Reusing Resource Blocks by Efficient Grouping for D2D in LTE Networks

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Abstract. D2D (Device to Device) communication is one of the key technologies that 3GPP intends to develop for 5G communication systems. It can not only reduce the burden of eNB, but also increase the capacity of the cellular network. It is also very useful when disasters happen, while the mobile communication systems are not available. Due to limited resource blocks (RB), researchers suggest that D2D pairs which can mutually tolerate the induced interference are grouped into a clique. Then the pairs in the same clique are assigned with the same RBs, so as to reuse RBs and increase the system capacity. The previous method evaluates SINR by using the locations of the devices and free space path loss formulae. In this way, however, the possible obstacles between a pair of devices are not considered. To deal with this problem, in this paper, we propose an approach where the SINR is evaluated by a practical way that employs the Reference Signals Received Power (RSRP) reported by the devices. Our approach can also prevent cliques from being formed improperly, so as to ensure its positive effect.

Keywords: D2D · Reuse RB · RSRP

1 Introduction

1.1 Motivation

With the rapid progress in the networks, the mobile network information also grows rapidly, leading to the introduction of D2D technology in the future LTE systems. D2D technology can reduce the burden of the base station, it can also increase the overall system capacity [1].

Resource allocation is an important issue for D2D technologies. In order to increase the system capacity, we need to improve the efficiency of spectrum utilization with limited radio resources. One of the methods is to group D2D pairs that can tolerate the interference from each other into the same clique. Then, assign the pairs in the same clique with the same RBs, so as to reuse the RBs. There are some problems with the method presented in the literature. As a result, we propose a highly feasible approach to reuse RBs.

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1.2 D2D Communications

In this paper, the environment under consideration is unicast D2D communication. The first phase for unicast D2D communication is Proximity Discovery. In order to prevent interference, a DUE (D2D User Equipment) transmits discovery signal for the partner to receive [2–4]. 3GPP specifies two types of the operation [2].

- Type 1 (UE-selected) is a procedure where resources for discovery signal transmission are selected from a pool of resources allocated by the eNB on a non UE specific basis.
- Type 2 (eNB scheduled) is a procedure where resources for discovery signal transmission are allocated by the eNB on UE specific basis.

In our proposed approach, which will be presented in Sect. 2, the Type 2 is employed at this phase.

After the proximity relationship is established between two devices, these two devices are named as a pair. Then the eNB needs to allocate some continuous uplink RBs for the pair to transmit direct data and direct control information. 3GPP also defines two modes for this function [2].

- Mode 1: eNB or relay node schedules the exact resources for a DUE to use.
- Mode 2: a DUE on its own selects resources from resource pools.

The mode 1 will be employed in our proposed approach.

1.3 Resource Reuse Schemes and Related Problems

One of the ways to increase the capacity of an eNB is to improve the efficiency of employed spectrum. Because the sensitivity of a UE is much lower than that of an eNB, a UE is less likely to be interfered by the other UE. Some researchers suggested that the D2D pairs that can tolerate the interference from each other are included into the same clique. Then the pairs in the same clique are assigned with the same RBs for transmission, so as to reuse the RBs [5]. Based on the clique forming concept of [5], author of [6] proposed to allow a cellular UE to share RBs with a clique of pairs. For convenience, we name the clique forming scheme used in [5] as LCF, which is the acronym of “Location based Clique Forming” scheme.

However, there are three problems with the LCF scheme. In this paper, we present an approach to prevent these problems. At first, we briefly describe the LCF scheme and mention the challenges faced.

1.4 LCF Clique Forming Scheme

There are basically two steps for the LCF to form cliques.

Step 1: Determining whether two pairs are harmonic to each other
The first step in forming a clique is to determine whether two pairs can tolerate the interference from each other. By referring to Fig. 1, in this paper, we define that two pairs are harmonic to each other if any of the four devices can tolerate the interference

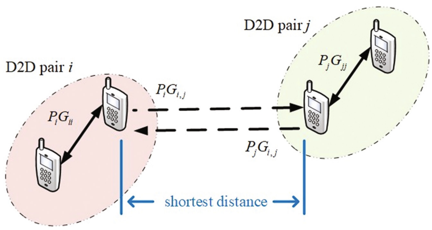

Fig. 1. Illustration for calculating SINR

coming from any device of the other pair when the devices use the same RBs. For LCF scheme, pair i and pair j are harmonic to each other if

$$SINR_{i,j} = \min\left(10\log(\frac{P_iG_{ii}}{P_jG_{i,j}+N}), 10\log(\frac{P_jG_{jj}}{P_iG_{i,j}+N})\right) \geq -6.7 \text{ dB}, \quad (1)$$

where P_i is the transmit power of D2D pair i, G_{ii} is the channel gain in D2D pair i, and $G_{i,j}$ is the free space channel gain between D2D pair i and pair j with the shortest distance between the devices of the two pairs. N is the thermal noise. All of the channel gain mentioned in LCF scheme consider only the free space path loss, which is calculated according to the following formula

$$\begin{cases} Max(20\log(\mathrm{d}) + 38.4, 22.7\log(\mathrm{d}) + 33.02), \mathrm{d} \leq 17.06 \text{ m} \\ Max(20\log(\mathrm{d}) + 38.4, 40\log(\mathrm{d}) + 11.73), \mathrm{d} \leq 17.06 \text{ m} \end{cases} \quad (2)$$

Here the threshold −6.7 dB for $\text{SINR}_{i,j}$ is the minimum SINR for decoding the lowest efficiency QPSK signal. This value corresponds to the condition that CQI = 1 in Table 1 [7].

Table 1. Mapping between CQI and modulation coding schemes (MCS)

CQI	modulation	SINR range (dB)	Code rate	Spectral efficiency
1	QPSK	−6.7<SINR≤−4.7	0.076	0.152
2	QPSK	−4.7<SINR≤−2.3	0.12	0.234
3	QPSK	−2.3<SINR≤0.2	0.19	0.377
4	QPSK	0.2<SINR≤2.4	0.30	0.601
5	QPSK	2.4<SINR≤4.3	0.44	0.870
6	QPSK	4.3<SINR≤5.9	0.59	1.175
7	16-QAM	5.9<SINR≤8.1	0.37	1.476
8	16-QAM	8.1<SINR≤10.3	0.48	1.914
9	16-QAM	10.3<SINR≤11.7	0.60	2.406
10	64-QAM	11.7<SINR≤14.1	0.45	2.730
11	64-QAM	14.1<SINR≤16.3	0.55	3.322
12	64-QAM	16.3<SINR≤18.7	0.65	3.902
13	64-QAM	18.7<SINR≤21.0	0.75	4.523
14	64-QAM	21.0<SINR≤22.7	0.85	5.115
15	64-QAM	SINR>22.7	0.93	5.554

Step 2: clique forming
The second step is to form cliques. In order to obtain high reuse rate of RBs, LCF scheme tries to make cliques as large as possible and then tries letting cliques to reuse the RBs assigned for cellular UEs. Here we only focus on the process to form cliques. Based on graph algorithm, every pair is regarded as a node. If two pairs are harmonic with each other, the two nodes, which represents the two pairs, are connected by an edge. By employing Bron-Kerbosch Algorithm, the maximum clique and some small cliques are obtained.

1.5 Problems with LCF Clique Forming Scheme

A. Problem 1

When applying (1) and (2) to check whether two pairs are harmonic, LCF scheme uses the coordinates of the two pairs to calculate SINR based on free space path loss formulas. However, if there is any obstacle between the two devices of a pair, this scheme would over-estimate the SINR in (1).

B. Problem 2

LCF scheme depends only on Bron-Kerbosch Algorithm to form cliques. That means a pair can be included into an existing clique as long as it is individually harmonic with every pair in the clique. However, when the number of pairs in a clique increases, the interference to every pair increases accordingly, and then some of the pairs may not meet the minimum SINR requirement for D2D communication.

C. Problem 3

When more and more pairs are included in a clique, the number of required RBs for some pairs could probably increase dramatically, and it may be unworthy for the clique members to reuse the same RBs.

In this paper, therefore, we propose an approach to overcome the three problems mentioned above.

We describe the proposed approach in Sect. 2. The simulation results are presented in Sect. 3. Finally, we address the conclusion and future works in Sect. 4.

2 Proposed Approach

The steps of our approach are the same as those of LCF, but the processes in the steps are different.

Step 1: Determine whether two pairs are harmonic – based on measured RSRP
During the phase of Type 2 Proximity Discovery, a discovery signal is transmitted on the RBs allocated by the eNB. We assume that the RSRP (Reference Signal Received Power) is obtained and reported to the eNB. Then, the P_iG_i and P_jG_j in (1) are obtained directly. This method can prevent the problem 1 with LCF scheme. Since a cellular UE

will return the RSRP to the eNB, it is a feasible assumption that a device of a D2D pair reports RSRP of the received discovery signal.

Step 2: Clique forming - consider all the interferences in the whole clique
The problem 2 mentioned above shows that if there are too many pairs in a clique and they make high interferences as a result, some of the pairs cannot communicate. The problem 3 even points out that it may be unworthy for the members of a clique to reuse the same RBs. In order to solve problem 2, we check the SINR of each pair of all possible cliques. If a clique includes a pair with SINR less than −6.7 dB, this clique is removed. As for the problem 3, we propose to raise the minimum SINR requirement for the definition of being harmonic and being a member of a clique. Then the definition for pair i and j to be harmonic is modified as follows

$$SINR_{i,j} = \min\left(10\log(\frac{P_iG_{ii}}{P_jG_{i,j}+N}), 10\log(\frac{P_jG_{jj}}{P_iG_{i,j}+N})\right) \geq SINR_{\min,k}, \tag{3}$$

where the $SINR_{\min,k}$ is the minimum SINR requirement corresponding to CQI = k in Table 1. Besides, the minimum SINR requirement for a pair being in a clique is also set as $SINR_{\min,k}$. For example, if k = 8, $SINR_{\min,8}$ = 8.1 dB. As for the LCF scheme, the requirement corresponds to k = 1, while it doesn't check SINR requirement for a pair to be in a clique.

With higher k, the number of pairs in a clique would decrease in average. However, once a pair is included in a clique, the required number of RBs would be less because of higher SINR.

3 Simulation Results

The simulation environment includes only one eNB and the D2D pairs are uniformly distributed with minimum distance 35 m apart from the eNB. The parameters are listed in Table 2. Both the minimum SINR requirement for being harmonic and being a member of a clique are set the same as $SINR_{\min,k}$, k = 1–15. The simulation result is presented in Fig. 2. If the eNB allocates RBs for every pair without reusing by ways of clique forming, the number of required RBs is 139. However, if the minimum SINR requirement for being harmonic and forming clique is $SINR_{\min,1}$ = −6.7 dB, the required number of RBs is still as high as 133, which corresponds to only 4% reduction. That means with low SINR threshold, there may be lots of pairs included in cliques, the interferences inside a clique would be high, and each pair may need more RBs. Finally, clique forming cannot effectively reduce the RB demand.

On the contrary, for more stringent SINR thresholds, for example k = 10, the cliques may include less pairs. However, the required numbers of RBs are not more because of higher SINR values. As the result, the total RB demand is reduced to only 40% of that without clique forming.

Table 2. Simulation parameters

Parameter	Value
Cell radius	500 m
Carrier frequency	2 GHz
System bandwidth (uplink)	20 MHz
Shadowing standard deviation	7 dB
Antenna gain	0 dBi
Transmission power	23 dBm
Noise spectral density	-174 dBm/Hz
Minimum distance between D2D user and eNB	35 m
Number of D2D pairs	20
Requested data rate for each D2D pair	3 Mbps
Minimum SINR requirement for clique forming, SINRmin,k,	k = 1~15

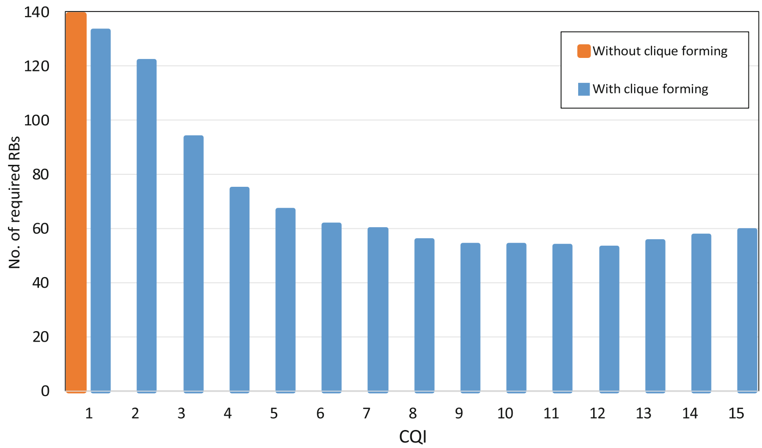

Fig. 2. Number of required RB versus SINR thresholds indicated by CQI

4 Conclusion and Future Works

In order to solve the three problems with the LCF clique forming scheme, we propose a new approach based feasible assumption. With regard to reusing RBs, we evaluate the efficiency based on different SINR thresholds that determines whether two pairs are mutually harmonic and whether a pair can be in a clique. Simulation results reveal that the lowest threshold, which just meets the minimal requirement for decoding, is not suitable because more RBs are needed with low SINR. On the contrary, higher SINR thresholds may result in better performance.

The future works is to consider more parameters and try to save more number of RBs by the clique forming method. It is also important to find a rule to choose a suitable SINR threshold, so as to get better performance.

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