Efficient Mechanism of eNB Bandwidth in D2D Communication in 5G

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Abstract. The device to device (D2D)communication will be a big part of 5G and is responsible for the direct communication between users in range without the relay of Base Station (BS). There are three modes that work in D2D communication based on radio resources and how they are used. In D2D the radio resources that are the same with cellular users the mode is named as reuse mode. The other option is to specify an amount of resources only for D2D users and it is called dedicated mode. In this paper will provide how the Users Equipments (UEs) and the D2D communication itself respond in a D2D communication when an eNB serving only in dedicated mode has to change to reuse mode in order to serve more users. Considering two scenarios, reuse and dedicated the mechanism will provide the values of interference and throughput of eNB in each scenario indicating which mode is better under specific circumstances.

1 Introduction

The D2D refers to direct communication between end users without transmission from a base station. The only system that supports that kind of communication is the Long Term Evolution Advanced standard (LTE-A) with the proximity-based services (ProSe)[1]. The LTE-A supports heterogeneous deployments designed to extend network coverage and increase its capacity using picocells, femtocells, relays between the transmitter and the receiver in order to communicate due to long distance between them or even if there is no network coverage for one of the two users [2]. BS is basically the e-NodeB which is responsible for the connection with UEs. Each e-Nodeb can manage more than one cell and can provide services to many UEs while each UEs can only connect to one and only e-NodeB each time. Because of many users using the same e-NodeB at the same time D2D transmitters can cause major interference in cellular network during resource sharing [3]. The authors of a study [4], consider a scenario where D2D and cellular transmissions can interfere to each other, and where several D2D transmissions can share the same cellular resources. Using the Graph Theory authors of [5] illustrated the interference relationships among different D2D broadcast groups. When an UE receives information from the BS, UE can intervened from, another UE which is transmitting in the same time. In [6], the authors propose alternative

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heuristic PFlike schemes and heuristic max capacity schemes in order to achieve a better performance for the D2D communication by sharing subchannels with UEs. Resource sharing is the basic problem of that system and e-NodeB should be able to deliver resources correct without causing interference to the users of cellular network because D2D communications only work on stable links and nodes with limited mobility. There are three case scenarios of coveragein D2D. If the UEs of a D2D link are in coverage the interference is avoided. If we are dealing with partial coverage [7] then the interference is inevitable. In case UEs are in different nonsynchronized cells or even out of coverage, the receiving UE needs more information to establish the connection. If that happens then a handover takes place meaning that the e-Nodeb is handling over UE to another e-NodeB that can coverage it. There are three transmission modes in such networks that UEs must select which one suits for them in their current state. In the first one (reuse) the same spectrum resource is shared between D2D and cellular users. In the second one (dedicated) the network is binding a section of available resources exclusively for direct communications of D2D devices. In cellular mode, the D2D traffic comes through the base station with the traditional way. That means without direct communication between D2D devices. The basic problem in D2D is to be able to select the appropriate communication mode, based on channel quality. Some authors [8] propose a tractable analytical approach to model the effect of flexible mode selection for UEs in a large scale network while others use joint mode selection and develop algorithms according to different objectives [9,10]. In this paper, we propose a mechanism working efficiently for D2D networks that performs in both reuse and dedicated modes. We identify the relationship between mode selection and resource block (RB) allocation including two case scenarios, dedicated and reuse mode. The remainder paper is organized as: Sect. 2 describes the system model. Section 3 shows the performance, Sect. 4 the perfomance evaluations are described and at the last one, Sect. 5, results are presented.

2 System Model

In LTE networks the available frequency is divided into resource groups, called Resource Blocks (RBs). Depending on the available bandwidth, each RB has a different frequency band, so each RB will have a frequency dependent on the channel bandwidth. Every device in order to achieve a D2D communication needs its base station to allocate some resources first. The needs of each user are not predictable in advance, but they are proportional to the bandwidth of an eNB. It depends on user's requirements on speed, and inversely proportional to the SINR between the device and the station. In our mechanism, we aim to maximize D2D user's satisfaction without overloading the eNB and minimizing the RBs required. In a D2D communication though in order to keep the D2D mode and to turn in cellular mode, the distance between the users is very important. The results about the RBs, the interference and the distance between users seeking D2D communication will lead to a comparison of the two reuse and dedicated modes.

$$Distance = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{1}$$

Some users operate in dedicated mode while others use reuse mode. In dedicated and cellular mode the transmitters do not share channel resources while in the reuse mode they do. On the other hand in reuse mode would cause interference at the receivers while in cellular and dedicated mode will not. Simultaneously serving all kind of connections in a network can cause interference between the connections. To avoid interference which only happens in reuse mode, eNB needs to know which pairs can reuse resources already allocated to cellular users and resources that can be used in more than one D2D communication pair. Since there is no interference in dedicated mode then the value of SINR is the same as SNR.

$$SNR = \frac{P_{Signal}}{P_{noise}} \tag{2}$$

$$SNR_{DB} = 10 \log_{10} \frac{P_{Signal}}{P_{noise}} \tag{3}$$

In the reuse mode however there are interference due to spectrum sharing and reuse of resources so here will be the value of the interference. In order to calculate the SINR we need to take in account the power of each base station and the channel loss (path loss) of each station and each device. Divided by the power of the spectral density of the white noise over the frequency distance between the carriers. Summing up the total power radiated by all the stations in our simulated area.

$$SINR_{(x_i)} = \frac{\frac{F_i}{|x_i|^a}}{\sum_{j \neq i} \frac{F_j}{|x_j|^a} + N} \tag{4}$$

The transmission rate depends on the SNR value so in both cases we will expect a noticeable difference between the two not only in SINR and SNR but also in Mbps. The number of resources in the reuse mode depends on the requirements of the users operating in cellular mode and on the number of resources that can be used by D2D pairs. It is possible that some D2D pairs may not be able to use some of the resources due to the transmitter power limitation of a D2D communication. So in our simulation to make the scenario more realistic there will be users who will be operating in cellular mode. This, in turn, means that the resources used by cellular users will not be able to be used by D2D users in the dedicated scenario while in the reuse scenario. For our convenience in programming, there will be two scenarios and there will be no dedicated and reuse users at the same time. User requirements for data transmission speeds is the basic criterion for our research. The mechanism targets on maintaining the quality of service provided by the network. This paper will focus primarily on how D2D communication works. We will mainly focus on dedicated and reuse functions. As is shown in Fig. 2 assuming we have an area with many UEs the eNB serve each one of them. Some of the users are cellulars (upload and download links as red and yellow) and others are DUEs. Between DUEs there are some pairs that share RBs that means they use reuse mode while others do not, meaning they are in dedicated mode. New users (greyed out in the figure) could request to be served and the algorithm should be able to take the best choice for them. The mechanism we are about to use achieves QoS for the users and we assume that instead of increasing the users the netowrk will be able to serve the users and satisfy their requirements, making it an efficient mechanism confronting the interference, the increasing number of users and thus the RBs that need to be used. We will simulate two different scenarios in three different number of users to compare at the end how the mechanism responds in each case. In this section each important parameter for our mechanism is described in order to explain and understand the mechanism th the Proposed Mechanism section and then set the values of each one parameter in the section of Performance Evaluation (Fig. 1).

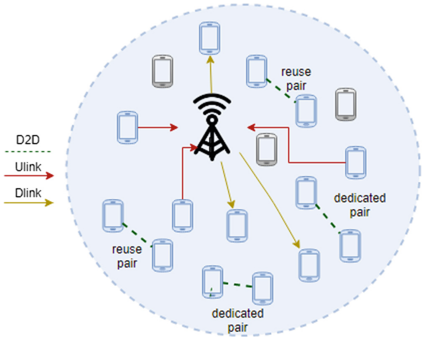

Fig. 1. System model map

3 Proposed Mechanism

In this paper, we emphasize the performance of the system in allocating resources to users in a network that is divided into Downlink and Uplink. In our simulation, we propose a mechanism that achieves an efficient way of sharing resources and therefore supporting more users on the network while addressing the interference that occurs. The network we will create in the simulation environment refers to an area with macro cells but also small cell stations that will be responsible for connecting users together for successful device-to-device pairing. The first scenario is the dedicated mode where all users will be served by the stations simultaneously with the cellular users. We know that the dedicated feature assumes that resources used by users are distributed only to those who need them and do not share them with others. This results in fewer users compared to the reuse mode but is more efficient in terms of interference. Since resources are not shared with other devices, we do not have interference value neither in or cellular communication links. In the second scenario, users will be in reuse mode. This means that the resources allocated to the devices can be reused if requested so the network will be able to support more users. Unlike before, in this case the users after sharing the spectrum, the devices has to deal with the interference and here the communication quality is not optimal.

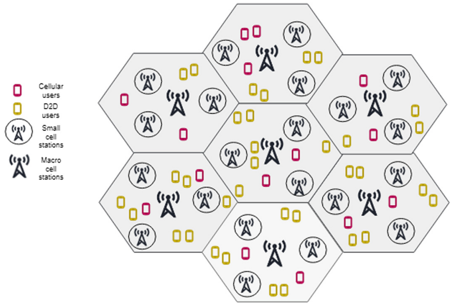

Fig. 2. Simulation topology

Each area cell has the same size and the area will be consisted of macro cell base stations and small cell base stations. The small cells will be placed on the edges of the macro cell coverage areas so that there are no gaps. Each device will operate either Uplink or Downlink and at different transmission rates. These parameters as well as the number of users and each value used can be differentiated by the user through the file that defines the variables. The performance study of the mechanism will be declared by the ability to efficiently connect the devices to other devices after first connecting to the base station in coverage. The ability of the mechanism to also serve users according to their requirements is also considered necessary. Each station has a specified number of resources. The number of resources depends on the bandwidth and the way they will be shared on the devices. Once resources are fixed but in a realistic scenario users can be defined but continue to grow the simulation should serve as many as possible but also inform us of the rate of use of resources needed and how many remained free. Interference is a key issue to address as the more our users grow, the more difficult it will be to obtain better SINR connections. In our scenarios not only SINR has to be declare but also the number of users, number of RBs and a maximum number of RBs that can be allocated to user i. The radio frequencies defined by 3 GPP for 5 G is divided in two Frequency ranges (FR). We are interested in FR2 with minimum bandwidth 50 MHz and maximum 400 MHz. In our scenario the base station we are about to use is Metro cell type, meaning that can serve more than 250 number of users and can be deployed in urban areas in channel bandwidth between 50, 100, 200 or 400 MHz. Also the maximum distance between the user equipment and the base station can be 100 s of meters.

4 Performance Evaluation

In this section is described the simulation scenario and models that are used for evaluation and then, the results are presented and explained. The scenario below defines a geographical area containing 19 macro cells with a coverage radius of 375 m and 50 small cells with a radius of 50 m. Macro cells base stations are shown with a blue triangle in the middle of the cells, while small cells are green with a triangle in a circle reflecting their coverage area. The users who can operate in D2D communication are the black squares and are 150. On the other hand the users that operate in cellular mode are the red squares. In the area we are experimenting with, the total number of users, that is, cellular but also D2D users can reach up to 300. For this reason we select the subcases with 100 and 30, 150 with 50 and 180 with 80 in D2D and cellular users respectively (Fig. 3).

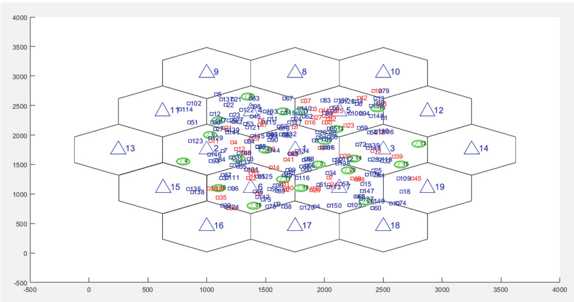

Fig. 3. Topology simulated in Matlab

The performance of the proposed mechanism is simulated in MATLAB. Assuming an area of 375 m. There is an eNB in the middle of the declared area of FR2 base station as its described previously in Sect. 3. The positions both of CUEs and DUEs are set randomly. The maximum distance between D2D users is set up to 100 m. Because of the base station type, the bandwidth will be set at 60 MHz and carrier frequency at 10 GHz as 5G is able to. Each device and each base station are numbered for better understanding of the topology and the results.

In the next figures we can see the performance of eNB while the mode of D2D users are set to dedicated and to reuse mode. Our results refer to three different cases in two different scenarios. In each case the number of devices in total are different, containing both cellular and D2D users. The results for each scenario are presented in the same figure in all three cases in order to be able to compare them. For the results five out of about 70 results are represented in order to be able to notice the different between the two scenarios (Fig. 4 and Table 1).

Algorithm 1. Mechanism for mode selection based on UE location

```
D2D pairs (i,j) in map
Number cellular users
SINR_DL
SINR_UL
RBs_DL
RBs_UL
for each UEi do do
    for each UEj do do
        if i ≠ j then
            if  is not already a pair with a device then then
                calculate the euclidean distance between the pair (i,j)
                if distance < 100m then
                    D2Dpairs +1
                end if
            end if
        end if
    end for
end for
for each D2Dpair (i,j) do do
    find the closest and best eNB based on SINR(DL)
    if RBs are enough to serve then then
        connect the pair in the proper scenario
    else
        find the next best eNB
    end if
end for
print  Number of D2D pairs
print  Network Throughput
print  SINR or SNR values
print  comparison figures
```

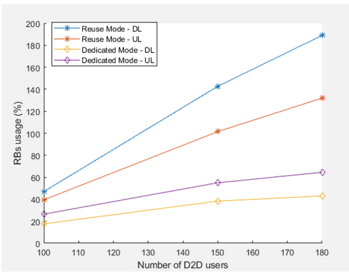

Fig. 4. RBs usage-D2D

Table 1. Parameters of the Simulation

Parameter	Value
D2D distance	100 m
Macro cells	19
Macro cell coverage	375 m
Small cells	21
Small cell coverage	50 m
Downlink bandwidth	60 MHz
Uplink bandwidth	40 MHz
RB bandwidth	180 KHz
Downlink resource blocks	300
Uplink resource blocks	200
Carrier frequency	10 GHz
UE's maximum power	23 dB
eNodeB maximum power	30 dB
SINR limits	−6 dB–17 dB

As expected, in the reuse mode the resource utilization rate exceeds 100 are enabled to be reused while in dedicated mode it remains low as resources that are committed to being reused by other users whether they are in D2D mode or cellular (Fig. 5).

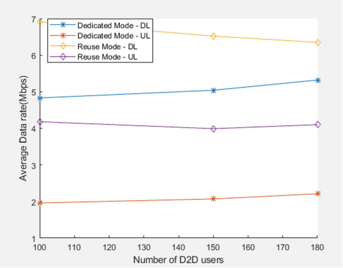

Fig. 5. AVG Data rate - D2D

Comparing the two scenarios, users using downlinks have clearly higher data rates than users using downlinks. This was expected as users' demands on DL speeds were higher than UL. The efficiency of the mechanism performance in both scenarios is presented at the overall network speed of the two levels (Fig. 6).

We can see that the user speed increases even when the number of the users increase. Someone could possibly think that when the system has to serve more users then the speed would be lower. That means that our mechanism is working

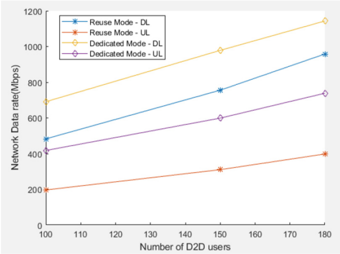

Fig. 6. NET data rate - D2D

properly and efficiently. The data rates occurred in dedicated mode are higher due to the nonexistent interference. Also, same as before, the speeds of DL are higher than UL and that happens due to the requirements of the users. The users need to have better DL speed than UL because that's the way they mostly need to use (Fig. 7).

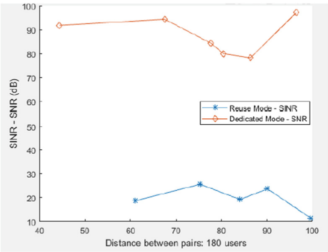

Fig. 7. Distance SINR - SNR 180 users

The mechanism, runs for three different scenarios, in the above figure we only see the scenario of 180 as the results are about the same in each one. The values of dB in dedicated mode is obviously much higher than the reuse mode because the SNR value is calculated here and it is correctly higher. We can observe a slight decreasing line in reuse mode as the distance between the users increases. In all three cases, the line declaring reuse mode has a descending order, meaning a higher SINR value, higher interference. That declares that the signal in reuse mode as the distance between the users increases is getting worse.

5 Conclusions and Future Work

In dedicated mode the D2D users that achieved communication are less than in reuse mode. That is expected because the resource blocks can't be reused, so the number of users an eNB can serve are less than in reuse mode. On the other hand, in reuse mode, the number of D2D succeeded communication are more but they have to deal with the interference problem. We can see that as the number of devices increases, so does the resources available to the system in both cases, resulting in the 180 devices needing more resources for user requirements in each case. We can clearly see the greater the distance between the devices the greater SINR value is. In conclusion we can say that the allocation of resources and the use of available resources is an integral part of the improvement and performance of wireless generation networks. The modes of communication compared during the mechanism show that since we cannot know in advance the potential requirements of users then the best way to serve them can not be selected. For future work we propose a mechanism with users moving dynamically for a more realistic scenario. Maintaining the distance between users is necessary for the status and behavior of users during communication. An approach proposing alternatives or techniques that could reduce interference as the distance between the devices increases.

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