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System capacity evaluation for mobility management in LTE-advanced D2D networks

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Abstract

Objectives: This study aims to evaluate the system capacity for mobility management in Long Term Evolution-Advanced (LTE-A) Device to Device (D2D) networks with suitable handover schemes. **Methods**: This paper introduces power control mechanisms for 5G based on the distance between D2D terminals. Interference is a major issue which reduces the performance of D2D communication. The proposed system introduces an algorithm based on greedy algorithmic approach for interference mitigation with easy handover for system capacity estimation. The implementation is carried out using LabVIEW platform and results are analyzed. **Findings**: The existing mobile communication approaches transfer calls through base stations irrespective of the distance between the mobile terminals. User mobility is an important factor for D2D communication and proper selection of mobility patterns that helps in increasing the energy efficiency and throughput by reducing interference. Efficient utilization of these mobility patterns are shown in the proposed method for developing an optimal time efficient mobility aware caching mechanism with lower complexity. In the recent works, less importance has been given for users' contact time duration while they are moving with different speeds. The simulation results show an enhancement in the system capacity of approximately 480 bits/Hz for 50 devices and 290 bits/Hz for 20 D2D users. The simulation results prove that the proposed approach gives better performance than the existing methods.

Keywords: D2D; handover; RPGM; LTE-A; SINR

1 Introduction

The exponential increase of multimedia mobile applications generates huge data traffic in Long Term Evolution-Advanced (LTE-A) networks. This increases the load of backhaul links and mobility caching mechanisms. This area is the promising approach to reduce the burden on backhaul links [1].

Mobility caching techniques allows mobile users in getting the required information from BSs to UEs and vice versa without using backhaul links [2].

Mobility caching techniques places an important role in reducing interference and delay problems. The existing mobility caching mechanisms use fixed network topologies. However user mobility requires continuous change of network topologies with respect to time.

Mobility caching approach allows D2D users to share the data between them easily without the use of base station [3]. This significantly reduces the data traffic and power consumption of BS. The contact and inter-contact times of D2D users are measured using temporal correlation factor of D2D user mobility. The contact time is the duration available for the D2D users when they are within the region of proximity [4]. The time intervals between contact times are called inter contact times [5]. A fixed fraction of data can be transmitted in one contact time if the user moving speed is at predefined levels. If the user mobility increases beyond the predefined levels, it affects both contact and inter-contact times. The amount of data that can be allowed through the D2D links is called data offloading ratio [6]. The effect of mobility is investigated when both average and inter-contact times of all the D2D pairs are same. The data offloading ratio increases with the increase in the average and inter-contact times speed. The channel quality depends on mobility patterns [7]. These required mobility patterns can be obtained by proper balancing of the cellular assisted D2D and user centric D2D systems. The main mobility parameters which decide the performance of D2D communication are probability of call setup, Random Waypoint (RWP), Brownian Motion (BM), call holding time and link setup time etc [8]. The mobility region can be divided into jammed and un-jammed areas. Heterogeneous access method connects the user equipment for D2D communication in the jammed areas. The main challenge is to track a compatible UE for D2D communication with the other UE, maintaining the same number of switches to avoid loss of power [9].

The cost of D2D transmission can be reduced by content encoding mechanisms. The contact and inter-contact times give the information about the D2D users' mobility [10]. Content partitioning allows calculating the D2D users caching capacity. The D2D mechanism minimizes the base station load and makes the handover easy. Mainly handover process is divided into parts: half handover and full handover [11]. While two mobile terminals involve in D2D communication, if they keep moving apart and if any one of the device finds a BS, then this D2D communication link breaks and these two must communicate through the BS. When both the mobile terminals involved in D2D communication are moved towards neighboring base stations, both are handed over to the corresponding base stations. This process is called joint handover mechanism [12]. The handover techniques based on fixed and hysteresis radio signal strength are described in [13]. The signal strength calculation is based on the distance between the devices. This compensates the shadowing effect on the signal strength. The handover delays of D2D communication affect the throughput. To overcome this handover delay effect on throughput the solutions given in [14] are considered. For handover decisions along with the signal strength residual bandwidth and monetary cost parameters also plays an important role.

Following the introduction, this paper is organized as follows. In Section 2 the system model is described. Section 3 describes interference mitigation for capacity estimation. Section 4 presents simulation results. Section 5 concludes the paper.

2 Network model and mathematical preliminaries

LTE-A system has the ability to combine 5 multiple bands with 100MHz frequency. These carrier multiple bands can be continuous (adjacent) or non-continuous. The non-continuous components are divided into inter-band and intra-band components [15]. It has 4x4 MIMO in uplink and 8x8 MIMO in downlink. MIMO is required only when signal to noise ratio is high. Some spectral efficiency methods are used when Signal to Interference Noise Ratio (SINR) is low. Based on the number of antennas available the modulation symbols are mapped and this process is called pre-coding. Code book based pre-coding and non-code book based pre-coding techniques are available to transmit the reference signals with data [16].

The model allows a mobile user to contact with the other mobile when both are in the region of proximity. Contact time is the time required to start the communication process between the two mobile terminals [17]. Correspondingly, the inter-contact time is the time taken by the two mobile terminals during contact time. The inter-contact D2D connectivity information during handover has been described in [18]. Hence, Reference Point Group Mobility (RPGM) based D2D Mobility aware caching mechanism is considered for system capacity estimation.

The most widely used mobility model is the Random Way Point (RWP) model, in which a device randomly selects its velocity and direction. In Gauss-Markov mobility model (GMM) the devices are affected by their history [19]. Figure 1 represents the geometrical formulation of the proposed D2D mobility model. Let the distance between the master and slave be D^1. It is assumed that both master and slave are moving with a uniform speed V. At time t=t_o, let the D2D receiver reaches a mobility reference point with an angle Θ at time t= t_o +1.

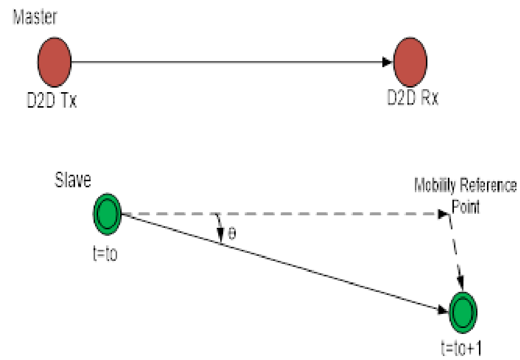

Fig 1. Geometrical representation of the proposed D2D mobility model

Figure 2 shows the RPGM based D2D mobility model. The mobility of the devices depends on obstacles, distance, freeways, etc. in the Pathway mobility model [20]. Reference Point Group Mobility model (RPGM) use spatial dependency when two or more device movement correlates with each other [21]. This model has a reference point which determines the overall movement of mobile terminals.

RWP model is not able to access spatial dependence mobility characteristics and RPGM mobility model is used to access the spatial dependence parameters of D2D pairs. This model considers the D2D transmitter as the master and the D2D receiver as the slave. There is a distance constraint for the transceivers and the RPGM model fails to perform handover operations, if the distance between the devices goes beyond the threshold level [22].

Coordinated multi point operation is a technique used to improve the performance of cell edges. The low power eNBs used to increase the performance of cell edges are called relay nodes. Micro (10^{-6}), Pico (10^{-12}), Femto (10^{-15}), Atto (10^{-18}) and Zepto (10^{-21}) cells are used to transmit or receive the data based on range of transmission. There are no milli and nano cells used. Femto cells are used for data transmissions with range varying from 50m to 100m. Around 10 to 50 users can directly communicate using femto cells without any interference.

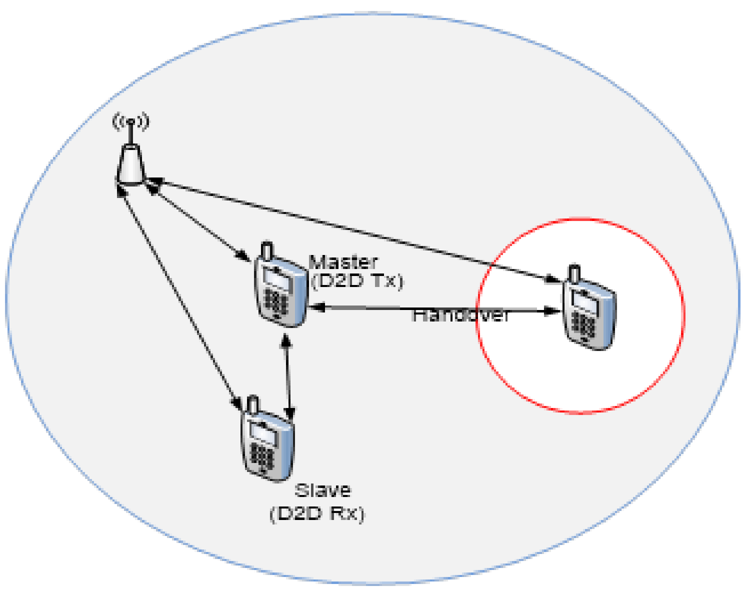

Fig 2. RPGM based D2D mobility model

In this paper, the caching placement approach is introduced to increase the data offloading ratio. The data offloading ratio is the amount of required data to be transmitted through the D2D links. When the D2D pairs offers large amount of data from the base stations, it leads to spatial reuse.

The inter contact time, waiting time and probability of contact time are the mobility parameters considered to obtain the proposed model. Inter-contact time is the time delay between the two contacts of D2D nodes. Contact probability is the probability of the D2D terminals to be in the common cell area [23]. The devices are assumed to be randomly distributed in a cell with a single BS and the users are capable of direct communication or selection nearby base station, based on the distance between the devices. A single hop or direct communication, multi-hop communication and cellular communication are the three types of possible communication modes. When a D2D transmitter requests for communication the evolved Node B (eNB) decides whether to allow for single hop or multi hop.

In single hop communication mode, the distance between devices is within the region of proximity and the transceivers are able to communicate directly without the use of base station [24]. In multi hop communication mode, the distance between devices is not within the region of proximity but the devices are able to communicate through another D2D terminal.

3 Interference mitigation for capacity estimation

Figure 3 shows the interference issues between D2D and cellular users when a single eNB is responsible for coordinating between two cells. The channel state information of both D2D and cellular users is received by the eNB while the devices utilize uplink resources. Cross-tier interference is observed while the D2D users communicate through eNB when the distance between the transceivers is not in the range of direct communication [25]. Hence the proposed power control mechanism obtains the shortest distance to reduce the power requirement of D2D users, Cellular users and eNBs. The proposed resource scheduling approaches minimize the interference.

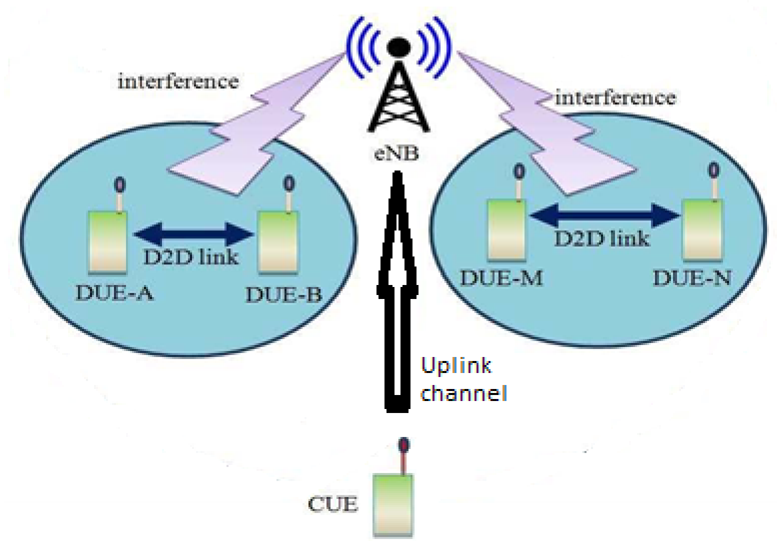

Fig 3. Interference issues between D2D pairs and cellular terminals

The D2D handover conditions while the users shifting from one cell to other is represented in Figure 4. Figure 4 (a) shows the condition of user terminals which are controlled by the base station BS1.

Figure 4 (a) Both the mobile terminals are managed by BS1. (b) User Equipment UE1 handover to the base station BS2 is hold until the D2D conditions are met by both the user equipment. (c) Handover to the base station BS2 is allowed when D2D conditions are met by both the user equipment.

Figure 4(b) shows the D2D condition when UE1 shifts to BS2 cell. This situation reduces the latency and increases the signalling overhead. Hence the proposed work allows BS2 handover to be postponed till the signal condition of the base station BS1 becomes weaker than the predefined D2D control conditions. D2D control condition is set to a threshold of SINR 6 dB. When the device to device conditions are satisfied by both users, handover to base station BS2 is allowed as shown in Figure 4(c).

When the D2D terminal shifts towards the area of handover as shown in Figure 3, the handover algorithm executes to scan and identify the nearby high capacity eNB. The handover process occurs only when the D2D terminals crosses the areas of zone 1 and zone 2. During call establishment the signals move in a straight path with an angular displacement of α. The entry and

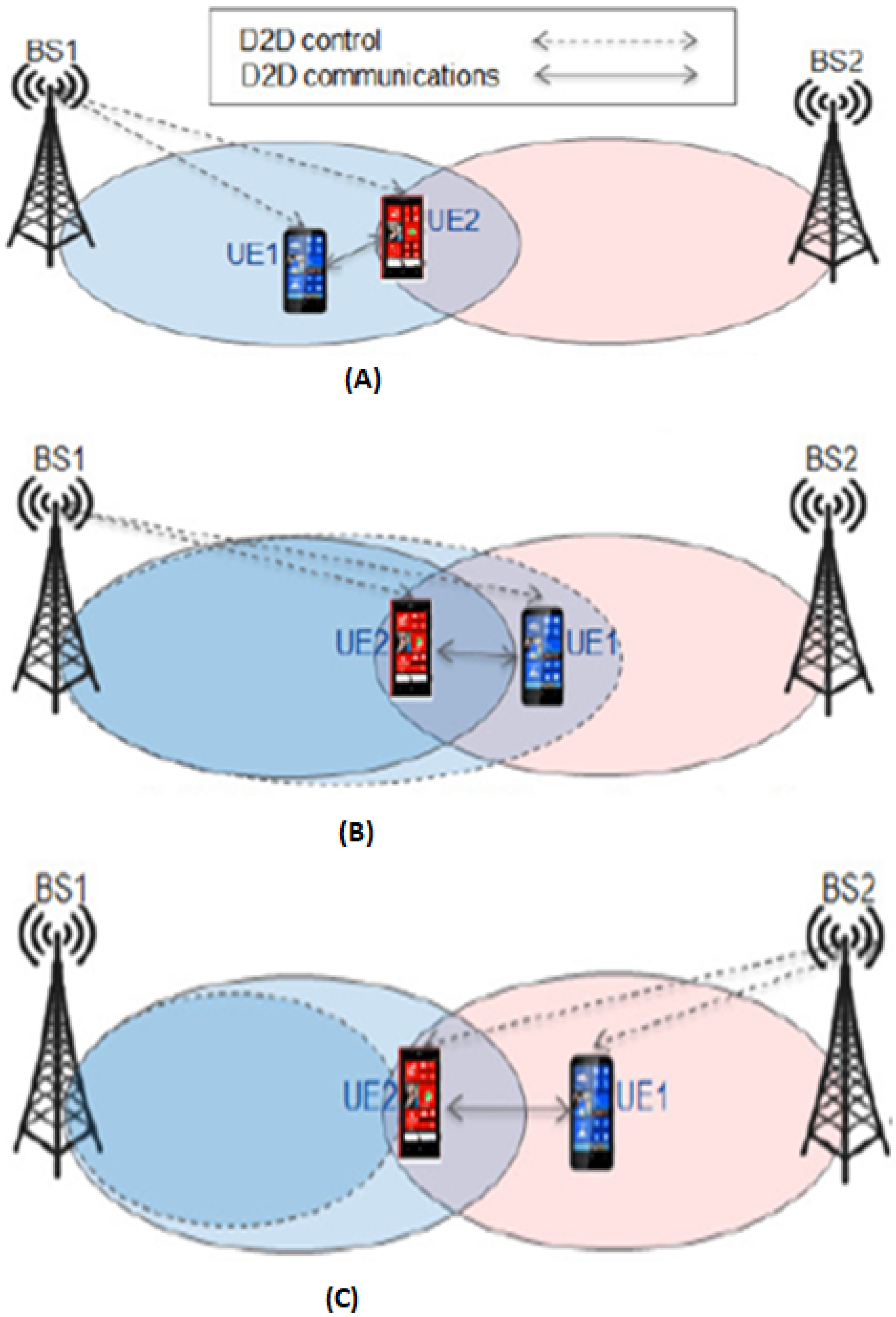

Fig 4. Representation of the D2D handover conditions while the users shifting from one cell to other

exit positions of the signals with the inner and outer cell are shown as point A and B. D2D performance metrics evaluation is made based on the following parameters:

Handover success is the condition when a D2D terminal successfully shifts from one eNB to other for call continuation [26]. Handover failure is the D2D terminal failure in moving from one eNB to the other for call continuation.

Ping pong effect indicates unnecessary handovers with adjacent eNBs when the D2D terminals almost approaching to their parent eNBs. In cellular communication mode, the distance between devices is not within the region of proximity and is not able to communicate through another D2D terminal. Hence the transceivers compulsorily use base station for communication [27]. The eNB allocates resources for both the D2D and cellular users. The D2D pairs utilize the cellular uplink resources. A cellular user can utilize a single Physical Resource Block (PRB) whereas the D2D terminals can utilize more than one PRB.

According to [28], it is shown that inter and intra-cell interferences can be mitigated by adopting the power control schemes. Three main intra-cell interferences can be observed while sharing the cellular resources for D2D communication. They are:

1. The interference between cellular transmitter and D2D receiver
2. The interference between eNB and D2D transmitter and
3. The interference between D2D transmitter and D2D receiver

Figure 5 shows that a D2D terminal approaching towards the area of cellular network. Let I be the entry point and O be the exit point of D2D user. It is assumed that the D2D terminal travels with a constant velocity V. let M be the middle point of the D2D link.

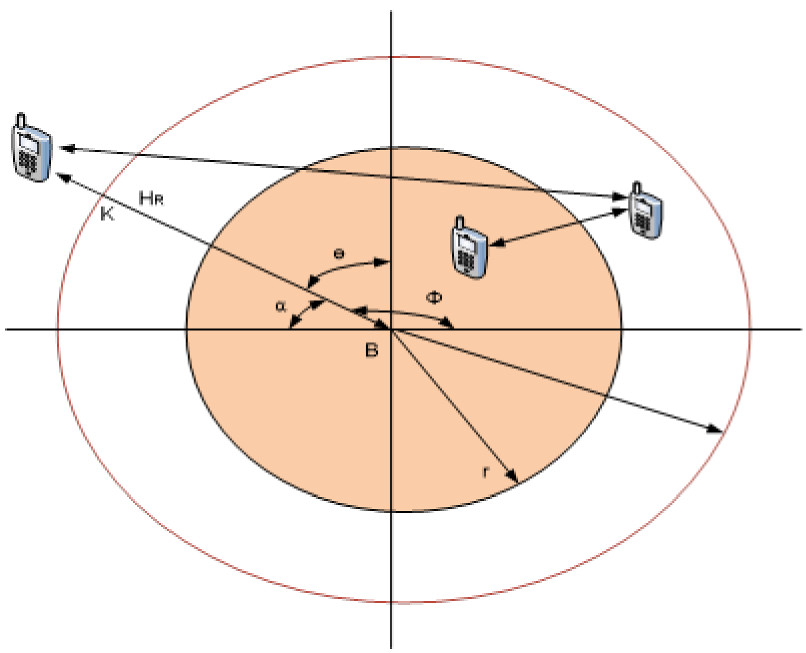

Fig 5. Handover between the devices while shifting from one cell to other

The circle shown inside is the handover boundary and the area between the outer and inner circle is coverage area of WLAN. Let r and R are the radii of inner and outer cells and B is the access point.

When the mobile terminal enters the WLAN area, the greedy algorithm executes to evaluate the requirement of handover between the inner and outer cells. The device will be in the WLAN area when there is a handover. The algorithm calculates the probability of handover without any interference from WLAN area to the cellular or D2D network if the device crosses the point K. For the k^{th} D2D user, the SINR can be obtained using

$$r_{k,n} = W_s \log_2 \left(1 + p_{k,n} g_{k,n}\right) \tag{1}$$

where $g_{k,n} = \frac{h_{k,n}}{W_s N_0}$ is the SINR of k^{th} cellular terminal due to n^{th} eNB. N_0 is the noise power spectral density. W_s is the bandwidth of cellular terminal.

The D2D transmit power can be obtained using

$$P_{D,C} = P_{max} * \frac{SINR_{MSC,D}}{SINR_{Eff,min}} \tag{2}$$

The term is the maximum power of the D2D terminal. $SINR_{MCS,D}$ is minimum SINR value of D2D terminal for constant MCS. $SINR_{Eff,min}$is the minimum effective SINR value for the first D2D terminal.

The D2D SINR is given by

$$Y_d^k = \frac{U_d^k \, P_d^k \, g_d}{\sum_{d^1=1}^{N_d} U_d^k \, P_{d^1}^k \, H_{d^1,d} + N_o} \tag{3}$$

where U_d^k is the k^{th} D2D terminal and P_d^k is its power. g_d is the channel gain of mobile terminals. $H_{d^1,d}$ is the channel gain of dth D2D user terminal from the d^1 D2D pair. P_d^k is the power level of kth d^1 D2D pair.

The greedy algorithmic approach for interference mitigation with easy handover is shown in Figure 6. From the Figure 6 it is observed that there are three tasks waiting for execution. Let us assume the release times of tasks r(a)=r(b)=r(c)=1 having deadlines d(a)=2, d(b)=∞, d(c)=5 with lengths l(a)=1, l(b)=2, and l(c)=3. If the tasks are allowed in the sequence a, b and c, the task c cannot meet its deadline. All the three tasks can be successfully completed only for the sequence a, c and b as shown in Figure 6.

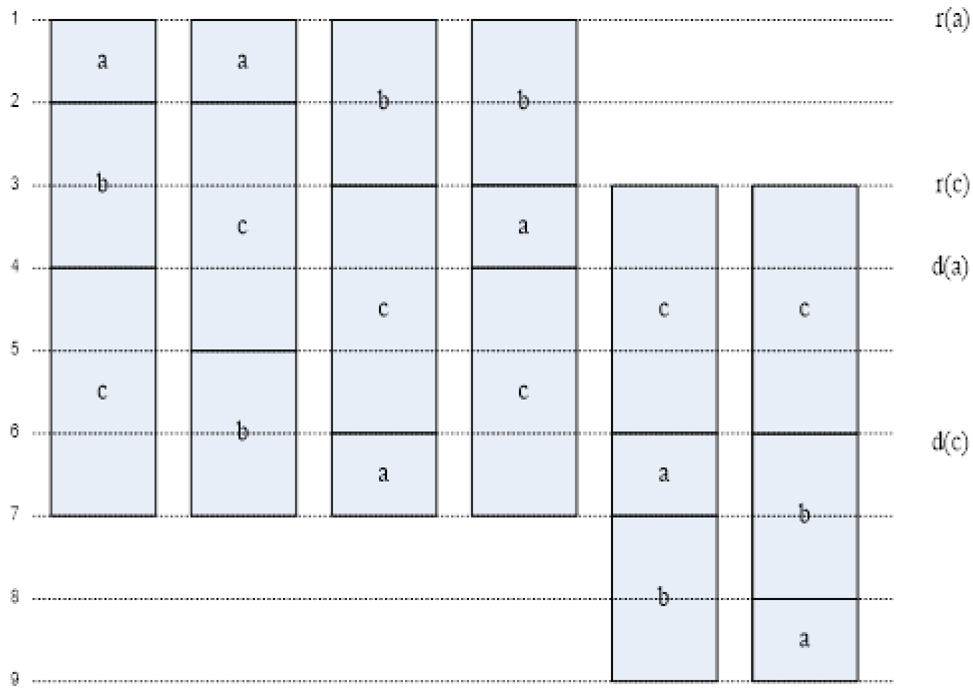

Fig 6. Greedy algorithmic approach for interference mitigation

The system capacity estimation S_c can be calculated by using

$$S_c = \log_2\left(1 + Y_d^k\right) \; bits/Hz \tag{4}$$

User equipment with same characteristics and a single cell is considered for simulation. For each UE a separate individual antenna is assumed and these UEs are differentiated as cellular, cell edge and relay based user equipment. All these use equipment are managed by a single eNB. This work focused on relay selection techniques assuming a D2D pair in each cell to initiate D2D communication links. However, all the cellular user terminals communicate through eNB via normal uplink.

The 'N' cellular user terminals and 'M' relay user equipments are assumed to initiate a relay assisted D2D link. There are two frequency hops. One is between the cell edge user equipment and the relay based UE and the other is between relay based UE and eNB. The inter cell interference is neglected. But the interference between the relay UE and D2D user is considered. The communication channel information between the base station and user's equipment are accessed through Channel State Information (CSI). Since the channels may get affected by noise and fading problems, the eNB and D2D users acknowledges CSI to get information about these problems. Handover delay methodology for the proposed method is as shown in Figure 7.

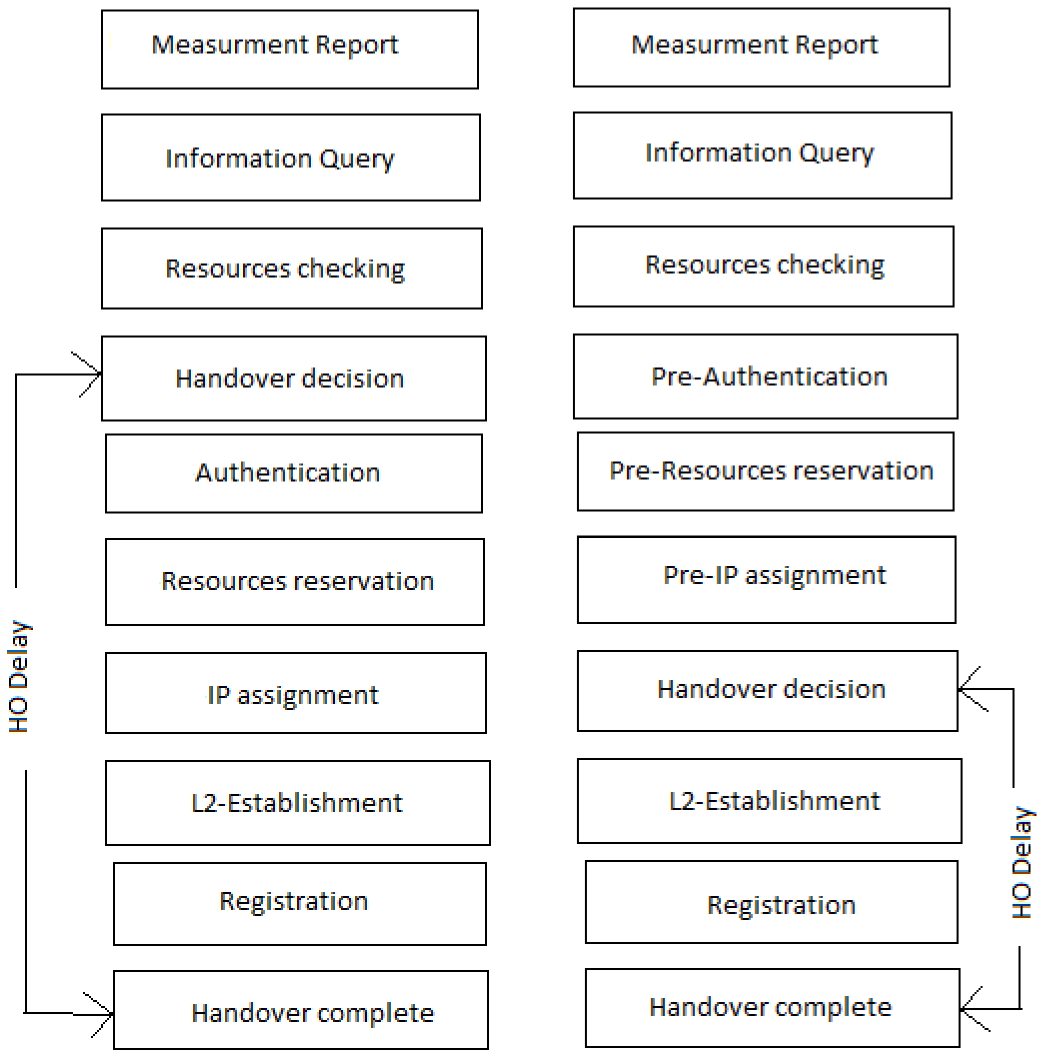

Fig 7. Standard method Proposed method Handover approach for the proposed technique

From the proposed approach the overall handover latency obtained is given by $HL - proposed = Tscan + Tre - ass + TPBU + TRA$

Substituting the network parameters the HL-proposed obtained = 0.6+25+11+30=66.6ms.

Algorithm: Greedy algorithmic approach for interference mitigation

1. Initialize release times of the tasks r(a) r(b) and r(c)

2. Initialize deadlines for the tasks with lengths l(a) l(b) and l(c)
3. Start the shortest task with earliest deadline
4. Calculate the power level for the released task using $P_{D,C} = p_{max} * \frac{SINR_{MSC,D}}{SINR_{Eff,min}}$

5. Obtain SINR using
$Y_d^k = \frac{U_d^k P_d^k g_d}{\sum_{d'=1}^{N_d} U_d^k P_{d'}^k H_{d',d} + N_0}$
6. Release the next earliest deadline task and repeat steps 4 and 5

4 Simulation results

The system capacity evaluation of the robust graph coloring approach is shown in Figure 8. The proposed work gives the system capacity approximately 480 bits/Hz for N=50 and 290 bits/Hz for N=20 as shown in Figure 9. The graph coloring approach gives the system capacity approximately 440 bits/Hz for N=50 and 260 bits/Hz for N=20 as shown in Figure 8.

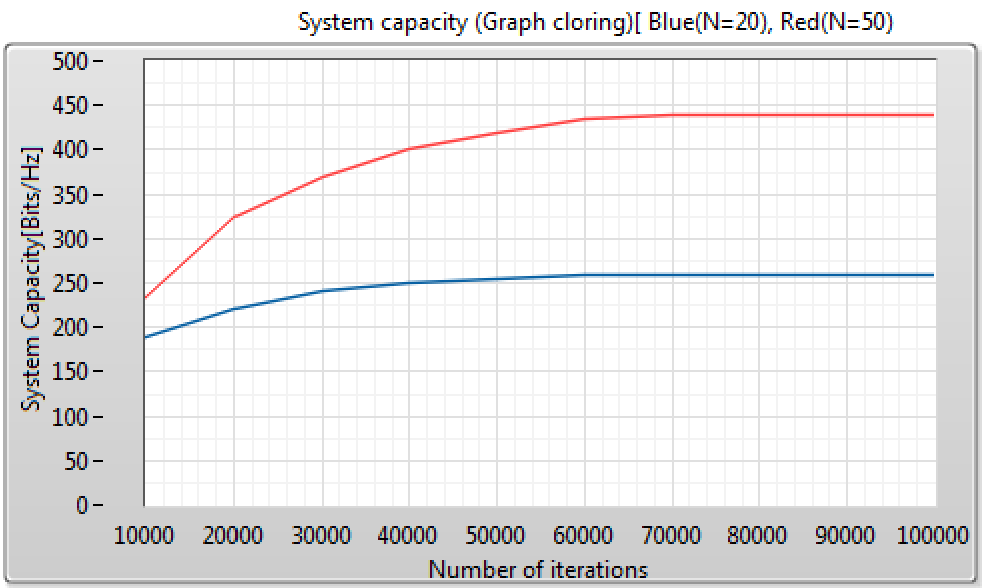

Fig 8. System capacity estimation using graph coloring approach

Both results are verified for 10000-100000 iterations. Hence a significant amount of increase in the system capacity can be obtained from the proposed approach. The proposed approach splits the problem into 3 phases. In the first phase, each D2D transmitter requests the resources from the receiver with low interference and shortest path. The reduction in power consumption increases the reuse gain, hop gain and proximity gain. This allows spectral and energy efficiency enhancements in cellular assisted networks. The system capacity evaluation for the proposed greedy based algorithm is shown in Figure 9.

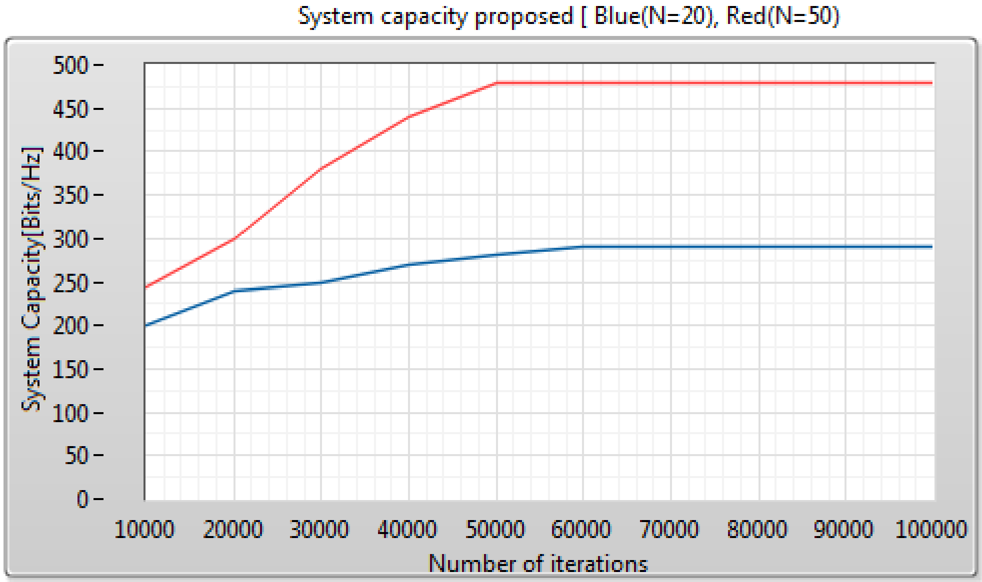

Fig 9. System capacity estimation for the proposed approach

In the second phase, power levels for the D2D pairs are obtained and in third phase system, capacity evaluation is performed using LabVIEW tool. An underlay data transmission technique proposed also increases throughput. But, in this method each base station is used as a relay for mono hop D2D communication.

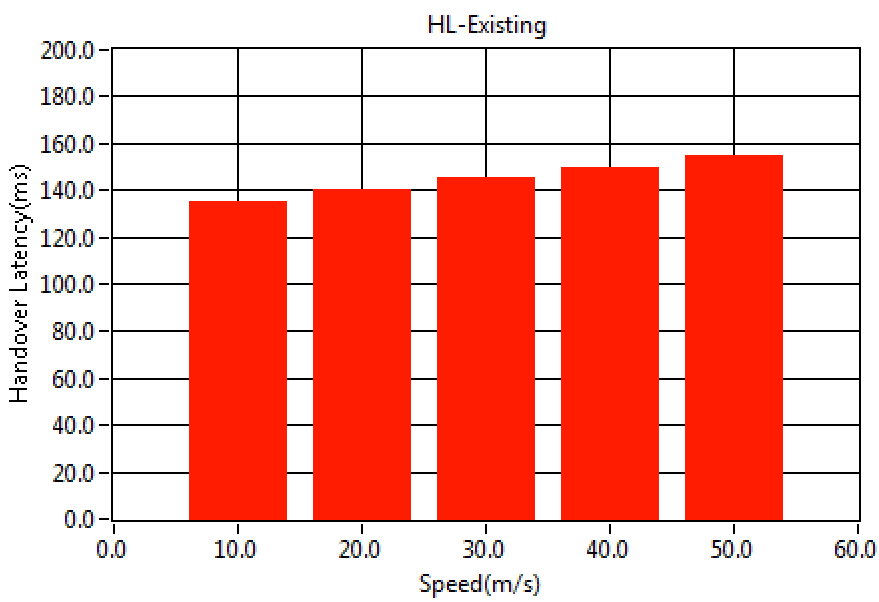

Fig 10. Handover latency of existing approach

The time taken for mobility management in the existing approach for different velocities of mobile nodes is illustrated in Figure 10. For mobile node velocity of 30m/s, the Handover delay obtained from the existing approach is 145ms. The existing method includes both scanning and authentication delays. Figure 11 shows the handover delay calculation results for the proposed method which includes only scanning delays. From the proposed results the total handover latency is estimated to be 66.6ms.

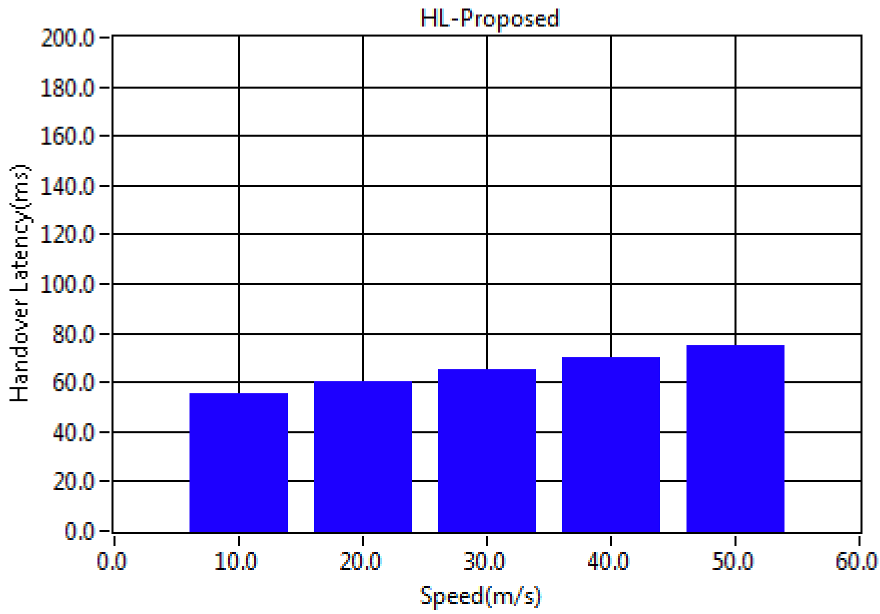

Fig 11. Handover latency of proposed approach

The simulation parameters used are listed in Table 1.

Table 1. Simulation parameters and values

Simulation parameters	Description
Number of cells	2
Network Type	LTE-A
Inner cell radius	100m
Outer cell radius	180m
Path loss exponent	3
Transmit power	20dBm
Handover latency from inner to outer cell	3s

User equipment transmission capabilities are not measured based on the distance between the user terminals. Also the interference parameters which must be considered are not taken for account when more number of users reuse the spectrum.

5 Summary and Conclusion

This study describes the different existing techniques available for interference mitigation to enhance the system capacity for D2D communication. The mobility management schemes like RPGM D2D mobility model and adaptive mobility schemes are described. The proposed work introduces an interference reduction algorithm based on greedy algorithm with minimum power levels required for D2D communication in LTE-Advanced networks. Then the system capacity evaluation is performed using LabVIEW tool. The results of the proposed work show that the system capacity is approximately 480 bits/Hz for 50 devices and 290 bits/Hz for 20 D2D users. These results are compared with the conventional approach which uses graph coloring approach.

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