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Interference Mitigation and Mobility Management for D2D Communication in LTE-A Networks

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Abstract

Interference and Mobility management are the main parameters which affect the signal capacity and reduce the transmission efficiency for D2D communication in LTE-A networks. When the users are in the same spectrum, due to the coexistence of D2D pairs and cellular users interference management becomes a critical issue. In this paper, we introduce an interference management algorithm that maximizes the performance of D2D communication in LTE-A networks for both uplink and downlink transmissions. Optimal routing selection techniques reduce the total path distance which helps to minimize the interference and improve the overall network capacity. Mobility management is also a challenging issue in IP-mobile networks. When two DUEs change their locations from one BS to the other, handover delay calculation becomes very important to maintain the communication without interruption. In this paper we show power control techniques which helps to reduce the effect of interference and also we addressed a method for the lower delay under complex mobility issues with uninterrupted D2D communication.

Index Terms: Device to Device Communication, Interference management, SINR, Mobility management, Handover delay.

1. Introduction

Device-to-device (D2D) communications allow user equipments to communicate directly with each other. Interference mitigation is a major issue for efficient D2D communication. Due to the coexistence of device to device pairs and cellular users, the D2D pairs generate effective interference towards base stations and cellular

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users. The interference to the D2D pairs significantly reduces the efficiency of the D2D communication. Channel assignment and power control algorithm techniques helps to mitigate the interference in D2D communication. High throughput can be obtained by properly adjusting the transmission power of all the nodes.

Resource allocation schemes to decrease the complexity of the network and to find interference limited areas are proposed in [2]. In these methods the cell is divided into two parts, the inner region which is near to eNB and the outer region which is away from eNB. However, there are no power control techniques to increase the performance of devices in the outer region. In these techniques since the cellular users do not share the same resources with device to device pairs, these schemes cannot be applied to the heavily deployed device to device pairs [15]. Fractional frequency reuse (FFR) is a scheme that reuses the same frequency in cellular networks to improve network capacity and spectral efficiency [1]. Interference alignment (IA) scheme used to reduce the interference effect [4]. But it requires global channel state information (CSI) to mitigate interference in the entire system. User selection methods are introduced to improve the sum rate [11]. However, it is constrained to the users with a single antenna. Hence the most effective technique to address interference mitigation is power control method [3]. In this method, a predefined maximum power level is calculated to control the interference and to guarantee the QoS requirement for D2D communication. Power reduction in turn maximizes the capacity of network. Two power control techniques are proposed in this paper. Femto cell and macro cell cellular networks are considered for the interference management in the first method. In the second method power requirements are calculated based on the distance between D2D users and CUEs.

When two mobile nodes are in communication they may change their locations and hence mobility management becomes a major issue. In the cellular mode, it is not a big task to maintain the services uninterrupted [6,10]. But in D2D mode it becomes a great challenge for mobility management since a proper algorithm is yet to be developed to maintain the communication without interruption. Handover delay (HD) for reliable communication between two user equipments while moving is a serious issue and a solution is shown in the proposed technique.

Following the introduction, this paper is organized as follows. In Section 2 the system model is described. Section 3 describes interference and mobility management. Section 4 presents simulation parameters and results. Section 5 concludes the paper.

2. Related Work

Interference reduces the capacity and transmission efficiency in D2D communication. Some of the interference types which impact on D2D communication are: Inter-symbol interference (ISI), Co-channel interference (CCI), Adjacent channel interference (ACI) and Cross-tier interference [12].

The disturbance of a signal with the other signals during communication is called Inter symbol interference. Co-channel interference appears between the two access points which use same frequency. Adjacent-channel interference is due to the extra power of the signal from the next channel. Cross-tier interference is the interference from one tier to another.

The interference appears in D2D communication is broadly divided into: Interference from D2D communication to cellular communication and Interference between D2D pairs.

Interference greatly reduces the efficiency, throughput and also other factors related to the D2D communication. The eNBs which shares channels in both uplink (UL) and downlink (DL) phases are contrived by the interference. Hence channel assignment and power control algorithms place an important role to mitigate interference problem in D2D communication [13]. The throughput and channel capacity can be increased by controlling the transmission power of all eNBs and CUs in LTE-A networks [15]. The D2D pair that reuses the channel is placed far away from the cellular user to avoid co-channel interference. Fig. 1 shows the interference problems between D2D pairs and CUs, where many DUEs coincide with a CUE in single cell. The channel state information can be obtained for all UEs when DUEs uses uplink channel resources at the eNBs. Because of multiple DUEs, cross-tier interference can be seen at the eNB. Hence it is to be greatly avoided to minimize the interference effect on the CUE. The proposed power control algorithm measures and reduces the power levels of DUE, CUE and eNBs based on distance. Decision of eNB usage is considered based on the distance between UEs.

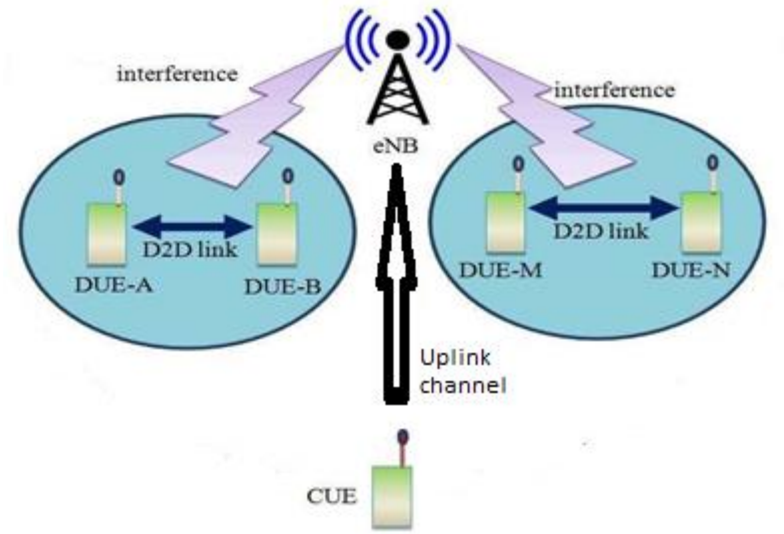
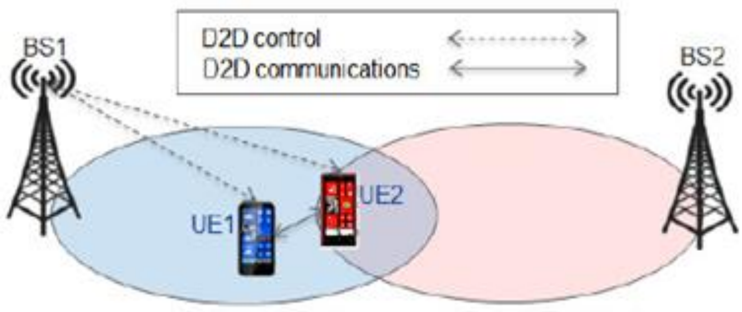


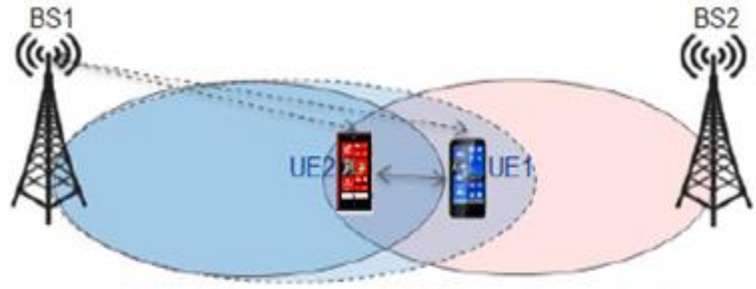
Fig.1. Interference problems between D2D pairs and CUs

The two main handover schemes for mobility management in D2D communication are D2D-Aware Handover and D2D-Triggered Handover schemes [6]. D2D-Aware Handover technique helps to reduce the latency when two devices are moving from one location to another. We propose a method which greatly reduces handover latency. D2D-Triggered Handover is a method of clustering the members of a D2D group to reduce the network signaling overhead due to information exchange between the base stations.

The D2D control and communications during the DUE mobility between two different base stations is illustrated in Fig.2. Fig. 2(a) depicts a situation where D2D pair initially controlled by BS1.



(a)



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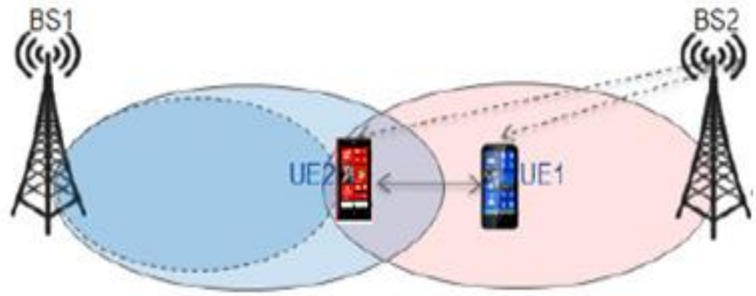

(c)

Fig.2. (a) Both UE1 and UE2 are controlled by BS1 (b) UE1 handover to BS2 is postponed until D2D conditions are fulfilled by both UEs (c) Handover to BS2 is executed when D2D conditions are fulfilled by both UEs

Fig.2(b) depicts a situation when UE1 move towards BS2. In this condition reducing the latency and signalling overhead becomes a challenging issue. We propose a solution in which BS1 postpones the handover till the signal quality of BS1 worse than a predefined D2D control condition to maintain the D2D control between two UEs. D2D control condition is set to the threshold value of signal-to-interference-plus-noise-ratio (SINR) i.e. -6 dB. Handover to BS2 is executed when D2D control conditions are fulfilled by both UE1 and UE2 as shown in Fig. 2(c).

3. Interference and Mobility management

3.1 Interference mitigation

Let d_j be the D2D pair, c_i be the cellular UE, P^{ci} be the transmission power of UE, P^{dtj} be the transmission power of D2D pair. Let the Gaussian noise variance to be σ and assuming the D2D pair d_j reuses the same base station, the Signal to Interference plus Noise Ratio (SINR) at the eNB according to [5] is

$$\gamma_{c_i d_j} = \frac{P^{c_i} G^{c_i, eNB}}{\sigma + P^{dtj} G^{dtj, eNB}} \tag{1}$$

Where $G^{dtj,eNB}$ is the channel gain between D2D transmitter and eNB, and $G^{ci,eNB}$ is the channel gain between eNB and cellular UE c_i.

Femto cell is the small low power base station. To find the Signal to Interference Noise Ratio (SINR) effect 'd' is assumed to be the distance between the D2D user 'm' and cellular base station 'M'. Let '*D*' be the distance between the D2D users and is assumed to be 10m to 100m.

The SINR of a macro cell user m is given by [12]:

$$SINR_m = \frac{P_M G_{m,M}}{N_o \Delta_f + \sum_{M^1} P_{M^1} G_{m,M^1} + \sum_F P_F G_{m,F}} \tag{2}$$

Where P_M and P_{M^1} are the transmit powers of the serving cell M and adjacent cell M^1. $G_{m,M}{}^1$ is the channel gain between the serving cell m and adjacent cell M^1. $G_{m,F}$ is the channel gain between the serving cell m and femto cell F. P_F is the transmit power of adjacent femto cell F. N_o is the white noise power spectral density. Δ_f is the subcarrier spacing.

The DUE SINR from [14] is given by

$$SINR_{DUE^K} = \frac{P_{DUE^K} \left| h_{DUE^K} \right|^2}{IEI^K + \sigma^2} \tag{3}$$

Where $P_{DUE}{}^K$ is the power transmitted by the device to device user equipment DUE which is calculated by using the equation

$$P_{DUE^K} = \min\left\{P_{\max}, P0 + \alpha PL\right\} \tag{4}$$

Where P_{max} is the maximum transmit power of the D2D user. P0 is the uplink device transmission power during noise condition of the receiver. α is the parameter which represents path loss effect and the value of it is set as $\alpha = \{0,0.1,0.2,0.3,\ldots\ldots\ldots 0.9,1\}$. PL is the downlink path-loss effect obtained from each user. $\left|h_{DUE^K}\right|^2$ is the gain of the target D2D pair and IEI^k is the In-band Emission Interference from the cellular user equipments.

Greedy algorithm is used to find the shortest path between the devices. The UE makes routing decisions based on the distance of the other UE either through BS or direct D2D communication. Table 1 gives the parameters considered for SINR.

Table 1. Parameters for SINR

Parameter	Value
Subcarrier spacing	15 KHz
Number of Users N	15
Base station transmit power	46 dBm
Propagation Path Loss λ	0.8
Source D2D UE transmit frequency *m*	2.1 GHz
Neighbor Cell Power Interference	-10.3 DBM
Capacity of Cell M	10^5 BPS
Destination D2D UE m'	19(BS number)

In this shortest path greedy algorithm each D2D UE knows its location through its global position system. The Greedy algorithm uses the following steps:

i. The source UE makes communication request from the destination UE when the distance between them is in the region of proximity. Then the source UE performs D2D communication with the destination UE with the proper authentication.

ii. If the destination user equipment is not in the range of source user equipment, source user equipment calculates the shortest path and requests nearby BS to transfer the call to the destination user equipment.

iii. The source user equipment sends the data packet to the relay which is the close to the destination user equipment.

Algorithm 1: Greedy Algorithm for Interference mitigation

1. **procedure** probability P_{SPR} (m, M, D, d_j)
2: **if** $\gamma_{ci,di} \geq D$ **then** % the first hop SINR requirement
3: $SINR_m = P_M G_{m,M} / (N_o \Delta_f + \sum_{M^1} P_{M1} G_{m,M^1} + \sum_F P_F G_{m,F})$
4: **while** destination node not reached **do**
5: Power transmitted DUE $P_{DUE^K} = \min\{P_{\max}, P0 + \alpha PL\}$
6: **end while**
7: **end if**
8: The DUE SINR from [8] is given by $SINR_{DUE^K} = (P_{DUE^K} \left|h_{DUE^K}\right|^2) / (IEI^K + \sigma^2)$
9: **end procedure**

3.2 Handover analysis for mobility management

The overall latency according to [7] is equal to

$$T_{scan} + T_{auth} + T_{re} - ass + TPBU + TRA \tag{5}$$

However, according to [8] MN's profile contains the MN-ID placed in nMAG, which authenticated the MN already. Hence, authentication delay can be removed during handover [9]. Hence overall latency according to [6] is

$$Total_{HD} = T_{scan} + T_{re} - ass + TPBU + TPBA \tag{6}$$

Since the mobile node keeps scanning for the surrounding networks existence continuously scanning delay cannot be removed. Hence in our proposed approach scanning delay considered. The proposed approach comparison with the standard approach is as shown in Fig. 3. First, the source user equipment calculates the distance of destination user equipment and checks for resources after authentication. If the source user equipment distance is in the line of sight communication, the source user equipment directly communicates with the destination user equipment by performing IP assignment and Registration. If the source user equipment distance is not in the line of sight communication, then the source user equipment checks for handover requirement and handover takes place when the destination user equipment is not under the same network. If both source and destination user equipments are under the same network and the distance between them is not in the line of sight communication, the BS establishes call setup process between them. In the proposed approach it is shown that the pre-authentication, pre-channel assignment, pre-IP assignment and preresource allocation processes will be completed before call setup when the distance between them is in the line of sight communication. It is also shown that the handover delay is greatly reduced due to pre-authentication, pre-channel assignment and pre-IP assignment.

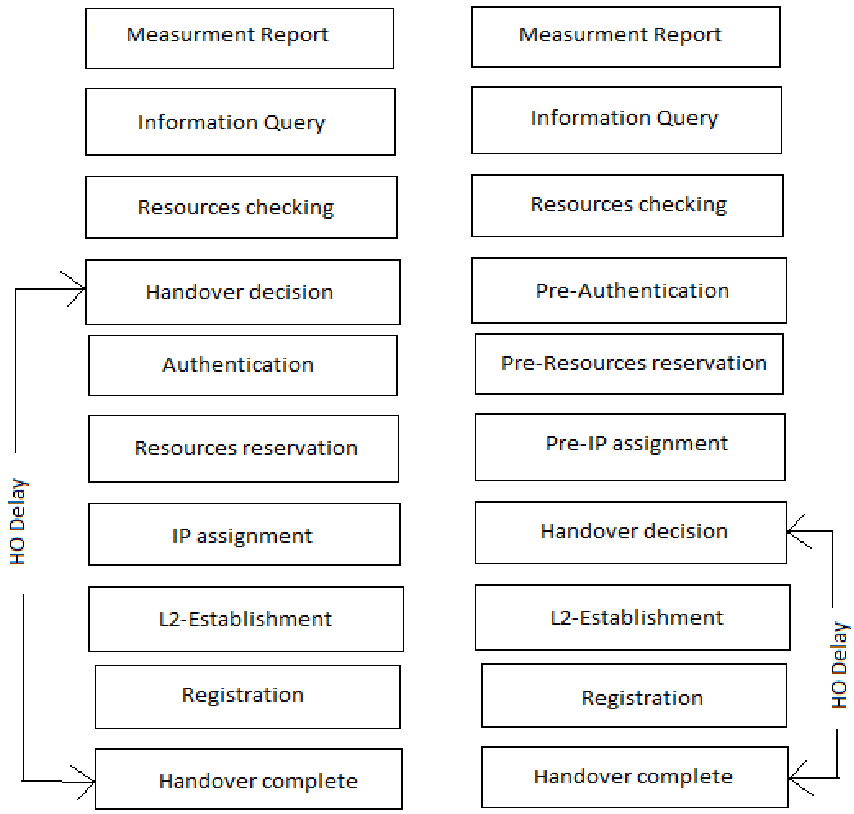

Fig.3. Comparison of proposed approach with the standard approach

Thus the overall HL of our approach is expressed as

$$HL_{proposed} = T_{scan} + T_{re} - ass + TPBU + TRA \tag{7}$$

4. Simulation Results

This section gives simulation results for the interference mitigation and handover delay. The Signal to Interference Noise Ratio results for the proposed system with increased D2D pairs is shown in Fig.4.

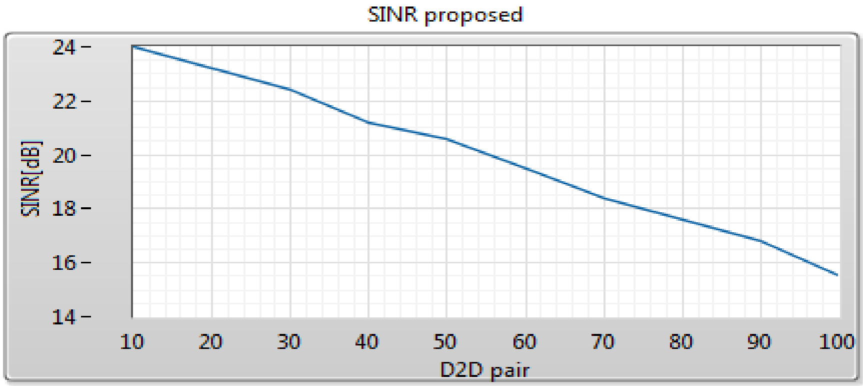

Fig.4. SINR values with increased D2D pairs (SINR-Proposed)

The maximum and minimum transmit powers of single eNB are assumed to be 46 dBm and 10 dBm. The transmit power of eNB is set to be 34 dBm. The cellular network cell radius is set to be 2000 meters. The Cellular user equipment and device to device user equipment pairs are randomly deployed. The transmitting range of D2D pair is considered to be 1000 meters. The Signal to Interference Noise Ratio results for the conventional approach is shown in Fig.5.

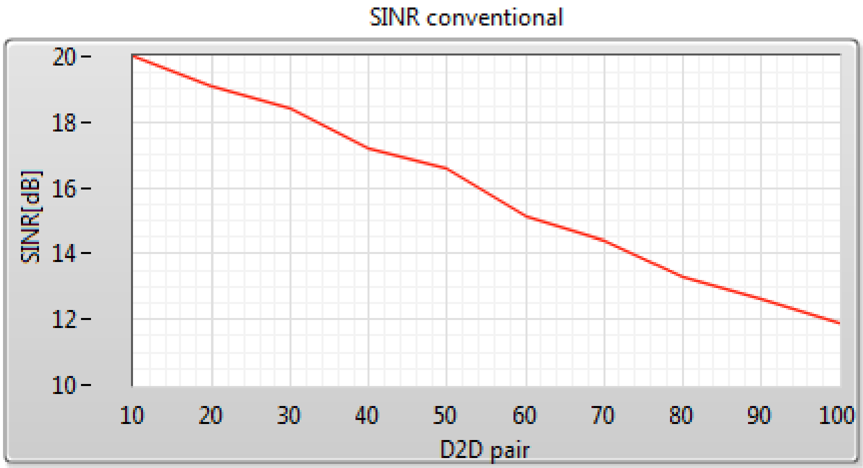

Fig.5. SINR values with increased D2D pairs (SINR-Conventional)

From the results it is observed that for 10 D2D pairs an SINR of 24dB is obtained from the proposed system and it is 20dB in the conventional method. Hence there is a increase in SINR by 4 dB from the proposed method. Simulation is performed under LabVIEW platform. Table 2 gives the parameters considered for SINR.

Table 2. Simulation parameters

Parameter	Value
Maximum Transmit Power of eNB	46 dBm
Minimum Transmit Power of *eNB*	10 dBm
Pathloss model for D2D users	$38.46+20\log_{10}(d_d)$ dB
downlink path-loss (P_L)	15.3 dB
Max allowed transmit power (*Pmax*)	200 mW
device specific transmission power (*Po*)	100 mW
System Bandwidth (*B*)	15 kHz
SINR threshold ξ (BS antenna height)	45 m
D2D pair distance	10m
Uplink bandwidth	5MHz

For our proposed approach of mobility management considering scanning delays the time required for overall handover latency is HL-proposed = Tscan + Tre − ass + TPBU + TRA = 0.6+25+11+30=66.6ms. Fig.6 illustrates the Handover Latency versus MN velocity of the existing approach proposed in [6]. It is noted that the Handover delay for the MN velocity of 30m/s is 145ms in the existing approach.

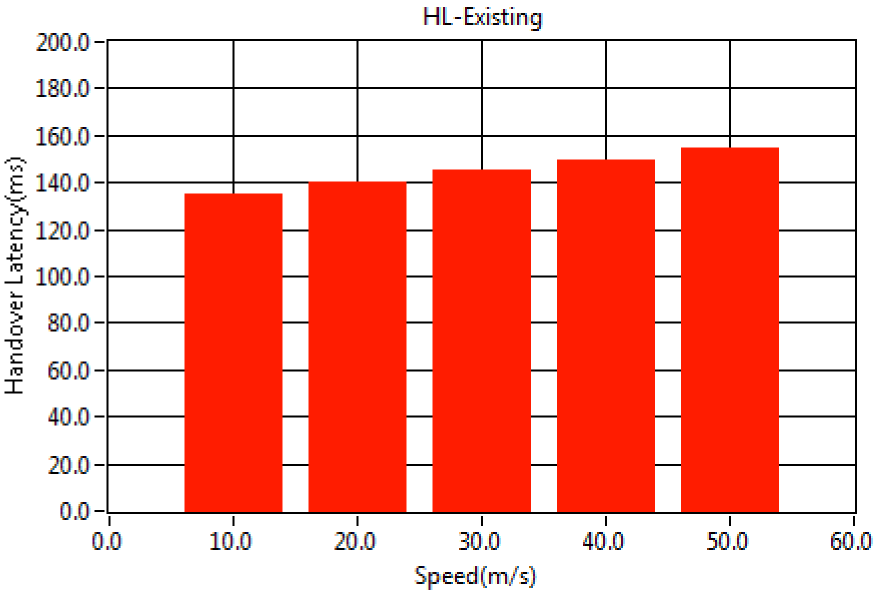

Fig.6. Handover latency versus MN velocity (Existing)

Fig.7 illustrates the Handover Latency versus MN velocity of the proposed approach. For simulation the velocity of MN is assumed from 10m/s to 50m/s. It is observed that the Handover delay for the MN velocity of 30m/s is 66.6ms in the proposed approach. Hence our proposed greatly helps in reducing delays during handover.

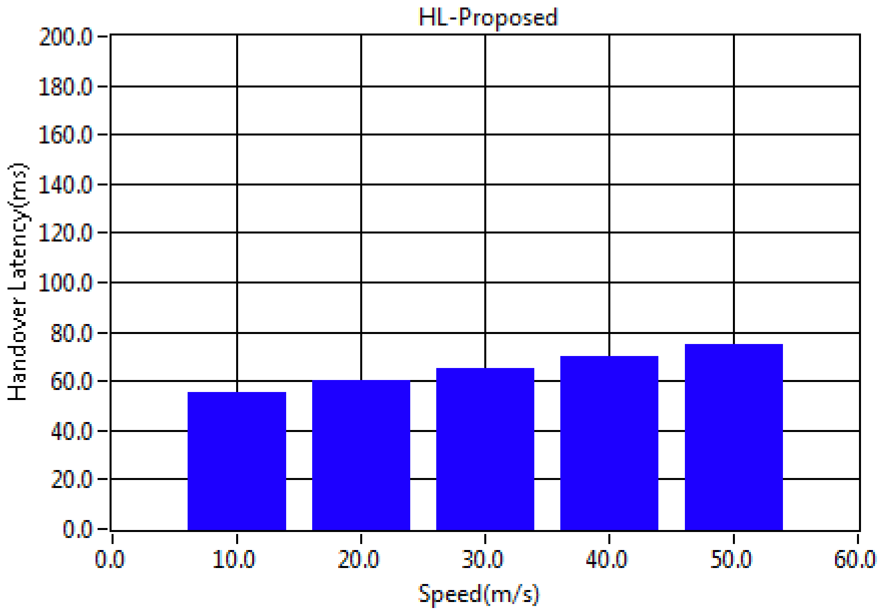

Fig.7. Handover latency versus MN velocity (Proposed)

The details of the proposed approach with other approaches are shown in Table 3.

Table 3. Performance evaluation parameters

Parameter			Value
Tscan	0.6	0.6	0.6
Tauth	0.6	0.6	
Tre-ass	250	25	25
TMN	0.1	-	-
TDAD	1070	-	-
TPBU	11	11	11
TPBA	11	-	-
TRA	30	30	30
Total	1373.3ms	67.2ms	66.6ms

5. Conclusions

Interference minimization and mobility management techniques are addressed in this paper for device to device communication in LTE-A networks. The power control techniques are shown to obtain improvements in SINR values. An improvement by 4 dB in SINR values is observed. For simulation we set the eNB transmit power to be 34dBm and the network cell radius to be 2000 meters.

In our proposed approach of mobility management a solution is obtained to minimize the handover latency. We studied the standard methods and the work shown by different authors to reduce handover latency. The time required for overall handover latency is calculated considering the requirements of authentication and scanning parameters when a DUE moving from one BS coverage area to the other. In the proposed approach we have shown that the time required for overall handover latency to be 66.6ms for the MN velocity of 30m/s and it is 145ms in the existing approach. Hence our proposed greatly helps in reducing handover delays when the MN shifts from one cell to the other.

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