Centralized Interference-Aware Resource Allocation for Device-to-Device Broadcast Communications

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***Abstract*—The Long Term Evolution-Advanced (LTE-A) networks are being developed to provide mobile broadband services for the fourth generation (4G) cellular wireless systems. Device-to-Device (D2D) communications is a promising technique to provide wireless peer-to-peer communication services and enhance resource utilization, as well as spectrum efficiency. In this paper, a centralized resource allocation scheme involving several Device-to-Device (D2D) broadcast groups underlaying cellular network is proposed. The great amount of interference caused by sharing the resources between different D2D broadcast users may significantly affect the performances of other D2D users. Therefore, an efficient resource allocation method is necessary to coordinate the interference. Specifically, we formulate the interference relationships among different D2D broadcast groups as an innovative interference-aware graph. We propose a centralized interference-aware graph based resource allocation algorithm that can effectively minimize the interfered D2D users between different D2D broadcast groups. This scheme aims to optimize the number of "conflict UEs" meanwhile mitigate different D2D broadcast groups from affecting the performances of each other.**

***Index Terms*—D2D; broadcast communication; resource allocation; interference-aware**

I. Introduction

It is a well known phenomena that the demand for wireless application is increasing rapidly nowadays, having led to the insufficiency of available resource. Getting the transmitter and receiver closer to each other increases the system capacity and data rates in a wireless system. D2D communications infrastructure has been proposed to take advantages of the physical proximity of communicating devices, increasing resource utilization, and improving cellular coverage [1], [2]. The problem of synchronization and discovery is also discussed[3]. However, the implementation of Device-to-device (D2D) communications faces a number of challenges, among which interference management is of much importance. One of the key issues is the interference management problem caused by the resource sharing among the different D2D communication groups.

Due to the characteristics of low power and short-range, the majority of research on D2D transmission focuses on the resource allocation scheme.A considerable amount of research is devoted to the resource allocation for D2D communication underlaying cellular network [4–7] In [4],[5], the authors discuss the QoS-based resource allocation scheme. Taking into consideration of QoS protection and fairness for D2D multicast groups in OFDMA-based hybrid systems, a resource allocation scheme is proposed in [4]. It not only enhances throughput gain and maintains the fairness for D2D communication. In [5], the authors introduce a new resource block-oriented resource allocation method where D2D users can reuse any resource block through the access of OFDMA when sharing the resource with cellular users in the uplink.

However, little research is available on the characteristics of broadcast. In general cases, D2D communication is always assumed to be D2D pairs instead of D2D broadcast groups. It is not until the progress of D2D specification in 3GPP focus on the D2D broadcast, resource allocation for D2D broadcast communication has become an essential research direction.

Graph theory provides some useful tools for modeling and analyzing and thus it has also been widely adoptedto solve the resource allocation problems for D2D communications. The authors in [7], propose an interference-aware resource sharing algorithm; however, it still emphasizes the interference management between D2D pairs and cellular users.

In this paper, we take advantages of Graph theory to formulate the interference relationships among different D2D broadcast groups into a novel interference-aware graph. With the interference-aware graph based resource allocation algorithm, we are able to effectively minimize the interference that D2D users confront between different D2D broadcast groups. The scheme aims to optimize the throughput of D2D communications over the shared uplink spectrum meanwhile lessen the affect posed on different D2D broadcast groups again each other.

II. System Model

As illustrated in Fig. 1, we consider a D2D broadcast transmission scenario in a cellular network, in which there exist a BS and several D2D broadcast groups. The BS

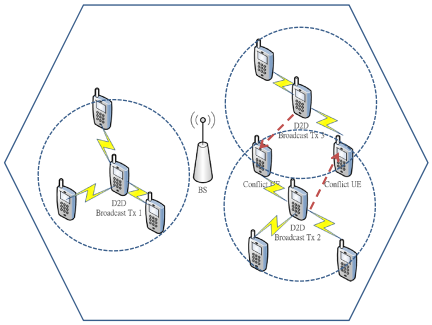

Fig. 1. System Model

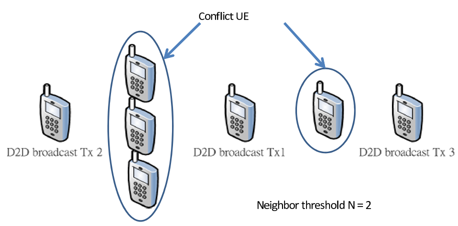

Fig. 2. Conflict UEs

knows about the D2D broadcast transmitters demand from the communication request, and then decides how to allocate the spectrum resource to the D2D broadcast transmitters. We focus on the inter-group interference resulting from resource sharing between different D2D broadcast communication groups.

Assuming that there are one BS, M D2D broadcast transmitters along with N D2D UEs, in the network, where T_m, m = 1,2,3......M, denotes a D2D broadcast transmitter, R_n, n = 1,2,3......N, denotes a D2D UE, and C_n denotes a allocated subchannel. D2D UEs randomly associate with the D2D broadcast transmitters T_m over the RSRP threshold. We define the D2D UEs as Conflict UEs" if they can can receive the signal over the RSRP threshold from more than one D2D broadcast transmitters. When the transmitters using the same subchannel broadcast simultaneously, the conflict UEs between the transmitters suffer serious interference. Hence, the D2D broadcast transmitters in the neighborhood with many conflict UEs between them should not be allowed to share the same channel. Take Fig. 2 for instance, there are three conflict UEs between D2D broadcast T_1 and T_2, and one "conflict UE" between D2D broadcast T_1 and T_3. Given that the neighbor threshold equals to 2,it means if there are two or more conflict UEs between any two D2D broadcast transmitters, the two D2D broadcast transmitters are regarded to be in the neighborhood, resulting in mutual interfrence once the neighboring transmitters using the same resource. Thus, we can simplify the Fig. 2 into Fig. 3. The key to overcoming of the resource allocation problem is to find the optimal RB assignment solution for D2D broadcast communication. Our goal is to minimize the number of conflict UEs.

Fig. 3. The adjacent graph

III. Proposed Scheme

A. Association

All D2D UEs associate with the D2D broadcast transmitters around them. Two steps for association proceed as follow. First, if the signal strength of the D2D broadcast transmitters exceed the RSRP threshold, the D2D UEs add them to the association candidate list. Then, the D2D UE randomly associates with a D2D broadcast transmitters from the list, and those left unchosen are added to the conflict matrix of the D2D UE.

B. Notation definition

We define conflict matrix C_{ij} as the number of the conflict UEs between D2D T_i and T_j. The total conflict matrix equals to C + C^T. We also define neighbor threshold N as the threshold that determine whether two D2D Txs are in the neighborhood. If the number of the conflict UEs between T_i and T_j is larger than N, we say that T_i and T_j are in the neighborhood which indicates they will interfere with each other if the same RBs are chosen. For the neighboring Txs, we will draw an edge on the graph to indicate they are in the neighborhood. We define adjacent matrix A, i.e.,

$$a_{ij} = \begin{cases} 1, \text{ if } \ C_{ij} > \text{Neighbor threshold} \\ 0, \text{ otherwise} \end{cases} \quad (1)$$

We define edge number array $E = \sum_j a_{ij}$ which indicates the number of edge of T_i that can be observed through the graph. We define priority array P = sort(E).

C. Resource allocation

Algorithm 1 Resource Allocation

for each $T_i \in$ priority array **do**
  while there is no other priority higher and has not choose channel T_i **do**
    $channel_list[i] = min\{i \mid i \in A\}$;
    $O = O \cup i$;
  end while
end for

As illustrated in Fig. 4, for all the D2D broadcast transmitters, we choose the channel in the order of the priority array. We define the set S,O,R. S indicates the set of all resources that can be used. O indicates the set of the resources that already used by the neighboring D2D broadcast transmitters. R indicates the set of resources that not been used, i.e.,

$$R = \{i \mid i \in S/O\} \quad (2)$$

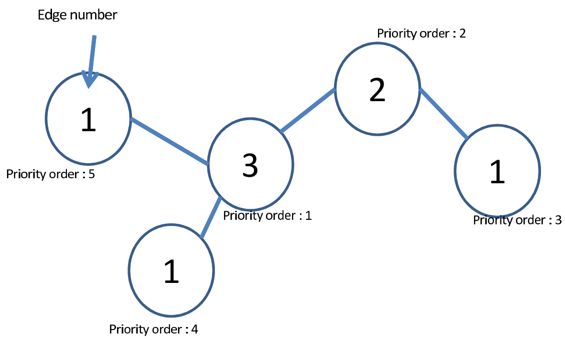

Fig. 4. Resource choosing order

TABLE I
PARAMETER SETTINGS

Parameter	Setting
Layout	Urban macro (500m ISD) + 1 RRH/Indoor Hotzone per sector
System bandwidth	10MHz
Carrier Frequency	2GHz
No. of cells	7
No. of sectors per cell	3
D2D UE load	25 UE/sector
D2D Broadcast Tx Power	23dBm
Minimum association RSRP for D2D communication	-112dBm
Path loss and Fading	reference
Traffic Model	VoIP traffic

Choosing start from the most edge Tx, The choose resource have a fixed order, if the first resource have been used by your neighboring Tx, we have to choose next resource till no one used the resource The detail of algorithm is shown as $Algorithm1$.

IV. SIMULATION

A. Simulation methodology

To evaluate the efficiency of the proposed scheme, the following simulations are conducted in accordance with the 3GPP D2D specification [8]. In each sector, totally 25 receiving D2D UEs are dropped following the specification. The D2D UEs dropping method according to the specification is special:2/3 UEs randomly and uniformly dropped within the clusters of small cell(s);remaining 1/3 UEs randomly and uniformly dropped throughout the macro geographical area;20% UEs are outdoor, and 80% UEs are indoor;In order to ensure that 80% of the UEs are indoor some of the UEs that are not dropped inside a building will be declared as indoor UEs. We will call them virtual indoor UEs. The detailed parameter is in TABLE 1 and the parameter of VoIP traffic model is in TABLE 2.

In addition, different number of D2D broadcast transmitters are dropped in each sector randomly following the uniform distribution.The performance metric under consideration is the average SINR and the outage probability.

TABLE II
PARAMETERS FOR VOIP MODEL

Parameter	Values
Codec	Source rate 12.2 kbps
Encoder frame length	20 ms
Voice activity factor l	Exponential distribution mean = 2.5 seconds
Voice payload per speech frame during active talk	With header compression 41 Bytes

B. Comparison with optimal solution

In this section, we do the simulation to verify that our optimization problem formulation is meaningful. We compared the performance of our proposed scheme with those of optimal solution. We use brute force to evaluation the performance of optimal solution. The optimal scheme include max average SINR and max channel capacity. First, we ran the simulation and observed the number of ”conflict UEs” of these schemes. In Fig.5, we defined the performance matrix ”conflict ratio” which is the ratio of conflict UEs and total UEs. We can observed that the conflict ratio of optimal SINR scheme and optimal channel capacity are low. Even the highest point in the graph does not reaches 10 percent. Thus, we can said that our optimization problem is meaningful due to the low ”conflict ratio” of optimal SINR and optimal channel capacity scheme.

Furthermore, we also compared the traditional performance metrics in communication systems. In Fig.6 and Fig.7, we can observed that the average SINR and channel capacity of our proposed scheme is only little lower than the optimal solution that maximize SINR and channel capacity.

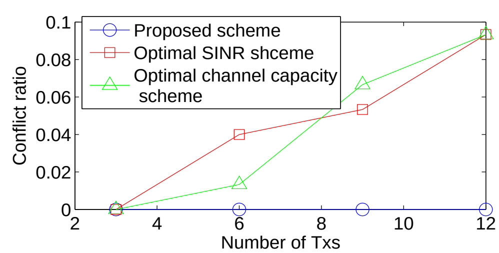

Fig. 5. Conflict ratio comparison

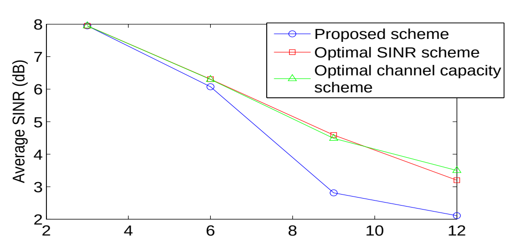

Fig. 6. Average SINR comparison

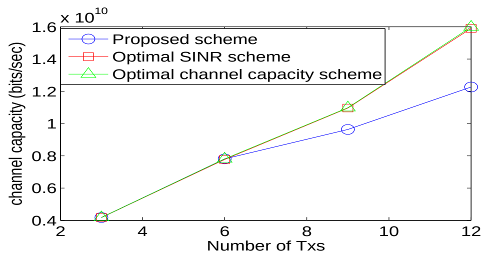

Fig. 7. Channel capacity comparison

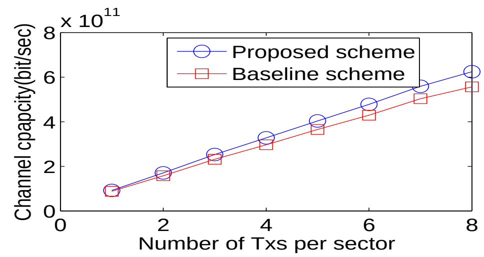

Fig. 9. Channel capacity

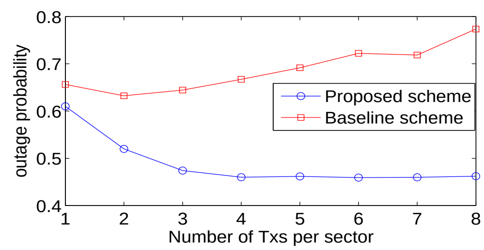

Fig. 10. Outage probability

C. Simulation Result

In this section we compared our proposed scheme with a baseline scheme. The baseline applies use our interference-aware algorithm, so that it knows the amount of the resource it should use and then allocates the resource randomly. Since the baseline scheme takes advantages of our algorithm, its performance is tolerable even compared with our proposed scheme. Fig.8 shows that the average SINR of our proposed scheme is higher than that of the baseline scheme. In addition, despite the accumulation in interference with the increasing number of the D2D broadcast transmitters, the performance of the both schemes only degrades a little on account of our proposed algorithm. In Fig.9, we can observe that the channel capacity grows up as the number of D2D broadcast transmitters increases. This is because that the chance to associate with a D2D broadcast transmitters with better signal strength increases, too. Though the number of D2D broadcast transmitters increase causes the interference slightly increase, the channel capacity increase due to more D2D UEs can receive better signal. We can prove it in Fig.10.

In Fig. 10, the outage probability(SINR$<$0) of the proposed scheme is lower than that of the baseline one, indicating our scheme outperforms in the successfully received ratio. Moreover, we can also observe that with the increase of the D2D broadcast transmitters, the outage probability of the baseline scheme grows higher under the effect of the larger interference. the outage probability of our proposed scheme grows lower due to our interference-aware mechanism.

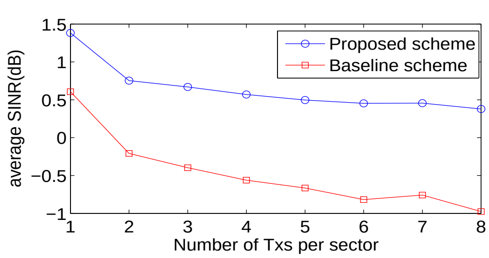

Fig. 8. Average SINR

V. Conclusion

In this paper, a centralized interference-aware graph based resource allocation algorithm is proposed to effectively minimize the interfered D2D users between different D2D broadcast groups. The simulation results prove our scheme provide not only a certification but also low calculation complexity for D2D broadcast communication. Even in a multi-cell scenario it is capable of managing the inter-cell D2D broadcast group interference as well. Different from the previous work concentrating on the relationship between cellular networks and D2D pairs, our proposed scheme investigates resource allocation from another aspect in the interference management between different D2D broadcast groups.

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