CHAPTER ONE

INTRODUCTION

Chapter One

Introduction

1.1 Preface

With rapid development of mobile communication technique and cellular networks as well as the popularity of intelligent terminals such as mobile phones and tablets, mobile users are showing explosive growth.

Cellular networks are developing toward higher data rates, greater utilization of network resources and larger network capacity, which will put forward higher requirements on the radio spectrum resources, Due to the limited spectrum in mobile communication networks, the growing traffic will lead to congestion in the network, therefore, how to achieve high data rate and large capacity in mobile communication networks with limited bandwidth resources has become the focus of related researches.

Device-to-Device (D2D) communication is a novel communication technology which has been confirmed in ad hoc networks as a new direction. It allows mobile terminals communicate with each other directly by using the licensed frequency resources under the control of cellular networks.

In current cellular networks, services are provided to User Equipment (UE) through Base Stations (BSs), that means data must first go through base stations to the core network, and then can be forwarded to the destination UE,
but this communication mode results in an enormous waste of spectrum resources for UEs close with each other.
Recently, Device-to-Device (D2D) communication has received much attention due to its potential to improve local service performance.

In D2D communication, UEs transmit data to each other over a direct link instead of through the base station. Compared with other short-range wireless communication technique, D2D communication can improve the system's spectrum resource utilization, reduce the load of base stations, core networks and the power consumption of UEs, as well as enhance the robustness of network infrastructures.

1.2 Problem statement

- Device-to-Device (D2D) users can simultaneously operate in the same frequency spectrum as a licensed cellular radio network.
- D2D devices cause interference to the cellular users which affect the performance of the network devices.
- The main challenge is to deal with co channel interference between D2D users and cellular users caused by spectrum resource reuse.

1.3 Aim and Objectives

The aim of project to mitigate interference in D2D communication underlying cellular system by choose mode selection, proper power control, and resource allocation.

The objective of the project is to:

- Study the architecture of D2D communication.
- Use scheme of power control.
- Calculate the transmit power of CUE and D2D for each of them.
- Determines the signal to noise plus interference ratio (SINR) to achieve the optimal system capacity.

1.4 Methodology:

To guarantee high spectral efficiency, D2D communication links are sharing radio spectrum resources with cellular users, but the performance of both D2D and cellular communication can be affected by the mutual interference between them.

In this thesis proposed two methods to decrease interference for single cell and multi cell, for single cell , choose a cellular user (CU) that can share uplink resource with D2D users and adjust power , while guaranteeing that the signal-to-interference-plus-noise ratio (SINR) at the D2Dreceiver ,but for multi cell use fractional frequency reuse.

To implement this model, use MATLAB Simulation, and observe the performance gain to spectral and energy efficiency.

1.5 Proposed solution:

- The model hybrid cellular D2D network as a set of L transmitter-receiver pairs that include both cellular User transmitting to their respective serving BSs and D2D pairs communicating in cellular uplink spectrum.
- Resolved the problem into a two step approach, with each step separately addressing resource allocation and power control.
- Calculate transmit power and achieved SINR by cellular User and D2D pairs when employing the LTE based power control and fractional frequency reuse.

1.6 Thesis outlines

The major goal of this research is investigate power control and resource allocation to improve user experience, system spectral efficiency, and energy efficiency for D2D communication.

In this thesis, chapter **1** introduces overview for evaluation of mobile communication and cellular network, problem which try to solve it, aim and objective of the project, and the methodology of the project. But in chapter **2**: introduces the background of Device to Device Communication, architecture of Device to Device Communication, Proposed D2D Scheme, Classification of D2D Communication, challenges of D2D Communication underlying Cellular Network, channel measurements and Related works. However in chapter**3** introduces overview for interference management of D2D communication, interference Scenario and system model. While in chapter **4** introduces Descriptive Analysis, Mathematical model and Simulation Results, finally in chapter **5** introduces conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

Chapter Two

Literature Review

2.1 Background

Fifth Generation (5G) communications will grow the overcoming mobile communications technology during 2020 in unity users, accumulating 3.6 billion users [8].

In modern research, a lot of work has been done on the development of Third Generation Partnership Project (3GPP) Long term Evolution (LTE) for higher system capacity and higher data rate [7]

In cellular network, the communication between cellular users is relayed through the Base Station (BS), even if the source and destination are closer to each other than to the BS, The main advantage of this kind of operation is easy resource and interference control, but the drawback is inefficient resource utilization[7] [9].

D2D Communication using cellular network spectrum is an efficient way to handle the local traffic in a cost efficient manner. A D2D link is a direct connection from D2D transmitter (D_T) to D2D receiver (D_R) in spectrum managed by cellular network, There are several gains related to D2D communication underlying a cellular infrastructure [7],namely proximity gain of user equipment that allows high bit rate, low delays and power consumptions [10] [11], the reuse gain that concedes radio resources to be utilized by cellular and D2D links simultaneously and finally hop gain that refers to applying an individual link in the D2D mode rather than using an uplink and a downlink resource when communicating via the BS in the cellular mode [12].

In this thesis focus on the interference management, and have proposed two schemes for resource allocation and power control. Our aim is to minimize total power consumption with certain rate targets on D2D links and cellular users, respectively.

Firstly introduced analyzing of interference in single cell by choose a cellular user (CU) that can share uplink resource with D2D users, while guaranteeing that the signal to interference plus noise ratio (SINR) at the D2D receiver and at the CU surpasses acceptable thresholds.

Secondly introduced analyzing of interference in multi cell by using fractional frequency reuse.

2.2 Architecture of Device to Device Communication:

2.2.1 Background in LTE-A Network:

The main cellular system that is expected to adopt the D2D communications is the LTE system. The architecture of an LTE system is divided into two basic subsystems: the Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN) and the Evolved Packet Core (EPC).

The EPC subsystem is a flat all IP system designed to support high packet data rates, On the other hand the E-UTRAN is the access network of the LTE system.

The main entities of E-UTRAN are the base stations referred to as eNBs and the cellular terminals referred to as UEs (User Equipment's).

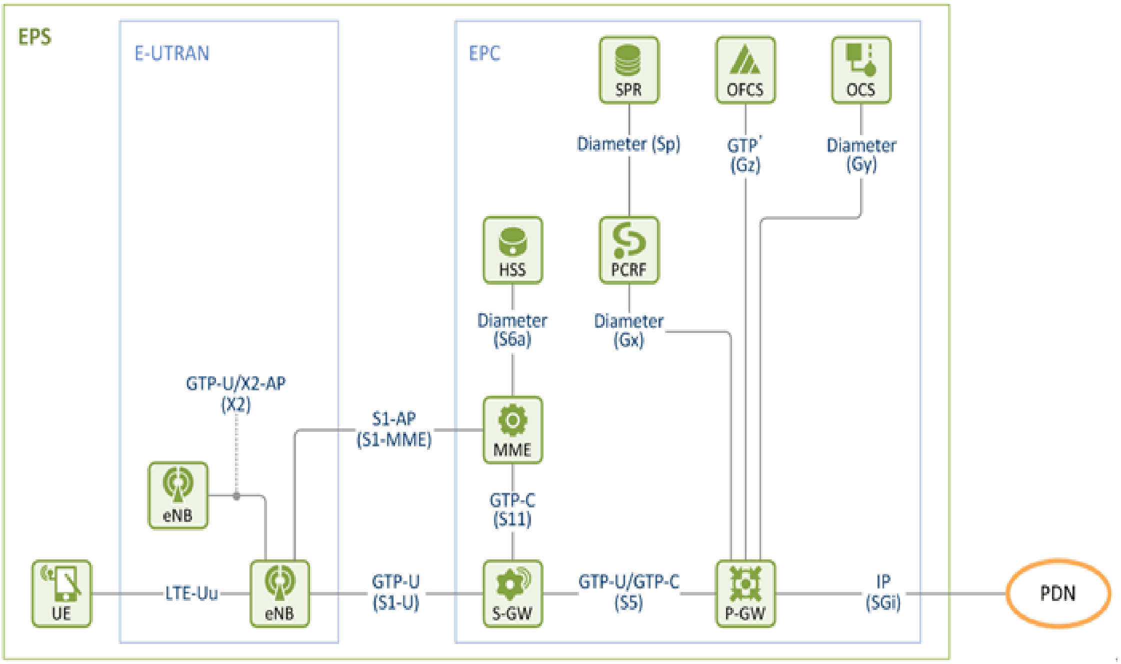

Figure 2-1: Architecture of LTE-A Network [5]

The communication between eNBs and UEs is organized in frames of 10 ms, while each frame is divided into 10 sub frames of 1 ms, Referring to transmissions from and to eNBs, there are two basic categories of sub frames, the downlink (DL) and the uplink (UL), respectively, In the frequency domain, each sub frame utilizes scalable bandwidth up to 20 MHz (and up to 100 MHz through the carrier aggregation mechanism) divided into subcarriers of 15 KHz spacing, Subcarriers are organized into resource blocks RBs of 180 KHz each, i.e., 12 subcarriers define an RB, the minimum allocation unit in the network, the introduction of the D2D communications must be done in respect to this architecture.

2.2.2 D2D Communication Scenarios:

In cellular network, direct communication is integrated with a cellular network and is naturally preceded by network supported proximity discovery.

The 3GPP system enablers for (proximity service) ProSe consists of the following functionalities [4]:

- EPC-level ProSe Discovery
- ProSe direct discovery models.
- ProSe direct communication Modes.
- UE-to-Network relay or UE-to-UE relay.

Architectural enhancements for the EPC core network are necessary in order to facilitate D2D and cellular links coexistence and for best D2D integration in LTE-A mobile networks.

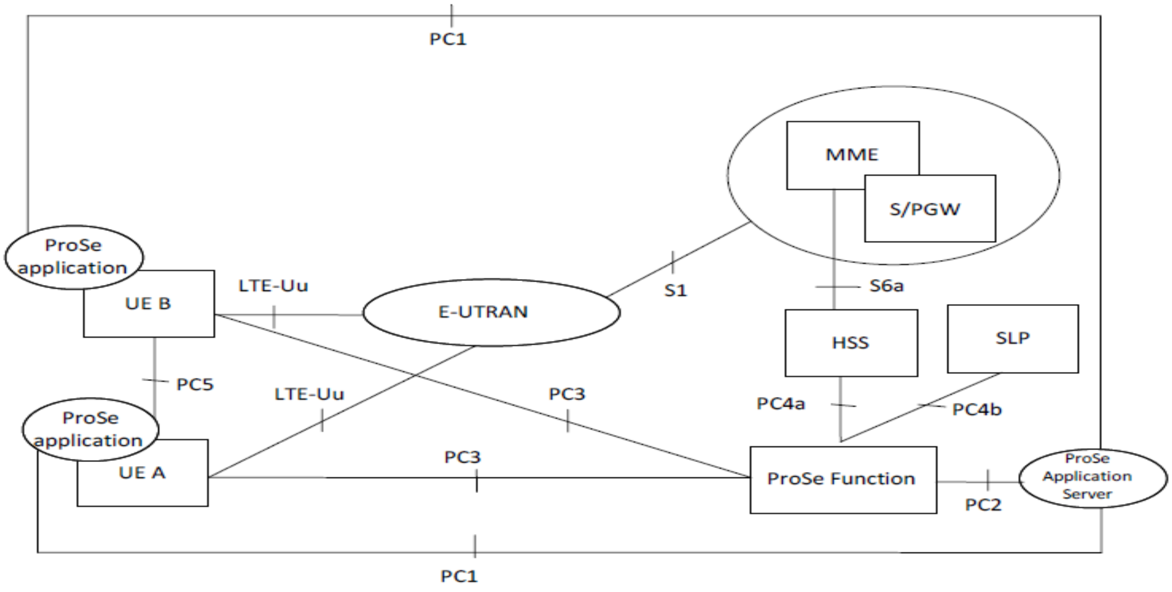

Figure 2-2: Architecture of D2D communication [14]

As depicted in Figure 2-2,the D2D system architecture under LTE-A consists of a number of new entities that are required for D2D [13],these entities are as follows:

- The **MME** responsible for signaling issues related to mobility (tracking and paging) and security access for the E-UTRAN, it will cache a copy of the user's profile related to ProSe after being authenticated by the HSS, and informs the eNodeB about the user's permission.
- The **HSS** is a data repository for subscribers' profiles and more specifically will check whether the requesting users are ProSe subscribers or not.
- The **SLP** can be a server residing in the network or a network equipment stack. It obtains location information for the UE.
- **ProSe App Server**: It implements the ProSe capability for building the application functionality. It is responsible to determinate if the registration of UEs can be accepted or not and to activate ProSe actions such as ProSe discovery for a specific application. The ProSe application in the UE (ProSe) communicates with the ProSe Application Server via the application layer reference point PC1[14] [1]
- **ProSe UE App**: This entity is responsible for building the application functionality. The ProSe UE App communicate and discover other ProSe UEs by means of the PC5 interface[15], It is used by different services such as Public Safety or media application in order to get the requests and find buddies in proximity .
- **The ProSe Function** is responsible of the different network actions to achieve ProSe requirements and it is used also to provide network services such as authorization, authentication, and data handling, The ProSe Function provides also the necessary charging and security functionality for usage of ProSe via the EPC.

The D2D communication architecture under LTE-A network defines 7 new interfaces to interconnect the new entities. These interfaces are called PC1, PC2, PC3, PC4, PC5, PC6 and PC7.

The major roles of ProSe Function are given as follows:

- Provisioning(via the Direct Provisioning Function - DPF) Direct Provisioning Function (DPF) is used to provision the UE with necessary parameters in order use ProSe direct services. For direct communication used for Public Safety DPF is also used to provision the UE with parameters that are needed when the UE is not "served by E-UTRA".
- **Direct discovery management** (via the Direct Discovery Name Management Function):Direct Discovery Name Management Function is used for open Prose Direct Discovery to allocate and process the mapping of ProSe Applications IDs and ProSe Application Codes used in ProSe Direct Discovery. It uses ProSe related subscriber data stored in HSS for authorization for each discovery request. It also provides the UE with the necessary security material in order to protect discovery messages transmitted over the air.
- **EPC discovery** (via the EPC-level Discovery ProSe Function)EPC-level Discovery ProSe Function has a reference point towards the Application Server (PC2), towards other ProSe Functions (PC6), towards the HSS (PC4a) and the UE (PC3)[4].

2.3 D2D Scheme procedure:

D2D scheme adopt a ProSe communication scenario where both ProSe Enabled UEs are connected to the same PLMN/cell. The eNB operates as a D2D controller, and such as, it is responsible for the following:

(i) the D2D RA and PC and (ii) the peer discovery and tuning for the D2D peers. Potentially, the capability for D2D transmission is provided to all UEs of the network.

The adopted D2D model can be summarized as follows:

- Each eUE produces its D2D identity and transmits it to the eNB during its first access to the network.
- eUEs make D2D spectrum requests using the standard spectrum request procedure, including, the D2D identity of the target D2D receiver (discovery massage).
- The eNB launches a peer discovery procedure for the requested D2D pair.
- The eNB allocates cellular resources to valid D2D pairs and informs both D2Dpeers, tuning them indirectly at the same spectrum portion. The D2D RA combined with a PC scheme guarantees the interference free conditions between cellular and D2D system.
- The eUE transmitter sends its data using the spectrum region that has been allocated by the eNB, while the eUE receiver tunes to the same spectrum region to receive the transmitted data.
- The eUE receiver acknowledges the reception (or not) of the data through the eNB following the conventional-standardized procedure [1].

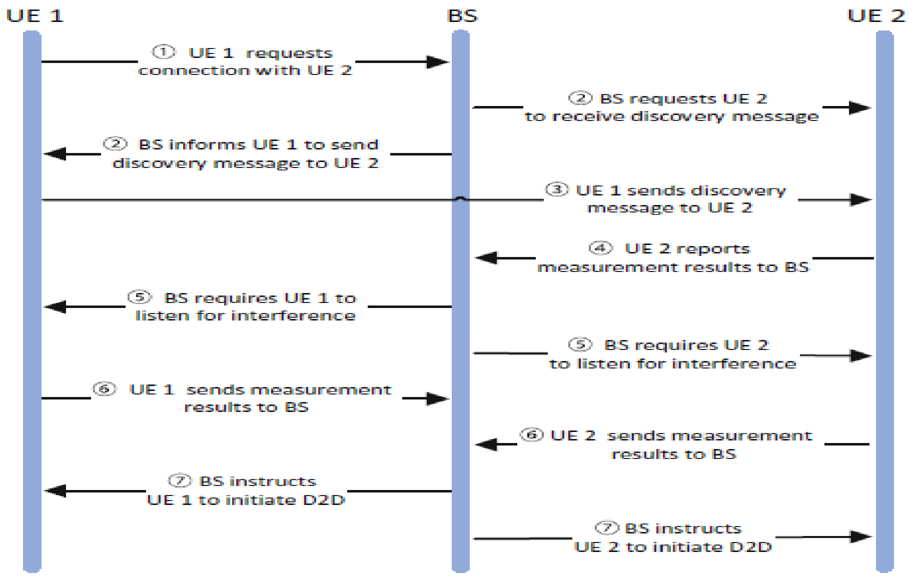

Figure2-3:D2D discovery procedure [2]

2.4 Classification of D2D Communication:

InbandD2D: In this category, D2D communications operate on licensed spectrum (i.e., cellular spectrum) which is also allocated to cellular links, that indicates to need High control over cellular (i.e., licensed) spectrum.

Inband D2D is further divided into underlay and overlay categories, In underlay D2D communication, cellular and D2D communication share the same radio resources, but D2D links in overlay communication are given dedicated cellular resources [6], in Inband QoS management is easy because the cellular spectrum can be fully controlled by eNB.

The disadvantages of Inband D2D communication are cellular resources might be wasted in overlay D2D, the interference management among D2D and cellular transmission in underlay is very complicated [1].

Outband D2D: The D2D communication under this category exploits unlicensed spectrum, The motivation behind using outband D2D communication is eliminating the interference issue between D2D and cellular links, Using unlicensed spectrum requires an extra interface and usually adopts other wireless technologies, such as Wi-Fi Direct, ZigBee, or Bluetooth.

Outband D2D is further divided into controlled and autonomous communication [6].

In controlled outband D2D communication, the control of second interface/ technology is under cellular network but in autonomous outband D2D communication, cellular network controls all the communication but leaves the D2D communication to the users (second interface/technology in not under cellular control) [1].

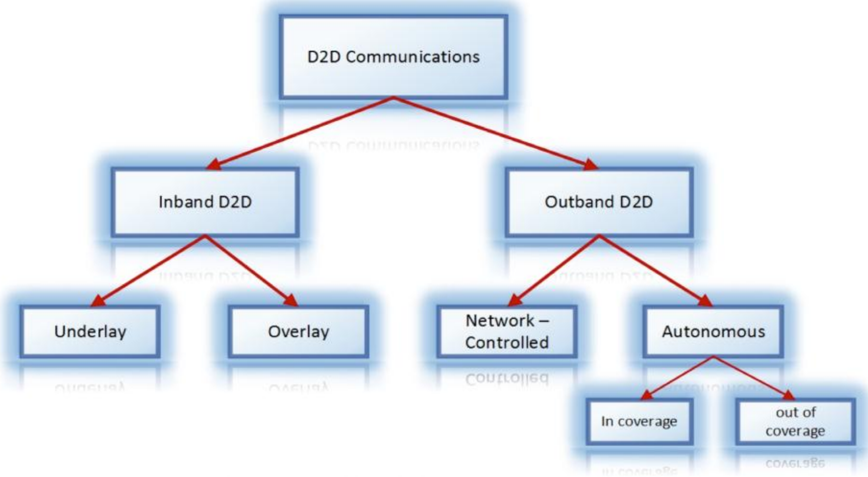

Figure 2-4: Classification of D2D communication

2.5 Challenges Of D2D Communication underlying Cellular Network:

D2D communication as an underlay in LTE–A network enables fast access to the spectrum band with controlled interference by the network infrastructure, With underlay implementation, D2D communications can provide higher spectral efficiency and network throughput, which are the two main requirements for the LTE–A network.

There are challenges facing the integration of D2D in LTE–A network as fellow:

A. Device Discovery

Device discovery is one of the major challenges in D2D communication, Devices can periodically broadcast their identity information so that other devices can be aware of their existence and decide whether or not, to respond to their discovery request, and subsequently initiate a D2D direct or device relaying communication. This is known as peer discovery, discovery is performed by exchanging signaling messages referred to as beacon signals, between users that want to communicate in D2D mode, between them and the eNB for control purposes is known as peer discovery, from D2D point of view, These beacon signals contain the identity of each potential D2D user, type of service, and also serves as pilot (reference) signals for measuring the channel quality indicator (CQI) of the direct path. Furthermore, the devices need to determine appropriate modulation and coding schemes to be used, as such, reference signals like LTE UL demodulation reference signal (DM–RS's) can be inserted at the D2DTx for channel estimation and demodulation at the D2DRx. The eNB uses the CQI value, mapped it to SINR, to establish the direct path between the D2D pair, when the SINR is above a pre-defined threshold i.e. favorable for D2D communication.

There are two main techniques in D2D discovery process, namely Priori and Prosteri discovery.

In a priori device discovery, the network (and/or the devices themselves) detects D2D candidates prior to establish a communication session between the devices, In the fully controlled mode, the announcing UE first registers to the network, and the receiving UE willing to engage in D2D communications sends a request to the network. In the loosely controlled mode, Such beacon assignments are broadcasted in the coverage area of the cell so that the announcing UE (transmitting a beacon) as well as the receiving UE (detecting beacons) can readily find one another.

In a posteriori device discovery process is initiated by the eNB, while a communication session is ongoing between users. In such case, the eNB identify the users as potential D2D pairs, by analyzing their IP addresses, and therefore, recommend them to switch over to D2D mode, so as to achieve better performance and higher gain.

B. Mode Selection

Proper mode selection plays an important role in determining the performance of D2D communication in cellular network

Basically, UEs can work in one of the four modes as illustrated in Fig. 2.3

D2D Silent Mode When available resources are not enough for D2D communications with dedicated resources, and spectrum reuse is impossible either owing to harmful interference, D2D users are incapable of data transmission and have to keep silent.

D2D Reuse Mode UEs communicate directly via D2D links by sharing the uplink or downlink spectrum resources of CUEs in cellular D2D underlay.

D2D Dedicated Mode Dedicated cellular spectrum resources are allocated for UE to communicate directly via D2D links.

Cellular Mode In this mode, two UEs can communicate with each other through the BS without co-channel spectrum sharing in traditional way.

Practically, different communication modes can be selected according to channel condition variation and service requirements. D2D reuse mode performs better interns of spectrum efficiency, but the co-channel interference caused by spectrum sharing is challenging. On the other hand, D2D dedicated mode and cellular mode can be chosen to ease the task of interference management and achieve better user experience with less satisfying spectrum efficiency, By selecting suitable transmission modes for potential D2D links, the overall network performance can be optimized while guaranteeing QoS requirements of involved users[2].

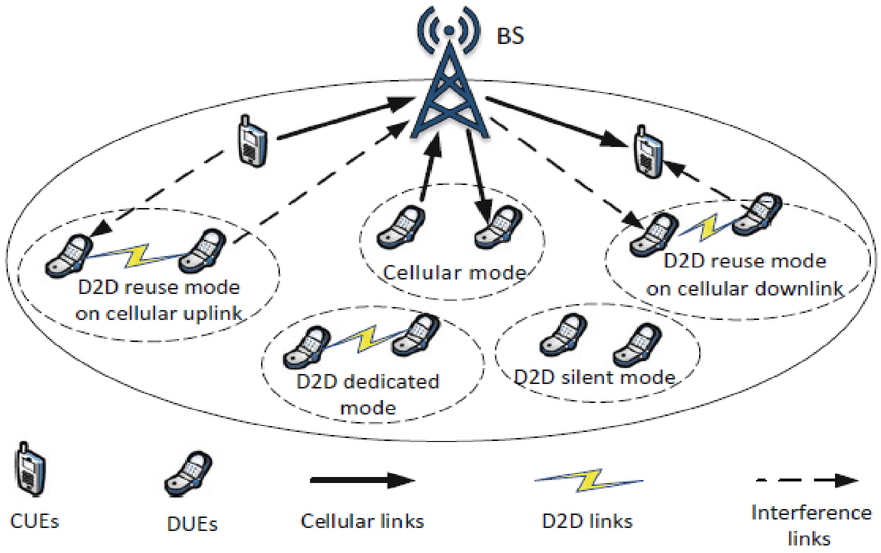

Figure2.5: D2D communication modes [2]

C. Radio Resource Management

An RB is the basic representation of radio resources in LTE–A networks. It occupies one slot in the time domain and 180 kHz in the frequency domain i.e. 12 subcarriers with 15 kHz subcarrier spacing. The RBs are assigned using either a centralized allocation scheme or a distributed allocation scheme. The eNB is responsible for the allocation of the RBs in the centralized resource allocation scheme, while the users select from a resource pool that is pre–configured statically or semi–statically by the eNB in the distributed resource allocation scheme. The distributed resource allocation scheme is therefore, gaining attention in D2D communication due to its scalability, low complexity and less overhead in resource assignment.

The same RBs can be spatially reused among different D2D pairs, this improves spectrum utilization, since more UE's that are distant apart can be simultaneously served with the same RBs. However, spatial reuse generates mutual interference among the D2D users, and therefore must be coordinated effectively. [42].

D. Mobility Management

Mobility management and handover have significant impact on the performance of D2D communication ‹Firstly, the maximum distance between D2D pairs in different deployment scenarios in accordance to QoS requirement and interference constraints to cellular links needs to be studied.

Secondly, movement of D2D transceivers from one cell to another during an ongoing communication session is practically possible, and thus, service continuity is required. Thus, a resilience handover process is required, in order to realize seamless communication on the D2D links. Alternatively, the D2D transceivers may be switched over to cellular mode when it is no longer possible to continue transmission in D2D mode, due to mobility or excessive interference levels experienced from neighboring cells, therefore new decision making handover algorithms to handle movement from single to multi cell scenarios, or switched to cellular mode need to be proposed

2.6 Channel Measurements:

The required channel measurements and measurement reporting depends on degree to which the network is involved in the resource assignment and LA[1],Measurements of the received strength of the RS transmitted by eNBs on the DL can be used to estimate the interference that the D2D transmissions will cause. Therefore, measurement reports of these can be useful to the eNB when it assigns resources for the D2D links. In the UL, The sounding reference signals (SRS) are usually transmitted on a wider bandwidth than the actual data transmission to facilitate estimating channel information. This is useful in D2D-assisted networks which have strict control of resource allocation. On the other hand, the demodulation reference symbols (DMRS), which are transported beside the PRBs of the payload, can be used for demodulation, channel estimation, channel equalization, and could possibly serve the same purpose in D2D communications [16][2] ,However, it remains to be studied whether other RS would be better suited for D2D communications. A possible procedure for channel exchange information is shown in Fig. 2-6.

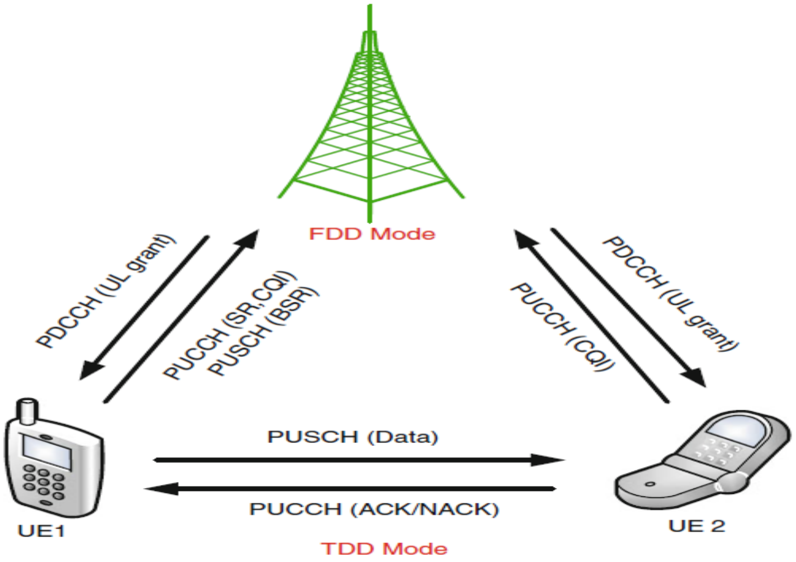

Figure: 2-6Channel exchange procedure [1]

Here assumed that eNB has full control over radio resource, which is allocated to D2D users through L_1/L_2 control signaling (e.g., Physical Downlink Control Channel (PDCCH)). Resources are allocated on per-TTI basis which is equal to 1 ms in LTE. Assume UE1 and UE2 have established a D2D connection and UE1 has data waiting to be transmitted to UE2. The eNB is responsible for resource allocation.

First, UE1 notifies the eNB that it has data to be transmitted to UE2. According to the LTE protocol, UE1 can send a buffer status report (BSR) to the eNB through the PUSCH for this purpose. If no UL resources are available for the BSR transmission, UE1 can send a one-bit scheduling request (SR) signaling through the Physical Uplink Control Channel (PUCCH). Once the eNB receives the SR from UE1, it will allocate a small amount of UL resources for the BSR transmission. After the eNB receives the notification (e.g., BSR) from UE1, it will allocate sources for the data transmission between UE1 and UE2. In an LTE-A system, the eNB usually considers the channel status when performing resource allocation. For the D2Dcommunications, the eNB can obtain the channel status of D2D links between UE1and UE2 by the periodic or a periodic channel quality indication (CQI) reports fromUE1 and UE2 through the PUCCH. It is assumed that UE1/UE2 can perform the CQI estimation from the received Sounding Reference Signal(SRS) transmitted by its D2D peer[1].

2.7 Related work:

Reference No	Author	Problem	Proposed solution
31	Wang, B.,	D2C interference based on channel based resource allocation.	algorithm to optimize the resource allocation, in which D2D links can reuse the resources of more than one cellular user
32	Chae, H. S.,	By applying D2D communication into cellular systems, interference between D2Dand eNB relaying UEs can occur if D2D UEs reuse frequency band for eNB relaying UEs	Propose a radio resource allocation scheme for D2D communication underlaying cellular networks using FFR.
3	Wang, H. and X. Chu	interference from cellular transmissions to the D2D link	propose a Distance constrained Resource sharing Criteria (DRC) for the base station to select a CUE for a D2D link,

10	Reider, N. and G. Fodor	mitigate the Cellular-to D2D (C2D) interference	control the maximum transmit power of the D2D transmitter
22	Yu, C.-H.,	Find resource allocation for D2D communication and control offload traffic to reduce interference.	Assume that a BS scheduler knows about the D2D communication need based on communication request between two potential D2Dusers, and the BS decides to offload that traffic to a directD2D connection. Based on handover and other measurements provided by the cellular and potential D2D users.
29	Zhang, Z.,		Study the performance of D2D communications underlying an uplink LTE network which utilizes both FPC and FFR.

28	Zhang, Z.,	Analyze the coverage performance of both CUEs and DUEs.	propose a D2D distance based power control scheme that can support dense D2D communication underlay an uplink cellular network

Since interference is a critical issue of mixed cellular and D2D environment, there is a wide research going on interference management.
The research work conducted in[3]like this project, both using (DRC) to mitigate interference in D2D and cellular system, but in this research proceed to describe the detailed procedure of the fixed PC mechanism in the cellular communication to ensure that the received SINR of the cellular UE meets a target value.

CHAPTER THREE

METHODOLOGY

Chapter Three

Methodology

3.1 Introduction:

D2D communication underlying cellular network is expected to operate within the same coverage area of an existing cell of LTE A network, when working in cellular mode or dedicated D2D mode, users are allocated resources, with orthogonal spectrum, which can lead to inefficient use of available spectrum.

To improve spectrum efficiency, D2D links can communicate by reusing the same spectral resources known as physical resource blocks (PRBs) with cellular links. However, co-channel interference brought by spectrum sharing must be coordinated carefully to guarantee the required QoS for UE, When downlink resources are reused by D2D links, D2D receivers and CUEs using the same spectrum resources would interfere. For DUEs reusing the downlink spectrum interference comes from other co-channel DUEs and the BS.

The goal of the interference management strategy in the D2D communication is to achieve a more spectrally efficient communications network without affecting the existing CNs. In this case, the interference management for sum capacity enhancement is divided into the resource allocation and the interference cancelation (IC). First, the resource allocation for the capacity enhancement can improve the spectral efficiency of the overall system by adapting the transmit power or the radio resource. This behavior is similar to the resource allocation to suppress the interference to the CNs. Second, the additional performance gain can be obtained from the BS-centric and D2D-centric interference cancelation.

3.2 Interference Scenarios:

3.2.1 Intracell versus Intercell Interference

Interference between BS, cellular UEs, and D2D UEs caused by resource sharing plays a key role in performance optimization.

D2D communication links may reuse some of the cellular spectrum resources, which means that intracell interference is no longer negligible. But in multicell systems, new types of intercell interference situations have to be dealt with due to the undesired proximity of D2D and cellular transmitters and receivers. The intracell and intercell interference scenario due to D2D communication [21][22]is shown in Fig.3-1

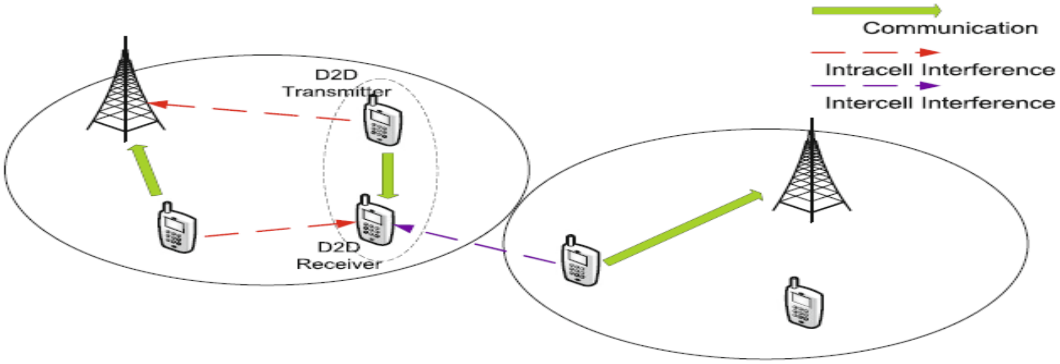

Figure 3-1:Intracell versus Intercell Interference[1]

3.2.2 Uplink versus Downlink Interference

When reusing the downlink RBs, D2D users suffers harmful interference from the eNB, due to the high transmits power of the eNB. This makes it difficult to guarantee the quality of D2D services, decreases the SINR and hence, results in poor performance of the D2D systems. On the other hand, reusing uplink RBs generates less undesirable interference to the D2D users, because the traffic overhead and control signaling of uplink are much lower than that of downlink in cellular networks. Hence, the total interference level in uplink spectrum is less than that in downlink spectrum[1].

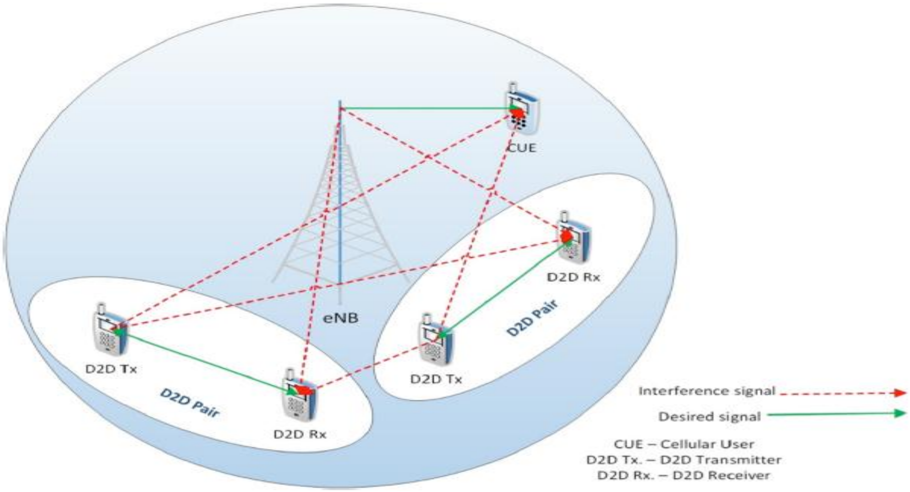

Figure 3-2: Uplink versus Downlink Interference

3.2.3 Network Scenario of One D2D Candidate versus Multiple D2D Candidates:

Interference scenarios into cellular networks depending on the radio resource reuse, interference between a cellular user and a D2D user and interference between a cellular user and multiple D2D users as shown in
Fig (3-3)

Interference between the BS, CUEs, and DUEs for D2D communication, interference scenario is considered where the resource sharing model involves only one D2D candidate in one resource or multiple D2D candidates with orthogonal resources due in part to the complexity involved for handling interferences among multiple D2D candidates [22].

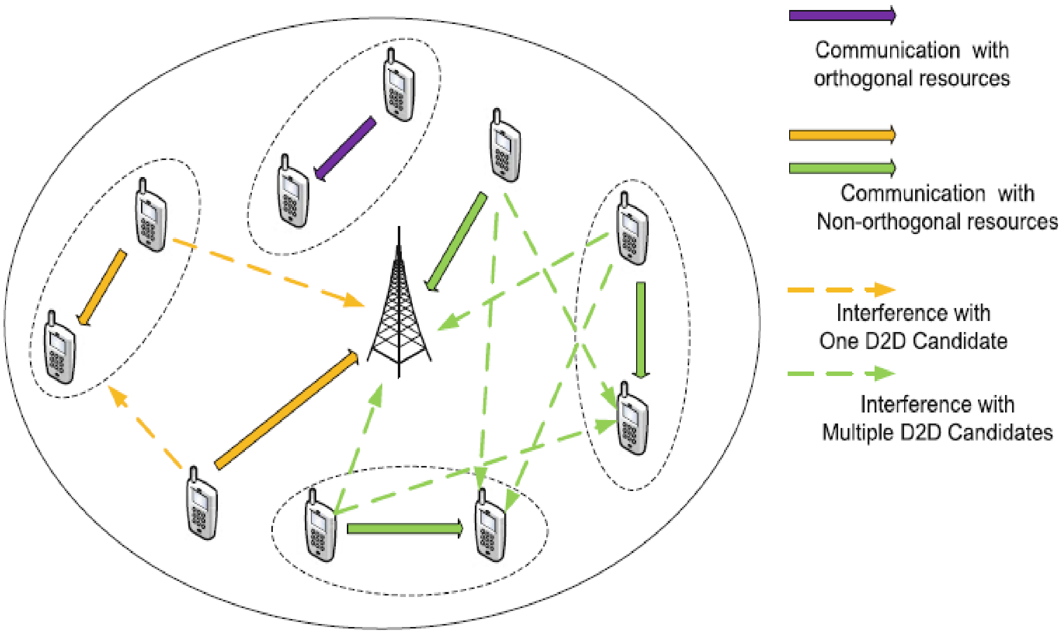

Figure 3-3: D2D Candidate versus Multiple D2D Candidates [1]

3.3 Interference Generated by D2D Communication:

Let us consider a single cell environment consisting of a single BS, a single cellular UE, and one D2D pair as illustrated in Fig3-4. It is assumed that all nodes are equipped with a single antenna. In Fig. 3-4, D_T and D_R are in close proximity to one another and want to communicate with each other. In this case, both nodes can be operated in D2D mode. That is, the D2D transmitter D_T and the D2D receiver D_R communicate with each other over a direct link by reusing a licensed spectrum such as the cellular resources instead of transmitting a data via the BS, whereas the connection is still controlled by the cellular BS

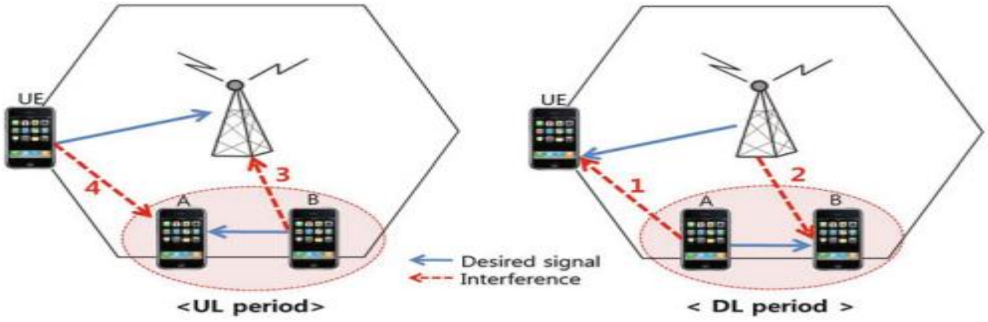

Figure 3-4: System model of the D2D communication underlying cellular system

The detailed interference scenario caused by the D2D communication is described as follows:

- **Downlink period:** When the D2D transmitter D_T communicates with its receiver D_R directly, the BS also broadcasts the data to the cellular user. As shown in Fig.3.4, therefore, two types of interferences will be occurring during DL period. One is the interference from the D2D transmitter D_T to the cellular UE which is attached to the BS (denoted by Case 1). On the other hand, it is possible that the D2D receiver D_R suffers from the interference generated by the cellular BS (denoted by Case 2). Therefore, the interferences for both cases degrade the overall performance of CNs and D2D systems, respectively. However, since the maximum transmit power of the BS is larger than that of the D2D transmitter D_T, the interference from the D2D transmitter D_T to the cellular UE results in trivial performance loss. Conversely, the overall system performance is more seriously degraded by the interference from the cellular UE to the D2D receiver D_R during the DL period. Note that since the BS has more capability than the cellular UE, It is able to manage the interference from the cellular UE to the D2D receiver D_R[20].

• **Uplink period:** interference from the cellular UE to the D2D receiver D_R can be eliminated by using the transmit beam forming (BF) technique

Similar to the D_L period, the coexistence of the D2D pair and the cellular UE causes two interference models. That is a D2D communication during U_L period generates not only D2D interferences to the cellular UE (denoted by Case 3) but also cellular interferences to a D2D pair (denoted by Case 4), In this scenario as well, the overall system performance is degraded by both interferences from the D2D transmitter D_T to the cellular BS and from the cellular UE to the D2D receiver D_R, respectively.

- The basic aim of interference in the D2D communication underlying the CNs are summarized in Table 3-1

Case	Period	Aggressor	Victim	Priority
1	DL	D2D transmitter D_T	Cellular	yes
2	DL	Cellular BS	D2D receiver D_R	No
3	UL	D2D transmitter D_R	Cellular	yes
4	UL	Cellular UE Connected to the BS	D2D receiver D_R	No

Table 3-1: Interference in downlink and uplink period [1]

3.4 Power Control:

Since the D2D communication takes place as an underlay communication to the cellular OFDMA network, the interference from D2D communication to the cellular network has to be coordinated and the BS should be aware of ongoing D2D connections.

Open loop power control is capability of the UE transmitter to set its uplink transmit power to a specified value suitable for receiver.

POL is the uplink power, set by open loop power control. The choice of □ depends on whether conventional or fractional power control scheme is used. Using □ = 1 leads to conventional open loop power control while

0 <□< 1 leads to fractional open loop power control

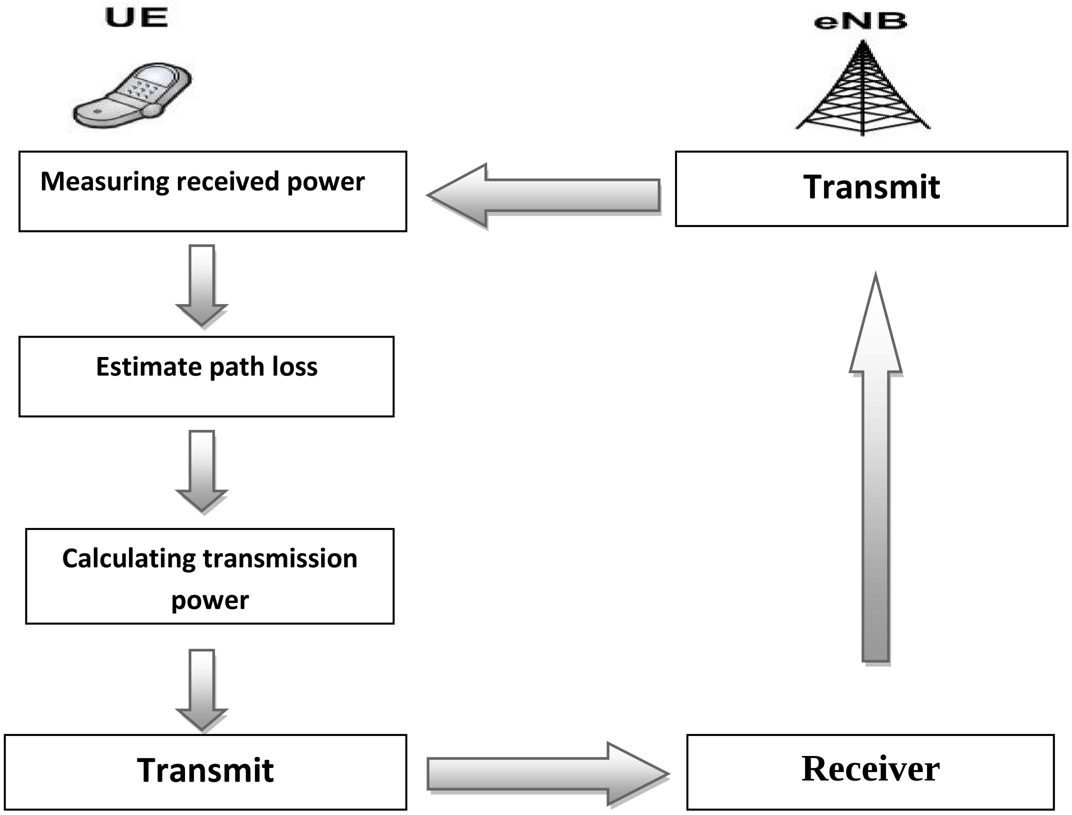

Figure 3-5: Block diagram of steps involved in setting uplink power using open loop power control

The Figure 3-5 shows a block diagram of the steps involved in setting the uplink transmit power using the open loop power control. Estimate of the path loss is obtained after measuring reference symbol received power (RSRP) and then the calculation for transmission power is performed based on equation (3.1)

$POL=\min\{Pmax, 10\log_{10}M+P_O+\alpha PL\}$ [dB m]…………………….…….(3.1)

3.5 Fractional Frequency Reuse technique:

OFDMA based systems is affected by CCI, this especially affecting the users from the edges of each cell. This happens when a user receives, besides the intended signal from its base station (BS) another signal from a neighboring BS at the same frequency. Because of this the quality of the received signal is altered. Frequency reuse is a solution that can help reduce CCI. The available bandwidth of a system can be divided in several sub bands each being allocated to a cell from a cluster

The basic idea of FFR is to partition the cell's bandwidth so the (i) cell edge users of adjacent cells do not interfere with each other and
(ii) Interference received by cell interior users is reduced, while (iii) using more total spectrum than classical frequency reuse.

The use of FFR in cellular network is tradeoffs between improvement in rate and coverage for cell edge users and sum network throughput and spectral efficiency [23]

The main objective is to apply FFR in order to improve the SINR and throughput and simultaneously reduce CCI. An indicative architecture and frequency band allocation are depicted in Figure (3-6).

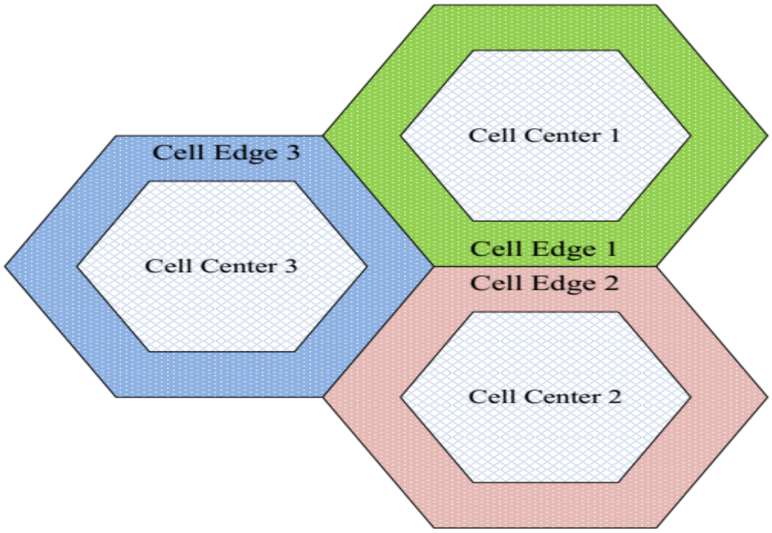

Figure3-6: fractional frequency reuse

3.6 System Model:

3.6.1 First: for single cell:

Model is considered a single cell environment, as illustrated in Fig.(3-5), where the base station is located in the cell center and all cellular user equipment's (CUEs) are uniformly distributed over the cell area.

Assumed that there is one D2D pair and N cellular users, although similar analysis can be used for the scenario with more than one D2D pair.

For any CUE the probability density function of its distance r_C from the BS is: PDF=f(r_c)= $\frac{2r_c}{R^2}$ [$r_c \in (0,R)$]while its angle θ is uniformly distributed over [0,2π]. D2D communications underlying a cellular network will be limited to local traffic, and application utilizing D2D communications should be designed accordingly [1],Thus, D2D transmitter (D_T) and D2D receiver (D_R) close to each other.

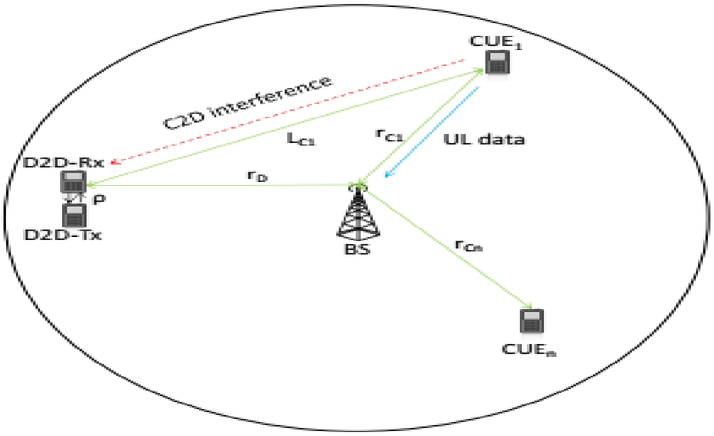

Figure 3-7: system model of D2D underlying a cellular Network [3]

In Fig. 4-1 assumed that D2D link uses the uplink resource of the cellular system. Then, the D2D pair should be near the cell edge [8]. The BS will choose radio resource of a particular CUE$_i$ among the N CUEs randomly distributed over the cell for sharing with the D2D pair. For example, in, D_R is receiving data from D2D Tx under the interference from CUE1's uplink transmission. L_{C1} denotes the distance corresponding to the C2D interference link between CUE1 and D2D-Rx. In general, the distance L_{Ci} between the CUE$_i$ and D2D-Rx is given as:

$$L=\sqrt{r_c^2 + r_D^2 - 2r_c r_D \cos\theta} \quad \text{....(3.4.a)}$$

In this D2D communication model with the uplink resource, the distance between two users in D2D pair $\rho \ll r_D$ is small and the power level required for the D2D link is much lower than the CUEs. Therefore, the D2C interference is negligible, whereas the C2D interference become crucial. When CUE$_i$ share the same resource with the D2D pair.

The received signal at the D2D-Rx can be expressed as:

$$Y_i = h_D\sqrt{(P_D\rho^{-\alpha})}X_D + h_{ci}\sqrt{(p_{ci}L_{ci})}\ X_{ci} + n_o \quad \text{....(3.4.b)}$$

Where:

- x_D denotes signal transmitted from D_T.
- x_{Ci} is the uplink signal that CUE_i transmits to the BS.
- h_D and h_{Ci} stand for fading coefficients in the D2D link and the CUE_i to D2DRx, respectively, both following the independent complex Gaussian distribution.
- $P_D P_{Ci}$ are the transmit power of the D2D-Tx and CUE_i, respectively.
- α is the path loss exponent .
- n_0 represents the additive white Gaussian noise (AWGN).
- The term $P_D\,\rho^{-\alpha}$received power at D2D-Rx for the D2D link.
- The term $P_C\,L_c^{-\alpha}$received C2D interference link

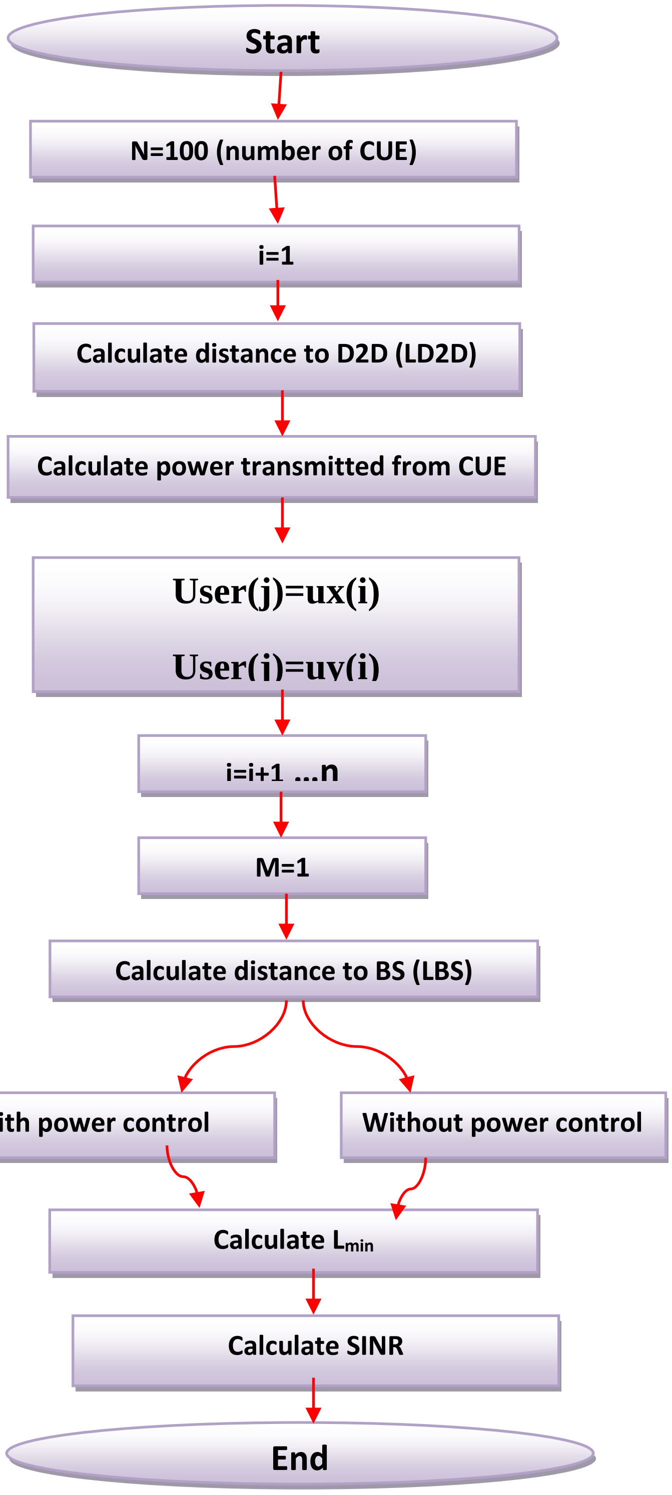

Figure 3-8: Flow Chart for single cell

3.6.2 Second for multi cell:

In conjunction with growing demands for mobile services, the necessity arose for enhanced system capacity. According to Shannon, the most effective method for improving capacity is increasing the available bandwidth. Without adding to the already expensive system bandwidth, this is performed by improving the spatial reuse of resources, and can be easily achieved given two realizations.

In this model used fractional frequency reuse in D2D Communication to mitigate interference in multi cell:

1. Divide the cell into an inner region and an outer region with the inner region radius r_{in}, and only allow D2D communications in the outer region where $r_d > r_{in}$.
2. Given the position of a D2D Rx, select a CUE in the inner region but with a position on the opposite side of the BS with respect to the D2D link.

To adopt this scheme in multi-cell systems, inter cell interference must be considered, accordingly, extended the performance analysis to a multi cell scenario with FFR.

In Fig 3-6 implemented FFR in d2d communication, assumed that for the cellular uplink, where the frequency bands for cell edge is different but in cell center for three cell is the same as Figure3-6 .

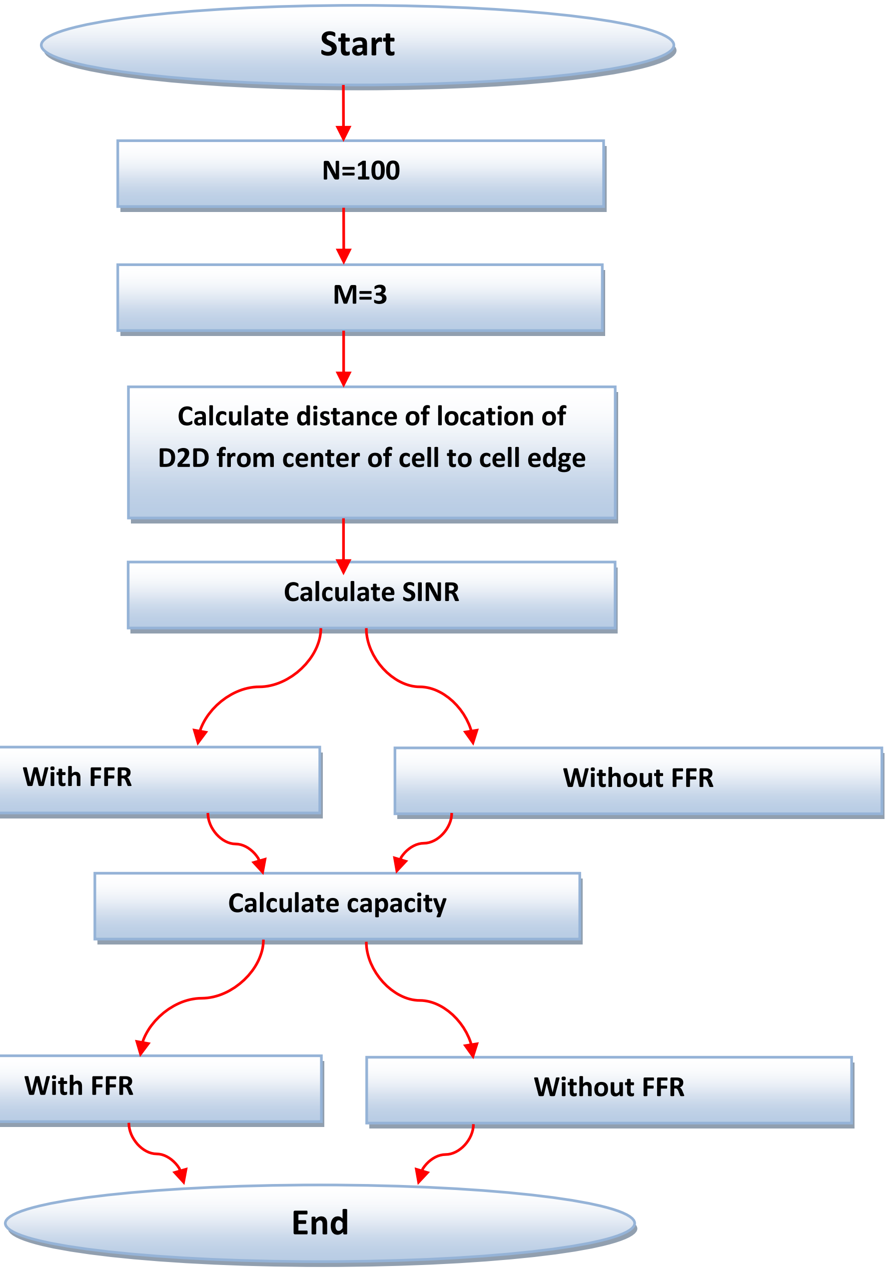

Figure 3-9: Flow Chart for multi cell

CHAPTER FOUR

RESULTS AND DISCUSSION

Chapter Four

Results and Discussion

4.1 Descriptive Analysis:

The proposed scheme improves performance of D2D and cellular UEs by reducing interference between them., The main concept of this model is consist of two parts, (in single cell and in multi cell).

In single cell, Reusing uplink cellular resources causes C2D interference rather than the D2C interference, A Distance-constrained Resource sharing Criteria (DRC) is proposed for Device to Device (D2D) communications underlying cellular systems to mitigate the interference from cellular transmissions to the D2D link [24]. The idea of (DRC) is selection the best resource of cellular users to reuse it for D2D pair and the interference in stable level.

This work depend on distance and power transmitted from cellular, and calculate the SINR to analyze the performance of system.

In multi cell, depended on resource allocation to mitigate interference, Fractional Frequency Reuse (FFR) partitions each cell into two regions, inner region and outer region and allocates different frequency band to each region. Based on this frequency band allocation, FFR may reduce channel interference and offer large system capacity

4.2 Mathematical model:

Proposed a simple mechanism to guarantee the signal to interference plus noise ratio (SINR) of the D2D receiver to a certain level to select the link which reused it by D2D:

$$\text{SINR}=\frac{h_D P_D \rho^{-\alpha}}{h_{ci} P_{ci} L_{ci}^{-\alpha} + \text{No}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

Open loop power control is capability of the UE transmitter to set its uplink transmit power to a specified value suitable for receiver, OFPC can be expressed in the power per unit bandwidth as:

$$P_c = P_o r_c^{k\alpha} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.2)$$

Where P_o is an initial power level of the CUE, and k is a cell specific path loss compensation factor.

4.3 Simulation setup:

MATLAB is an integrated technical computing environment that combines numeric computation, advanced graphics, visualization، and a high level programming language. It uses to graph functions, solve equations, perform statistical tests, and do much more.

The code which describes the simulation is shown in appendix (A) and simulation environment is shown in table 4-1 below:

Parameter	**Value(s)**
Initial power	-78dBm
Cell radius(**R**)	500m
Path loss exponent (**α**)	4
D2D link distance (**ρ**)	50m
Path loss exponent factor(**k**)	0.8
Noise power density	-174dBm

Table 4-1: simulation Parameter

4.4 Simulation Results:

After the execution of simulation software program .get the following results in terms of tables and graphs.

First in single cell: assumed AWGN channels with the fading gain h following an exponential distribution, this figures investigated how to properly choose a CUE for the D2D link, by using Distance constrained Resource sharing Criteria (DRC) for the base station to select a CUE for a D2D link, with the C2D interference controlled by keeping a minimum distance between them.

Figure 4-1: illustrates the distribution of cellular users in the cell, and one D2D pair in cell edge (0,-400).

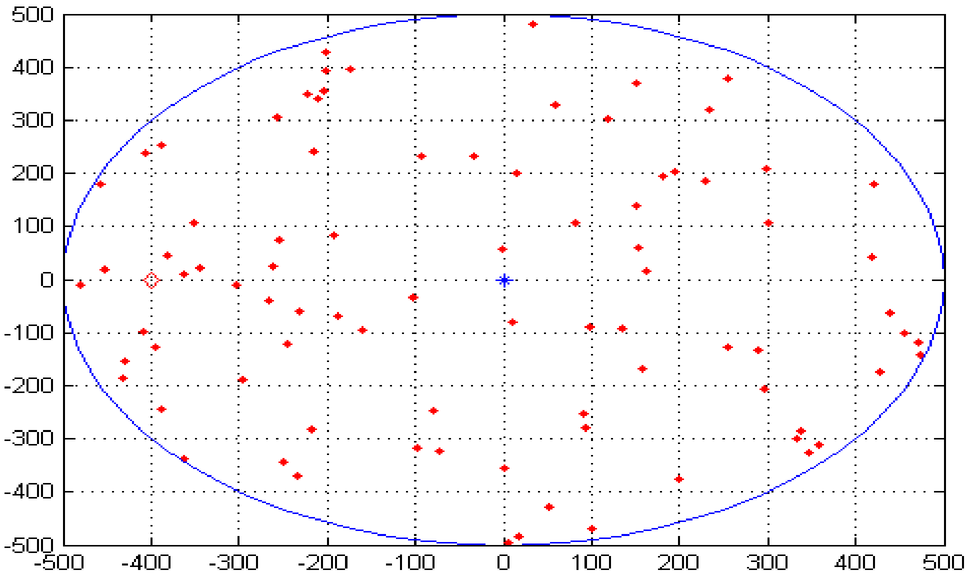

Figure 4-1: Distribution of users in cell

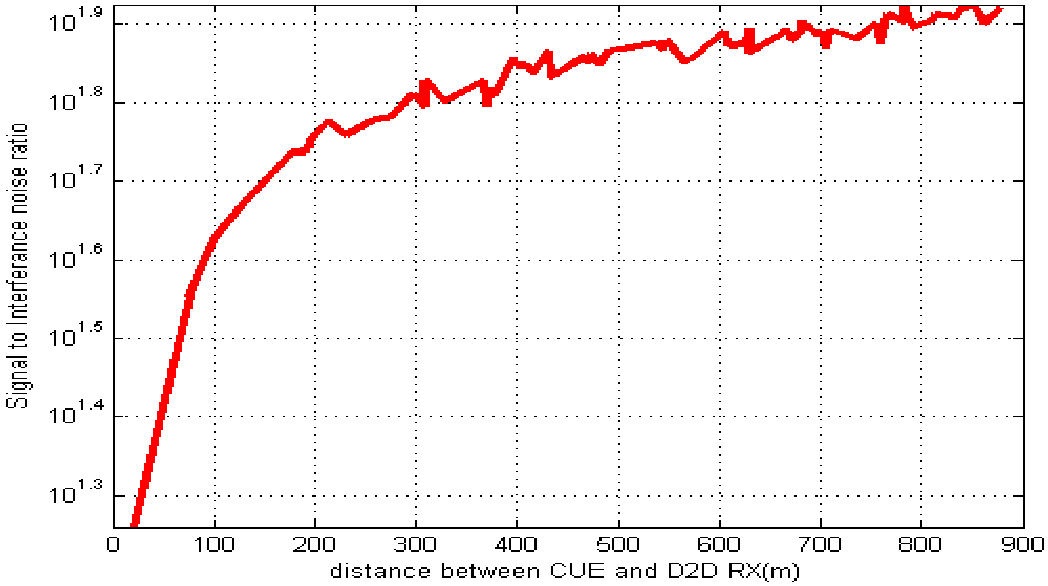

Figure 4-2: signal to interference noise ratio versus distance between user and D2DRX

In Fig 4-2: SINR increase when the distance between user and D2DRX increased. And calculated the distance threshold $L_{min=}$ 150.437,

$L_{min}$is a pre-selected distance constraint to control the interference from the selected CUE to the D2D UE1 to be interference in the stable level $L \geq L_{min}$.

D2D transmitter D_T employs various PC schemes to satisfy the predefined SINR for a required QoS of the cellular UE at the expense of the controlling signals from the BS‹in these two figures proposed to control the maximum transmit power of the CUE transmitter by using open loop fractional power control (OFPC) scheme as figure(4-3),but in figure (4-4) explain the power of each users in cell and notice increasing of distance between users in cell causes increasing of power transmitted from cellular user equipment

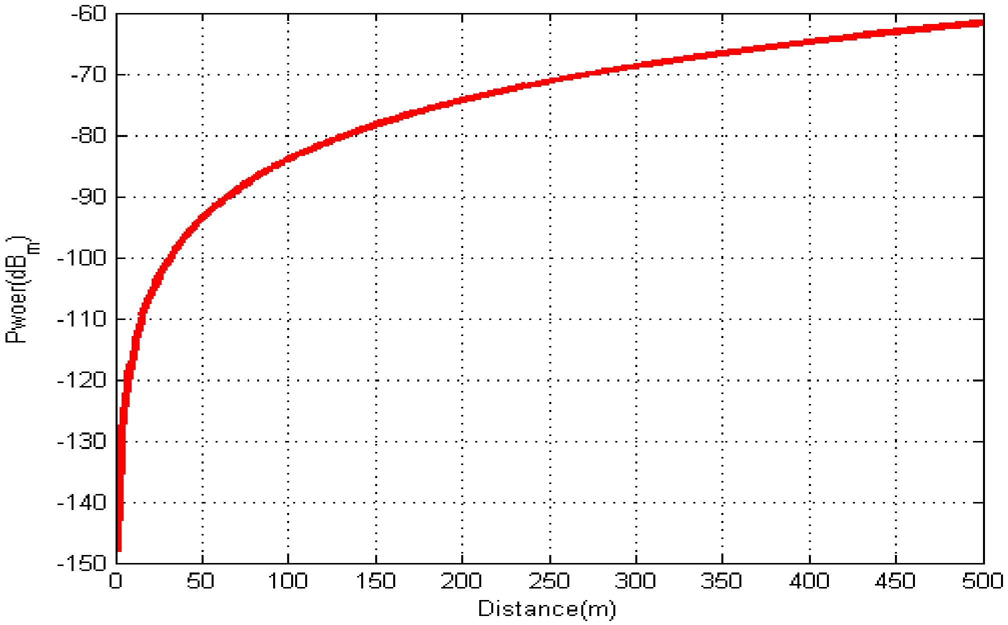

Figure 4-3: Relation between distance and power

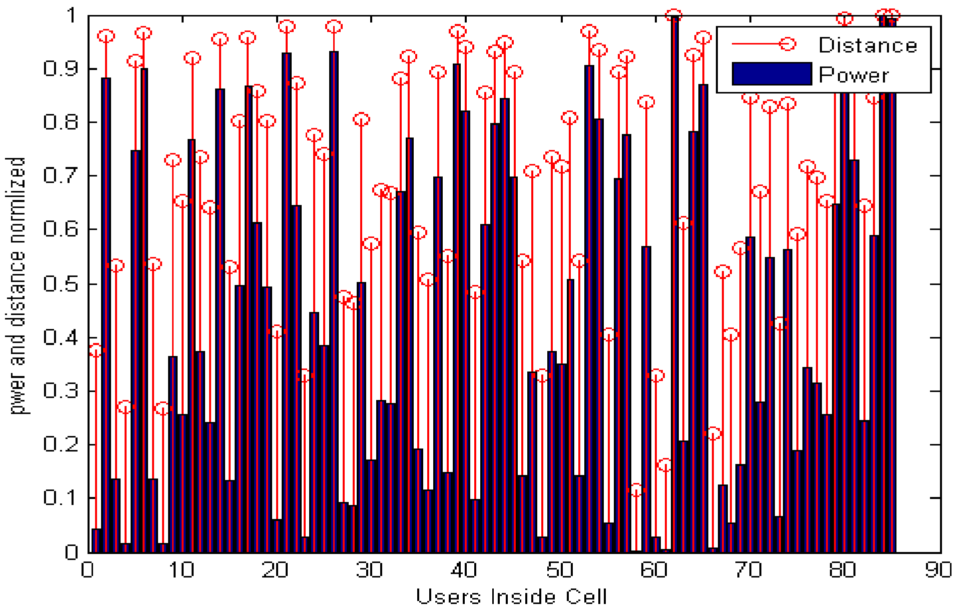

Figure 4-4: power and distance normalized versus users in cell

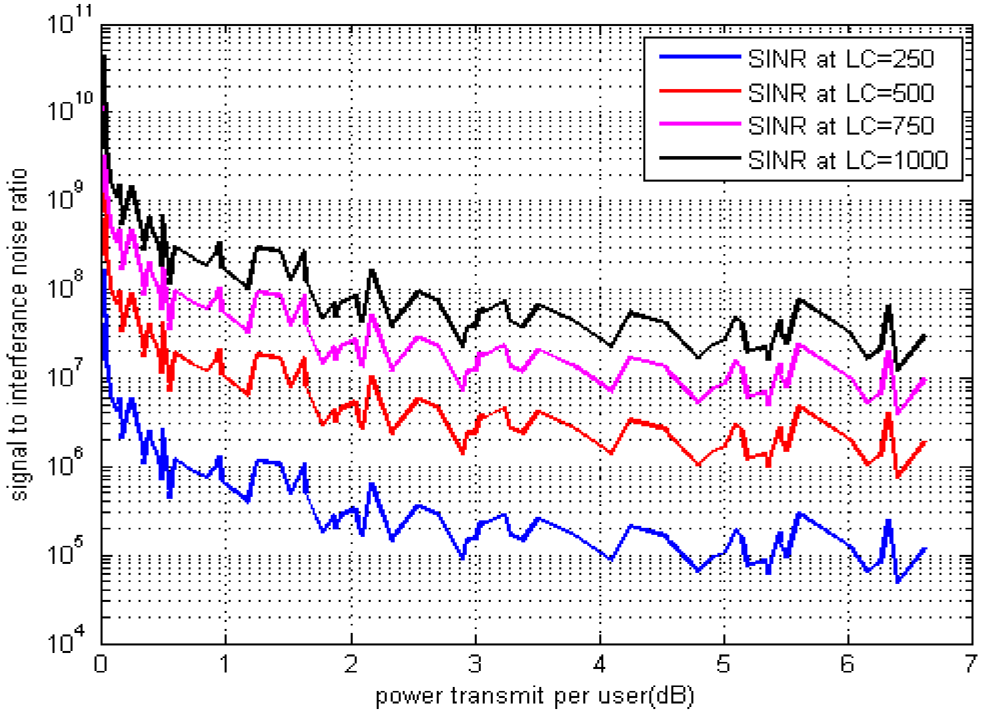

Figure 4-5: power transmit per user versus SINR

in figure (4-5) analyzed the effect of power transmitted from CUE ,which it adjusted by OFPC, increasing of power causes decreasing of SINR, but the value of SINR became in stable level. In addition noticed, under power control, the value of SINR decreased when the distance between CUE and D2DRX increased.

Second in multi cell: To mitigate interference in multi cell, used factional frequency reuse, in this model, assumed cluster consist of three cell, each of them have inner region and outer region. Each of inner region have the same frequency band but outer region have different frequency band.

Assumed, total bandwidth 20 MH , bandwidth is divided into four band, 0 to5 MH for inner cell, 5 to 10 MH for outer first cell , 10 to 15 for outer second cell, 15 to 20 MH for outer third cell as Figure(4.7) show the channel bandwidth assignment which it divided to four band.

The code which describes the simulation is shown in appendix (c) and simulation environment is shown in table (4-2) below:

parameter	**Value(s)**
Total bandwidth (**W**)	20MH
Radius of inner cell(**R**)	300m
Uplink Max Tx Power	23 dBm (200 mW)
Path loss (dB)	40 log(d), d = distance in meters

Table 4-2: Simulation Parameter

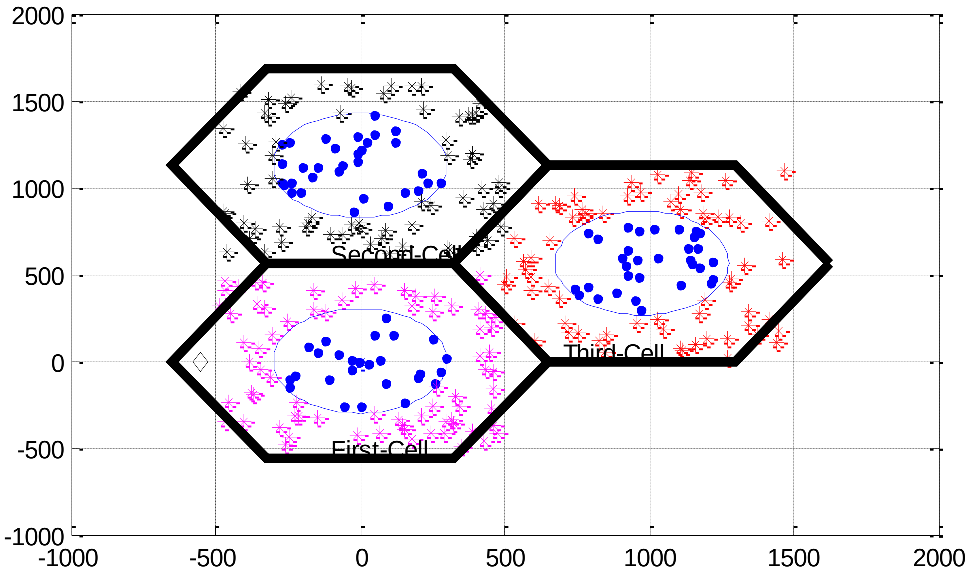

Figure4-6: Fractional Frequency Reuse

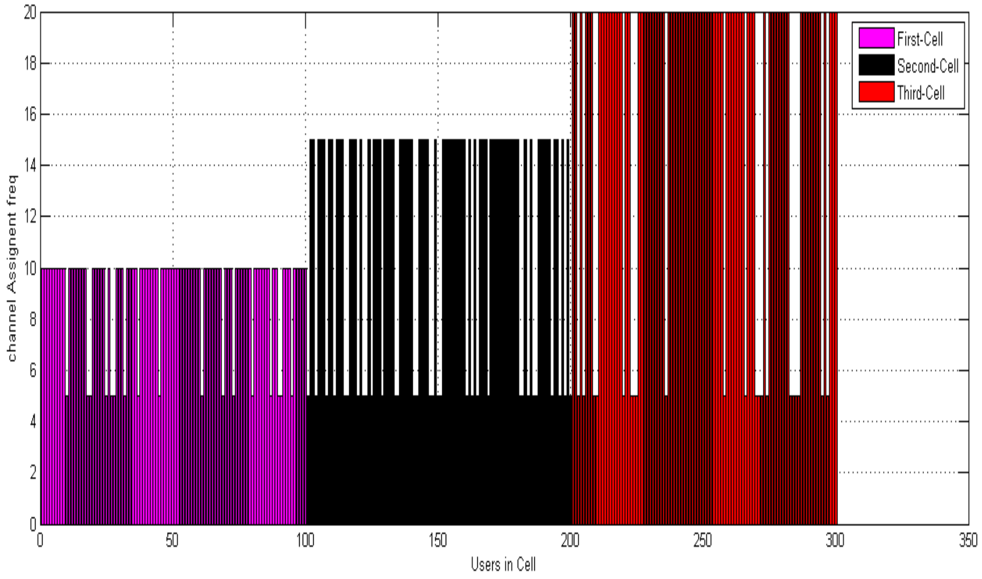

Figure4-7: Users in cell versus Channel assignment

To analyze this model, assumed three D2D pair, each of them in inner region in each cell, assume the cell radius of inner region 300 m .but the cell radius for total cell without FFR 500m.

In this model, assumed D2D pair or cellular user in cell edge of inner region (in second or third cell) (worst case), has the same frequency of D2D pair in first cell.

To implement the effect of FFR in this model, studied the distance of location for D2D pair from the center of the cell edge of inner region to cell edge of total cell without FFR.

Assumed the D2D pair in inner region in first cell in figure4.6, the D2D pair faces interference from inner region from other cells which it has same frequency.

Calculated the distance from tow center and from D2D pair, and calculate the SINR as figure 4.8

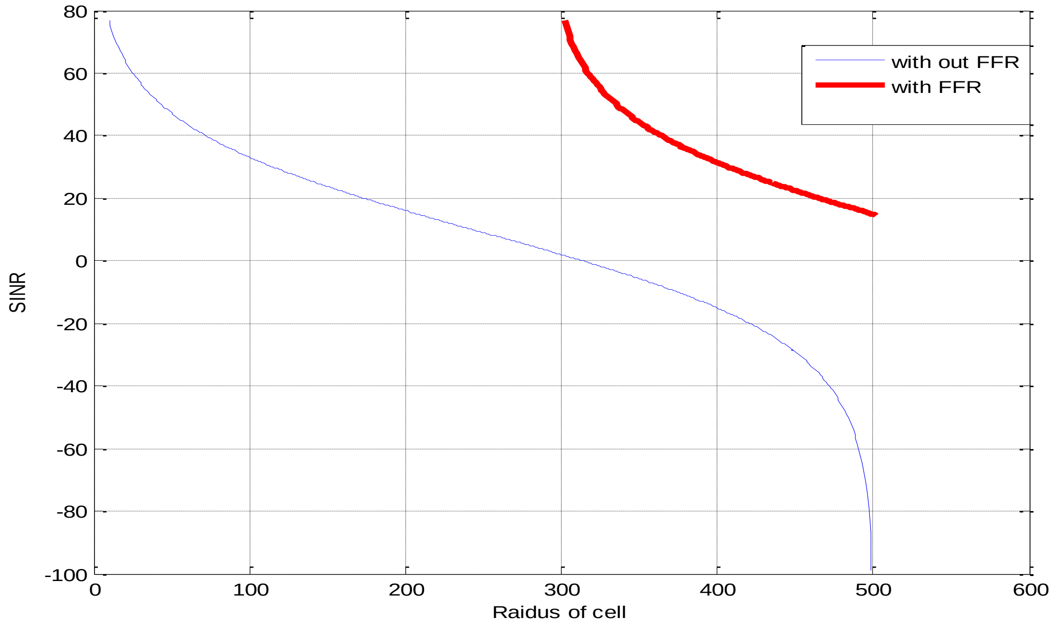

Figure 4-8: Radius of cell versus SINR

In above figure, observe value of SINR is decreased because the power of signal is strong near base station, and decrease with distance. The worst case when D2D in cell edge of inner region (300m), observe the SINR enhanced and in acceptable level, If location of D2D in cell radius greater then 300m (outer cell), the interference become zero because in outer cell has different frequency theses causes the SINR become high.

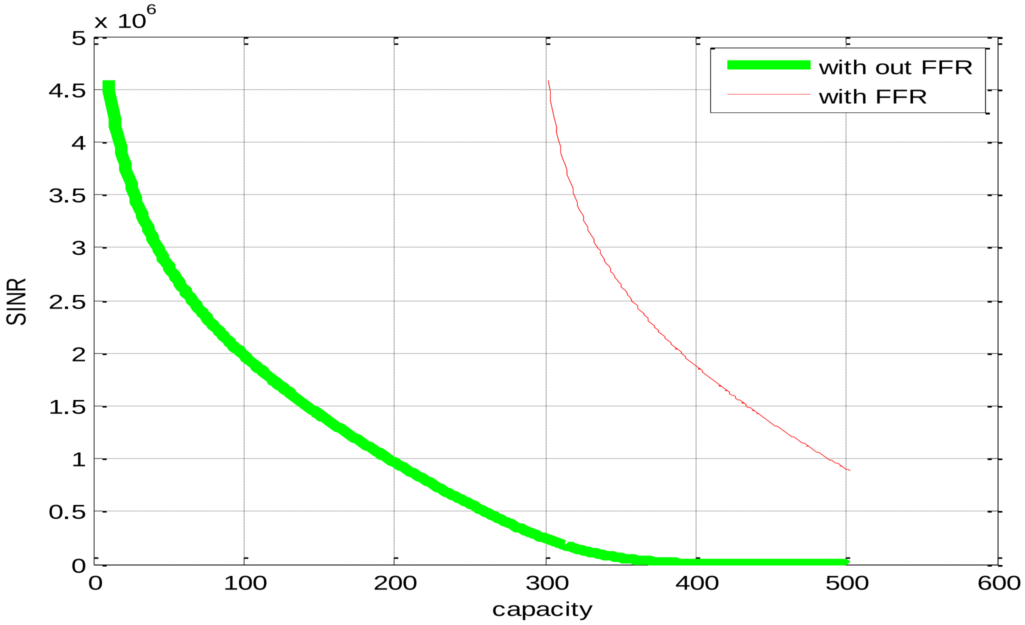

Figure 4-9: Capacity versus SINR

Figure 4.9shows location of D2D from center of cell to cell edge, if D2D > (300m) capacity is enhanced and SINR is increased, these with FFR, when location of D2D in inner cell(less than 300m), the interference increased and SINR decreased.

coverage probability helps us to measure the level of QoS in 4G networks which it is the probability that a user's SINR will be greater than the threshold value given p(SINR)>T.

In figure 4-7 threshold SINR = 2 dB (approximate value).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

Chapter Five

Conclusion and Recommendations

5.1 Conclusion:

D2D communication is an advanced technology that can increase the spectral efficiency of the system and reduce energy consumption of mobile terminals by reusing the radio resource of cellular links.

This research investigated resource allocation for D2D communications underlying a cellular network. For the case when a D2D link shares resource with a cellular user, it proposed a distance based resource allocation scheme, in which the BS can select a best cellular user to mitigate the interference from the cellular link to the D2D link.

In this research calculated L_{min}= 150.437which it is the minimum value of distance to make the interference in acceptable level and calculated SINR to analyze the performance of system, in addition proposed a radio resource allocation scheme for D2D communication underlying cellular networks using FFR. In the proposed scheme, D2D and cellular UEs use the different frequency bands chosen as users locations.

The proposed radio resource allocation scheme can alleviate interference between D2D and cellular UEs.

From performance evaluation result of the proposed scheme under various simulation scenarios, showed D2D communication could significantly improve total performance of the cellular network.

5.2 Recommendations:

This research presents few method should be taken into account to improve the performance of D2D communication, some other issues can be considering for future research these include.

- Implement this work for multi of D2D pair communication and analyze the performance of system.
- Assume the location of DUEs in any outer area is modeled as a homogeneous Poisson point process (PPP) ,Similarly the location of CUEs in any inner area is also modeled as a PPP .
- Implement the other power control scheme to adjusts the power transmitted from cellular users equipment or power received to D2DRX..
- Analyze the performance of D2D communications sharing the uplink channel of a cellular system and observe the outage probability to notice the coverage of system.

\

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Appendix A

```
clearall
[xx,yy]=circle2(300,[0 0]);
[xx1,yy1]=circle2(300,[0 ,2*650*cosd(30)]);
[xx2,yy2]=circle2(300,[650*cosd(60)+650,650*cosd(30)]);
%while(1)
%% Circle Parameter
[x1,y1]=circle22(650,[0,2*650*cosd(30)]);
[x2,y2]=circle22(650,[0,0]);
[x3,y3]=circle22(650,[650*cosd(60)+650,650*cosd(30)]);
pause(0.1);
%% Power Consumption Calculation
edge=300;
f1=20;
f2=40;
k1=1;k2=1;k3=1;
N=100;
j1=1;j11=1;j2=1;j12=1;j3=1;j13=1;
Po=(10^-7.8);
k=0.8;alpha=4;
ux=rand(1,N)*1000-500;
uy=rand(1,N)*1000-500;
ux1=rand(1,N)*1000-500;
uy1=rand(1,N)*1000+600;
ux2=rand(1,N)*1000+500;
uy2=rand(1,N)*1100;
%% First Cell
distancetoBS1=sqrt(ux.^2+uy.^2);
fori=1:N
if(distancetoBS1(i)<=edge)
userx1(j1)=ux(i);
usery1(j1)=uy(i); dist1(j1)=sqrt(userx1(j1)^2+usery1(j1)^2);
pow12(j1)=Po*dist1(j1).^(k*alpha);
    j1=j1+1;
else(distancetoBS1(i)>edge && distancetoBS1(i)<=edge+100)
userxo1(j11)=ux(i);
 useryo1(j11)=uy(i); disto1(j11)=sqrt(userxo1(j11)^2+useryo1(j11)^2);
```

```
 j11=j11+1;
end
end
N_INR_user=j1-1;
N_OUT_user=j11-1;
Lci=sqrt((userx1+400).^2+usery1.^2);
Pci=rand(1,j1-1)*0.3+0.5;
hci=rand(1,j1-1)*0.3+0.4;
hci=rand(1,j1-1)*0.3+0.4+i*(rand(1,j1-1)*0.3+0.4);
hci_s=sum(hci.*conj(hci),1);%hci_s=hci^2
hdi=rand(1,j1-1)*0.3+0.4+i*(rand(1,j1-1)*0.3+0.4);
hdi_s=sum(hdi.*conj(hdi),1);%hdi_s=hdi^2
%% Second Cell
distancetoBS2=sqrt(ux1.^2+(uy1-2*650*cosd(30)).^2);
fori=1:N
if(distancetoBS2(i)<=edge)
userx2(j2)=ux1(i);
usery2(j2)=uy1(i); dist2(j2)=sqrt(userx2(j2)^2+usery2(j2)^2);
pow122(j2)=Po*dist2(j2).^(k*alpha);
    j2=j2+1;
else(distancetoBS2(i)>edge && distancetoBS2(i)<=edge+100)
userxo2(j12)=ux1(i);
 useryo2(j12)=uy1(i); disto2(j12)=sqrt(userxo2(j12)^2+useryo2(j12)^2);
 j12=j12+1;
end
end
N_INR_user2=j2-1;
N_OUT_user2=j12-1;
Lci=sqrt((userx1+400).^2+usery1.^2);
Pci=rand(1,j1-1)*0.3+0.5;
hci=rand(1,j1-1)*0.3+0.4;
hci=rand(1,j1-1)*0.3+0.4+i*(rand(1,j1-1)*0.3+0.4);
hci_s=sum(hci.*conj(hci),1);%hci_s=hci^2
hdi=rand(1,j1-1)*0.3+0.4+i*(rand(1,j1-1)*0.3+0.4);
hdi_s=sum(hdi.*conj(hdi),1);%hdi_s=hdi^2
%% Third Cell
distancetoBS3=sqrt((ux2-650*cosd(60)-650).^2+(uy2-650*cosd(30)).^2);
```

```
fori=1:N
if(distancetoBS3(i)<=edge)
userx3(j3)=ux2(i);
usery3(j3)=uy2(i); dist3(j3)=sqrt(userx3(j3)^2+usery3(j3)^2);
pow123(j3)=Po*dist3(j3).^(k*alpha);
    j3=j3+1;
else(distancetoBS3(i)>edge && distancetoBS3(i)<=edge+100)
userxo3(j13)=ux2(i);
 useryo3(j13)=uy2(i); disto3(j13)=sqrt(userxo3(j13)^2+useryo3(j13)^2);
 j13=j13+1;


end
end
N_INR_user3=j3-1;
N_OUT_user3=j13-1;
Lci=sqrt((userx1+400).^2+usery1.^2);
Pci=rand(1,j1-1)*0.3+0.5;
hci=rand(1,j1-1)*0.3+0.4;
hci=rand(1,j1-1)*0.3+0.4+i*(rand(1,j1-1)*0.3+0.4);
hci_s=sum(hci.*conj(hci),1);%hci_s=hci^2
hdi=rand(1,j1-1)*0.3+0.4+i*(rand(1,j1-1)*0.3+0.4);
hdi_s=sum(hdi.*conj(hdi),1);%hdi_s=hdi^2
%% Reset of Code
Pd=(10^3);
roh=50;
alpha=4;
N0=(10^-17.4);
% SINR=hd^2*Pd*roh^(-alpha)./(hci.^2.*Pci.*Lci.^(-alpha)+N0);
SINR=((abs(hdi_s))*Pd*roh^(-alpha))./((abs(hdi_s)).*Pci.*Lci.^(-alpha)+N0);
%SINR2=sort(SINR);
[Lco,SINRo]=reorder(Lci,SINR);
%LC=sqrt(distancetoBS.^2+distancetoD2dRX.^2-
2.*distancetoBS.g*distancetoD2dRX)

%% Without D2D
SINR1=(abs(hdi_s))*Pd*roh^(-alpha)./(abs(hci_s).*pow12.*250.^(-alpha)+N0);
SINR2=(abs(hdi_s))*Pd*roh^(-alpha)./(abs(hci_s).*pow12.*500.^(-alpha)+N0);
SINR3=(abs(hdi_s))*Pd*roh^(-alpha)./(abs(hci_s).*pow12.*750.^(-alpha)+N0);
```

```
SINR4=(abs(hdi_s))*Pd*roh^(-alpha)./(abs(hci_s).*pow12.*1000.^(-alpha)+N0);
%% With D2D
SINRD1=(abs(hdi_s))*Pd*roh^(-alpha)./(abs(hci_s).*pow12.*250.^(-alpha)+N0);
SINRD2=(abs(hdi_s))*Pd*roh^(-alpha)./(abs(hci_s).*pow12.*500.^(-alpha)+N0);
SINRD3=(abs(hdi_s))*Pd*roh^(-alpha)./(abs(hci_s).*pow12.*750.^(-alpha)+N0);
SINRD4=(abs(hdi_s))*Pd*roh^(-alpha)./(abs(hci_s).*pow12.*1000.^(-
alpha)+N0);
%%
[pow121,SINR1]=reorder(pow12,SINR1);
[pow122,SINR2]=reorder(pow12,SINR2);
[pow123,SINR3]=reorder(pow12,SINR3);
[pow124,SINR4]=reorder(pow12,SINR4);
%% Channel Asignment
%% First Cell
fori=1:N
if(distancetoBS1(k1)<=edge)
ca_in_outer1(k1)=5;
else
ca_in_outer1(k1)=10;
end
k1=k1+1;
end
%% Second Cell
fori=1:N
if(distancetoBS2(k2)<=edge)
ca_in_outer2(k2)=5;
else
ca_in_outer2(k2)=15;
end
k2=k2+1;
end
%% Third Cell
fori=1:N
if(distancetoBS3(k3)<=edge)
ca_in_outer3(k3)=5;
else
ca_in_outer3(k3)=20;
end
```

```
k3=k3+1;
end
%% Output
figure(4)
%%
ylabel('signal to interferance noise ratio'),xlabel('power transmit per user'),grid
semilogy(pow121,SINR1),hold on
semilogy(pow122,SINR2,'r')
semilogy(pow123,SINR3,'m')
semilogy(pow124,SINR4,'k'),hold off
%%
figure(5)
ylabel('signal to interferance noise ratio'),xlabel('power transmit per user'),grid
semilogy(pow121,SINRD1),hold on
semilogy(pow122,SINRD2,'r')
semilogy(pow123,SINRD3,'m')
semilogy(pow124,SINRD4,'k'),hold off
grid,legend('SINR at LC=250','SINR at LC=500','SINR at LC=750','SINR at LC=1000')
%%
figure(1)
plot(0,0,'*'); hold on
plot(-550,0,'kd');
plot(userx1,usery1,'b.');
plot(userxo1,useryo1,'M*');
plot(userx2,usery2,'b.');
plot(userxo2,useryo2,'k*');
plot(userx3,usery3,'b.');
plot(userxo3,useryo3,'R*');
plot(xx,yy),plot(xx1,yy1),plot(xx2,yy2),
plot(x1,y1,'k','linewidth',4);
plot(x2,y2,'k','linewidth',4);
plot(x3,y3,'k','linewidth',4);hold off
text(-100,-500,'First-Cell')
text(-100,620,'Second-Cell')
text(700,50,'Third-Cell')
```

```
grid;
% if R>500 && R<650
%     N=20
% end
% if

%%
figure(2)
ylabel('signal to interferance noise ratio'),xlabel('distance between CUE
and D2D RX'),
semilogy(Lco,10*log10(SINRo)),grid
%end
%%
figure(3)
stem(dist1/max(dist1),'r'),hold on
bar(1:j1-1,pow121/max(pow121)),hold off
legend('Distance','Power')
ylabel('pwer and distance normlized'),xlabel('Users Inside Cell'),grid
%%
figure(6)
bar(1:N,ca_in_outer1,'M');hold on
bar(N+1:2*N,ca_in_outer2,'K')
bar(2*N+1:3*N,ca_in_outer3,'R')
ylabel('channel Assignentfreq'),xlabel('Users in Cell'),grid
legend('First-Cell','Second-Cell','Third-Cell')
holdoff
```

Appendix B

```
clearall
[x,y]=circle2(500);
%while(1)
pause(0.1);
N=100;
j=1;
Po=(10^-7.8)
k=0.8;alpha=4;
ux=rand(1,N)*1000-500;
uy=rand(1,N)*1000-500;
distancetoBS=sqrt(ux.^2+uy.^2)

fori=1:N
if(distancetoBS(i)<=500)
userx(j)=ux(i);
usery(j)=uy(i);
dist(j)=sqrt(userx(j)^2+usery(j)^2)
pow12(j)=Po*dist(j).^(k*alpha)
    j=j+1;
end
end
Lci=sqrt((userx+400).^2+usery.^2)
Pci=rand(1,j-1)*0.3+0.5;
% hci=rand(1,j-1)*0.3+0.4;
hci=rand(1,j-1)*0.3+0.4+i*(rand(1,j-1)*0.3+0.4);
hdi=rand(1,j-1)*0.3+0.4+i*(rand(1,j-1)*0.3+0.4);
Pd=(10^3);
roh=50;
alpha=4;
N0=(10^-17.4);
% SINR=hd^2*Pd*roh^(-alpha)./(hci.^2.*Pci.*Lci.^(-alpha)+N0);
SINR=hdi.^2*Pd*roh^(-alpha)./(abs(hci.^2).*Pci.*Lci.^(-alpha)+N0);
[Lco,SINRo]=reorder(Lci,SINR);
%LC=sqrt(distancetoBS.^2+distancetoD2dRX.^2-
2.*distancetoBS.g*distancetoD2dRX)
```

```
%%
SINR1=hdi.^2*Pd*roh.^(-alpha)./(abs(hci.^2).*pow12.*250.^(-alpha)+N0);
SINR2=hdi.^2*Pd*roh.^(-alpha)./(abs(hci.^2).*pow12.*500.^(-alpha)+N0);
SINR3=hdi.^2*Pd*roh.^(-alpha)./(abs(hci.^2).*pow12.*750.^(-alpha)+N0);
SINR4=hdi.^2*Pd*roh.^(-alpha)./(abs(hci.^2).*pow12.*1000.^(-alpha)+N0);
[pow121,SINR1]=reorder(pow12,SINR1);
[pow122,SINR2]=reorder(pow12,SINR2);
[pow123,SINR3]=reorder(pow12,SINR3);
[pow124,SINR4]=reorder(pow12,SINR4);
figure(4)
%%
semilogy(pow121,SINR1,'linewidth',2),hold on
semilogy(pow122,SINR2,'r','linewidth',2)
semilogy(pow123,SINR3,'m','linewidth',2)
semilogy(pow124,SINR4,'k','linewidth',2),hold off
grid,legend('SINR at LC=250','SINR at LC=500','SINR at LC=750','SINR at LC=1000')
ylabel('signal to interferance noise ratio'),xlabel('power transmit per user(dB)'),
figure(1)
plot(0,0,'*'); hold on
plot(-400,0,'rd');
plot(userx,usery,'r.');
plot(x,y),hold off
grid
figure(2)
semilogy(Lco,10*log10(SINRo),'r','linewidth',3),grid
ylabel('Signal to Interferance noise ratio'),xlabel('distance between CUE and D2D RX(m)'),
%end
figure(3)
stem(dist/max(dist),'r'),hold on
bar([1:j-1],pow12/max(pow12)),hold off
legend('Distance','Power')
ylabel('pwer and distance normlized'),xlabel('Users Inside Cell')
```

Appendix c

```
%% With FFR
clearall
i=1;
%% BASE STATION
fordist=10:500
d=[distdistdist];
R=dist;
P=10^(20)/1000;
D=1000-2*dist;
sigma=10^(-17.4)/1000;
alpha=4;
epselent=0.8;
gz=40*log10(d);
figure(1)
SINR1(i)=gz(1)*P*R^(alpha*(epselent-1))/(gz(2)*P*R^(alpha*(epselent))*D^(-
alpha)+gz(3)*P*R^(alpha*(epselent))*D^(-alpha)+sigma^2);
k1(i)=dist;
c1(i)=180000*log2(1+SINR1(i));
i=i+1;
end
figure(1)
plot(k1,10*log10(SINR1)), hold on ,
ylabel('SINR'),xlabel('Raidus of cell'),grid
%% DEVICE to DEVICE
i=1;
fordist=10:210
d=[distdistdist];
R=dist;
P=10^(20)/1000;
D=1000-2*dist;
sigma=10^(-17.4)/1000;
alpha=4;
epselent=0.8;
gz=40*log10(d);
SINR2(i)=gz(1)*P*R^(alpha*(epselent-1))/(gz(2)*P*R^(alpha*(epselent))*D^(-
alpha)+gz(3)*P*R^(alpha*(epselent))*D^(-alpha)+sigma^2);
```

```
k2(i)=dist+292;
c2(i)=180000*log2(1+SINR2(i));
i=i+1;
end
plot(k2,10*log10(SINR2),'r','linewidth',3),
plot(300*ones(1,81),[0:80],'r','linewidth',3),hold on
figure(2)
plot(k1,c1,'g','linewidth',5);hold on,
plot(k2,c2,'r');hold on
ylabel('SINR'),xlabel('capacity'),grid
```