Optimization of Adaptive Received Signal Strength Threshold Value by Using Particle Swarm Optimization in Long Term Evolution-Advanced (LTE-A) Network

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***Abstract*—Mobility management plays an important role in mobile network to support seamless communication in Long Term Evolution -Advanced (LTE-A) network. The important part in communication is handover execution. To provide seamless communication system, the handover execution for the user from one base station to the others must be done in a smooth way. Thus, there is a need to develop some techniques to the system to improve the handover execution. One of the problems in the existing network is the fixed handover threshold value. In this work, a framework has been proposed to analyze the handover performance as the speed and summation of handoff signaling and Radio Link Failure (RLF) timer varies due to poor radio conditions case. A mathematical equation has been derived from the proposed framework. From the result, it has been found that the proposed framework was able to identify the value of dynamic threshold value (Sath), which is the adaptive received signal strength (RSS) for handover.**

***Index Terms*—Mobility Management; Seamless Communication; Handover Threshold; Long Term Evolution Advanced (LTE-A); Radio Link Failure (RLF); Received Signal Strength(RSS).**

I. INTRODUCTION

Wireless communication systems are rapidly evolved nowadays. The research and development of wireless networking and communication technologies has created different types of wireless communication, 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 [1]. 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 moves from the coverage of one network access point to another access point [2][3]. Depending on the access network that each point of attachment belongs to, the handover can be either horizontal or vertical [4]. A horizontal handover or intra-system handover takes place between the same network technologies. An example of horizontal handover is the handover between two geographically neighboring BSs of a LTE cellular network. On the other side, the switching between points of attachment or base stations that belongs to the different network technologies is called Vertical handoff [5]. An 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 has 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 [5][6].

In 3GPP Release 8, there are two types of handover procedures in connected-state mobility support for User Equipment (UE), which is the backward handover and the Radio Link Failure (RLF) handover. Both of these two types of handover procedures require the source eNB to prepare a handover 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 the connected state procedure, which is called the 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 [7].

In LTE, the type of handover is hard handover. Thus, when hard handover is used for the handover, it means that there is a short interruption in service in the process of handover. This kind of interruption occurs on both intra and inters 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[7]. If the radio connection becomes very poor and the UE is unable to decode the handover command, it will start the RLF timer. While the timer is counting, the UE searches a suitable target cell and tries to re-establish its connection with the target base station, while the UE remains in connected-state.

Since the LTE-A has different types of handover, only two types of handover were considered in this work. One of the handover types is the intra-Mobility Management Entity (MME) handover, which is the handover that occurs in the same LTE-A network and same MME nodes. The other one is the inter-MME handover, in which the handover happens between two nodes of MME in the same LTE-A network [8].

In this paper, since the objective is to make the adaptive threshold values for handover execution, there is a need to develop a technique to optimize the distance between the mobile user and the boundary of the serving cells. For this part, particle swam optimization (PSO) technique has been used.

The optimum value of d. PSO has been used by many applications of several problems. The PSO algorithms follow the behavior of animal's societies that do not have any leader in their group. An example of animals categorized in this group are the bird flocking and fish schooling. Typically, a group of animals that have no leader will find food that has the closest position with a food source (potential solution) by random and it will be followed by the other members in the group. Animal which has a better condition will inform it to its flocks and the others will move simultaneously to that place. This would happen repeatedly until the best conditions or a food source discovered. The process of PSO algorithm in finding optimal values follows the work of this animal society [9].

II. Analytical Handover Framework

In this section, an analytical framework on the handover process of the UE from the currently evolved NodeB (eNB) to the target eNB is proposed as shown in Figure 1.

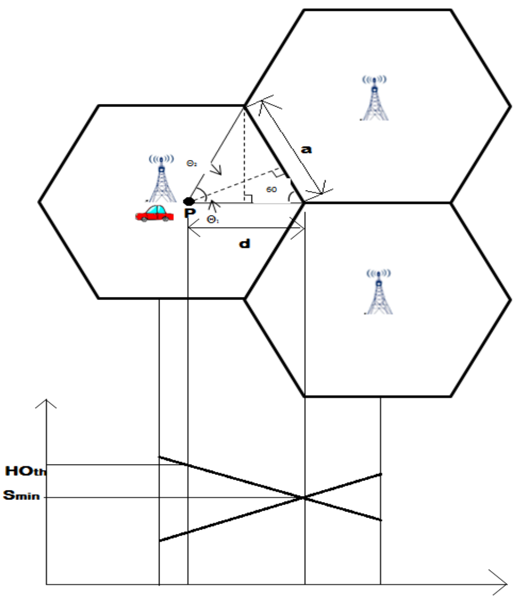

Figure 1: Analysis of the handoff process

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 the previous research by ShantidevMohanty [10], this paper made an analysis of handover between different network. The framework considers the initial point where the start of the UE movement point is situated right in the middle of the cell edge.

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

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

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

Once the UE discovers that it will enter into another coverage area, which is the target eNB, the UE will face 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 handoverthreshold value, HOthreshold .

From Figure 1, when the UE reaches point P (the distance of P from the cell boundary is d), the RSS from the current eNB will drop below the HOthreshold. Therefore, when the UE reaches 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.

To ensure a smooth procss and to keep a seamless connectivity, the handover must be done before the RSS of the UE drops below the Smin before the UE moves to the new coverage area.

When the location of UE reaches point P as in Figure 1, the UE is assumed to move in any direction with equal probability. As the motion of UE direction is assumed, the speed of the UE also is assumed to remain the same from point P until the UE moves 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 is not too large. For example, if the UE moves from point P with a speed of110km/h and the distance from point P toward the boundary cell is 50 meters, it is possible that the vehicle will not change the speed as 50 meters is a very short travel distance compare to the speed.

A. *Probability of false handover initiation*

It is clear from Figure 1 that the handover can only be done if the UE moves from point P to the direction of range [$\theta \in (0,\theta T)$] where, $\theta T = \theta 1 + \theta 2$. Otherwise, the handover initiation is false. Therefore, the probability of false handover initiation, P_a is:

$$P_a = 1 - \int_0^{\theta_T} f_\theta(\theta) d\theta = \frac{5}{6} - \frac{1}{\pi} tan^{-1} \frac{a_2}{d'} \quad (2)$$

where a is a radius of the cell.

B. Probability of handover failure execution

After some derivations of mathematical equation, the derivative of probability handover failure is given by

$$p_f = \begin{cases} 1 & \tau > \frac{\sqrt{{a_2}^2 + d'^2}}{v} \\ p(t < \tau) \frac{d'}{v} < \tau < \frac{\sqrt{a^2 + d'^2}}{v} \\ 0 & \tau \leq \frac{d'}{v} \end{cases} \quad (3)$$

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:

$$p_f = \begin{cases} 1 & \tau > \frac{\sqrt{{a_2}^2 + d'^2}}{v} \\ \frac{1}{\theta_1} arccos \left|\frac{d}{v\tau}\right| \frac{d'}{v} < \tau < \frac{\sqrt{{a_1}^2 + d'^2}}{v} \\ \frac{1}{\theta_2} arccos \left|\frac{d}{v\tau}\right| \frac{d'}{v} < \tau < \frac{\sqrt{{a_2}^2 + d'^2}}{v} \\ 0 & \tau \leq \frac{d'}{v} \end{cases} \quad (4)$$

C. Adaptive RSS threshold value estimation by using Particle Swarm Optimization (PSO) technique

This part is to determine the value of adaptive RSS threshold (Sath) to initiate the handover process by using speed and handoff signaling delay information. Sath is estimated as follows:

First, the value of d is calculated for a desired value of pf by using this equation:

$$p_f \begin{matrix} \frac{1}{\theta_1} arccos \left|\frac{d}{v\tau}\right| \frac{d'}{v} < \tau < \frac{\sqrt{{a_1}^2 + d'^2}}{v} \\ \frac{1}{\theta_2} arccos \left|\frac{d}{v\tau}\right| \frac{d'}{v} < \tau < \frac{\sqrt{{a_2}^2 + d'^2}}{v} \end{matrix} \quad (5)$$

where, there are two equations with different angle θ1 and θ2. v is user speed, d is the distance of UE to the boundary of the serving BS, and τ is the summation of RLF timer and handover signalling delay. Equation (5) is a nonlinear equation of d. A calculation for a closed form expression may not be always possible. Thus, an approximate value of d is calculated using:

$$p_f = \frac{arccos\left(\frac{d}{v\tau}\right)}{\arctan\left(\frac{a}{d}\right)} = \frac{\frac{\pi}{2} - \frac{d}{v\tau}}{\frac{\pi}{2} - \frac{d}{\sqrt{d^2 + a^2}}} \quad (6)$$

In order to find the optimum value of d with respect to certain value of pf, PSO technique is used. In this research, pf value used is pf = 0.02, which means that only two from 100 handover attempt will fail and the other 98% attempt will succeed to be handover to the target base station.

Since the algorithm of PSO emulates from animals societies, the movement of the algorithm will follow the behavior of the animal group or swarm. The ability of these PSO technique is that the algorithm will explore different regions of the search space to locate an optimum value. This process is call the exploration. Exploitation, on the other hand, is the ability to concentrate the search around a promising area in order to refine a candidate solution [9]. With their exploration and exploitation, the particles of the swarm fly through hyperspace and they hasve two essential reasoning capabilities: their memory of their own best position - local best (lb) and knowledge of the global or their neighborhood's best - global best (gb). The position of the particles is influenced by velocity.

Let $xi(t)$ denotes the position of particle in the search space at time step. The position of the particle is changed by adding a velocity, $vi(t)$ to the current position:

$$xi(t+1) = xi(t) + vi(t+1) \quad (7)$$

where:

$$vi(t) = vi(t-1) + c1r1(localbest(t) - xi(t-1)) + c2r2\,(globalbest(t) - xi(t-1)) \quad (8)$$

with $xi(0) \sim U$ ($xmin, xmax$), acceleration coefficient $c1$and c, and random vector $r1$and $r2$.

Initially, all of the particle velocity is assumed to be zero. Set iteration i=1. At the i th iteration, find the two important parameters for each particle j that is the best value of $xj(i)$ (the coordinates of particle j at iteration i) and declare as Pbest(j). The best value for all particles $xj(i)$, which is found up to the i th iteration, Gbest with the value function that has the smallest goal among all the previous iteration.

Then, the position or coordinates of particle at the ith iteration is calculated by using Equation (8). The last step, is when the PSO checks whether the current solution is convergent. A convergence is when the positions of all particles lead to an equal value. If the current solution is convergent, then the iteration will stop and the optimum value will be given. In this situation, the final value from the PSO technique is the value of d.

Once d is calculated, the corresponding value of Sath is calculated using the path loss model and the cell size of the serving BS.

$$Sath = 10 \log_{10}[\Pr(a - d)] \quad (9)$$

Once Sath is calculated, the handover trigger unit monitors the RSS from the serving BS and the handover will be executed, when the RSS value from the serving BS drops below Sath.

III. RESULTS AND DISCUSSION

A. Probability of false handover initiation

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

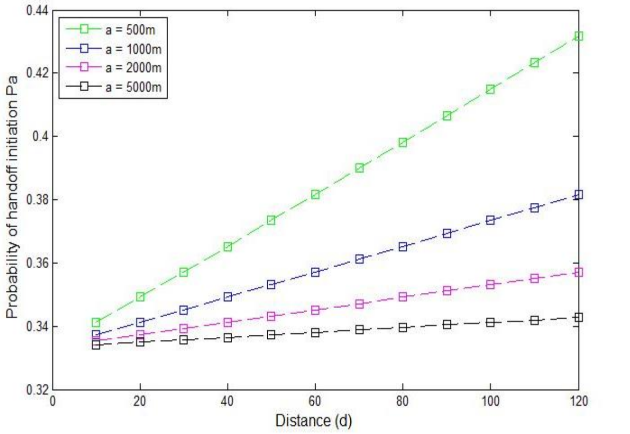

Figure 2: Relationship between false handoverinitiation probability and d

B. Probability of handover failure

Figure 3 shows the relationship between the UE speed and the 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 increases as the speed of UE increases.

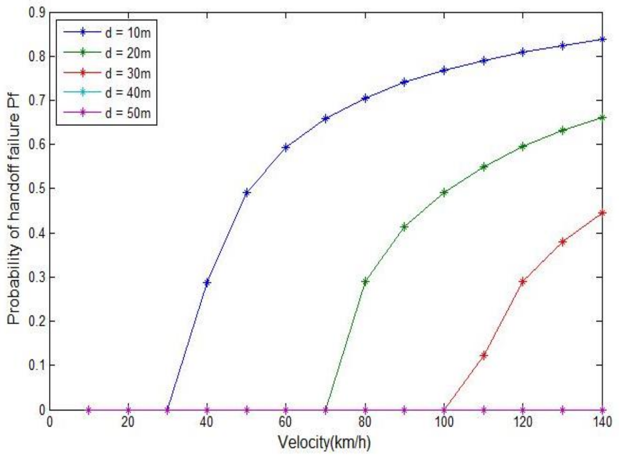

Figure 3: Relationship between probability of handoverfailure and speed for angle θ1 (less than 30 degree) and τ = 1s

Figure 4 shows the relationship between the probability of handover failure and speed for inter-MME handover. As the speed of UE increases, the probability of handover failure also increases. 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 was 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 transfers the UE's downlink user plane data to the target eNB in order to minimize packet loss. If 3GPP releases 8 specifications; there is one handover procedure, which is call Radio Link Failure (RLF) handover procedure. This procedure is also known as the RRC Connection Reestablishment. RLF handover is a UE-based mobility which 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 detects the radio link problem, the RLF timer will start counting, which is 500 ms or 1000ms set up by 3GPP[11]. 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 remains in its connected state.

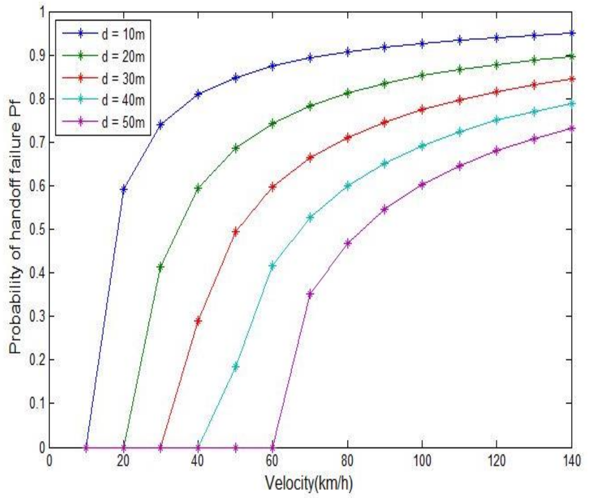

Figure 4: Relationship between probability of handoverfailure and speed for angle θ1 (less than 30 degree)and τ = 3s

The re-establishment is successful if the target cell has been prepared by the source eNB, which means that the source eNB receives 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.

C. Adaptive RSS threshold value estimation by using Particle Swarm Optimization (PSO) technique

Figure 5 shows the fitness against the number of iteration for the optimization of the distance UE to the boundary of the base station, d. The less fitness value shows the more accurate target point for the d value. From Figure 5, it is shown that with more iteration, the chart is approaching convergence value, which means that the value approaching the lowest value of fitness is approaching to more accurate value for the target parameter d with respect to pf = 0.02. From the result, the best point for d is 300m.

Then, the best value taken from the optimization is inserted into the RSS threshold equation. For our simulation, we considered a macrocell system with a cell size of a = 1km. A macrocell reference distance = 300m. The target handoff failure probability is pf = 0.02. The speed of mobile's in a macrocellular system are between 0 km/h to 140 km/h, respectively.

From Figure 6, it shows that the higher the speed of user, the higher value of RSS threshold level, but with the same distance. The relationship between Sath and UE speed for different values of handoff signalling a delay (τ). For different values of v, the required value of d is calculated by using equation (6). Then, by using the equation (9), the required value of Sath is calculated with different value of τ with different speed of user equipment, which is between 0 km/h to 140 km/h. Based on the figure shown above, for a particular value of τ, Sath increases as UE speed increases. This implies that, for an UE to move with higher speed, the handover should be initiated earlier compared with a slow-moving UE. This condition guarantees the desired handover failure probability is independent with the UE speed. It is also shown that Sath increases as τ increases. This is because, when τ is large, the handover executed earlier is compared to when τ is small. The small and large values of τ respond to intra and intersystem handover, respectively. Therefore, the result shows that Sath is an adaptive RSS threshold with respect to τ and *v*.

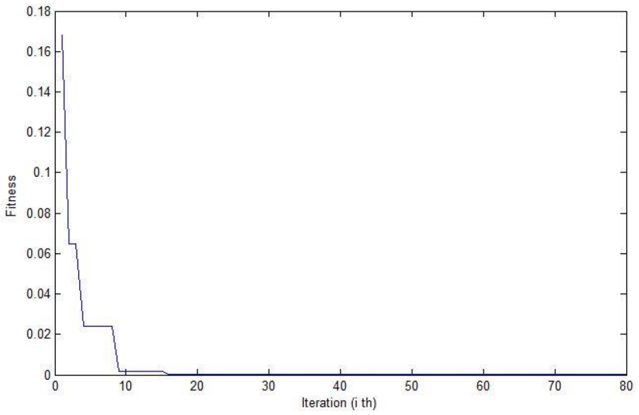

Figure 5: Fitness result from Particle Swarm Optimization technique (PSO) with 80 iterations

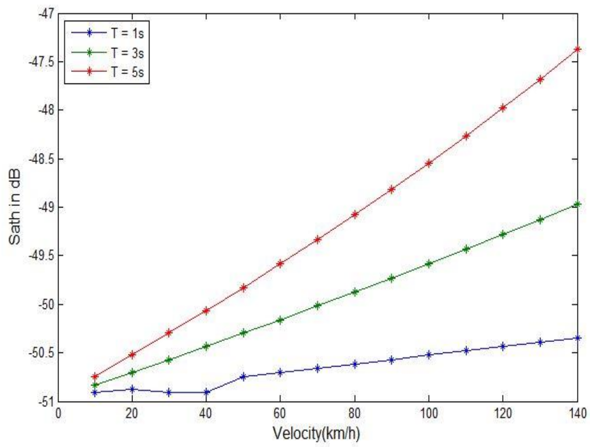

Figure 6: RSS threshold (Sath) for different speed values in macrocell system

IV. CONCLUSION

In this work, a handover framework which consists of the movement of UE from the eNB source to the target eNB with some selected angles 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 shown that by using a 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. Thus, the adaptive threshold value has been proposed. It shows that with the same distance, the adaptive RSS threshold can make the decision for handover from one base station to another base station, which is more effective compare to a single threshold value. With the adaptive threshold value, the handover will be executed based on certain speed and distance with different value of threshold level which is more productive in order to reduce handover failure. For future work, a comparison between the handover failure for dynamic handover threshold with different types of base station such as femto, pico, micro and macrocell network for intra and inter-sytem handover in LTE-A network is proposed.

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