INTERFERENCE MANAGEMENT PROCEDURE IN DEVICE TO DEVICE COMMUNICATION TECHNOLOGY IN 5G CELLULAR NETWORK

NUSRAT JAHAN

ROLL: BKH1511026F

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BACHELOR OF SCIENCE IN INFORMATION AND COMMUNICATION ENGINEERING

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This Research paper submitted in fulfillment of the requirements for the award of the degree of Bachelor of Science Information and Communication Engineering

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DECLARATION

This thesis paper is submitted for approval to the department of Information and Communication Engineering (ICE), Noakhali Science & Technology University, Noakhali in partial fulfillment of the requirements for having the Bachelor of Science (B.Sc) degree in ICE. This is also needed to certify that this thesis paper is submitted under the B.Sc course of ICE, NSTU titled ICE-4218. So, I hereby declare that this project report has not been submitted elsewhere for the requirement of any kind of degree, diploma or publication.

Nusrat Jahan

Student of Dept. Information and Communication Engineering

Noakhali Science & Technology University

Roll No. : BKH1511026F

Session : 2014-15

ACCEPTANCE

This thesis paper is submitted to the Department of Information & Communication Engineering, Noakhali Science & Technology University, Noakhali, in partial fulfillment of the requirements for having the Bachelor of Science (B.Sc) degree in Information & Communication Engineering.

Professor Dr. Md Ashikur Rahman Khan

Chairman

Dept, of Information and Communication Engineering

Noakhali Science & Technology University

Noakhali - 3814, Bangladesh

ABSTRACT

Device-to-Device communication (D2D) process are used in 5G cellular network. D2D allows communication between two devices, without participation of the Base station or the evolved NodeB (eNB). In 5G cellular networks, with D2D communication enabled within is considered as two-tire networks. These two tire networks are referred to as macro-cell tire and device tire. The two-tier network needs to be designed with smart interference management strategies and appropriate resource allocation schemes. In two-tire network architecture cellular users and D2D users share common Resource Blocks (RBs). Such paradigms allow potential increase in the number of supported users but it increase the cost of interference. Because of this we need to design an efficient interference management system. Interference can be reduced by appropriate resource allocation and power control. We propose a two steps approach. In the first step we concerns with the efficient RB allocation to the users. The second one is the transmission power allocation. . We discuss about a minimum interference resource allocation algorithm based on the TDMA method and power control scheme. Firstly peer has to detect, then select the best mode (D2D or Cellular) depends on the distance. Two peer discover technique are used, one is fully dependent on the base station network and another is semi dependent on the network. We present an optimized mode selection process .For D2D users and cellular users resource are allocated, depends on the path gain. We proposed a minimum interference algorithm to allocate resource. In order to control power three power control scheme has been used. Hence in terms of increased number of users, interference reduction and power minimization can be done efficiently. After simulation using MATLAB we analysis the developed algorithm. We see that D2D communication is fast and efficient if we able to mitigate interference

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LIST OF ABBREVIATIONS

RF	Radio frequency
D2D	Device to Device
BS	Base station
RBs	Resource blocks
TDMA	Time division multiple access
FDMA	Frequency division multiple access
MIMO	Multiple Input Multiple Output
CR	Cognitive radio
LOS	Line of sight
ICI	Inter cell interference
CU	Cellular user
UE	User end
TU	Target user
CUE	Cellular user end
DUE	Device user end
3GPP	3rd Generation partnership project
QoS	Quality of service
SINR	Signal to interference plus noise ratio
PC	Power control
CM	Cellular mode
SM	Sharing mode
HetNets	Heterogeneous network
MinInterf	Minimum interference
SIC	Successive interference cancellation

CHAPTER 1

INTRODUCTION

1.1 Background Study & Problem Statement

From the 1970s through the early 1990s the wireless communication methods and service have been enthusiastically adopted by people throughout the world. With the help of wireless technology we can transform data from one device to another without using a cable, by using radio frequency (RF) signal. Time to time next integrated Versions of network is introduced with the increase of demand for higher data rates and capacity.Various generations of mobile Network are 1G, 2G, 3G, 4G and 5G, shown in figure 1.1.

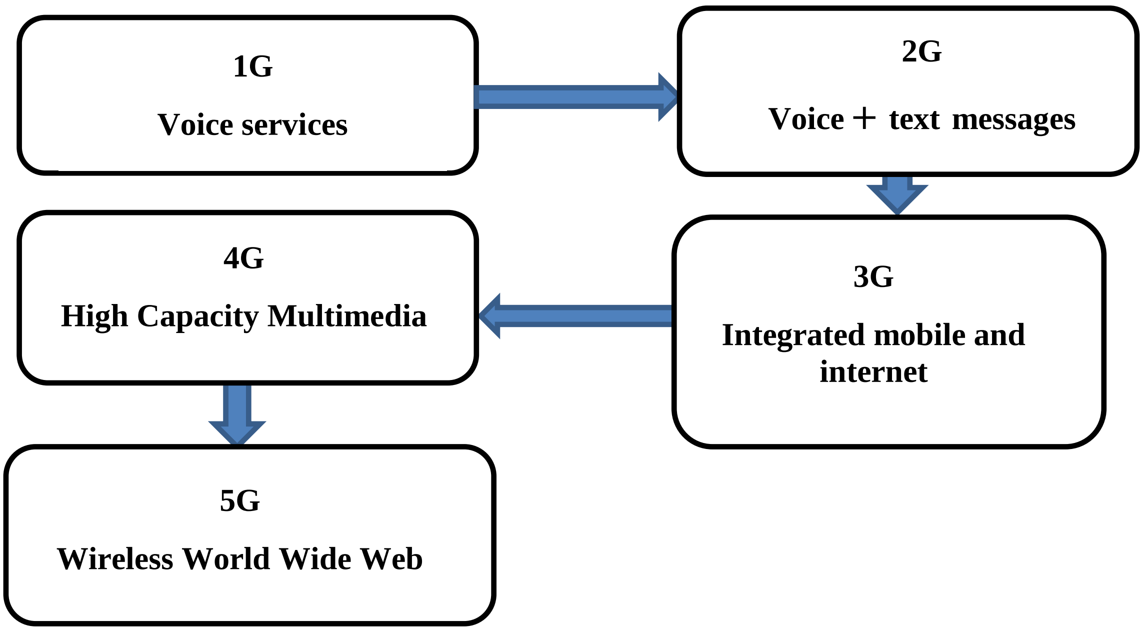


Figure 1.1 Basic features of generation of wireless communication

In the first four generations of cellular networks devices are not allowed to directly communicate with each other in the licensed cellular bandwidth and all communications take place through the base stations. This is time consuming and increases workload on the base station.

Wireless networks become one of the major contributors of power consumption with the fast growth of wireless users and their traffic demands. It has been shown by recent studies that there are over 4 million Base Stations (BSs) and each of them consumes an average of 25MWh per year and the number of BSs is growing fast, especially in developing countries [1]. Such huge energy consumption has raised public concerns about electricity costs, and greenhouse gas emissions that are known to have a significant impact on global climate. Therefore, substantial research attention has been paid to green wireless networking recently. Device-to-Device (D2D) communication has emerged as a promising technique for reducing power consumption and improving capacity in wireless networks. A general scenario supporting device-to-device (D2D) communication are shown in figure 1.2.

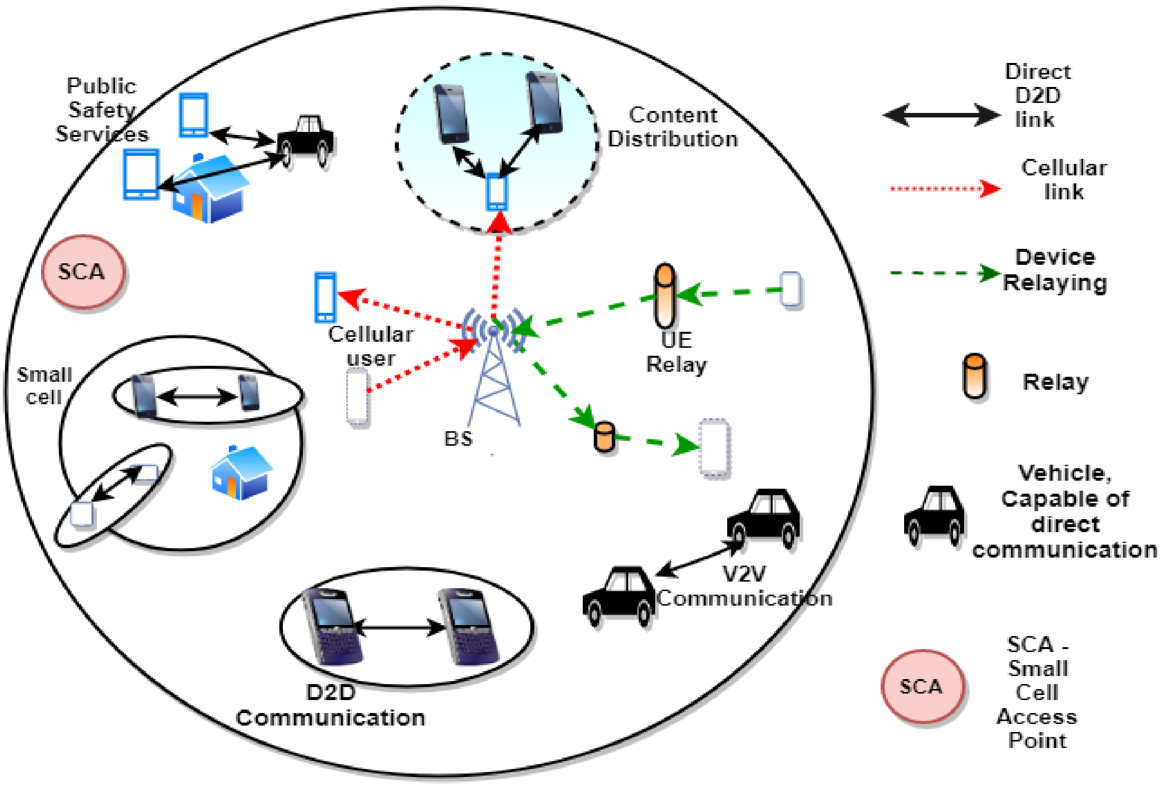


Figure 1.2 A general scenario supporting device-to-device (D2D) communication.

Device to device communication technology is used in 5G wireless cellular network that reduce data transferring time and reduce workload from the base station. Device-to-Device (D2D) communication allows two nearby devices to communicate with each other in the licensed cellular bandwidth without a base station (BS) involved or with limited BS involvement. Typically, communicating D2D devices are located close to each other. Low-power and energy-efficient transmission is achievable because of this physical proximity. On the other hand, Spectrum efficiency can be improved because of two reasons. The first one is that when two UEs are communicating in D2D mode, only one communication link is required instead of two, as shown in Figure 1.3. The second reason is that it is possible to allocate the same radio resources for cellular as well as D2D links in a cell. This concept is called resource reuse and is proposed to promote efficient radio resource utilization.

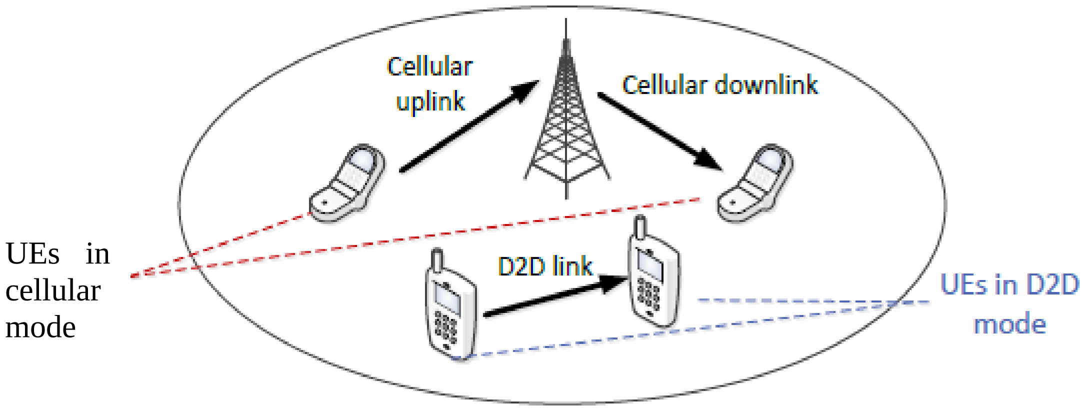


Figure 1.3 D2D communication in a cellular system

There are various technical aspects and challenges of D2D communication in wireless networks. D2D communication on the cellular network brings new challenges and design problem such as optimization of power consumption, resource allocation and reuse of cellular frequencies. To take full advantage of D2D communications it is essential to reduce those complexity. The technical challenges in D2D communications underlaying a cellular network is shown in Figure 1.4.

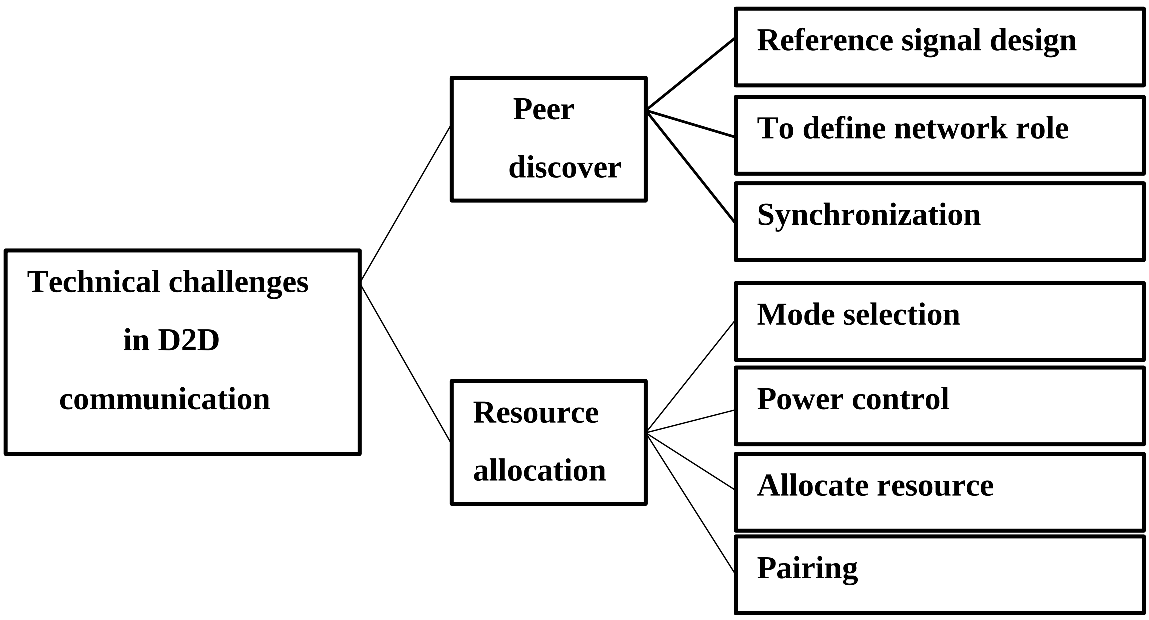


Figure 1.4 Technical Challenges in D2D communication

The first endeavor towards the implementation of Device-to-Device communication in cellular network was Qualcomm's FlashLinQ [2]. Number of concerns are involved with the implementation of D2D communication such as peer discovery, interference management, power control, resource allocation and security of the communication. In the current market, technologies such as Wi-Fi or Bluetooth provide some device-to-device communication functionality.

The fifth generation cellular networks enable with D2D communication is considered as two-tire networks [3]. The two tire in this networks are the macro-cell tire and the device tire. Conventional cellular communication is supported by the macro cell tire and D2D communication is supported by the device tire. The two tire cellular network has advantage over the conventional cellular architecture such as one hop communication, optimization of power level, spectrum reusability, improve coverage area etc. D2D communications can take place either overlaying or underlaying in-band a cellular network or out-band. D2D users can act cooperatively, form clusters and facilitate content dissemination. In the overlay case, D2D communications use dedicated resources, while in the underlay case D2D communications share common resources with the residual cellular network. In this research paper, we will focus on the underlay policy, where the cellular and the D2D users share common radio resources, organized into resource blocks (RBs). RBs are combinations of frequency and time symbols which are allocated to the users of the network [4]. In terms of spectral and power efficiency RBs assignment and power control are key factors for the efficient operation of the network.

In this research paper we will discuss about multicell interference management in D2D communication. In multi-cell environment multiple neighboring cells exist for serving the users of the network. Interference can be mitigated by power control, followed by optimal resource allocation. Different approach are adopted by different researchers for interference mitigation between D2D links and cellular links. This can be categorized as interference avoidance scheme, interference cancellation scheme or interference coordinate scheme, shown in figure 1.5.

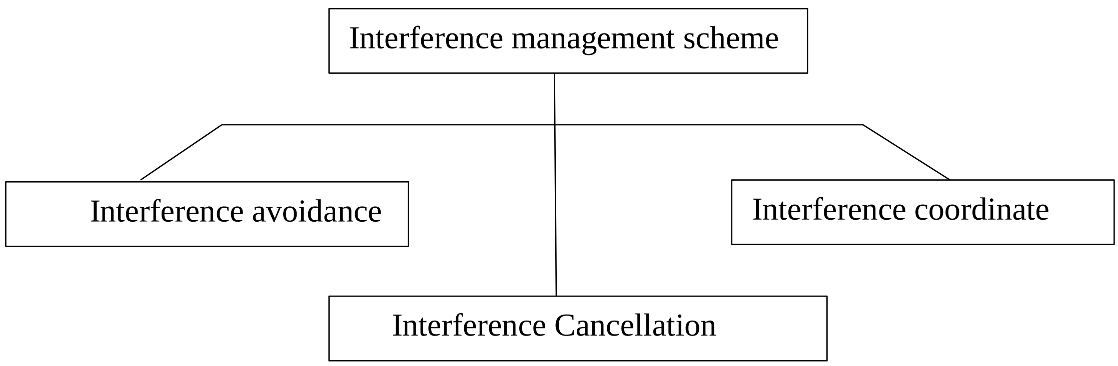


Figure 1.5 Interference management scheme in D2D

Interference situation of a cellular system allowing D2D communications makes the role of power control and resource allocation in the system becomes more vital. It is important to notice that the level of interference caused by D2D links depends on the allocated resource and transmit power of each UE. Therefore there is a great need of investigating how power control and resource allocation should be done in a cellular system when D2D links are present, as well as how they would affect the spectrum and energy efficiency of the system.

1.2 Research Objectives

Interference situation of a cellular system allowing D2D communications makes the role of power control and resource allocation in the system becomes more vital. It is important to notice that the level of interference caused by D2D links depends on the allocated resource and transmit power of each UE.

Therefore there is a great need of investigating how power control and resource allocation should be done in a cellular system when D2D links are present, as well as how they would affect the spectrum and energy efficiency of the system.

Our contributions are summarized in the following:

i. To show a peer discovery algorithm depends on the distance.
ii. To present an optimization problem for mood selection in D2D based on TDMA model.
iii. To develop an effective minimum interference resource allocation algorithm.
iv. To analysis the developed algorithm.

CHAPTER 2

LITERATURE REIVEW AND OVERVIEW

2.1 5G network

Fifth generation cellular network that provides broadband access is known as 5G. Combining cutting-edge network technology and the very latest research, 5G should offer connections that are multitudes faster than current connections, with average download speeds of around 1GBps expected to soon be the norm.

It's all about making better use of the radio spectrum and enabling far more devices to access the mobile internet at the same time. The world is going mobile and we're consuming more data every year, particularly as the popularity of video and music streaming increases. Existing spectrum bands are becoming congested, leading to breakdowns in service, particularly when lots of people in the same area are trying to access online mobile services at the same time. 5G is much better at handling thousands of devices simultaneously, from mobiles to equipment sensors, video cameras to smart street lights. Features of 5G network are shown in figure 2.1.

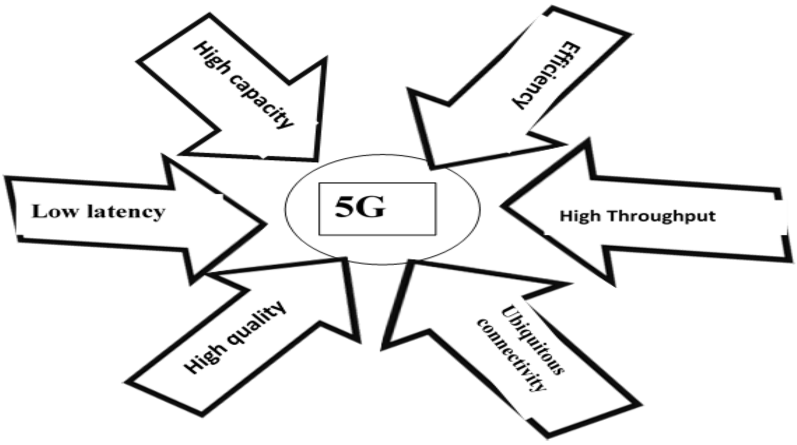


Figure 2.1 Features of 5G

Features of 5G:

a. Bidirectional large bandwidth
b. Large broadcasting
c. 25 Mbps connectivity speed

d. Uploading and downloading speed up to 1GBps
e. Support virtual private network
f. More attractive and effective
g. Provide high resolution for crazy mobile user
h. High connection density

5G technology is adorned with many as well as distinct features, which applicability is useful for a wide range people irrespective of their purposes.

2.1.1 5G network architecture

To contemplate 5G network in the market now, it is evident that the multiple access techniques in the network are almost at a still and requires sudden improvement. Current technologies like OFDMA will work at least for next 50 years. Moreover, there is no need to have a change in the wireless setup which had come about from 1G to 4G. Alternatively, there could be only the addition of an application or amelioration done at the fundamental network to please user requirements. This will provoke the package providers to drift for a 5G network as early as 4G is commercially set up .To meet the demands of the user and to overcome the challenges that has been put forward in the 5G system, a drastic change in the strategy of designing the 5G wireless cellular architecture is needed. A general observation of the researchers has shown in that most of the wireless users stay inside for approximately 80 percent of time and outside for approximately 20 percent of the time.

In present wireless cellular architecture, for a mobile user to communicate whether inside or outside, an outside base station present in the middle of a cell helps in communication. So for inside users to communicate with the outside base station, the signals will have to travel through the walls of the indoors, and this will result in very high penetration loss, which correspondingly costs with reduced spectral efficiency, data rate, and energy efficiency of wireless communications. To overcome this challenge, a new idea or designing technique that has come in to existence for scheming the 5G cellular architecture is to distinct outside and inside setups. With this designing technique, the penetration loss through the walls of the building will be slightly reduced. This idea will be supported with the help of massive MIMO technology in which geographically dispersed array of antenna's are deployed which have tens or hundreds of antenna units. Since present MIMO systems are using either two or four antennas, but the idea of massive MIMO systems has come up with the idea of utilizing the advantages of large array antenna elements in terms of huge capacity gains.

To build or construct a large massive MIMO network, firstly the outside base stations will be fitted with large antenna arrays and among them some are dispersed around the hexagonal cell and linked to the base station through optical fiber cables, aided with massive MIMO technologies. The mobile users present outside are usually fitted with a certain number of antenna units but with cooperation a large virtual antenna array can be constructed, which together with antenna arrays of base station form virtual massive MIMO links. Secondly, every building will be installed with large antenna arrays from outside, to communicate with outdoor base stations with the help of line of sight components. The wireless access points inside the building are connected with the large antenna arrays through cables for communicating with indoor users. This will significantly improves the energy efficiency, cell average throughput, data rate, and spectral efficiency of the cellular system but at the expense of increased infrastructure cost. With the introduction of such an architecture, the inside users will only have to connect or communicate with inside wireless access points while larger antenna arrays

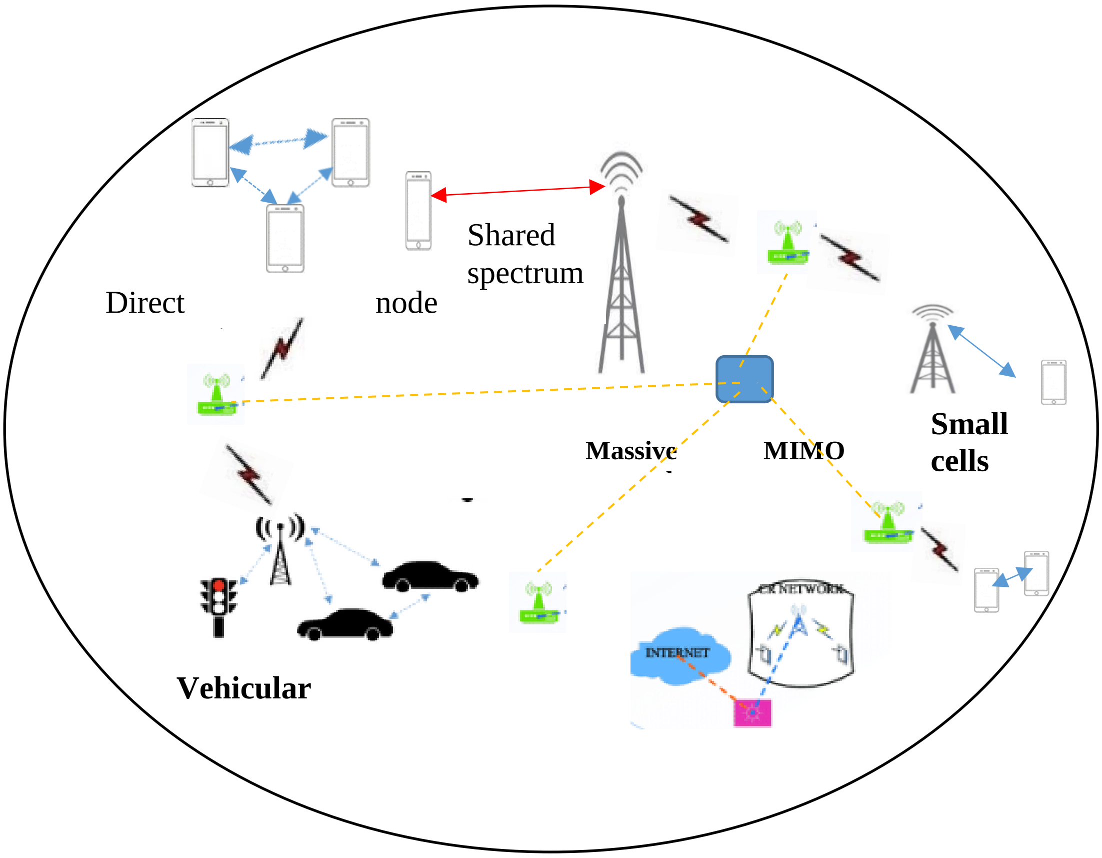


Figure 2.2 Proposed heterogeneous 5G cellular network architecture.

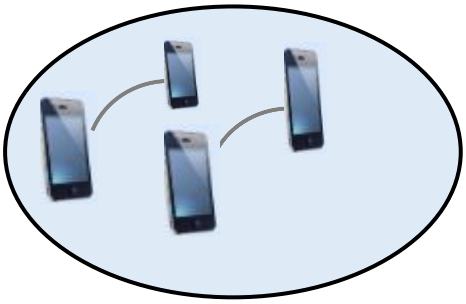
remained installed outside the buildings .

For indoor communication, certain technologies like Wi-Fi, Small cell, ultra wideband, millimeter wave communications [5], and visible light communications [6] are useful for small range communications having large data rates. But technologies like millimeter wave and visible light communication are utilizing higher frequencies which are not conventionally used for cellular communications. But it is not an efficient idea to use these high frequency waves for outside and long distance applications because these waves will not infiltrate from dense materials efficiently and can easily be dispersed by rain droplets, gases, and flora. Though, millimeter waves and visible light communications technologies can enhance the transmission data rate for indoor setups because they have come up with large bandwidth. Along with the introduction of new spectrum, which is not being conventionally used for wireless communication, there is one more method to solve the spectrum shortage problem by improving the spectrum utilization of current radio spectra through cognitive radio (CR) networks [7]. Since the 5G cellular architecture is heterogeneous, so it must include macrocells, microcells, small cells, and relays. A mobile small cell concept is an integral part of 5G wireless cellular network and partially comprises of mobile relay and small cell concepts [8].

It is being introduced to put up high mobility users, which are inside the automobiles and high speed trains. Mobile small cells are positioned inside the moving automobiles to communicate with the users inside the automobile, while the massive MIMO unit consisting of large antenna arrays is placed outside the automobile to communicate with the outside base station. According to user’s opinion, a mobile small cell is realized as a regular base station and its allied users are all observed as a single unit to the base station which proves the above idea of splitting indoor and outdoor setups. Mobile small cell users have a high data rate for data rate services with considerably reduced signaling overhead.

2.1.2 D2D in 5G

D2D communications are expected to be an essential feature of mm-Wave 5G cellular network in order to improve network capacity and build connection between tow wireless devices. In mm-Wave 5G cellular network, two kinds of D2D communications can be enable: local D2D com munication and global D2D communication, shown in figure 2.3.


(a)

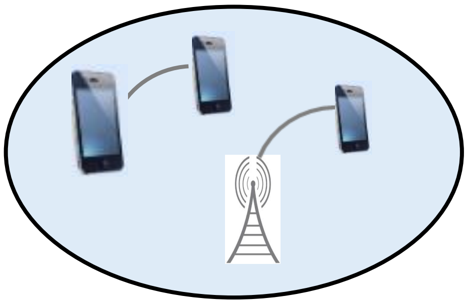

(b)

Figure 2.3 (a) Local D2D (b) Local D2D and D2B.

Local D2D communication: Two wireless device within the one small cell communicate directly without referring to the base station or via relays if LOS is not available. Global D2D communication: Communication held between two different base stations via the backbones network.Here D2D communications may face two kinds of potential interference within each cell: a) If there are multiple local D2D communication then interference among different local D2D communications

b) Interference between local D2D communication and D2B/B2B communications

Highly directional antenna is used to avoid interference. To reduce attenuation small cells are created. Most of the existing work on D2D communications focus on the design of optimized resource sharing algorithms by managing the interference [9, 10].

2.1.3 Devices in the 5G Era

Devices in the 5G networks should be capable of operating in multiple spectrum bands, ranging from RF to mm-wave, also being compatible with existing technologies such as 3G and 4G. Due to the need for offering best possible service to the desired traffic, devices should actively manage all the available network connections including D2D links. Devices also have to share contextual information with network layers so that network resources can be efficiently utilized. Figure 2.4 outlines the characteristics of 5G wireless device platform concept. The need to support several RATs with multiple RF-chains imposes tremendous challenges for 5G device chipset and front-end module suppliers as well as system and platform integrators.

The requirements for cell edge enhancement and the need for higher-order spatial multiplexing also increase the complexity of the antenna systems. Another key component of 5G devices is the advanced baseband signal processing chain [11]. The even denser deployment of network nodes

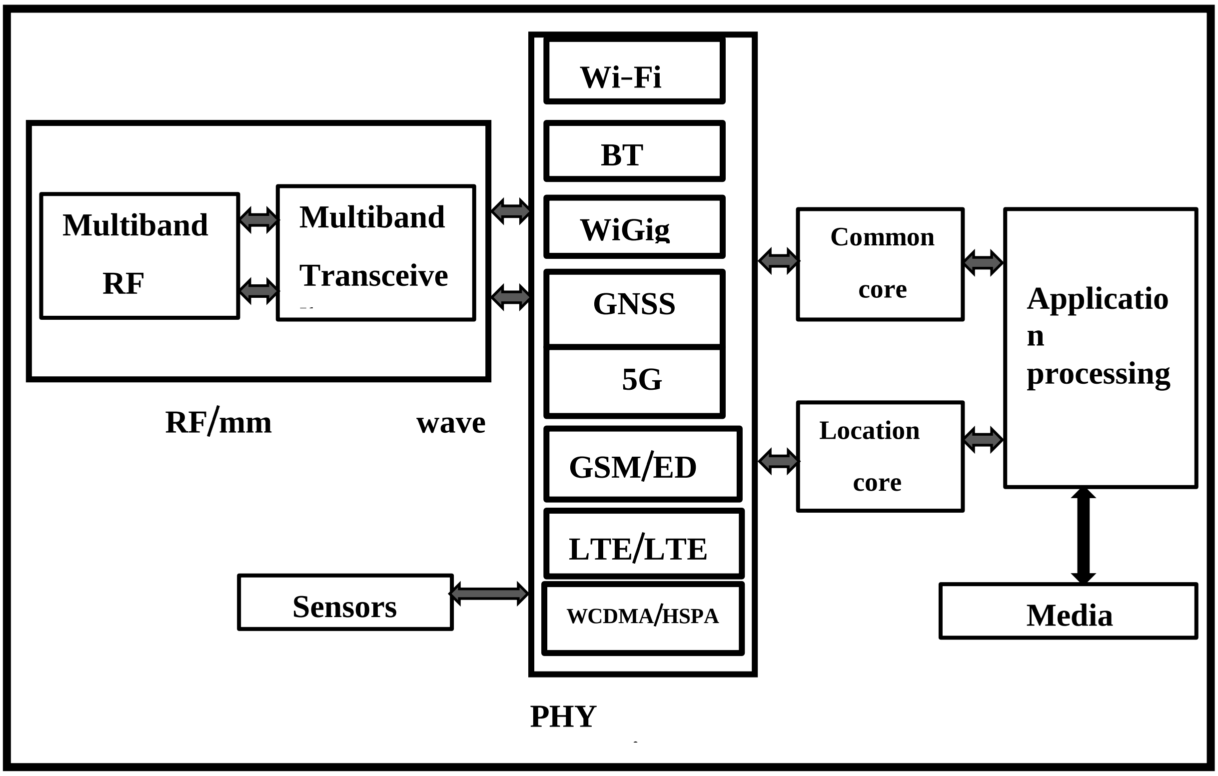


Figure 2.4 Device platform concept for 5G Wireless

combined with various sources of interference require that the devices must be able to autonomously detect, characterize and suppress interference from any source including intra-cell, inter-cell as well as D2D interferences. The task of interference cancellation is exacerbated by the existence of strong self-interference in the case of simultaneous transmission and reception. Furthermore, the advanced signal processing within mobile terminals will not be limited to interference suppression only. Features such as massive MIMO coupled with mm-Wave frequency challenges will also require such advanced signal processing. All of these enhanced features have to be implemented in a way that energy consumption is optimized with a small form factor wireless device platform. As energy efficiency will be an important feature for 5G user experience, it is desirable that the devices integrate energy efficiency metrics in connectivity management, and include energy harvesting technologies within the wireless system architecture.

2.1.4 Spectrum in the 5G era

5G systems are expected to provide data rates on the order of gigabits per second, anytime and anywhere. To add significantly more capacity compared to the current mobile technologies initial proposed frequency bands for 5G are around 600-700 MHz, 3-4 GHz, 26-28 GHz and 38-42 GHz. The additional spectrum and greater capacity will enable more users, more data and faster connections. It is also expected that there will be future reuse of existing low band spectrum for 5G. Existing system and 5G spectrum are shown in figure 2.5.

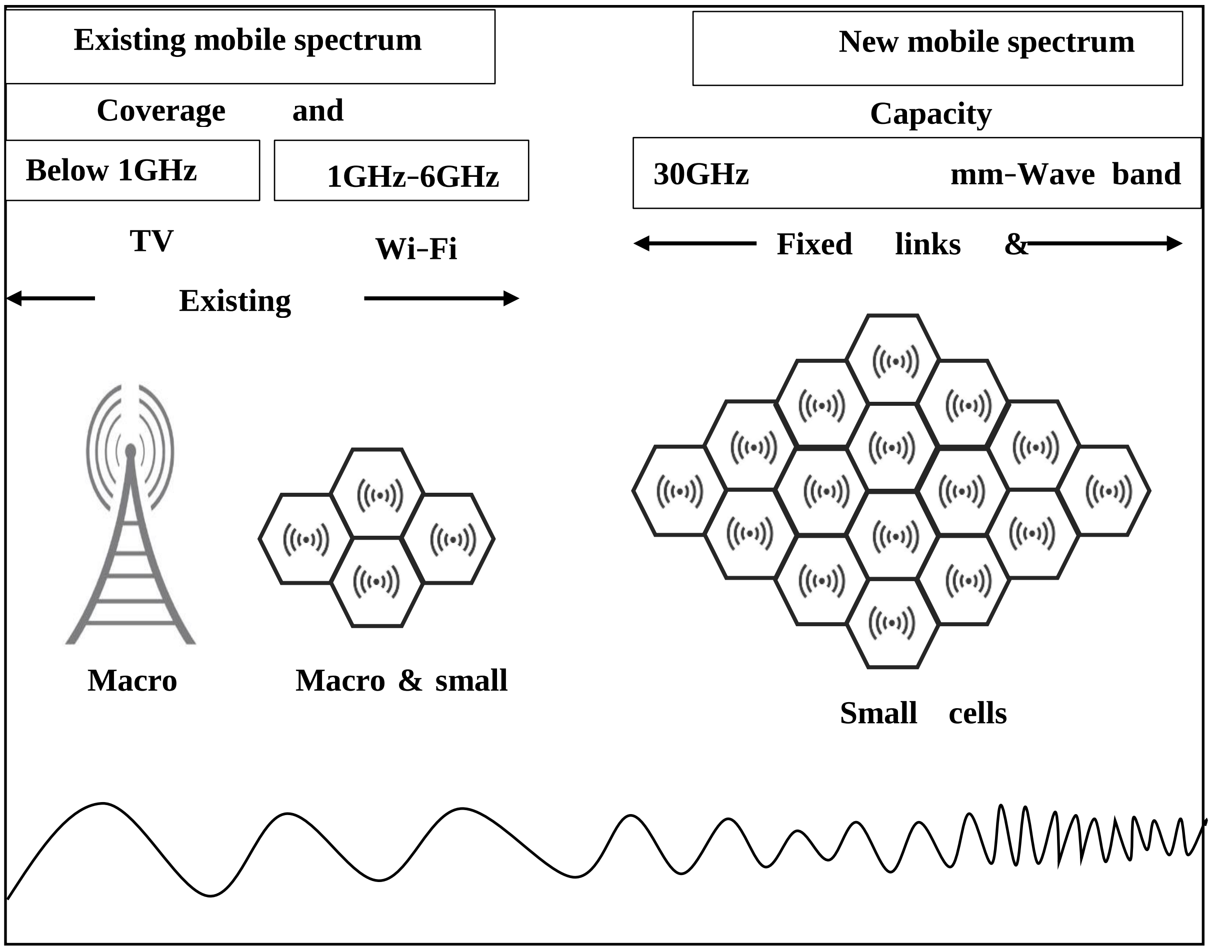


Figure 2.5 Existing system and 5G spectrum

The increased spectrum in the mm-Wave band above 30 GHz will provide local coverage as they only operate over short line of sight distances. Future 5G deployments may use mm-Wave frequencies in bands up to 86 GHz.

2.2 Literature survey

The fifth generation (5G) cellular network is heading towards device centric approach, network setup and managed by the devices themselves. D2D communication is being considered as an essential component of the 5G networks. Several research has been carried out in the last few years to achieve the full benefits of D2D communication.

In 2014 a work on D2D communication was done by the authors [2]. They illustrate that two tire network needs to be designed with smart interference management strategies and appropriate resource allocation schemes so that there will be minimal impact on the performance of existing macro-cell BSs. This work provide an overview of tow tire networks and describe different types of D2D communication based on the degree of the involvement of the cellular operator. Some pricing schema for different types of device relaying was also described in this work. But they don't show how we have to allocate resources and how to manage interference when cellular users and D2D users are in the same spectrum. In multi-cell interference management efficient RBs assignment and power control are of fundamental importance. Controlling power effectively mitigates interference in cellular networks. By giving the focus on power optimization a work is done in 2017 [12]. With satisfying minimum SINR requirements and worst case ICI limit in multiple neighboring cell they show in jointly how to optimize the power of a cellular user (CU) and a D2D pair for their sum rate maximization. In order to maximize the sum rate they propose a power control algorithm. When ICI to a single neighboring cell is considered the propose algorithm is optimal. Another work was done by the members of IEEE in 2015 [13]. The author take into consideration a D2D underlaying communication network for interference cancellation, along with the transmission powers for maximizing the utility of the network. Significant gain are enjoyed by the users in terms of spectral efficiency.

Resource allocation strategy in D2D communication can be centralized or distributed. In traditional cellular networks the eNB needs to determine the assignment of RBs to the users of the network in an efficient and timely manner. Towards 5G networks and enabling the D2D communication capabilities of the users, respective RB allocation approaches can be found in [14]. The authors propose scheduling algorithms for the problem of Resource Block (RB) allocation in D2D. That enabled networks taking into account each user's delay requirement. Here the eNB needs to determine the optimal assignment of resources to the users at time scales of milliseconds according to 3rd Generation Partnership Project (3GPP) specifications including devices that may communicate directly. Focusing on the uplink RB allocation problem for the D2D enabled networks most of the related work is restricted to single cell environments, while very little attention has been paid so far to the respective multi-cell case. The D2D RB selection problem is analyzed as a game, in a simple scenario with one cellular user per cell in [15]. The players of the game are the BSs and they compete with each other in order to serve the D2D users with less harm. However, the existence of the Nash Equilibrium (NE) point of the game is not analytically proven, and it is only examined via numerical simulations. The previous works focus on maximizing the total sum of rates in the network via game theoretic approaches and pricing for the resources. In 2016 a research work was published [16]. Here the problem of both RB and power allocation is addressed. Initially, the authors aim at minimizing the interference caused by the D2D links to the cellular links of the network, and subsequently a power control approach is applied in order to maximize total system throughput.

Table 2.1 Literature survey table

Year	**Author**	**Title**	**Limitation**
2017	Ali Ramezani-Kebrya, Min Dong, Ben Liang, Gary Boudreau, S. Hossain	"Joint Power Optimization for D2D Communication in Cellular Network with Interference Control"	Algorithm is optimal when ICI to a single neighboring cell.
2016	Jiang, Wang , Sun, Liu	"Resource Allocation and Dynamic Power Control for D2D Communication Underlaying Uplink multicell Network."	Don't address the joint problem
2015	Zhou, Liang, Kalle Ruttik, Olav Tirkkonen	"Interference Cancelling Power optimization for D2D Communication"	Only show interference cancellation
2014	Mohsen Nader Tehrani, Murat Uysal, Halim Yanikomeroglu	"D2D Communication in 5G Cellular Networks, Challenges and Solution"	Don't show how to allocate resource when cellular users and D2D users are in the same spectrum

2014	Namyoon Lee, Xingqin Lin, Jeffrey G. Andrews, and Robert W. Heath Jr.	“Power Control for D2D Underlaid Cellular Networks: Modeling, Algorithms and Analysis”	Only show the power control procedure, don’t show resource allocation system.
Year	**Author**	**Title**	**Limitation**
2011	Chia-Hao Yu, Klaus Doppler, C´assio B. Ribeiro, and Olav Tirkkonen	“Resource Sharing Optimization for Device-to-Device Communication Underlaying Cellular Networks”	They show an optimized resource sharing procedure. We don’t get idea about the joint problem, power control & resource allocation.
	Hyang Sin Chae, Jaheon Gu, Bum-Gon Choi, and Min Young Chung	“Radio Resource Allocation Scheme for Device-to-Device Communication in Cellular Networks Using Fractional Frequency Reuse”	The show radio resource allocation based on the frequency reuse method, don’t describe about TDMA method.

In our thesis paper we try to present a methodology through which we can reduce the complexity of the interference management system for mode selection. Our work is based on peer discovery, resource allocation and power control scheme.

CHAPTER 3

METHODOLOGY

Device-to-Device (D2D) communication has emerged as a promising technique for reducing power consumption and improving capacity in wireless networks. Peer discovery is the first step of D2D link establishment, in which the UEs and/or the BS detect the presence of D2D candidates. Then applying appropriate power control and resource allocation we can reduce interference in D2D cellular system.

3.1 Peer discover algorithm development

For the system mode assume a circular cell in which users are uniformly distributed over the cell area and the base station is located in the center of the cell. Assigned communicating pairs by choose two users randomly. We also assume that only D2D pairs that participate in the discovery process exist in the cell. The discovery process is initiated simultaneously by D2D pairs. Assume one separate channel which is reserved for the purposes of discovery of D2D pairs. New D2D pairs share the same channel for discovery. Moreover, it is assumed that a separate channel that is used for the transmission of acknowledgements exists. However, these messages are not described or taken into consideration.

During the discovery process messages are exchanged between D2D pairs and the base station and between users of the same D2D pair. A certain signal-to-interference-plus-noise ratio (SINR) threshold, CELL, must be satisfied when message exchanges between D2D users and the base station occur. Satisfaction of the SINR threshold indicates the correct reception of a message. Moreover, message exchanges between the devices of a D2D pair should also satisfy an SINR threshold, D2D. It is straightforward that interference between D2D pairs during the discovery process is inevitable, since the same channel is shared among all new D2D pairs.

For the transmission scheme, time division multiple access (TDMA) model is assumed. Time is divided in time slots and each user transmits in the beginning of each time slot with a certain transmission probability. If two or more users transmit in the beginning of the same time slot, a collision occurs. However, in case of collision, a message might still be correctly received if CELL or D2D are satisfied for transmission to the station or a device, respectively.

Since network provides synchronization and information about the total number of D2D pairs that participate in the discovery process to devices, here the role of the network is very important for the discovery of D2D pairs,. This information is used to transmit with the optimum transmission probability in the beginning of each time slot.

3.1.1 Centralized fully network-dependent discovery algorithm

In the first discovery process the base station has a substantial role as it coordinates the messages in every step of the algorithm. The devices transmit or listen only upon request from the base station. A visual representation of the first algorithm is displayed in Figure 3.1.

ALGORITHM:

Step 1: UE1 informs the base station that it wants to communicate with UE2.

Step 2: The base station requests UE2 to expect a discovery message from UE1.

Step 3: Base station requests UE1 to send the discovery message to UE2.

Step 4: UE1 sends the discovery message to UE2.

Step 5: if the message is not received by UE2, which means that D2D was not satisfied, retransmissions occur. However, it is more efficient to define a maximum time interval during which UE1 may keep retransmitting.

Step 6: After UE2 receives the discovery message from UE1, it reports the measured SINR value of the message to the base station.

Step 7: The base station requests both UE1 and UE2 to listen for interference from existing users in the cell. This means that, if there are N existing pairs in the cell, they will have to listen for N time slots.

Step 8: Both UE1 and UE2 report the measured interference to the base station. In this step, both UE1 and UE2 transmit to the base station.

Step 9: The base station requests the devices to communicate with each other using D2D mode. It is assumed that both messages to UE1 and UE2 are transmitted simultaneously by the base station.

After the successful transmission of all messages as defined by the algorithm, the two devices are considered to be a D2D pair. Throughout the process, the base station receives information about the path gains between itself and the devices. This information allows it to decide whether the link between the devices is favorable for D2D communication. However, if it is not, the method still requires the first three steps of the algorithm to be executed.

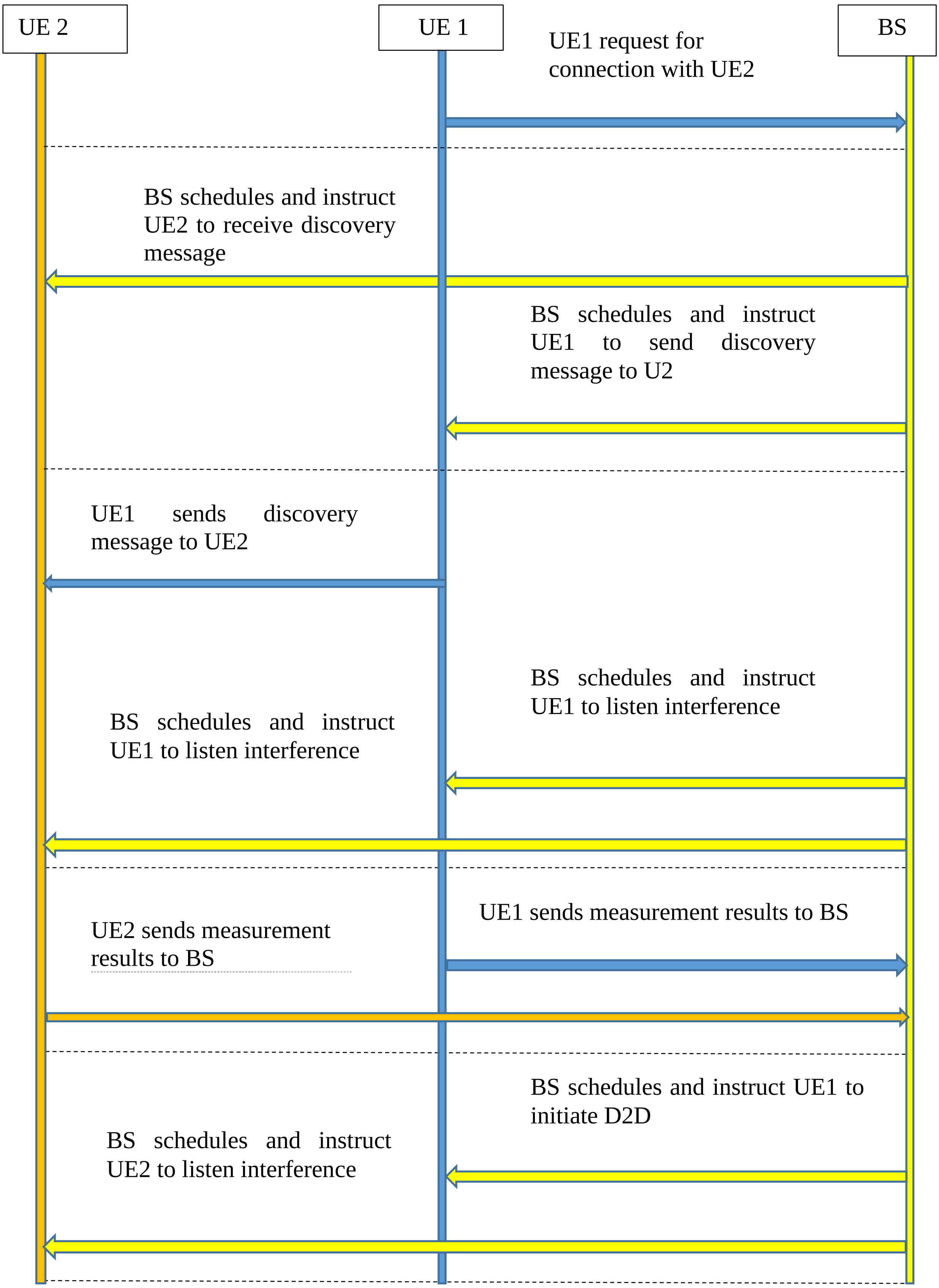


Figure 3.1 Centralized fully network-dependent discovery algorithm.

3.1.2 Semi centralized semi-network-dependent discovery algorithm

The method is less dependent on the network for discovering D2D pairs. However, the role of the network is still important, as it receives information by the D2D pair and decides on whether the devices should work in the D2D mode or not. The role of the base station is less dominant as the initial steps of the algorithm does not include message transmissions to the base station.A visual representation of the second discovery algorithm is displayed in Figure 3.2.

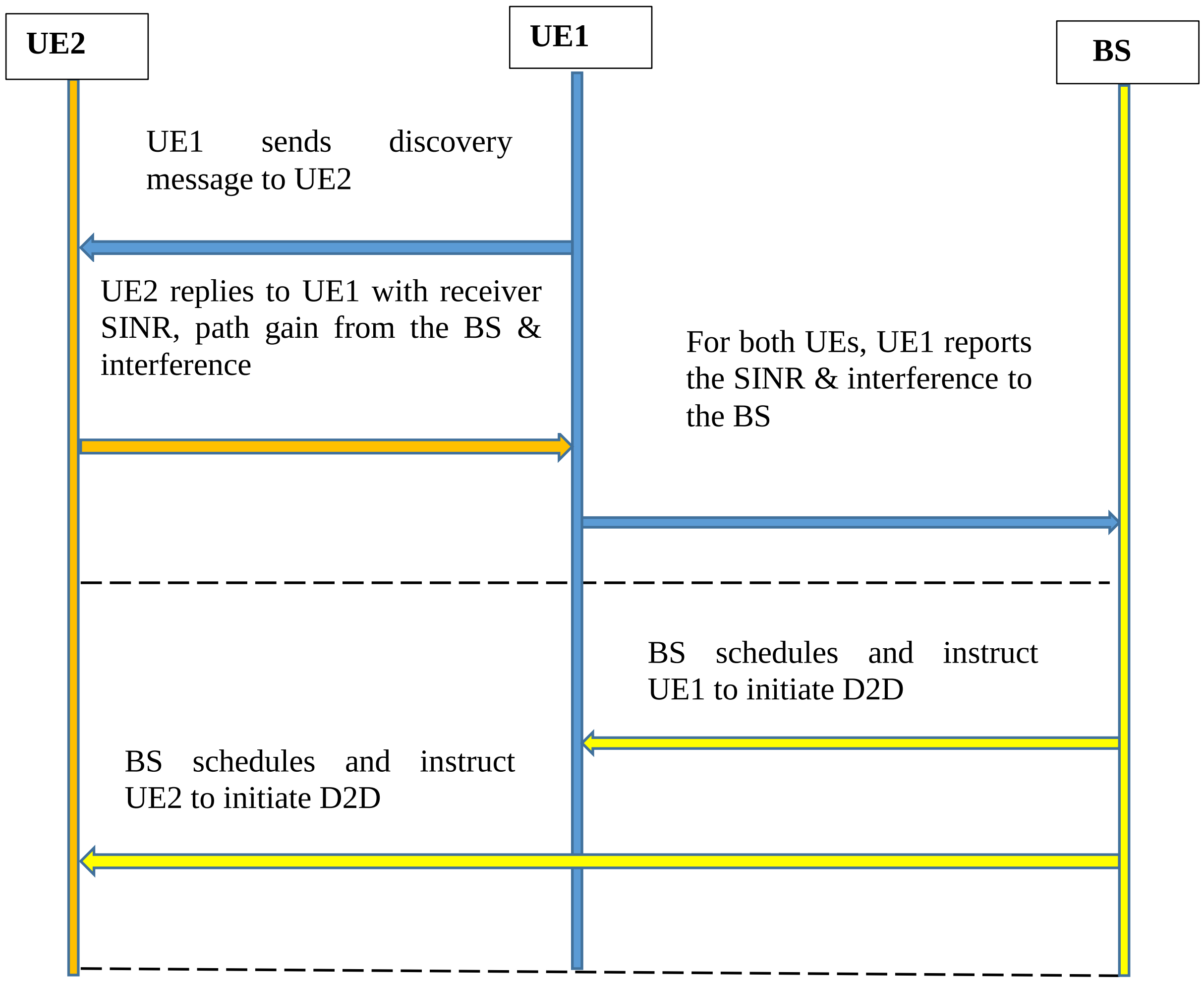


Figure 3.2 Semi centralized semi-network-dependent discovery algorithm.

The discovery process here is initiated by UE1, without requesting permission from the base station. Moreover, both devices listen for interference from other users immediately upon the reception of the first message sent by UE1 to UE2.

Step 1: UE1 broadcasts a discovery message, requesting to communicate with UE2. Upon the reception of this message by UE2, both UEs listen for interference by existing users in the cell and estimate their path gains to the base station using system signals like synchronization signals.

Step 2: UE2 reports the received SINR and the path gain to the base station, and the received interference by existing users to UE1.

Step 3: UE1 reports to the base station the SINR and interference measurements for both itself and UE2. In the fourth step, the base station requests both UEs to initiate the D2D communication.

Here we see that the second discovery algorithm requires the transmission of less messages compared to the first one. Moreover, in order to prove that new pair is not D2D pair only the first step is required to be executed. The disadvantage of the algorithm is that UE2 needs to constantly listen for transmissions from UE1.

3.2 Mode selection and resource allocation

Mode selection can be done by the network or by the UEs. Mode selection is concerned with choosing the correct mode cellular or D2D. It is done based on the some performance parameter- to achieve high spectral efficiency, low latency and low transmit power.

Mode selection is generally coupled with power control. To formulate the mode selection problem, one may associated decision variable with each UE. Decision variable captures the selected mode and then add a variety of objectives and constraints.

A simple objective could be that the channel gain of the selected mode should be higher than that of other possible modes. More sophisticated objectives like optimal spectrum reuse, weighted sum-rate maximization etc. could also be used.

Constraints could be minimum QoS at receiver, maximum transmit power etc.

$$mode = \begin{cases} cellular, & if\ P^t = \max(P^{rx}) > \beta \\ D2D \quad , & otherwise \end{cases}$$

Here P^{rx} is the receive signal strength from the base station and β is the specific threshold value.

For a tagged TU if P^t is larger than a specific threshold β, then this TU is not appropriate to work in the D2D mode due to its potentially large interference to cellular UEs. It should operate in the cellular mode and directly connect with the strongest BS, (the BS that offers the highest received signal strength) otherwise, it should operate in the D2D mode.

3.2.1 Interference management scheme

There are many open challenges that need to be thoroughly addressed to maximize the performance gain of D2D communication. These challenges include mode selection, neighbor discovery, interference and radio resource management, energy consumption, the coexistence of D2D with small cells, mobility management, and network security. Among them, mode selection (MS) in a heterogeneous scenario comparing all tiers simultaneously is very important and complex.

From the figure 3.3 we see the possible interference scenario in a 3-tier cellular network.

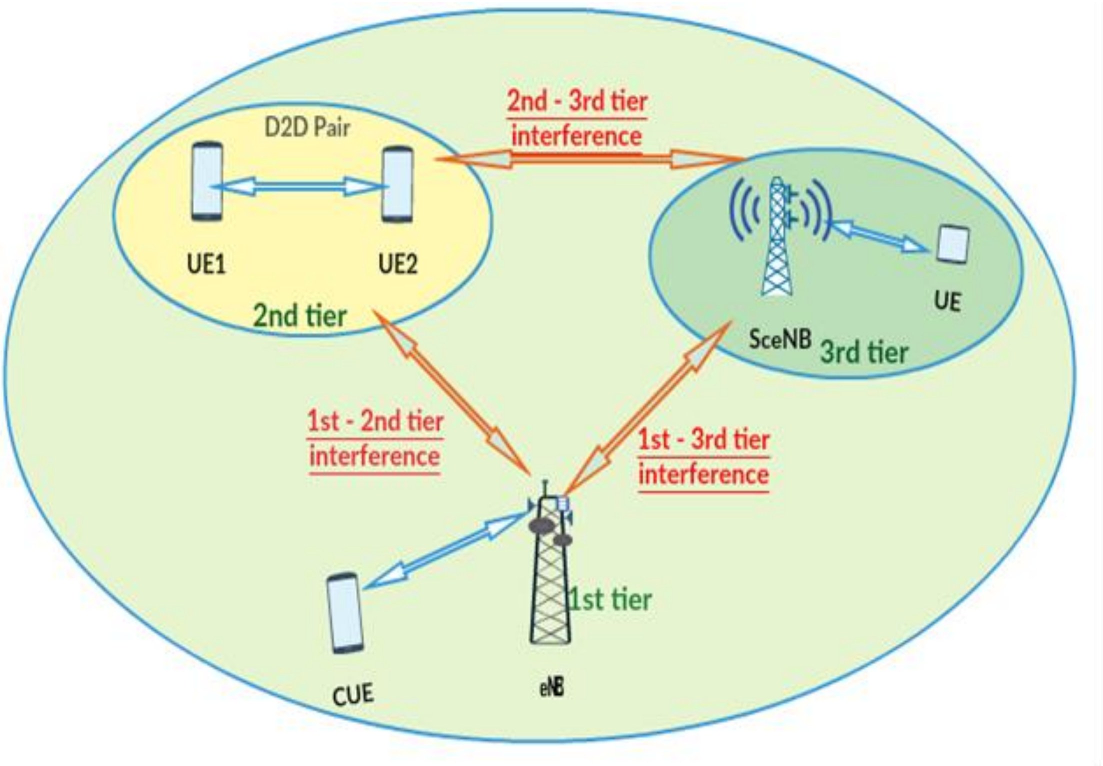


Figure 3.3 Interference in D2D communication in 3-tier network architecture

There are interference between the 1st-tier and the 2nd -tier, the 1st-tier and the 3rd-tier, and interference between the 2nd-tier and 3rd-tier. Interference can be managed by selecting appropriate mode of transmission to avail the benefits of D2D communication. In spectrum sharing scenario there are two modes of operation either cellular mode (CM) where DUEs exchange the information via eNB by using orthogonal spectrum or sharing mode (SM) where CUE and DUE both share the same spectrum resources.

In a multi-tier network, co-tier, and cross-tier both interferences exist. Therefore, designing the optimal network geometry model is an important issue to overcome the interference problem in dense HetNets. For design and analysis of cellular networks deterministic and stochastic geometry approaches are used. Deterministic methods are suitable only for topologies with fixed cell sizes not for heterogeneous network topology.

On the other hand, stochastic geometry is a promising approach to predict probabilistic parameters of randomly designed HetNets such as SINR (signal-to interference-plus-noise ratio), transmission power, throughput, coverage probability and load distribution [17]. So to select the appropriate mode of transmission for D2d pairs we can use the stochastic geometry model in our proposal, shown in figure 3.4.

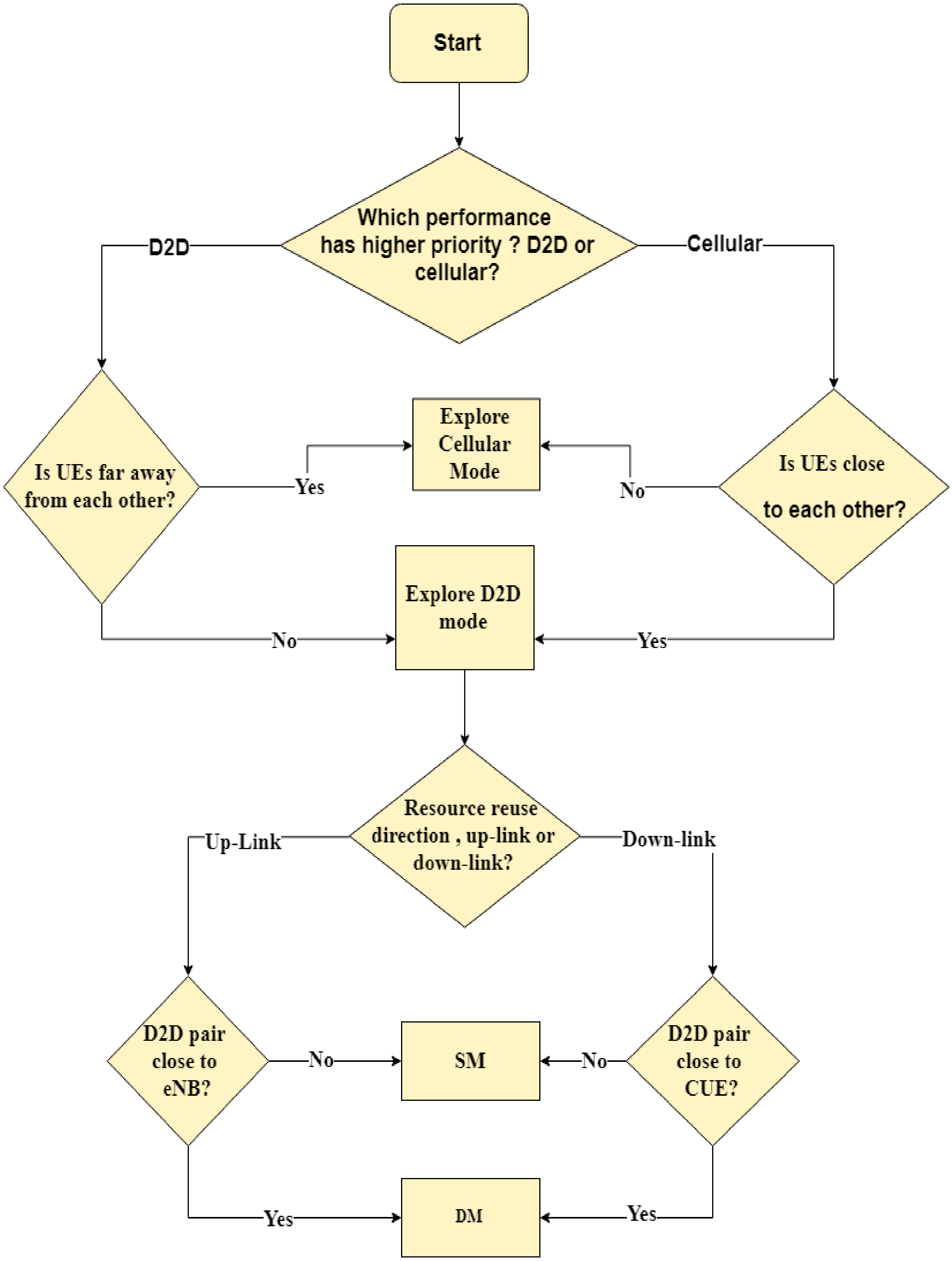


Figure 3.4 Flowchart of the mode selection algorithm in D2D communication

Different properties of a heterogeneous network like device location, the position of macro and small cells, the mobility of user etc. are considered as a random (stochastic) process of specified probability distribution [18]. To determine the spatial distribution of BS and users, we will use the Poisson Point Process (PPP).

Our techniques will work on two phases for an effective D2D communication in a heterogeneous cellular network considering the impact of interference from all 3-tiers simultaneously. Firstly select the transmission mode depend on the distance and received power then choose the uplink and downlink connection base on the resource allocation.

3.2.2 Resource allocation

Here the term "resources" depends on the channel access scheme. For instance, "resources" would mean time-slots in time division multiple access (TDMA) systems or frequency bands in frequency division multiple access (FDMA) systems. The concept of radio resources in TDMA and FDMA systems is best explained by Figure 3.5. Radio resource allocation means figuring out how radio resources should be allocated to meet the instantaneous capacity and QoS demand of the users.

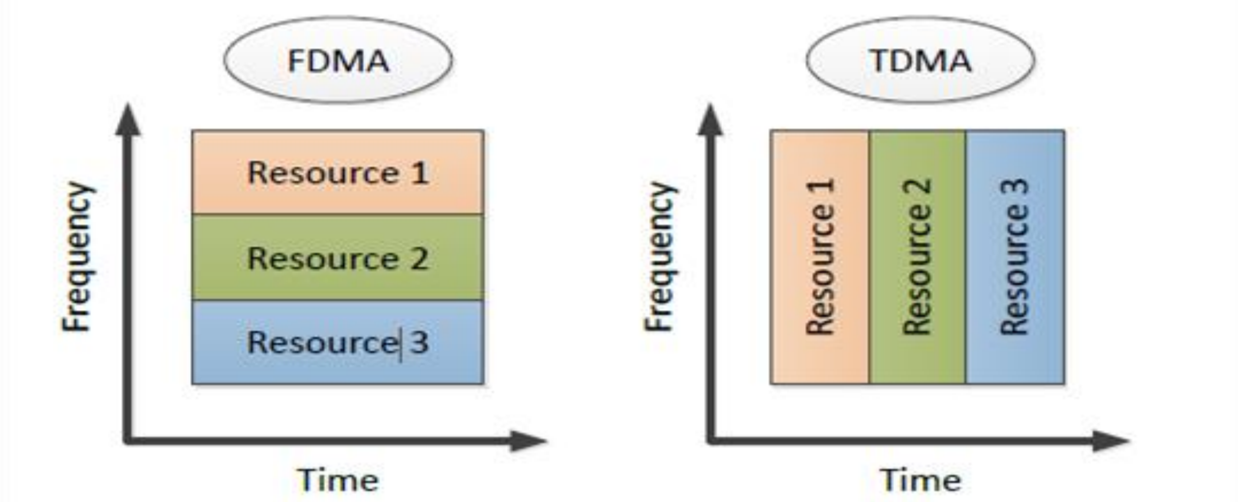


Figure 3.5 FDMA and TDMA radio resource

For each communication link (either cellular or D2D) sufficient resource blocks must be allocated. The number of required resource blocks can vary according to the application. Video streaming applications, for instance, would require more resources than email applications.

If possible, orthogonal resources should be allocated to all links so that no intra-cell interference will be generated. However, this cannot happen if there are not enough orthogonal resources. In this situation, resource reuse is necessary. This is a problem because UEs sharing the same radio resource generate interference to each other. Due to the random positions of the UEs, selection of resource for each link becomes critical as it will affect the interference generated to other links sharing the same resource. This is where resource allocation algorithms come into play.

3.2.3 Minimum interference allocation

Minimum Interference algorithm assumes that all path gains for cellular and D2D links are known. Using the path gains, interference generated to and received from other links sharing the resource can be estimated.

Interference generated to other links is estimated as the sum of path gains between the D2D transmitter to all receivers sharing the same resource.Interference received from other links is estimated as the sum of path gains between the D2D receiver to all transmitters sharing the same resource.Let $G_{t,r,j}$ be the path gains between transmitter-t and receiver-r using resource-j. For a given resource j, the following quantities are defined for each D2D link l.

$$G_{InterferenceGenerated,l,j} = \sum_{r} G_{\ l,r,j}$$

$$G_{InterferenceReceived,l,j} = \sum_{t} G_{\ t,r,j}$$

In order to clarify what $G_{InterferenceGenerated}$ and $G_{InterferenceReceived}$ mean, consider a cell having two resource blocks called RB1 and RB2. Initially, the cell has one cellular UE transmitting using RB1 and one D2D pair transmitting using RB2. A D2D candidate is detected in the system. The resource allocation algorithm must decide whether this D2D candidate should reuse RB1 or RB2.In Figure 3.6 path gains in the system G_1…….. G_6 are illustrated.

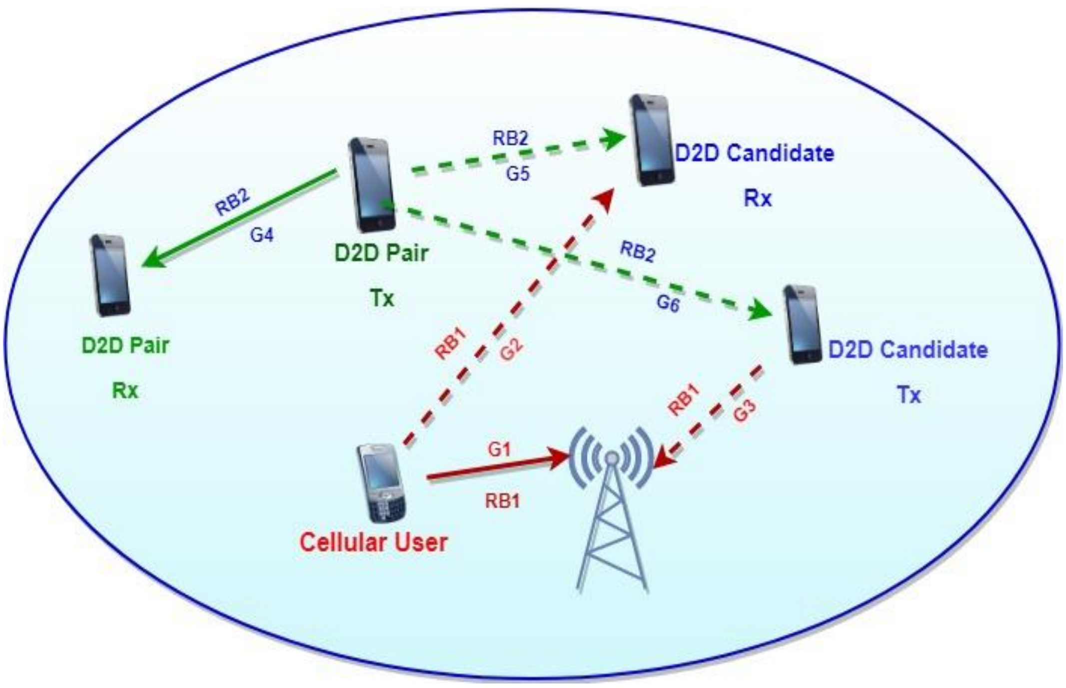


Figure 3.6 Path gains considered in MinInterf algorithm

If the D2D candidate uses RB1, its transmitter will generate interference to the base station, and its receiver will receive interference from the cellular UE.

Hence, $G_{InterferenceGenerated,RB1} = G_3$ and $G_{InterferenceReceived,RB1} = G_2$.

If the D2D candidate uses RB2, its transmitter will generate interference to the existing D2D pair's receiver, and its receiver will receive interference from the existing D2D pair's transmitter.

Hence, $G_{InterferenceGenerated,RB2} = G_6$ and $G_{InterferenceReceived,RB2} = G_5$.

Minimum interference (MinInterf) allocation algorithm:

Step 1: Randomly allocate orthogonal resources to cellular UEs

Step 2: **for** each D2D candidate do

Step 3: **if** there is an orthogonal resource-l left then

Step 4: **if** $G_{Cellular\ mode} \leq G_{D2D\ mode}$ then

Step 5: D2D candidate transmits in D2D-Mode on resource-l

Step 6: **else**

Step 7: D2D candidate transmits in Cellular-Mode on resource-l

Step 8: **end if**

Step 9: **else**

Step 10: **for** each available resource-j do

Step 11: U(j) = $\left[G_{InterferenceGenerated,j} + G_{InterferenceReceived,j}\right]$

Step 12: **end for**

Step 13: D2D candidate transmits in D2D-Mode on resource-j corresponding to the minimum value of U

Step 14: **end if**

Step 15: **end for**

3.3 Power control scheme of D2D communication

Due to the reuse of the spectrum, D2D communication must have proper control, because serious interference may violate the original intent of D2D communication. PC (Power control) can suppress co-channel interference and optimize the performance of the system, which is an effective way to achieve the personal QoS requirements. In recent years, domestic and foreign research institutions have carried out the research of power control and made some progress. Figure 3.7 is the comparison chart before and after the implementation of power control scheme.

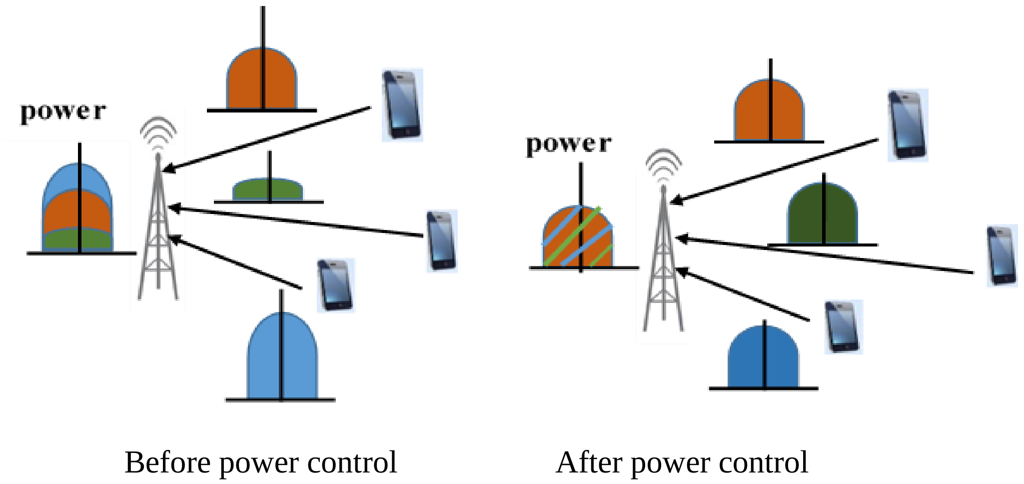


Figure 3.7 Comparison of power control before and after power control.

Since the quality and requirements of cellular network terminal through communication are different, the scheme of power control is flexible and various, but the main purpose is to suppress the interference. Here we discuss three schemes of power control.

a. Distributed power control
b. Joint control of power and beam
c. Joint control of power and rate

3.3.1 Distributed power control

There are two main types of DPC (Distributed power control) scheme: TPC (Target-tracking DPC) and OPC (Opportunistic DPC). In the TPC scheme, once the actual level of SNR (Signal to noise ratio) level is different with our setting SNR target, the transmission power will be adjusted to target power value of SNR]. In short, while achieving the target SNR level, it can also achieve a minimum total power consumption [19].

In the OPC scheme, a low SINR (Signal to interference and noise ratio) level can't meet the requirements of QoS, and a high SINR level will lead to system capacity shrink. OPC puts forward a SIP (Signal interference product) which uses the diversity of multi-user conflict link to detect the transmission desire of users. If the transmission power is large, a user can reduce his target SINR to prevent disproportionate power consumption, otherwise, the user can increase his target SINR to improve the utilization of radio resources by using limited channel conditions.

OPC can avoid power emission, and every user has the opportunity to set their own reasonable SINR target to enhance the capacity of the system.

As shown in figure 3.8, we can take full use of interference avoidance algorithm to establish the constraint model of power control and set the parameters of cellular network coverage range, antenna gain, noise coefficient and power spectral density, etc [20].

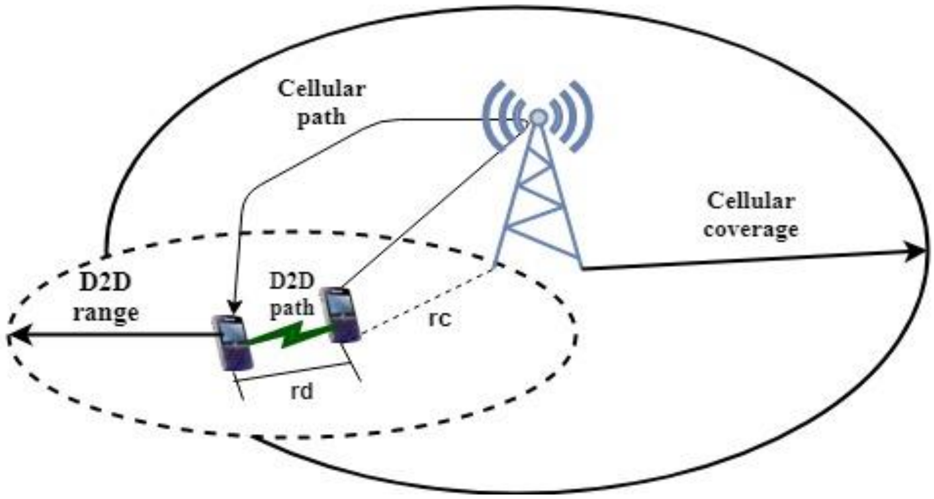


Figure 3.8 D2D communication under cellular network

Also, we can set communication distance between two terminals, SNR, transmission power threshold, and adopt the bias scheme and admission control to analogy the two terminal communications of cellular network. We can verify the convergence and performance of DPC scheme] through the system simulation. And finally, through avoiding invalid power consumption and maintaining the feasibility of the system, we can achieve the purpose of power control and interference suppression.

3.3.2 Joint control of power and rate

The joint control of transmission power and rate can maximize the speed of cellular communication, and ensure the quality of D2D communication services at the same time. When a pair of D2D users share cellular network resources, SIC (Successive interference cancellation) and SUD (Single user detection) can be realized [21]. The SIC is beneficial when cellular users have strong interference to the D2D receiver. When the interference is weak, D2D receiver can process the noise directly. So for a weak interference, the transmission rate and the transmission power of the cellular communication don’t need to be controlled. D2D communication under cellular network is showed in figure 3.8, when the cellular network users have strong interference to the D2D receiver, the transmission power optimization strategy will be implemented to control the transmission rate. And when the interference is weak, the transmission rate optimization strategy will be implemented to control the transmission power. According to the different scenarios and users requirements, a similar optimal algorithm also can be set up on the basis of this scheme to find out the optimal value of the power and rate to meet respective demands.

3.5.3 Joint control of power and beam forming

Considering the characteristics of D2D and cellular network, the scheme based on SVM (Support vector machine) can be used to solve the problem of constrained optimization existing in both cellular network user terminal and the D2D user terminal [22,23]. SVM is a supervised learning algorithm that uses known or similar scenes and functions to identify unknown or similar situations. Firstly, it transforms the constrained optimization problem into the minimization of the total power of all the terminals, which satisfies both the service quality requirement and the interference level. And then it uses the existing statistical channel state information [24,25] to put forward an approximate method for releasing the constraint conditions. We use SVM algorithm to solve the optimization problem of transmission power and beam forming weight vector for each user [26]. Then we can get the EC (Ergodic capacity) and ASER (Average symbol error rate) of the ergodic capacity of each user in the network. According to different scenario requirements, the purpose of power control can be achieved through the reasonable performance analysis of the simulation.

3.4 Simulation method and data analysis

In this study, we used MATLAB for simulating the designed network system. Specially we use MATLAB version 2016. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems. We also Excel to analyses data.

System model

The cellular network is modelled as a hexagonal grid. Each hexagon represents a cell with radius R. The antenna system is assumed to be omnidirectional, which means one base station serves exactly one cell. In order to better evaluate intercell interference, wrap-around technique is used. D2D transmitters are randomly dropped within the cell with uniform distribution.

We try to present an interference management scheme. We hope that this scheme will helps us to reduce interference in D2D communication in cellular system.

CHAPTER 4

RESULT AND DISCUSSION

Fifth generation (5G) network is the result of an aggregation of numerous technologies like, mmWave communication, D2D communication, Massive MIMO, Cognitive Radio Networks, Visible light communication . D2D is considered as a core of the 5G cellular network. To obtain the complete advantage of D2D communication we need an efficient interference management procedure in multicell environment. Interference management is considered as one of the most critical issue when it is between cellular users and D2D users. In our thesis work we try to present an interference mitigate scheme. In this chapter we discuss about our desire result.

4.1 Comparison between D2D & base station involvement communication

Considering different connection setup time between devices and base station we get a chart. From the chart we see the D2D communication require less time than the involvement of the base station.

Table 4.1 Data to compare D2D with base station involvement (D2Bs2D) communication.

Device A set up time	BS set up time	Device C set up time	D2Bs2D	D2D
0.5	0.1	0.5	1.1	1
0.15	0.5	0.12	0.77	0.27
Device A set up time	BS set up time	Device C set up time	D2Bs2D	D2D

0.17	0.2	0.15	0.52	0.32
0.1	0.4	0.1	0.6	0.2
0.9	0.6	0.5	2	1.4

After analysis data using Excel we get the comparison chart, shown in figure 4.1.

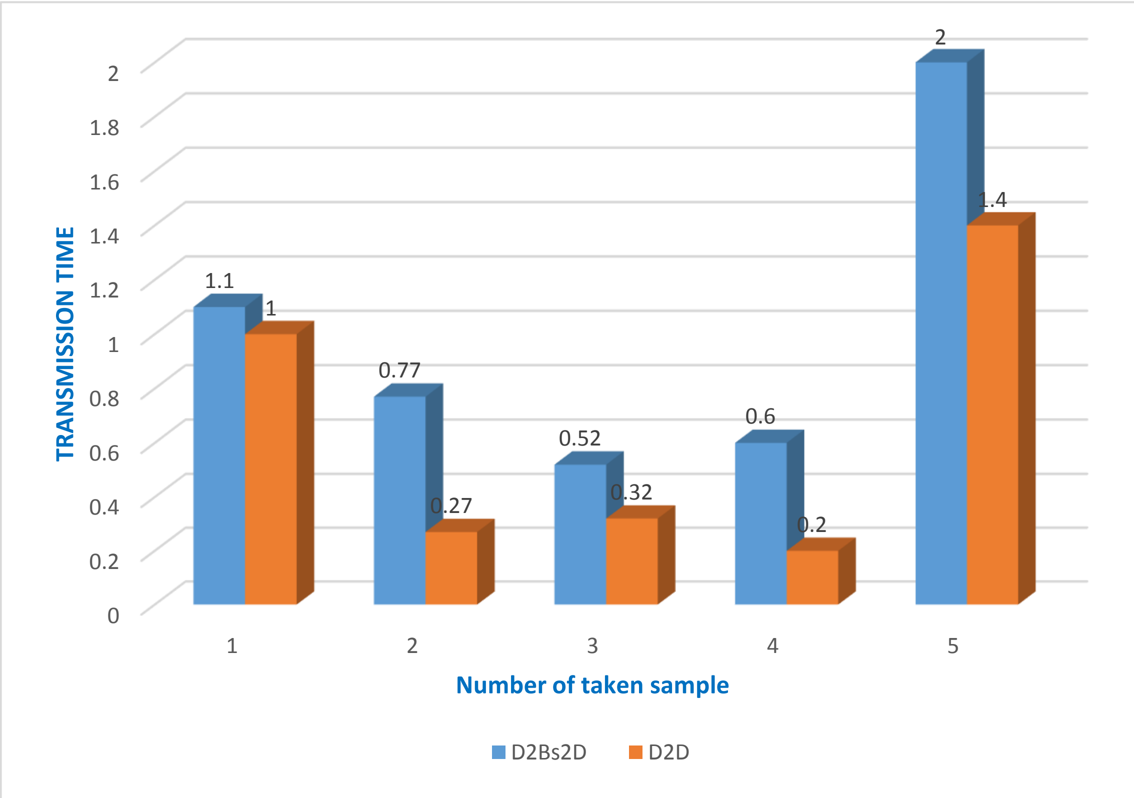


Figure 4.1 Comparison between D2D and D2Bs2D

For the sample number 1 from figure 4.1, we see that when the setup time for device A, C and Bs is respectively .5, .5 & .1, the D2D communication require time is 1 and D2Bs2D is 1.1. We see that D2D communication require less time than the D2Bs2D system. Here we also observe the same result for other samples.

4.2 Find out the D2D pair & analysis the interference

Simulation is done using MATLAB R2016. By using MATLAB R2016, we started to design multiple cell scenario with BS at the center figure 4.2.

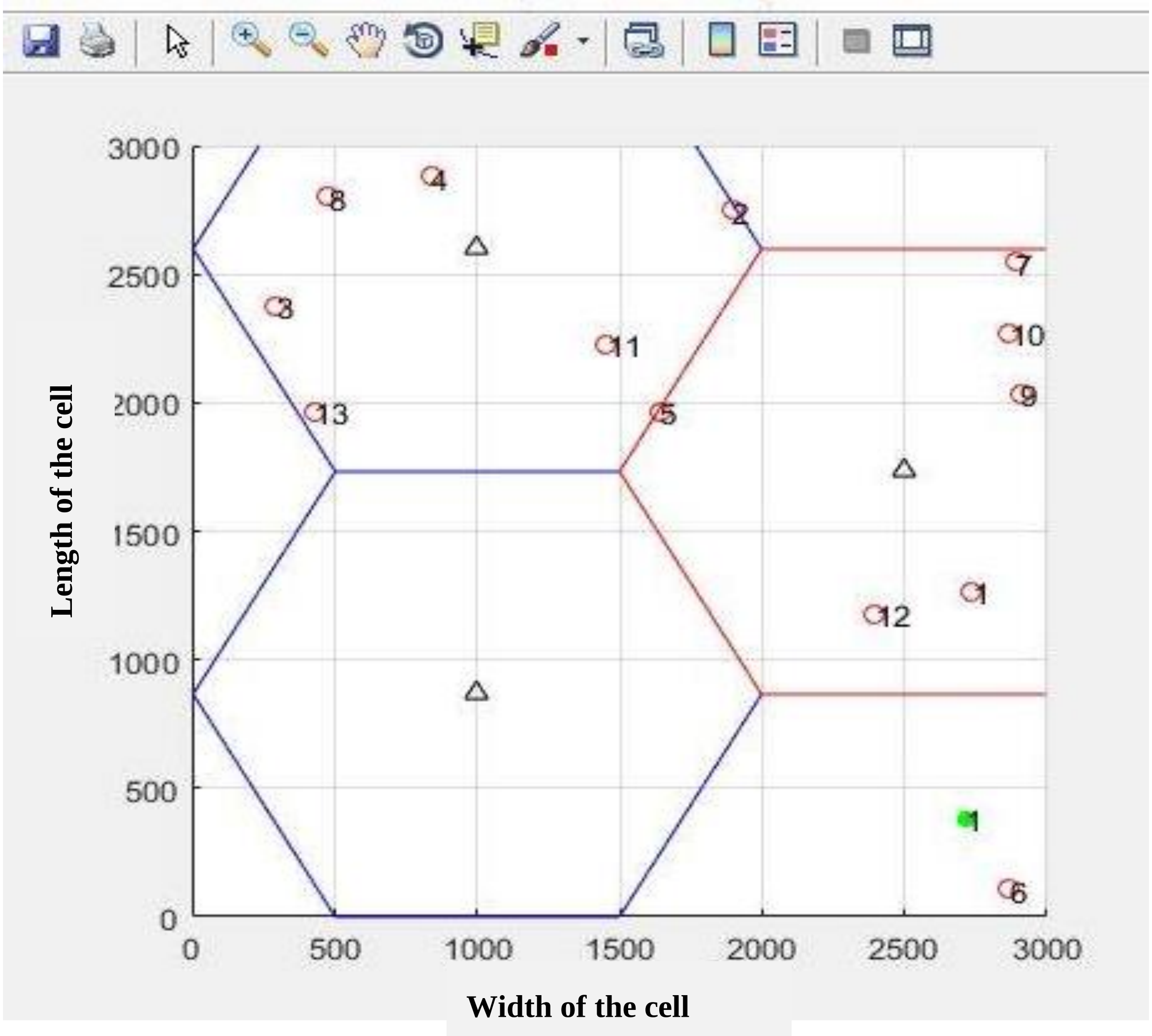


Figure 4.2 Snapshot of multicell using MATLAB

We can see the cell coordinates and the BS also CUE which is represented by green circle, we have N candidate pairs of D2D communication (each red circle represents D2D candidate user) randomly distributed in the area where the BS is down.

First we measure the distance between user devices and base station. Depending on the measure distance we calculate SINR value and also measure generating power and receive power. Then we calculate interference and find out the best D2D pair at the minimum distance. According to the given value at table 4.2 we get the 5 best D2D pair.

Tables 4.1 Parameter used for simulation

Parameters	**Value**
Number of D2D Devices	3-15
Number of RB	1
Path loss exponent	2.6 dB
Additive White Gaussian Noise (AWGN)	1-3 dB
Transmitter Gain ($\boldsymbol{GTx}$)	20-25 dBm
Receiver Gain ($\boldsymbol{GRx}$)	20-25 dBm

Here path loss is the relation between the link distance d and the mean attenuation in a given environment

$$A_{pl} = C(d/do)\gamma$$

Where γ is the path loss exponent, and C is the attenuation at the reference distance d = d_0.

We find out that mode selection is very important in D2D communications, because it guarantees the improvement of spectrum and energy efficiency regardless of the distance between D2D pairs or the number of D2D pairs in the cell. When D2D transmitter and receiver are close to each other the gains of D2D are best achieved. If the distance between communicating UEs is too large, forcing D2D communications would in fact decrease system throughput and increase required transmit power. D2D UEs should not be allowed to radio resource reuse. MinInterf always results in the best SINR performance, compared to other resource allocation algorithms.

CHAPTER 5

CONCLUSION

The popularity of mobile communications has increased immensely the past decade. We argued that mobile operators need innovative solutions to cope with the rising demand of data traffic and that's lead us towards the 5G. Our main focus research topic is D2D communications in emergency scenario. A D2D link is a direct connection between two communicating devices.
In this thesis we have presented a strategy for direct uncentralized case of device-to-device (D2D) communication in the emergency Scenario. The main normal concept of D2D communication is as follows: the base station (BS) detects when two devices requesting a communication session are in each other's proximity. Then the BS can choose between a cellular or a D2D link. Multiple D2D links may operate simultaneously, increasing the spectral efficiency. More advantages of D2D- over other technologies of 5G can be seen in figure 1.2. The D2D sessions take place in the same (licensed) frequency band as the cellular communication or unlicensed band. D2D links interfere with each other. This interference problem is the main challenge when facilitating D2D communications as proposed.

5.1 Conclusion

Interference minimization in D2D communication underlaying cellular network is addressed in this paper. Here we try to show interference mitigation technique, mode selection and peer discover. From this research and its results a number of conclusions can be formulated and a number of research directions can be identified that can serve as future work
With performing this research the main research question we want to answer is: How to create a suitable interference management scheme for D2D communication?
In this work our contributions are:

i. We explained the concept of device to device communications briefly by knowing the major steps to originate a D2D call like peer discovery and the methods used for peer discovery, resource allocation, interference management and we explained the architecture of D2D in LTE-A and necessary device and spectrum for 5g era .
ii. We show the peer discover technique, mode selection algorithm and the resource allocation and power control technique to mitigate interference. The algorithm are based on the emergency scenario to select D2D pair. Based on the TDMA mode we proposed minimum interference resource allocation algorithm.

iii. We also discuss about the result of our proposed system. Finally, we constructed a realistic urban cell scenario for peer discovery and selection of D2D pair in abnormal conditions without the usage of Base station. We showed that we can think more for introducing new era that mobile devices can do the work of the networks by their own.

5.2 Future work

Research on D2D communication in uncentralized emergency scenario has been under the attention of scientific researchers for a short time and therefore is in its initial stages. We introduced a novel methodology of selection of D2D pair in the same spectrum. We believe this work provides an appropriate framework for realizing D2D communication in uncentralized emergency scenario. However, future study is required to learn more on the selection process.
Present wireless technology is meeting all the requirements of the user but for some application such as automated driving car we need more real time response. In this types of application we can implement D2D communication technology. In case of emergency communication such as public safety communication D2D communication technology will be able to play an essential rule

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APPENDIX

Simulation code

```
clc;
close all;
clear all;
%Hexagon parameters
R=1000;
len=3000;
wid=3000;
CUE=1;
D2D=randi([3 15],1);
L0=30.18; %fixed Propagation Loss
sigma_shadowing=4;
gamma=2.6;
n=D2D/2;
active_dist1=0;
active_dist2=0;
active_pair1=0;
```

```
active_pair2=0;

active_hybrid1=0;

active_hybrid2=0;

Genode=48;

%Drawing the Hexagon

nx11=len/(2*R);

nx=round(nx11);

ny1=wid/(2*R);

ny=round(ny1);

% one hexagon coordinaties:

al=0:((2*pi)/6):2*pi;

xh=R*cos(al);

yh=R*sin(al);

xcell=[];

ycell=[];


hold on;
```

```
% first rectangular spaced hexagons set
x0=R;
y0=sqrt(3)*R/2;
x=x0;
y=y0;
j=5;%cell numbering
 for nxc=1:nx
        for nyc=1:ny
                 plot(x+xh,y+yh,'b');
                 plot(x,y,'k^');
                 xcell=[xcell x];%recording cell coordinates
                ycell=[ycell y];
                 j=j+1;
                y=y+sqrt(3)*R;
        end
        x=x+3*R;
        y=y0;
end
```

```
% second rectgular spaced hexagons set
x0=2.5*R;
y0=sqrt(3)*R;
x=x0;
y=y0;
for nxc=1:(floor(nx11))
    for nyc=1:(floor(ny1))
        plot(x+xh,y+yh,'r');
        plot(x,y,'k^');
        xcell=[xcell x];%recording cell coordinates
        ycell=[ycell y];
        j=0;
        y=y+sqrt(3)*R;
    end
    x=x+3*R;
    y=y0;
end
axis equal;
```

```
axis([0 len 0 wid]);
grid;
%Generating the users randamly and uniformaly
xuser=rand(1,CUE).*len;
yuser=rand(1,CUE).*wid;
D2Dxuser=rand(1,D2D).*len;
D2Dyuser=rand(1,D2D).*wid;
scatter(D2Dxuser,D2Dyuser,'red')
scatter(xuser,yuser,'blue','filled')
for i=1:1:CUE
text(xuser(i)+0.05,yuser(i)+0.05,num2str(i)); %giving each user a
number on the graph
end
for i=1:1:D2D
text(D2Dxuser(i)+0.05,D2Dyuser(i)+0.05,num2str(i)); %giving
each of D2D user a number on the
graph
end
%Calculating the distance between each user and each BTs
```

```
for j=1:1:length(xuser)
    dist(j,:)=sqrt((D2Dxuser-xuser(j)).^2+ (D2Dyuser-
yuser(j)).^2);
end
for j=1:1:length(D2Dxuser)
    for i=1:1:length(D2Dyuser)
        masafa(j,:)=sqrt((D2Dxuser(j)-xuser).^2+
    (D2Dyuser(i)-yuser).^2);
    end
    distx=masafa';
end
for j=1:1:length(D2Dxuser)
    masafa1(j,:)=sqrt((D2Dxuser(j)-D2Dxuser).^2+
(D2Dyuser(j)-D2Dyuser).^2);
end
distD2Dx=masafa1';
for j=1:1:length(xuser)
    masafa2(j,:)=sqrt((xuser(j)-xuser).^2+ (yuser(j)-yuser).^2);
end
```

```
distCUEx=masafa2';

distD2D=masafa1./1000;

dist=masafa./1000;

distCUE=masafa2./1000;

%Generating power,Gain,AWGN for each device

GTxmin=20;

GTxmax=25;

for i=1:1:D2D

        for j=1:1:D2D

        if i~=j

        GTx(i,j)=randi([20 25]);

        end
         end
 end
GRxmin=20;

GRxmax=25;

for i=1:1:D2D

        for j=1:1:D2D
```

```
if i~=j
GRx(i,j)=randi([20 25]);
end
end
end
PTxmin=20;
PTxmax=25;
for i=1:1:D2D
for j=1:1:D2D
if i~=j
PTx(i,j)=randi([20 25]);
end
end
end
for i=1:1:D2D
for j=1:1:D2D
if i~=j
AWGN(i,j)=randi([1 3]);
end
end
```

```
end
% getting minimum distance
K=min(distD2D(distD2D>0));
[Atten]=prop_channel(L0, gamma,distD2D, sigma_shadowing);
for i=1:1:D2D
    for j=1:1:D2D
        Atten(i,j)=Atten(j,i);
    end
 end
 for i=1:1:D2D
    for j=1:1:D2D
        if i==j
        x(i,j)=0
        S(i,j)=0
        else
        x(i,j) =PTx(i,j)+GTx(i,j)+GRx(i,j)-Atten(i,j); %Main
Signal
        S(i,j) = PTx(i,j)+GTx(i,j)+GRx(i,j)-Atten(i,j); %
    interference
    end
```

```
    end
end
  for i=1:1:D2D
      for j=1:1:D2D
              interf(i,j)=0;
              if i~=j
                      for m=1:1:D2D
                              if m~=j&&m~=i %main condition to calculate
                      interference
                              interfx(i,j)=interf(i,j)+10^(S(m,j)/10);%total
                      interference
              end
       end
       interf(i,j)=interfx(i,j)+10^(AWGN(i,j)/10);
            end
      end
end
for i=1:1:D2D
      for j=1:1:D2D
              if i==j
```

```
            x(i,j)=0
            S(i,j)=0
            else
            sinr(i,j) = 10.^(x(i,j)/10)/interf(i,j);
        end
    end
  end
 sinr=10*log10(sinr); %dB
 sinr( sinr==-inf )=0;
 % number of pairs
 pairsnum=0;
 tmp3=sinr;
 tmp3( tmp3<0 )=-inf;
for i=1:1:D2D
        for j=1:1:D2D
        if tmp3(i,j)>0 && tmp3(j,i)>0
        pairsnum=pairsnum+1;
        tmp3(i,j)=0;
        tmp3(:,i)=0;
```

```
    tmp3(j,:)=0;
    end
  end
end
% best D2D pairs:
% here we choose best SINR in the two directions
tmp1 = sinr;
mincom=0;
for i=1:1:length(sinr);
    for j=1:1:length(sinr)
        if tmp1(i,j)>0 && tmp1(j,i)>0
        if tmp1(i,j)<=tmp1(j,i)
        mincom(i,j)=tmp1(i,j);
        else if tmp1(i,j)>=tmp1(j,i)
    mincom(i,j)=tmp1(j,i);
    end
      end
    end
  end
end
```

```
active_pair1 = max (max(mincom));
  for i=1:1:length(sinr);
    for j=1:1:length(sinr)
        if tmp1(i,j)== active_pair1
        active_pair2=tmp1(j,i);
    end
   end
end
outage_sinrx=(floor(n)-pairsnum)/floor(n);
outage_sinr=outage_sinrx*100;
% best D2D pair according to shortest distance
countdist=0;
tmp = distD2D;
tmp(tmp==0) = Inf;
c = min(tmp,[],D2D);
[num idx] = min(c(:));
[q p] = ind2sub(size(c),idx);
if sinr(q,p)>0 && sinr(p,q)>0
```

```
active_dist1=sinr(q,p);

active_dist2=sinr(p,q);

countdist=countdist+1;

outagedistx=(floor(n)-countdist)/floor(n)

outagedist= outagedistx*100

else

outagedist=100

end
```