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Performance Analysis of Handover Initiation Parameters in Long Term Evaluation – Advanced (LTE-A) Network

Azita Laily Yusof[1*], Muhammad Aiman Zainali[1], Norsuzila Ya'acob[1]

[1] Faculty of Electrical Engineering,
Universiti Teknologi MARA, Shah Alam, MALAYSIA

*Corresponding Author

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Abstract: In mobile network, mobility management plays an important role in order to support seamless handover in Long Term Evolution - Advanced (LTE-A) network. It is predicted that in the near future there will be an increase demand of voice and data traffic. Currently, LTE-A network purely depends on the hard handover that may cause disconnection to occur if the handover is not fast enough. When handover executes, it may experience failure because of the early handover, the late handover or handover to wrong cell. Thus, the cases of packet loss or communication interruption problems will occur. In this research, handover initiation parameters in LTE-A network is investigated. Firstly, a formulation of analytical framework has been developed to analyze the handover performance. Then, mathematical equations have been derived from the developed framework by incorporating the value of user's speed and handover signaling delay parameters. Under this framework, the probabilities of handover failure were analyzed in order to observe the handover performance when the speed of user is increased. The numerical results show that if fixed value of Reference Signal Receive Power (RSRP*th*) is used, the number of handover failures increased as the speed increased. It also shows that it is essential to predict the handover signalling delay in advance to reduce the handover failure rate in LTE- A network.

Keywords: Handover signaling delay, long term evaluation- advanced, mobility, seamless handover

1. Introduction

LTE-A network is expected to support high data rate up to 1Gbps in downlink for low-mobility scenarios such as nomadic or local wireless access and up to 500Mbps in uplink. Thus, the handover process plays a very important role inside LTE-A network. The handover process in LTE-A network is called hard handover. Hard handover is simpler and less complex when compared with the soft handover, but it does have some limitations on it. This type of handover experienced high outage probability, disruption time, high data lost and carrier interference, and thus it will cause an unreliable handover procedure resulting in poor connection performance especially for broadband applications and multimedia services [1]. So, several parameters should be considered since there is a limitation on the existing handover algorithm in LTE network in order to avoid the loss of data, reduced outage probability, ensure efficiency and increased reliability of handover procedure for the future generation of LTE-A network.

There were two cases related to radio link failure during handover which are failure caused by late handover and failure due to too early handover. If the handover is triggered too early, it will cause ping-pong handover as the signal strength of target cell is too low which may cause the radio link to re- establish connection with the previous serving cell. On the other hand, the other case occurs when the handover is triggered too late, the User Equipment (UE) will experience radio link failure such as drop call before the handover is initiated during the handover process [2]-[4]. Thus, the speed and time spent for a user within coverage area play an important role as parameters for evaluating received signal strength in terms of the network performance [5]-[8]. A poorly designed handover process tends to make more cases of data loss

**Corresponding author: laily012001@yahoo.com*

or radio link failure thus, it is necessary to enhance existing handover algorithm in order to increase the system capacity and improve the overall system throughput. The rest of this paper is organized as follows. Section 2 explains the related works to improve the handover performance in LTE network and Section 3 describes methodology of this research. Section 4 addresses the findings obtained from the simulation. Conclusion and the possible job guidelines are provided in Section 5.

2. Related Works

Over the past few years, the growth of wireless communication technologies resulting increment on number of handovers in LTE network. To support seamless handover in LTE-A network, several handover algorithms have been proposed. Furthermore, researches on mobility management of LTE network have been conducted since the year 2010 and many recent works have been proposed in different handover algorithms.

Reference [8] had done a study on various handover strategies which have been proposed and compared in previous research. From the research, they found out that two parameters i.e. the

Receive Signal Strength Indicator (RSSI) and UE velocity are two very important criteria used to mitigate the number of unnecessary handover and to provide the improved quality of service available to user. It was also concluded that, these two scenarios have achieved the maximum number of results in terms of decreased handover and increased number of capacity.

Reference [9] was a new handover decision algorithm between Femtocell and Macrocell based on several parameter which is Received Signal Strength RSS, handover margin and speed. The RSS of Femtocell and Macrocell are compared and calculated using the equation of RSSfe

$$RSSfe = RSSf + (\frac{NTx}{d}) \times RSSm \quad (1)$$

Where, RSSfe is the RSS of Femtocell, NTx is the Normalized Transmit power of cell based on the transmit powers of Macrocell and RSSm is the RSS of Macrocell. The speed used to compare in this algorithm only 50km/h and 3km/h to handover from femto to macro and macro to femto. The proposed algorithm reduced unnecessary Handover and Packet Loss Ratio compared to traditional algorithm and vertical algorithm.

Reference [10] have proposed a handover algorithm based on the received signal strength to evaluate the hard handover performance in LTE network. This paper proposed the handover measurement technique based on Receive Signal Strength (RSS) and average-path gain. The RSS algorithm has been modified with time-to-trigger (TTT) and this proposed algorithm resulted in reducing the average number of handovers by increasing the size of TTT. From this research, it is shown that by increasing the measurement bandwidth will results in decreasing the number of handovers and with higher speed, there will also be higher numbers of ping-pong handover. From the results, it is shown that the number of handover decreases when the speed of the user increases.

The handover performance with interdependence of control parameters such as handover margin (HM), A3Off with respect to inter-site distance (ISD) between Macro and Pico with random movement of user equipment was examined in a study published in [11]. The author concludes that the success of the handover control parameters was dependent on the inter-site distance macro-pico as well as the type of handover. There were more pico-macro handovers, which resulted in handover success based on macro-Pico inter-site distance. This was due to macro-eNB (MeNB) having a higher transmit power than pico-eNB (PeNB), while other handover types such as pico-pico and macro-pico handover were found to be less in number for the same reason. In addition, the possibility for macro-pico handover increases with increase in inter-site distance macro-pico.

There are many research on mobility management that have been done before. At this moment, all the handover types in LTE networks are all break before entry or hard handover. Although the handover has been introduced to provide seamless handover mode by minimizing complexity and delay but hard handover does results in potential loss of data unit service. Thus, it is necessary to investigate handover initiation parameters in order to avoid handover failure as much as possible.

3. Research Methodology

In the handover process, the transfer of an ongoing data or active call that is disconnected from the base station serving and subsequently connected to another cell tower called target base station that experience degradation of the bandwidth or connectivity failure. Subsequently, this situation will lead to cases of unnecessary handover delay, handover signaling and probability drop call, as LTE-A network needs to register when a user is connected to the new network. Therefore, the initiation handover procedure is important, as it will become a trend in the near future management of mobility management. In this section, an analytical handover framework on the handover process of the UE from serving evolved NodeB (eNB) to the target eNB is developed as shown in Figure 1.

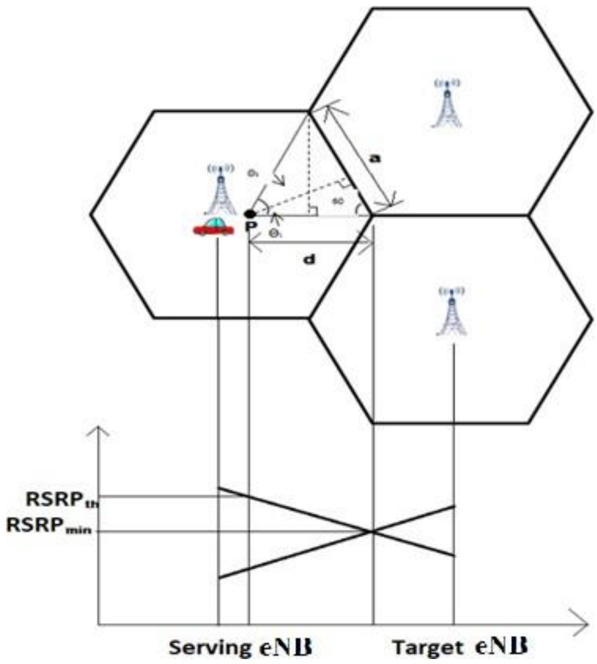


Fig. 1 - An Analytical of Handover Framework

Referring to Figure 1, there are some limitations that have been chosen as following assumptions. Firstly, the hexagon cell shape has been used because it is more practical and simpler model of the radio coverage for each eNB. Also, the hexagonal shape geometry's coverage area closely resembles a circular radiation pattern and thus allowing it to cover wide geographical region. Secondly, the pattern of UEs movement is usually either in straight or random line with constant speed, when moving from old eNB to the new eNB. Thirdly, the propagation environment in the LTE-A network coverage is modeled by using Log Normal Shadowing Path Loss Model and the UE direction is uniformly distributed in [-π, π].

Figure 1 shows three macrocells with eNB on each cell which are situated at the center of the hexagon where a is the radius of the cell, d the distance between UE and cell boundary, and RSRPth is the threshold value of the RSRP to initiate the handover process. This implies that when the RSRPmin of UE goes below the threshold, the UE will start to initiate handover process to the new target eNB. θ1 and θ2 is the angle which is later divided by two in between the path way for the UE moves from point P to the boundary cell. For the smooth and to keep seamless connectivity, the handover must be done before the

$$P_a = 1 - \int_0^{\theta_T} f_\theta\,(\theta) d\theta \qquad (2)$$

where, handover can only be done if the UE moves from point P to the direction of range [θ ϵ (0, θT)] where, θT = θ1 + θ2. Otherwise, the handover initiation is false. The probability of handover failure by considering θ1 and θ2 is given as in (3)

$$pf = \begin{cases} 1 & \tau > \dfrac{\sqrt{a^2 + d'^2}}{v} \\ \dfrac{1}{\theta_1} \arccos\left|\dfrac{d}{vt}\right| & \dfrac{d'}{v} < \tau < \dfrac{\sqrt{a^2 + d'^2}}{v} \end{cases}$$

$$\frac{1}{\theta_2}\arccos\left|\frac{d}{vt}\right| \quad \frac{d'}{v} < \tau < \frac{\sqrt{a^2+d'^2}}{v}$$

$$\{ \quad 0 \qquad \tau \leq \frac{d'}{v} \qquad (3)$$

where, UE is moving with a constant speed, v and τ is the summation of Radio Link Failure (RLF) timer called as handover signaling delay. In 3GPP release 8 specifications [12], there is one handover procedure which is called RLF handover. RLF handover is a UE-based mobility which provides a recovery mechanism when source cell partially failed to transmit data to target eNB due to poor radio conditions. However, the RLF handover process caused additional delay and, ultimately, a longer interruption in operation. Therefore, there is a need to consider this parameter and also speed of UE in order to make the handover initiation RSRP of the UE drops below the RSRPmin that is before the UE moves to the new coverage area. When the UE location reached the point P as in Figure 1, the UE is assumed to move in any direction with equal probability. Thus, the probability of false handover initiation, Pa as in (2) process runs smoothly.

4. Results and Discussion

4.1 Performance Evaluation of False Handover Initiation Probability (Pa)

As seen in Figure 2, it shows that with a particular value of a, the probability of false handover initiation will increase proportionately when d value increases. These results lead to a wastage resource of the wireless system. It is also shown in the figure that the problems of false handover initiation become worsens when the size of the cell decreases. With cell radius 5000m, the probability of false handover (Pa) at distance 120m is 34% and Pa value increase to 47% when the cell radius 500m. When the cell size decreases, the capacity will improve. Thus, it is necessary to select the proper value of d in order to reduce the probability of false handover initiation.

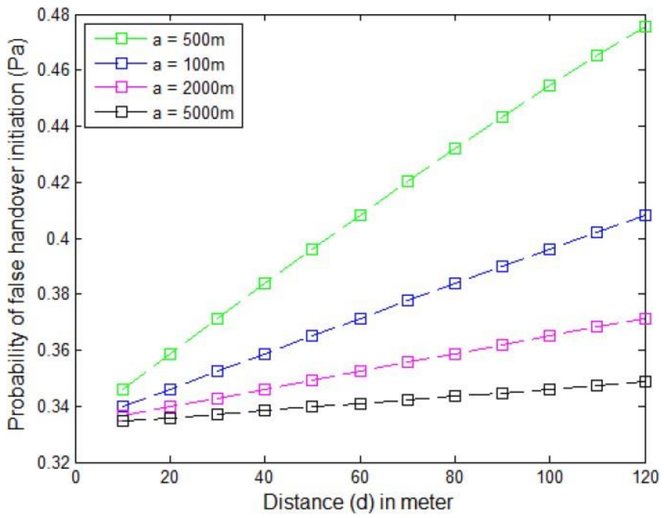


Fig. 2 - Relationship between false handover initiation probability and distance

4.2 Performance Evaluation of Handover Failure Probability (Pf)

Figure 3 and 4 show the relationship between probability of handover failure and speed for two angle movements with different values of d. From the results obtained, if fixed value of RSRPth is used, the handover failure probability increases as the speed of UE increases for handover signaling delay of 1s. The range time of 1 s is selected by considering the time taken to transfer message for the same Mobility Management Entity (MME) plus the RLF timer for different eNB handover.

The poor signal will cause UE to experienced failure while decoding the Handover Command from the source eNB. When the RLF timer has expired, the UE will search for the target cell and attempt to re-establish its connection to the target eNB while the UE remains in its linked state. The re- establishment is successful if the target cell has been prepared by the source eNB, which means if the source eNB received the measurement report from the UE. The RLF handover procedure incurred additional delay versus the backward handover procedure and, consequently, a longer interruption in service.

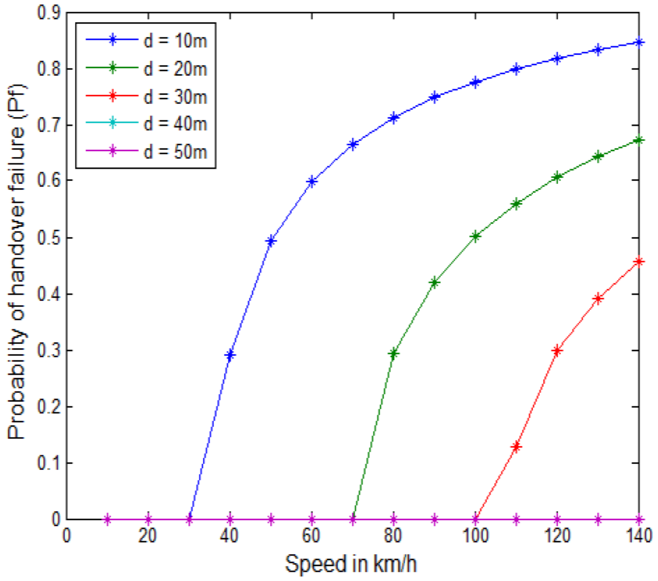


Fig. 3 - Relationship between probability of handover failure and speed for angle θ1 (less than 30 degree) with handover signaling delay of 1 s

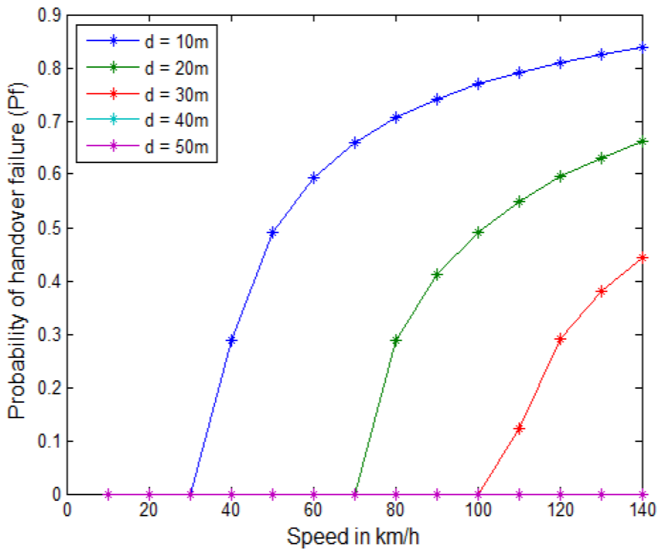


Fig. 4 - Relationship between probability of handover failure and speed for angle θ1 (more than 30 degree) and with handover signaling delay of 1 s

Figure 5 and 6 show the relationship between probability of handover failure and speed for two angle movements with different values of d. As the speed of UE increases, the probability of handover failure also increases. The τ is assumed to 3 s. Different MME handover will tooks longer time signalling than the same MME handover. Moreover, it can be seen that different MME handover has higher probability of handover failure when compared to the same MME handover. Throughout different eNB handover process, the content of UE control plane and user plane are transferred from the source eNB to the target eNB. Source eNB also transferred the UE's downlink user plane data to the goal eNB in order to reduce packet loss.

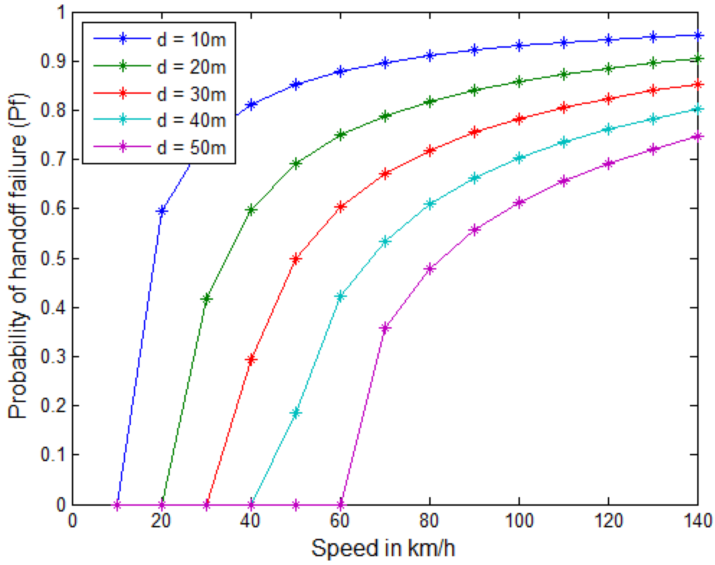
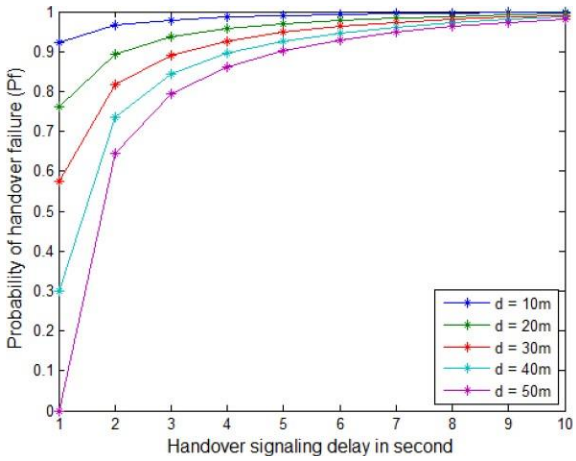


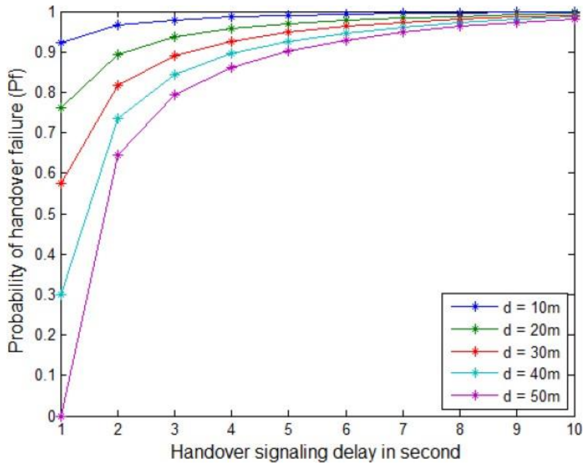
Fig. 6 - Relationship between probability of handover failure and speed for angle θ1 (less than 30 degree) and with handover signaling delay of 3 s

4.3 Performance Evaluation of Handover Failure Probability for Different Handover Signaling Delay

As discussed earlier, the handover signaling delay varies in the case of the same MME and different MME handover depending on the complexity of the network, e.g., congestion level, wireless link state and user distance from their home network. Figure 7 (a) and (b) display the relationship between the probability of handover failure and the handover signaling delay when using a fixed RSRPth value, a fixed d value is used. The higher value of c corresponds to the same MME conditions, and the lower value corresponds to the different MME handover case. Figure 7 (a) and (b) show that the probability of handover failure increases as the signaling delay for handover increases when a fixed value of RSRPth is being used. Therefore, it is useful to estimate the handover signaling delay and later integrate the value into an adaptive value of RSRPth to initiate the handover accordingly, in order to make less handover probability.



(a)



(b)

Fig. 6 - Relationship between handover failure probability and τ (a) for θ < 30 ° (b) for θ >30 °

5. Conclusion

To summarize, the study shows that when a fixed value of RSRPth is used, the likelihood of handover failure probability increases as the speed of the UE increase. Also, the failure of the handover increases with handover signaling delay increased for a fixed RSRPth value. Moreover, the analysis shows that an unnecessarily large value of RSRPth should not be used as it will later increases the probability of false handover initiation and hence, affected the performance of the system negatively. For future research, we would propose to use an adaptive value of RSRPth for the initiation of the handover which will depend on the pace of the user and the handover signaling delay at a given time to minimize the failure while handover and at the same time to reduce the excessive load on the system which may occur due to false initiation of the handover.

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