Throughput Maximization in D2D Enabled Cellular Networks

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Declaration Form

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We, Nishat Anjum and Fahmida Hossain, declare that the work presented in this project is the outcome of the investigation performed by us under the supervision of Dr. Md. Abdur Razzaq, Associate Professor, Department of Computer Science and Engineering, University of Dhaka. We also declare that no part of this project has been or is being submitted elsewhere for the award of any degree or diploma.

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Abstract

In a cellular network system one way to increase its throughput is to allow direct communication between closely located user equipments when they communicate with each other instead of conveying data from one device to the other via the eNodeB. Future cellular networks such as $IMT-Advanced$ are expected to allow underlaying direct Device-to-Device (D2D) communication. Throughput of the cellular network can be optimally maximized by sharing the same radio resources between D2D pair and cellular user. When sharing the same resources, interference between them comes in consideration. This interference between D2D and cellular communication can be coordinated by efficient resource allocation to benefit the overall performance.

In this work we have proposed an Algorithm which takes decision of allowing Device-to-Device (D2D) communication based on the distance between devices and available resources. Our proposed method decides to share uplink (UL) or downlink (DL) resources efficiently. Here what is our main purpose is to maximize the sum throughput of cellular network by enabling D2D communication and efficient resource sharing with the cellular user.

Contents

Chapter 1

Introduction

1.1 Introduction

Major research works have been evolved as well on the development of next-generation wireless communication systems such as 3GPP Long Term Evolution (LTE) and WiMAX. Currently the evolution of such systems have been started under the scope of IMT-Advanced Standard. Recently, Device-to-Device (D2D) communication as an underlay to cellular networks has been evolved as a technology component to the LTE-Advanced. UEs communicating directly, by employing D2D connectivity, can achieve better performance than that offered by the eNodeB. Performance can be maximized by sharing the same Radio resources of cellular user with the D2D pair.

In telecommunications, 4G is the fourth generation of cell phone mobile communications standards. It is a successor of the third generation (3G) standards. A 4G system provides mobile ultra-broadband Internet access, for example to laptops with USB wireless modems, to smartphones, and to other mobile devices. Two 4G candidate systems are being commercially deployed the mobile WiMAX standard and the first-release Long Term Evolution (LTE) standard. International Teleommunication Union-Radio Communications sector (IUT-R) specified a set of requirements for 4G standards, named the International Mobile Telecommunications Advanced specification (IMT-Advanced).

An IMT-Advanced system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to laptop computer wireless modems, smartphones, and other mobile devices. Facilities such as ultra-broadband Internet access, IP telephony, gaming services, and streamed multimedia may be provided to users. It intended to accommodate the quality of service (QoS) and rate requirements set by further development of applications like mobile broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV advantage that it has a completely open market

LTE (Long Term Evolution), marketed as 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals. It is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using new modulation techniques. The standard is developed by the 3GPP (3rd Generation Partnership Project). The main purpose of LTE was to increase the capacity and speed of wireless data networks using new DSP (Digital Signal Processing) techniques and modulations. A further purpose was the redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency compared to the 3G architecture. The LTE wireless interface is incompatible with 2G and 3G networks, so that it must be operated on a separate wireless spectrum.

The LTE specification provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s and QoS provisions. LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD).

The IP-based network architecture, called the Evolved Packet Core (EPC) and designed to replace the GPRS Core Network, supports seamless handovers for both voice and data to cell towers with older network technology.

1.2 Device to Device Communication

Multimedia services are increasingly being consumed through mobile devices such as laptops, netbooks and mobile phones. Hence, there is an increasing demand for high data rate wireless access. This increasing demand for higher data rates for local area services and gradually increased spectrum congestion have triggered research activities for improved spectral efficiency and interference management

One aspect of the design of IMT-Advanced systems that has not received sufficient attention so far is the emergence of high data-rate local services. Such local services can provide the high data rates needed to consume rich multimedia services through mobile computers such as tablets, laptops, netbooks and smart phones. Compared to other local connectivity solutions based on, for example, Bluetooth or WLAN, the Device-to-Device(D2D) communication supported by a cellular network offers additional compelling advantages. First the network can make advertising services available within the cell. Hence, for automated service discovery, the UEs do not have to constantly scan for available WLAN APs or Bluetooth devices. This is especially advantageous when considering that the constant scanning of Bluetooth devices or WLAN APs is often switched off by users to reduce the power consumption.

1.3 State of the Art Work and Motivation

Several wireless standards have addressed the need for D2D operation in the same band as the eNodeB, Access Point or central controller. Examples of such standards are WLAN networks based on IEEE 802.11 standards, Terrestrial Trunked Radio (TETRA) and HIPERLAN. In all these examples D2D communication is assumed to occur on dedicated resources, which limits the spectral efficiency of the combined cellular and D2D communication.

In IEEE 802.11 The ad-hoc/Independent Basic Service Set (IBSS) mode of WLAN ad-hoc communication can be used for setting up direct communication between UEs. It does not support enhancements such as Enhanced Distributed Channel Access (EDCA) but it works for D2D communication with a limited number of UE and coverage area.

In Hiperlan 2 UE would send a resource request over a slot, for example several Orthogonal Frequency Division Multiplexing (OFDM) symbols for direct communication with other UE the central controller. The main drawbacks are that the allocation is always for a single UE and the central controller as well as other UE in direct mode cannot transmit at the same time. This does not make efficient use of the available radio resources.

TETRA is a set of standards developed by the European Telecommunications Standards Institute (ETSI) that describes a mobile radio communication system targeted primarily at the needs of public emergency services. Several frequency channels are reserved purely for D2D communication. However, a fixed allocation of channels to D2D communication reduces the resources available for the eNB-UE communication.

One of the main purpose of these D2D communication is to largely improve the services in the local area scenarios. Device-to-Device (D2D) communication as an underlaying network to cellular networks [1, 2] can share the cellular radio resources for better bandwidth utilization. In addition to cellular operations, UE may communicate directly with each other over D2D links while remaining control under the eNodeBs. The D2D pair can communicate directly with coordination from the eNodeB. The channel response can include the path loss, shadow and fast fading effects. The Channel State Information (CSI) of all the active links is assumed to be present at the BS for better coordination.

The sharing of radio resources between D2D and cellular user is determined by the eNB. If D2D users are assigned resources that are orthogonal to the cellular user, they cause no interference to each other and the analysis is easier. On the other hand, the resource utilization efficiency can be higher in non-orthogonal resource sharing. D2D communication can share UL or DL radio resources with the cellulat user. Here in our work we have tried to make an optimal decision to share UL or DL resource based on the current scenario of network and allocated the resources.

In this work we proposed a new Algorithm for eNodeB which maximizes the throughput of the Cellular Network by enabling D2D communication and Efficient Radio Resource allocation to the D2D pairs. It ensures the best sharing of the UL and DL resources and maximizes the throughput.

1.4 Contributions

In this work, first of all we addressed the spectrum sharing problem between cellular user and underlaying D2D communication. We considered the non-orthogonal spectrum sharing mode. In this mode, Interference between them may cause. We identified and analyzed the interference problem of the primary cellular network caused by the D2D transmitter during the UL and DL phase separately. We generated the SINR of each cellular user and D2D pair with interference and selected the best SINR cellular user resource to share with the D2D pair. We also measured the sum throughput of the whole cell to make decision on allowing cellular or D2D communication. We performed simulation to prove the efficiency of the proposed algorithm over the random selection of radio resources.

Chapter 2

Related Research Works

We described details in chapter one about the IMT-Advanced Standard and LTE network. D2D communication is a very new technique under this network which purposes to largely improve the services in the local area scenarios. This tecnique ensures the best utilization of radio resources. There has been considerable research on spectrum sharing between cellular network and infrastructure-less wireless networks.

2.1 Interference Management

Due to heavier download traffic, uplink (UL) spectrum is under-utilized in frequency division duplex (FDD) based cellular system with equal bandwidths allocated for uplink (UL) and downlink (DL) transmission [2, 3, 4]. In [3], the researchers suggested that network capacity can be improved significantly when ad hoc users make use of unoccupied UL sub-channels.

The authors in [2] also proposed a spectrum reuse protocol where D2D users are only allowed to communicate with each other during the UL frame of the network. This is due to the fact that during UL only the base station (BS) is exposed to interference by the D2D users. In this scheme, the D2D user measures its pathloss from the known BS power and the received power during DL control frame. The D2D user then calculates its transmit power such that SINR ratio of the BS does not fall below threshold level.

2.2 Power Control Mechanism

In [5], the authors investigated another D2D communication that is based on the statistics of the SINR of all users scheme. SINR behavior is formulated based on the position of the D2D pair. Then power control method is applied to the D2D communication such that SINR degradation of the cellular link does not fall behind a certain level. The results showed that the SINR distribution of the D2D users (with distance constraint) is comparable to that of the cellular user in most of the cell area. The authors also observed that the UL resource sharing is more beneficial for the system when the D2D pair is farther away from the BS. When the D2D pair is closer to the BS, the DL resources sharing performs better. In [6], the authors studied D2D communication using Wi-Fi ad-hoc mode in the license exempt bands. The authors concluded that mobile devices (in close proximity) when communicate directly instead of infrastructure modes, can reduce contentions/collisions and also avoid bottleneck on an access point.

2.3 P2P File Sharing

Several authors studied D2D communication over cellular architecture in the context of P2P file sharing [7]. In [8], the authors suggested that an extended peer (non cellular user) from P2P network can communicate with cellular users as a client/server based communication between them. [7] proposed a P2P file sharing application for cellular users using session initialization protocol (SIP) as control protocol and then elaborated the modifications that should be made to SIP in order to meet the requirements of that application.

2.4 Resource Allocation Modes for D2D

In [9] the authors have discussed the resource allocation modes for D2D communication. They proposed three Allocation modes and also discussed the best mode selection mechanism. Modes are:

- Non-Orthogonal Sharing mode (NOS): D2D and cellular users share the same radio resources, causing interference to each other. The eNB coordinates the transmit power for both links.

- Orthogonal Sharing mode (OS): D2D communication gets dedicated resources and leaves the remaining part of resources to the cellular user. There is no interference between cellular and D2D communication
- Cellular Mode (CM): The D2D users communicate with each other through the eNB that is vary similar to cellular communication. The portion of resources allocated to each user is to be optimized.

Some considerable applications of D2D communications are video streaming, online gaming, media downloading, peer-to-peer(P2P) file sharing etc. Here in our work we have considered the non-orthogonal resource sharing mode. We developed an efficient selection method of resource sahring for better spectram utilization.

Chapter 3

Proposed Work

3.1 System Model and Assumption

In our proposed work, we consider a system model similar to [10]. This model includes n number of Cellular Users which are D far away from eNodeB and m number of D2D pairs where $m \leq n$. The distance between two devices of D2D is represented by L.

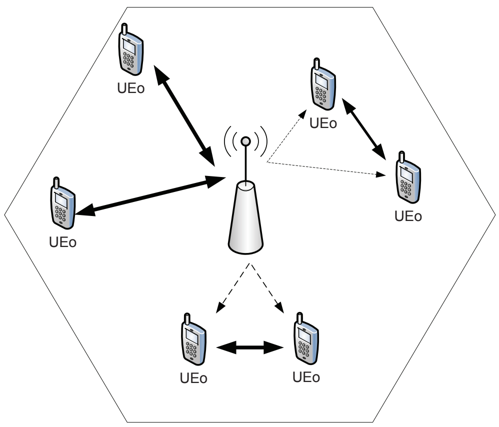

Figure 1: System Model of D2D Enabled Cellular Network

In fig.1 UE0 and UE1 are in Cellular communication mode otherside (UE2 and UE3) and (UE4 and UE5) are two D2D pairs. Here our main purpose is to maximize the total throughput of cellular network enabling the D2D communication. We considered the non-orthogonal resource sharing mode where the radio resource of cellular user (UE2 or UE3) is allocated to the D2D pair efficiently. We will complete this job using The Channel Quality Indicator (CQI) of each cellular user. CQI is a measurement of the communication quality of wireless channels. Here CQI is computed by making use of performance metric, Signal-to-Interference plus Noise Ratio (SINR).

There is an increasing number of LTE frequency bands that are being designated to use with LTE. In our network model we consider the LTE-Standard Frequency Division Duplex (FDD) and Time Division Duplex (TDD) based cellular system. FDD spectrum requires pair bands, one of the uplink and one for the downlink. There is a large number of allocations or radio spectrum that has been reserved for FDD, LTE uses. The FDDLTE frequency bands are paired to allow simultaneous transmission on two frequencies.

Here we assumed that All UEs are GPS system enabled. Each active UE within the cell reports their location (x,y) to the Base Station. Base Station maintains a Database which contains necessary informations to detect D2D possibility and allocate radio resources efficiently that maximizes the throughput of cellular system.

3.2 Radio Resource Technology

In LTE system bandwidth is divided into equal size physical RBs. Each RB physically occupies (0.5ms) 1 slot in the time domain and 180 kHz in the frequency domain with subcarrier spacing of 15 kHz. Fig. 2 illustrates the LTE DL physical resource. LTE has adopted Orthogonal Frequency Division Multiplex (OFDM) based radio interface due to its higher spectral efficiency and resilience against multi-path delay spread. There is, however, one important difference between the feasible assignments on the UL and DL shared channels. In LTE, the multiple access scheme for DL (from eNodeB to UEs) is OFDM access (OFDMA). The radio access technology in UL is single carrier frequency division multiple access (SCFDMA) due to its characteristics of low peak-to-average power ratio (PAPR) that enables higher transmit power efficiency for the UEs. The physical properties of SC-FDMA require that RBs allocated to a single user to be contiguous in frequency. The minimum scheduling period in the frequency domain is one physical RB; therefore the smallest unit of resource that can be assigned is two RBs [10].

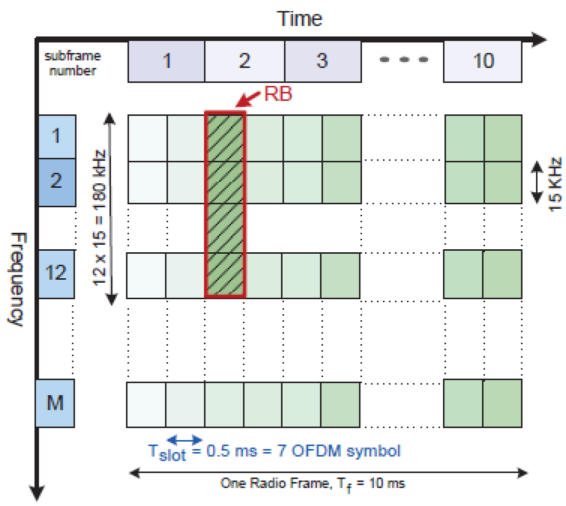

Figure 2: LTE-Standard Radio Resource Block [10]

3.3 Problem Definition

D2D commutation takes place underlaying the primary cellular network. According to the suggestion [11], we allow D2D connections if the distance between D2D is lesser than L_{thld} = 25m. We acknowledge the Radio Resources to be valuable. For maximizing the throughput of cellular network, D2D communication shares the same radio resources with cellular communication rather than using dedicated resources. Hence, the interference of D2D communications to the cellular network needs to be considered. During the downlink resource sharing period fig. 3 cellular UE5 is exposed to interference when any D2D transmitter (UE0 or UE4) transmits using the same allocated frequency band. Also, D2D receiver (UE1 or UE3) will suffer from interference from the eNodeB.

On the other hand, during the Uplink Resource sharing period fig. 4 the D2D transmitter (UE2 or UE3) causes interference only to the immobile eNodeB. D2D receiver (UE0 or UE4) also suffers from interference from the UE5.

In our research work we took the interference issue in our consideration and

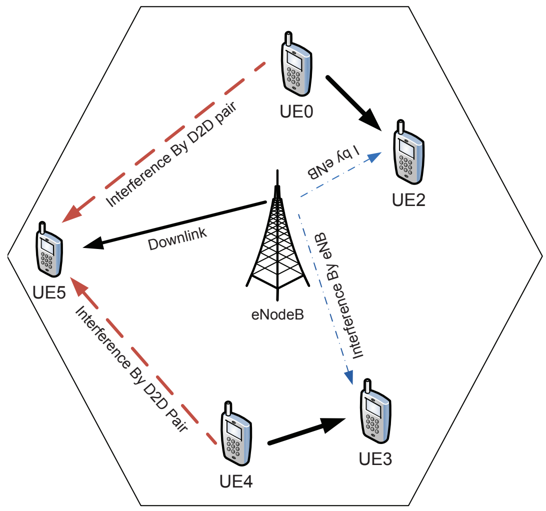

Figure 3: Interference During Downlink Period

built an efficient Algorithm for Radio Resource allocation that maximizes the whole cell throughput. our algorithm makes an optimal decision to share the UL or DL resources. We generated the sum throughput of D2D pair and cellular communication while sharing the same resources. Any UE with higher channel quality indicator (CQI) can share resources assigned to them with the D2D.

3.4 Generation of System Equation

In this section, the proposed method for maximizing the throughput of D2D enabled network has been discussed. In our proposed method to maximize the throughput of cellular network we want to enable D2D communication and allocate the same Radio Resource of any active cellular user to the D2D pair. Here the eNodeB (eNB) will maintain a database containing the information of primary Cellular User and Secondary D2D pairs. Based upon this information eNB will allocate the resources to the D2D pair. eNB will manipulate the resouce allocation algorithm each time it receives a call initiation or call release request. When BS receives a request it checks if

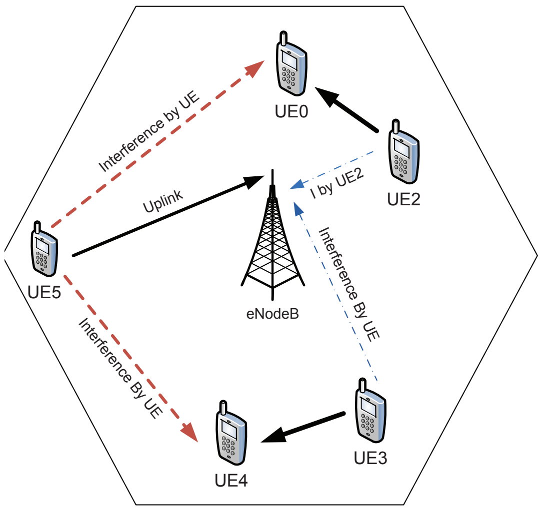

Figure 4: Interference During Uplink Period

D2D communication is possible or not by calculating the distance between the devices and the availability of resources. eNodeB maintains an SINR List of each cellular user equipment (UE) while sharing the radio resource to the D2D pair. The Higher SINR UE is selected to share its resources.

In this case eNodeB allocates the radio resource of specific cellular user c to the D2D pair d based upon the channel quality Information (CQI) which is generated by the SINR formula.

Here **C** = { c_1 , c_2 , c_3 ...... c_n } represents the list of active Primary Cellular User. c_n = n^{th} cellular user.

D = { d_1 , d_2 , d_3 .... } represents the List of active D2D pairs. The number of D2D pairs must be less than the number of Cellular User $D \leq C$.

C_UL_R = { c_{ul_1} , c_{ul_2} , c_{ul_3} ..... c_{ul_n} } List of Cellular User's Uplink Resource Blocks . c_{ul_n} represents the Uplink (UL) resource of n^{th} cellular user.

Similarly C_DL_R ={ c_{dl_1} , c_{dl_2} , c_{dl_3} ...... c_{dl_n} } List of Cellular User's Downlink Resource Blocks. c_{dl_n} represents the Downlink (DL) resource of n^{th} cellular user.

L_{thld} represents the approximated threshold distance between devices of the D2D pair. Distance between two devices must be lesser than this threshold value.
$SINR\_UL$ = { $SINR_{c1\_UL}$, $SINR_{c2\_UL}$, $SINR_{c3\_UL}$,...... $SINR_{cn\_UL}$ } represents Sorted List of SINR for Cellular users while sharing Uplink Resource. $SINR_{cn\_UL}$ is the SINR of n^{th} cellular User when sharing the UL resources.
$SINR\_DL$ = { $SINR_{c1\_DL}$, $SINR_{c2\_DL}$, $SINR_{c3\_DL}$,..... $SINR_{cn\_DL}$ } represents the Sorted List of SINR for Cellular users while sharing Downlink Resource. $SINR_{cn\_DL}$ is the SINR of n^{th} cellular User when sharing the DL resources.
Throughput will be generated using the Shannon Capacity Formula Throughput = log_2(1+SINR) where SINR = Signal to Interference and Noise Ratio. Here we use a single-slope distance dependent path loss model with a pathloss exponent of 1.8 to 6. Receiver power is generated using this eguation

$$P(d) = \frac{P(d_0)}{d^{\alpha}} \tag{1}$$

where P(d) denotes the received power at distance d from the transmitter and P(d_0) the transmit power of eNodeB. α is the pathloss.

3.4.1 D2D possibility Detection

We assumed that each active UE within the cell reports their location (x,y) to the Base Station Periodically. eNodeB will maintain a table of all UEs location. When any new UE generates a request for communication, eNodeB will look up the table and fetch the locations. It checks D2D possibility by generating the distance between two Devices of this pair using the simple Geometric Equation.

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

3.4.2 UL Resource Sharing Mode

When sharing the uplink Resource, Base Station and D2D receiver are interfered by the Cellular user. If d Pair shares the UL resource of c_1 user then

SINR of Cellular user c_1

$$SINR_{c1\_UL} = \frac{P_1}{N_0} \tag{3}$$

where P_1 = Power received by Cellular User c_1

SINR of D2D pair d

$$SINR_{d\_UL} = \frac{P_d}{N_0 + I_{c1d}} \tag{4}$$

I_{c1d} = Interference received by d Pair caused by c_1 cellular userI_{c1d} = Max(P_{1i} ,P_{1j}).
where i and j is the i^{th} and j^{th} devices of d pair.

SINR of eNodeB B

$$SINR_{B\_UL} = \frac{P_B}{N_0 + I_{dB}} \tag{5}$$

where P_B = Power Used by eNodeB B.

I_{dB} = Interference received by d pair caused by eNodeB.
I_{dB} = Max(P_i ,P_j).
where i and j is the i^{th} and j^{th} devices of d pair.

The Sum throughput of cellular user c_1 and d

$$\begin{aligned} UL\_capacity &= log_2(1 + \frac{P_i}{N_0}) \\ &+ log_2(1 + \frac{P_d}{N_0 + I_{c1d}}) \\ &+ log_2(1 + \frac{P_B}{N_0 + I_{dB}}) \end{aligned} \tag{6}$$

3.4.3 DL Resource Sharing Mode

In Downlink resource sharing scheme, UE is interfered by the D2D pair If d Pair shares the Downlink resource of cellular user c_1.

SINR of Cellular user c_1

$$SINR_{c1\_DL} = \frac{P_1}{N_0 + I_{dc1}} \tag{7}$$

where P_1 = Power received by Cellular User c_1

I_{dc1} = Interference received cellular user c_1 caused by D2D pair d.
I_{dc1} = Max(P_{i1} , P_{j1})
where i and j is the i^{th} and j^{th} devices of d pair.

SINR of D2D pair d

$$SINR_{d\_DL} = \frac{P_d}{N_0 + I_{Bd}} \tag{8}$$

where P_d = Power received by D2D pair d

I_{Bd} = Interference received by d pair caused by eNodeB.
I_{Bd} = Max(P_i , P_j)
where i and j is the i^{th} and j^{th} devices of d pair

SINR of eNodeB B

$$SINR_{B\_DL} = \frac{P_B}{N_0} \tag{9}$$

The Sum throughput

$$\begin{aligned} DL\_Capacity &= log_2(1 + \frac{P_i}{N_0 + I_{dc1}}) \\ &+ log_2(1 + \frac{P_d}{N_0 + I_{Bd}}) \\ &+ log_2(1 + \frac{P_B}{N_0}) \end{aligned} \tag{10}$$

3.5 Algorithms

As we mentioned earlier that all active UEs report their locations to the eNodeB periodically. eNB updates its table and also keep track of the distances between the devices of D2D pair. If the distance gets larger than the Threshold value, the D2D communication switches to the Cell mode.

eNB calculates SINR of each UE c_n while sharing UL or DL resource. It generates two desdending ordered Sorted list of UEs SINR. one for UL Resource another for DL resource.

After generating all parameters, eNB goes to take decision of D2D mode or Cellular mode communication. For this purpose it calculates the Sum throughput of the network. If throughput maximizes than eNB allocates the Resource to the D2D pair otherwise it takes turn to the cellular mode communication.

When eNodeB receives any Call release request, it releases the allocated Resources and updates the Resource list of the eNodeB database.

Algorithm 1 The Main Algorithm, *at eNodeB*

```
1: while eNB receives a Call Initiation Request do
2:     if (D2D Possibility Detection() == TRUE) then
3:         Calculate SINR of each active UE (Alg. 3)
4:         Allocate Resource to D2D (Alg. 4)
5:     else
6:         cell mode Communication
7:         add cs to list C
8:         add c_uls to list C_UL_R
9:         add c_dls to list C_UL_R
10:    end if
11: end while
```

Algorithm 2 D2D Possibility Detection

```
1: calculate Distance dis using equation no 2
2: if dis ≤ L_thld && available Resource for sharing then
3:     return TRUE
4: else
5:     return FALSE
6: end if
```

Algorithm 3 SINR Calculation

```
1: while active UE list C is not null do
2:     Pick c_{n_ul} from C_UL_R list where n = {1,2,3,4, ..... }
3:     Pick c_{n_dl} from C_DL_R list where n = {1,2,3,4, ......}
4:     calculate SINR_{cn_DL} using eq-7
5:     calculate SINR_{cn_UL} using eq-3
6:     calculate Sum throughput of c nad d while sharing resource
7: end while
8: Sort the SINR_UL and SINR_DLlist and throughput List
```

Algorithm 4 Allocate Resource to D2D pair,*at eNodeB*

$SINR_{max_UL}$ = Pick the highest value of $SINR\_UL$ List
$SINR_{max_DL}$ = Pick the highest value of $SINR\_DL$ List
Pick the highest value between $SINR_{max_UL}$ and $SINR_{max_DL}$
Calculate the sum $Throughput_{sum}$
if $Throughput_{sum}$ is better **then**
    Allocate Resource to D2D pair (highest SINR UE)
    add new D2D pair to D list
    Remove the Resource from C_UL_R or C_DL_R
else
    cell mode Communication
    add cs to list C
    add c_uls to list C_UL_R
    add c_dls to list C_UL_R
end if

Algorithm 5 Resource Release Algorithm

while eNodeB receives Call release Request **do**
    if Request from D2D pair **then**
        Remove the d pair from D2D List
        Add the shared Resource to the C_UL_R or C_DL_R
        Break
    end if
    if Request from Cellular user **then**
        Remove cs from list C
        Remove c_uls from list C_UL_R
        Remove c_dls from list C_UL_R
        Break
    end if
end while
Sort the $SINR\_UL$ and $SINR\_DLlist$

Chapter 4

Experimental Result

4.1 Implementation and Parameters

To demostrate the functionality of our proposed work, we performed extensive simulation of the proposed Algorithm. We developed a simulator using JAVA programming language that realistically modeled our system network. To build the network model the parameters we considered –

Table 1: Simulation parameters

Parameter	Value
Spectrum Allocation (UL and DL)	$120 - 300$ MHz
Cell Radius	10km
Cell Layout	Circular
UE Noise Figure	9.0 dB
UE Thermal Noise Density	9.0 dB
Pathloss α	2
Thresold Distance	25m
eNB Transmit Power	20W
Number of UEs	200
Maximum Number of active UE	100

Here we assumed a Circullar Cell with radius 10Km. The distance dependent pathloss α is considered constant. As our main purpose is to maximize the throughput by sharing the UL or DL resources, primarily we generated 10 cellular mode Cellular user. After that we allowed for D2D mode communication with same resource sharing mode. We considered the minimum distance between two devices is 25m. For generating a better graph we manipulated 50 simulation steps.

4.2 Performance Metrics

The following figures show the performane of our Proposed method. We can see that our proposed Algorithm maximizes the throughput of the cell network. This is the result of fact that our Algorithm performs better than the Random resource allocation algorithm and also cellular mode communication.

4.2.1 Comparison between Random and Proposed Throughput Maximization Algorithm

To compare the proposed throughput maximization algorithm, We plot the total throughput with varying number of active UEs in the cell.

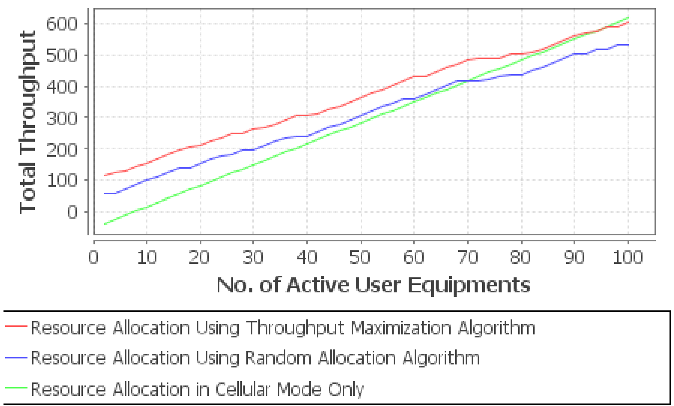

Figure 5: Network Throughput for different algorithms with the proposed algorithm

The cell throughput is higher for the proposed heuristic algorithm than the random algorithm for all active number of UEs in the cell. This is due to the fact that random D2D RB assignment causes significant amount of interference on the primary cellular network. For example, with the number of 40 active UEs per site, normalized cell throughput is 5% higher in the case of heuristic algorithm than the random algorithm. The proposed algorithm is more efficient to avoid interference to the cell UEs as it selects the best SINR Cellular UE for resource Sharing.

4.2.2 UL or DL resource Sharing Metric

The following figure fig.6 shows the UL and DL resource usage. We can see that in our proposed algorithm the UL resource block usage is higher than the DL resource block. This is due to the fact that during UL only the

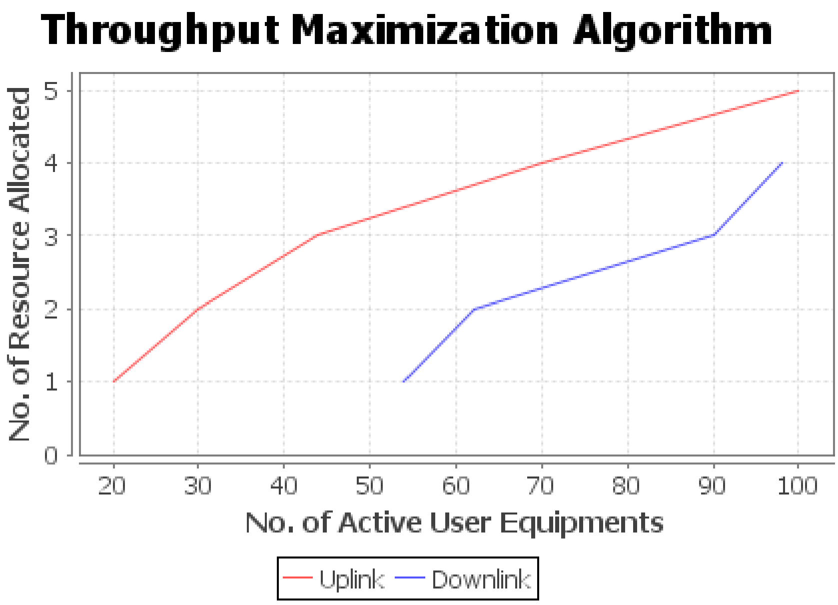

Figure 6: no of UL or DL resource allocated vs no of active users

base Station is exposed to interference by the D2D users.

4.2.3 Number of D2D and Cellular link vs no Active cellular user

The following figure fig.7 depicts the variation of the cellular communication and D2D communication.

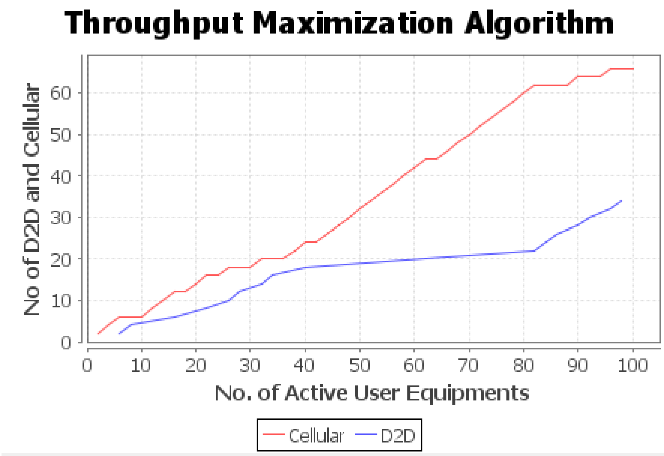

Figure 7: no of D2D and Cellular link vs no of active cellular user

4.3 Result

We can see from all the metrics that the performane of our proposed method is far better than the random algorithm. Our proposed method takes a good decision on selecting the UL or DL resource sharing mode for the D2D pair. from the metrics we can see a better throughput maximization of the cellular network using our algorithm.

Chapter 5

Future Enhancement and Conclusion

5.1 Future Enhancement

We decided to expand our Algorithm for UEs mobility and multicell environment. When two devices are situated under the control of different Base Stations but approximately very closer to each other, our Algorithm will perform D2D communication session setup and Resource Allocation efficiently.

5.2 Conclusion

In our research work we have tried to analyze throughput of the wireless cellular network. The network performance improves when D2D communications share radio resources with the primary cellular users. Our main purpose is to efficiently allocate resources to D2D pair and cellular users so that the total throughput of the network maximizes. It also ensures better utilization of radio resources.

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