An OTDOA based Efficient Algorithm for Location Updating and Connection Handover in BDS

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Abstract- **In this paper, a technique for efficient positioning of user equipment and implementation of connection handover for device to device (D2D) communication application is discussed. This D2D application, being addressed as Battery Deposit Service (BDS), is a utility for optimizing battery of smartphone by reducing energy consumed in communication over network. Addition of an energy efficient positioning & handover strategy for D2D connections will allow the system to perform better with an increased quality of service (QoS). The technique for handover is based on Observed Time Difference Of Arrival (OTDOA) positioning approach along with the Positioning Reference Signal (PRS), mentioned in Release 9 of LTE technology, to calculate the position of a User Equipment (UE) within a network and performing handover beyond certain threshold boundary. It is shown through simulations that the proposed scheme will reduce the probability of connection dropping, thereby improving performance of whole system.**

Keywords**: Positioning Reference Signal (PRS), Time Difference of Arrival (TDOA), Hyperbola of Constant Time Difference (HoCTD), Long Term Evolution, D2D communication**

I. INTRODUCTION

As the number of smartphone users grows dramatically, localization-based services have become more and more important in many different areas for their ability to provide network users with additional value added services. One such service is addressed in [1, 2] for smartphone battery optimization. This service is named as Battery Deposit Service (BDS) and it is designed as an application of device to device communication underlaying LTE advance networks. The service is dedicated for optimizing smartphone battery by reducing energy consumption over network communications.
There are many similar applications that have boosted research on location finding techniques [3, 4]. The most popular technique to be used in the mobile and wireless networks is the Global Positioning System (GPS) [5]. This technique provides the high accuracy in free space and LOS environments but its performance greatly degrades in NLOS indoor and urban scenarios. High accuracy about the position of a wireless device is still a crucial issue to be satisfied, so different solutions must be taken into account.

Time of Arrival (TOA), Time Difference of Arrival (TDOA), Angle of Arrive (AOA), and Received Signal Strength (RSS) techniques are the most researched [6]. For TOA approach, the arriving time of the base station downlink signal to the mobile user is measured to give the straight distance between them. TDOA techniques are very similar to TOA and use the difference between different TOAs measurements to construct the correct position of the mobile. In Contrast to TOA approach, TDOA does not require strict network time synchronization and has advantages for project implementation. The AOA-based techniques use an antenna array and judge the direction of the mobile station with the incident angle of the received signal to calculate the coordinates of the mobile station. Finally, RSS-based approaches rely on the attenuation introduced by the propagation of the signal from the base station to the mobile user.

TOA-based technique, already used in the 3rd generation European mobile cellular network, is also one of the accepted positioning techniques to be used in the Long Term Evolution (LTE) release 9 [7]. For the TOA or TDOA algorithm, the accuracy of the position estimate greatly depends upon the precision of the timing calculation. The LTE standard, specified by the 3rd Generation Partnership Project (3GPP) consortium [7], has defined a dedicated downlink signal for Observed Time Difference of Arrival (OTDoA) positioning, i.e. the Positioning Reference Signal (PRS). This paper proposes a distance estimation method for BDS with the use of PRS signal.

In the proposed method, the TDOA technique is adopted and the coarse time and the precise time are estimated respectively.

This rest of the paper is organized as follows. In Section II, the basic TDOA technique is summarized. The proposed algorithm for positioning and handoff is discussed in Section III. Section IV gives details of obtained simulation results. The paper is finally concluded in section V.

II. OBSERVED TIME DIFFERENCE OF ARRIVAL (OTDOA) POSITIONING TECHNIQUE

Figure 1 illustrates how two cooperating receivers can calculate path difference from the time difference of arrival, and how this calculated path difference corresponds to a hyperbolic function [8]. There are two important applications where this problem occurs:
A. Mobile terminal positioning: The available measurements are either network-assisted or mobile-assisted, using up-link

or down-link information. For an overview, see [3, 4]. The current 'yellow page' service is based on *Received Signal Strength* (RSS) of signal with known power and a course *Angle* measurement from the sectorized antennas [5]. This gives quite course estimation. It is a well-known fact that a much higher accuracy which is insensitive to fading is based on time of arrival (TOA). In present systems, it may be also possible to compute only the time difference of arrival (TDOA) or enhanced observed time difference (E-OTD) measurements. Another important source of information for tracking moving objects is map information, see [7].

B. Electronicwarfare: Here the main problem is to accurately locate enemy transmitters for making appropriate counter measures. The TDOA approach discussed here may offer higher accuracy than any traditional triangulation approaches, where the angular measurements potentially have larger inaccuracy than TDOA measurements.

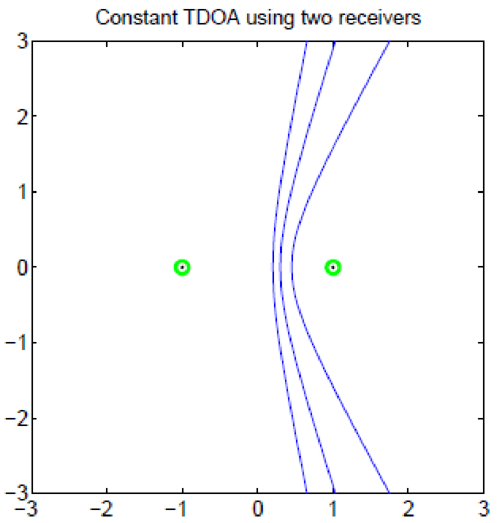

Fig 1. The hyperbolic function representing constant TDOA for three different TDOA's (0.4, 0.6 and 0.9 scale units, respectively).

3GPP initially provides three reference signals for downlink in LTE physical layer standard [8]: Multicast Broadcast Single Frequency Network Reference Signals, Cell-specific Reference Signals and UE-specific Reference Signals. After in-depth study, it was found that the positioning accuracy was influenced due to the near-far effect of these signals [9]. Hence, 3GPP LTE Release 9 specification designed Positioning Reference Signal (PRS) specifically for location. Positioning system gets positioning reference signal from the received signal to estimate its delay with a series of processing.
Positioning reference signal sequence $rl;ns(m)$ is defined as follows:

$$r_{l,ns}(m) = \frac{1}{\sqrt{2}}\big(1 - 2c(2m)\big) + \frac{j1}{\sqrt{2}}\big(1 - 2c(2m+1)\big) \quad (1)$$

where, $m = 0, 1, ---- ,(2N_{RB}^{max,DL}-1)$
$N_{RB}^{max,DL}$ denotes the max number of physical resource blocks and equals to 110, *ns* is the slot number in one radio frame, l is the OFDM symbol number within a slot and $c(m)$ is a pseudo-random sequence generated by the Gold code. The generation process is as follows:

$$\begin{cases} c(i) = \big(x_1(i+N_c) + x_2(i+N_c)\big)\, mod\ 2 \\ x_1(i+31) = \big(x_1(i+3) + x_1(i)\big)\, mod\ 2 \\ x_2(i+31) = \begin{pmatrix} x_2(i+3) + x_2(i+2) \\ x_2(i+1) + x_2(i) \end{pmatrix} mod\ 2 \end{cases} \quad (2)$$

where $N_C = 1600$, $x_1(i)$ and $x_2(i)$ are m-sequences.
They are initialized as follows,

$$x_1(0) = 1,\ x_1(i) = 0,\ i = 1, 2, 3, -----, 30 \quad (3)$$

$$c_{init_{x_2}} = \sum_{i=0}^{30} x_2(i).2^i \quad (4)$$

Before the beginning of each OFDM symbol, the pseudo-random sequence generator must be initialized and the initial value is:

$$c_{init} = 2^{10}(7(n_s+1) + l + 1)(2N_{ID}^{cell} + 1) + 2N_{ID}^{cell} + N_{CP} \quad (5)$$

where $N_{CP} = 1$ in standard cyclic prefix and $N_{CP} = 0$ in extended cyclic prefix.

When $r_{l,ns}(m)$ is generated, the corresponding complex-valued modulation symbols are:

$$a_{k,l}^{(p)} = r_{l,n_s}(m') \quad (6)$$

and mapped to the resource blocks, where p=0 is the antenna port number. The protocol specifies that the positioning reference signal emits from antenna port 0. A standard cyclic prefix has been used in this paper.

C. Process of finding location of UEs using the PRS:
The whole process of finding UE locations is based on three important steps.

Step 1. UE receives PRS from the helper relays

Step 2. Now based on the received PRS, UE will measure the observed time difference of arrival (OTDA) and then it will report Received Signal Time Difference (RSTD) to cell.

Step 3. Then, based upon the reported reference signal time difference (RSTD) by UE, eNodeB will now calculate the longitude and latitude of the UE (which can be based on any algorithm, not specifically standardized).

Positioning Reference Signal is usually transmitted in downlink subframes (as per upper layer configurations discussed later in this article) on antenna port 0. I should be noted that PRS should not be sent on resource element used for PBCH, PSS or SSS. The PRS sequences are generated on the basis of slot number, OFDM symbol number, user ID, normal CP or extended CP.

Figure 2 shows the overall process of finding UE locations using three steps.

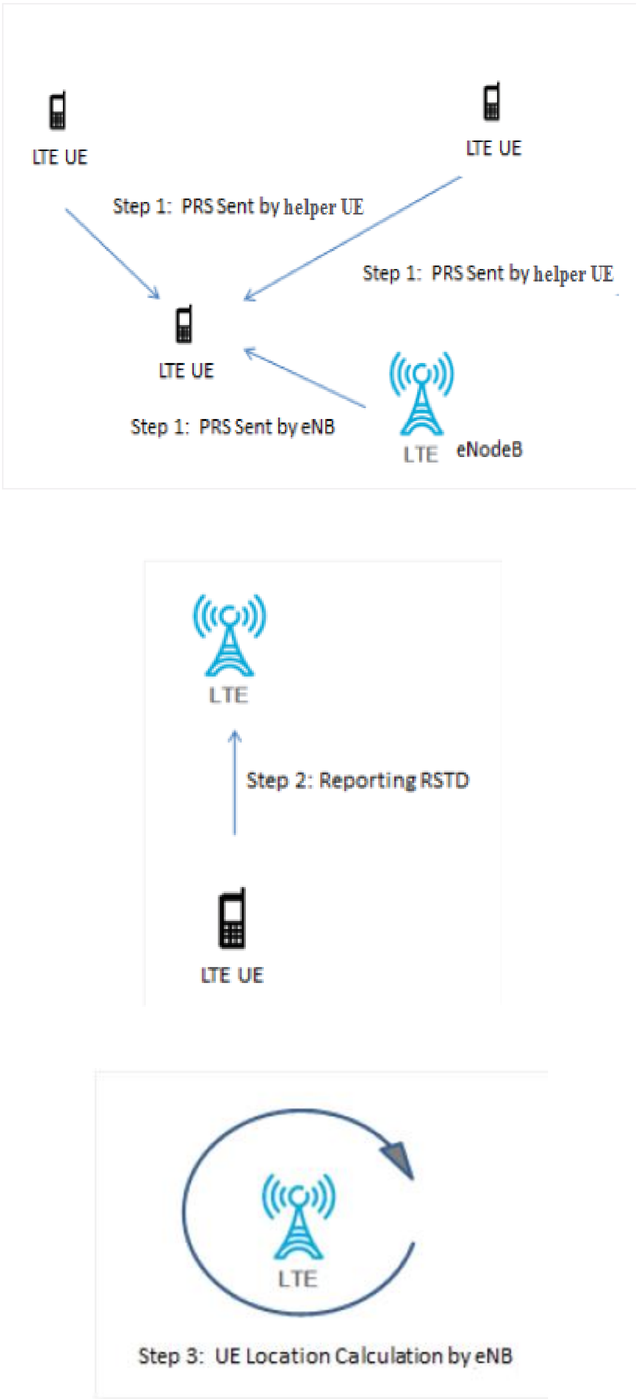

Fig 2. Process of finding UE location by using PRS

III PROPOSED METHOD

In this method, a number of helper transmission signals are generated which are then combined with different delays and received powers to model the reception of all the helper signals by one UE. The UE will perform correlation with the Positioning Reference Signal (PRS) to calculate the delay from each helper and subsequently the delay difference between all pairs of helpers. These delay differences are then used to compute hyperbolas of constant delay difference, which are plotted relative to known helper positions and intersect at the position of the UE.

A. Transmitter Configuration

For getting a transmission scenario, a set of helper configuration is generated with the number of helpers taken as N. For simplicity, here N is taken as 4. For the purpose of simulation, the configurations are derived from Reference Measurement Channel (RMC) R.5 which describes a 3 MHz bandwidth DownLink Shared Channel transmission using 16-QAM modulation. For each helper the configuration is constantly updated to make the D2D user identity unique and the PRS parameters N_{PRS}, I_{PRS} and PRS_{Period} are set.A random position given by x and y coordinates for each helper is obtained by eNodeB.

The positions of the helpers and the UE are plotted for convenience. The reference UE lies at (0,0) and the helpers are distributed evenly around the UE within D2D connection range i.e. 100m span. This plot is shown in figure 3.

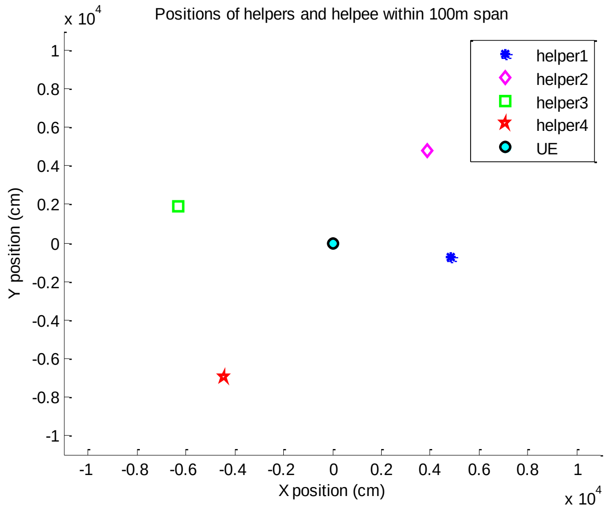

Fig 3. Positions of the helpers and the helpee (UE)

For each helper, a tsignal is transmitted, by reference UE, consisting solely the PRS. This is done by creating an empty resource grid and then generating and mapping PRS onto the grid. The resultant grid is now OFDM modulated to generate a waveform for transmission. The OFDM signals to be transmitted from UE are given by:

$$x(k) = \sum_{k=0}^{N-1} X(k) W^{-nk}, \; n = 0,1, \ldots\ldots, N-1 \qquad (7)$$

and the analog form of these signals are

$$x(t) = \sum_{k=0}^{N-1} X(k) e^{j2\pi f k t} \qquad (8)$$

where f is the fundamental frequency and the time width of one OFDM symbol T=1/f.

The signal $x(t)$ are transmitted through the wireless channel and the channel impulse response is

$$h(t) = \partial(t - t_k) \qquad (9)$$

where t_k is transmission time from the anchor node k to the destination node.

The received signal $y(t)$ through the channel is expressed as

$$y(t) = x(t - t_k) \quad (10)$$

These transmitted waveforms are plotted in figure 4.

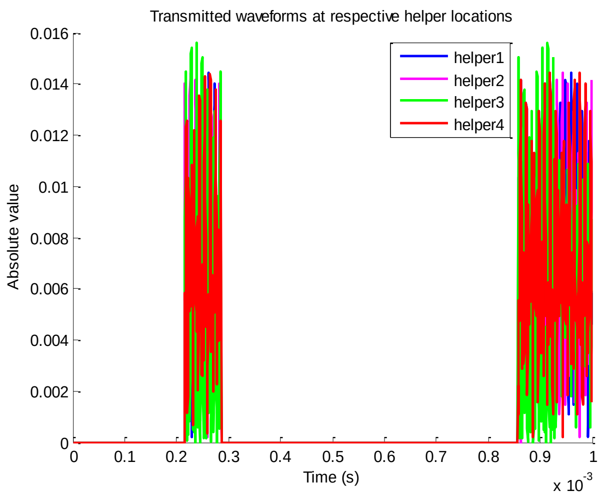

Fig 4. Transmitted waveforms at respective helper locations

B. Computing delays from helpers to UEs

Using the known helper positions, the time delay from each helper to the UE is calculated by eNodeB utilizing the knowledge of the distance between the UE and helper, radius, and the velocity of propagation of signal. Using the sampling rate, the sample delay is calculated and stored in sampleDelay. These variables will then be used to model the environment between the helpers and the UE but the information will NOT be provided to the UE. The information is kept with eNodeB for analysis.

Assuming that the transmission time from the two anchor nodes to the destination node are t_1 & t_2 respectively, the received signals are as follows:

$$y_1(t) = \sum_{k=0}^{N-1} X(k)e^{j2\pi fk(t-t_1)} \quad (11)$$

$$y_2(t) = \sum_{k=0}^{N-1} X(k)e^{j2\pi fk(t-t_2)} \quad (12)$$

Lets define Z_{12} calculated from the integral value of the product of the above signals within the time width of the one symbol,

$$Z_{12} = \int_t^{t+T} y_1(t)[y_2(t)]^* dt \quad (13)$$

On solving further, we get

$$Z_{12} = \sum_{k=0}^{N-1} X(k)e^{j2\pi fk(t_2-t_1)} \quad (14)$$

Hence, the phase of Z_{12} can be obtained as follow,

$$\phi_{12} = \text{angle}\ \{Z_{12}\} \quad (15)$$

The phase ϕ_{12} one-to-one corresponds to the time difference (t_2 - t_1), which can be derived from the phase simply by the look-up table method. It is easy to be seen, that the above formula is a statistical value and reflects the overall time difference.

Due to the cyclical nature of the phase, the time difference derived from Eq.(15) is limited. The time difference (t_2- t_1) can be divided into two parts,

$$t = t_2 - t_1 = t_I + t_f \quad (16)$$

where t_I is the integer multiple of one sampling interval delay and t_f is less than one sampling interval delay. We can make use of the signal correlation to estimates t_I in [9] and t_f is obtained from Eq. (14, 15). When more than three results of the time difference are calculated, the coordinates of the destination can be estimated.

The received signal at the UE is then modeled by delaying each helper transmission according to the values in sample delay, and attenuating the received signal from each helper using the values in radius. The radius here is used in conjunction with the Winner II Urban Macro Line Of Sight (LOS) path loss model. The received waveform from each helper is also padded with string of zeros to ensure that all waveforms are the same length.

The received waveforms are plotted in figure 5.

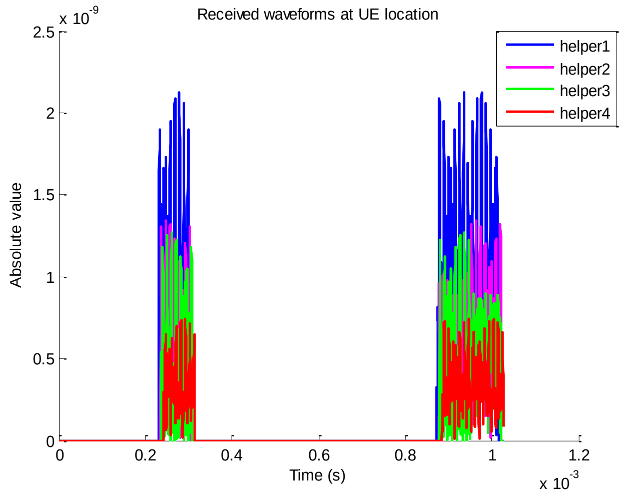

Fig 5. Received waveforms at UE location

C. Estimate Arrival Times

The arrival time of incoming signals from each helper are established at the UE by just correlating the incoming signal with a localy generated PRS with the D2D user identity of each helper. Note that the absolute arrival time cannot be used at the UE to calculate its position as it has no information on how far away the helpers are but only knows the difference in distances given by the difference in arrival times. Hence the peak correlation value of signal from each helper is used as a delay estimate to allow comparison.

A plot of received signal correlations is shown in figure 6.

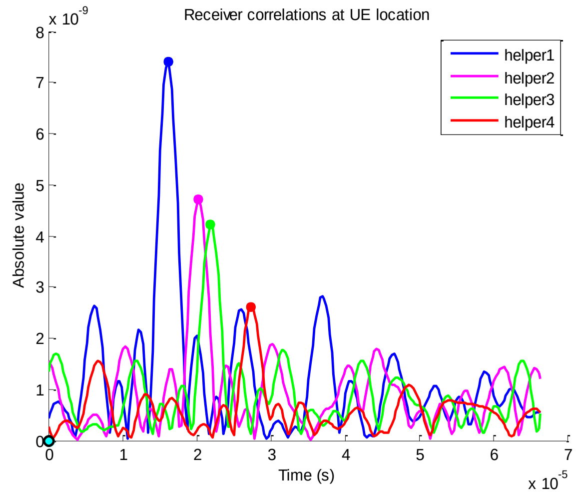

Fig 6. Received signal correlations at UE location

D. Compute TDOA and plot constant TDOA hyperbolas

With the help of arrival times, time differences of arrival instances between each pair of helpers are calculated. A particular value for time difference of arrival between a pair of helpers can result from UE being located at any random position where two circles, each centered on a helper, intersect. The two circles will have radii which differs by the distance covered at the speed of light in given time difference. A complete set of possible UE positions across all of the possible radii for one circle (with other circles maintaining a radius appropriate to time difference as already described) forms a hyperbola. The "hyperbolas of constant delay difference" for all the different pairs of helpers are then plotted relative to the known helper positions and their intersection gives the position of UE.

Figure 7 shows the positions of helpers and helpee (UE) and the corresponding hyperbolas of constant delay difference.

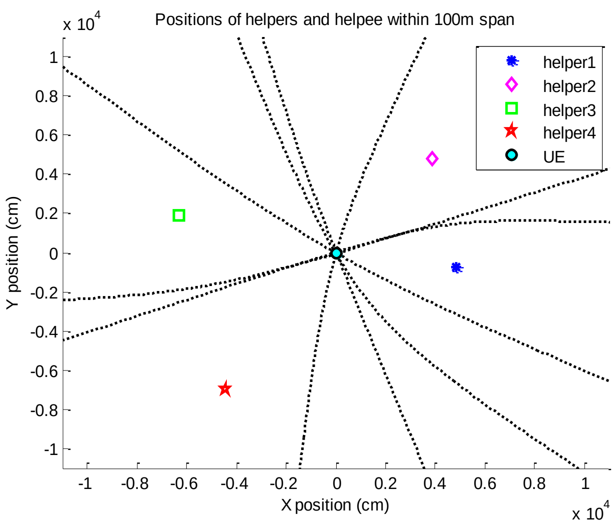

Fig 7. Positions of helpers and helpee (UE) and the corresponding hyperbolas of constant delay difference.

E. Connection Handover

A handover of D2D connection will be required if any of the following situations persists:

a) Signal reception from helper UE to helpee UE is not proper or is weak.
b) Helper UE battery is going below the "helping threshold" which is the threshold battery level of helper UE above which it can serve as a helper.
c) Helper UE is moving out of D2D connection range i.e. 100m span radius.

In conditions (a) & (b), handover will automatically be requested by helpee UE. However, in condition (c), eNodeB can automatically detect that a handover is needed if it follows location update algorithm for both helper and helpee UE as discussed previously.

After detection of need of handover, now the actual handover is to be performed. For this, the eNodeB is expected to keep track of minimum 4 UEs that offered to help when the helpee UE requested. These 4 UEs will be the ones whose RSS was maximum but little less than the 1st selected helper. So, now eNodeB will check the availability of all these 4 helpers and if available, the best match will be assigned as new helper. Here soft handoff will take place i.e. new helper will be assigned the frequency in use of previous connection.

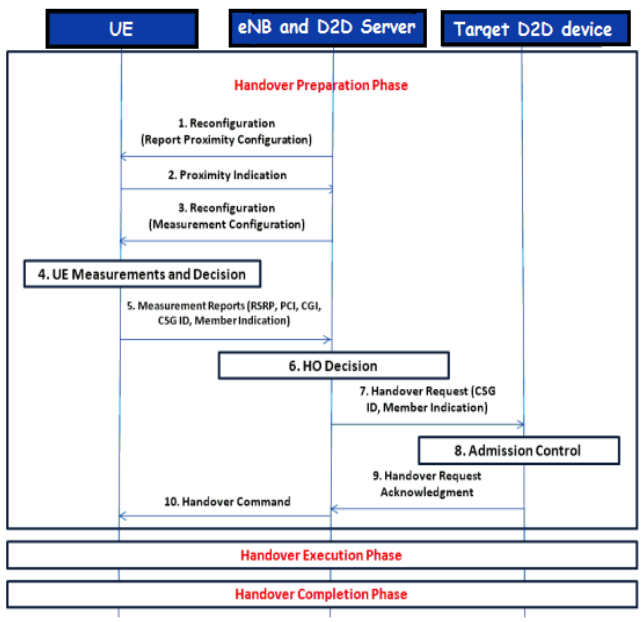

Fig 8. Handover scenario in D2D communications

Figure 8 shows the overall D2D handover procedure with a focus on the handover preparation phase. The signalling steps shown are all applicable to handovers during the RRC CONNECTED state, i.e., the state at which the user is having an active call. However, they are still applicable to handovers during the RRC IDLE state, but only up to step number 4 after which the remaining few steps would not be needed. This minor difference between the handover procedure in both states will be clarified in the next subsection while explaining the step of UE Measurements and Decision.

This proposed handover strategy considers RSSI, the velocity of the UE, the SINR, the user type and the duration UE maintains the signal level above the threshold level. The threshold is the minimum level required for the handover [10]. This proposed strategy will start by monitoring the UEs initially indulged in BDS or any other D2D service. If the velocity of UE moving were above 3km/h, they are allowed to go to the next procedure. Four interested helpers (UEs), with the highest available RSSI are determined. The UE which can support the bandwidth as well as having the highest SINR will be chosen. After this handover will immediately occur.

The whole process is explained with the help of flowchart shown in figure 9

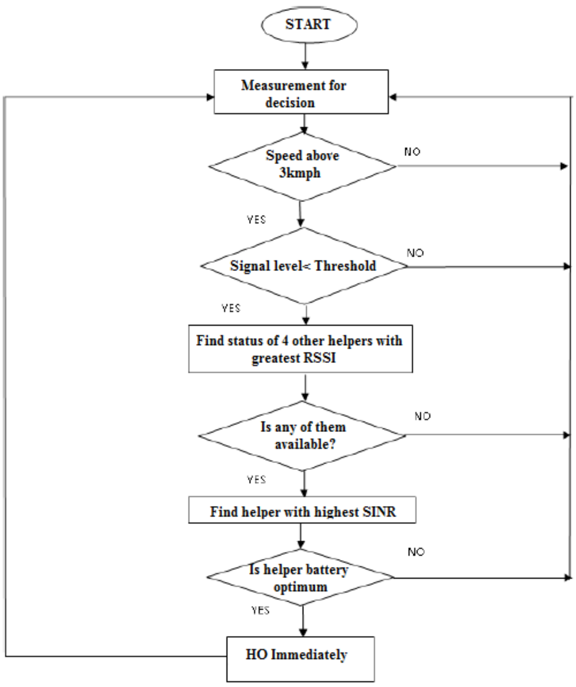

Fig 9. Technique for handover in D2D

IV SIMULATION RESULTS

This paper implemented an event driven simulation model in Matlab. The parameters used for simulation are summarized in Table I. The constant energy cost factor is referenced from the report on power consumption in RRC CONNECTED state of the UEs moving at a speed of 3 kmph with discontinuous reception period (DRX) set to 160 ms and release timer set to 5 seconds [11]. Other parameters are also chosen to simulate realistic scenario. The model is developed to simulate the effects of these design parameters by fixing the radius over which a UE can find potential helpers. The simulation is initialized with a network scenario where the UEs are located at uniformly at random locations within a hexagonal cell. Each UE will have a random level of battery. Also, the smart connection handoff solutions proposed in this paper aims at maximizing the single small cell control on D2D communications so that the connection dropping and blocking rates can effectively be minimized; E2E latency can be kept minimal; and decrease network signaling overhead. The inter-frequency deployment where macro and small layers are allocated with non-overlapping parts of the radio spectrum is the area of our interest in this paper. In such a scenario, if D2D control is given to the macro cell, benefits of small cell offloading may not be maximized due to lack of control of the macro layer on the small cell resources. Furthermore, not only in interfrequency deployment of macro and small cells but also in intra-frequency deployment, D2D will be control by the macro layer.

TABLE I: SIMULATION PARAMETERS

Parameters	Values
Cell Radius	500 m
No. of UEs	500
Speed of UEs	0.1 – 3 m/s
Pause duration	0 – 300 s
Walk duration	30 – 300 s
Path loss compensation factor α	0.8
Communication battery budget	300 J
Base power P_o	-69 dBm
Maximum transmit power T	24 dBm
Modulation order	QAM 16
Carrier frequency	2 GHz
eNode B antenna height	25 m
UE antenna height	1.5 m
Cooperation threshold γ_1,γ_2	0.3, 0.3
Cooperation path loss threshold	110 dB
Handoff gain H	5 dB
Log Normal fade margin L	11.3 dB
Cell Antenna gain G	10 dB
No. of PRS sub frames N_{PRS}	2
PRS Index I_{PRS}	0

The simulation results show that the connection dropping probability of D2D connections will be considerably reduced by introducing the proposed handoff scheme. This is shown in figure 10. Also the blocking probability would be reduced due to use of D2D connection scheme. This is shown in figure 11. Table II give a rough overview of the accuracy and precision of some important positioning techniques in urban area. It must be mentioned that the values of the tables represent measurements under specific circumstances. They cannot be taken as valid for every situation since they depend on the environment and the environment is not stable but they can be used as a guideline. The precision represents the reliability of the techniques.

TABLE II: POSITIONING ACCURACY AND PRECISION IN URBAN AREAS

Positioning scheme	Accuracy	Precision
Cell ID	526m	80%
Angle of Arrival	100m-200m	67%

OTDOA	624m	95%
Pilot Correlation Method	80m	67%
Database Correlation Method	25m	67%

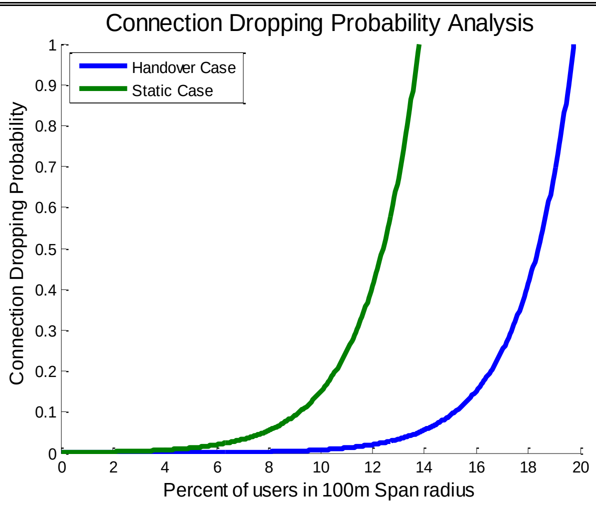

Fig. 10. Connection Dropping Probability Analysis

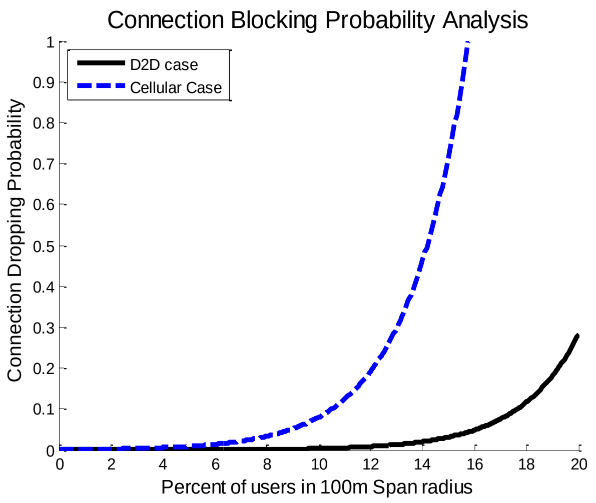

Fig. 11. Connection Blocking Probability Analysis

V CONCLUSIONS

In this paper a positioning algorithm have been suggested for finding the position of a transmitter, given TDOA measurements computed from the received signal for at least three receivers. A simulation study illustrated the TDOA problem in general and the performance of the suggested algorithm. Based on this positioning algorithm, a D2D connection handover scheme is also discussed in the paper which will help in decreasing both the D2D connection dropping and blocking probability considerably as shown in figures 10 and 11. The results obtained can be used as a reference model for evaluating and optimizing an operating BDS network. In this case, the results shows that the scheme under study(BDS) is a well established. The result can further be used for drop-call probability model simulation for further confirmation.

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