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A bipartite graph based proportional fair scheduling strategy to improve throughput with multiple resource blocks

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ABSTRACT

The fifth-generation wireless communication is expected to provide a huge amount of capacity to cater to the need of an increasing number of mobile consumers, which can be satisfied by device-to-device (D2D) communication. Reusing the cellular user's resources in an efficient manner helps to increase the spectrum efficiency of the network but it leads to severe interference. The important point in reusing cellular user resources is that D2D communication should not affect the cellular user's efficiency. After achieving this requirement, the focus is now turned toward the allocation of resources to D2D communication. This resource allocation strategy is to be designed in such a way that it will not affect communication among the cellular user (CU). This scheme improves various performance objectives. This paper aims at designing a proportional fair resource allocation algorithm based on the bipartite graph which maintains the quality of service (QoS) of CUs while providing D2D communication. This algorithm can be merged with any other scheme of resource allocation for improving QoS and adopting changing channels. In this scheme, a D2D pair can be allocated with one or more than one resource blocks. The MATLAB simulations analyze the performance of the proposed scheme.

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1. INTRODUCTION

As mobile communication providers struggle to meet the present demand of mobile users, new in-depth data apps are becoming more prevalent in mobile customers' daily lives (e.g., proximity service). In addition to this, despite having a very effective performance at both the physical and medium access control (MAC) layers, 4G cellular technologies are trailing behind cellular users' rising statistical need. As a result, academics are looking for brand new paradigms to modernize cell network voice call solutions. One of these paradigms is known as direct-to-device (D2D) communication. It is anticipated that D2D communication will be a viable technique in the next generation of mobile technologies and will be one of the primary applications in the development of 5G networks. In direct device-to-device communication or D2D communication, devices interact with one another directly without the need for any intermediary nodes. D2D communication makes use of a cellular spectrum and cellular infrastructure to provide three types of benefits: i) it has extremely high bit rates, less delay, and low amount of energy consumption due to the proximity of user equipment (UE); ii) cellular and D2D links can use the same radio resources simultaneously thus improving the reuse factor of a spectrum within a cell i.e., reuse gain; and iii) it is not being required to use a resource for both an uplink (UL) and a downlink, as is the case now, provides a number of benefits.

Inband D2D and outband D2D are the two different types of D2D communication. Inband D2D is the first category, and outband D2D is the second category. The first category i.e., the inband D2D includes communications that employ licensed cellular spectrum for cellular and direct D2D links. Since there is a huge amount of control over cellular communication, is usually the motivation for picking it. The inband D2D can then be subdivided into the categories of overlay D2D and underlay D2D. Underlying D2D communication links are the same for cellular and D2D users, so there is no difference between the two. Whereas overlay communication, on the other hand, is provided with specialized cellular resources. Unlicensed spectrum is used for D2D communication in the second category, named outband. The main issue that has to be resolved here is the introduction of interference between the cellular and D2D user. Since the unlicensed spectrum is used, it necessitates the use of an additional interface and, in most cases, it depends on the use of other wireless technologies. The outband D2D is also classified into two types. They may be controlled or autonomous while in D2D mode. In controlled outband D2D communication, the cellular network controls the second interface and technology; however, in autonomous outband D2D communication, the cellular network controls all communication but leaves the D2D communication to the users. In controlled outband D2D communication, the cellular network does not control the D2D communication. A simple but broad methodology for resource allocation is presented for inband multicell architecture, and it is as follows: When using the overlay, the uplink spectrum is split into two pieces that are orthogonal to one another, with fraction η assigned to D2D communication and 1-η to cellular communication; in underlay, the spectrum is divided into β bands, and D2D UEs can access $\beta([0,1])$ of them randomly and independently.

A D2D link, in general, is what creates a connection between transmitting user equipment (UE) and the UE that is meant to receive the transmission; this results in single-hop communication. There is also the possibility of a multi-hop network that functions in a manner similar to that of a mobile ad-hoc network (MANET). In a multi-hop D2D network, the intermediate UEs act as relays between a base station and a UE or between two UEs. The performance as well as the quality of service (QoS) of local area services, context-based apps, and other applications is something that may be improved via the use of device-to-device communication. Offloading traffic from the base station is how this is performed, which ultimately results in an improvement in network throughput and spectrum efficiency. Sharing the resources of cellular users with D2D users and reusing those resources amongst each other is the procedure that is involved in this method. An approach to resource allocation is described in order to increase the performance of mobile peer-to-peer D2D communications [1]. This approach is presented as a downlink cellular network underlay. The authors maximize the system total rate over resource sharing by using a reverse iterative combinatorial auction as the allocation technique in both D2D and cellular modes [2]. The proportional fair allocation in [3] is determined by two different factors: first, the priority weights that are allocated to users, and second, the proportionate distribution of resources based on these weights [3]. The revolutionary proportional fair scheduler for heterogeneous wireless networks allocates any arbitrary resource amount to users who are supplied by several technologies at the same time [4]. This scheduler for heterogeneous wireless networks is based on linear programming. The answer to the optimization issue is an automated division of people and technologies into clusters, followed by an equitable distribution of resources within each cluster. In [5], resource allocation for D2D communications that use non-orthogonal channels with cellular communications is a major issue. Two essential issues are solved in this problem: i) how to replicate cellular users in sharing their resources and ii) how to efficiently allocate resources in terms of channels for D2D devices [6] or how to replicate cellular users in sharing their resources. Numerical results show that the suggested strategy outperforms the optimal solution by up to 93.54% and provides more than 80% of the system utility with substantially less complexity than the situation without community participation.

D2D [7] connections underneath a cellular infrastructure have been suggested as a technique to take use of the physical closeness of communicating devices. This enhances resource utilization and improves cellular coverage. A decrease in power consumption, an increase in throughput, and an improvement in spectrum efficiency are all possible outcomes of these three qualities. A method of resource allocation is demonstrated for multicast D2D communication [8]. The objective is to raise the total throughput of active cellular users while at the same time ensuring that the signal-to-interference-and-noise ratio (SINR) is not exceeded by D2D pairings [9]. Both the heuristic method and the greedy algorithm are used in this process. It has been noted that greedy algorithms and heuristic algorithms both accomplish an extremely high D2D rate. This demonstrates that the suggested methods are capable of supporting a very high throughput for D2D multicast. It is generally agreed upon that the difficulty level of the research problem represented by the resource allocation approaches for a D2D underlay network is rather high [10]. This study offers D2D users a resource allocation strategy that prioritizes profit above efficiency. It has been asserted that the resource blocks may be utilized for D2D users without having an impact on the communication of cellular users [11]. As a consequence of this, a suboptimal method that utilizes the relative channel gains between eNodeB and users as well as between cellular users and D2D users is provided in order to randomize the allocation of resources to D2D users. This method was developed in order to randomize the allocation of resources to D2D users. This method also allows for the randomization of the allocation of resources to cellular users. As a result of the simulation, they observe that CU throughput does not decline and D2D user throughput rises, hence sustaining the QoS [12]. As a result, D2D communication is still controlled by eNodeB. The results suggest that permitting D2D communications as an underlay network can boost network performance and spectral efficiency. Doppler *et al.* [13] claimed that resource allocation could be done more quickly in this research. This method has a lower processing complexity than the proportional fair algorithm and produces acceptable results [14]. The main issue still exists in determining if the resource blocks are available to all existing users. D2D communication, which is the foundation of a 3GPP LTE-advanced cellular network, is now being researched as a possible facilitator of local services with minimum interruption to the primary cellular network [15]. Rebato *et al.* [16] stated that the number of cellular users in the network is restricted and those D2D users are permitted to share the same channel if they are only separated by a short distance from one another. Direct D2D communication, as opposed to relay D2D communication, is what contributes to an improvement in the throughput of the network. Shariat *et al.* [17] are interested in the frequency domain packet scheduling (FDPS) issue [18]. This problem occurs in an orthogonal frequency division multiple access (OFDMA) system. This method was modified to include the trading of physical resource blocks between various users in order to offer a more comprehensive view of the whole scheduling procedure [19]. As a result of this study, a novel approach that is based on swapping was suggested as a way to solve the FDPS issue in an OFDMA system. The recommended technique aims to enhance system throughput while taking into account constraints on the number of data queues.

Feng *et al.* [20] discussed the issue of radio resource allocation in D2D communications. This issue is treated as a mixed integer nonlinear programming problem. The challenging aspect of this optimization issue is coming up with a solution within a limited amount of time for the scheduling window. As a consequence of this, an alternative greedy heuristic strategy has been created by making use of channel gain information in order to cut down on interference to the core cellular network. In these simulations, the LTE standard parameters were used. Despite this, the cell throughput has reduced as the number of D2D connections has grown. Lee *et al.* [21] presented a strategy that would encourage local peer-to-peer communication by employing a D2D radio as an underlay network to an International Mobile Telecommunications-Advanced cellular network. This would be done. In a situation with several cells, the objective is to maintain a sufficient link budget for the D2D radio while also preventing interference from occurring in the cellular network. According to the findings, it is possible to achieve the desired SINR with a good D2D connection by accurately estimating the maximum power that can be sent through the D2D link, all while having a minimum effect on the cellular network. Wang *et al.* [22] said that vehicle ad hoc networks have attracted a lot of interest, due to both safety concerns and economic motives. This was mentioned in the passage. The 3GPP is aiming to make it possible for devices to communicate with one another using the long-term evolution (LTE) Release 12 software [23]. This would allow LTE to become a competitive broadband communication technology for public safety networks, which are utilized by first responders. The current D2D standardization processes in 3GPP for LTE have been the primary emphasis of this article; nevertheless, the majority of the findings presented here are likely to be applicable to any upgraded D2D standard for cellular communication.

Li *et al.* [24] explored the resource allocation for D2D communications, in which they took into consideration the intricate social linkages that exist in the social domain. Then, in order to maximize the social group utility of each D2D user, a social group utility maximization game is designed. This game uses statistical analysis to evaluate the performance of the social and physical domains working together. Because the growth of resource utilization is insufficient when a set of cellular user equipment (UE) and a pair of D2D UEs coexist in a cellular channel, Zhao *et al.* [25] proposed a method of radio resource allocation based on a greedy algorithm and successive interference cancellation (SIC). This was done because the growth of resource utilization is insufficient [26]. The suggested method makes it possible for cellular user equipment (UE) and three pairs of D2D user equipment (D2D UEs) to coexist in a cellular channel. The findings from the simulation demonstrated that the strategy that was presented is prominent and has pleasing performance [27]. Both the greedy algorithm and the SIC approach are used in order to achieve the goals of optimizing the performance of the D2D system and minimizing interference between D2D connections and cellular links, respectively. Cooperative routing, which employs the fresher encounter algorithm, has the dual benefits of enhancing energy efficiency and resolving problems associated with node death [28]. It has been suggested to use the multipath delay commutator fast Fourier transform in order to increase both the throughput and the speed [29].

2. PROPORTIONAL FAIR SCHEDULING

It is critical to maintaining good synchronization between CUs and D2D pairs in order to facilitate resource sharing and manage interference. The synchronization method also allows for proper hand-off of D2D pairs. For D2D discovery, one device should continue to send a reference signal so that other devices in its vicinity can be detected. After discovering the peers, a device can choose a pair with the best SNR or short distance. In general, the peer discovery process can be either done by a base station or by the mobile device itself, i.e., it can be done with the help of the network or can be done in an autonomous manner. When the peer discovery is done by a base station, the power and energy of mobile devices are saved as they are power limited whereas if the peer discovery is done by mobile device, it is power and energy-consuming.

2.1. Scheduling methods for cellular network

The wireless communication system has to provide a very high data rate to multiple users at the same time which requires the system to be optimized. This optimization problem has to provide solutions for assigning resource blocks effectively with reduced interference and for reducing the power consumption of the base station when there is a change in channel conditions or when there is no perfect channel state information (CSI) available to us in the case of time-varying channels. Different devices and different applications require different values of data rate. Optimization has to consider this also. In order to allocate radio resources, we have to consider the rate requirements of different users. The method to maintain fairness among them is also to be considered. This consideration and allocation have to be done by the medium access control (MAC) scheduler. In addition to the aforesaid requirements, this scheduler also considers the QoS requirements while allocating scarce resources.

Round robin (RR), maximum rate (MR), and proportional fair (PF) are the three types of scheduling algorithms that may be found in LTE networks. These strategies can be contrasted with one another in terms of the performance of the network and the degree to which they are fair. RR is the simplest scheduling algorithm among the available three methods. This algorithm aims at providing good fairness among users. It allows each and every user to utilize the channel for a particular time duration and the slot repeats after all the users have used it once. The disadvantage of this algorithm is that it allows the channel to users who have very low SINR values, which ultimately lowers the throughput of the network. This algorithm does not take CSI into consideration. Hence QoS cannot be guaranteed. This algorithm is beneficial when all the users have similar SINR values. The second one is the MR scheduling algorithm. Unlike RR, this method considers the CSI information of users while assigning intervals to them. This guarantees higher throughput and efficiency as the channels are allocated to the users when they have good channel conditions which is the major advantage of this algorithm. The drawback is that fairness is lost. The third method is the PF scheduling algorithm. This algorithm overcomes the drawbacks of the first two methods of scheduling. This is achieved by calculating the average CSI information and using it in addition to the current CSI data. Hence maintains both average throughput and fairness among all the users. If the maximum channel quality function is achieved, afterward, the scheduler will allot a resource block labeled ‘k’ to the user identified as ‘c’ in the nth subframe. This is capable of being expressed as (1).

$$c = \underset{c=1,2\ldots C}{\arg max} \frac{[R_{c,k}[n]^{\gamma}]}{[T_{c.k}[n]^{\delta}]} \tag{1}$$

where $R_{c,k}[n]$ represents the achievable data rate and $T_{c.k}[n]$ represents the average throughput for the cellular user ‘c’ with the ‘k’ resource block is located in the ‘n’ sub frame. Here, i) the PF algorithm is used when $\boldsymbol{\gamma}$=1 and $\boldsymbol{\delta}$=1; ii) the MR algorithm is used when $\boldsymbol{\gamma}$=1 and $\boldsymbol{\delta}$=0; and iii) the RR algorithm is used when $\boldsymbol{\gamma}$=0 and $\boldsymbol{\delta}$=1.

2.2. Proportional fair resource allocation

The various performance objectives can be achieved by this resource allocation. The same resource block can be shared among a CU and D2D pair if the PF metric product can be maintained as maximum for any possible combination of users. The Resource allocation for D2D communication is of two types, which are overlay and underlay D2D communication. In overlay D2D communication, to eliminate the possibility of interference, the cellular users and D2D users are provided with orthogonal channels. However, the gain is not improved as spectral efficiency is not achieved. In underlay D2D communication, the CUs and D2D pairs are allocated with the same which may produce interference to CUs. This interference can be avoided with an interference avoidance technique which ultimately improves gain in spectral efficiency. Figure 1 explains the process flow of proportional fair algorithm. In order to maintain a fair balance between throughput and fairness among the users, the PF resource allocation method is described for the underlay network. When the CU and D2D users share the resources in terms of orthogonality, in the overlay mode, the interference will be minimized, but the spectral efficiency is not improved. In case of underlay mode, the CU and D2D users share the same resources, but both of them will be under the control of base station. This may increase the interference a little with a greater increase in spectrum utilization.

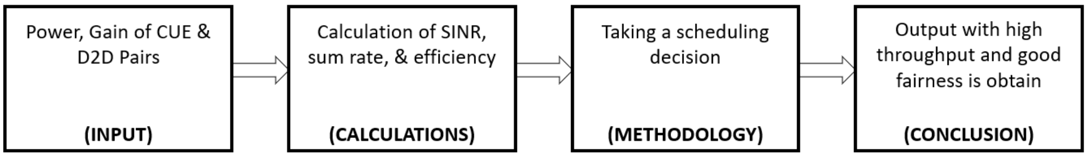

Figure 1. Process flow diagram

To do so, the SINR of CU and D2D is measured by the base station and compared with the minimum SINR required to maintain the minimum rate of service. If the received SINR of CU is higher, then, the D2D users can be allocated with some power. A bipartite graph is assumed with resource blocks and D2D pairs as its two vertices. Identification of maximum weight (MW) for bipartite matching is done. In order to allocate resource blocks, may be single or multiple blocks, the maximum weight bipartite matching (MWBP) is used. Since the radio resources of CUs are reused by D2D users in the underlay method, the possibility of improvement in gain is present. However, this leads to interference with CUs, thus disturbing the communication of CU. Hence, limiting the interference to CUs in order to maintain the QoS is a challenging task while establishing D2D communication. After satisfying the criteria, D2D communication can be established with resource allocation. This resource allocation also improves the performance objectives such as network throughput, delay, and data rate and also maintains fairness. Fairness among user data rates can be achieved by RR resource allocation, but throughput cannot be increased. High network throughput can be achieved with MR resource allocation, but fairness cannot be maintained in terms of data rate. If it is needed to maintain a balance between throughput and fairness, the preferred scheme is PF only. The first part of the PF resource allocation method is how to control the transmitting power of a D2D when a resource block is assigned to it. The second part of the resource allocation is to assign resource blocks to the D2D users feasibly.

2.3. Power allocation for D2D pairs

Initially, the base station has decided about the combination of resource blocks and CUs in each sub frame. So, the prioritized job is for scheduling D2D users and their power allocation. For a sub-frame 'n', let us have as follows. A resource block (k) is assigned to a cellular user (CU) that has the identifier "c." The most critical and pressing task at hand is to determine whether or not resource block "k" may be utilized as a shared resource that can be shared with D2D pair "d" without compromising the QoS given by CU "c." This is the work that has to be done the quickest. In the second step of this process, our objective is to determine the highest rate that a D2D pair is capable of reaching on the source block without going above the rate requirement set by the CU. If $S_c^k[n] / \sigma_N^2$ is the received signal-to-noise ratio (SNR) at the base station for the resource block "k" without D2D communication if $S\ ck\ S_c^k[n] = P_c g_{cB}^k[n]$ represents the received signal power at the base station in the n^{th} sub-frame. Let's assume that the desired SNR needed at the base station for a successful transmission is higher than the received SNR. In a sub-frame designated as 'n,' for a resource block designated as 'k', a D2D transmitter d_T is transmitting with a power such that the interference produced by it does not reduce the SINR of CU 'c' not more than agreed target threshold ${\gamma_c}^{tgt}$.

To depict, the gap in SINR of CUs is utilized for allocation of power to the D2D pairs. Here, a perfect CSI model is assumed. Since the base station has access to data on channel gain for a sub-frame for each resource block "k", the maximum amount of power that each D2D transmitter is allowed to transmit "d_T" It is possible to calculate "c" for each CU that has been given the resource block "k". The rate $r_d^k[n]$ after determining the optimal power for each D2D pair on resource block "k", Shannon's capacity theorem is used to derive "n" for each sub-frame. This is done after the optimal power is established. Assuming that the D2D transmitter d, which is making use of the resource block "k" in the sub-frame "n", is the cause of the interference, $I_{d_T}^k[n]$, then

$$\frac{P_c g_{cB}^k[n]}{\sigma_N^2 + I_{d_T}^k[n]} \geq {\gamma_c}^{tgt} \tag{2}$$

$$I_{d_T}^k[n] \leq \frac{P_c g_{cB}^k[n]}{\gamma_c{}^{tgt}} - \sigma_N^2 \qquad (3)$$

2.4. Resource allocation using bipartite matching

An issue with PF optimization that is formulated in terms of the long-term temporal average rates can be transposed so that it becomes analogous to a problem that is equivalent to it in terms of the rate at which each sub-frame is generated. If the greatest number of resource blocks, “M,” that may be assigned to a D2D pair, “d,” according to the equation, the optimization problem can be turned into a problem involving the maximization of the local gradient in each subframe. This can be done by using the objective function (4).

$$\begin{aligned} &max \sum_k \sum_d \frac{x_d^k[n] r_d^k[n]}{R_d[n-1]} \forall n \\ &s.t. \sum_k x_d^k[n] \leq M \\ &and \sum_d x_d^k[n] \gamma_c^k[n] \geq \gamma_c{}^{tgt} \end{aligned} \qquad (4)$$

Here, the indicator function is an optimization variable represented by $x_d^k[n]$ which is defined as,

$$x_d^k[n] = \begin{cases} 1, if\ there\ source\ blockk\ is\ allocated\ to\ user\ 'd' \\ 0, otherwise \end{cases}$$

$R_d[n-1]$ represents the average rate of d^{th} D2D pair until the $[n-1]^{th}$ sub-frame. This optimization problem can be related to an integer linear programming (ILP) problem, the solution for which has to be obtained indirectly. Using maximum weight bipartite graph, a solution for this optimization problem can be given. A bipartite graph whose vertex sets are D2D pairs and another resource block set is defined to allocate a maximum of one resource block. The weight allocated to the link, or, the PF metric, for each edge in the bipartite graph is given by $\lambda_d^k[n] = \frac{r_d^k[n]}{R_d[n-1]}$. This is represented in Figure 2.

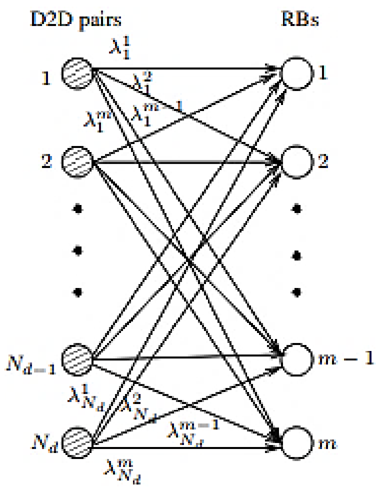

Figure 2. Bipartite graph for allocating maximum one resource block (M = 1) to a D2D pair

While allocating numerous resource blocks to D2D pairs, the resource allocation method of the CU is not a problem at all. Because of this, any of the mechanisms for allocating resources that are currently in place may be used for CUs. We are able to allot more than one resource block to D2D pairs so long as the allocation of resource blocks for the CUs is known. This allows us to better manage our resources (by way of certain pre-existing scheduling techniques at the base station). In addition, we proceed on the premise that the least SINR need for CU “*c*” for each resource block “*k*” in sub-frame “*n*” is already known, even in the circumstance in which the CU is accountable for the allocation of more than one resource block. The PF metric may be calculated after the power levels that are required for each resource block for each D2D transmitter have been determined. In most situations, the level of complexity that constitutes the worst-case scenario for calculating edge weights is reached when a D2D pair shares a maximum of M resource blocks. This results in a complexity of $O(N_D \times m^2)$. We use the Blossom algorithm and the primal-dual approach to calculate the maximum weight matching of the entire bipartite network. This algorithm has a computational complexity of $O(n^3)$, where n is the total number of nodes in the graph given by $n=(m+1)\ N_D$. Therefore, overall complexity of the algorithm is $(N_D \times m^2 + n^3)$.

3. RESULTS AND DISCUSSION

Simulations at the system level have been executed in MATLAB in order to evaluate the effectiveness of the approach that we have proposed. Considered to be a single cell is one with an inter-site distance (ISD) of 100 m. The antenna arrangement is SISO omnidirectional. For the uplink, a system bandwidth of 5 MHz is taken into account. Within the cell, there is a balanced distribution of CU and D2D transmitters. The distance between a D2D receiver and transmitter is how we define a D2D communication's range (R_{D2D}). Within the specified range, D2D transmitters are uniformly spaced from D2D receivers. A summary of all simulation-related parameters is provided in Table 1.

Table 1. Simulation parameters

Parameter	Values
Cell layout	Single Hexagonal cell
Number of available RBs	10
Number of subcarriers per RB	12
RB bandwidth	180 KHz
CU transmit power	250 mW
D2D transmit power	250 mW
Number of active CU (Nc)	10
Number of active D2D (N_D)	10%, 20%, …, 100% of active CUs
Path loss	PL = 128.1+37.6log(d)
UE noise figure	3 dB

We take into account the environment of multipath fading channels. In addition to pathloss, our model takes into account both rapid and slow fading as separate phenomena. The following expression will give you the overall channel gain in decibels,

$$g_{j,k} = 128.1 + 37.6 * \log d_{j.k} + X_\sigma + Y_{p,d}$$

where $d_{j,k}$ is the distance between either eNodeB j and user k or that between user j and user k (user can be a CU or a D2D user), in kilometer and $g_{j,k}$ is the channel gain between them. X_σ and $Y_{p,d}$ represents the slow fading random variable and fast fading random variable respectively. In this scenario, we are going to assume that this single cell has an omnidirectional antenna. Throughout the course of this investigation, one of our primary focuses was on PF scheduling for D2D pair connections that are supported by cellular networks. We do this by utilizing the additional SINR of CUs that is above the needed SINR threshold for D2D pairs, and then distributing those powers to those pairs. This is done in order to ensure that the minimum SINR of CUs can still be maintained after the addition of D2D pairs. For the purpose of conducting a performance study on the method that was provided for scheduling, Jain's fairness index was used. The computation for this indicator involves establishing whether or not the normal user data rates are fair to all parties. The definition of Jain's fairness index is:

$$\eta = \frac{(\sum_i^U R_i)^2}{U \sum_i^U {R_i}^2}$$

where U is the total number of users and R is the average data rate of user I throughout the course of N sub-frames, respectively. If the Jain's fairness index is somewhat near 1, then it may be claimed that the user data rates are allocated equitably. The throughput of the network, CUs, and D2D pairs increases with increasing D2D range for single resource block allocation (M=1). This can be seen in Figure 3. Figure 3 and Figure 4 demonstrate, respectively, the change in throughput with increasing distance between the D2D transmitter and the receiver. These figures are for the single resource block allocation system and the multiple resource block allocation scheme (D2D range). The two figures show that when the D2D range expands, network and user throughput both decline but CU throughput essentially stays the same. Therefore, the fact that D2D communication is possible within a particular range is quite important. D2D pairs should be near together in order to benefit from network performance improvement.

Figure 5 and Figure 6 show how the throughput changes as the number of D2D pairings in the cell increases. Both the overall network throughput and the D2D user throughput are growing, as we can see. We also see that there is no discernible reduction in the throughput of CUs.

As a result, we may conclude that the network can support D2D pairings while still preserving CUs' quality of service. Additionally, increasing the number of resource blocks M that a D2D pair is permitted to share leads to an improvement in the throughput of both the entire network and D2D users. Table 2 and Table 3 show the throughput comparison for the maximum ratio and proportional fair algorithm for the various number of D2D pairs with M=1 and M=2.

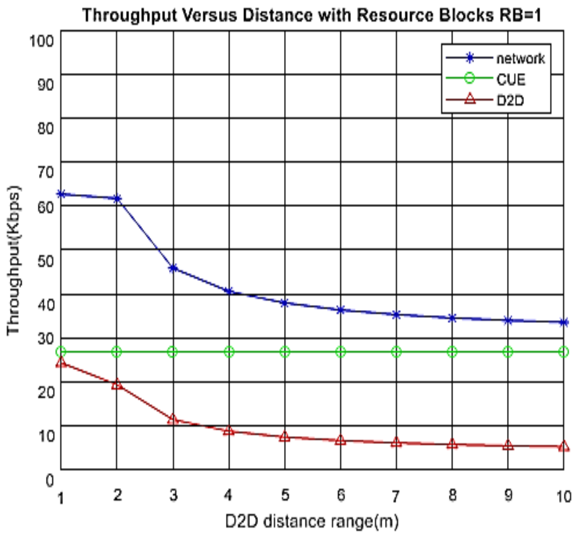

Figure 3. Allocate many resources from a single block, network throughput, CUs, and D2D pairings with growing D2D range (M=1)

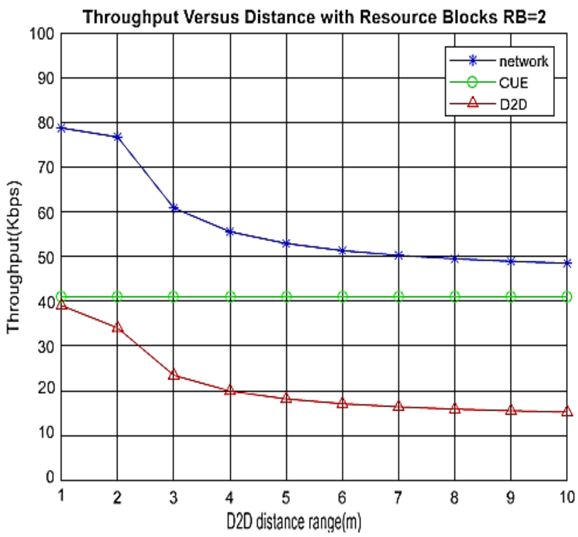

Figure 4. Allocation of many resources in a single block based on network throughput, CUs, and D2D pairings with increasing D2D range (M=2)

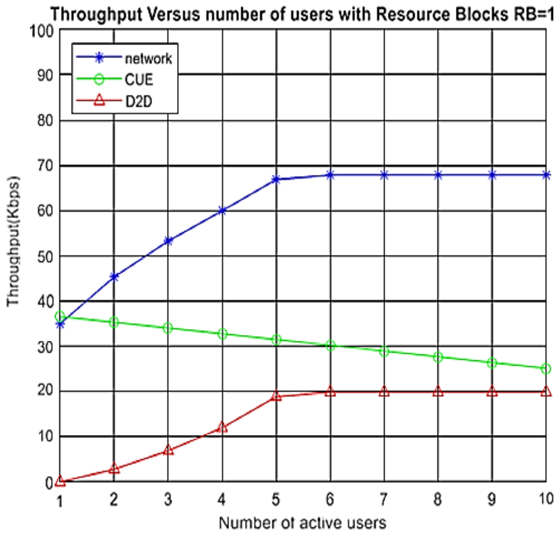

Figure 5. Increase in network throughput, CU utilization, and D2D pair counts for shared-pool resource allocation (M=1)

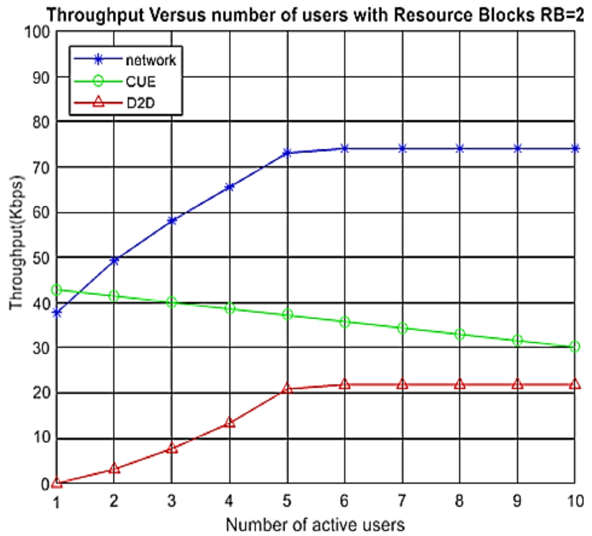

Figure 6. Network, CU, and D2D pair throughput as the number of D2D connections grows under a given resource allocation framework with numerous resource blocks (M=2)

Table 2. Comparison of PF and MR algorithm with M=1

No. of D2D pairs	2	4	6	8	10	12	14
MR	2.12	4.21	5.66	7.02	9.55	11.44	11.24
PF	2.37	4.39	5.86	7.82	9.85	12.07	11.94

Table 3. Comparison of PF and MR algorithm with M=2

No. of D2D pairs	2	4	6	8	10	12	14
MR	4.13	8.37	11.81	14.82	19.35	20.65	18.21
PF	4.31	8.55	11.93	14.93	19.69	20.82	18.55

Jain's fairness index is used in Figure 7 to compare and contrast PF scheduling for single resource block allocation and multiple resource block allocation for D2D users. We see that the fairness index with PF scheduling maintains strong fairness among D2D users as the number of D2D pairs grows. Throughput and fairness are well-balanced by the PF algorithm. This demonstrates how effectively fair our suggested algorithm treats D2D users.

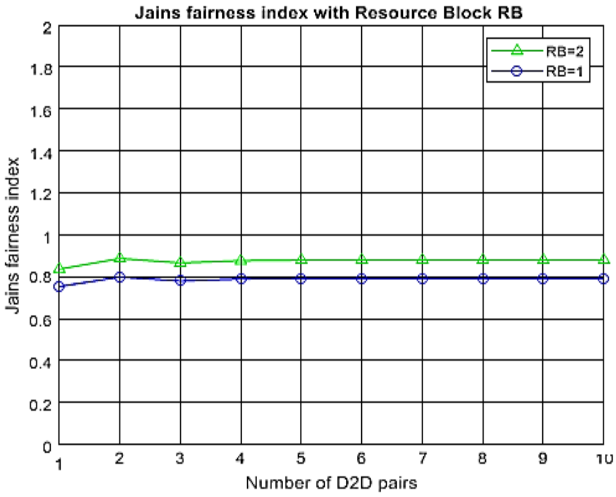

Figure 7. Jain's fairness index for growing D2D pairings with single and multi-resource block allocation

4. CONCLUSION

Within a cellular network, we investigated PF scheduling for D2D pairings as part of this paper's research. We assign powers to D2D pairs by utilizing the excess SINR of CUs that is over their required SINR threshold. This allows us to maintain the minimum SINR of CUs after adding D2D pairs, which is required in order to keep the minimum SINR. This is done in order to keep the minimal SINR of CUs. Following this, we will use a matching algorithm that is based on a bipartite graph to establish the ideal pairing between resource blocks and D2D pairs. This will ensure that each D2D pair only receives a maximum of one resource block. The technique is subsequently extended to D2D pairings for allocating multiple resource blocks. With a simple change, our suggested approach may be used to allocate any number of resource blocks. The outcomes demonstrate that we are able to provide D2D users with fairness and fast throughput. Despite the fact that CU throughput does not drop significantly while D2D user throughput increases as the number of D2D users in the network grows, there is a net improvement in network throughput. This is the case even though CU throughput does not drop significantly. In addition, we note that while CU throughput does not drop significantly, D2D user throughput does increase. As a direct result of this and taking into consideration the fact that eNodeB continues to exercise control over D2D communication, it is possible that cellular networks could integrate with it.

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