

# Resource Allocation Algorithms for Indoor D2D Communication



K Dhivya, C.Arun, C Vidhya Shree, R Sweta, S Tamilarasi

**Abstract:** Device to Device (D2D) communication in cellular networks is defined as direct communication between two mobile users without traversing the data through the base station (BS). Indoor D2D communication refers to transmission between two users within a building or in a closed space. Resource allocation is a plan for using available resources efficiently and the resources are allocated for optimal functioning of the D2D network. The algorithms for optimizing D2D network is characterized by the parameters like matching network, noise, throughput maximization and few more. In this work, our aim is to develop resource allocation algorithms for indoor D2D communication. An efficient resource allocation algorithm for device to device communication and a suitable frequency allocation technique in order to avoid call blockage should be designed. The main challenge in this work is to allocate resources to D2D users without affecting cellular users efficiency. These optimal resource allocation works efficiently and also adapt to time and location variation. The process involved in each algorithm is elaborated.

**Keywords —** Resource Allocation, Indoor D2D, Base Station, Optimizing D2D Network, MATLAB.

## I. INTRODUCTION

D2D Communication in Cellular Networks is a technology through which two mobile users can communicate directly without traversing through the core network. D2D communication is a new concept in Cellular Networks. It allows User Equipments (UEs) in proximity to communicate using a direct link rather than having their radio signal travel all the way through the Base Station (BS) [1]. This technique plays a significant role in upcoming cellular networks as it promises less delay in communication between users. D2D user remains under the control of base station but communicate directly to other D2D users. In D2D communication, cellular users who are in proximity can exchange their information over a direct link.

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Thus, reducing the traffic load of the Base Station [2]. This D2D communication helps to save energy and resources. This improves data rate and reduces the transmission delay as it communicates directly to other users. It enhances the user experience at the cell edges. It is generally non-transparent to the cellular network and it can occur on the cellular frequencies or licensed spectrum. D2D communication through the BS has low data rate mobile service like voice call and text messaging in which users are in close space for direct communication. With increase in mobile users, the traffic rate will reach a peak limit. D2D helps to facilitate the inter-operability to improve the spectral efficiency in crowded communication networks. Recently, D2D communication in a cellular network has gained much popularity.

The merits of D2D communication in cellular networks are

- reducing the overloaded cellular traffic
- expanding the cellular coverage
- increasing energy efficiency
- high data rate transmission.
- spatial reuse of radio resource
- latency is reduced
- hop gain is improved

In terms of spectrum allocation D2D Communication follows either the overlay or the underlay approach [3]. Underlay D2D Communication has cellular spectrum containing direct links and cellular links and reuses the cellular resources thus improving the efficiency of the spectrum. In overlay D2D Communication, interference is reduced because a dedicated portion of available spectrum is used for D2D Communication and the rest of the spectrum is used for cellular communication [2].

Unicast D2D transmission provides communication between a sender and a receiver whereas multicast transmission is communication between a sender and multiple receivers with minimal usage of resources. Here in multicast communication, data rate are different for each receivers. Multicast transmission is categorized into two types namely

- (i) single rate.
- (ii) Multi rate transmission.

Former one transmits data with same rate to the receiver and the latter one transmits data with various rates. In wireless communication, the presence of fading leads to allocation of resources like power and frequency to maximize the system performance. There are various power allocation algorithms and few frequency allocation algorithms available.



5G will use spectrum in the existing LTE frequency range (600 MHz to 6 GHz) and in millimeter wave bands (24–86 GHz).

The paper is structured as the following. In Section II, we explained the evolution of D2D communication. In Section III, we present an overview of the resource allocating algorithms namely proportional fairness algorithm, heuristic resource allocation algorithm and coalition formation game algorithm. Finally, the conclusion and future work are given in section IV.

### II. EVOLUTION OF D2D

D2D communication is recognized as one of the technology components in the evolving 5G architecture as specified by the Third Generation Partnership Project(3GPP) release -12. It was first implemented in Qualcomm's FlashlinQ in 2010. The 5G technology uses the Beam Division Multiple Access (BDMA). D2D communication involves peer discovery. The 4th generation LTE system was originally designed to provide cellular broadband wireless communication for the users in specific frequency bands. The LTE network consists of several basestations. Due to increase of traffic in the network which is due to the increased number of users, the D2D communication was introduced. According to 3GPP, the short range wireless technologies like Wifi-direct, Bluetooth, LTE-direct can be used to enable the D2D communication. The D2D communication is classified into two groups namely Inband and Outband [4]. Inband is further classified as underlay and overlay networks whereas Outband is classified as network-controlled and autonomous. The autonomous category is further classified into in-coverage and out-of-coverage. Inband refers to the cellular spectrum whereas outband refers to the unlicensed spectrum. The advantage of inband D2D includes increase in spectral efficiency, Qos management is easy. The disadvantages of inband communication are complications in resource allocation, power control etc. D2D users and cellular users cannot transmit simultaneously. The advantages of outband communication include resource allocation is easy and interference is reduced. The disadvantages are power management is not efficient and the packets have to be encoded and decoded. The key techniques in D2D communication include D2D discovery, synchronization, communication mode switching, power control, interference coordination, wireless resource management. The parameters used for effective resource allocation are no of carriers, scheduling period, throughput, logarithmic sum of average user data rates of cellular and D2D users, SINR etc.

### III. RESOURCE ALLOCATING ALGORITHMS

Resource allocation is process of allocating the available resources efficiently. We need available resources to enable communication between two devices using a direct link. The resources available are frequency and power. Resource allocation is one of the crucial issues in D2D communication because the interference caused by the D2D users is high. Hence resource allocation is important. It is done to maximize the network throughput, minimizing delays,

achieving fairness among the data rates. There are four modes of resource allocation available. They are

- (i) Downlink resource allocation
- (ii) Uplink resource allocation
- (iii) Separate resource sharing
- (iv) Cellular mode sharing.

In this paper, we are interested in allocating frequencies to various users. Resource usage efficiency is increased if the resources are shared and high performance is achievable if the cellular users and D2D pairs exist in the same radio resources. There are three available methods for allocating resources.

- (i) Centralized resource allocation
- (ii) Distributed resource allocation
- (iii) Hybrid resource allocation.

There are many resources allocation algorithms available and this paper concentrates mainly on three resource allocating algorithms.

- A. Proportional Fairness Algorithm.
- B. Heuristic Resource Allocation Algorithm.
- C. Coalition Formation Game Algorithm.

Here, we discuss each resource allocation algorithms with its process and advantages.

#### A. PROPORTIONAL FAIRNESS ALGORITHM:

In this algorithm, resources are equally allocated to all the users and are based on holding a balance between two users. The main aim of this algorithm is to increase the network throughput and to maintain a basic quality of service to all users. Here we assume the scenario where resource blocks scheduling for cellular users are performed at the base station already. Then these resource blocks are reused by D2D users without affecting CUE's communication.

The resource blocks are allocated to D2D users and the information is communicated between these users.

Steps involved in this algorithm:

- Step 1 : Power and Gain of CUE & D2D pairs are obtained as input.
- Step 2 : Calculation of SINR, Sum rate & efficiency.
- Step 3 : Scheduling decisions are taken to allocate the resource to the users.
- Step 4 : Throughput and fairness are obtained and evaluated.

The power and gain of cellular users and D2D pairs are calculated which is used to calculate SINR. The difference between actual value and required value of SINR to guarantee the least rate to cellular users is exploited to allocate power to D2D users. Resource blocks are allocated to D2D users using Bipartite matching. These blocks are reused without affecting cellular user's efficiency [5].

This allocation depends on D2D channel condition and interference is caused to cellular user's transmission by D2D communication. Bipartite graph has two sets which are resource block set and D2D pair set. Weight is calculated by Maximum Weight Bipartite Matching (MWBP) and used

to allocate resource block to D2D users.

In this algorithm, resource allocation problem is divided into two parts [6].

- Power allocation
- Resource allocation

In power allocation, we assume that resource block is allocated to cellular users and so power allocation & scheduling is concentrated. Initially resource blocks are checked whether it can be shared among cellular users and D2D users. Then maximum rate of D2D pair is quantified which should not affect the cellular users efficiency and power is allocated to each users. In resource allocation, optimization problem is solved and weight is calculated.

Then the calculated weight is used to allocate resource blocks to D2D users without affecting Qos of cellular users. Finally fairness is investigated.

The advantages of proportional fairness algorithm are

- Sumrate is increased
- Throughput is increased
- Delay is reduced
- Interference is maintained
- QoS is improved

Using this proportional fairness algorithm, throughput with respect to distance as well as throughput with respect to number of users is increased. When more number of resource blocks are available, delay is reduced and throughput is further increased [7]. This resource block availability helps to maintain interference among the users and also quality of service is improved. PF algorithm maintains a good balance between throughput and fairness.

### B. HEURISTIC RESOURCE ALLOCATION ALGORITHM:

In this Algorithm, Resource Allocation can be done in a faster pace. This technique has less computational complexity than proportional fair algorithm and it provides reasonable performance. performance is formulated using logarithmic sum of user data rate.

The process of heuristic algorithm is done by three phases. The first phase is initialization process. In this phase, we will get the values of number of D2D Users, number of cellular users, number of resource block [8].

The second phase is about resource allocation for CUEs. In the final phase D2D users are allocated with resources.

Steps involved in this algorithm:

- Step 1 : Number of CUE, D2D users & resource blocks are obtained as input.
- Step 2 : The X & Y matrix are generated and calculated.
- Step 3 : Resources are allocated to the users.
- Step 4 : The output is obtained with reduced computational complexity and improved performance.

X matrix corresponds to cellular users and Y matrix corresponds to D2D users. The major problem persisting is to

check whether the resource blocks are available for all the existing users. This problem is called assignment problem.

To resolve the above problem, heuristic algorithm adopts Hungarian algorithm. Hungarian algorithm solves one to one assignment problem. This problem is divided into two scheduling problems

- (i) one carrier to CUE problem
- (ii) one carrier to D2D user's problem

Hungarian algorithm is applied to CUE problem first as CUE has high priority than D2D users. After solving this problem, scheduling will be done. The advantage of the heuristic algorithm are

- Simple
- Cheap
- Less computational complexity

It helps to allocate resources enhancing the efficiency, reducing the inference and maintaining Qos of cellular users and D2D users.

### C. COALITION FORMATION GAME ALGORITHM:

As mentioned in section I, the data traffic will be tripled up. So, in order to keep up the data traffic and growth of mobile users, we go for resource allocation in HCN (heterogeneous cellular networks). These networks consist of macro cells, micro cells, nano cells. Interference between users within a cell i.e. intra cell interference leads to spectrum sharing.

Coalition is used to optimize resource allocation, manage the interference and further enhance the system performance. Consider there are C cellular users and D number of D2D users.

There is C+1 coalition possible where the additional coalition is from mm Wave band. When the number of D2D pairs is increased in a coalition, the interference resulting will be high among users.

Mm Wave communication rate is very high than cellular communication. In this algorithm, every D2D pair as game players tends to form coalitions to share resources of cellular users or mm Wave resource to increase the system sum rate.

Steps involved in this algorithm:

- Step 1 : SINR & distance between sender and receiver are obtained as input.
- Step 2 : Calculation of achievable channel rate occupied by D2D pairs.
- Step 3 : Frequency and resources are allocated to users by switching operations within coalitions.
- Step 4 : Maximization of system sum rate is performed.

D2D pair can form coalition with cellular user or mm Wave to maximize the system sum rate. D2D pair can decide on which coalition to share resources based on the system sum utility. This algorithm tells on what strategy to be adopted by D2D pair to choose coalition and with whom to share resource.

This algorithm helps in finding a coalition structure which maximizes the overall system utility. The channel rate between all the users i.e.



coalitions is calculated and the maximum channel rate with corresponding users are considered for transmission. The result is system sum rate is maximized. The data traffic will be tripled up. So, to keep up the data traffic and growth of mobile users, we go for resource allocation in HCN (heterogeneous cellular networks). These networks consist of macro cells, micro cells, nano cells. Interference between users within a cell i.e. intra cell interference leads to spectrum sharing. Coalition is used to optimize resource allocation, manage the interference, and further enhance the system performance [10].

Consider there are  $C$  cellular users and  $D$  number of D2D users. There is  $C+1$  coalition possible where the additional coalition is from mm Wave band. When the number of D2D pairs is increased in a coalition, the interference resulting will be high among users. Mm Wave communication rate is extremely high than cellular communication.

In this coalition formation game algorithm, every D2D pair as game players tends to form coalitions to share resources of cellular users or mm Wave resource to increase the system sum rate. The channel rate between all the users i.e. coalitions is calculated and the maximum channel rate with corresponding users are considered for transmission. The result is system sum rate is maximized. The procedure of this algorithm is first D2D user is randomly chosen ( $D1$ ) and another user is selected randomly. That user can be cellular user or D2D user ( $U1$ ).

This  $U1$  and  $D1$  are grouped into one coalition. Then another user is selected randomly ( $U2$ ). The  $U2$  and  $D1$  form another coalition. The channel rate of two coalitions is calculated. In similar fashion,  $C+1$  coalition are created. The Resource allocation starts with getting inputs such as SINR and the distance between the required users and distance between those users and base station and these inputs are used for calculating the channel rates [11].

The channel rates are then compared continuously, and the maximum channel rate is identified. Then it is checked whether  $D1$  is in any one end of the channel, if not then  $D1$  is grouped to the channel having maximum rate to share its resources. In the similar fashion, resources for other D2D users are allocated using the maximum channel rate. When the number of D2D pairs is increased in a coalition, the interference resulting will be high among users. Mm Wave communication rate is extremely high than cellular communication.

This algorithm tells on what strategy to be adopted by D2D pair to choose coalition and with whom to share resource. This algorithm helps in finding a coalition structure which maximizes the overall system utility. The channel with highest rate is chosen and the users are allocated with the frequency of that channel. The user in need of resource is given this channel for its transmission of data. The result is system sum rate is maximized. Coalition games are categorized into four schemes [9] as

- Full Mm Wave Communication (FMC)
- Random Communication (RC)
- Cellular Coalition Game (CCG)
- Full Cellular Communication (FCC)

Full Mm Wave Communication (FMC) is a scheme where all the D2D pairs are interconnected through a direct D2D communication in mm Wave band, and every CUE occupies one of the cellular carrier channels without spectrum sharing. Random Communication (RC) is a scheme where the system allocates the available resources to the D2D pairs in a uniform random way. In other words, for any D2D pair, the system randomly selects a cellular user's spectrum resource or the resource in mmWave band.

Cellular Coalition Game (CCG) is a scheme utilizes coalition algorithm which performs switch operations based on well-defined preference order with a limited number of iterations to solve the problem of the resource allocation among cellular bands for multiple D2D pairs in cellular network.

Full Cellular Communication (FCC) is a scheme which uniform randomly allocates cellular users' uplink spectrum resources to the D2D pairs. This method is similar to RC but it does not involve any mmWave band because transmission rate of cellular communication is much smaller than that of mmWave communication.

## IV. CONCLUSION

In this paper, we investigated resource allocation techniques for indoor D2D communication and its resource allocation algorithms in order to avoid call blockage. D2D communication can improve the network efficiency and also limits the cellular users interference to maintain Qos. The resource i.e. frequency is allocated to various users based on the request order without affecting cellular users efficiency. In this way a secured and reliable connection is established between different D2D Pairs. An efficient resource allocation algorithm for device to device communication and a suitable frequency allocation technique is explained.

Future work involves simulation of the proposed algorithms in both indoor and outdoor D2D communication and to verify the efficiency of the cellular users. Also includes checking the effectiveness of the proposed algorithm in the real time application.

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