Handoff Optimization in Macrocell and Femtocell LTE Heterogeneous Network

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***Abstract*—Nowadays, everybody use handphones to communicate or surf the internet. In order to cope with the users demand and capacity, Long Term Evolution (LTE) has been introduced as the new technology which is consists of macrocell, picocell and femtocell heterogeneous networks. The deployment of this femtocell will help to offload traffic in macrocell LTE heterogeneous network. However, this deployment has negative impact on the handoff performance especially when mobile devices roam across heterogeneous access networks. Therefore; this research presents frameworks to minimize the unnecessary handover for femtocell to femtocell and macrocell to femtocell in LTE heterogeneous network. Two parameters are used which are speed and handoff types in order to see the variation of Reference Signal Received Power (RSRP). The simulation results show that the value of distance should be adaptive to the velocity and handoff types of UE in order to reduce the unnecessary handover and hence improved the handoff performance in LTE heterogeneous network.**

***Index Terms*—Long Term Evolution (LTE); Femtocell, Heterogeneous Network; Reference Signal Received Power (RSRP); Probability False Handoff Initiate (Pa); Probability Handoff Failure (Pf).**

I. Introduction

Long Term Evolution (LTE) is a new technology that becomes important part of everyday's life and in the future which is consists of heterogeneous networks. Third Generation Partnership Project (3GPP) in Release 8 defines the standard for LTE and Release 10 to defining the standards for LTE-Advanced. The LTE heterogeneous network has a macrocell as a largest coverage composed of picocells, femtocells and relays [1]. Each of this coverage has their own Base Transceiver Station (BTS). In LTE, Base Transceiver Station (BTS) is known as an eNode B (eNB). eNode B is the radio access node that responsible for radio transmission and reception from User Equipment (UE) in one or more cells.

Figure 1 shows the System Architecture Evolution (SAE) as the core network architecture for establishing a LTE network. It has been evolved from the GPRS core network. By using the existing network infrastructure, it makes the implementation on the LTE network less cost. In order to satisfy the seamless characteristics in LTE, the heterogeneous network should always be the best connection. During driving or walking, mobile users are necessary to switch their connection to others eNodeB to maintain the connectivity. In addition, users always expect all their services to be accessible anywhere and from any device [2].

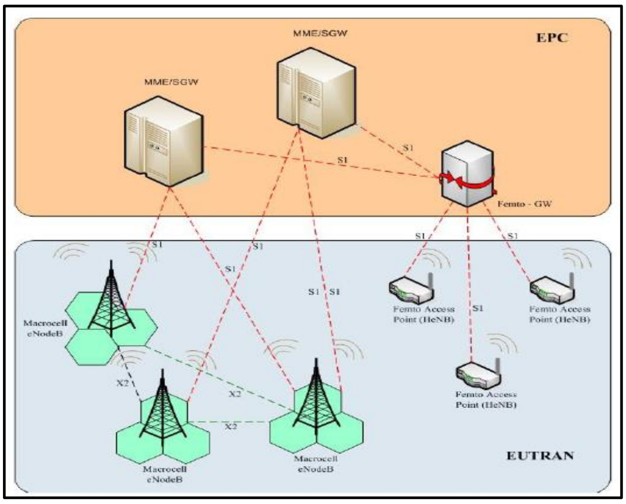


Figure 1: Architecture of LTE [source Ubicomm 2010]

When a mobile user moves away from eNodeB, the Reference Signal Received Power (RSRP) will decrease and hence, a handoff process will occur. Handoff is the process of transferring ongoing session from one attachment point to another associated with the current connection while a call is in progress [3]. It is often initiated either by crossing a cell boundary or by deterioration in quality of the signal in the current channel [4]. Nowadays there are many phone companies coming in and the competition increased. Customers now are more aware and picky about signal availability, especially in their area. They complain and demand a lot. Therefore, it is important to analyse the mobile signal strength measurement in order to reduce the handover failure.

Few studies have been done previously regarding RSRP. Author in [5] studied the load based cell selection algorithm for faulted handover in indoor femtocell network while author in [6] studied about the algorithm for LTE intra-frequency handover. The purpose of the study was to propose a new handover algorithm which can reduce the handover failure rate and ping-pong handover compared to the A3 algorithm. However, these papers only use different factors such as UE speed or the load of network. In [7] and [8], a detail description of various handover technique is presented for LTE in macrocell and femtocell system, respectively.
Thus, this research is conducted to analyse and minimize the unnecessary of handover for femto to femto and macro to femto in LTE heterogeneous network base on the RSRP. The

rest of this paper is organized as follows. Section II provides the framework using macrocell and femtocell framework. The simulation results of False Handoff Initiate (Pa), Probability Handoff Failure (Pf) and RSRP are provided in Section III. This is followed by conclusion in Section IV.

II. Framework

In this simulation framework, the hexagon cell shape has been applied because it is simplistic and conceptual model of the radio coverage for each eNodeB [9]. The hexagon cell shape actually very close and approximates with a circular radiation pattern which can cover a geographical region. In this paper, two hexagon cells were created and femtocells are deployed randomly in cell coverage area. The modification has been made by deploying femtocell in macrocell network as compared to paper in [11]. Figure 2 shows the hexagon cell with two femtocells while Figure 3 shows the hexagon cell with one macrocell situated at the center of the hexagon and femtocells deployed randomly within the macrocell. Based on the proposed framework, the effect of macrocell and femtocell deployment in LTE heterogeneous network is studied in order to see the relationship of RSRP based on velocity and handoff types.

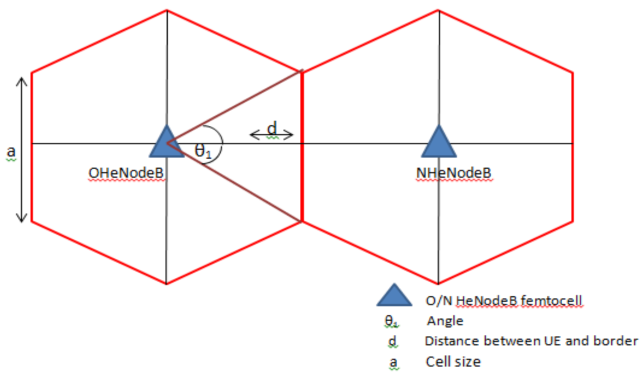


Figure 2: Proposed analytical framework using femtocells

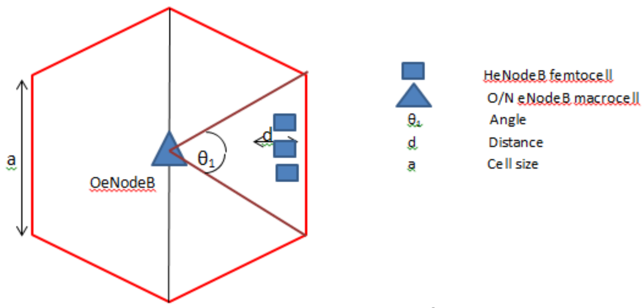


Figure 3: Proposed analytical framework by deploying femtocell in macrocell network

In this research, RSRP for macrocell and femtocell has been analyzed to see the variation of signal strength between the macrocell and femtocell when the UE moves with different value of speeds. We assume that UE can move to any direction with range [$\theta \in (-\frac{\theta 1}{2}, \frac{\theta 1}{2})$], where $\theta_1 = \tan^{-1}(\frac{a\_inc}{2d\_inc})$. Therefore, the probability of false handoff initiation is given by:

$$p_a = 1 - \int_{-\theta 1}^{\theta 1} f\theta(\theta)d\theta = 1 - \frac{2}{\pi}\tan^{-1}\left(\frac{a\_inc}{2d\_inc}\right). \quad (1)$$

Known that the direction of motion of the UE from Old EnodeB, [$\theta \in (-\theta_1, \theta_1)$) the time it will take to go beyond coverage area is given by:

$$t = \frac{d \sec\theta}{v} \quad (2)$$

Therefore, the probability handoff failure equation as below:

$$p_f = \begin{cases} 1 & \tau > \frac{\sqrt{\frac{a^2}{4}+d^2}}{v} \\ \frac{1}{\theta 1}\cos^{-1}\left(\frac{3.6d}{vt}\right) & d/v < \tau < \frac{\sqrt{\frac{a^2}{4}+d^2}}{v} \\ 0 & d/v \geq \tau \end{cases} \quad (3)$$

III. Results and Discussion

To evaluate the handover performance, some parameters are set according to its scenarios. The parameters based on speed of UE and handoff types are proposed. The simulation values used are shown as in Figure 4.

Parameter	Value
Macro cell size radius	750m
Femto cell size radius	30m
Max speed of mobile for Macro cell	200km/h
Max speed of mobile for Femto cell	30km/h
Standard deviation of shadowing effect	6dB
Transmit power Macro cell, Tx	46dBm
Transmit power Femto cell, Tx	20dBm
Target handoff failure probability, Pf	0.02

Figure 4: Parameter of the simulation

A. Probability of Failure Handoff Initiation (Pa)

The simulation result has been done to see the relationship between Pa and distance for intra and inter handoff in femtocell and macrocell network. The value of distance, d is fixed to see the variation of Pa with different value of cell size, a.

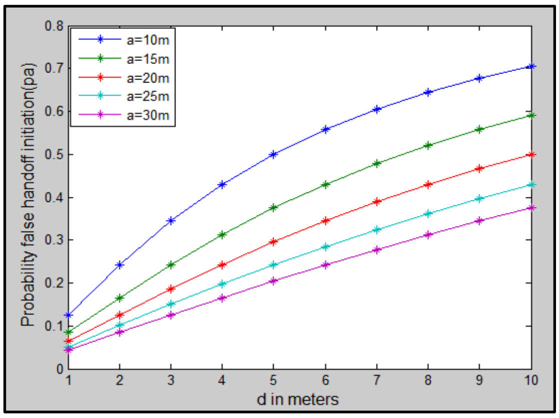


Figure 5: Relationship between Pa and d with different value of cell size for femtocell network

Figure 5 shows the Pa versus d with different value of afford handoff between femtocells. Basically in femtocell, it will cover for low speed and in this situation, we assume that it is in walking condition. From the graph, we can see that when the d increased, the Pa increased for different value of a. This is because when Pa increased, UE will face unnecessary handovers that occurred during a short interval, so called ping-pong effect especially when the cell size becomes smaller. Therefore, it is not suitable to use fixed value of d as it can increase the probability of failure handoff initiation.

B. Probability of Failure Handoff Failure (Pf)

Figure 6 shows the relationship between probabilities of handoff failure and UE speed for femtocell network. For this simulation, the cell size is 30 meter and the signaling delay is 300 msec. The signaling delay assumed 300 msec because there is no intra system in femtocell. The figure shows the numerical value of Pf for different value of d. From the graph, it shows that the Pf value increased as the velocity increased. If the handover distance very close to the border, the Pf value will increase drastically. This will affect the speed coverage of the UE if it is very close. Based on the key performance index (KPI), the Pf value should be equal or less than 2% value. These mean that an adaptive value of distance is required in reducing the probability of handover failure.

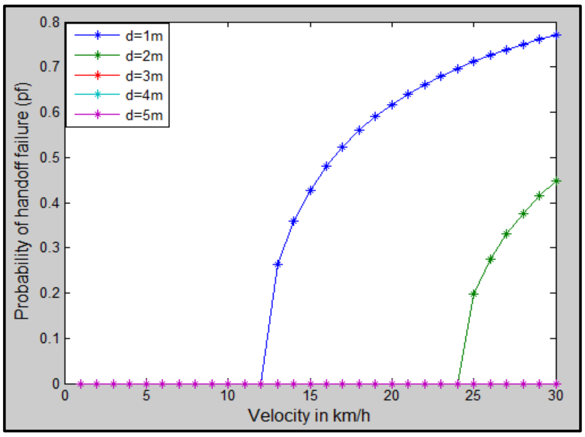


Figure 6: Relationship between Pf and UE speed for femtocell (τ =300m sec)

Figure 7 shows the relationship between Pf and UE speed for inter system handoff (S1) with signaling delay of500 msec. From both graphs, different value for signaling delay is used. The signaling delay for X2 was smaller than S1. This is because X2 cover the eNodeBinter handover (macrocell to macrocell) while S1 cover the handover between MME/SeGW and HeGW (macrocell to femtocell). Based on both simulation, we can see that each distance were directly proportional to the Pf when the velocity increased. This is because the UE velocities are continuously fluctuates due to the noise and interference. These two causes can affect and increase the Pf value. In addition, UE requires more distance to handover when the velocity increased. From both graph, it also show that for larger value of d, Pf value are smaller as compared to smaller value of d. This relation shows that the value of distance, therefore the value of RSRP min should be adaptive to the velocity of UE in order to reduce the Pf value.

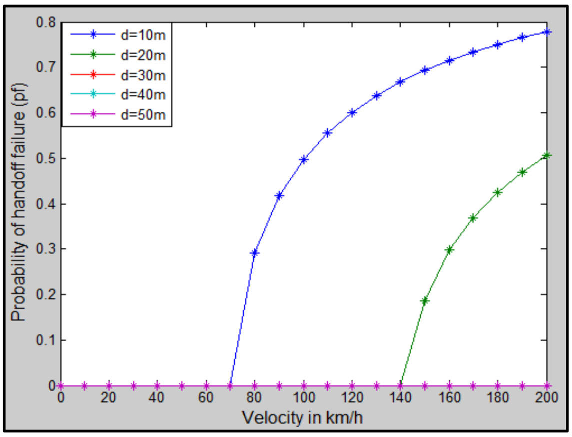


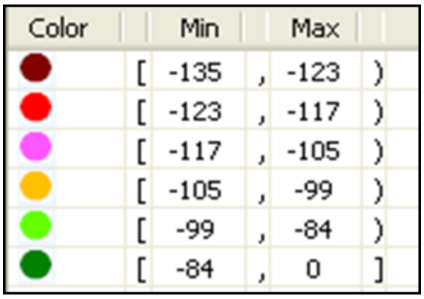
Figure 7: Relationship between Pf and UE speed for macrocell (τ =500m sec)

C. An Adaptive Reference Signal Received Power (RSRP)

In 4G, the data for Reference Signal Received Power (RSRP) performance can be determined using Key Performance Index (KPI) as shown in Figure 8.

$$L(i) = \frac{\sum_{j=1}^{j=y} (P_l)_j}{\sum_{k=1}^{k=z} (P_s)_k} \qquad (4)$$

where $\sum P_l$ is the total packets loss and $\sum P_s$ is the total sending packets from the source during a connection session. By considering all generated connections (i.e. n parameter) in a simulation run time, the average e2e packet loss ratio is calculated as in (5).



Color	Min	Max
	[-135	, -123)
	[-123	, -117)
	[-117	, -105)
	[-105	, -99)
	[-99	, -84)
	[-84	, 0]

Figure 8: Standard RSRP (dBm) KPI [10]

From the figure shown, dark green indicates excellent signal, green indicates good signal, yellow indicates moderate signal and pink until red indicate bad signal [10].

The simulation has been done to see the relationship between RSRP and speed increases for inter handoff for femtocellandmacrocell. The value of d is adaptive to see the variation of RSRP with different value of speed. The equation for d can be expressed as follow:

$$d_1 = \cos(theta*0.02)*(v/3.6*t) \qquad (5)$$

$$d_{real} = \sqrt{d1^2 + Anth^2} \qquad (6)$$

where v is the speed of user and t is time for inter handoff femtocell and inter handoff macrocell to femtocell. In

Equation (6), Anth is represent the antenna height of HeNodeB.

Figure 9 shows the RSRP versus velocity (km/h) when the UE move from femtocell to another femtocell by assuming t=300msec. At low speeds the RSRP value is between -61.02 dBm to -60.04 dBm. This RSRP is very good comparing with the standard KPI. In addition, it can reduce the handover failure and achieve the standard KPI.

Figure 10 shows the RSRP when the UE move from macrocell to femtocell. The RSRP is between -97.38 dBm until -97.31 dBm. Based on the simulation, the RSRP for macrocell is less than femtocell. This is because mostly femtocells are used in the place that has bad RF coverage for macrocell. This simulation results show a better performance of using our proposed adaptive RSRP in initiating a handoff when the speeds vary.

The signal strength becomes higher when the speed increased. This is because when the speed increased, the required time for HeNB to request authentication to the serving gateway (SGW) and forwarding to the home location registration (HLR) become fast and make it as priority.

IV. Conclusion

As a conclusion, based on simulation result obtained we can conclude that the value of d must be adaptive so that the handoff initiation can occur according to the mobile speeds and handoff types. Future study will be focused on the simulation scenario based on handoff types and speeds of UE with the proposed adaptive value RSRP. Practical in drive test which could give more fundamental exposure on GENEX PROBE, X-CAL or other related tools also will be include.

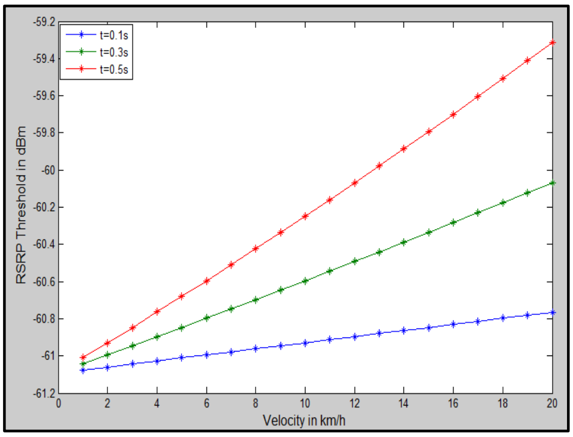


Figure 9: Relationship between RSRP and UE speed for femtocell (τ =300 sec)

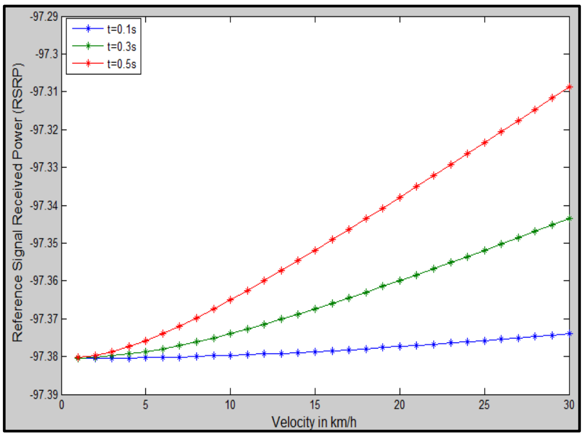


Figure 10: Relationship between RSRP and UE speed for macrocell (τ =500m sec)

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