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Handover Framework for Mobility Performance in Long Term Evolution-Advanced (LTE-A) Network

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ABSTRACT

In mobile network, mobility management plays an important role in order to support seamless communication in Long Term Evolution - Advanced (LTE-A) network. It is important to optimize some technique and specific service to the mobile users in order to improve the handover execution. One of the problem in the existing network is the fixed handover threshold value. In this work, a framework has been proposed to analyse the handover performance as speed and summation of handoff signalling and Radio Link Failure (RLF) timer varies due to poor radio conditions case. A mathematical equation has been derived from the propose framework. The types of handover that have been considered in this work are intra-MME and inter-MME for LTE-A network. From the result, it has been found that with the propose framework, the probability of false handover initiation and handover failure increase as speed increase at a fixed handoff threshold value.

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INTRODUCTION

Rapid progress in the research and development of wireless networking and communication technologies has created different types of wireless communication systems, such as Bluetooth for personal area, IEEE 802.11- based WLANs for local area, Universal Mobile Telecommunications System (UMTS) for wide area, and satellite networks for global networking. These networks are complementary to each other(Mohanty, S. and I.F. Akyildiz, 2006). In the 4G wireless environment, a mobile user is able to continue using the mobile device while moving from one point of attachment to another. The process is called a handover, by which a User Equipment (UE) keeps its connection active when it move from the coverage of one network access point to another access point(Abdoulaziz, I.H., 2012; Abrar, S., 2012). Depending on the access network that each point of attachment belongs to, the handover can be either horizontal or vertical (I.H.A.L.R.Z.F., 2012). A horizontal handover or intra-system handover takes place between the same network technologies. Example of horizontal handover is the handover between two geographically neighbouring BSs of a LTE cellular network. On the other side, the switching between points of attachment or base stations that belong to the different network technologies is called Vertical handoff (Jayasheela, C.S., 2013). Example of the vertical handover is the handover between an IEEE WLAN and a LTE BS.

The process of the handoff can be divided into three steps, namely system discovery, handoff decision and handoff execution. During the system discovery, mobile terminal equipped with multiple interfaces have to determine which networks can be used and what services are available in each network. During the handoff decision phase, the mobile device determines which network it should connect to. During the handoff execution phase, connections are needed to be re-routed from the existing network to the new network in a seamless manner. This requirement refers to the Always Best Connected (ABC) concept, which includes the authentication, authorization as well as the transfer of user's context information (Jayasheela, C.S., 2013; Pahal, S., 2013).

In 3GPP Release 8, there are two types of handover procedures in connected-state mobility support for User Equipment (UE) which is backward handover and Radio Link Failure (RLF) handover. Both of these two types of handover procedures require the source eNB to prepare a handover

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decision for the target cell. Before the handover decision is made, the resource for the UE must be reserved at the target cell. Otherwise the UE will switch to idle-state where the UE attempts to complete handover by transitions back to connected state procedure which is called NON-Access Stratum (NAS) recovery. The target cell may belong to the source eNB which is intra-eNB handover or target eNB which is inter-eNB handover (Incorporated, Q., 2010).

In LTE, the type of handover is hard handover. Thus, when hard handover is used for the handover, meaning that there is a short interruption in service in the process of handover. This kind of interruption occurs on both intra and inter handover. Backward handover can be described as network-controlled/UE-assisted mobility. Handover related information is exchanged between the UE and the source eNB via the old radio path (thus, the usage of the term ‘backward’). Specifically, the radio conditions need to be good enough for the source eNB to be able to decode the Measurement Report from the UE and subsequently prepare the target cell for handover. The radio conditions also need to be good enough for the UE to be able to decode the Handover Command from the source eNB (Incorporated, Q., 2010). If the radio connection become very poor and the UE unable to decode the handover command, it will start the RLF timer. While the timer counting, the UE searches a suitable target cell and try to re-establish its connection with the target base station while the UE remain in connected-state.

Since in LTE-A have different type of handover, only two types of handover being considered in this work. One of the handover type is intra-Mobility Management Entity (MME) handover which is the handover occurs in the same LTE-A network and same MME nodes. The other one is inter-MME handover which is the handover happens between two nodes of MME also in the same LTE-A network.

An analytical handover framework:

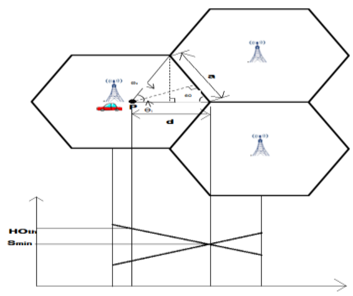

Fig. 1: Analysis of the handoff process.

In this section, an analytical framework on the handover process of the UE from current evolved NodeB (eNB) to the target eNB is proposed as shown in Figure 1. The following mathematical equations have been derived with reference to Figure 1 showing the movement of UE from the eNB to another which is called the target base station. From previous research by Shantidev Mohanty, this paper make an analysis of handover between different network. The framework consider the initial point where the start of the UE movement point situated right in the middle of the cell edge.

A scenario where the UE currently connected on the current base station has been considered. On this framework, UE is moving with a speed v. The v is assume to be uniformly distributed in [Vmin,Vmax]. Thus, the probability density function (pdf) of v is given by

$$f_v(V) = \frac{1}{Vmax - Vmin} \qquad Vmin < V < Vmax \qquad (1)$$

During the course of movement, the UE will discovers that it will going to move into the coverage area of the target eNB and hence it need to perform a registration with the serving eNB. Since the UE move from one coverage area to another coverage area, thus the UE may have the possibility of moving into another cell when the RSS of the current eNB decreases continuously.

Once the UE discover it will enter into another coverage area which is the target eNB, the UE will faces a new challenge to decide whether it is the right time to initiate the registration to the new eNB or not. The existing protocol proposes to initiate the registration when the Received Signal strength (RSS) from the serving eNB drops below a certain value of fixed handoff threshold value, $HO_{threshold}$.

From Figure 1, when the UE reaches the point P (the distance of P from the cell boundary is d), the RSS from the current eNB will drop below the $HO_{threshold}$. Therefore, when the UE reaches the point P, it will initiate the registration to the new eNB. At this point, the UE may not have sufficient signal strength to send the registration message to the target eNB. Hence, the UE may send the registration message to the target through the current base station. This process is called pre-registration. Then, the current eNB will send the registration message to the target eNB by using the X2 interface.

For the smooth and to keep a seamless connectivity, the handover must be done before the RSS of the UE drops below the S_{min} before the UE moves to the new coverage area.

When the UE location reached the point P as in Figure 1, the UE is assume to move in any direction with equal probability. Thus the probability density function (pdf) of UE direction of motion, θ is

$$f_\theta(\theta) = \frac{1}{\pi} \qquad 0 < \theta < \pi \qquad (2)$$

As the motion of UE direction is assumed, the speed of the UE also has been assumed to remain the same from point P until the UE move out from the coverage area of the current base station. This assumption should be reliable since the distance from point P to the cell boundary and not too large. For example, if the UE moves from point P with a speed of 110km/h and the distance from point P toward the boundary cell is 50 meters, so it is possible that the vehicle will not change the speed as 50 meters is a very short travel distance compare to the speed.

So it is clear from Figure 1 that the handover only can be done if the UE move from point P to the direction of range [θ ϵ (0,θT)] where, θT = θ1 + θ2. Otherwise, the handover initiation is false. Therefore, the probability of false handover initiation, P_a is

$$P_a = 1 - \int_0^{\theta_T} f_\theta(\theta)d\theta = \frac{5}{6} - \frac{1}{\pi}\tan^{-1}\frac{a_2}{d'} \qquad (3)$$

Where a is a radius of the cell.

The direction of motion of the UE from point P is β which is β ϵ [(0,θT)], then the time of UE to move out from the coverage area, t is given by

$$t = \frac{d' \sec \beta_1}{v} \quad \text{for } \beta 1 \in (0, \theta 1)$$

$$(4)$$

$$t = \frac{d' \sec \beta_2}{v} \quad \text{for } \beta 2 \in (\theta 1, \theta 2)$$

Where d is a distance from point P toward the edge of the cell and v is the speed of UE travelling in the cell.

Since the angle of direction θT is the total of angle θ1 and θ2, thus the time of UE to move out from the coverage area also have to be calculated into two equation depend on which direction the UE want to move.

From the mathematical equation derivation, thus the pdf of β is

$$f_\beta = \begin{cases} \frac{1}{\theta_1} & 0 < \beta < \theta_1 \\ \frac{1}{\theta_2} & \theta_1 < \beta < \theta_2 \\ 0 & otherwise, \end{cases} \qquad (5)$$

From equation (4), t is the function of β, t =g(β) where

$$g_1(\beta_1) = \frac{d' \sec \beta_1}{v} \qquad (6)$$

$$g_2(\beta_2) = \frac{d' \sec \beta_2}{v}$$

Therefore, the pdf of t is

$$f_t(t) = \sum_i \frac{f_\beta(\beta)}{|g'(\beta)|} \qquad (7)$$

Where βi are the roots of the equation of t =g(β) in the range of [0,θT], thus the derivative probability of handover failure is given by

$$p_f = \begin{cases} 1 & \tau > \frac{\sqrt{a_2^{\,2}+d'^2}}{v} \\ p(t<\tau) & \frac{d'}{v} < \tau < \frac{\sqrt{a^2+d'^2}}{v} \\ 0 & \tau \le \frac{d'}{v} \end{cases} \qquad (8)$$

From the probability handover failure, τ is the summation of RLF timer and handover signalling and p(t < τ) is the probability when t < τ.

Thus, the probability of handover failure by considering θ1 and θ2 is given by

$$p_f = \begin{cases} 1 & \tau > \frac{\sqrt{a_2^{\,2}+d'^2}}{v} \\ \frac{1}{\theta_1} \arccos\left|\frac{d}{v\tau}\right| & \frac{d'}{v} < \tau < \frac{\sqrt{a_1^{\,2}+d'^2}}{v} \\ \frac{1}{\theta_2} \arccos\left|\frac{d}{v\tau}\right| & \frac{d'}{v} < \tau < \frac{\sqrt{a_2^{\,2}+d'^2}}{v} \\ 0 & \tau \le \frac{d'}{v} \end{cases} \qquad (9)$$

RESULT AND DISCUSSIONS

3.1 Probability of false handover initiation:

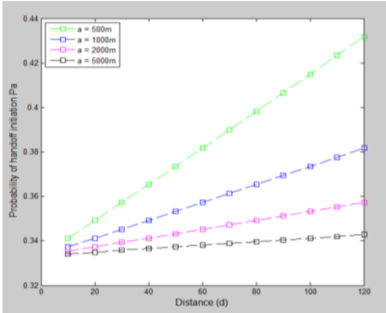

Fig. 2: Relationship between false handover initiation probability and d.

As seen in Figure 2, it is shows that with a particular value of a, the probability of false handover initiation increases when d increases. This result leads a wastage resource of the wireless system. It is also shown in the figure that the problems of false handover initiation become more worse when the size of the cell decreases. When the cell size decreases, the capacity is increases. Thus, it is necessary to select the proper value of d in order to reduce the probability of false handover initiation.

1.2 Probability of handover failure:

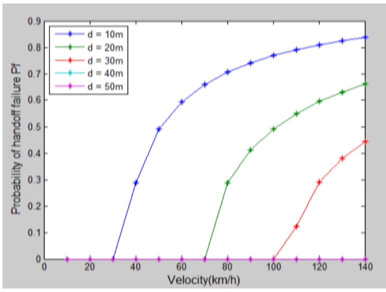

Fig. 3: Relationship between probability of handover failure and speed for angle θ1 (less than 30 degree) and τ = 1s.

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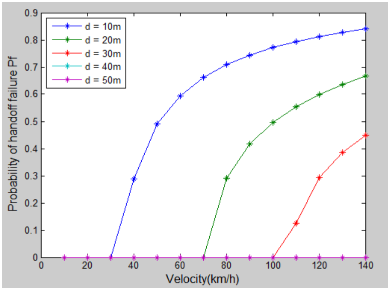

Fig. 4: Relationship between probability of handover failure and speed for angle θ1 (more than 30 degree) and τ = 1s.

Figure 3 and Figure 4 show the relationship between UE speed and probability of handover failure for intra-MME handover for different values of d. From the result obtained, if fixed value of $HO_{threshold}$ is used, the handover failure probability increased as the speed of UE increased.

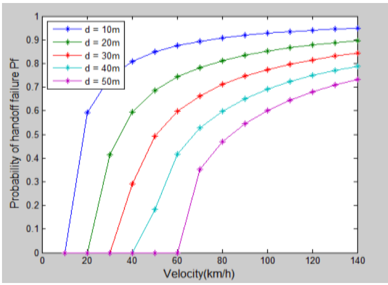

Fig. 5: Relationship between probability of handover failure and speed for angle θ1 (less than 30 degree) and τ = 3s.

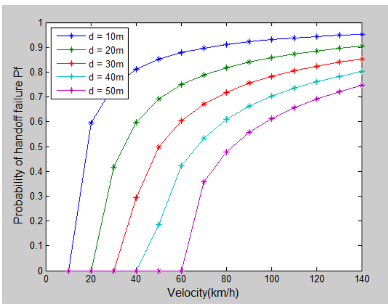

Fig. 6: Relationship between probability of handover failure and speed for angle θ1 (more than 30 degree) and τ = 3s.

Figure 5 and Figure 6 show the relationship between probability of handover failure and speed for inter-MME handover. As the speed of UE increased, the probability of handover failure also increased. The main differences between intra-MME and inter-MME handover is the time taken to make the handover decision. The τ for intra and inter-MME handover is assumed as 1s and 3s, respectively. The range time of 1s is selected by considering the time taken to transfer message for the same MME plus the RLF timer for inter-eNB handover while 3s is the time taken to transfer message between different MME plus the RLF timer for intra-eNB and both for poor radio condition cases.

It can be seen that inter-MME handover has higher probability of handover failure as compared to intra-MME handover. During the inter-eNB handover, the content of UE control plane and user plane are transferred from the source eNB to the target eNB. Source eNB also transfer the UE's downlink user plane data to the target eNB in order to minimize packet loss. In 3GPP release 8 specifications; there is one handover procedure which is call Radio Link Failure (RLF) handover procedure. This procedure also known as the RRC Connection Reestablishment. RLF handover is a UE-based mobility which is provides a recovery mechanism when source cell partially fails to transmit data to target eNB due to poor radio conditions. The poor signal will make UE fail to decode the Handover Command from the source eNB. Therefore, when the UE detect the radio link problem, the RLF timer will start counting which is 500 ms or 1000ms set up by 3GPP[10]. Upon the expiration of RLF timer, the UE will search for the target cell and attempts to re-establish its connection to the target eNB while the UE remain in it connected 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 incurs additional delay versus the backward handover procedure and, consequently, a longer interruption in service. Thus, inter-MME handover takes longer time signalling than intra-MME handover.

Conclusion:

In this work, a handover framework which consist the movement of UE from source eNB to the target eNB with some selected angle of movement with derivation of mathematical equation is proposed. From the mathematical equation, the probability of false handover initiation and handover failure are analyzed. From the result analysis, it is shows that by using fixed value of handoff threshold value, the probability of handoff failure increased as the speed or the summation of RLF timer and handover signalling increased. Thus, it can be concluded that it is not efficient to use the same handoff threshold value in the network for the different type of handover and variance of speed. Based on the results, the future work will be aimed to analytically model and optimize the handover threshold value performance in LTE-A network.

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