

User Satisfaction Based Resource Allocation Schemes for Multicast in D2D Networks

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Abstract— The D2D communication has high potential to serve multiple users with high data rate within a proximity in the next generation cellular networks. In this paper, we consider a multicast scenario of D2D users where each user wishes to receive the same multicast data at varying data rates. Based on our best knowledge, finding an optimal solution to satisfy the user request in the said context requires unreasonable time. Therefore, we have proposed approximation algorithms with two objectives (i) maximize the satisfied throughput, (ii) maximize the number of satisfied users when the available resource blocks are limited. The simulation results show that the proposed algorithms offer a worst-case performance guarantee and outperform the other conventional schemes in terms of throughput, satisfied users count, and fairness.

Keywords— D2D Networks, multicast, resource allocation, satisfied user.

I. INTRODUCTION

The device-to-device (D2D) communications have attained a lot of attention recently and is expected that by 2019, 75% of the overall mobile generated data consists of video content. Also by the next decade, mobile traffic will increase by 100 folds [1]. In an underlay based D2D scenario, D2D users (DUs) reuse the same frequencies with the cellular users (CUs) to communicate with other DUs. Recently, the multimedia broadcast or multicast service has attained a lot of significance. As an example, it is expected that in 2020 Olympics D2D will be implemented fully to provide live video broadcast to thousands of viewers in the stadium. In this scenario, how can the users be served when they have different handheld devices and may request the same data at varying video quality demand. This motivated our research.

The resource allocation in D2D is a challenging issue due to varying channel quality (CQI), data request rates, interference etc. There are mainly two categories of video multicast service based on the service rate. A single rate based scheme serves the entire user at a single CQI. In [2], authors have considered most robust channel quality (CQI) to multicast all the users at once. This method promise fairness, but will not be efficient in terms of QoS when the majority of the users have high CQI and only a few users have low CQI. In [3], the authors considered the extreme of the former case. This method serves the user in groups with the best channel quality at every serving time interval.

The other type of multicast service is the multi-rate scheme; in which the network will be divide into different layers and use different network coding to serve the users at different rates based on the diversity of user's channel quality. In [4, 5], the authors proposed a subgroup based service method, where users are served in groups. This method of group formation considers

throughput and user fairness. There are similar schemes [6, 7], where the author proposed an algorithm FAST, a subgroup-based scheme for OFDMA network. Here, the group formation computes the best throughput as a product of the number of users and the maximum CQI they use.

In the following works, the authors used CU as a relay node to transfer the data to a D2D user [8, 9]. In [8], a new relay based D2D communication scheme is proposed. In this case, certain D2D users act as relays to forward data to their counterpart DUs and optimize the achievable data rate of D2D users. This proposal of power control based data rate maximization for D2D communication outperforms the direct cellular mode. In [9], the authors have used single frequency based D2D with TDD based multicast. Initially, they enforce the channel quality of the uplink i.e. from the CU (relay) to D2D to be at least equal to channel quality of the downlink. Then, serve the users with the CQI that could maximize the throughput by allocating all the resource blocks (RBs) in downlink (DL) and reusing them to relay in uplink (UL). However, as per this method, the second hop D2D users must have a channel quality at least same as the first hop CUs that serve them, which may not be possible in a random scenario. In [10], authors have proposed a two hop Wi-Max network and proved its NP-Hardness by modelling the network as 0/1 knapsack problem.

In our problem scenario, the users request the same multicast data at different rates while having varying CQI when the total available RBs are limited. This scenario makes our work unique compared to the existing works. We have two objectives: (i) maximize the satisfied throughput and (ii) maximize the number of satisfied users in the said context. We model this problem as a two-hop network. First, prioritize the users; later we serve the CUs in the first hop in the DL time slot, and forward (reuse) the data to DUs in the second hop during UL slots.

Our main contributions are as follows. Our proposed algorithms are polynomial time with time complexity of $O(N^2)$ with worst-case lower bound of $2 \times \max(N_C, N_D)$ as shown in the theoretical analysis. Finally, the simulation results show that performance of our proposed algorithms is better than the candidate algorithms.

We organize the rest of this paper as follows. In section II, we put forward our system model and in section III, we describe the algorithm. Section IV, narrates our simulation results and finally in section V, we conclude this paper.

II. SYSTEM MODEL

Our system model consists of a base station e-NB, that multicast the same video content to all the users. There are N users interested in receiving the same video at different bit rates

and are distributed as N_C CUs and N_D DUs in a single cell. In Fig. 1, we represent a CU n as CU_n , $1 \leq n \leq N_C$ and a child DU m connected to a CU_n is represented as DU_{nm} , and altogether there are N_D DUs, $1 \leq m \leq N_D$. Each user i ($1 \leq i \leq N$) may have different CQIs due to their varying distance from the e-NB. Let C_n be the CQI of user CU_n and C_{nm} be the CQI of user DU_{nm} . Let dR_n and dR_{nm} (bits/sec) be the data request of a CU_n and a DU_{nm} , respectively based on their device capacities as shown in Fig. 1. We denote the term *tree* (t_c^n) to refer to CU_n and all its connected DUs and c is the CQI from e-NB to the CU_n . We assume that the total available RBs at the e-NB are T .

The CUs are directly served by the e-NB in the downlink timeslots (DL) and DUs are served by their corresponding parent CUs in the consecutive uplink time slots (UL) to reuse the RBs. As a result, all the child DUs that reuse the same RBs at a particular UL time slot will be compelled to use the same CQI. It also helps to prevent interference between the peer DUs that use the same channel. So there will be no interference. However, the CQI at the UL needs to be either same or smaller than the CQI value used for the DL, as we cannot transmit more data in UL than what we receive in the DL. If the RBs received by a CU in DL have not used in the immediate UL slot, then those RBs have to be discarded. They cannot be used in next UL slot. There may need multiple transmission sessions to satisfy a user's data request. However, all the RBs assigned in a session will be continuous and bear the same CQI in the UL slot.

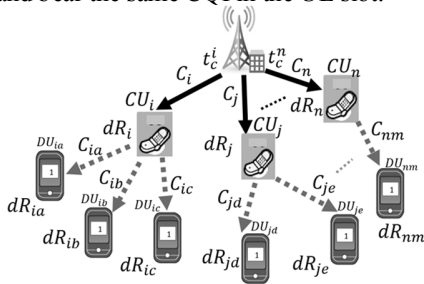


Figure 1. Network scenario of D2D and CUs with their data requests.

A. Maximizing the satisfied throughput (ST)

The term *satisfied throughput* refers to the data rate of the user whose data request has completely met. Let our objective of maximizing the satisfied throughput can be represented as follows: $\max \sum_{i=1}^N \sum_{r=1}^T d_{ir}^c \cdot x_{i,r}$ (1)

The term d_{ir}^c is the data rate (bits) obtained when a RB r is assigned with the CQI level c to user i and variable T is the number of total RBs. The term $x_{i,r}$ is a binary indicator to represent if RB r has been assigned to user i .

Subject to:

$$\sum_{i=1}^N R_{i,DL} \leq T \quad 2(a); \quad \sum_{i=1}^N R_{i,UL} \leq T \quad 2(b)$$

$$\forall \text{ user } i: R_{i,UL}^{t+1} \leq R_{i,DL}^t, \text{ where } t \text{ and } t+1 \text{ are a pair of slots} \quad (3)$$

For any CU, all the RBs assigned at a particular transmission instant should have the same CQI in the DL. (4)

All the RBs reused by DUs from the respective parent, should have the same CQI at a transmission instant. (5)

$$\max(RB_{DL}, RB_{UL}) \leq T \quad (6)$$

In constraint 2(a) and 2(b) the terms $R_{i,DL}$ and $R_{i,UL}$ represent the number of RBs assigned to each user i in the DL and UL slots, respectively. In the DL or the UL slot, the sum of all the

RBs assigned to N users should be at maximum T . In constraint (3) $R_{i,DL}^t$ and $R_{i,UL}^{t+1}$ are the number of RBs allocated to a user i in the DL at time slot t , and reused from it in the UL slot at time $t+1$, respectively. These RBs are transmitted in a pair of consecutive DL and UL time slots t and $t+1$. This constraint restricts the total data used in the uplink cannot be more than the data available in the downlink at any pair of transmission instant. The constraint (6) states that in the UL and DL we may use at maximum T RBs.

B. Maximizing the number of satisfied users (SU)

We formulate the objective function as follows:

$$\max \sum_{i=1}^N S_i \quad (7)$$

Let $S_i = 1$ if the requested data rate of user i can be satisfied by our resource allocation and $S_i = 0$ otherwise. The constraints (2) - (6) of previous problem in sub-section II.A are also applicable here.

III. ALGORITHM

A. Maximizing the satisfied throughput (ST):

In our algorithm, as RBs are limited, not all users can be satisfied. As a result, we need to find the priority to determine the serving order.

To begin with, we determine the number of RBs needed to satisfy the data request of each user. First, we determine the number of RBs required by a CU_n as computed in equation 8(a) below.

$$N_{CU_n}^{RB} = \left\lceil \frac{dR_n}{d_c^n} \right\rceil \quad 8(a); \quad N_{DU_{nm}}^{RB} = \left\lceil \frac{dR_{nm}}{\min(d_c^n, d_c^{nm})} \right\rceil \quad 8(b)$$

where $N_{CU_n}^{RB}$ represents the number of RBs required by a first hop CU_n . The terms dR_n, d_c^n represents the data request rate and number of bits assigned when a RB given to CU_n with CQI c respectively. (Ex: if CUs data request is 90 bits, CQI is 4, then we need at least 3RBs to satisfy the request assuming CQI x offers $10x$ bits/RB.) The number of RBs required by a DU_{nm} in the second hop is computed as in 8(b). Here, $N_{DU_{nm}}^{RB}$ represents the number of RBs required by DU_{nm} , connected under CU_n and d_c^{nm} represents the number of bits/RB assigned from CU to user DU_{nm} with CQI level c . Thus, the least CQI between two hops will be the bottleneck.

Later, we compute a weight factor W_i as shown in (9), to prioritize the users. $W_i = \frac{dR_i}{N_i^{RB}}$ (9)

In general, N_i^{RB} refers to the number of RBs required by any user i as computed above and dR_i is the data request rate of user i . Higher the weight, higher the priority. Our rule to select the user with the same priority (P_i) are as follows:

Rule 1: If two users of different tree have the same W_i , the user of the tree with the lower CQI gets the higher priority.

Rule 2: If the users that belong to the same tree have the same W_i , we select the users in random order. Table 1 shows the number of RBs, weight of the user (W_i), and priority (P_i) of each users in Fig. 2.

Next step will be resource allocation. The CUs get RBs in DL slot and DUs reuse them in the consecutive UL slots based on their priority value. When we allocate RBs we keep track of each user allotted RBs and its CQI as an ordered pair (r, c) indicating that some user assigned with r RBs at channel quality c .

Table 1. Priority computation steps.

User	No. of RB	dR_i	$W_i = \frac{dR_i}{N^{RB}}$	Priority P_i
CU_3	4	400	100	P_1
DU_{31}	2	200	100	P_1
CU_2	4	300	75	P_2
DU_{32}	4	300	75	P_2
DU_{12}	4	220	55	P_3
CU_1	2	100	50	P_4
DU_{11}	3	150	50	P_4
DU_{21}	3	150	50	P_4

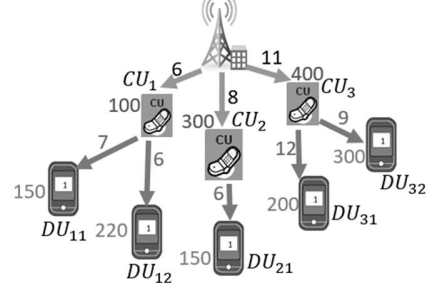


Figure 2. An example to illustrate the user channel quality and data request

By equation (10), we reclaim 3 RBs of CQI 11 from t_{11}^3 .

After reclaim, CU_3 has (4,8) and (1,11) in DL and DU_{31} has (4,8) and (1,11) in UL by reusing from CU_3 and CU_2 RBs. The remaining RBs become $(2+3) = 5$. Once we reclaim, all the users that using the reclaimed RBs will lose that data bits. This process is applicable to all trees that use the shared RBs with other users. Continuing with our example, the next user DU_{32} of the same priority (P_2) will reuse 4 RBs of UL with CQI 8 from its parent CU_3 which has 5 RBs. Now, DU_{31} and DU_{32} will share one RB of CQI 11 (which it reuse from CU_3) by lowering to CQI 9, as channel quality of DU_{32} is lower than DU_{31} . As a result, both the users DU_{32} and DU_{31} will receive (4, 8) and (1, 9) RBs in UL (See Table 2, step 4).

Table 2. RB assignment table.

Step	1	2	3	4	5	6
User1	DL	UL	DL	UL	DL	UL
CU_3	(4,11)		(4,8)	(4,8)(1,11)	(4,6)	(4,6)(1,8)(1,11)
DU_{31}		(4,11)		(4,8)(1,9)		(4,6)(1,8)(1,9)
CU_2			(4,8)		(4,6)	(4,6)(1,8)
DU_{32}				(4,8)(1,9)		(4,6)(1,8)(1,9)
DU_{12}						(4,6)
CU_1					(4,6)	
DU_{11}						(4,6)
DU_{21}						(4,6)(1,8)

Next we serve DU_{12} of priority (P_3). However, its parent CU_1 has not yet received the data, so we serve CU_1 with $CU_1(4, 6)$ at DL slot and reuse the same RBs to DU_{12} in the next UL slot and the remaining RBs become $(5 - 4) = 1$. So, the priority user DU_{12} gets $DU_{12}(4, 6)$. The transmission to CU_1 were received by other CUs CU_2 and CU_3 simultaneously at DL (step 5). So, we try to reclaim excess data from the system. We can observe that there are 3 RBs of CQI 8 (240 bits) which can be replaced by 4 RBs of CQI 6 (240 bits). By this, all the users update their assigned RBs. So, already satisfied users namely CU_2 , CU_3 , DU_{32} and DU_{31} lose 3 RBs of CQI 8 and get 4 RBs of CQI 6 as an update to their previous assignment (see Table 2, step 6). The remaining RBs become $1 + 3 = 4$. The next priority (P_4) user DU_{11} will reuse the RBs from the parent CU_1 , so it receives $DU_{11}(4, 6)$ RBs. Similarly, the next user DU_{21} of priority (P_4) reuse RBs from its parent, so it receives 4 RBs of CQI 6 from its parent CU_2 and 1 RB of CQI 8 at the consecutive uplink slots $DU_{21}(4, 6)$ and (1, 8) as the total data in UL.

Assume, if the CQI of DU_{21} was lower say CQI 5, then all the DUs had to lower their CQI to 5 to reuse the same RBs with DU_{21} . This process is called *downgrade*. As a result, we need to re-compute the number of RBs needed by all those DUs to remain satisfied at current minimum CQI 5. If any user's need exceeds the available RBs, we discard the current DU and go the next user. We do not downgrade if the overall collected throughput becomes lower. This is our RB assignment.

Let us consider an example in Fig. 2 to understand our algorithm, where users have different data request rates denoted beside the user and channel qualities shown over the arrow. This algorithm takes iterative steps to select the suitable user to serve with suitable number of RBs and CQI to assign for multicast. Finally, we assign RBs based on the result of these iterative steps.

To begin with, we assume $N_c = 3$ CUs, $N_D = 5$ DUs and total $T = 10$ RBs available. For easier understanding, we have assumed that CQI x offers a data rate of $10x$ bits per RB. From Table 1, our first priority (P_1) user will be CU_3 . First, we assign 4 RBs of CQI 11 (440 bits) to CU_3 denoted (4, 11) in the DL slot to satisfy it. Table 2, shows the RB assignment at different DL and UL slots. In the next UL slot the same 4 RBs can be reused by the same priority user DU_{31} at CQI 11 to satisfy. (See Table 2, step 2). The remaining RBs = $(10-4) = 6$. Later, next priority (P_2) user CU_2 will be assigned 4 RBs at CQI 8 (320 bits), in DL slot which will be simultaneously received by CU_3 . (See Table 2, step 3). The remaining RBs = $(6-4) = 2$.

Now, CU_3 has excess RBs than it actually needs, i.e. currently obtained 320 bits from 4 RBs of CQI 8 can replace older 3 RBs of CQI 11 (330 bits) while retaining 1 RB of CQI 11 to maintain a total data rate required to satisfy the user CU_3 . As a result, we recollect 3 RBs back to the system. This process will be termed as *reclaim*, in which the users share the RBs of most minimum valued CQI among them than using the exclusive RBs. Note that, the RBs of CQI 8 received by CU_3 will also be used by its child DU_{31} . So, when we recollect RBs from CU_3 the same RBs used by DU_{31} will also be taken back. We use (10) to determine the number of RBs that can be reclaimed.

$$N_{CU_n}^{RB} - \left\lfloor \frac{dR_{sat}^{max} - A}{d_{CQI}^{min} (hop1_t^{sat}, hop2_t^{sat})} \right\rfloor \quad (10)$$

The term $N_{CU_n}^{RB}$ refers to the RBs CU_n originally had. Here, dR_{sat}^{max} is the maximum data request rate among all already satisfied users in the tree t_c^n , to which CU_n belongs to. The term A refers to the data received by CU_n at lower CQI due to the other CU in the current DL transmissions. In the same way $hop1_t^{sat}$ and $hop2_t^{sat}$ refers to the all currently satisfied users in the first and second hops that use the same RBs which we intend to reclaim.

We use d_{CQI}^{min} to represent the data rate of a user with the minimum CQI among the satisfied users in t_c^n . For example, as soon as CU_3 receives CU_2 's data we search tree t_{11}^3 . Here $N_{CU_3}^{RB} = 4$ RBs of CQI 11, $dR_{sat}^{max} = 400$, and $A = 320$ as CU_3 received 320 bits in the current DL transmission. Finally, $d_{CQI}^{min} = 110$ which is the CQI bits of minimum channel quality (CQI 11) of the satisfied users CU_3 and DU_{31} among both the hops in t_{11}^3 .

Our algorithm has two rounds. In the first round, we select the users based on W_i value until we finish all RBs. In the second round, we delete those users selected in round one and try to choose remaining users similarly. Finally, we choose the best solution from these two rounds.

B. Algorithm to Satisfy maximum number of user (SU).

In multicast, as the number of RBs assigned to a CU could be shared by other CUs, so satisfying one CU may also satisfy other CUs without additional RBs and will be more profitable. The rule to find the number of RBs remains the same as in 8(a) and 8(b). However, the rule to find weight W_i for each user vary a little in this case as shown in (11). If the user is a CU, then S_{CU} will be the number of satisfied CUs when N_{CU}^{RB} RBs are assigned to CU_n .

$$W_n = \frac{S_{CU}}{N_{CU}^{RB}} \quad (11) \quad W_{nm} = \frac{S_{CU} + S_{allDU}}{N_{DU}^{RB}} \quad (12)$$

On the other hand, the weight W_{nm} of a DU will be determined as in (12). Here, S_{CU} is the number of satisfied CUs and S_{allDU} is the number of satisfied DUs of all trees whose parent CUs receives data when N_{DU}^{RB} RBs are assigned. The remaining part of the algorithm remains same as satisfied throughput one.

C. Theoretical analysis

In our problem, when we assign a RB to DL at CQI i , the UL can only reuse that RB at CQI \leq CQI i . Therefore, when we have \mathbb{C} number of CQI levels, each RB can be assigned to DL, and reused in UL by $w = \mathbb{C}(\mathbb{C} + 1)/2$ combinations. As we have T RBs, there are $\binom{T+w-1}{w-1}$ combinational cases to assign in DL and UL to find the optimal solution. However, the time complexity of this method is nearly of the order $O(T^{w-1})$, which is impractical for typical value $T = 100$ and $\mathbb{C} = 15$. Here we prove that our proposed algorithms can guarantee a worst-case lower bound with respect to the optimal solution.

Lemma 1: The throughput of our proposed multicast algorithm is at least lower bounded by the throughput of a unicast solution. $P_M(A) \geq P_U(A)$ (13)

In (13), $P_M(A)$ and $P_U(A)$ are the throughput of multicast and unicast algorithm at an instance A respectively. It means that when we multicast, at least a single user will benefit.

Lemma 2: The throughput of our unicast solution will be at least half of the throughput of optimum unicast solution.

$$P_U(A) \geq 0.5 P_U(A^O) \quad (14)$$

Proof: Similar to [10] the objects (users) arranged in the decreasing order of profit/weight ratio. Then the user i are chosen like 0/1 knapsack one by one in two rounds. In the first round if the k^{th} user could not be accepted, then the k^{th} user will be accepted in the second round. Finally, the algorithm selects the maximum result of the two rounds. So, in general if $P(i)$ is the profit of user i then we have the unicast solution as the following.

$$\sum_{round\ 1} P(i) + \sum_{round\ 2} P(i) \geq \sum_{i=1}^k P(i) \quad (15)$$

Our algorithm $P_U(A)$ also follow the similar rule and choose the maximum of two rounds.

Thus it is trivial to arrive at (14), where $P_U(A^O)$ is the throughput of optimum unicast solution.

Theorem 1: The approximation ratio of optimal multicast solution to our multicast solution is at most $2 \times \max(N_C, N_D)$.

Proof: Let us consider the optimal multicast scenario, where a transmitted RB at most be received by all the first hop CUs (N_C) in the DL slot and the same RB at most be reused by all the DUs (N_D) in the UL slot. Therefore, the profit of optimal multicast solution $P_M(A^O)$ is smaller than or equal to $P_U(A^O) \times \max(N_C, N_D)$. Therefore, $\frac{P_M(A^O)}{P_M(A)} \leq \frac{P_U(A^O) \times \max(N_C, N_D)}{P_M(A)}$. Thus, by Lemma 1 and Lemma 2, we have $P_M(A) \geq P_U(A) \geq 0.5 P_U(A^O)$. Finally, we can derive the approximation ratio of our multicast algorithm as follows:

$$\frac{P_M(A^O)}{P_M(A)} \leq \frac{P_U(A^O) \times \max(N_C, N_D)}{0.5 P_U(A^O)} = 2 \times \max(N_C, N_D) \quad (16)$$

This forms the worst-case approximation ratio of our multicast algorithm.

D. Time complexity

The time complexity of sorting N users will be $N \log N$. Later, when each tree receives an indirect data from nearby tree's transmission it might need to search for reclaim operation. In a worst case, every reclaim operation would take $N_C(N_C - 1)$ computations; $N_C < N$. Similarly, when a DU receives data, it needs to check every other DU for possible downgrade of its CQI. This would computationally cost $N_D(N_D - 1)$ operations; $N_D < N$. As a result, in total the complexity will be $(N \log N) + N_C(N_C - 1) + N_D(N_D - 1)$. In a worst case if $N = N_C$; or $N = N_D$ then $2N(N - 1)$, which is $O(N \log N) + 2N(N - 1)$. As we execute our algorithm in two rounds, the total computation complexity of this algorithm will sum up to $O[2N \log N + 4N(N - 1)] = O(N^2)$.

IV. SIMULATION RESULTS

In this section, we discuss our simulation results. We simulated the LTE-D2D scenario with MATLAB. We created two scenarios to demonstrate our simulation setup (i) in the first scenario, we maintained a constant 100 RBs and (ii) in the second scenario, a constant user set of 30. The CQI range 1-15, TTI 1ms, carrier frequency 2.5GHz, transmission power of eNB, DU are 46dBm, 23dBm to use in the path loss model and 12 sub carriers 0.5ms for an RB. We compared our simulation results with CMS [2], where all users served by the most robust CQI at every serving interval. We modified OMS [3] for a two-hop setting. By using these two methods also our problem can be solved. So we use to compare with our algorithm.

Fig. 3 shows the variation of satisfied user's throughput (ST) (bits/sec) against the number of users when the input RBs are a constant. From Fig. 3, we can observe that as the number of users increase, the throughput also increases as more users that get satisfied. When the users increase from 20 to 30, the sharp increase in the throughput is due to the availability of RBs after reclaim, and favorable CQI. In the case of CMS and OMS, the satisfied throughput will be comparatively lower than the proposed algorithm (ST). As proposed algorithm has a priority rule, which emphasizes the user who has the maximum throughput to get satisfied and reclaim operation.

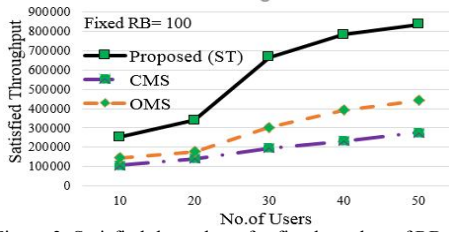


Figure 3. Satisfied throughput for fixed number of RBs.

In Fig. 4, we determine the number of satisfied users, when RBs have fixed to 100. We can observe that even though initially all 100 RBs are available, not every user could get satisfied, because some users have their RBs requirement greater than the available RBs. In the case of CMS and OMS, the satisfied users increase gradually, and at a lower rate compared to the proposed algorithm ST.

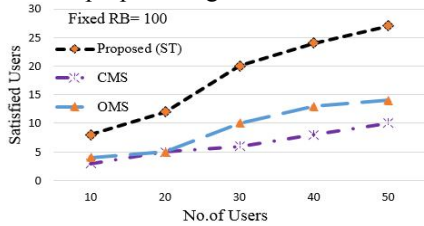


Figure 4. Satisfied users count for fixed number of RBs.

In Fig. 5, we measure the Jain's fairness index [7]. The proposed method (ST) maintains an average fairness index of 0.6 as the number of users increase. It is due to higher number of satisfied users as a result, fairness index also follows the same trend. The average value of fairness index is 0.25 and 0.3 in the case of CMS and OMS, respectively.

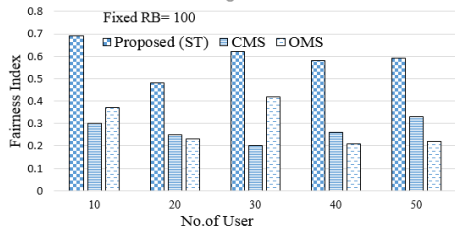


Figure 5. Fairness Index for fixed number of RBs.

In Fig. 6, we measure the number of satisfied users by our algorithm of maximizing the satisfied users (SU). We can observe that as the number of available RBs increases it allows more users to get satisfied. As the user set is constant, the channel conditions remain the same throughout, so we observe a gradual increase in the performance curve with the increasing number of RBs, Nevertheless it is higher than CMS and OMS due to our user selection rule.

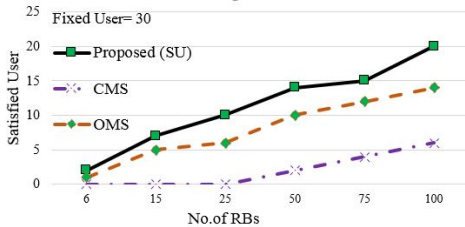


Figure 6. Satisfied users count for fixed number of users.

In Fig. 7, we measure the throughput (bits/sec) for fixed user set by varying the number of RBs. As the more users get satisfied, the collected throughput due to those satisfied users

also increase. As the proposed method selects the users that are capable of increasing the number of satisfied users in every multicast session, it performs comparatively better than the candidate algorithms CMS and OMS.

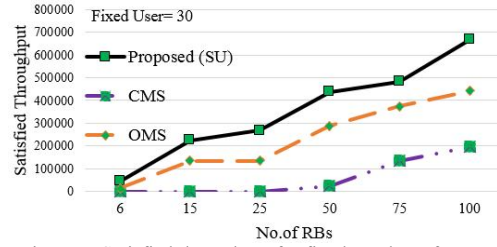


Figure 7. Satisfied throughput for fixed number of users

V. CONCLUSION

In this paper, we studied the resource allocation issue for multicast D2D users with individual requests. We have proposed two algorithms to maximize the satisfied user throughput and to maximize the number of satisfied users when the RBs are limited. We proved that these algorithms have a worst-case lower bound and have polynomial time complexity. In addition, the simulation results show that the measured parameters namely satisfied throughput and satisfied number of users, Jain's Fairness Index in both the algorithms have better performance compared to other candidate algorithms. In future, we extend this work to suit for high mobility users with dynamic channel quality variations.

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