCIT59427.2023.10431269

***Abstract*—Device to device (D2D) multicasting is a promising approach of network communications in Fifth generation (5G) cellular network for providing spectrum efficient communications. In underlay D2D mode, interference mitigation is a crucial concern to maintain the appropriate QoS. In this paper, we have addressed that the modified Hungarian method can be followed to arrive at an efficient resource block (RB) allocation strategy in cluster based D2D communications. With a suitable motivational example, we demonstrate the RB allocation technique using modified Hungarian method. Based on this, we have developed an intelligent clustering algorithm and an efficient resource allocation to maximize the obtained sum-rate of the network. Using network simulator 2 (NS2), the performance of the proposed approach is evaluated through extensive simulations in terms of obtained throughput, service coverage and spectrum efficiency. A comparative study between the proposed interference aware D2D multicasting and the well known incremental frequency assignment policy has also been presented.**

***Index Terms*—5G D2D Clusters, Cluster Head, Cellular Users, RB allocation, Modified Hungarian method.**

I. Introduction

In modern wireless technology, providing high speed data rate and seamless services to the cellular users have become a challenging task. Fifth generation (5G) cellular network is systematizing device to device (D2D) communications in order to meet these objectives. Due to the exponential growth in the number of cellular users (CUs), network access entity such as base station (BS) has to put a rigorous effort to manage the users requirements. D2D helps to reduce the overhead of BS by offloading the network load through direct communications. It establishes a direct link between two nearby devices which are in close proximity. Unlike Wi-Fi users, D2D users involve in communications through licensed spectrum, thus it enjoys the benefits of faster access of radio resources and provides high speed data transfer. Such type of communications are very effective when CUs are located far away from the BS or in the disaster prone areas where transmitted signal is failed to reach the destination.

Disaster management, social networking services, on demand official communications, video sharing inside a stadium, online TV, urgent message transfer for public safety, location specific advertisements, human machine interactions are the most popular applications of D2D communications [1]. These type of proximity based communications can be served partially or without support of any physical infrastructure [2]. D2D communication incorporates many advantages in cellular communications in terms of spectrum efficiency, load balancing, energy efficiency, throughput maximization. D2D communications in underlay mode allows the sharing of licensed spectrum between the CUs and D2D users through opportunistic use [3, 4].

Cluster based D2D communication has achieved much attention to improve the performance of D2D communication. It reduces the traffic of the BS by allowing suitable number of users to be served in a group. It also helps to increase the system's coverage by accommodating more users from the boundary area [5]. One user from the group is selected as cluster head (CH) which takes the responsibility to deliver the content to the other members. However, in underlay D2D communications, admitting D2D multicasting is a challenging task due to the crisis in the spectrum availability. Here, both the CUs and cluster based D2D users opportunistically use the available licensed spectrum. In such scenario, admittance of suitable D2D multicasting requires appropriate management of spectrum resources to handle the interference due to the ongoing cellular communications and newly admitting cluster based D2D users. It has been witnessed that modified Hungarian method has been used for the purpose of resource allocation in D2D communications [6]. This paper addresses that the Hungarian method can be revised to arrive at an efficient resource allocation technique for D2D multicasting in underlay cellular communication. The objective of the proposed interference aware resource allocation is to frame a suitable D2D multicasting in underlay cellular network with appropriate resource allocation using revised Hungarian method.

The remaining part of the paper is organized as follows. In section II, related work is discussed. The system model for D2D communication in underlaying cellular communication is explained in section III. Section IV presents motivation behind our work. Interference aware resource allocation algorithm is summarized in section V where idea of modified Hungarian method is used. Finally, section VI illustrates the performance of the proposed approach followed by the conclusion in Section conclusion.

II. RELATED WORKS

In this section, we have performed a comprehensive literature survey on D2D communication and multicasting of 5G cellular network. Existing studies are there, addressing resource allocation and spectral utilization in D2D enabled cellular network to avoid the spectral scarcity. Studies reveal that efficient resource handling can be done through power control, mode selection and channel allocation [7]. A multi-channel based scheduling algorithm is designed in [8] based on giving the priority to computed SINR values. Experimental results show that the proposed algorithm gives better performance than the single one-channel-based algorithm. A genetic algorithm based joint power and resource optimization technique is proposed in [9] for 5G and beyond 5G system. In [10], the authors have used traditional Munkres algorithm to allocate resources for obtaining higher data rate. Here they have considered predefined cluster size while ignoring the inter cluster interferences. Depending on the Channel State Information (CSI) a joint optimization strategy that combines a low-complexity algorithm with the Hungarian method is proposed in [11] to improve the throughput of the downlink cellular network. In [12] both graph coloring algorithm and pilot allocation techniques are used to manage interference and spectrum allocation. This results in more bandwidth consumption. Concept of utilizing both licensed and unlicensed spectrum at the same time has been introduced in [13] where Stackelberg game strategy is incorporated for efficient resource allocation. Unlike this, in our work we have proposed interference aware resource allocation in D2D multicasting using modified Hungarian method.

Employing relay nodes in the communication network allows efficient data transfer from distant users. This has the dual advantage of extending coverage and alleviating the load on the base station [14]. The benefits of employing relay-based communication are further amplified when integrated into clustering techniques. Cluster based D2D communication is a viable solution for offloading the base station load, increasing spectral efficiency and delivering data at high rate [16]. Clustering techniques got attention both in overlay and underlay D2D communications [17]. Resource allocation in cluster based underlaid cellular network to optimize the overall network throughput while maintaining fairness to the boundary users is a challenging task and need much attention. Towards this, we have used modified Hungarian method to optimize resource allocation in a 5G cellular network where cellular communication, cluster based D2D communication and individual D2D communication can be handled in a combined way. Our proposed approach is modular and can be applied for all possible cluster based relaying techniques.

III. THE SYSTEM MODEL

We consider an underlay cellular network where BS is located at the center of the cell. Let P number of cellular users represented by the set $\mathcal{U}_{Ce} = \{J_1, J_2, \dots J_P\}$ co-exist with Q number of D2D users represented by the set $\mathcal{U}_B = \{J_1^{'}, J_2^{'}, \dots J_Q^{'}\}$. We consider the user set $\mathcal{U}$ (where $\mathcal{U} = \mathcal{U}_{Ce} \cup \mathcal{U}_B$) are distributed randomly in a single cell scenario. BS manages the RB allocation to the cellular users and D2D users as a central controller from the available RB set $\mathcal{W} = W_1, W_2 \dots W_{K^*}$. Cellular users do not cause interference to each other due to orthogonal channel allocation [18]. Interference occurred between the cellular users and the D2D users and among D2D users which are multiplexed into the same RBs. We assume that D2D user reuses the same uplink resources $\mathcal{W}$ used by cellular users for traditional cellular communications. Such networking environment is also shown in Figure 1. Note that, a free space propagation model has been considered to compute the obtained data rate of the i^{th} D2D user from CH_j, where the received signal to noise plus interference ratio (SINR) is given by [19]:

$$\gamma_{ji} = \frac{P_j.G_{ji}}{\sigma^2 + I}. \tag{1}$$

In Eqn. (1), I is the interference caused by the usage of same RB, G_{ji} is the gain, P_j and σ^2 are transmitting power and noise respectively. Considering w as the channel bandwidth the obtained data rate is given by:

$$\nu_{ij}^{w} = w \log_2(1 + \gamma_{ji}). \tag{2}$$

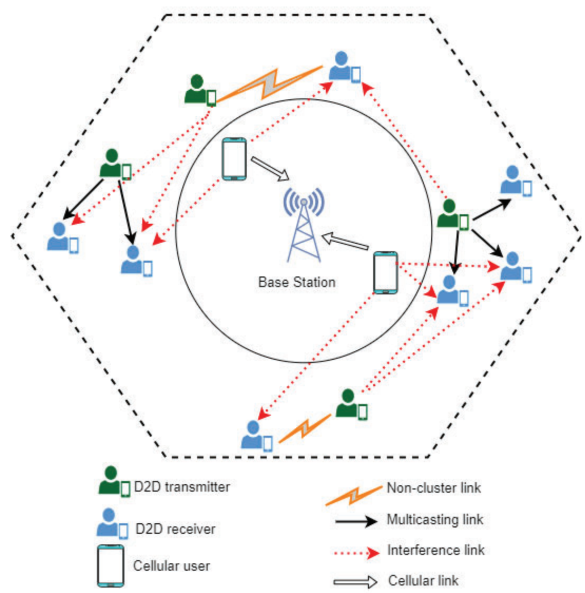

Fig. 1: Network environment

IV. MOTIVATION AND THE MODIFIED HUNGARIAN METHOD

In D2D multicasting, the responsibility of a BS is to cherish the underlying cellular communication as well as the D2D multicast communications. In such network, there exists the possibility of inter-cluster interference and interference due to the ongoing cellular communications on sharing the licensed RBs. Thus appropriate RB allocation is utmost important to mitigate the interference. Modified Hungarian method can be used to arrive at an efficient RB allocation algorithm for D2D multicasting in such competing scenario. Let us demonstrate it with an example considering in [20] to explain a methodology which can lead a substantially better performance. The requesting communication link and possible interference scenario among different users is shown in Figure 1. We have mapped eight jobs as requested communication links enveloping cluster based users and non cluster users and the available RBs are considered as machines. Note that we have considered 5 number of such available RBs. The obtained data rate on each RB is also shown in Table I. The working principle of modified methodology is based on the following steps:

- Consider the maximum value of each column and subtract each cell value of that particular column from the maximum cell value which results atleast one 0 in each column as shown in Table II.
- Assign corresponding RB represented by the particular row to all the requested links represented by 0 and mark them as served.
- In case of multiple 0 in a single column, allocate the link to the RB which has minimum 0, thus represents minimum assigned load to that RB.
- After allocating RB to a particular link, remove remaining 0s of that particular column as presented in Table III.
- Assignment of the RBs to the requested links that maximizes the sum-rate of the whole network are depicted in Table IV.

We argue to address an efficient RB allocation with interference mitigation that can maximize the overall network performance using modified Hungarian method.

V. Proposed Interference Aware resource allocation Algorithm

The idea of the proposed approach is to establish underlay D2D communication for the boundary users with appropriate RB allocation among the set of requested pairs denoted by $\mathcal{U}_B$. First the user pairs which are nearest from the BS are identified as cellular user pairs represented as $\mathcal{U}_C$. Then boundary users are selected to form different groups known as clusters and are served through D2D multicasting. These users are represented as $\mathcal{U}_D$, clusters are represented by the set $\mathcal{M}$ and cluster heads are represented by the set $\mathbb{CH}_{temp} = A_1, A_2 \dots A_n$ where $1 \leq n < Q$. Users which can not be included into any clusters are considered as non-cluster users and denoted by the set $\mathcal{U}_N$. We allow these users for establishing a direct D2D link between them by checking the availability of the RBs. Based Modified Hungarian algorithm [20] and our framed methodology explained in Section IV, we have formed a table $\widehat{A}$ where we found the suitable RB allocation among the cluster based users and non-cluster users by considering data-rate as primary concern to maximize the overall network performance. Note that the proposed approach converts the modified Hungarian method from minimization problem to maximization problem by subtracting all the elements of a column from the largest element of that column of $\widehat{A}$. The formal descriptions of cluster formation and RB allocation are described in Algorithm 1 and Algorithm 2 respectively.

TABLE I: Example list 1

	Link1	Link2	Link3	Link4	Link5	Link6	Link7	Link8
RB1	300	250	180	320	270	190	220	260
RB2	290	310	190	180	210	200	300	190
RB3	280	290	300	190	190	220	230	260
RB4	290	300	190	240	250	190	180	210
RB5	210	200	180	170	160	140	160	180

TABLE II: Example list 2

	Link1	Link2	Link3	Link4	Link5	Link6	Link7	Link8
RB1	0	60	120	0	0	30	80	0
RB2	10	0	110	140	60	20	0	70
RB3	20	20	0	130	80	0	70	0
RB4	10	10	110	80	20	30	120	50
RB5	90	110	120	150	110	80	140	80

TABLE III: Example list 3

	Link1	Link2	Link3	Link4	Link5	Link6	Link7	Link8
RB1	[0]	60	120	[0]	[0]	30	80	$\otimes$
RB2	10	[0]	110	140	60	20	[0]	70
RB3	20	20	[0]	130	80	[0]	70	[0]
RB4	10	10	110	80	20	30	120	50
RB5	90	110	120	150	110	80	140	80

TABLE IV: Example list 4

	Requested Link	Sum-rate
RB1	Link1, Link4, Link5	300, 320, 270
RB2	Link2, Link7	310, 300
RB3	Link3, Link6, Link8	300, 220, 260
RB4	-	-
RB5	-	-

TABLE V: Parameter list

Parameters	Value
Cellular layout	Single cell
File size	1 Mbits
System bandwidth	5 MHz
Threshold data rate	7 Mbps
Power gains factor	-33.58 dB
Noise power σ^2	-107 dBm
Path loss exponent α	4
Shadow fading standrad deviation	4 dB
BS transmit power	46 dBm
D2D radius	$50 - 100$ meters

VI. Performance analysis

The proposed approach is evaluated considering different performance metrics such as number of cluster heads, number of served users, sum rate, number of requests and spectral efficiency. A comparative study with well known incremental approach [21, 15] is also presented.

Algorithm 1: *Interference aware D2D multicasting*

Input: $\mathcal{U}$, set of RBs $\mathcal{W} = W_1, W_2 \ldots W_{K^*}$, D2D radius $\mathcal{R}_{Th}$, BS coverage distance $\mathcal{R}_{BS}$
Output: $\mathcal{U}_B, \mathcal{U}_{Ce}$, cluster based served user set $\mathcal{U}_{Cl}$, set of non-cluster users $\mathcal{U}_N$

//Initialization
  $\mathcal{U}_B \leftarrow \emptyset, \mathcal{U}_{Ce} \leftarrow \emptyset, \mathcal{U}_{Cl} \leftarrow \emptyset, \mathcal{U}_N \leftarrow \emptyset$;
while $\mathcal{U} \neq \emptyset$ **do**
  for *all* $K_i \in \mathcal{U}$ **do**
    Compute the distance D_{Ki} from BS to K_i ;
    if $D_{Ki} \geq \mathcal{R}_{BS}$ **then**
      Update $\mathcal{U}_B = \mathcal{U}_B \cup \mathcal{K}_i$;
    else
      Update $\mathcal{U}_{Ce} = \mathcal{U}_{Ce} \cup \mathcal{K}_i$;
for *all* $J_i \in \mathcal{U}_{Ce}$ **do**
  Select any one RB $w^* = W_1, W_2, \ldots W_{K^*}$ from the set $\mathcal{W}$;
  Assign RB w^* to J_i ;
  Update $\mathcal{W}_{w^*} = \mathcal{W}_{w^*} \cup J_i$;
for *all* $J_i^{'} \in \mathcal{U}_B$ **do**
  $C \leftarrow 0$;
  $Mem_{J_i^{'}} \leftarrow 0$;
  Consider $J_i^{'}$ as reference user;
  Set $\mathcal{U}_B^{'} \leftarrow \mathcal{U}_B - J_i^{'}$;
  for *all* $Z_i^{'} \in \mathcal{U}_B^{'}$ *where* $J_i^{'} \notin \mathcal{U}_B^{'}$ **do**
    Compute distance $\Re$ between $J_i^{'}$ and $Z_i^{'}$;
    if $\Re \leq \mathcal{R}_{Th}$ **then**
      $C \leftarrow C + 1$;
      Save $Z_i^{'}$ as a receiver of $J_i^{'}$ represented by the set $Mem_{J_i^{'}}$
  if $C \geq 2$ **then**
    Assign $J_i^{'}$ in temporary cluster head set $\mathbb{CH}_{temp}$;
  else
    if $C = 1$ **then**
      $\mathcal{U}_N = \mathcal{U}_N \cup J_i^{'}$;
      Save $Z_i^{'}$ as the direct receiver of $J_i^{'}$ represented by the set $Mem - Direct_{J_i^{'}}$;
      $Mem_{J_i^{'}} \leftarrow 0$;
    else
      Reject $J_i^{'}$
for *all* $A_x \in \mathbb{CH}_{temp}$ **do**
  Design a Matrix $\widehat{A}$ using Algorithm 2;
Return $\mathcal{W}$, $\mathbb{CH}_{temp}, \mathcal{U}_N$;

Algorithm 2: *Interference aware RB allocation*

Input: $\mathcal{W}$, $\mathbb{CH}_{temp}$
Output: $\widehat{A}$, Sumrate of the users $\mathbb{S}_{rate}$, allocated RB set $\widehat{W}$

while $\mathbb{CH}_{temp} \neq \emptyset$ **do**
  for *all* $A_x \in \mathbb{CH}_{temp}$ **do**
    Find longest distance receiver of A_x from its corresponding set Mem_{A_x};
    for *all* $\widehat{w} \in \mathcal{W}$ **do**
      Computer datarate $\nu^w_{Mem_{A_x}}$ of Mem_{A_x} on w and put in $\mathcal{L} \times \mathcal{J}$ table of $\widehat{A}$. $\mathcal{L}$ represents number of available RBs b present in the set $\mathcal{W}$ and $\mathcal{J}$ represents number of D2D requests including cluster based link and non cluster based link;
while $\mathcal{U}_N \neq \emptyset$ **do**
  for *all* $Dir_y \in Mem - Direct_{J_i^{'}}$ **do**
    for *all* $\widehat{w} \in \mathcal{W}$ **do**
      Computer datarate $\nu^w_{Dir_y}$ on w and put in the table of $\widehat{A}$;
for *all* $J_p \in \mathcal{J}$ **do**
  Find maximum value of each column J_p^{Max} and subtract each cell value J_p^{Val} of that column from the maximum value $J_p^{Res} = J_p^{Max} - J_p^{Val}$ which results atleast one 0 in each column, $1 \leq p \leq (\mathbb{CH}_{temp} + \mathcal{U}_N)$;
for *all* $K_q \in \mathcal{L}$ **do**
  for *all* $J_p \in \mathcal{J}$ **do**
    Search all zeros of row K_q , $1 \leq q \leq K^*$;
    By checking the minimum O on RBs assign corresponding RB represented by the row K_q to all links represented by 0 and mark as served.;
    Add the cell values $\mathbb{S}_{rate} = \mathbb{S}_{rate} + \nu^w_{K_q J_p}$;
    Delete remaining zeros of the same column;
Return $\widehat{A}$, $\mathbb{S}_{rate}$, $\widehat{W}$;

A. Simulation environment

We have performed the entire simulations using NS2 through a realistic model of the simulation environment. The major simulation parameters are listed in Table V. A random distributions of users in an area of 500×500 square meters is considered with the BS positioned at the center. The users at the periphery constitute the focus group, being situated within the limited coverage range of the BS. The number of users considered is 150 - 400 incrementing in a step of 50 from which the requesting boundary users are identified.

B. Results and discussion

In Figure 2, we plot number of CHs formulated for different number of requesting boundary users considering two different available RBs. It is evident that the number of CHs is increasing with the increase in the user density for both the available RBs due to increase in number of clusters to accommodate the increasing users. Further, for fixed number of users, increasing the available RBs also causes an increase in number of CHs because flexibility of having more RBs causes a suitable number of users to be served with more desired rate through more number of formulated clusters also evident in Figure 4. This establishes the judicious allocation of the RBs from the proposed approach.

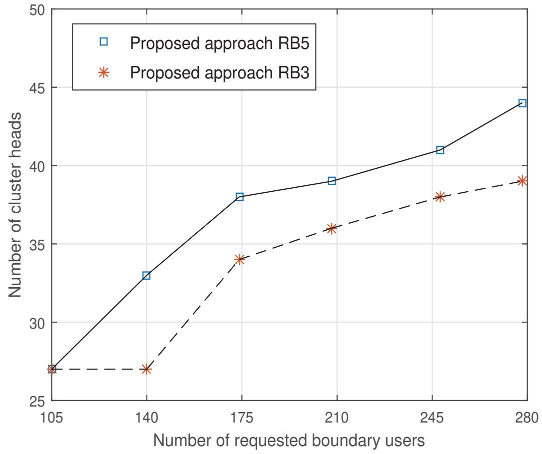

Fig. 2: Number of CHs vs Number of requested D2D users

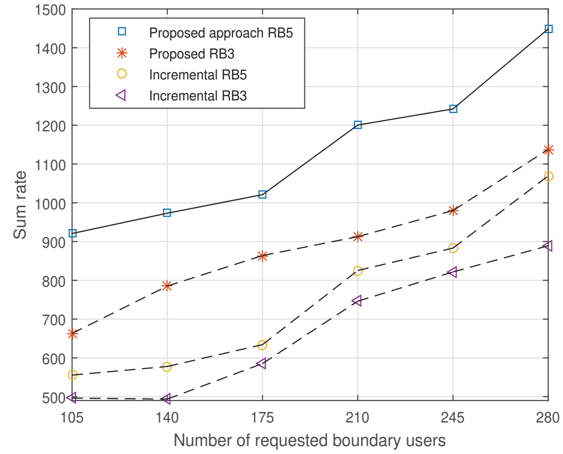

Fig. 4: Sumrate vs Number of D2D users

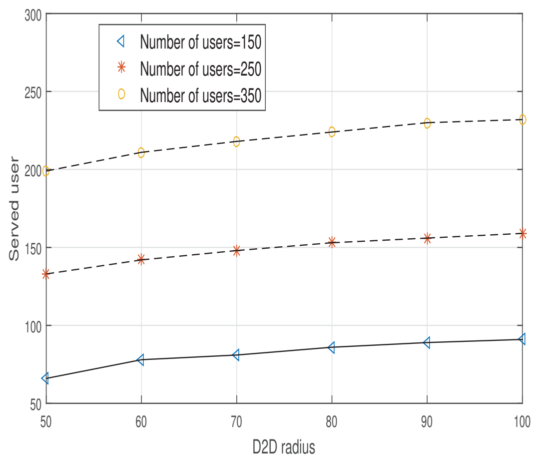

Fig. 3: D2D radius vs Served users

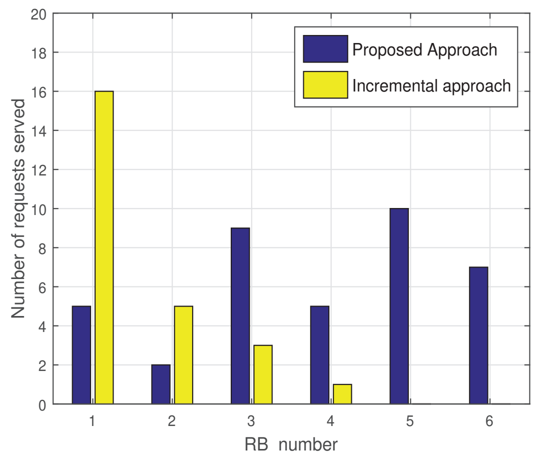

Fig. 5: Number of request served vs RB number

In Figure 3, we consider service coverage as performance metric where we vary the D2D radius from 50 meters to 100 meters and plot the number of served users considering a fixed number of RBs as 5. The results are for three different number of users. It is evident that the served users are increasing with the increase in D2D radius which is quite expected. Interesting to note, even with fixed RB and fixed radius there is a proportional increasing trend of service coverage with the increase in network load. This justifies our efficient clustering approach with appropriate RB allocation.

In Figure 4, considering two different available RBs of 3 and 5, we present a comparative study on obtained sum-rate between the proposed approach and the well known incremental frequency assignment approach. Here, we notice an increasing trend of obtained sum-rate with the increase in the number of requesting D2D users as expected. However, we also observe that the performance of the proposed approach outperforms incremental approach as the proposed approach judiciously assigns the RBs with appropriate clustering to satisfy the requested link. On contrast, incremental approach only consider the first available RB in sequence to satisfy the request.

Next, we consider a set of 6 available RBs and present a comparative results on number of served requests from our proposed approach and incremental approach. As shown in Figure 5, the proposed approach ensures a comprehensive distribution of users across the available RBs by truly evaluating the network load and thus causes better spectrum utilization. The incremental approach fails to study the network load and results in inefficient usage of spectrum resources.

In Figure 6, we compare the performance of the proposed approach in terms of spectral efficiency. In this simulation, we have considered two different number of available RBs such as 3 and 5 and fixed D2D radius of 50 meters. We observe that there exists an increasing trend in spectral efficiency with the increase in the number of users as well as the number of RBs which is expected. However, the proposed approach outperforms the incremental assignment policy in all cases.

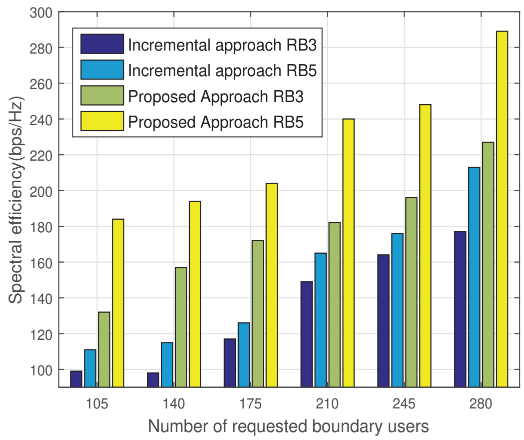

Fig. 6: Spectral efficiency vs Number of Requested D2D users

Our approach uses modified Hungarian method that causes our efficient clustering with uniform distribution of served users among the available RBs resulting in an enhanced performance in comparison to the incremental approach.

VII. Conclusion

Appropriate RB allocation plays a pivotal role to determine the network performance in underlay D2D communications which is mainly based on opportunistic spectrum use. This is because, such networks operate on limited availability of spectrum resources and this demands efficient usage of available spectrum. This paper addresses the application of modified Hungarian method for efficient RB allocation in cluster based D2D communications. It has been shown that the proposed approach not only results in improved performance in comparison to the other well known approach but also results in effective use of available RBs to provide suitable service coverage.

References

[1] F. Jiang, L. Zhang, C. Sun, and Z. Yuan, "Clustering and resource allocation strategy for D2D multicast networks with machine learning approaches," *China Commun.*, vol. 18, no. 1, pp. 196-211, 2021.

[2] K. Shamganth and M. J. N. Sibley, "A survey on relay selection in cooperative device-to-device (D2D) communication for 5G cellular networks," *Int. Conference on Energy, Communication, Data Analytics and Soft Computing*, pp. 42-46, 2017.

[3] M. M. Salim, H. A. Elsayed and M. S. Abdalzaher, "A survey on essential challenges in relay-aided D2D communication for next-generation cellular networks," *J. of Netw. and Computer Applications*, vol. 216, pp. 103657, 2023.

[4] M. S. M. Gismalla et al., "Survey on Device to Device (D2D) Communication for 5GB/6G Networks: Concept, Applications, Challenges, and Future Directions," *IEEE Access*, vol. 10, pp. 30792-30821, 2022.

[5] K. Ali, H. X. Nguyen, Q. -T. Vien, P. Shah and Z. Chu, "Disaster Management Using D2D Communication With Power Transfer and Clustering Techniques," *IEEE Access*, vol. 6, pp. 14643-14654, 2018.

[6] T. Kim and M. Dong, "An Iterative Hungarian Method to Joint Relay Selection and Resource Allocation for D2D Communications," *IEEE Wireless Communications Letter*, vol. 3, no. 6, pp. 625-628.

[7] J. Steffi and S. Nandakumar, "A review on resource allocation techniques in D2D communication for 5G and B5G technology," *Peer-to-Peer Networking and Applications*, vol. 14, pp. 243-269, 2021.

[8] D.H. Kim and S.J. Oh, "Multi-channel-based scheduling for overlay inband device-to-device communications, *Wireless Network*, vol.23, no. 8, pp. 2587-2600, 2017.

[9] M. Waqas, W. Ejaz, G.A.S. Sidhu and S. Aslam, "Resource optimization of D2D-assisted CR network With NOMA for 5G and beyond systems," *IEEE Internet Things J.*, vol. 9, no. 21, pp. 21232-21245, 2022.

[10] S. S. Moghaddam and N. Afzalkhani,"A Munkres-Based D2D Resource Allocation Algorithm Aware of Cluster Information," *2022 Workshop on Microwave Theory and Techniques in Wireless Communications*, pp. 171-176, 2022.

[11] P. Huu, M. A. Arfaoui, S. Sharafeddine, C. M. Assi and A. Ghrayeb, "A Low-Complexity Framework for Joint User Pairing and Power Control for Cooperative NOMA in 5G and Beyond Cellular Networks," *IEEE Trans. on Communications*, vol. 68, no. 11, pp. 6737-6749, 2020.

[12] H. Masoumi, M. J. Emadi and S. Buzzi, "Coexistence of D2D Communications and Cell-Free Massive MIMO Systems With Low Resolution ADC for Improved Throughput in Beyond-5G Networks," *IEEE Trans. on Communications*, vol. 70, no. 2, pp. 999-1013, 2022,

[13] M. Sun, X. Xu, X. Tao and P. Zhang, "Large-Scale User-Assisted Multi-Task Online Offloading for Latency Reduction in D2D-Enabled Heterogeneous Networks," *IEEE Trans. on Network Science and Engineering*, vol. 7, no. 4, pp. 2456-2467, 2020.

[14] I. Raziah, Y. Away and N. Nasaruddin, "An Adaptive Best Relay Selection for Energy Efficient Cooperative D2D Communications," *2019 Int. Conference on Radar, Antenna, Microwave, Electronics, and Telecommunications*, pp. 69-73, 2019.

[15] F. Afroz, K. Sandrasegaran and H. Al Kim, "Interference Management in Lte Downlink Networks", *Int. J. of Wireless & Mobile Networks (IJWMN)* vol. 7, No. 1, pp. 91-106, 2015.

[16] P. Mukherjee and T. De, "Content Independent Location Based Clustering for 5G Device to Device Communications." *Wireless Pers. Commun*, vol. 118, pp. 2573-2599, 2021.

[17] A. Vaishnav, A. R. Swain and M. R. Lenka, "Improved Affinity Propagation Clustering for D2D Communication in 5G," *2022 OITS International Conference on Information Technology (OCIT)*, pp. 403-408, 2022.

[18] S. Alemaishat, O. A. Saraereh, I. Khan and B. J. Choi, "An Efficient Resource Allocation Algorithm for D2D Communications Based on NOMA," *IEEE Access*, vol. 7, pp. 120238-120247, 2019.

[19] B. P. Tewari and S.C. Ghosh, "Wi-Fi assisted 5G D2D communications in unlicensed spectrum," *J Ambient Intell Human Comput*, vol. 13, pp. 1715-1734, 2022.

[20] Q. Rabbani, A. Khan, and A. Quddoos, "Modified Hungarian method for unbalanced assignment problem with multiple jobs," *Applied Mathematics and Computation*, vol. 361, pp. 493-498, 2019.

[21] P. Mukherjee and T. De, "Energy Aware Cluster Head Rotation for D2D Multicasting," *10th Int. Conference on Signal Processing and Int. Networks*, pp. 840-845, 2023.