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Resource Sharing Technique for Device to Device Link in License Band LTE-A

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Abstract

Cellular Communication Networks are becoming more advanced, secure, Speedy and reliable, while moving from one generation to another generation. Higher throughput, better channel capacity, reduce delay time and network failure are the prime concern during development of a new cellular architecture and standards. As the efficiency of the network increases by introducing advance technologies, it also upsurges the network complexity and cost for development of new compatible equipment. In this paper various resource sharing methods based on mode selection as well as power control has been reported. Optimization of sum rate for cellular mode, dedicated mode and frequency reuse mode has been illustrated. An algorithm based on sum rate maximization and power control has been proposed for resource sharing. Simulation result shows that the proposed algorithm gives optimum result for mode selection and resource sharing in intracell single link and multiple link device to device communication.

Keywords: *D2D, UE (user equipment), CU (cellular user), eNodeB, Massive MIMO, LTE-A*

1. Introduction

D2D communication will play vital role in LTE-A. Researchers estimated that by 2020 there will be a total of 50 billion devices connected to the internet. These devices will have unique identity, dynamic and self-adapting capability, self-configuring capability and also they will communicate with each other by the help of inter operable communication protocol. All this devices will have capabilities to connect with licensed band mobile networks and they will be integral part of LTE-A. The objectives of LTE D2D are (1) strong resource management by means of tighter spectrum reuse and achieving the offloading, (2) better performance *i.e.*, higher data rate, low end to end delay and energy efficient, (3) reliability and scalability *i.e.*, operator initiated services, security can be guaranteed and (4) regulatory and standardization [12]. D2D communication in mobile network systems is defined as direct link communication between two different mobile user's equipment without the direct connection of eNodeB. D2D communication is possible in cellular spectrum and ISM band spectrum. Device to Device (D2D) communication is an essential part of Long-Term Evolution Advanced (LTE-A). LTE-A is a mobile communication standard for beyond 3G. LTE-A is an advancement of LTE. 3rd Generation Partnership

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Project (3GPP) in release 10, mentioned D2D and its features. D2D communication involves direct communication between two or more mobile user equipment (UEs) in a single cell or between multiple cells and sharing existing licensed band spectrum base on RF power control with or without the intervention of base station or eNodeB(evolved NodeB) of LTE's radio access network.

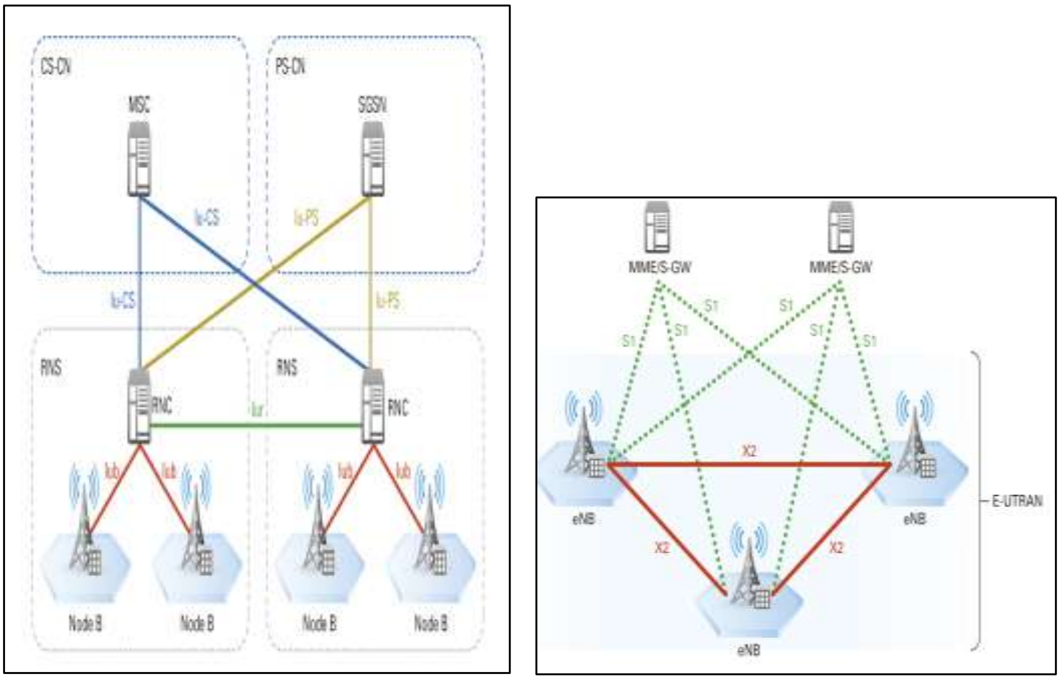

Figure 1. (a) 3G UTRN Architecture and (b) E-UTRN

Figure 1 shows two different architectures of 3G mobile communication network. Radio Network Controller (RNC) is the leading element of 3G UTRN (Universal Terrestrial Radio Access Network) [10]. It is linked to the circuit switched core network (CS-CN) by the help of MSC. It is also connected to packet switched core network using SGSN (Serving GPRS Support Node). Base stations of 3G UTRN is known as Node B. The mobile User equipment (UEs) are connected through the Node B. RNC is responsible for resource management and spectrum sharing between UEs and NodeB. Figure 1(b) shows another architecture of 3G E-UTRN where direct communication between eNBs are done by high speed X2 link and communication with other networks (circuit or packet switched network) is done by S1 link through MME/S-GW (Mobility Management Entity/Serving Gateway). In this type of architecture the UEs are communicated among themselves through the eNBs and resources are assigned by corresponding eNBs. The Device to device (D2D) communication between two or more UEs may be accompanied under the supervision of eNBs. In a single cell scenario one eNB can assigned dedicated resource in terms of certain frequency band for D2D connection between two UEs or among several UEs. Otherwise UEs can use the same frequency band *i.e.*, the frequency band for downlink or uplink for D2D communication. Of course, the interference will be the major challenge to handle as UEs are using same frequency band for direct communication between themselves as well as communication between UEs and eNodeB. D2D communication can be of three types- (a) Peer to peer, (b) Cooperative communication and (c) multiple hop communication. In each types resource allocation procedure will be different [13]. The primary interference controlling parameter is the received RF power at eNodeB. Figure 2 Shows different types of possible D2D communication in LTE-A.

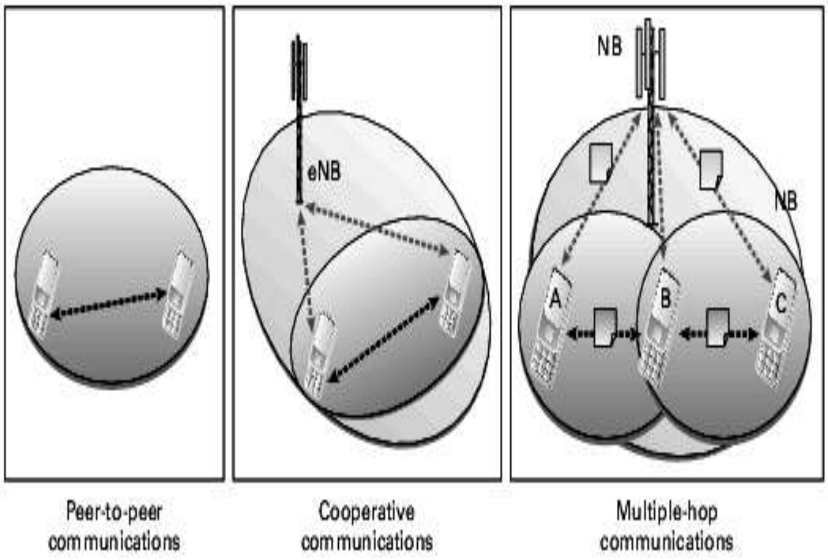

Figure 2. Different Types of D2D Communication

In case of peer to pear communication, there establishes a dedicated link between two UEs and without the involvement of eNodeB, they exchange information between themselves. In cooperative communication eNB directs the communication between two UEs and keep monitoring them. In multi hop communication multiple UEs are exchange simultaneous data directly among themselves. The eNB initiates and allocates resources for such connections. Interference management is a great challenge in D2D communication. Interference reduces the received RF power levels at UEs. Therefore, a suitable algorithm for RF power control can be developed for controlling the in band or out of band interferences. A dedicated resource can be assigned for D2D communication or reuse of same frequency band can be done for power control [11]. D2D enabled device can work on different power control modes where if in one situation UEs encountered by noise interferences causing power loss then may switch to another operating mode. Thus the good power level always can be maintained at UEs. Figure 3 shows different kind of interferences in D2D communication.

2. Related Work on D2D Mode Selection Techniques

There are several techniques for mode selection based on power control has been proposed till date. It has been reported in literature [1] that spectrum sharing is possible between licensed cellular network and infrastructure less wireless network. More over D2D user can communicate among each other using the same resource spectrum as the cellular user uses to communicate with base station. In this research paper two realistic models for D2D communication has been proposed. They are cell-wide D2D user distribution model and clustered D2D user distribution model.

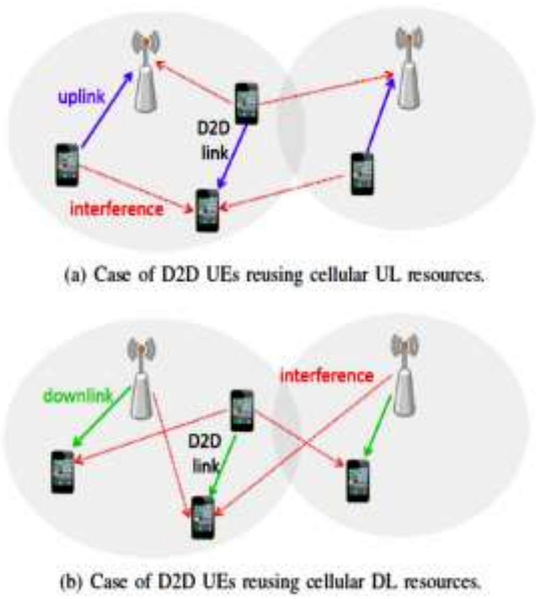

Figure 3. Interference in D2D Link

Here both classes of users (cellular user and D2D user) are distributed uniformly in the cells. In a cluster model D2D transvers are placed randomly and distributed uniformly in the cell. It has been claimed that the second model is more realistic in modern urban environments with densely populated cellular users. However, it has been observed that D2D user can communicated during uplink frame of the network causes less interference than making the connection during downlink. It is because of the fact that during uplink, D2D users affected by the interference of their signal as there will be only one receiver that is fixed Base station but if they communicate during down link then there is a probability of having interference at every cellular user in the system [20]. To establish a D2D link, first of all D2D user need to determine available channels for use and required power on each channel which need to be send on those respective channels. They should determine the amount of power in each channel without crossing allowed interference level at the base station.

Let N =the number of orthogonal channels
D= the distance between D2D transmitter and the eNodeB.
α = path loss exponent
k= the margin in the SINR at the base station P_{TDD} is the transmitted power of D2D user
P_{TBS} = the transmitted power of the eNodeB
P_{RDD} = the received power of D2D user

Total path loss can be calculated by equation (1) and P_{TDD} can be obtained from equation (2)

$$D^{\alpha} = \frac{P_{TBS}}{P_{TDD}} \quad (1)$$

$$(K-1)\, N\, D^{\alpha} \geq P_{TDD} \quad (2)$$

Equation (1) and (2) have been used in literature [1] for obtaining the minimum power requirement for establishing D2D link in both the proposed model named as cell-wide model and clustered model. The probability of presence of a single-hop Device to device link that does not causes cellular link to break is much more higher in case of D2D model. It has also been reported that in case of multi hop D2D link the probability of existence of such link farther increased. However, the results does not shows how to do optimum power allocation for the considered scenarios. It also does not tell about the upper limit on the maximum transmission rate of all available D2D link.

In literature [2, 3] it has been reported that by using appropriate power control method not only the interference between cellular and D2D communications can be avoid but also it gives privileges to the eNodeB to select modes of communication i.e. whether the D2D or cellular. Therefore, two power control cases has been discussed in [3], firstly both the cellular and D2D communications are considered as opposing services without any priority and greedy sum–rate maximization technique is applied for the calculation under the supreme transmit power restriction. In the second case, priority to the cellular users have considered with a minimum approved transmission. Moreover, three different resource allocation modes has been illustrate as per the Figure 4. They are (1) Non-orthogonal resource sharing mode (NonMod), (2) Separate resource sharing mode (SepMod) and (3) Cellular mode (CellMod). In case of NonMod D2D users utilize the same bandwidth as the cellular user, therefore it causes interference to each other. In this case the Base station coordinates the transmit power for both the links. In case of SepMod D2D users get 50% of the total available resources of Cellular user. As the resources are assigned prior to the communication and both link may utilize different resources, it provides no interference between cellular and D2D communication. In this case the use of maximum transmit power achieve the maximum sum rate. In case of CellMod the D2D user communicate with each other via the base station and the corresponding BS acts like a relay nod. All nodes uses orthogonal resources and communication between UEs to BS uses 25% of the resources whereas BS to UEs uses 25% for D2D transmission. Rest 50% remain reserved for cellular communication.

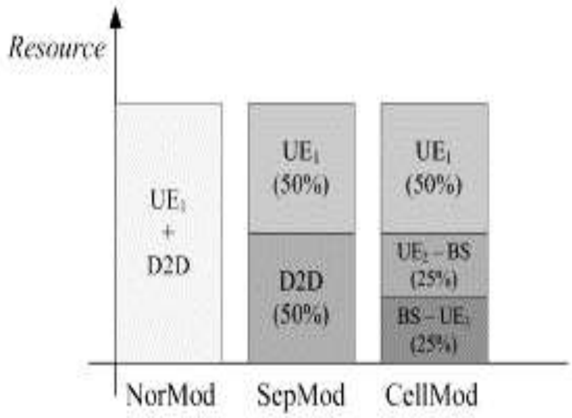

Figure 4. Illustration of Three Possible Resource Allocation Mode

It has been reported in [3] that if R_{ULre} is the sum rate for NonMod in uplink, R_{DLre} is the sum rate for NonMod in downlink, R_{SepMod} is the sum rate of SepMod and $R_{cellMod}$ is the sum rate of CellMod, then the resource allocation mode which gives the maximum sum rate for uplink and down link is given by equation (3) and (4) respectively.

$$R_{ULmax} = \max\left(R_{ULre}, R_{SepMod}, R_{cellMod}\right) \quad (3)$$

$$R_{ULmax} = \max\left(R_{ULre}, R_{SepMod}, R_{cellMod}\right) \quad (4)$$

The results of literature [3] provides an idea of prioritized communication between cellular and D2D for three different modes of operation by controlling the power. But the result does not provide a clear idea of direct communication between to UEs without the involvement of base station which means here the mode selection is the task of base station, UEs does not have the capability of selecting appropriate mode of operation. Literature [4, 5] has been focussed on reusing of cellular band for the establishment of D2D link. By the help of proper power control scheme it is possible to reusing the uplink or downlink resources for D2D communication with minimum interference between cellular UEs and D2D UEs. A good D2D link SINR can be achieved by properly defining the maximum power on the D2D link. The SINR of the UL cellular transmission is given by equation (5)

$$\xi = \frac{P_1 C_1}{P_2 C_2 + \sigma^2} \tag{5}$$

Where P_1 and P_2 denote the transmit powers of the cellular and D2D UEs respectively, C_1 and C_2 are corresponding link gains. σ^2 is the AWGN power. In addition of SINR, authors of [5] also illustrated resource allocation scheme based mode selection by the help of calculating maximum sum rate as mentioned in [3].

The result shows that by using proper power control interference can be managed between D2D UEs and cellular UEs. It has been reported in literature [6], that an algorithm for mode selection can be developed for selecting three different modes based on received RF power and the distance among several UEs. The mode selection procedure has been illustrated in single cell scenario and multi cell scenario. There are three different modes. They are Reuse mode, dedicated user mode and Cellular User mode. In reuse mode there may be reuse of uplink resources and reuse of downlink resources [21, 23].

In dedicated mode dedicated resources are allocated to the UEs for D2D communication. In case of Cellular mode D2D communication established by the help of base station and transmission of data is through the base station. Authors of [6] has been focused on measurement of SINR for providing the limiting parameter of rate guaranty to give priority to the cellular user for the mode selection. For a single cell scenario a normalized cell of radius 1 and a path loss model with path loss exponent of 4 has been considered. The received power at distance d has been given by equation (10)

$$P(d) = \frac{P_t}{d^4} \tag{10}$$

The sum rate of cellular and D2D communication has been calculated in the similar way as mentioned in literature [2, 3].In case of multi cell scenario optimal mode selection not only depends on interference from other cell but also load condition of the cell. The data rate for D2D link in cellular mode will be lesser when the cell is overloaded and the base station or eNodeB will assign less dedicated RBs to the D2D link. In [7], the projected algorithms takes care of three basic stuffs- (1) whether the D2D gets devoted resources or not, (2) reclaims the same resources of cellular or not and (3) functions in cellular mode.

In literature [8] Mixed Integer Nonlinear Programming (MINLP) has been formulated for optimum resource allocation between D2D link and cellular link. Greedy heuristic algorithm has been illustrated for sensing the interference to the primary cellular network by utilizing channel gain information. In LTE system the total bandwidth is divided into equal size physical RBs. Each of these RBs physically occupies 1 slot of 0.5 ms in time domain and 180 KHz in frequency domain with sub carrier spacing of 15 KHz. LTE uses OFDMA for down link and SC-FDMA for uplink. During the down link communication UEs may incur from interference by the D2D transmitter, whereas during uplink the immobile base station or eNodeB suffers from the interference by the D2D transmitter. Figure 5 (a) shows the LTE downlink physical resources and Figure 5 (b) shows Interference problem during uplink and downlink as reported in [5].

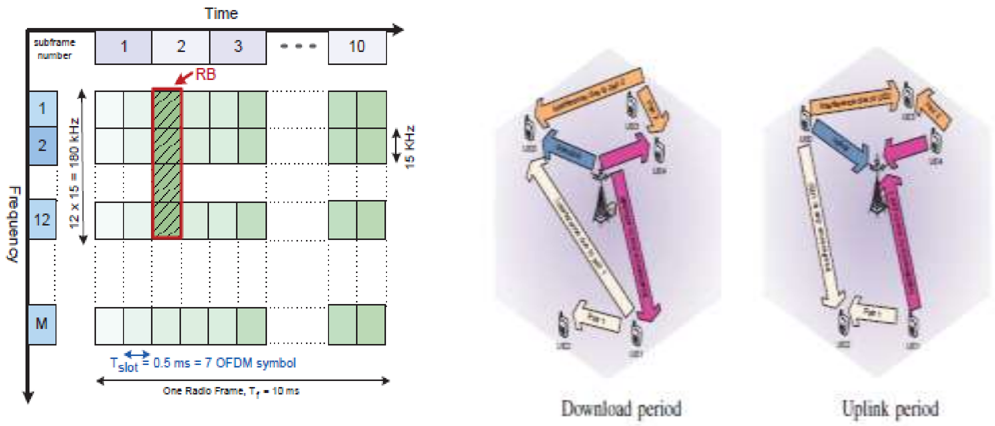

Figure 5. (a) LTE Downlink Physical Resources and (b) Interference Problem During Uplink and Downlink

Literature [9, 10, and 18] focussed on three different modes of operations, Non-orthogonal mode, orthogonal mode and Cellular mode. The concept of Sum rate optimization has been illustrated for best possible mode selection. The analysis is focused on the optimization of sum rate subject to spectral efficiency limits and maximum transmit power restrictions. In cellular mode the constraint is maximum energy transmit and the optimum RB allocation between D2D and cellular connection is in closed form. The proposed resource sharing method has been compared with path loss based selection method and the result shows that the proposed method provide gain over the path loss based selection method. In [24, 25], joint resource allocation and power control based on iterative algorithm has been proposed. Fractional programming has been reported and it is obtained by the help of iterative approach. Authors reported that the proposed technique converges fast and can be the optimal solution for resource allocation. From various literate it has been observed that although varies techniques of D2D communication has been proposed the main focus is given on power control and resource allocation issues. There are several challenges found for providing a proper algorithm of mode selection for D2D link with higher value of throughput. In the dedicated mode it is required to compromise the allocation of resource bocks between D2D UEs and Cellular UEs whereas in Reuse mode the spectral efficiency reduces and problem of in band interference arises between D2D UEs and cellular UEs.

3. Proposed Algorithm for Mode Selection

To establish D2D link, resources or RBs need to be available at the time of request. Each eNodeB has limited no of RBs. eNodeB will decide how many RBs are available for D2D connection. There will be three modes of operation. Several literatures also reported the existence of these three modes-(1) cellular mode (2) Reuse Mode and (3) D2D dedicated link mode. Selection of mode will be depended on location of UEs in the cell, amount of interference, transmitted power and required throughput. Let we understand the problem of selection of a particular mode by the help of flow diagram in Figure 6.

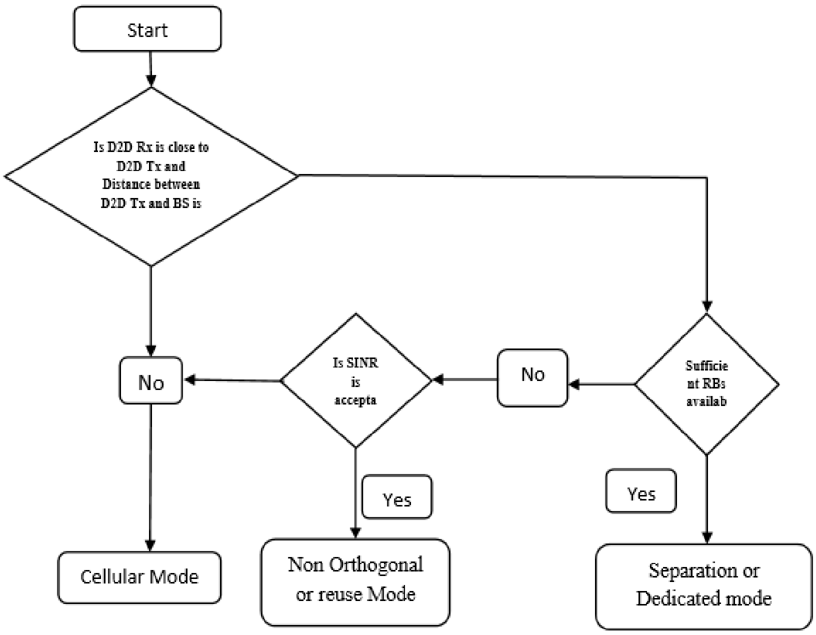

Figure 6. Flow Diagram of Mode Selection in Single Cell Scenario

In a single cell scenario, there exist one eNB at the centre of the cell. That eNB can estimate no of UEs and their position in the cell. It also has the knowledge of available RBs. If the distance between UEs from eNodeB is more than some predefined value (for example UEs are at cell border) then cellular mode will be activated. If the distance between two UEs from the eNB is less than a predefined value and number of RBs is more than some predefine value then eNB will assign resources to UEs for a dedicated D2D link. If number of RBs is less than predefine value then it will calculate the SNIR value for reusing the same RBs which are assigned for cellular communication, if the SNIR is more than the threshold value then it will go for Reuse mode, otherwise it will go for cellular mode. Mode selection depends on the SINR value. Let Reuse mode has been selected after comparing the SINR. Let jth RB has been allocated to the kth cellular user (CU). The ith D2D pair is reusing that link resources. Let $P_{i,j}$ is the Tx power of ith D2D pair on the jth RB, then channel capacity or throughput of ith D2D links on the jth resource block is given by

$$C\,(P_{ij}) = W \log_2 \left(1+\frac{P_{i,j}\ h_{i,i}}{P_{k,j}\ h_{ki}+No}\right) \tag{11}$$

Where W=bandwidth of corresponding RB
h_{ii} = Tx to Rx channel gain,
h_{ki}= interference channel gain
No =AWGN noise power.
$P_{k,j}$= power of the kth Tx to jth Rx.
Mode selection for multi cell scenario works as follows-

1) Step1: D2D UEs send initial searching signal to each other and calculate powers of received signals (P_{ij} and P_{ji}).
2) Step2: D2D link terminals estimate SINR with/without own eNodeB signal present in downlink.
3) Step3: D2D link terminals estimate SINR power in uplink with/without terminals transmitting in own cell.
4) Step4: D2D link terminals direct the initiate data to the base station to backing the mode selection.

5) After the fourth step, the corresponding base station or eNodeB chooses based on the quantity of RBs in dedicated mode and CU modes that can be assign to the D2D stations in uplink/downlink.
6) After this process, eNB decided on the extreme transmitted power the D2D terminal can use for several direct modes.
7) Then it evaluates the SINR for each mode and also calculates the throughput based on SINR.
8) Finally, it selects the mode which provides height throughput

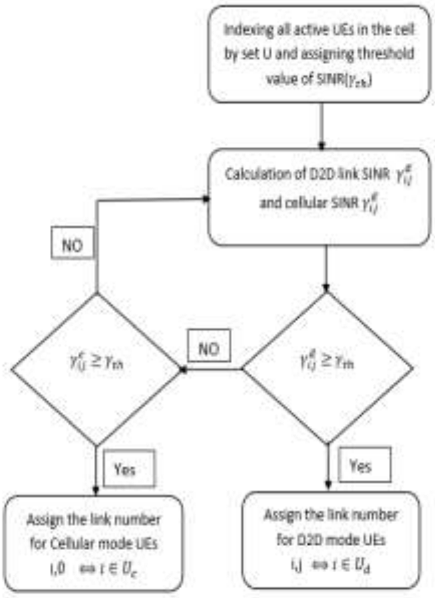

Figure 7. Shows Flow Chart for Multiple Link Scenario based on the Proposed Algorithm

4. Simulation Result

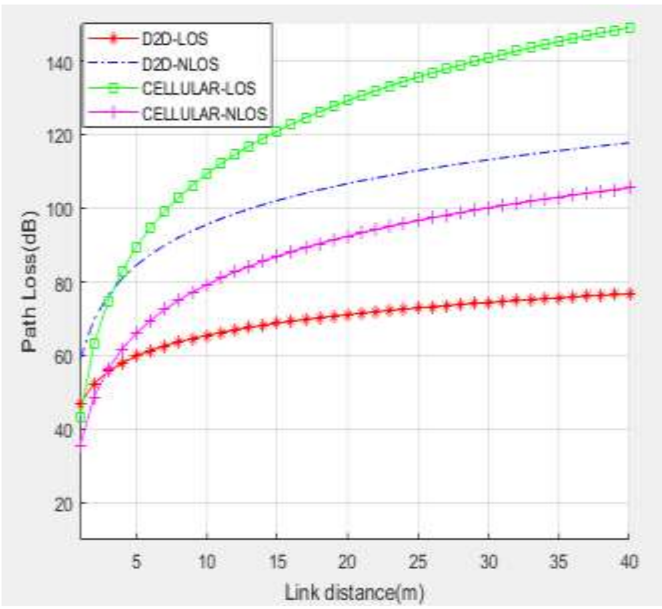

Figure 8. D2D Link Distance vs Pathloss Plot for Different Modes

As the link distance increases pathlosss also increases .Simulaion result shows that d2d mode communicaion provides less path loss than cellular mode communication.

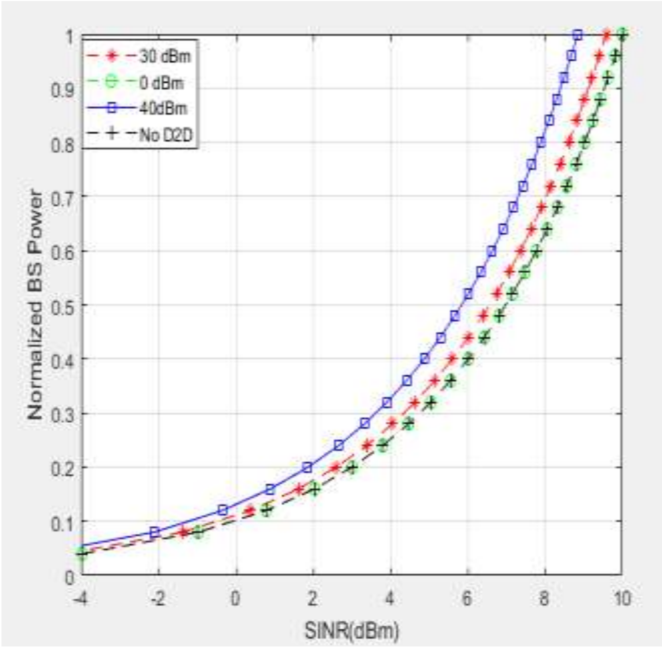

Figure 9. Normalized Base Station Power vs SINR

Figure 9. shows SINR plot for D2D link communication. Simulation result shows that the d2d link provides acceptable SINR when same resource has been shared among D2D UEs along with cellular UEs.

5. Conclusion

Investigation of RB distribution among D2D UEs along with cellular UEs by the help of optimum selection of proper modes and optimum power allocation to the channel is the main concern of this paper. Device to device communication using licensed spectrum is a novel technique and is not available commercially till date. Here we have reported a technique for mode selection and resource sharing of D2D communication for Intracell single and multiple link scenario. Simulation result best on the proposed algorithm shows that D2D link provides acceptable SINR without breaking existing cellular link in Intracell communication model.

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