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Diverse Resource Allocation Techniques in D2D Networks

Rishabh Chakraborty, Rohit Agarwal, Srishti Mallick, K. Saravanan

Abstract: ***D2D communication is going to be the upcoming technology which is going to change the era of wireless networks due to its flexibility. Due to the limited availability of Spectral resources, the co-channel interference is increasing. Co- channel interference occurs when number of User Equipment (UEs) share the same frequency block or commonly known as Resource Block (RB). Many researchers have ideated different Resource Allocation (RA) algorithms using modern optimisation methods like Fuzzy Logic, Game theory, Graph colouring and clustering. RA helps to provide proper channel to UEs and thus ensures proper utilisation of spectrum which is limited. With proper RA, the overall interferences can be mitigated easily and therefore it enhances the parameters such as QoS (Quality of Service), SNR, Throughput, power consumption, etc which are used to check the quality of the wireless network. In this paper review of these various RA methods, literature and deep analysis for clustering algorithm is carried out for different values of RBs and comparison Data Rates for various values of Bandwidth. A modified Spectral clustering method is propounded which will handle the number of clusters formation on the basis of requirements. The proposed RA technique is going to deal with the interferences step by step using modified Greedy algorithm and minimise the interference value until it can't be further minimised. Data Rate is calculated using Shannon's Theorem from the SINR values obtained.***

Keywords: ***Clustering, Co-channel interference, D2D, Data Rate, RA, SNR and spectrum.***

I. INTRODUCTION

Device to device communication (D2D) is going to be an auspicious technology due to its added advantages. This makes D2D a propitious technology in modern world.
Some of these advantages are (1) Direct communication between two UEs with or without involvement of BS (2) More power savings due to closer distance among the devices connected (3) Enhances energy efficiency (4) Reduces Delay (5) More flexible and can be easily integrated with any device.

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***** Correspondence Author
Rishabh Chakraborty*, Department of Electronics Engineering, Vellore Institute of Technology, Vellore, India. Email: imrish97@gmail.com
Rohit Agarwal, Department of Electronics Engineering, Vellore Institute of Technology, Vellore, India. Email: rohitagar771@gmail.com
Srishti Mallick, Department of Electronics Engineering, Vellore Institute of Technology, Vellore, India. Email: srishtimallick104@gmail.com
Saravanan K, Professor, Department of Electronics Engineering, Vellore Institute of Technology, Vellore, India. Email: kasisaravanan@vit.ac.in

Although D2D is having many advantages but it faces some challenges which are need to be recovered to make it more efficient. Some of these challenges are (1) Interference among Cellular UEs (CUEs) and D2D UEs (DUEs) (2) Handover (3) Peer discovery (3) Radio resource allocation (4) Energy consumption.

The main problem which is being faced by this technology is various types of interferences. Co- channel interference occurs due to limited number of frequency RBs used by many CUEs and DUEs in a given coverage area. The basic network diagram consisting of CUEs and DUEs can be observed in Figure 1 shown below.

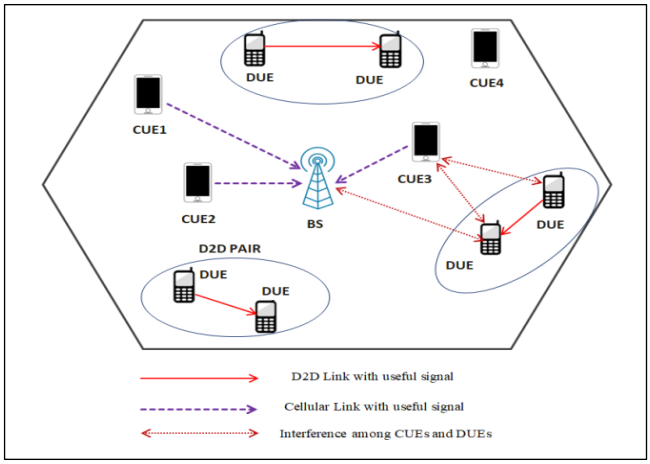

Figure 1 Pictorial representation of a network

Thus interferences are the undesired signals which occur between CUEs to CUEs, DUEs to DUEs, CUEs to DUEs and DUEs to DUEs. Among them the most harmful interference is between CUEs to DUEs as we already have many CUEs whole over the entire world and additionally increasing a new technology is going to create hindrance to the existing technology. Thus to mitigate this co- channel interference many novel schemes have been propounded which will allow proper channel to the UEs based on the level of interferences. Due to which the Signal to Interference Noise Ratio (SINR) increases gradually which further enhances the Data Rates of the network. Now we are in the world of Machine learning, Artificial Intelligence, Data Science and numerous amounts of data are easily available as technology is getting smarter day by day. Therefore, many researchers have proposed novel methods for optimizing the radio RA technique using Fuzzy logic, clustering, Spectral clustering, Graph colouring approaches.
In this paper we are going to highlight the merits and demerits of these propounded algorithms.

And also do an analysis on the clustering methods to mitigate the critical interferences faced in a D2D network. Additionally, we have plotted the interference curve, SINR curve and comparison of Data Rates for our proposed algorithm as well.

II. LITERATURE STUDY

This section will highlight on theoretical aspects of study. It will include different proposed algorithms and their merits and demerits in reducing overall co-channel interference in a network by providing proper channel to the UEs.

1. L. Zhuoming, C. Xing, Z. Yu, W. Peng, Q. Wei and L. Ningqing, "Fuzzy mathematics and game theory based D2D multicast network construction," in Journal of Systems Engineering and Electronics, vol. 30, no. 1, pp. 13-21, Feb.2019, doi: 10.21629/JSEE. 2019.01.02. In this paper modeling of multicast network of D2D communication was carried out with latest mathematical approaches namely Fuzzy logic and Game Theory. They have generally distributed their work into two major steps (1) Assembling all the terminals (2) Formation of network terminal those lie in the same group.

Before assembling all the terminals it was assumed hypothetically that all the terminals would receive the same information while sharing data regionally and also can easily detect the available frequency. They have grouped the users showing same characteristics with some relay using clustering. Then a multi cast tree like network is formed in which the UEs can detect the state of the channel and share better links with different UEs. In this network, the BS is the main parameter and the UE closer to the BS transmits data. The model is made in such a way that each node gets the best channel and thus maintains the high speed.

Hereafter, the main idea was to check the allocated resources in different groups formed. The terminals which are associated with them can reuse these cellular resources from other UEs, but the process becomes more serpentine. Therefore, they proposed a distributed algorithm on the idea of member and membership using Fuzzy logic. Using this uncertain relationship among the terminals and the available frequency resources were justified. They made a big assumption that the terminals which are associated with their model has the capability to sense the Spectrum, easily synchronize and search on their own in D2D communication. Thus as the UEs can easily detect the frequency available for them and the number of iterations in the process is also less, due to which the process becomes faster and the load in BS is reduced to certain extent.

The main advantage of their proposed model is that there is multicasting and multicast network always performs better and even if network failure occurs in any group, the other group can work easily. The added advantage in their proposed model is that in every step the performance of the system gets better and thus delay doesn't occur in the process and therefore it provides higher speed. But the main challenge is that as we know Fuzzy logic is itself based on assumptions and they have made some additional assumptions that the UEs can detect the best frequency resource on its own. Additionally, the UE closest to the BS might initially get the best channel, but as it is connected to other UEs and if the other UEs can't detect the best frequency resource automatically, then the complete process will face an error.

2. L. Zhao, H. Wang and X. Zhong, "Interference Graph Based Channel Assignment Algorithm for D2D Cellular Networks," in *IEEE Access*, vol. 6, pp. 3270-3279, 2018, doi: 10.1109/ACCESS.2018.2789423. In this paper, a greedy algorithm is used for the allocation of channel with the help of Graph colouring approach. Here, each channel is associated with a colour and the number of colours is equal to the number of channels. The bidirectional graph contains all the information of the interference. The interference is mitigated by colouring all the vertices of the Graph by following the colouring algorithm. The sole idea is to colour all the uncoloured edges of the graph. The initial step of the algorithm assigns different channels to each UE one by one. The next step is to assign the best fit colour to the uncoloured vertex which minimizes the overall interference. Now, the need is to find the colour that has not been used in the largest of the neighbourhood. This allotment is done based on the sum of suffered interferences of the user equipment, where the node with the highest interference is served first. Consequently, the served vertex is removed from the set. In this way, the interference suffered at a vertex is minimized. The algorithm terminates when all the vertices of the graph have been assigned a colour. The main drawback is that they did not consider the effect of channel allocated to different UEs initially and the interferences associated with them.

3. Huang, Xu&Zeng, Mengjia& Fan, Jing & Fan, Xiangxiang& Tang, Xuefeng. (2018). A Full Duplex D2D Clustering Resource Allocation Scheme Based on a K -Means Algorithm. Wireless Communications and Mobile Computing. 2018. 1-8. 10.1155/2018/1843083.In this paper single cell network is considered for resource allocation. To reduce the complexity and the intensity of frequency interference, they have divided the model into limited area of D2D communication and the limited area where DUEs reuses. The important point to be taken into consideration here is that the DUEs decided to reuse the uplink resources of the CUEs. Here, it was assumed initially that the distance between the BS and the UEs in space is known by the BS itself. They have done a logarithmic distribution to put the CUEs and DUEs in the network. As the distance between the BS and the DUE decreases, there is more prone to interferences. So, to overcome this they proposed a model in which they tried to make the D2D coverage area smaller. A threshold value of interference is calculated and the interference received at the BS due to the DUE is compared with this threshold value. So, by using K-means clustering they clustered the coverage areas on the basis of the interference level of the D2D pairs. As the distance between DUEs decreases, interferences associated with it increases. So taking this basic principle into consideration their proposed model is subdivided into four basic steps after formation of clusters: (1) Randomly select any cluster out of all the clusters formed (2) The distance between them is calculated and the inverse of it is added to the smallest interference value in that cluster. (3) The summed square (i.e. total summation squares subtracted from mean value) is calculated for the cluster centre and the points of UEs suffering from interference in that particular cluster. (4) By using least square principle and Lagrange principle, the average value is calculated for UEs in all the clusters and iteration is done until the cluster with minimum interference level is shown.

Additionally, they modified the RA and spectrum utilisation by taking into consideration about the QoS.

The main advantage of this model is that they are taken into consideration about all the interferences occurring in a CU and DU network as discussed in section 1n their RA they allocated the RB of CU to the best D2D pairs which suffer minimum interference.

Thus it increases the overall system performance. However as K-means is only limited to distance measured but interference is not only a function of distance.

4. Kasi, S.K., Naqvi, I.H., Kasi, M.K. et al. Interference management in dense inband D2D network using spectral clustering & dynamic resource allocation. Wireless Netw 25, 4431–4441(2019), In this paper the Resource Allocation algorithm is used to mitigate the intra-clustering interference. Initially they performed Spectral clustering using modified kernel weights. The DUEs are distributed into various clusters. Intra cluster interference is the interference at each UE due to other UEs within the same cluster sharing the same RB. The number of UEs is much more than the number of RBs in a network. Hence, the objective is to reduce the intra-cluster interference in each cluster. A heuristic RA algorithm has been developed that minimizes the intra cluster interference for each cluster. Grouping each UE in a cluster and likewise covering all the clusters in a given area, then the formation of intra cluster degree vectors for all the graph edge combination. Then the cluster with the maximum intra clustering interference is found out. Also, the UE which experiences the maximum interference is ascertained. Now for this UE, find the best frequency resource for which the intra cluster interference is minimized, through exhaustive search. The graph edges of the similarity graph of Spectral clustering are iteratively updated after each step. The procedure is repeated until the least interference value has been found and the intra-clustering interference cannot be minimized further. The minimum intra cluster interference is calculated at the cost of computation. However, the work done is extraordinary but still the number of cluster formation can still be reduced by forming less Eigen vectors of the Laplacian matrix in Spectral clustering. Co-channel interference decreases as the number of clusters reduces. So, by further normalisation in their process the formation of clusters can be reduced to some extent.

III. CLUSTERING ANALYSIS

While performing clustering, recently most of the researchers follow two approaches as we can see in Figure 2 and Figure 3.

In the first model of clustering method, the main objective is formation of a Cluster Head (CH). CH is the advanced node out of all the nodes in a network. The other nodes are known as sensor nodes. CH can collect data in the form of energy from all the sensor nodes connected to it. Hence, it has the maximum energy. In case of Wireless Network, the CH is directly linked to the BS.

In the second model different clusters are formed, each cluster may have personal BS or a single BS depending on the network topology. Here, there are no CHs and the nodes are interconnected to each other. The nodes which are linked to each other in the same cluster is called intra cluster and the nodes connected to the nodes which are in different clusters is called cross cluster.

The second model is better as compared to previous model as in this grouping of data is done both internally as well as externally. All the nodes connected to each other works as transmitter as well as receiver. So, when co-channel interferences occur in the network the levels of interference can be detected easily within a shorter period of time. Thus it reduces latency of the overall network. Moreover, the data can be collected easily using this model as the objects present in the clusters share some properties with the objects in same or different clusters. Thus it gives more appropriate data and

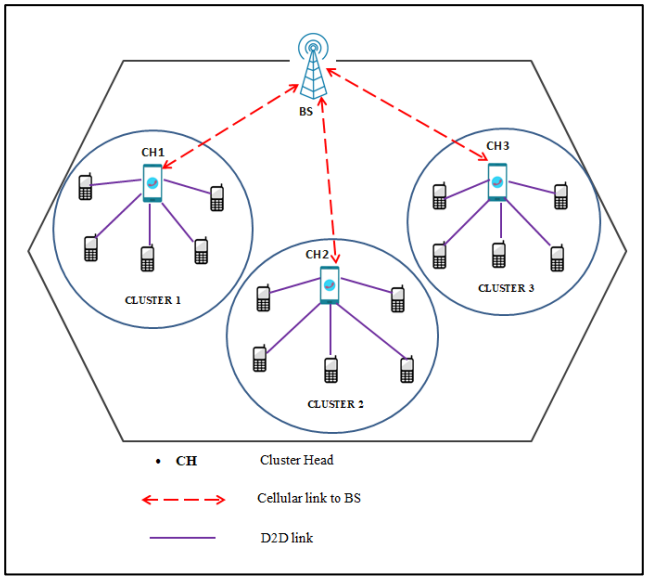

Figure 2 Clustering using the concept of CH

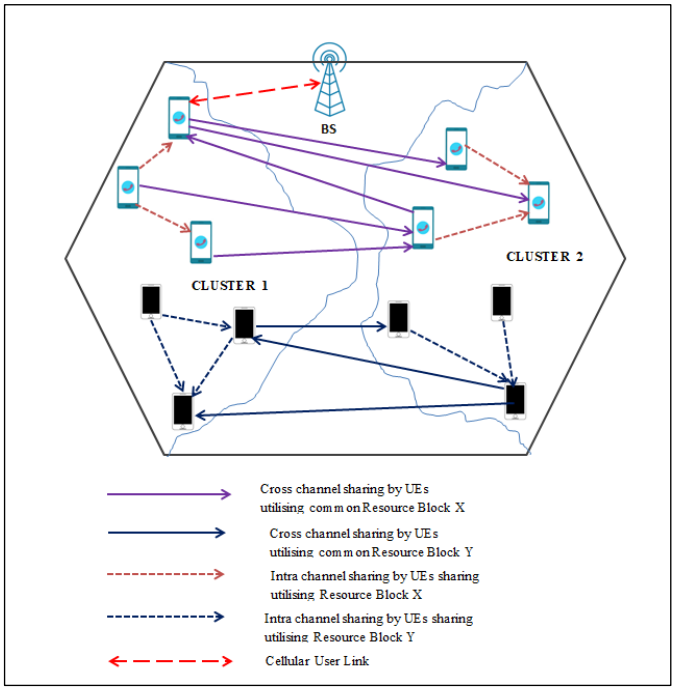

Figure 3 Clustering using the concept of intra and cross clustering

IV. PROPOSED ALGORITHM

This section will highlight about the processes involved in carrying out RA to mitigate the co-channel interference in a network. The corresponding graph which is simulated using MATLAB is also shown in this section for better understanding.

4.1. INTRODUCTION

The most important part of any Wireless network is to provide a proper channel by allocation proper frequency resources to them, so that they don't interfere with each other. It is because many users in a network share the same RB, so there is high probability of co-channel interference in a network. Resource Allocation is a function of frequency, space and time. So, allocation of proper spectrum is really mandatory to overcome these critical interferences.

Thus we proposed an efficient RA algorithm in a clustered environment as in Figure 3, where initially we checked the UEs sharing common RB. In a general D2D network if any one UE suffers from interference than it will transmit to the DUEs connected to it. In this way inter interferences occur from one UE to another. So, a novel RA algorithm is propounded which described using the Flow chart as shown in Figure 4. In our algorithm we have considered the effect of channel allocation after formation of clusters. In the figure 4, I represents the inter channel interference and d is the Euclidean distance between the DUEs. For comparative analysis, we have considered the proposed models of RA, in which channel effect was not considered initially. Due to which a huge deviation occurs in the proposed model as compared to previous models in mitigating co-channel interference from a denser in-band network.

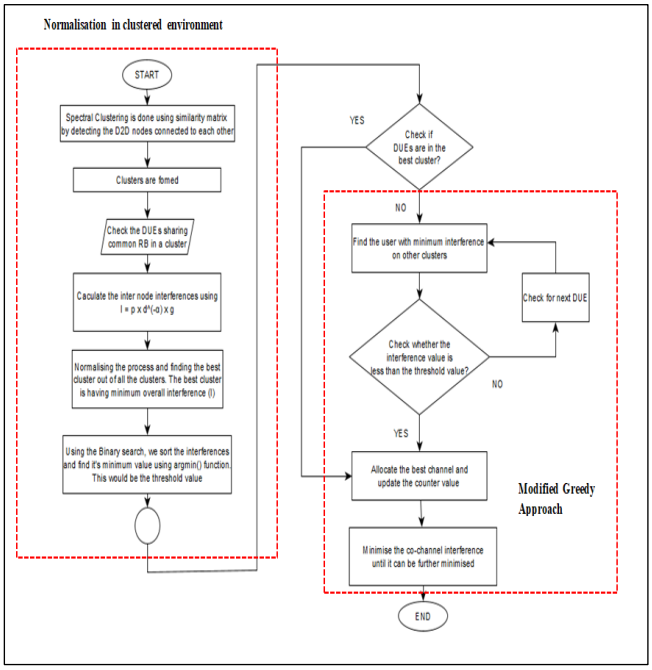

Figure 4 Proposed RA algorithm

Table 1 Simulation parameters

S. No	DESCRIPTION	VALUES
1.	Number of BS	1
2.	Number of DUEs	100
3.	D2D transmission power (p)	30 dBm
4.	Path loss exponent (α)	1.8
5.	SNR	6 dB
6.	Noise Spectral Density ($\mathcal{N}_0$)	7
7.	Bandwidth used (W)	10 MHz
8.	Maximum RBs	10

4.2. Observations

From the following simulated results, we can observe that as the number of RBs increases the deviation in the proposed model in mitigating interference is more as compared to previous models where channel effect is not considered at all. The huge deviation occurs due to increase in the gain value.

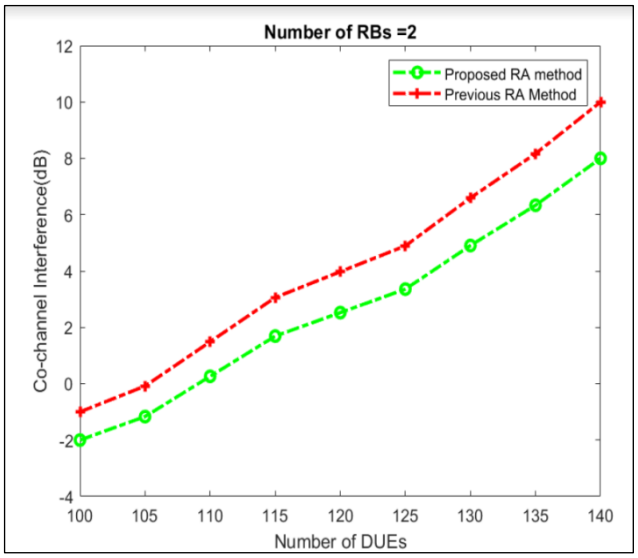

Figure 5 Average co-channel interference for 2 RBs

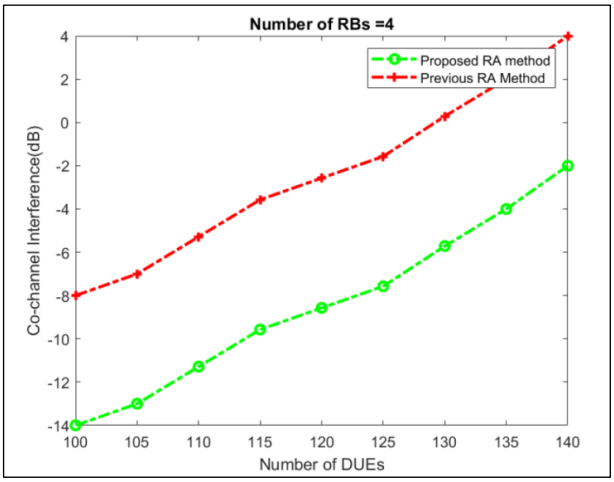

Figure 6 Average co-channel interference for 4 RBs

4.3 Executing SINR

Hereafter, to test the performance of the system, SINR is calculated. SINR, **φ**is given by the following equation 1,

$$\boldsymbol{\varphi} = \frac{\mathbf{p}\mathbf{d}_1^{-\alpha}\mathbf{g}}{\mathcal{N}_0\mathbf{W}+(\sum_{clusters}\mathbf{d}_2^{-\alpha}\mathbf{g})} \qquad \mathbf{(1)}$$

where,
p = Transmitted power of D2D user
φ= Ratio of useful power to sum of noise power and interference power
$\mathcal{N}_0$ = Noise Spectral Density
d_1 = Euclidean distance between nodes in space
g =Channel gain
α = path-loss exponent
d_2 = Euclidean distance between D2D nodes in the individual clusters

4.3.1 Observation of SINR

From the SNR curve, we can observe as the number of RBs increases the SNR value increases gradually which is a good indication.
The higher the SINR value better will be the performance of the system and better will be its channel capacity. Thus with the proposed model we obtained a linearly increasing curve for SINR. Initially, for number of RBs equal to 2, SNR is -0.5 dB and for the maximum RB used which is 10, the SNR increases by huge amount which equals to 29.3 dB.

Table 2 Data Rates for various Bandwidth and RBs used

S. No	Number of RBs used	SNR
1	2	-0.5 dB
2	4	12 dB
3	6	17.6 dB
4	10	29.3 dB

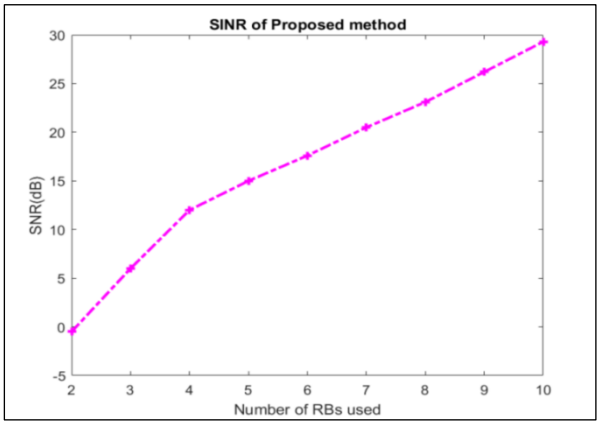

Figure 7 SINR

4.3.2 Data Rate

Data Rates for the network can be calculated with the SINR values obtained using Shannon's Theorem, which is given as

$$\sigma = W * \log_2(1 + \varphi) \qquad (2)$$

where, W= Bandwidth

A comparative analysis is performed for the Data Rates for different values of Bandwidth and number of RBs used.

Table 3 Data Rates for various Bandwidth and RBs used

S. No.	BANDWIDTH	σ for RB=2	σ for RB=5	σ for RB= 10
1	25 MHz	22.982 Mbps	125.695 Mbps	243.373 Mbps
2	50 MHz	45.967 Mbps	251.39 Mbps	486.74 Mbps
3	100 MHz	91.934 Mbps	502.78 Mbps	973.494 Mbps

From Table 3, we can see that there is a comparatively higher Data Rate in our proposed model as the number of RBs increases which is a good sign to measure the performance of the wireless network. Initially for number of RB=2 and BW=25 MHz, Data Rate is 22.98 Mbps and as number of RB increases to 10 the Data Rate increases by almost 10 times of the previous value. Thus, by mitigating the overall interference and assigning a proper channel to the UEs, Data Rates are increased to a larger extent which is a good sign as the demand of Data Rates are increasing day by day.
Using these parameters, a comparative bar graph is plotted for pictorial representation.

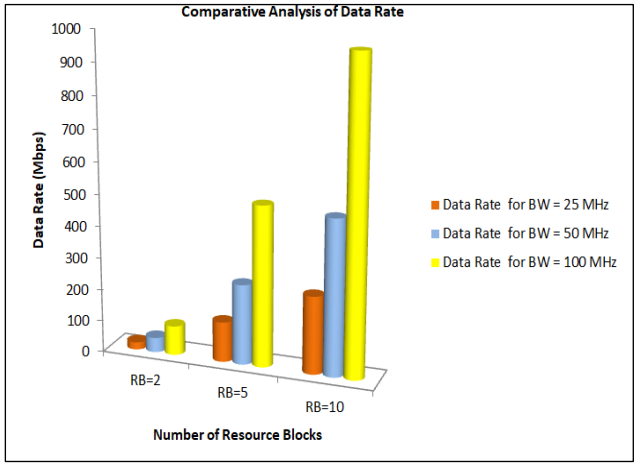

Figure 8 Comparisons of Data Rates

V. CONCLUSION

Mathematics has played an important role in today's world of AI, ML, and Data Science to tackle down any problem easily and making any process optimal. The normalising processes like Fuzzy logic, clustering, graph theory helps in compiling the data which shows similar characteristics. It is always easy to mitigate any problems if they are segregated out and buckled up into different groups and then handles them separately. Thus these techniques help in normalising any process faster and thus save a lot of time for programmers. We have seen their applications in different RA techniques for the upcoming D2D technology. Fuzzy logic is purely assumption based approach and can't be easily integrated with Machine learning applications. However, for normalising any process we can use it. The best method for making modern technology more optimal is clustering. Clustering using K-means, KPCA helps to group similar data easily and thus it makes the process simpler. However, in recent times Spectral clustering is dominating because of its added benefits as it is not limited to only distance based calculations as in traditional clustering methods like K-means. It is hybrid of clustering as well as Graph theory which makes it more optimal to tackle the critical interferences in a network easily. Therefore, to summarise Spectral clustering with the concept of intra cluster and cross cluster modeling gives better result in handling interferences in a dense network. In our proposed model we have seen the deviation in our interference graph and the reduction in interference value with the number of RBs used as compared to other models. Hence, it shows better interference removal capacity as compared to the previous RA models.

The increasing value of SINR depicts the performance of the system is enhanced as proper channel is allocated to the UEs one by one. The Data Rate increases which was the main goal as the demand of it increasing in due time.
The proposed model will also reduce the load in BS and therefore energy consumption will decrease and the process becomes faster. The delay in the network is reduced.

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AUTHORS PROFILE

Rishabh Chakraborty, is an undergraduate in his final year of B. Tech in Electronics and Communication Engineering from Vellore Institute of Technology, Vellore, India. His areas of interests are Wireless Networks, Algorithms, Data Structures, Computer Communication, Device to Device communication and Data Science. He was a core committee member of IEEE Communication Society student chapter in VIT for two years and conducted many seminars and participated in many hackathons.

Rohit Agarwal, is an undergraduate in his final year of B. Tech in Electronics and Communication Engineering from Vellore Institute of Technology, Vellore. His interests lie in the area of Software Development, Data Structures, Device to Device Communication and 5G.

Srishti Mallick, is an undergraduate in her final year of B. Tech in Electronics and Communication Engineering from Vellore Institute of Technology, Vellore. Her research interests are of Wireless Networks, Device to Device Communication and 5G.

Dr. Saravanan K, received M. Tech Degree in Electronics and Communication Engineering from Pondicherry Engineering College and Ph.D. from Anna University, Chennai. He is currently working as Professor in Department of Communication Engineering, VIT, Vellore. He published 12 papers in various National and International journals. His research interests are of Wireless Networks, Network Security, Device to Device communication and 5G.