Sudan University of Science and Technology
College of Postgraduate Studies

Performance Analysis of Device-to- Device Communication Pair Selection Algorithms

تحليل اداء خوارزميات اختيار زوج الاتصال من جهاز لجهاز

A Dissertation Submitted in Partial Fulfillment for the Requirements for the M.SC Degree in Electronics Engineering

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

α	*path loss exponent*
A_{PL}	Path Loss
C	attenuation at the reference
d , d_0	distance
A_{SH}	additional attenuation in dB w.r.t
μ	standard deviation in dB
σ_{SH}	standard deviation in dB
L_{Ci}	distance between the CUEi and D2D-Rx
r_{ci}	*distance between cellular user equipments and base station*
r_D	*distance between* $D2D - Rx$ *and base station*
y_i	Received signal at the D2D-Rx
h_D	*Fading Coeffiecent in D2D linkZ*
h_{Ci}	*Fading coeffiecent in CUE interference link to D2D Rx*
P_D, P_{Ci}	*transmit power of* $D2D - TX$
x_D , x_{Ci}	*both signals of* $D2D - TX$ *and CUE signal to BS*
$P_D \rho^{-\alpha}$	received power at D2D-Rx for D2D link
$P_{Ci} L_{Ci}{}^{-\alpha}$	received power at D2D-Rx for C2D interference link

C	Attenuation at Reference distance
G_{TX}	*Antenna TX Gain*
G_{RX}	*Antenna Rx Gain*
Δ_{SHi}	*Shadowing*
h_{Di}	*Fading Coeffiecent in D2D link,,*
$L_{Ci}{}^{-\alpha}$	Path Loss
N_0	*AWGN.*

LIST OF ABBREVIATIONS

ACK	Acknowledgement
ARQ	Automated Repeat Request
B.W	Bandwidth
BRA	Balanced Random Allocation
BS	Base Station
BTS	Base Transceiver station
CPA	Cellular Protection Allocation
CQI	Channel Quality Indicator
CRN	Cognitive Radio Networks
CSI	Channel State Information
CUE	Cellular User Equipment
D2D	Device to Device Communications
DCI	Downlink Control Information
DFT	Discrete Fourier Transform
DUE	Device to Device User Equipment
Enb	Enhanced Node B
eNodeB	Base Station in LTE-A
ETSI	European Telecommunication Standard Institute
FHS	Frequency Hopping Sequences
gNodeB	Base station in 5G
GPS	Global Positioning System
HARQ	Hybrid Automatic Repeat Request
HARQ	Hybrid Automated Repeat Request
IP	Internet Protocol
ITU-T	International Telecommunication union
LA	Link adaptation

LTE-A	Long Term Evolution-Advanced
MANET	Mobile Ad-hoc Network
MBS	Mobile base Station
MCS	Modulation and Coding Scheme
MI	Mutual Information
MIMO	Multiple Inputs Multiple Outputs
MME	Mobile Management Entity
MMSE	Minimum Mean Square Error
MS	Mobile Subscribers
MSE	Mean Square Error
MSLA	Maximum SINR with Limit on distance of discovery =500m Algorithm
MSNA	Maximum SINR with no limit on distance of discovery Algorithm
NACK	Negative Acknowledgement
OFDM	Orthogonal Frequency Division Multiplexer
PARA	Peak to Average Power Ratio
P-GW	Packet Network Gateway
PRB	Physical Resource Block
ProSe	Proximity Service
ProSE	Proximity Services
PSBCH	Physical Sidelink Broadcast Channel
PSCCH	Physical Sidelink Control Channel
PSDCH	Physical Sidelink Discovery Channel
PSSCH	Physical Sidelink Shared Channel
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
Qos	Quality of Service
RB	Resource Block

RF	Radio Frequency
RRA	Random Resource Allocation
Rx	Receiver
SC-FDMA	Single Carrier Frequency Division Multiple Access
SDA	Shortest Distance Algorithm
SDL	Sphere Decoder Like
SINR	Signal to Interference Plus Noise Ratio
SNDR	Signal to Noise plus Distortion Ratio
SNR	Signal to Noise Ratio
SR	Scheduling Request
Tx	Transmitter
UCI	Uplink Control Information
UE	User Equipment

DEDICATION

I Dedicate This Work to my Family for Their Endless Love, Support and Encouragement

Thanks for Always Being There For Us

ACKNOWLEDGEMENT

All praises and thanks for Almighty God, the divine force of this universe, the source of all knowledge and wisdom endowed mankind, who made this possible and blessed us a potential and ability to contribute a drop of material to the existing ocean of knowledge.

I would like also to express our gratitude to supervisor **Dr.Fath Elrahman Ismael** who strongly supported from the very beginning and provided me with valuable advice. Great thanks for him for the endless support and encouragement. Without his guidance and encouragement, I would not be able to do this.

The successful completion of this project depends largely on the encouragement and guidelines of many others. I would like to take this opportunity to express my gratitude to my family and to the people who have been instrumental and gave me help, support, and well wishes.

Abstract

With the development of mobile services and technologies, short-term data sharing between nearby users, small-scale social and business activities, and location-based services for local users will become an important source of business growth on the wireless platform. Device to Device based near user discovery technology will improve the user experience in these service modes. However, the suitable pair selection which is very challenging and optimize the system performance. Wireless technology has a number of D2D pairs selection algorithms exist; so there are many arguments for evaluating its performance to optimize the system. This research will conduct an optimal mode selection policy process that takes into account channel conditions and proposes a selection algorithm, the shortest detection distance between D2D hardware algorithm (SDA), the maximum SINR with no detection algorithm distance (MSNA) and the maximum SINR with detection distance limit to 500m algorithm (MSLA) mode selection algorithm to maximize the overall network. The system model and the operational algorithms will be represented. The analysis will be made based from the results of Matlab simulation. The obtained results showed that the average number of D2D pairs increases by increasing the area of the mobile phone distribution. In addition, it is found that the more devices available, the higher the average number of active pairs.

المستخلص

مع تطوير خدمات وتقنيات الهاتف المحمول ، ستصبح مشاركة البيانات قصيرة المدى بين المستخدمين القريبين والأنشطة الاجتماعية والتجارية صغيرة النطاق والخدمات القائمة على الموقع للمستخدمين المحليين مصدرًا مهمًا لنمو الأعمال على النظام الأساسي اللاسلكي. ستعمل تقنية اكتشاف المستخدم القريب من جهاز إلى جهاز على تحسين تجربة المستخدم في أوضاع الخدمة هذه. ومع ذلك ، فإن اختيار الزوج المناسب يمثل تحديًا كبيرًا ويحسن أداء النظام. التكنولوجيا اللاسلكية لديها عدد من خوارزميات اختيار أزواج جهاز لجهاز موجودة ؛ لذلك هناك العديد من الحجج لتقييم أدائها لتحسين النظام. سيجري هذا البحث عملية سياسة اختيار الوضع الأمثل التي تأخذ في الاعتبار ظروف القناة وتقترح خوارزمية اختيار ، وأقصر مسافة للكشف بين خوارزمية أجهزة جهاز لجهاز ، والحد الأقصى لنسبة الاشارة للضجيج والتداخل بدون تحديد مسافة لخوارزمية الكشف والحد الأقصى لنسبة الاشارة للضجيج والتداخل مع حد مسافة الكشف إلى خوارزمية اختيار وضع خوارزمية 500 متر لتعظيم الشبكة الكلية. سيتم تمثيل نموذج النظام والخوارزميات التشغيلية. سيتم إجراء التحليل بناءً على نتائج محاكاة الماتلاب. أظهرت النتائج المتحصل عليها أن متوسط عدد أزواج جهاز لجهاز يزداد بزيادة مساحة توزيع الهاتف المحمول. بالإضافة إلى ذلك ، وجد أنه كلما زاد عدد الأجهزة المتاحة ، زاد متوسط عدد الأزواج النشطة.

CHAPTER ONE

INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1 Preface

As wireless communication technology continues to evolve from one generation to another, the connection systems requirements develop alongside to meet the expectations of users. Such expectations are brought about by the entire evolution process, which represents the ever-increasing demand for a higher system throughput. Nowadays, as the demand for higher transmission rates continues unabatedly, a new generation of wireless technologies is being introduced into the communication society to meet the insistent demands of users. The key differences among the various generations of wireless communication systems (i.e., starting from the first generation 1G to the fifth generation systems) are manifested in variations in data rates, data security, latency, and the quality of services (QoS) .These are often improved in successive generations for a more efficient system throughput, as well as QoS performance[3].

New communication technologies must be capable of exchanging data on-demand over proper network connections, and must be able to scale the network capacity. Device-to-device (D2D) communications are considered to be a promising technique that allow mobile devices to communicate with one another directly without going through access points or Base Stations [2].

1.2 Problem Statement

Wireless technology has a number of D2D pairs selection algorithms exist; so there are many arguments for evaluating its performance to optimize the system.

1.3 Proposed Solution

This research will conduct an optimal mode selection policy process that takes into account channel conditions and proposes a selection algorithms, the shortest detection distance between D2D hardware algorithm (SDA), the maximum SINR with no detection algorithm distance (MSNA) and the maximum SINR with detection distance limit =500m algorithm (MSLA) mode selection algorithm to maximize the overall network.

1.4 Aim and Objectives

The aim of this project is to evaluate and compare the different discovery methods for D2D communication in case of disaster scenario and to investigate the effectiveness of using the D2D, which leads to improved system performance, and the number of devices connected to wireless systems.

1.5 Methodology

In this thesis, I investigated the policy process for optimum mode selection in a D2D-enabled 5G network. In particular, I looked at how to perform highly challenging pair selection in D2D pair selection and system optimization. Referring to Related Works, the algorithms determined the shortest detection distance between D2D hardware algorithm (SDA), the maximum SINR with no detection algorithm distance (MSNA) and the maximum SINR with detection distance limit to 500m algorithm (MSLA).I did a number of mathematical operations to represent the system within strategy will be as follows:

- Beacons will be sent for device discovery broadcasted using side link channelPSDCH using preconfigured discovery resource pools
- Filtration of these beacons by receiver (Rx) and acknowledge response with all main information: temporary ID, location, SINR will be sent.

- Resource pools configurations for D2D transmission and reception will be sent on PSCCH and PSSCH up to eight resource pools.
- Decision of selection of D2D pair's candidate will be the responsible of the transmitter (TX) according to the algorithm that we will use for discovery.

Using Matlab, the average number of active pair using a different algorithm was represented, average SINR ,Probability of outage and average Number of active pair for different distances threshold

The obtained results showed that the average number of D2D pairs increases by increasing the area of the mobile phone distribution. In addition, it is found that the more devices available, the higher the average number of active pairs.

1.6 Thesis Outlines

This thesis is organized as follow: Chapter One is devoted to Introduction, Problem Statement, Proposed Solution and objectives. In Chapter Two literature review, and related work, Chapter Three starts focus on the algorithms, and system calculations. Chapter Four the performance evaluation by means of simulation results. Chapter Five is the conclusions and, future work related to this research is discussed.

CHAPTER TWO

BACKGROUND AND LITERATURE REVIEW

CHAPTER TWO

Background And Literature Review

Mode Selection in D2D communications for 5G communications systems built here by focus on un centralized scenario for selection of D2D pairs in discovery phase in emergency scenario without the usage of gNodeB so call scenario in emergency situation will be based on decentralized D2D in LTE-A. Synchronization and radio parameter acquisition In order to demodulate the data, transmitter (Tx) and receiver (Rx) have to be synchronized in time and frequency and to know who will be responsible of synchronization this depend if Tx is in-coverage or out-coverage :In coverage synchronization is provided by gNodeB, Out coverage synchronization is provided by UEs[2].

2.1 Background

Every successive generation of wireless communications technology attempted to produce better speeds and additional functionality for our cellphones.

1G was the first cell phone, 2G was the first text messaging cell phone, 3G was the beginning of true internet surfing, and 3G has enabled real-time application services to mobile phone customers with high-speed data.

LTE is based on orthogonal frequency division multiplexer (OFDM) and multiple inputs multiple outputs (MIMO) technology, which are being developed continuously by 3GPP.

This mobile telecommunications system has a global reach and offers broadband wireless service using LTE and WIMAX telecommunication technologies. [3].

LTE has been managed with GSM/UMTS and CDMA operators. 4G provide a lot of integrity through OFDM with Wi-Max, it can be delivered up to seventy Mbps over a wireless technology, and the indoor user reaches up to 1Gbps. 4G encompasses a facility to transfers information like audio, video, and photos during a voice call. But as more users came online LTE has reached the limit that is capable of data rate.

The increasing number of users, huge amount of data and the need for high data rate push us towards the 5G network. 5G networks are characterized by unique features like ubiquitous connections, low latency, and high-speed data transfer, Ubiquitous connectivity requires user equipment (UE) to support a variety of radios and bands due to the global different operating bands. The 5G networks will support real-time applications and services with zero delay tolerance, and of course to achieve zero latency we need very high-speed data rate which will be of the order of Gigabits per second to users and machines.

2.2 5G Candidate Technologies

A variety of new technologies are now being explored for 5G networks.

Ultra-dense networks, massive MIMO, mmWave, D2D communications, and cloud radio access networks, non-orthogonal multiple access, M2M communications, mobile edge computing, wireless caching, and full duplex communication are examples of technologies.Following is a quick description of various technologies and how they contribute to the 5G needs.

2.2.1 Ultra-Dense Wireless Network

Cell division and condensation was one of the most obvious solutions. System capacity has expanded since the birth of the mobile phone business. UDN was recently released as one of the primary options to tackle the difficulties. In order to meet the extraordinarily high density and high 5G peak rate requirements.Although it may appear straightforward, adding massive tiny cells has proven difficult, necessitating new techniques to limit interference and reconnect, as well as new solutions [15].

2.2.2 MIMO Tremendous Technology

MIMO, or wide-band antenna technology, is an expansion of MIMO in which the number of antennas is substantially more than the number of downlink data streams. Massive MIMO relies on antennas in both the transmitter and receiver to deliver increased throughput and improved spectrum efficiency.

The Benefits of a Massive Game. However, the MIMO system not only improves throughput and spectral efficiency, but it also has many other advantages such as simpler signal processing, rate and user customisation, scheduling, better energy efficiency, and an expanded number of users via private networks. Increase the number of people that can be serviced by doubling the capacity.

2.2.3 Millimeter Wave Connection

Millimeter-wave (mmWave) frequencies, meaning frequencies ranging from about 30 to 300 GHz, offer enormous potential and new frontiers for cellular wireless systems. Compared with the published low frequency range, it has very abundant mmWave band frequency resources. The enormous bands available in Together, these frequencies offer the possibility of scaling orders of magnitude in capacity in relation to the current bandwidth at lower frequencies, thus attracting great interest for 5G systems [11].

2.2.4 Waveform and Multiple Accesses

In this multi-access traditional schemes orthogonal resources are allocated to different users either in time or frequency domain in order to avoid interference between users. However, compared to current orthogonal multiple access (OMA) technologies by allowing multiple users to share the same time and frequency, non-orthogonal multiple access (NOMA) technologies can greatly increase the number of users served, improve spectral efficiency and user equity, and reduce latency when compared. With current orthogonal multiple access (OMA) technologies.

2.3 Requirements of 5G

One of the main technical solutions to boost the 5G network that started in LTE and my main topic will be D2D communication. D2D when it was first revealed that it looks like MANETs and Cognitive Radio Network (CRN) since both are groups of portable nodes that make up a temporary decentralized network but there are a lot of flaws facing MANETs which makes them not quality of service guaranteed. These shortcomings are the unreliability of wireless channels, the lack of central control; the challenges that MANET faces that prevent it from providing the required Quality of Service (QoS) guarantees. There are also a lot of issues with CRN including white space detection, collision avoidance, synchronization, and spectrum sensing. If we go towards D2D Networks, it can be controlled by base station, partially controlled or device controlled as shown in Table 2.1[1].

Table 2.1 Comparisons between MANETs and D2D [1]

MANETs	D2D Communication
Multi-hop Networks	One-hop networks
No QoS guarantee	QoS guarantee
No improvement in Spectral efficiency	Spectral efficiency
No centralized control	Centralized control, partially control or device control
No handover	Hand over available
Poor resource utilization	Efficient resource utilization

2.4 Device to Device Communications

Device-to-Device (D2D) communications have emerged as a promising technology for the next generation mobile communication networks and wireless systems (5G). As an underlay network of conventional cellular networks (LTE or LTE-Advanced), D2D communications have shown great potential in improving communication capability, erasing communication delay, reducing power dissipation, and fostering multifarious new applications and services.

D2D communication may be used to implement many kinds of services that are complementary to the primary communication network or provide new services based on the flexibility of the network topology. D2D multicast communication such as broadcasting or group casting is a potential means for D2D communication where mobile devices are able to transmit messages to all in-range D2D-enabled mobile devices or a subset of mobile devices which are members of particular group. Additionally networks may require devices to operate in near simultaneous fashion when switching between cellular and D2D communication modes. As a result, there is a need for protocols which can manage D2D communication in these hybrid deployment scenarios. In band communications, in which D2D users can use the same licensed spectrum as cellular user equipment's (CUEs). This category is further divided into overlay and underlay transmissions. That is, depending on the intended application, D2D communications can use dedicated resources (time/frequency), i.e., the overlay approach, or reuse the resources of other CUEs in the cell, i.e., the underlay approach. The allocation of dedicated resources is important for applications such as multi-casting and public safety, whereas resource sharing can improve efficiency of the available resources. Out band communications, in which D2D users use the unlicensed spectrum, such as the industrial, scientific, and medical (ISM) bands, for their transmissions. This, on the one hand, results in the elimination of interference to and from CUEs and, on the other hand, decreases the network control over D2D communications. In addition, D2D communications need to adapt to other technologies transmitting in the same unlicensed band [6].

In D2D communication UEs are enabled to select among different Transmission Modes (TM)s which are defined based on the frequency resource sharing. Figure 2.1 shows the TMs in D2D enabled 5G network [12].

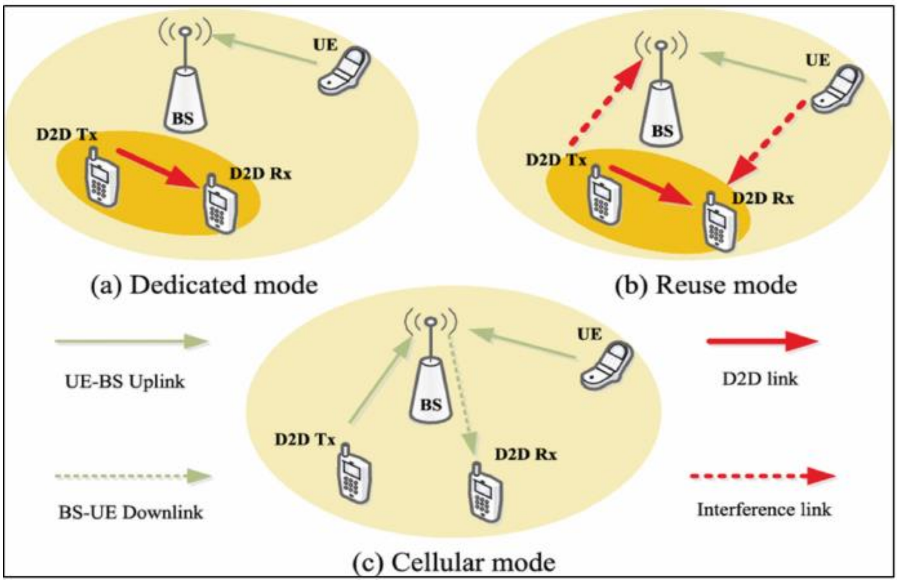


Figure 2.1 Three transmission modes of D2D communications [12]

• **Dedicated mode** where the D2D communication is direct and data is transmitted through the D2D link by the orthogonal frequency resources to the cellular users so there is not any interference.

• **Reuse mode** where data is transmitted through the D2D link by the reusing the same frequency resources that are considered for a cellular user or another D2D link so the reused mode causes interference at receivers. However, the system spectrum efficiency and user access rate may be increased.

• **Cellular mode** where the D2D communication is relayed via eNB and it is treated as cellular users.

2.4.1 Peer Discovery

Peer discovery needs to be efficient, so that D2D links are quickly detected and established. 2D communication may be a relatively new technology in cellular networks. Therefore, widely accepted solutions for peer detection are still missing; Researchers are looking for new and different techniques for peer discovery. From a network perspective, device discovery can be controlled by the base station either tightly or gently. Peer detection in cellular networks is divided into "discovery beacons" with or without UE equipment. Beacons are a 128-bit service layer identifier used for D2D detection; they are expressions that can represent identity, services, interest, or location. A device can broadcast over the air an expression as if we were a coffee shop, where the device with an app that filters relevant expressions from whatever it detects through the air interface so it can get expressions of emergencies or other interesting things. Therefore, our centers can be sent to another mobile phone and we can calculate SINR based on any algorithms [24].

2.4.2 D2D Discovery in Centralized Network

In this scenario D2D depends on core network so beacons are used for D2D discovery but if no beacon is transmitted, discovery should be completed with the help of eNodeB or the core network. eNodeB determines if D2D pair belong to its cell by checking the IP addresses of the packets or comparison a token possessed by the D2D pair. UEs may send service or interest lists to mobile management entity (MME) and acquire notification from other UEs with same interest. The packet network gateway (PGW) determines if D2D pair belongs to same cell by detection a routing-back IP packet. However, to implement the solutions, new functions should be added to P-GW. When the UE is in coverage, transmission mode 1 (network-directed) is used where the eNodeB can dynamically assign resources to the UE for D2D transmission. In this transmission mode, the eNodeB can guarantee no collision between any side link transmission and any uplink transmission, or between side link transmissions [25].

In the below figure 2.2 Shows air interface between D2D Network architecture:

PC1: Interface between ProSe application within the UE and ProSe Application Server.

PC2: The interface between ProSe Application Server and ProSe function.

PC3: The interface between the UE and ProSe function.

PC4: The interface between the EPC and also the ProSe function.

PC5: it's a one-to-many communication interface between two D2D UEs

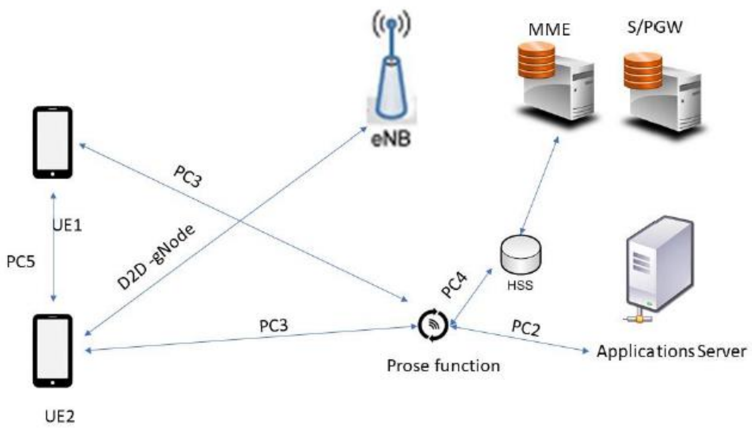


Figure 2.2 D2D Architecture [25]

2.4.3 Channel Quality Indicator

One of the most important feedbacks about the channel status that is sent to the network is CQI which stands for Channel Quality Indicator. The CQI values are from 0 ~ 15. 15 indicate the first-rate channel quality and 0, 1 shows the poorest channel. According to the value UE reports, network transmits statistics with distinctive transport block size. If network receives excessive CQI value from UE, it transmits the statistics with larger delivery block size and vice versa.

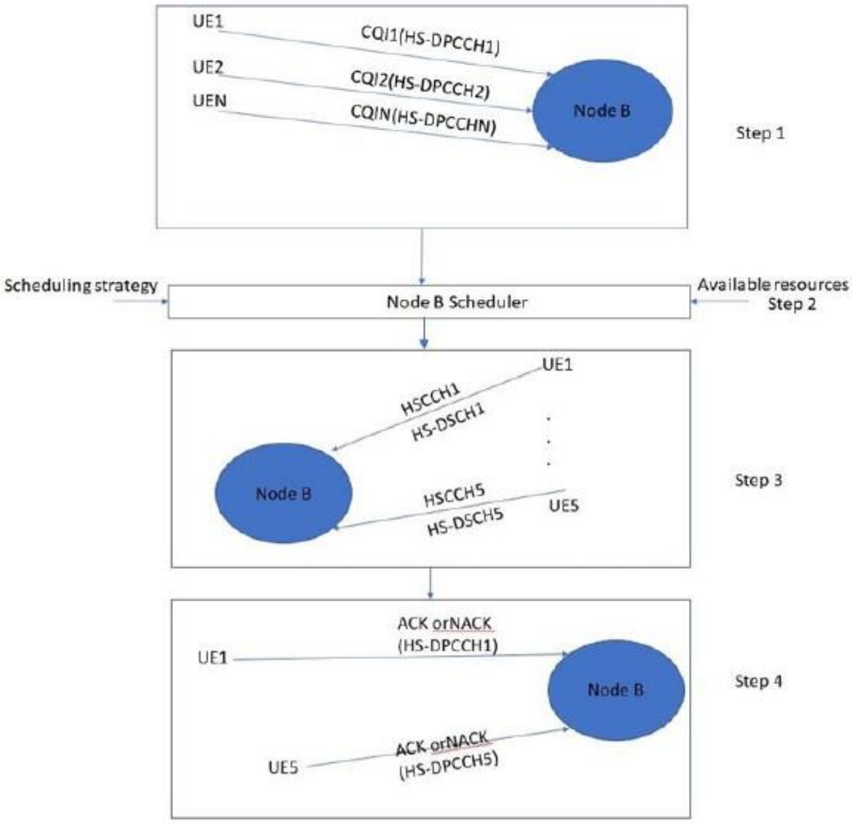


Figure 2.3 CQI Carried Channels

PUCCH (Physical Uplink Control Channel) carries a set of information called "UCI (Uplink Control Information)". (This is similar to PDCCH which carries DCI (Downlink control information)".

PUSCH (physical uplink shared channel) its main function is to carry RRC (Radio resource control) communications messages, UCI (uplink Control Information) and application data. Uplink RRC messages are carried using PUSCH. The PUSCH carries both user data as well as control signal information.

UCI stands for Uplink Control Information. It is carried by PUCCH or PUSCH. UCI is the opposite channel of DCI, but the information/role of UCI is very small comparing to DCI.

The information carried by UCI is:

- SR (Scheduling Request)
- HARQ ACK/NACK
- CQI

SR is a Physical Layer message for UE to ask Network to send UL Grant (DCI Format 0) in order that UE will transmit PUSCH .[35]

2.4.4 Downlink Frame Structure

In LTE, each downlink frame is of 10 ms length, and consists of 10 sub frames. Every sub frame of length 1 ms, which is known as transmission time interval (TTI), consists of two 0.5 ms slots. Each slot, in turn, consists of seven OFDM symbols. In the frequency domain: the system B.W is split into several subcarriers, each of bandwidth of 15 kHz. If B= 10 MHz ,600 subcarriers that is obtained using a 1024-point DFT are used for data and information management A set of 12 consecutive subcarriers for a length of one slot is known as Physical Resource Block (PRB) [34].

Feedback The feedback info sent by the (UE) is known as the Channel Quality Indicator (CQI). The 4-bit CQI value indicates an estimate of the modulation and coding scheme (MCS) that the UE can receive dependably. It is based on the measured received signal quality on the downlink. The BS controls how often and when the UE feeds back CQI.

There are two types of feedback: Aperiodic feedback and Periodic feedback. In aperiodic feedback, the UE sends CQI only when it is asked to by the eNode. On the other hand, in periodic feedback, the UE sends CQI periodically to the eNode; the time between 2 consecutive CQI reports is communicated by the eNode to the UE at the beginning of the CQI reporting process. In each type of these feedbacks, the best possible frequency resolution for CQI reporting is a sub-band, which consists of Q contiguous PRBs.

According to the system bandwidth and the type of feedback, q ranges from two to eight.

The UE will report CQI at different frequency in aperiodic CQI feedback. Specifically, in broadband feedback, the UE reports one broadband CQI value for the whole system B.W. In Sub-band-level feedback, the UE reports CQI for each sub-band. In UE selected sub-band feedback, the UE reports the position of M preferred sub-bands that have the highest sub-band CQIs and a single CQI value for these sub-bands. In periodic CQI feedback, only wideband and UE selected sub-band feedback are possible. Even in the latter, the CSI feedback is very limited; the sub-bands are further clustered into bandwidth parts, and the UE reports the CQI of only one sub-band from each bandwidth part.

2.4.5 D2D Peer Discovery in Un Centralized Scenario

If UEs transmit beacons to advertise their presence, peer discovery might be completed by themselves. Several existing wireless technologies depend on peer discovery with beacons e.g., Bluetooth and Wi-Fi Direct. This D2D discovery without the gNodeB support is the best solution for public safety networks. In this scenario transmission mode 2 (UE-selected) is used where the UE selects which resources to use for transmission. Transmission mode 2 is applicable to all scenarios, in coverage and out coverage. The resources are selected at random to minimize the collision risk [24].

2.4.6 D2D Physical Channels

Side link is a kind of communication links between device and device without going through gNB. It means that it requires new physical layer design. But to minimize the design changes of existing implementation, the new physical layer is designed not to differ too much. We will use very similar waveform in D2D communications based on SC-FDMA in both directions.

Physical Side Link Broadcast Channel (PSBCH), which carries system information and synchronization signals; Physical Side Link Control Channel (PSCCH) which carries UE-to-UE control plane data.

Physical Side link Discovery Channel (PSDCH), which supports UE direct discovery transmissions.

Physical Side Link Shared Channel (PSSCH), used for user plane data transmissions.

2.5 Resource Allocation

After Peer discovery, need available resources for enabling communication over the direct links, Resource allocation has three techniques:

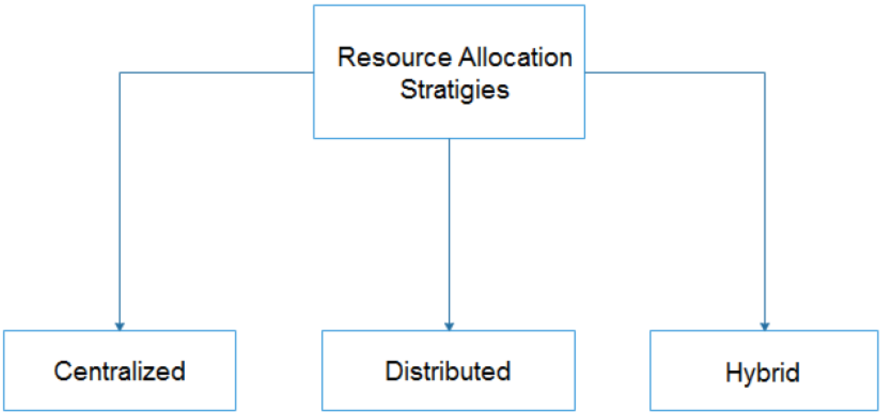


Figure 2.4 Resource allocation Techniques [27]

• **Centralized**: which is used in case of small networks as it causes network complexity in large networks

• **Distributed**: Which is used in large networks as it tends to decrease network scalability.

• **Hybrid**: is a research open solution [27].

2.5.1 Random Resource Allocation (RRA)

This algorithm randomly selects from the available resources to be reused by D2D pairs without any constraints, this is the simplest one to apply but of course it is not practically used in real network as we will have high interference by the way of resources selection randomly [28].

2.5.2 Balanced Random Allocation (BRA)

BRA is an improvement for RRA, we select resources by the minimum number of times a resource has been used. [28]

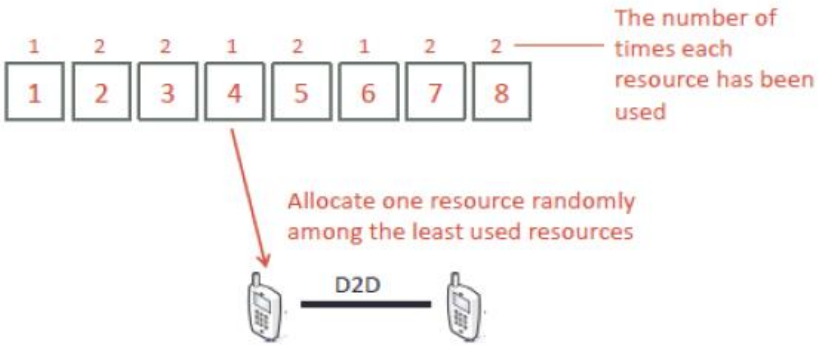


Figure 2. 5 Balanced Random Allocation [28]

2.5.3 Cellular Protection Allocation (CPA)

This algorithm used two constraints for resource allocation minimum number of times a resource used and maximum cellular path gain [28]

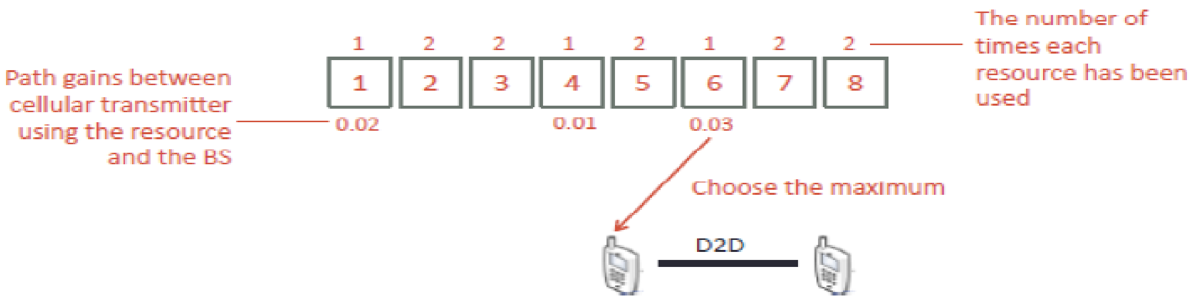


Figure 2.6 Cellular Protection Allocations [28]

2.6 Power Control and Security

Adjusting transmission power for reusing the frequency is an area of interest for the researchers. It is particularly important in case of uplink transmissions because of the near-far effect and co-channel interference. Security needs to be well considered during implementation of the D2D Communications in cellular network as channels are vulnerable to a number of security attacks like eavesdropping, message modification, and node impersonation [29].

2.7 Interference Management Schemes

We divide the schemes by interference avoidance, interference cancellation and interference coordination Techniques [29].

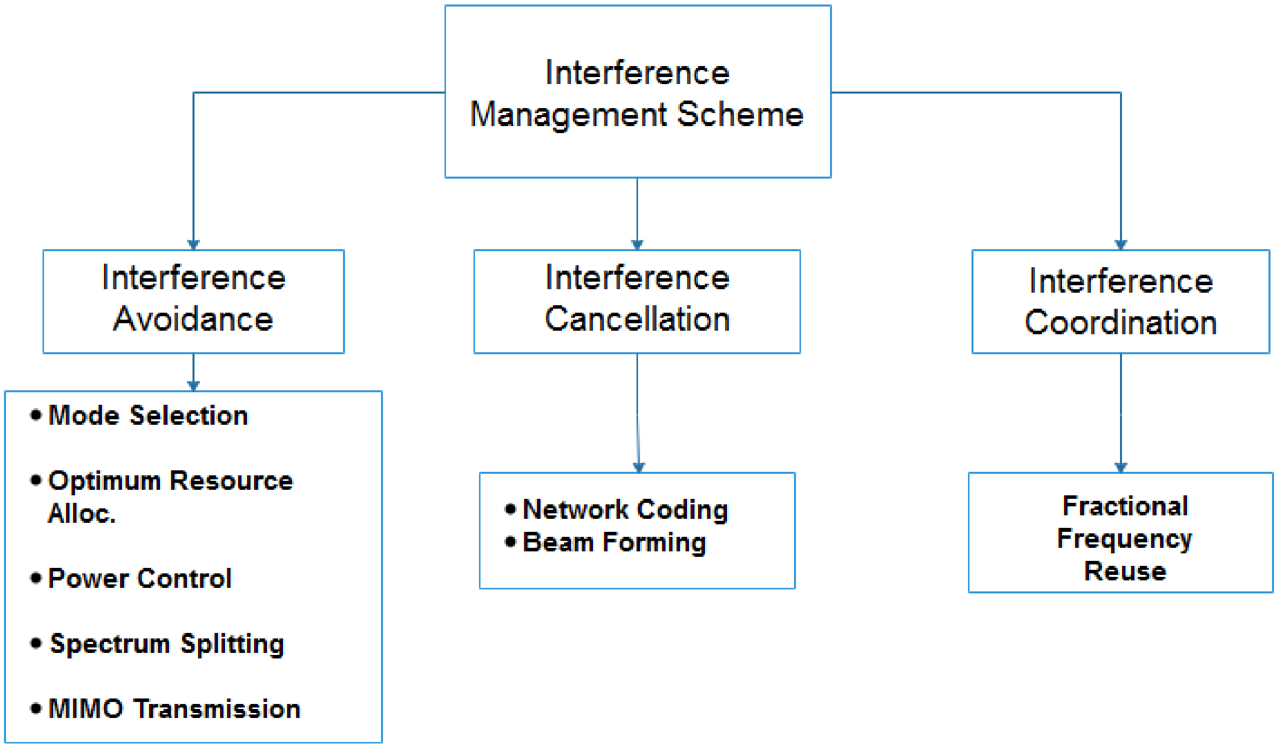


Figure 2.7 Interference management Schemes [29]

2.8 Related Works in Mode Selection

The authors of [14], the mode selection, resource group assignment and power allocation problems in D2D communications were studied and they formulated resource allocation problem to maximize the sum rate of network. They used the Mixed-Integer Non- Liner Programing to solve it but they did not consider the mobility of users and quality of connection in their assumptions.

The authors of [17] considered the energy efficient aspect in mode selection, the success probability for both links; cellular, D2D was considered, and relation between the success probability and signal-to-interference was analyzed but they did not present any geometric area related to this analyzed that can used as mode selection map.

The authors of [18], Jedidi and Besbes proposed a new approach for D2D discovery applicable for the public safety scenario. The scheme was based on spreading approach using orthogonal codes. The transmitted signal of a victim is spreaded to an orthogonal code from Hadamard matrix so when received with the amount of other signals, it can be isolated. The detection depends on the correlation process between the received signals and the expecting spreaded SOS. A successful detection relies on a threshold value.

Hayat and Ngah in [23] proposed Device discovery for D2D communication in in-band cellular networks using sphere decoder like (SDL) algorithm. The group of devices forms a lattice structure, and it is positioned in the coverage area. The hyper sphere is constructed based on the power knowledge of a discoverer device which helps for accurate and fast device discovery in a lattice structure. Besides, sphere decoder like (SDL) algorithm is applied for quick and precise discovery in the lattice structure.

In [20] the mode selection issue for then D2D UEs move from one cell to other cells are considered. The presented method in this work is able to efficiently offer the attractive energy efficiency, data rate, and packet delivery ratio benefits.

In [21]the mode selection and spectrum sharing problem in D2D communications was analyzed and they considered one cell and they presented locations that D2D pairs can operate in reused mode by assuming other users were fixed.

In reference [6] a D2D clustering approach is used to enhance the performance of public safety networks. In each cluster, a single device, the cluster head, is selected to communicate with the base station in either uplink or downlink direction, or both. The cluster head relays the information from and or to the other cluster members. Neighboring UEs use orthogonal resources, and thus interference is not an issue. The cluster head is the UE which can achieve the highest throughput from and/or to the base station. On the one hand, this is beneficial as this provides the highest possible throughput to the cluster. On the other hand, not all devices are suitable for serving as cluster head. Dismounted personnel wear small communication means with limited battery capacity. Choosing one of them as a cluster head can severely impact their UEs battery life and ultimately leave a first responder without a working means of communication. Our preference is to use a dedicated cluster head with suitable communication equipment and power supply to perform this task.

CHAPTER THREE

SYSTEM MODEL AND SIMULATION

CHAPTER THREE

System Model and Simulation

3.1 System Model

The focus of this project will be only on uncentralized scenarios for the selection of D2D pairings. The peer discovery process should be efficient, so that D2D relationships are identified and formed rapidly. In cellular networks, D2D communication may be a relatively recent technology. As a result, universally acceptable methods for peer discovery remain elusive. From the network's standpoint, device discovery can be firmly or loosely managed by the base station. In cellular networks, peer discovery is classified as with or without UEs transmitting "discovery beacons." [19] [20].

A device can be broadcasting through the air an expression like we are a coffee shop, a device with application filters out relevant expressions from all it detects through air interface so we can get expressions for emergency or other interesting things. So, we can send our positions to other mobile and we can calculate SINR based on any algorithm.

This D2D discovery without the gNodeB support is the best solution for public safety networks. In this scenario transmission mode2 (UE-selected) is used where the UE selects which resources to use for transmission. The resources are selected at random to minimize the collision risk [7].The overall procedure of D2D (Sidelink) communication and corresponding Physical/MAC feature will pass through three main steps which are the synchronization, discovery and at last the communication. The Methods of Discovery in uncentralized case strategy will be as follows:

a) Beacons will be sent for device discovery broadcasted using side link channel PSDCH using preconfigured discovery resource pools [22]

b) Filtration of this beacons by receiver (Rx) and acknowledge response with all main information: temporary ID, location, SINR will be sent.

c) Resource pools configurations for D2D transmission and reception will be sent on PSCCH and PSSCH up to eight resource pools [23]

d) Decision of selection of D2D pair’s candidate will be the responsible of the transmitter (TX) according to the algorithm that we will use for discovery.

3.1.1 Small Area and Large Area Scenarios

They designed a single cell scenario with a BS in the center damaged by a disaster, so the edges or resource allocations by gNodeB were absent, so they considered the single cell a small area without coverage, from Fig.3.1 the coordinates from the cell and BS also can be seen CUE which is represented by a blue circle only For clarity and knowledge of the uncovered region parameter, filter pairs of D2D contacts (each red circle representing a filtered D2D user) randomly distributed in the region where the BS is located below. Only one resource group (RB) is reused for all communication links so that it can measure the maximum interference in the system.

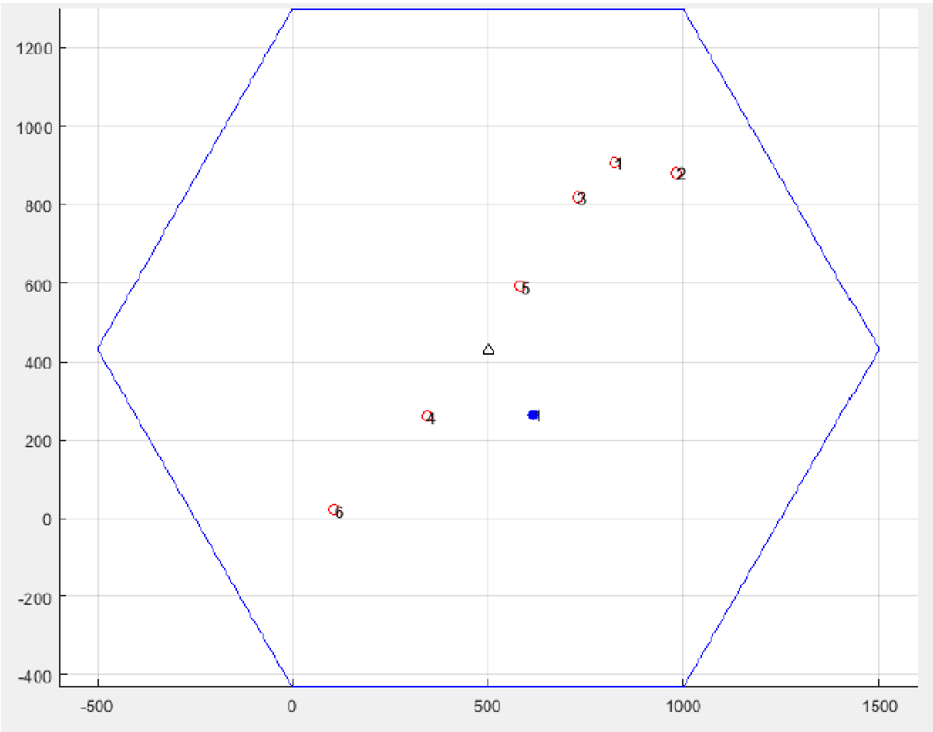


Figure 3.1 Single cell representations in MATLAB

3.1.2 Large Scale Area (multicell)

In this scenario the only difference between it and the previous one is the disaster area which is larger, this scenario occur may because of war or in natural disasters like earthquake or volcanic eruptions. Used all the previous parameter but only changed the size of the area as shown in Figure 3.2

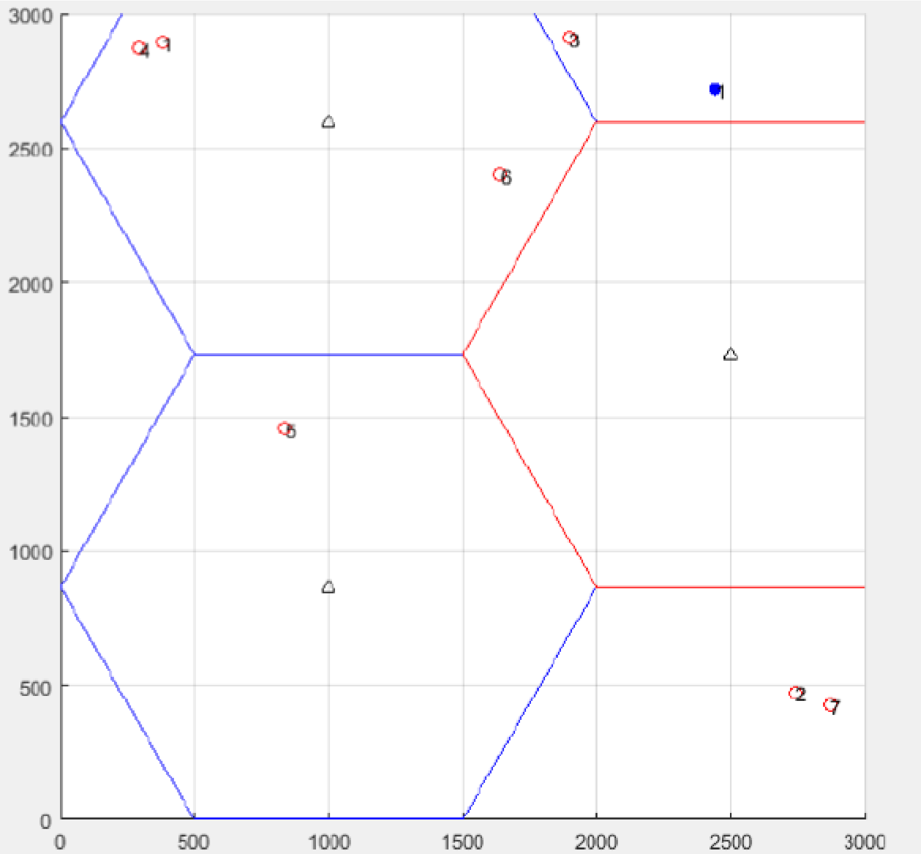


Figure 3.2 Multicell using MATLAB

3.2 Channel model

Models are needed for wireless system design and operational deployment of such systems, the main three components of Channel model:

- **Path Loss** It is the relation between the link distance d and the mean attenuation in a given environment

$$A_{PL} = C\left(\frac{d}{d_0}\right)^{\gamma} \qquad 3.1$$

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

- **Shadowing** It is Random attenuation, fluctuation around the path loss due to presence of large obstacles (buildings, hills,) which shadow the propagation path the large-scale fluctuations of the attenuation are well described by a log-normal distribution.

$$F_A A_{SH} = (\frac{1}{\sqrt{2\pi\sigma_{SH}^2}}) \exp(-(As_H - \mu)^2 / 2\sigma_{SH}^2) \qquad 3.2$$

Where variable A_{SH} is the additional attenuation in dB w.r.t. the path loss, μ is the mean and σ_{SH} is the standard deviation in dB

- **Multipath fading** the multipath attenuation derives from the combination at the receiver of more signal components (reflections or echoes) with phase and amplitude differences. Where αn and **τ**n are the attenuation and the propagation delay of the n-th respectively.

3.3 SINR Calculations

One of the main parameters that can Devices or BS can make resource allocations according to it is signal to interference plus noise ratio.

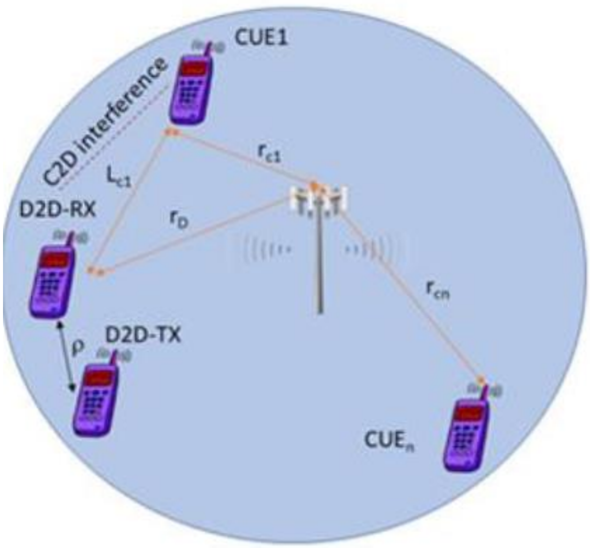


Figure 3.3 SINR Calculation

The distance between the CUEi and D2D-Rx is given as

$$L_{Ci} = \sqrt{(r_{ci}^2 + r_D^2 - 2\, r_{ci}\, r_D \cos\theta_i} \qquad 3.3$$

r_{ci} = *distance between cellular user equipments and base station*

r_D = *distance between D2D − Rx and base station*

θ_i = [0,2π]

Received signal at the D2D-Rx

$$y_i = h_D\sqrt{P_D}\rho^{-\alpha}\, x_D + h_{Ci}\sqrt{P_{Ci}}\, L_{Ci}{}^{-\alpha} x_{Ci} + N_0 \qquad 3.4$$

$\mathbf{h_D}$ *Fading Coeffiecent in D2D linkZ,* $\mathbf{h_{Ci}}$ *Fading coeffiecent in CUE interference link to D2D Rx,* $\boldsymbol{P_D}$, $\mathbf{P_{Ci}}$ *are transmit power of D2D − TX and CUE,* $\mathbf{x_D}$, $\mathbf{x_{Ci}}$ *are both signals of D2D − TX and CUE signal to BS,* $\boldsymbol{P_D}\boldsymbol{\rho}^{-\alpha}$ received power at D2D-Rx for D2D link, $\mathbf{P_{Ci}L_{Ci}}^{-\alpha}$ received power at D2D-Rx for C2D interference link, $\mathbf{N_0}$*AWGN*.

So SINR:

$$\gamma_{Di} = \frac{|\,hD\,|^2\, P_D \rho^{-\alpha})}{|\,h_{Ci}|^2\;P_{Ci}L_{Ci}{}^{-\alpha} + N_0} \qquad 3.5$$

Calculate the SINR at every D2D receiver (Rx) which have interference signal

$$SINR_{DL\,\gamma Rx1\,Candidate} = \frac{P_{D2DTx1\,Candidate}\,.G1}{P_{D2D\,TX2\,Candidate}\,.G9 + P_{D2D\,TX3}.G5 + N_0} \qquad 3.6$$

Where

G1= $G_{TX}\;.\;G_{RX}\;C.\;L_{C1}{}^{-\alpha}\,.\,|h_{D1}\;\;|^2.\;\Delta_{SH1}$

G5= $G_{TX}\;.\;G_{RX}\;C.\;L_{C5}{}^{-\alpha}\,.\,|h_{D5}|^2.\;\Delta_{SH5}$

G9= $G_{TX}\;.\;G_{RX}\;C.\;L_{C9}{}^{-\alpha}\,.\,|h_{D9}|^2.\;\Delta_{SH9}$

Interference from eNode B and CUE can be neglected

$$SINR_{DL\,\gamma Rx2\,Candidate} = \frac{P_{D2DTx2}\;.G3}{P_{D2D\,TX1\,Candidate}\,.G6 + P_{D2D\,TX3}\,.G7 + N_0} \qquad 3.7$$

G3= $G_{TX}\;.\;G_{RX}\;C.\;L_{C3}{}^{-\alpha}\,.\,|h_{D3}|^2.\;\Delta_{SH3}$

G6= $G_{TX}\;.\;G_{RX}\;C.\;L_{C6}{}^{-\alpha}\,.\,|h_{D6}|^2.\;\Delta_{SH6}$

$G7 = G_{TX} \;.\; G_{RX}\; C.\; L_{C7}{}^{-\alpha}.\, |h_{D7}|^2.\; \Delta_{SH7}$

$$SINR_{DL\,\gamma Rx3\,Candidate} = \frac{P_{D2DTx3}\;.G2}{P_{D2D\,TX\,Candidate}\,.G4 + P_{D2D\,TX}\,.G8 + N_0} \qquad 3.8$$

Where

$G2 = G_{TX} \;.\; G_{RX}\; C.\; L_{C2}{}^{-\alpha}.\, |h_{D2}|^2.\; \Delta_{SH2}$

$G4 = G_{TX} \;.\; G_{RX}\; C.\; L_{C4}{}^{-\alpha}.\, |h_{D4}|^2.\; \Delta_{SH4}$

$G8 = G_{TX} \;.\; G_{RX}\; C.\; L_{C8}{}^{-\alpha}.\, |h_{D8}|^2.\; \Delta_{SH8}$

Where **C** Attenuation at Reference distance, $\boldsymbol{G_{TX}}$ *Antenna TX Gain*, $\boldsymbol{G_{RX}}$ *Antenna Rx Gain*, $\boldsymbol{\Delta_{SHi}}$ *i Shadowing*, $\mathbf{h_{Di}}$ *Fading Coeffiecent in D2D link*, $\mathbf{L_{Ci}}^{-\alpha}$ Path Loss, $\mathbf{N_0}$ *AWGN*.

3.4Different techniques of selecting D2D pair

3.4.1 Shortest distance of discovery between D2D devices algorithm (SDA)

In selecting this algorithm it will be based on the shortest distances between devices ignoring SINR values even though we have a minimum sinr value for the system to work, the minute has started. SINR threshold with 0, then 10 and 20 dB to analyze differences in SINR threshold increment on the system. Expect only one D2D pair, and the probability of disconnection is high with respect to the number of D2D distributed devices. This algorithm can be used by D2D devices for the rescue team to search for survivors in their surroundings.

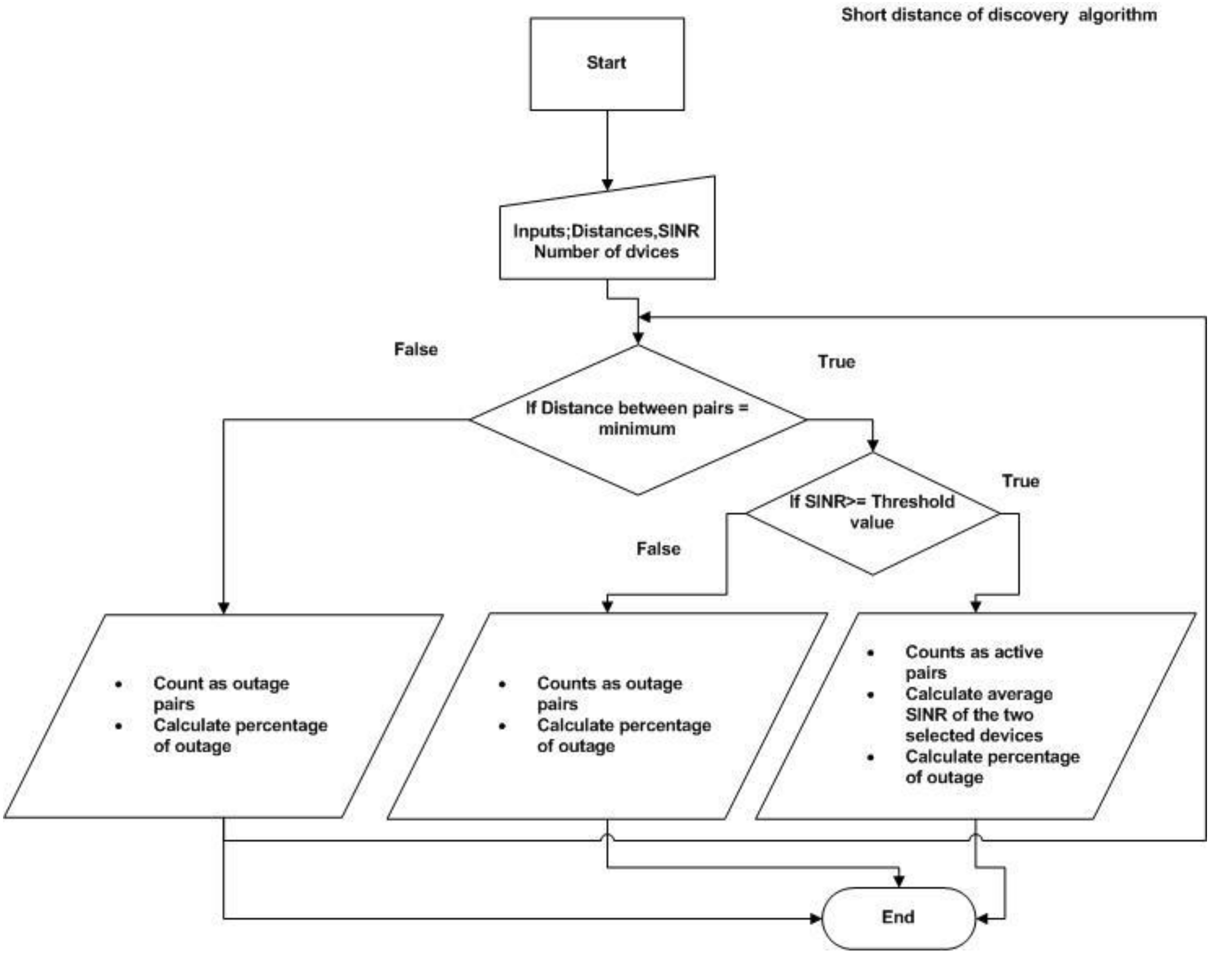


Figure 3.4 SDA flowchart

3.4.2 Maximum SINR with no limit on distance of discovery algorithm (MSNA)

In this algorithm, the algorithm selection will depend on the SINR values, as it chose the D2D pair if it meets the minimum SINR and chooses the best pair with the maximum SINR values in both directions, this algorithm may theoretically be the best as we did not take into account the detection distance threshold, and also If we solve this problem by rebroadcasting the beacons then there is a time range for detection.

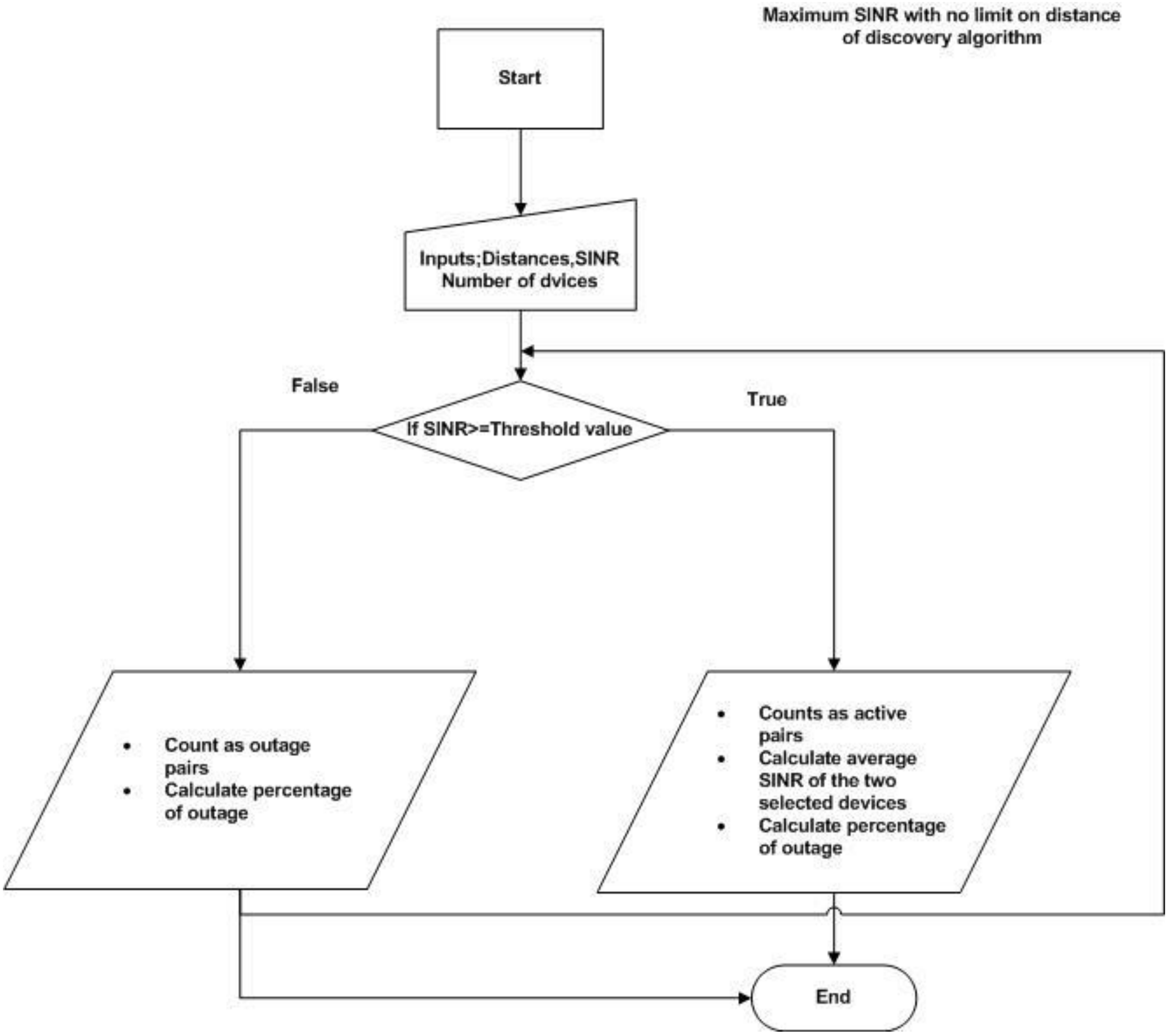


Figure 3.5 Maximum SINR with no limit on distance of discovery algorithm Flowchart

3.4.3 Maximum SINR with limit on distance of discovery to500m algorithm (MSLA)

In this algorithm distances threshold for mobile discovery is up to 500 m as in LTE Direct standards so we can use this algorithm with portable Base station as in LTE-A

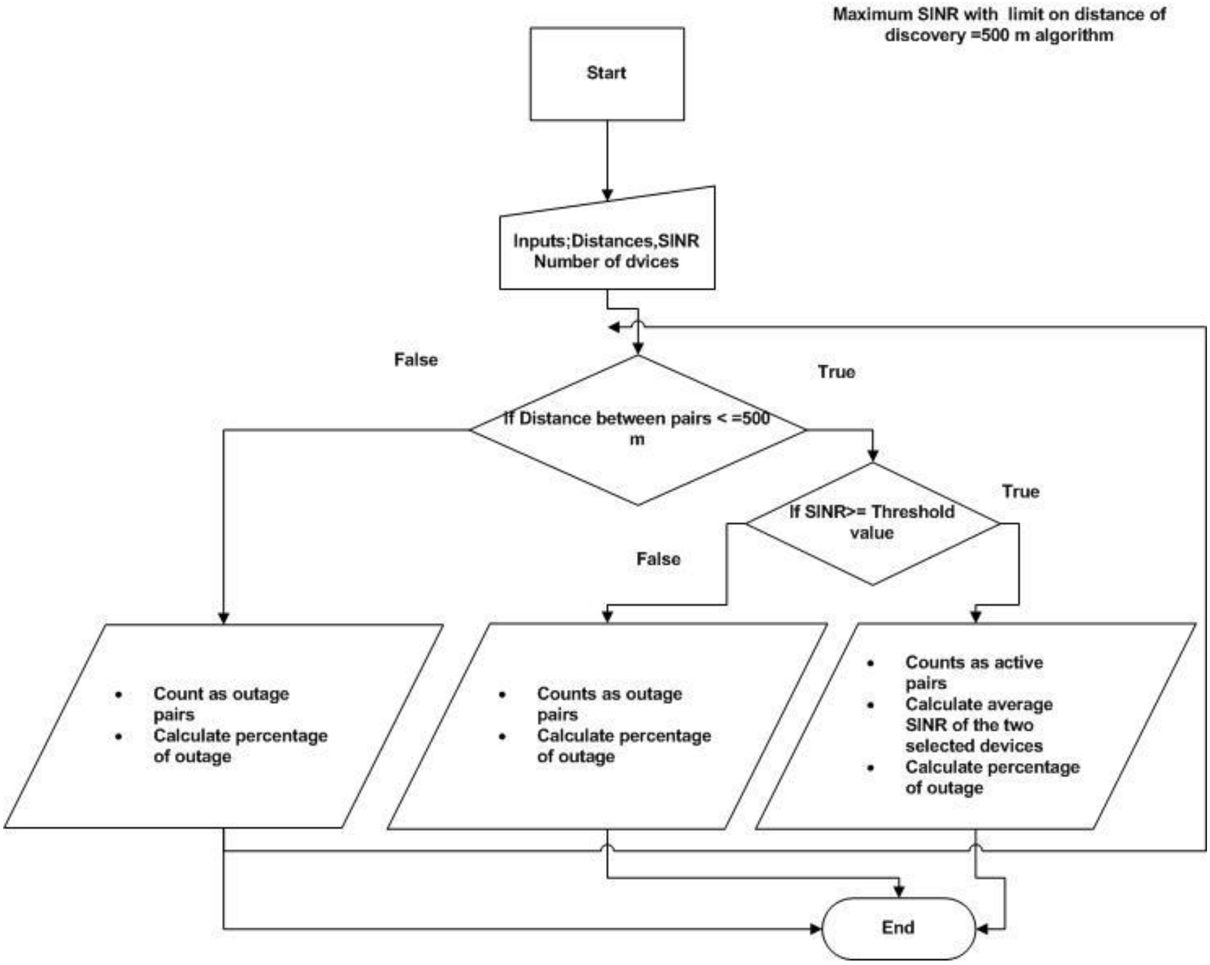


Figure 3.6 Maximum SINR with limit on distance of discovery to 500m algorithm Flowchart.

The system model he designed is capable of distributing multiple D2D devices randomly calculate the position and distance between each device as shown in Figure 3.7 and to calculate our SINR key parameter between each D2D device. They built our wireless channel by adding key parameters to calculate the signal to interference plus noise ratio (SINR), to obtain reliable measurement using the values of the medium channel model parameters as well as average results from 400 runs per number of randomly distributed devices also since it may not be detected Peer detection Number of filter devices Even with a better metering than the specified device, consider applying a random-numbered D2D pair selection algorithm to distributed devices to get accurate results of what to expect in a real-life scenario. When creating reliable models for future 5G system design, a path loss model should be constructed to balance the correlation and predict signal strength as shown in the table.4.1. Consider implementing a randomly numbered D2D pair selection algorithm on distributed devices to obtain accurate results for what to expect in a real-life scenario [32].

Table 3.1 System Main parameter

Number of iterations(simulation runs)	400
Fixed Path Loss	30.18
D2D Link distances small area(single cell)	Max 2 Km
D2DLink distances large area(multicell)	Max 4.3 Km
Path loss exponent	2.6 dB
Shadowing	4dB
Number of RB	1
Transmitter Gain(G_{Tx})	20-25 dBm
Receiver Gain(G_{Rx})	20-25dBm
Additive White Gaussian Noise (AWGN)	1-3dB
Number of D2D Devices	3-15

CHAPTER FOUR

RESULTS AND DISCUSSION

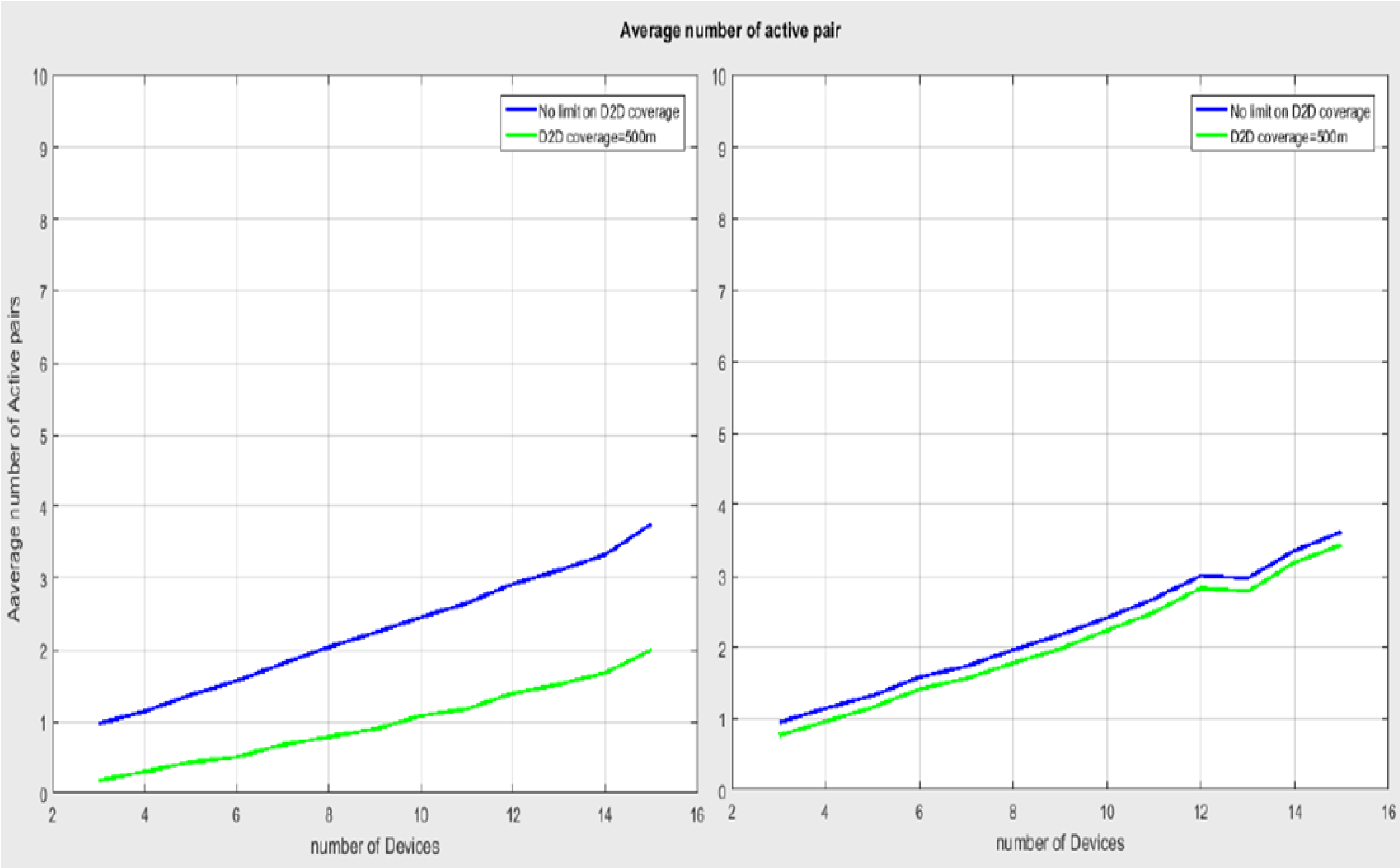
CHAPTER FOUR

RESULT AND DISCUSSION

The results in this part are based on Matlab simulation and are produced from the mathematical equations mentioned in the previous Section in Chapter Three. Following the classification of the device peer discovery techniques, The Matlab code is included in the appendix. Table 3.1 is a list of the primary simulation parameters that were utilized in the simulation results. These parameters are commonly utilized in wireless cellular network simulation.

Average number of active pair using different algorithm

This is the first plot for a multicellular cell and a single cell, Figure 4.1(A) represents simulation in multiple cells and the Figure 4.1(B) is the single cell also for all the following graphs that they represent in the same sequence. Consider the large area to be the multicellular region and the small area to be the single cell because there is no BTS to generate the cells. In Figure 4.1,They compared the average number of active D2D pairs for a different number of devices in a disaster situation using the maximum SINR with no detection algorithm distance limit MSNA-blue plot representation and the maximum SINR with detection distance limit to 500m algorithm representation MSLA-green plot in the multi-cell large-sized macro-area cells and single-cell small-sized micro-cell scenarios. The blue graphic represents the average number of active D2D pairs without applying any condition SINR should only be above 0 dB and this applies to all selected D2D pairs with respect to the number of devices. The green graphic represents the average number of active D2D pairs with a coverage range between devices of 500 meters applied for the number of devices.



A) multicellular cell B) single cell

Figure 4.1 Average numbers of active pair

The green plot in multiple cells is about 50% less than it was in a single cell, as they distributed the devices and the maximum distance between the devices is 2 km and the green plot represents D2D with a maximum distance of 500 meters and thus the probability of getting an active D2D pair is higher than the multicell. In multi cells, the maximum distance between devices is 4 kilometers. The blue plot in Multicell is larger in a small percentage than in single cell because the distribution of mobile devices with low likelihood of interference with regard to distances is significantly higher in Multicell than in single cell since MSNA does not depend on detection distances.

Furthermore, due to the enlarged area and MSLA dependency on the maximum detection distance of 500 m, the variations in the number of D2D pairings that originated in a single cell utilizing both techniques are small when compared to numerous cells. They found that the more devices there were, the higher the average number of active pairs.

4.2 Average SINR

As shown in the below figure 4.2 , The green plot represents the average SINR in two directions as we select the best pair with highest SINR value MSNA Algorithm. The blue plot represents the average SINR in two directions with restrictions of selection of pairs with maximum distance between devices is 500 meters MSLA Algorithm while the red plot represents the average SINR in two directions of pairs of shortest distance between Devices applying shortest distance of discovery Algorithm SDA.

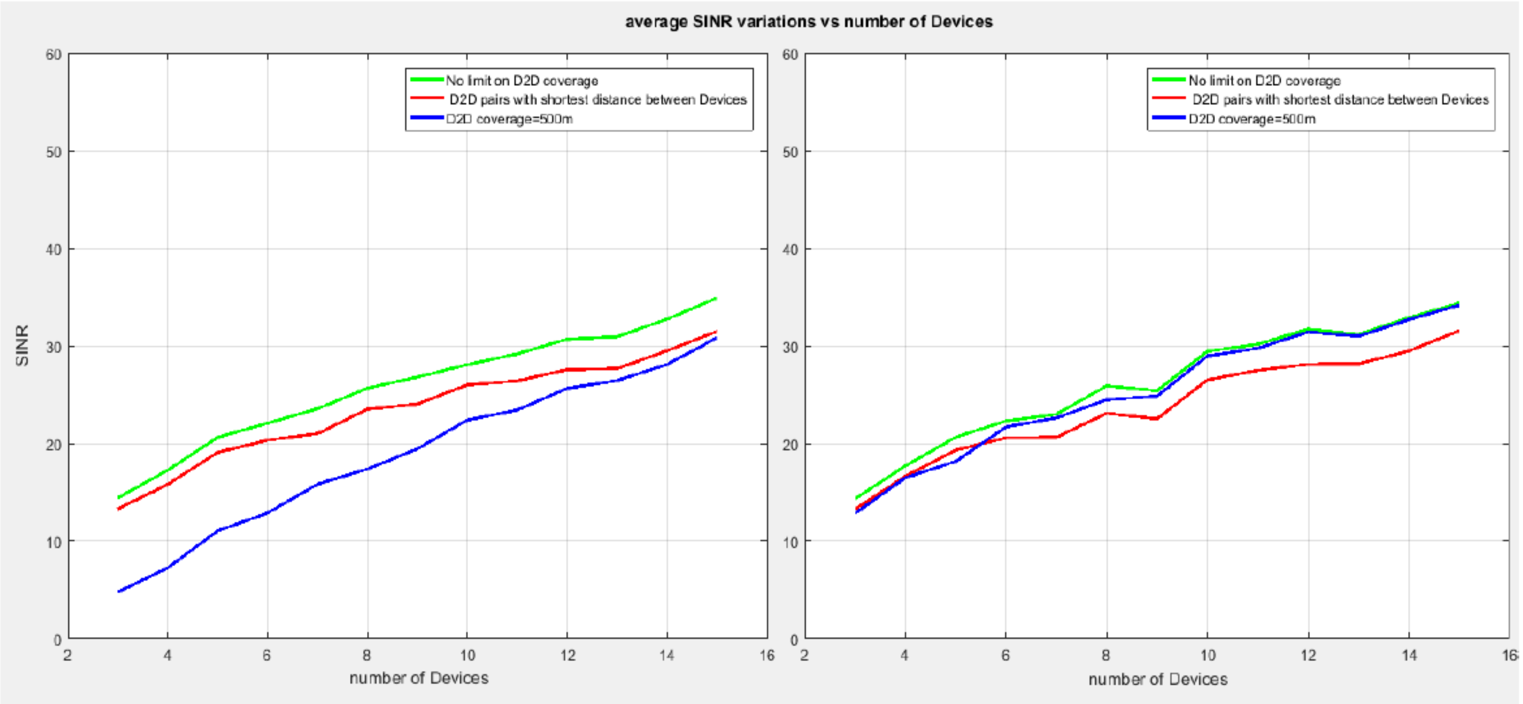


Figure 4.2 Average SINR using different algorithms VS Number of Devices

In this scenario choose a pair and obtain the mean SINR as in the green drawing the shortest distance from the detection algorithm (SDA) is represented in red they are on average SINR differences versus the number of devices using previous technologies in a single cell and multicell. It is clear that the average SINR without distance restrictions will be higher in both scenarios green plot but in a single cell scenario we see the average SINR maximum technology 500 meters higher From the shortest technical distance such as the probability of getting a D2D pair with a high SINR rate compared to a D2D pair with shorter distances between them is very high, and unlikely in multiple cells where the shortest distances or more kilometers rejected in the average SINR with a threshold of 500 meters until the red plot However, the representation in multiple cells is higher than the blue color even in a certain number of devices by increasing the number of devices leads to a normal state in which the blue plot rises from the red same as the single cell scenario.

4.3 Probability of outage

In the below figure 4.3, the Y-axis represent the outage in percentage with respect to number of devices in X-axis distributed randomly so 3.5% for the blue plot which represent the number of D2D pairs without any distance restrictions MSNA and is very low percentage and 29% for the red plot which represent the selection of D2D pair according to the shortest distance between devices SDA and 80% in the green plot represents the outage of active D2D Pairs using maximum distances between devices 500 m for selection of D2D pairs MSLA which means very high outage.

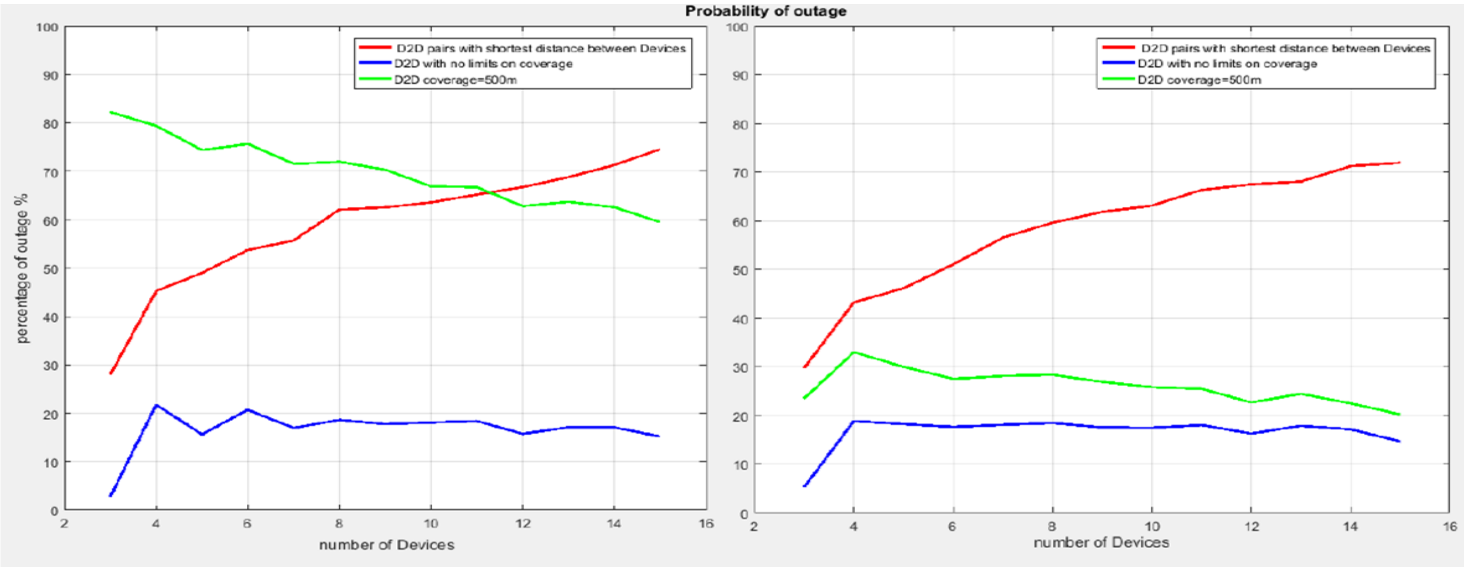


Figure 4.3 Probability of outage vs. Number of Device

As with their interruption rate calculation, calculate .The total number of active D2D pair is determined and the number of active D2D pair is subtracted from it using the algorithm then we obtain the discontinuity percentage for each algorithm.

4.4 Average Number of Active pair for different distances threshold

Each segment represents the average number of pairs identified using a specified number of devices and with respect to the maximum distance between devices for pair selection in a multi-cell and single-cell scenario so that we can notice that as the number of devices increases from the average the number of pairs also increases as we increase the threshold of distance between devices , The average number of D2D pairs increases and compared to the multiple cells by increasing the area of the mobile phone distribution and this affects the average number of D2D pairs by reducing it.

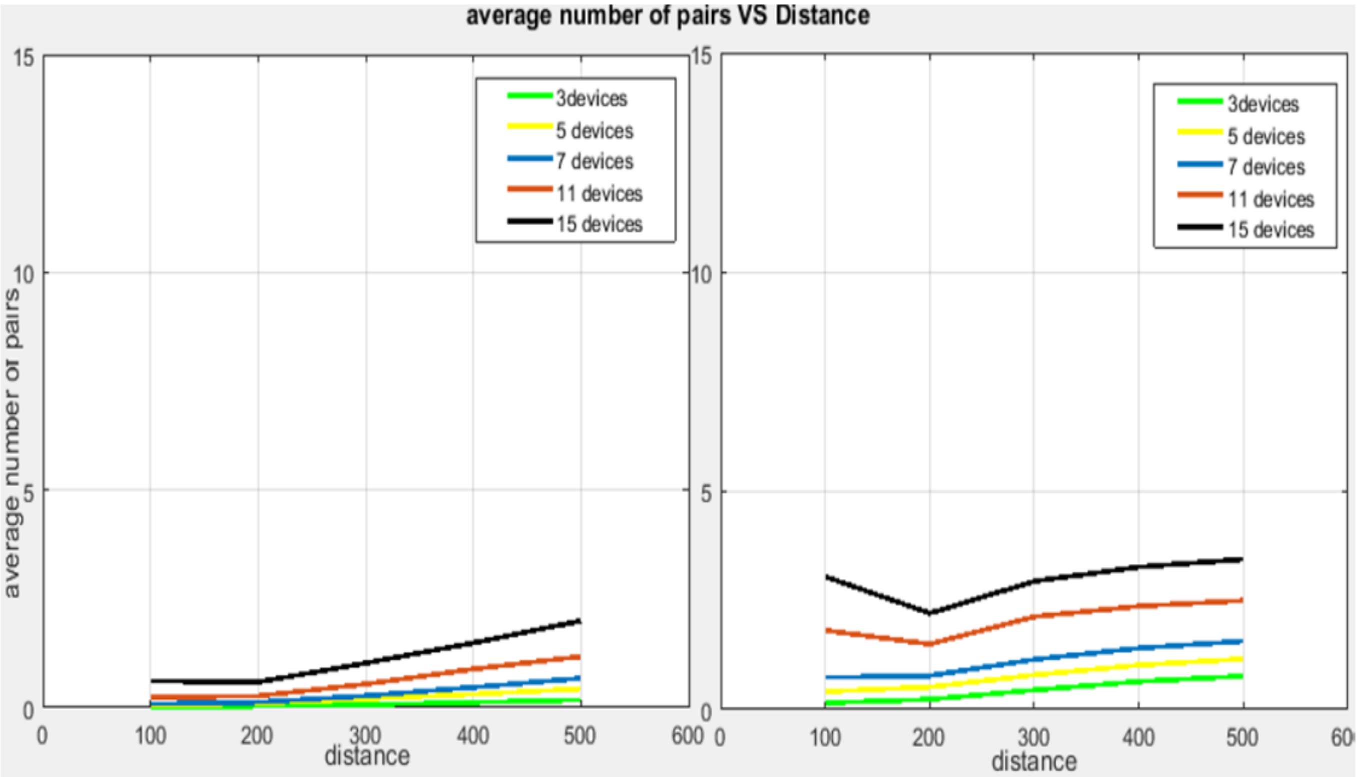


Figure 4.4 Average numbers of pairs Vs. Distance.

There are two main factors that influence Interruption ratio which is the number of devices and the maximum number of pairs from this number of devices arose in what we saw an effect.Change the limit regarding the number of devices and the calculation of the output knowing this, we can increase and decrease the detection threshold distance between devices a great influence on the percentage of interruptions**.**

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

CHAPTER FIVE
CONCLUSION AND FUTURE WORK

5.1 Conclusion

In this thesis, the device-to-device communication performance is compared and evaluated using 5G system discovery methods. Phase device analog discovery and D2D use. The peer detection system was introduced using three main algorithms. Shortest detection distance between D2D devices (SDA) Maximum SINR without detection algorithm distance (MSNA) and Maximum SINR with detection distance limit to 500 meters (MSLA) The algorithm is applied in single cell scenarios for emergency and multi-cell scenarios, get results using Matlab. It is found that the devices are active pairs. In a SINR average scenario, the shortest distance is represented by a detection algorithm (SDA), which represents, on average, SINR differences versus the number of devices using previous technologies in single and multicellular cells. Obviously, the mean SINR without distance constraint will be higher in both scenarios, in the single cell scenario; the average SINR found a maximum of 500 meters at the shortest technical distance. Note that the less efficient the algorithm, the algorithm used is an algorithm for the shortest SDA distance because it will only identify the active D2D pair and ignore all other devices so that the number of devices increases the probability of power outages. Two main factors that affect the outage rate are the number of devices and the maximum number of pairs. The greater the number of devices, the greater the number of pairing pairs.

5.2 Recommendations

This study looked on the usage of fixed multi D2D in 5G systems.
However, there are certain outstanding concerns that can be pursued in future research endeavours, such as:

- A simple model for simulating a small emergency scenario was built. More research may be done to introduce a bigger region where Relays with multi User scenarios for many cells can be employed.

- Scheduling and interference management are not handled in this thesis work to simplify complexities. As a result, future study may include a more comprehensive evaluation of relay nodes that considers the scheduling impact of interferences and the associated Path loss.

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APPENDICES

D2D Pair detection Matlab Code

%Constants:-

```
R=250; R2=500; % Hexagon Raduis
len=1500; len2=5000; % lenght of the whole area
wid=1500; wid2=5000; % Width of the whole area
pt=24; %Transmit Power(dbm)
Bw=20*10^6; %Total Bandwidth (Hz)
f=1.9*10^9; %Carrier frequency (Hz)
d0=10; %Reference distance in m
y=3.7; %Path loss Exponent
c=3*10^8; %Speed of Light
lammda=c/f; %Wavelenght (m)
k=20*log(lammda/(4*pi*d0)); %Constant Depend on antenna (db)
a1=-110; b1=-135; %Noise Range upper and lower limits (dbm)
W=1 ; E=3; %Interferance Range upper and lower limits(dbm)
for p= 1:15
b= [2:2:16 25 30 40 50 100 200 250];
D2D=b (p); %no. of D2D devices
```

% Drawing the Hexagon

```
nx11=len/(2*R); nx=round(nx11) % x size
ny1=wid/(2*R); ny=round(ny1); % y size
grid on;
```

% one hexagon coordinates

```
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;
for nxc=1:nx
for nyc=1:ny
plot(x+xh,y+yh,'b'); plot(x,y,'k^');
grid on;
xcell=[xcell x]; ycell=[ycell y]; %recording cell coordinates
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,'b'); plot(x,y,'k^'); grid on;
xcell=[xcell x]; ycell=[ycell y]; %recording cell coordinates
y=y+sqrt(3)*R;
end
x=x+3*R; y=y0;end
axis equal; axis([0 len 0 wid]); grid on;
```

%Generating the Users Randamly and Uniformaly

```
D2Dxuser=rand(1,D2D).*len; D2Dyuser=rand(1,D2D).*wid;
D2Dxuser2=rand(1,D2D).*len2; D2Dyuser2=rand(1,D2D).*wid2;
subplot (3,5,p) , scatter(D2Dxuser,D2Dyuser,'red','filled');
for i=1:1:D2D
text(D2Dxuser(i)+50,D2Dyuser(i)+50,num2str(i)); %giving each of D2D user a number
end
```

% Calculating SINR

```
for i=1:1:D2D
for j=1:1:D2D
DIST(i,j)=sqrt((D2Dxuser(i)-D2Dxuser(j)).^2+(D2Dyuser(i) D2Dyuser(j)).^2);
Pr_dbm(i,j)=pt+k-y*log((DIST(i,j)/d0)); %Received Power (dbm)
n1_dbm(i,j)=(a1+(b1-a1).*rand); % Noise Range(dbm)
INT_dbm(i,j)=(W+(E-W).*rand); %Interferance(dbm)
SINR_dbm(i,j)=Pr_dbm(i,j)-n1_dbm(i,j)-INT_dbm(i,j);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
DIST2(i,j)=sqrt((D2Dxuser2(i)-D2Dxuser2(j)).^2+(D2Dyuser2(i)-D2Dyuser2(j)).^2);
%Calculating the distance between each user
Pr2_dbm(i,j)=pt+k-y*log((DIST2(i,j))/d0); %Received Power (dbm)
n12_dbm(i,j)=(a1+(b1-a1).*rand); % Noise Range(dbm)
INT2_dbm(i,j)=(W+(E-W).*rand); %Interferance(dbm)
SINR2_dbm(i,j)=Pr2_dbm(i,j)-n12_dbm(i,j)-INT2_dbm(i,j); % SNIR(dbm)
end
end
distD2D= DIST;
Received_power= Pr_dbm./100;
SINR= SINR_dbm./100;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
distD2D2= DIST2;
Received_power2= Pr2_dbm./100;
SINR2= SINR2_dbm. /100;
```

% Best D2D Pair According to Shortest Distance

```
active_pair1=0; active_pair4=0; active_pair5=0; active_pair6=0; active_pair7=0;
for i=1:1:D2D
for j=1:1:D2D
if (distD2D(i,j)<500 && distD2D(i,j)~= 0 )
active_pair1=active_pair1+1;
l=i; KL=j; kj=distD2D(i,j);
X = sprintf('%d AND %d will be pair. threshold is 500m and distance between them is %d
\n',l,KL,kj);
disp(X)
else
active_pair1=active_pair1;
end
if (distD2D(i,j)<100 && distD2D(i,j)~= 0 )
active_pair4=active_pair4+1;
l4=i; KL4=j; kj4=distD2D(i,j);
X = sprintf('%d AND %d will be pair. threshold is 100m and distance between them is %d
\n',l4,KL4,kj4);
disp(X)
else
active_pair4=active_pair4;
end
if (distD2D(i,j)<200 && distD2D(i,j)~= 0 )
active_pair5=active_pair5+1;
l5=i; KL5=j; kj5=distD2D(i,j);
X = sprintf('%d AND %d will be pair threshold is 200m and distance between them is %d
\n',l5,KL5,kj5);
disp(X)
else
active_pair5=active_pair5;
end
if (distD2D(i,j)<300 && distD2D(i,j)~= 0 )
active_pair6=active_pair6+1;
l6=i; KL6=j; kj6=distD2D(i,j);
X = sprintf('%d AND %d will be pair. threshold is 300m and distance between them is %d
\n',l6,KL6,kj6);
disp(X)
else
active_pair6=active_pair6;
end
if (distD2D(i,j)<400 && distD2D(i,j)~= 0 )
active_pair7=active_pair7+1;
l7=i; KL7=j; kj7=distD2D(i,j);
X = sprintf('%d AND %d will be pair. threshold is 400m and distance between them is %d
\n',l7,KL7,kj7);
disp(X)
```

```
else
active_pair7=active_pair7; end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
all_possible_pairs (p) = (D2D * D2D ) - D2D
active_no_of_pairs_according_to_distance_500(p)=active_pair1
percent_of_acive_pair_according_to_distance_500(p)=(active_no_of_pairs_according_to_distan
ce_500(p)/all_possible_pairs(p))*100
percentage_of_outage_according_to_distance_500(p)=100-
percent_of_acive_pair_according_to_distance_500(p)
active_no_of_pairs_according_to_distance_100(p)=active_pair4
percent_of_acive_pair_according_to_distance_100(p)=
(active_no_of_pairs_according_to_distance_100(p)/all_possible_pairs(p))*100
percentage_of_outage_according_to_distance_100(p)=100-
percent_of_acive_pair_according_to_distance_100(p)
active_no_of_pairs_according_to_distance_200(p)=active_pair5
percent_of_acive_pair_according_to_distance_200(p)=
(active_no_of_pairs_according_to_distance_200(p)/all_possible_pairs(p))* 100
percentage_of_outage_according_to_distance_200(p)=100-
percent_of_acive_pair_according_to_distance_200(p)
active_no_of_pairs_according_to_distance_300(p)=active_pair6
percent_of_acive_pair_according_to_distance_300(p)=
(active_no_of_pairs_according_to_distance_300(p)/all_possible_pairs(p))* 100
percentage_of_outage_according_to_distance_300(p)=100-
percent_of_acive_pair_according_to_distance_300(p)
active_no_of_pairs_according_to_distance_400(p)=active_pair7
percent_of_acive_pair_according_to_distance_400(p)=
(active_no_of_pairs_according_to_distance_400(p)/all_possible_pairs(p))* 100
percentage_of_outage_according_to_distance_400(p)=100-
percent_of_acive_pair_according_to_distance_400(p)
end; end
```

%Best D2D Pair According to SINR

```
active_pair2=0; active_pair8=0; active_pair9=0;
for i=1:1:D2D
for j=1:1:D2D
if (SINR(i,j)<-18 && SINR(i,j)~= Inf )
active_pair2=active_pair2+1;
l2=i; KL2=j; kj2=SINR(i,j);
X = sprintf('%d AND %d WILL BE PAIR. Threshold is -18 dBm and SINR between them is %d
\n',l2,KL2,kj2);
disp(X)
else
active_pair2=active_pair2;
end
if (SINR(i,j)<-22 && SINR(i,j)~= Inf )
active_pair8=active_pair8+1;
```

```
l8=i; KL8=j; kj8=SINR(i,j);
X = sprintf('%d AND %d WILL BE PAIR. Threshold is -22 dBm and SINR between them is %d \n',l8,KL8,kj8);
disp(X)
else
active_pair8=active_pair8;
end
if (SINR(i,j)<-16 && SINR(i,j)~= Inf )
active_pair9=active_pair9+1;
l9=i; KL9=j; kj9=SINR(i,j);
X = sprintf('%d AND %d WILL BE PAIR. Threshold is -16 dBm and SINR between them is %d \n',l9,KL9,kj9);
disp(X)
else
active_pair9=active_pair9;
end; end; end;
all_possible_pairs(p) = (D2D * D2D ) - D2D
active_no_of_pairs_according_to_SINR_18(p)=active_pair2
percent_of_acive_pair_according_to_SINR_18(p)=
(active_no_of_pairs_according_to_SINR_18(p)/all_possible_pairs(p) ) * 100
percentage_of_outage_according_to_SINR_18(p)=100-
percent_of_acive_pair_according_to_SINR_18(p)
active_no_of_pairs_according_to_SINR_22(p)=active_pair8
percent_of_acive_pair_according_to_SINR_22(p)=
(active_no_of_pairs_according_to_SINR_22(p)/all_possible_pairs(p) ) * 100
percentage_of_outage_according_to_SINR_22(p)=100-
percent_of_acive_pair_according_to_SINR_22(p)
active_no_of_pairs_according_to_SINR_16(p)=active_pair9
percent_of_acive_pair_according_to_SINR_16(p)=
(active_no_of_pairs_according_to_SINR_16(p)/all_possible_pairs(p) ) * 100
percentage_of_outage_according_to_SINR_16(p)=100-
percent_of_acive_pair_according_to_SINR_16(p)
```

%Plotting Active Pair VS No. of Devices

```
plot(b,active_no_of_pairs_according_to_distance_500,'b-*','LineWidth',1.5);
hold on
plot(b,active_no_of_pairs_according_to_SINR_18,'r-d','LineWidth',1.5);
plot(b,active_no_of_pairs_according_to_datarate_3,'k-<','LineWidth',1.5);
grid on
legend ('Distance ', 'SINR ', 'Datarate ');
xlabel('NO. OF DEVICES'); ylabel('Active No. of Pairs');
title('Active No. of Pairs VS NO. OF DEVICES');
set(gca,'XTick',0:20:250); figure
```

% Plotting Percentage of outage VS No. of Devices

```
plot(b,percentage_of_outage_according_to_distance_500,'b*','LineWidth',1.5);
```

```
hold on
plot(b,percentage_of_outage_according_to_SINR_18,'r-d','LineWidth',1.5);
plot(b,percentage_of_outage_according_to_datarate_3,'k<','LineWidth',1.5);
grid on
legend ('Distance ', 'SINR ', 'Datarate ');
xlabel('NO. OF DEVICES');
ylabel('Percentage of outage');
title('Percentage of outage VS NO. OF DEVICES');
set(gca,'XTick',0:20:250); figure
```

% Plotting Active Pair VS No. of Devices Using Distance Threshold

```
plot(b,active_no_of_pairs_according_to_distance_100,'b-*','LineWidth',1.5);
hold on
plot(b,active_no_of_pairs_according_to_distance_200,'r*','LineWidth',1.5);
plot(b,active_no_of_pairs_according_to_distance_300,'k*','LineWidth',1.5);
plot(b,active_no_of_pairs_according_to_distance_400,'g*','LineWidth',1.5);
plot(b,active_no_of_pairs_according_to_distance_500,'y*','LineWidth',1.5);
grid on
legend ('Distance 100 ', 'Distance 200 ', 'Distance 300 ' , 'Distance 400 ' ,'Distance 500 ');
xlabel('NO. OF DEVICES');
ylabel('Active No. of Pairs');
title('Active No. of Pairs VS NO. OF DEVICES using Distance threshold and area 1500');
set(gca,'XTick',0:20:250); figure
```

% Plotting Percentage of outage VS No. of Devices Using Distance Threshold

```
plot(b,percentage_of_outage_according_to_distance_100,'b*','LineWidth',1.5);
hold on
plot(b,percentage_of_outage_according_to_distance_200,'r*','LineWidth',1.5);
plot(b,percentage_of_outage_according_to_distance_300,'k*','LineWidth',1.5);
plot(b,percentage_of_outage_according_to_distance_400,'g*','LineWidth',1.5);
plot(b,percentage_of_outage_according_to_distance_500,'y*','LineWidth',1.5);
grid on
legend ('Distance 100 ', 'Distance 200 ', 'Distance 300 ' , 'Distance 400 ' , 'Distance 500 ');
xlabel('NO. OF DEVICES'); ylabel('Percentage of outage');
title('Percentage of outage VS NO. OF DEVICES using Distance threshold');
set(gca,'XTick',0:20:250)
figure
```

% Plotting Active Pair VS No. of Devices Using SINR Threshold

```
plot(b,active_no_of_pairs_according_to_SINR_16,'r-d','LineWidth',1.5);
hold on
plot(b,active_no_of_pairs_according_to_SINR_18,'b-d','LineWidth',1.5);
plot(b,active_no_of_pairs_according_to_SINR_22,'k-d','LineWidth',1.5);
grid on
legend ('SINR -16 dBm ', 'SINR -18 dBm ', 'SINR -22 dBm ');
xlabel('NO. OF DEVICES'); ylabel('Active No. of Pairs');
```

```
title('Active No. of Pairs VS NO. OF DEVICES Using SINR Threshold');
set(gca,'XTick',0:20:250); figure
```

% Plotting Percentage of outage VS No. of Devices Using SINR Threshold

```
plot(b,percentage_of_outage_according_to_SINR_16,'r-d','LineWidth',1.5);
hold on
plot(b,percentage_of_outage_according_to_SINR_18,'b-d','LineWidth',1.5);
plot(b,percentage_of_outage_according_to_SINR_22,'k-d','LineWidth',1.5);
grid on
legend ('SINR -16 dBm ', 'SINR -18 dBm ', 'SINR -22 dBm ');
xlabel('NO. OF DEVICES'); ylabel('Percentage of outage');
title('Percentage of outage VS NO. OF DEVICES Using SINR Threshold');
set(gca,'XTick',0:20:250); figure
```