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Optimized Model for Mitigating Handover Issues in Long Term Evolution Networks

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Abstract- In this study, an improved handover decision making for Long Term Evolution (LTE) networks in an effort to reduce probabilities of handover failure and unnecessary handovers was achieved. The proposed handover algorithm optimized the Preeti's speed-position handover algorithm by employing rolling average parameters. The latter helped to obtain improved estimation and prediction of mobile terminal speed and positions at varying instances of time over a given sojourn time within a cell coverage area. The study also deployed a speed envelop for accurate determination of micro and macro cell handover velocities. The rolling average offered a means to capture different "in-call" speed outcomes over varying periods. Height correction factor was introduced for path loss estimation model to cater for varying height of mobile terminals. The work was implemented using Matlab as an application tool and tested against the preeti model. Resulting outcomes indicated an efficient drop in the probability of handover failure and unnecessary handovers.

Keywords- *LTE, Handover, Rolling Average, Micro and Macro Cells, Mobile Terminals, Path Loss*

I. Introduction

A cellular or mobile network is a wireless communication network which provides network to mobile users in a geographical region consisting of various cells. Mobile communication works by connecting two users using the equipment owned by the network provider who manages the service.

Mobile communication has evolved over the past few decades because of the ever-increasing number of mobile users. Network providers have to solve the issue of limited bandwidth and throughput constantly. Mobile networks have moved from the first generation(1G) to the fifth generation (5G) currently being deployed in some countries. Each generation offers faster throughput and better bandwidth than the previous generation.

A unique characteristic of mobile communication which makes it very attractive is mobility. This means that users can make use of the network on-the-go. Handover makes this possible. Handover is a way of achieving continuous services as the user travels in between cells [1]. It can also be described as the process of changing channel parameters (frequency, time slot, code or the combination of any of them) of the existing connection while communication is still present [2].

A prominent challenge with handover is that if new connection is established before old connection is released, probabilities are that the data reception is interrupted for a short period of time and will most likely induce service disruptions. This can be avoided by user connection to a new cell before terminating its connection from the former cell. However, connecting to a new cell before breaking from an old one is the primary basis for soft handovers which LTE does not support because of its orthogonal frequency division multiplexing structure

There is also need to prevent a ping-pong effect. This occurs when a user equipment is transferred from one cell to another, but is quickly handed back to the original cell as a result of frequent movement of the user between the pair of cells or high signal fluctuations at the common boundary of the pair of cells. Therefore, handover should occur at the correct time with the help of network parameters to ensure that the QoS is not degraded and multiple handovers in the case of ping pong is avoided.

II. REVIEW OF RELATED WORKS

In [3], the authors used a neural network to select the best available network during handover based on preferences defined by the user equipment. However, the neural network is unsupervised and the data used here was carefully chosen to give a high performance rate.

The authors in [4] made research efforts to develop a vertical handover decision algorithm. Their algorithm had a special feature of maximizing the overall mobile station battery lifetime and also aimed at achieving traffic load balancing across the networks. This algorithm had some successes and pit falls. The algorithm was able to extend the battery life time by 20 percent but could not effectively manage the network traffic load.

In [5], a GPS based handoff technique for handoff probability enhancement in NGWS (Next Generation Wireless System) was proposed. The GPS determined the direction of MT (Mobile Terminal) thereby ensuring an efficient handoff.

The reliability of this work is dependent on the different periods the angles are stored in memory and compared for a specific period. The implementation however required huge data with huge memory capacity.

In [6], a handover scheme for reducing ping pong movement during handover was presented. The old link connecting the source eNodeB and SGW/MME during the ping pong movement is kept and the handover completion part delayed. The algorithm proposed here detects if the ongoing handover is a ping pong effect or a normal type of handover. However, the work considered the velocity of UEs within 70km/h.

Mobility Robustness Optimization (MRO) algorithm can be used to improve LTE handover. However, this algorithm can also affect handover performance due to uneven interference distribution within the region of handover. Also, complex channels and load conditions can also make handover optimization difficult in heterogenous networks. In [7], the authors proposed a network-controlled handover scheme to solve the problems. However, it was sensitive to channel quality and velocity of the mobile node

In [8], a two position assisted fast handover schemes under high mobility scenarios was designed. The first scheme reduced handover delay by preparing for handover before the handover starts. The second scheme minimizes unnecessary handoffs and improves handoff success rate by calculating the location of the best handover cell using the UE's position information.

The authors in [9] presented a fuzzy-rule based algorithm which is QoS aware which used bandwidth, end to end delay, jitter and Bit error rate as parameters for handoff decision making. The algorithm was simulated using Conversational, Streaming and Background traffic classes. This algorithm performs better where delay is not needed.

A scheme based on static and dynamic parameters was proposed in [10]. Static signal strength may not be enough to trigger a handover process, so network load, speed of the mobile and application type may be looked at along with it.

In [11] a framework of handover decision for LTE networks under high mobility speed of up to 500km/h using a location-based handover algorithm was proposed. The distance of the train from the eNodeB is calculated by the vehicle speed sensor and periodically sent to source eNodeB. With this location information and received signal strength, the source eNodeB makes handover decision. Results from this algorithm decreases the probability of unnecessary handover by 10% when compared to the traditional handover. In [12], the authors proposed an LTE handover algorithm was proposed for high speed rail. The motion direction and GPS information of the train is used to develop a handover scheme that can trigger a handover procedure instead of measured information in an A3 event-based scheme. This algorithm when simulated has a better performance than the A3 event-based scheme in terms of reduction of latency. Though they proved to be better than the traditional handover schemes, there is still a considerable number of handovers which leads to message overhead.

A new algorithm to improve the traditional A3 event based algorithm was proposed in [13]. The rate of change of cell resources was considered in addition to received signal power and received signal algorithm. The algorithm when simulated and compared to the former reduced unnecesary handover by 47% and improved success rate by 13.5%.

The authors in [14] proposed an advanced technique that integrates user's direction to reduce the number of target-eNodeBs being considered and its history information to determine the target eNodeB. The User equipment searches its history when it is close to the handover area to connect to the target cell. If this trajectory is not found in the UE's history, then the UE and serving cell uses the cosine function to find a target cell. This technique reduces searching time, handover failure and number of handovers.

In [15], the Markovian chain analysis of continuous time and discrete space was used to analyse data gotten from the operation and maintenance centre. This was used to model handover channel utilization in cellular networks. A handover probability traffic model was also obtained. It was noticed that to get a good handover blocking probability model, the number of channels will be increased proportionally with the offered traffic load in erlang.

A Fuzzy Based vehicle handover decision Controller for next generation networks targeted on network selection during handover processes was presented by [16]. At least fifteen parameters were considered and divided the handoff procedure into six systems (A - F). System A which is in the user equipment gives a periodic report of available networks in its location. It also provides quality of service parameters like signal strength, type and range. System B located at the base station collects and stores these parameters. System C receives the parameters and feeds it into D. System D has been programmed with sets of instructions. System E is knowledge based and studies the instructions in D to set priorities and boundaries. System F which is a 'defuzzication' system selects the best networks and transmits the message to B to carry out a vertical handover. However, the controller needed more parameters to faster and more accurate.

In [17], an inbound handover method to enhance bit rate and load balancing in small cells (SC) heterogeneous networks (HetNets) was proposed. The effect of interference from both macro cells (MC) and SC tiers was factored in so that the user equipment is transferred from a congested MC and forced to perform the handover to the small cell tier with enough data rate by selecting a proper small cell target with the maximum signal to interference plus noise ratio (SINR) from a reduced neighbour cell list (NCL). Results show that third method was able to perform inbound handover while keeping the data rate at maximum level.

In [18], the authors proposed two novel handover schemes; RSSI-based handover scheme and Multi-criteria handover prediction scheme. In the first scheme, the UE measures the RSSI of the access points (AP) and compares it to the standard threshold. The UE connects with the AP with the highest RSSI. The second scheme measures the un-used bandwidth of all eNBs nearby. Stations with enough bandwidths are then considered for handover.

An artificial neural network to determine a better hysteresis margin for handover was introduced in [19]. This approach was used to reduce ping pong effect during handover.

The authors in [20] analysed handoff mechanism in LTE network. They developed a mechanism with speed and distance considered as important parameters. The future locations and speeds of the users were predicted with the help of the Gauss Markov mobility model. The distances are also predicted at different intervals from the values generated. The received signal values and received signal quality were measured from these values and compared to threshold values which systems are defined by.

An algorithm based on bandwidth availability and received signal power levels of the eNodeB was proposed by [21] and compared to several LTE handover schemes like Power Budget Handover and Integrator scheme. The results showed improvements in three areas; number of packets lost during handoff, latency and throughput.

This paper aims to improve the work done by preeti et al. The selected algorithm is the speed, position and signal strength-based handover algorithm. A rolling average approach is introduced to predict velocities more accurately. The rolling stone average accounts for rapid in-call velocities. The analysis of the handover decision making algorithm presented in this study will progress from mobile station speed and position estimation to path loss models, received signal strength and the quality of received signal strength and the probability analysis in handovers

III. PROPOSED MODEL

With small cells being deployed in LTE networks, the user distance from the base station is much shorter compared to the macro-cell networks. While there are benefits in using small cells, there is equally the challenge of mobility management relating to handover decision. The smaller cells will result in increased number of handovers. Thus, intelligently reducing the number of handovers through mathematical approaches will bring about better UE experience and reduce network burdens.

The total traffic generated in the network is estimated mathematically by [22] as:

$$T_a = T_{f0} + T_{m0} + T_{s0} + N(T_{s1} + T_{m1}) \quad (1)$$

Where;

T_{f0} = New traffic generated by high speed mobile users

T_{m0} = Traffic generated by moderate speed mobile users

T_{s0} = Traffic generated slow mobile speed users

T_{s1} = Rate of traffic generated by low speed users in microcells

T_m = Rate of traffic generated by moderate speed users in microcells

N = Number of microcells

To achieve efficient handovers, future locations and velocities of mobile users are predicted by employing the Gauss Markov mobility mode. The Gauss Markov prediction helps in estimating the right time for initiation of the handover procedure.

From the Gauss Markov model obtained from [22], the speed and direction are seen in the following expressions.

$$V_n = \propto V_{n-1} + (1-\propto)V' + \sqrt{(1-\propto^2)\delta_{n-1}} \quad (2)$$

$$\theta_n = \alpha\theta_{n-1} + (1-\alpha)\theta' + \sqrt{(1-\alpha^2)\gamma_{n-1}} \quad (3)$$

Where; n = time instant

α = a tuning parameter

V_n =speed of mobile station in the network at time n

θ_n = direction of mobile station in the network at time n

V' = mean speed when time tends to infinity

θ'= mean direction when time tends to infinity

δ = uncorrelated Gaussian processes with zero mean and unit variance for estimating direction

ϒ = uncorrelated Gaussian processes with zero mean and unit variance for estimating position

A. *Optimized application of Gauss Markov mobility Model*

The improved use of Gauss Markov model for prediction of mobile station speed and classification into categories of speed: fast, fast moderate, moderate, moderate slow and slow. Thus, based on the mobility classification that the mobile station falls under, the mobile station can thus be handed over to the proper target networks (i.e. base stations). Our interest is to optimize the algorithm to further enhance the network performance in terms of reducing handover failure probability and unnecessary handover probability.

The proposed optimization presents a ROLLING AVERAGE APPROACH to the quantities of V' and θ'. By acquiring and analysing V' and θ' as moving average data. This is achieved by estimating the position and speed of mobile terminals more correctly within the cell.

To model a simple rolling average estimate for V' and θ' is to express V' and θ' as sets of data for some time before the nth instance (i.e. the current instance)

Let the arbitrary instance at the origin for data acquisition in the network be t_o and the current instance be t_n.

$$V'_{Roll} = \left(\sum_{(n-x)\neq 0}^{n} V'\right)/No\ of\ periods\ between\ x\ and\ n$$

$$= \sum_{(n-x)\neq 0}^{n} V'/T_{no} \quad (4)$$

T_{no} = number of periods from some instance (n-x), before n

$T_{no} \neq$ Summation of periods, rather T_o implies how many periods between some instance (n-x) before current instance and the current instance n

Our optimized model amounts to:

$V_n =$

$$\propto V_{n-1} + \left[(1-\propto)\left(\textstyle\sum_{(n-x)}^{n} V'/T_{no}\right)\right] + \sqrt{(1-\propto^2)\delta_{n-1}} \quad (5)$$

Where $\sum_{(n-x)\neq 0}^{n} V'/T_{no} = V'_{Roll}$ (describes the rolling average velocity for the sojourning mobile terminal)

$\theta_n =$

$$\alpha\theta_{n-1} + \left[(1-\alpha)\left(\textstyle\sum_{(n-x)}^{n} \theta'/T_{no}\right)\right] + \sqrt{(1-\alpha^2)\gamma_{n-1}} \quad (6)$$

where

$(\boldsymbol{\sum_{(n-x)}^{n} \theta'/T_{no}}) = \theta'_{Roll}$ (implying rolling average direction/position of the moving mobile terminal from some instance of time before now (n-x) up till now n)

The optimized Gaussian models for position and speed becomes:

$$V_n = \propto V_{n-1} + [(1-\propto)V'_{Roll}] + \sqrt{(1-\propto^2)\delta_{n-1}} \quad (7)$$

$$\theta_n = \alpha\theta_{n-1} + [(1-\alpha)\theta'_{Roll}] + \sqrt{(1-\alpha^2)\gamma_{n-1}} \quad (8)$$

The coordinates of any UE in the LTE network at time instants n and detecting period T from equations (2) and (3) as given below:

$$X_n = X_{n-1} + V_{n-1} \times T \cos\theta_{n-1} \quad (9)$$

$$Y_n = Y_{n-1} + V_{n-1} \times T \sin\theta_{n-1} \quad (10)$$

Where X_n & Y_n = coordinates of users at time instants n and detecting period T

B. Prediction of Position of Mobile Station Using Time of Arrival

The proposed optimization algorithm seeks to use the obtained distance between eNodeB and base station to obtain the position of the mobile terminal using Time of Arrival (TOA). The TOA method is based on combining estimates of the time of arrival of the transmitter signal as the signal arrives at several different nodes. Figure 1 shows the TOA method.

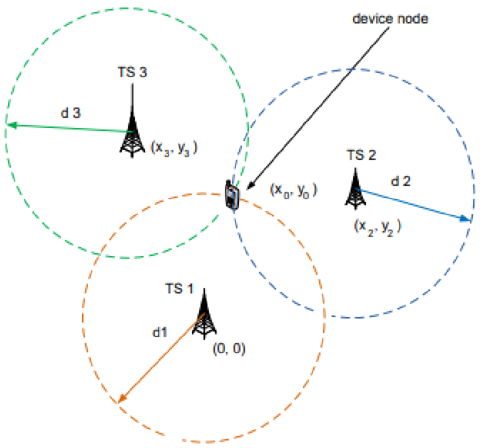

Figure 1. Illustration of the TOA method

The Time of Flight (ToF) (t_i) estimate can be used to obtain distance (d_i) between transmitter and receiver by the equation given:

$$d_i = (t_i - t_0)c \quad (11)$$

where

i = 1,2,3,4…

c = speed of light

t_i= Time of Flight

t_0 = Actual time instance at which the transmitter device starts transmission

d_i = distance between mobile terminal (T_x)and eNodeB (R_x) obtained from equation 6.

To find the coordinates of a node of interest, the following equations are used

$$d_i^2 = x_i^2 + y_i^2 \;\&\; d_i^2 = x_0^2 + y_0^2 \quad (12)$$

The distance between mobile users and different base stations is given by:

$$d_{in} = \sqrt{(Y_n - Y_i)^2 + (X_n - X_i)^2} \quad (13)$$

d_{in}= distance between mobile user and base station

(X_i, Y_i) = Co-ordinates of eNodeB

$$d_{in}^2 = (Y_n - Y_i)^2 + (X_n - X_i)^2 \quad (14)$$

From figure 1, an analogy can be drawn from equation 10.

$$d_2^2 = (X_2 - X_0)^2 + (Y_2 - Y_0)^2 \quad (15)$$

$$d_3^2 = (X_3 - X_0)^2 + (Y_3 - Y_0)^2 \quad (16)$$

where

(0,0) = coordinate of reference node TS1

(X_0, Y_0) = coordinate of device node

(X_2, Y_2)= coordinate of reference node TS2

(X_3, Y_3)= coordinate of reference node TS3

d_i= distance between TS1 and device node

d_2= distance between TS2 and device node

d_3= distance between TS3 and device node

The three equations for (d_1^2, d_2^2, d_3^2) can be solved by combining all the available set of measurements, using a least square approach to achieve a more accurate estimate:

By substituting d_1^2 from d_2^2,

$$d_2^2 - d_1^2 = x_2^2 - 2x_2x_0 + y_2^2 - 2y_2y_0 \quad (17)$$

In the same way, subtracting $d_1^2 =$ from d_3^2,

$$d_3^2 - d_1^2 = x_3^2 - 2x_3x_0 + y_3^2 - 2y_3y_0 \quad (18)$$

From equation 17

$$2x_2x_0 + 2y_2y_0 = x_2^2 + y_2^2 - d_2^2 + d_1^2 \quad (19)$$

From equation 18

$$2x_3x_0 + 2y_3y_0 = x_3{}^2 + y_3{}^2 - d_3{}^2 + d_1{}^2 \quad (20)$$

Equations 19 and 20 can be expressed in matrix form

$$2\begin{bmatrix} x_2 & y_2 \\ x_3 & y_3 \end{bmatrix}\begin{bmatrix} x_0 \\ y_0 \end{bmatrix} = \begin{bmatrix} x_2{}^2 + y_2{}^2 - & d_2^2 + & d_1^2 \\ x_3{}^2 + y_3{}^2 - & d_3^2 + & d_1^2 \end{bmatrix} \quad (21)$$

$$\begin{bmatrix} x_2 & y_2 \\ x_3 & y_3 \end{bmatrix}\begin{bmatrix} x_0 \\ y_0 \end{bmatrix} = \frac{1}{2}\begin{bmatrix} k_2^2 - & d_2^2 + & d_1^2 \\ k_3^2 - & d_3^2 + & d_1^2 \end{bmatrix} \quad (22)$$

Where $k_i^2 = x_i^2 + y_i^2$

The above matrix is the Time of Arrival position estimation matrix.

The matrix expression for Time of Arrival position estimation matrix can be re-written as:

$$Hx = b \quad (23)$$

Where:

$$H = \begin{bmatrix} x_2 & y_2 \\ x_3 & y_3 \end{bmatrix}, x = \begin{bmatrix} x_0 \\ y_0 \end{bmatrix}, b = \frac{1}{2}\begin{bmatrix} k_2^2 - & d_2^2 + & d_1^2 \\ k_3^2 - & d_3^2 + & d_1^2 \end{bmatrix} \quad (24)$$

The solution to the equation $Hx = b$ is given as:

$$x = H^{-1}b \quad (25)$$

C. *Cost Hata Path-Loss Model*

For LTE networks with operating frequency from 500MHz – 2000 MHz, the cost Hata 231 path loss model estimates the path-loss.

$$L(dB) = 46.3 + 33.9\log(f) - 13.82\log h_t - \alpha\,(h_r) + (44.9 - 6.55\log(h_t))\log d + C_m \quad (26)$$

Where

$\alpha h_r\ (dB)$ = correction factors

f = network operating frequency in MHz

h_t= transmitting antenna height (m)

h_r= receiving antenna height (m)

C_m= Environmental factor constant

$$C_m = \begin{cases} 0\ dB\ for\ medium\ and\ suburban\ areas \\ 3\ dB\ for\ urban\ network\ locations \end{cases}$$

Mobile station height correction factor $a(h_R, f)$ is factored into the Hata path-loss model for improved prediction of losses and is further dependent on the user location; if the land is hilly or mountainous being an outdoor network scenario or several mobile terminals on different floor levels of large buildings.

$$a(h_R, f) = \left(1.1\log_{10}\frac{f}{MHz} - 0.7\right)\frac{h_R}{m} - \left(1.56\log_{10}\frac{f}{MHz} - 0.8\right) \quad (27)$$

$$a(h_R, f) = \begin{cases} 8.29(\log_{10}(1.54h_R))^2 - 1.1;\ 150 \le f \le 200 \\ 3.2(\log_{10}(11.75h_R))^2 - 4.97;\ 200 \le f \le 2500 \end{cases} \quad (28)$$

D. *Investigating the Received Signal Strength (RSS) and Signal quality*

From the calculation of the distance between base station and mobile users, we can predict the RSS value received by a UE from a base station using the RSS or received signal power (RSP) equation given:

$$RSP_i = P_{tx} - P_{loss} - F(\mu, \sigma) \quad (29)$$

Equation 29 provides us with the precise calculation of the received signal strength of any given mobile terminal in any given cell. From equation 29, we have that:

P_{tx} = transmission power of base station

F(μ, σ) = shadow fading parameter/ shadow fading effect

The received signal quality is dependent on the received signal strength value and is estimated by the model:

$$RSQ_i = \frac{M \times RSP_i}{\sum_{j\neq 1}^{max} RSP_i + N_o} \quad (30)$$

Where M = number of channels for macro cell size base stations

N_o= Ground White Noise

E. *Speed limits, Probability of Unnecessary handovers and Handover failures*

The handover algorithm is initialized when the Received Signal Quality (RSQ) of a given mobile user drops below a set threshold level. After the handover initialization, there is an inspection and categorization of the class of speed at which the mobile user is exercising mobility or sojourning in the network. UE'S sojourn at different velocities within the LTE network. These velocities are categorized into upper and lower speed limit. The probability of having unnecessary handover or handover failure is expected to be different for different sojourning velocities (i.e. for the lower and upper limits) we thus cannot calculate these velocities without the probability of handover for each class of speed.

A mobile node is unable to receive IP packets on its new association point until the handover process finishes. The period between sending (or receiving) of its last IP packet through the old connection and the first packet through the new connection is the handover latency. A handover failure occurs if the traveling time inside the cell coverage area is shorter than the handover latency τi, i.e. the traveling distance d is smaller than vτi.

Thus, the upper and lower limit for the sojourning speed in the LTE network are calculated based on the probability of unnecessary handovers, probability of handover failure and then handover delays as given in [22] is shown below

$$V_1^u = \frac{2R}{t_1+t_2}\sin(\pi P_{nmax}) \quad (31)$$

$$V_2^u = \frac{2R}{t_1}\sin(\pi P_{fmax}) \quad (32)$$

The Probabilities of unnecessary handovers and handover failure as given in [22] can be given as

$$P_f = \begin{cases} \frac{1}{\pi}\, sin^{-1}\left(\frac{v\tau_1}{2R}\right), & 0 < t \le \frac{2R}{\tau_1} \\ 1, & v > \frac{2R}{\tau_1} \end{cases} \quad (33)$$

$$P_n = \begin{cases} \frac{1}{\pi}\, sin^{-1}\left(\frac{v(\tau_1+\tau_2)}{2R}\right), & 0 < t \le \frac{2R}{\tau_1} \\ 1, & v > \frac{2R}{\tau_1} \end{cases} \quad (34)$$

IV. RESULTS

This section presents tests and analytical outcomes carried out to validate the study approach employed in the optimization process. The network scenario adopted in this study models varying cell coverage area but without any hierarchical component. This means that the handover algorithm does not give preference to the macro-cells and will thus consider handing over sojourning mobile terminals to micro-cells only when such a handover has high failure probability. The optimized algorithm treats both macro and microcells as having equal tendencies of receiving sojourning mobile terminals depending on the network parameters and not the cell coverage area size. This helps to avoid over congestion of the macro cell. Velocities within the speed envelopes of the macro cell were picked and plotted against their respective probabilities of unnecessary handover and handover failure as shown in figures 2 to 5.

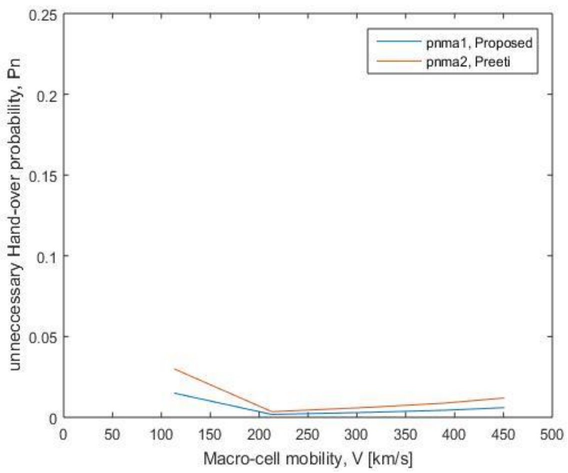

Figure 2. Graphic illustration of macro cell mobility and tendency of unnecessary handover

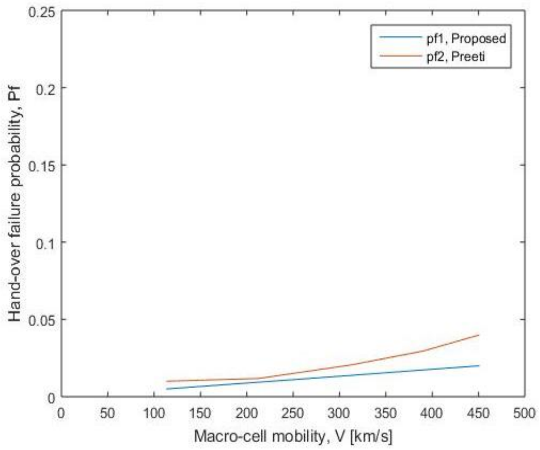

Figure 3. Graphic illustration of macro-cell mobility and tendency of handover failure

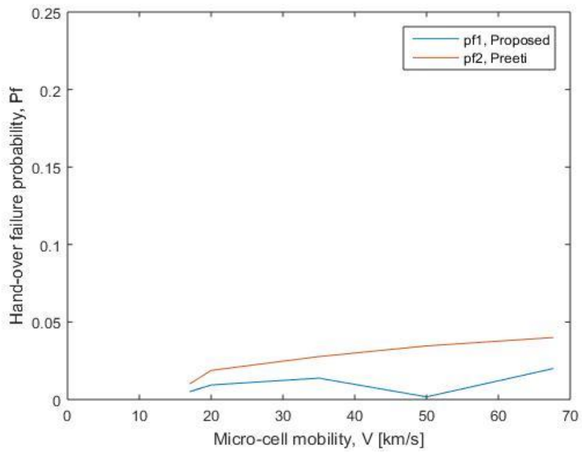

Figure 4. Graphic illustration of micro-cell mobility parameter and tendency of handover failure

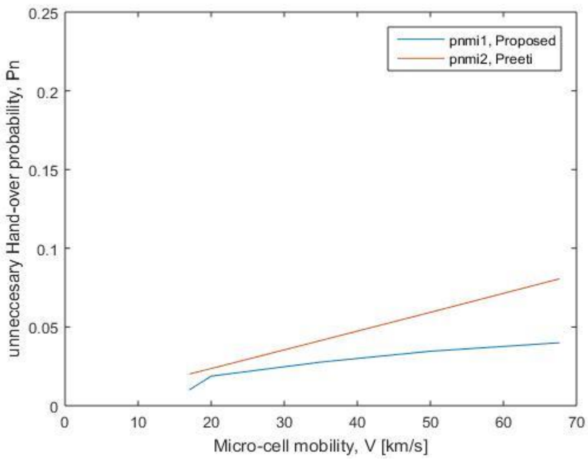

Figure 5. Graphic illustration of micro-cell mobility parameter and tendency of unnecessary handover

Figures 2 and 5 show the tendencies of unnecessary handover in macro and micro cells. The proposed algorithm shows an improvement when plotted alongside preeti's model thereby reducing the ping pong effect. It is also better than the traditional handover algorithm by extension.

Figures 3 and 4 show the tendency handover failure in micro and macro cells. It also shows an improvement when compared to the values gotten from preeti's model and by extension the traditional handover algorithm.

V. CONCLUSION

This study has put forward an optimized non-invasive handover decision making algorithm. This study is an optimization of a 2017 position-mobility handover algorithm, developed based on a hierarchical LTE network architecture featuring both micro and macro eNodeBs within the network. The optimization approach is termed non-invasive because the study is geared towards optimizing the premise for which a sojourning terminal experiences a successful handover. Part of the optimization approach was premised on the introduction of rolling average velocity of mobile terminals as well as the introduction of rolling average position of mobile terminals to more accurately predict the sojourning velocity and position of mobile terminals. The study testing and results were obtained using matlab application tool with significant improvement in the probability of successful handover.

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