A Timer based on Overlapping Area for Avoiding Ping-Pong Handover in LTE Networks

Kinan Ghanem
Department of Electronics and Communications Engineering,
Tishreen University, Lattakia, Syria

Haysam Al-Radwan
Department of Electronics and Communications Engineering,
Tishreen University, Lattakia, Syria

Ahmad Ahmad
Faculty of Information technology
Al-Baath University, Homs Syria

Abstract- **Handover (HO) technique in LTE networks suffers from Ping-pong movement. Ping-pong HO can reduce the quality of the mobile user's connection and increase the numbers of handovers. Also, it raises the network load and generally degrades the network performance. The work aims to present a novel approach to reduce the undesirable effects of ping-pong HO in LTE Mobile Networks using timer (based on overlapping area). The study focused on the ping-ping phenomenon taking into account maintained the dropped calls rates at lowest levels. The optimal timer values are determined based on the width of overlapping area, user velocity and type of eNodeB. Analyzed results showed that the changes of overlapping area directly affect the timer values of the proposed algorithm. Optimal timer values should be selected precisely according to the width of the overlapping area, user velocity and timer value in order to reduce the ping-pong HO.**

Keywords - Ping-Pong handover, Timer value, LTE, Overlapping area, dropped calls rate.

I. INTRODUCTION

Handover is a crucial procedure for maintaining the connection between the mobile users. There are two types of HOs to communicate users between different cells. The first type is called hard HO which is employed in the GSM and LTE mobile networks. The second type is called soft HO which is implemented in IS-95 and 3G mobile networks. LTE is based on OFDMA technology, which is primarily a frequency division process. This means that the user has to switch into a different set of frequency subcarriers when it hands over between two evolved Node-B (eNBs). Soft HO has better performance on both link and system level and it has the advantages of smoother transmission and less ping-pong effects. However, it wastes the radio resources and has the disadvantages of complexity. Hard HO suffers from ping-pong phenomenon which means two consequent HOs between the source station and target station and vice versa [1-4].

The ping-pong HO is a very common phenomenon in the LTE mobile networks, which may cause call dropping and degrading of the HO performance. Moreover, it wastes the limited radio resources because it reserves two connections for a short time. It occurs due to the repeated movement of UE between the source and the target eNB, or high signal fluctuation at the common boundary of the eNBs. Coverage parameters, antenna configuration, users' location area and their movement are the main considerations that can cause the ping pong [5].

Previous works on hard handover led to several algorithms to improve the HO technique in LTE networks. Many studies have been conducted in the area of ping-pong HO in LTE Networks [6-8]. Two main general methods, hysteresis [6] and TTT (Time To Trigger) with threshold [9-10], have been widely used to solve the Ping-pong HO problem. Previous studies vary from statistical analysis in the literature [11-14] to follow algorithms rely on probability prediction using neural networks in [15] and [16]. In [5], a novel handover algorithm, based on keeping the old path between the source eNB and (Serving gateway/ Mobility management Entity) SGW/MME during the ping-pong movement and delaying the completion handover part is presented. However, the effects of overlapping area on the ping-pong phenomenon have not been addressed carefully.

The rest of the paper is organized as follows. In section II we present the intra-EUTRA HO procedure. The proposed technique which reduces ping-pong HO - based on timer value- is described in section III. The mathematical calculation of the timer value based on the overlapping area is illustrated in section IV. Section V shows the simulation results, also conclusions and future outlook are given in section VI.

II. LTE INTRA-EUTRA HANDOVER PROCEDURE

In LTE, the HO decision is made in the eNB without connecting to the MME. The required HO information is exchanged between the eNBs via the X2 interface. According to the 3GPP, the HO procedure is divided into two parts mainly: the HO preparation and execution parts and HO completion part. Fig. [1] Shows the intra-EUTRA HO steps and a summary of the HO procedure is summarised in [5].

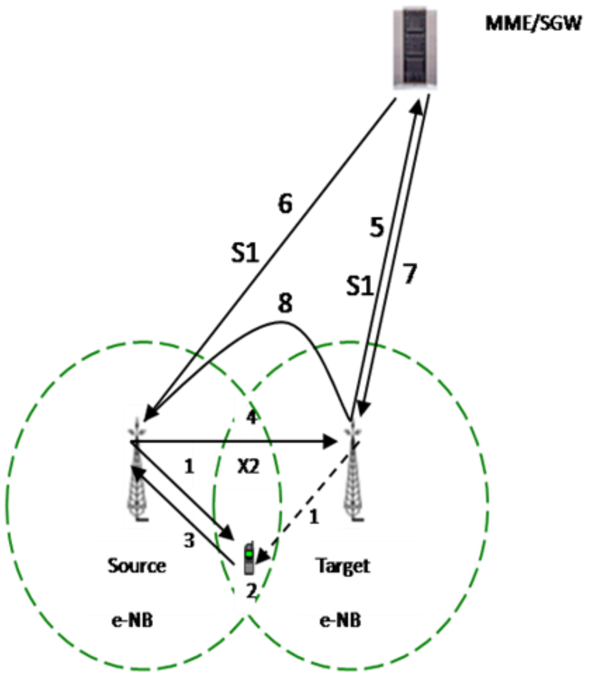

Fig. 1. Summary of the different steps of preparation, execution and completion HO process performs by eNBs. 1) Downlink HO measurements, 2) processing of downlink measurements, 3) uplink reporting, 4) HO preparation and execution via x2 interface, 5) path switch request, 6) release the old path, 7) Path switch acknowledgement, 8) Release resources [4, 5].

III. PING-PONG DETECTION ALGORITHM FOR INTRA LTE HO

In the proposed algorithm explained in Fig. 2 a timer is used to delay the HO completion part from the HO process. If the difference between the Signal strength of the target (SS-target) and SS-source always shows that the SS-target is sufficiently stronger than the SS-source after expiring the timer then there is no ping-pong HO. However, if the difference between the SS-target and SS-source does not show that, then the movement is ping-pong. In this case, the HO should be delayed and the old path (MME/SGW-source eNB) should be kept during the ping-pong interval. In another word only the completion part of the HO procedure can be delayed to avoid the swinging between of the (old and new) paths as it can be seen in (Fig. 2).

The proposed algorithm has 3 phases as explained below. As it appears in fig. 3, the preparation and execution HO phase means that the new connection between the UE and the target eNB is made but the old S1 interface is still in use (Blue line in fig. 3). For the HO completion part there is completely new connection path via new S1 interface. It is good to mention that in the completion phase the old S1 path is released and a new S1 interface is initiated to be used.

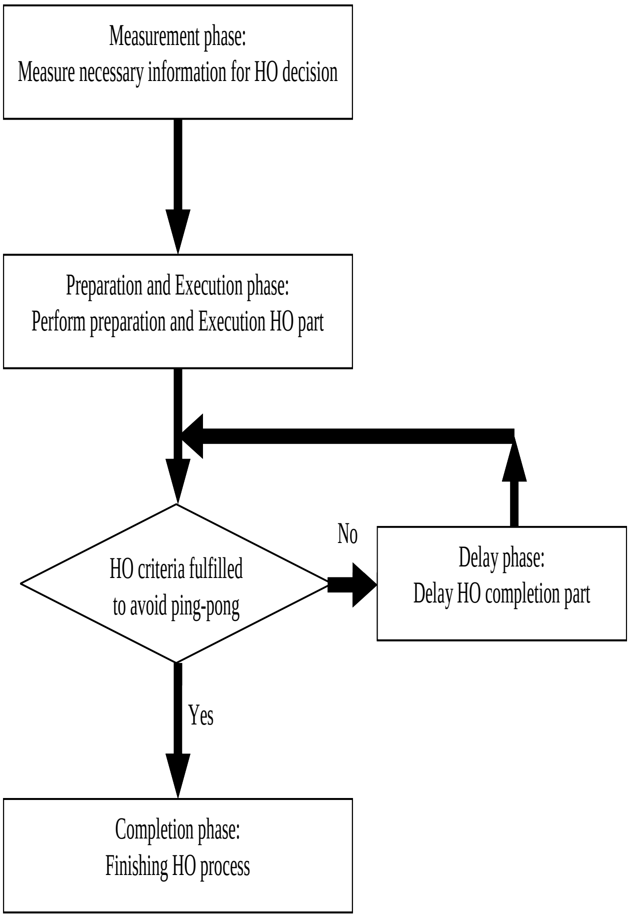

Fig.2. proposed technique for ping-pong avoidance In Intra E-UTRA (Evolved Universal Terrestrial Access) networks

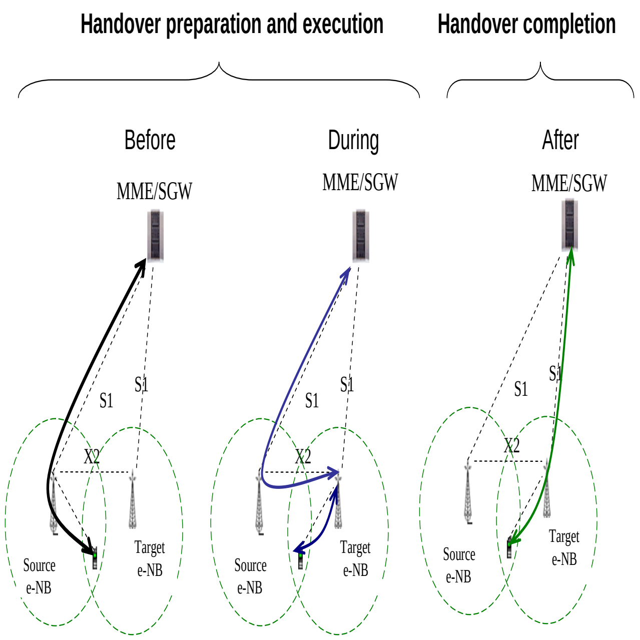

Fig. 3. the phases of the proposed algorithm

IV. ANALYSIS OF THE PROPOSED ALGORITHM

How to define the difference SS (target-source) mathematically?

For each mobile phone in the overlapping area, the average of the standard deviation can give the best SS(target-source) requires to perform a handover.

$$SS_{(soucre1)} + SS_{(source2)} + \ldots SS_{(source\ i=N)}$$

$$Average_{source} = \sum_{i=1}^{i=N} \frac{SS_{(sourcei)}}{N}$$

$$SS(target1) + SS(target2) + \ldots SS(target\ i=N)$$

$$Average_{target} = \sum_{i=1}^{i=N} \frac{SS_{(target)}}{N}$$

$$Total\_Average = \frac{\sum_{i=1}^{i=N} \frac{SS_{(sourcei)}}{N} + \sum_{i=1}^{i=N} \frac{SS_{(target)}}{N}}{2} \quad (1)$$

Total average is used to trigger the parameters and perform the HO completion part. The difference between the received signal strength from the target and the source (SS(target-source)) of the proposed algorithm should be chosen to be less than Total_Average.

$$SS_{(target-source)} < Total\_Average = \frac{\sum_{i=1}^{i=N} \frac{SS_{(sourcei)}}{N} + \sum_{i=1}^{i=N} \frac{SS_{(target)}}{N}}{2}$$

V. MATHEMATICAL MODEL FOR MAXIMUM TIMER VALUE

Let us suppose that the width of the overlapping area equal to d, the distance between the User Equipment (UE) and the source is r, whereas the distance between the target and the UE is r`, and D is the distance between two eBNs. UE velocity is chosen to be v and it refers to the speed of the mobile user in m/sec, d` the active HO area (red colored area in fig. (4)). The red area points to the area that the mobile user should perform the HO completion before passing it. So due to the velocity of the UE the overall HO time should be completed before the d`/v, where is d` is the distance that the SS(target-source) can match.. Moreover, The red area is the area of ping-pong HO and also it is the area which that may have high probability of dropped calls.

D=r+r`, r-r`=d`, where is d` can be calclulated as
d`=r-D+r=2r-D (2)

The maximum value for delaying the HO should not exceed d`/v, and the Timer value should be less than d`/v (<d`/v). let us assume that the required time to perform the Ho preparation and execution is t1, and the required time to perform the handover completion is t2. The Timer value is set to be t3, and the interruption time which is the UE radio connection is dead t4. The total time to finish the complete HO procedure is assumed to be T`.

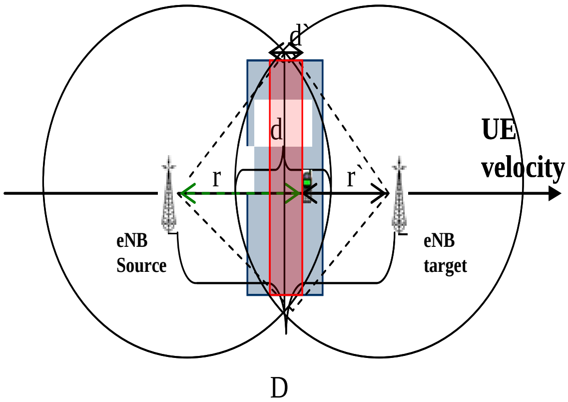

Fig. 4. Overlapping area between 2 eNBs, red area refers to the active HO area

T`=d`/v=t1+t2+t3+t4 (3)

The interruption time, i.e., the time during which the UE radio connection is dead=t1, T2 HO Execution time, T3 HO trigger until completion.
Let us suppose that t1+t2+t4= HO overall execution time equal to 100 ms (It varies from 60 to 100 ms):

T`=100+t3, T3=T`-0.1 Sec (Timer in sec) (4)

It is good to mention that d` differs upon the cell size and the cell type. LTE cell sizes may range from femto-cell for indoor/home coverage, to over 30 km (18.64 miles). However, a typical LTE cell size will be 1 to 5km (0.6 - 3 miles), and generally congruent with 2G/3G cell deployments.
If we suppose that the overlapping area is equal 10 % of the cell size, and the cell diameter in the urban areas equal to 1000 meter than the width of the overlapping area (d=100 meters). Let us suppose that the active HO area equals to 50% of the overlapping area (d`=d/2=50 meters) then the maximum time for the timer should be T=d`/v whereas, v assigns to the velocity of the UE. If we suppose that the velocity is 25 meter per second than the maximum value is 50/25= 2 Sec. For cell diameter equals to 2400 meters, d=240 meters, Then d`=d/2=120 m, as a result of that the maximum timer value is 120/40= 3 Sec (for velocity equals to 40 meters per second). Table (1) explains the effects of different overlapping areas on the timer values for high speed UE equal to 30 m/sec (108 km/h).

Increasing the width of overlapping area allows having higher timer value as it can be seen in fig. (5). For different cell diameters -in a real environment-, there will be a different overlapping area as it can be seen in fig. (6). As a result, different Timer values (based on velocity changes) should be applied to complete the HO decision. Rapid changes in the overlapping areas caused by network topology, cell size and the antennas type play significant role in selecting the accurate timer value to reduce the ping-pong HO effects.

TABLE (1): ADAPTIVE TIMER VALUE FOR DIFFERENT CELLS SIZE AND A VELOCITY EQUALS TO 30 M/SEC (108 KM/H)

Cell diameter	overlapping area	d	d`=d/2	T`=d`/v	T=T`-0.1
1000	10%	100	50	1.667	1.567
1500	10%	150	75	2.5	2.4
2000	10%	200	100	3.33	3.23
2500	10%	250	125	4.167	4.067
3000	10%	300	150	5	4.9
4000	10%	400	200	6.666	6.566

The relationship between the overlapping area and the timer value for different velocities is shown in the fig. 6.

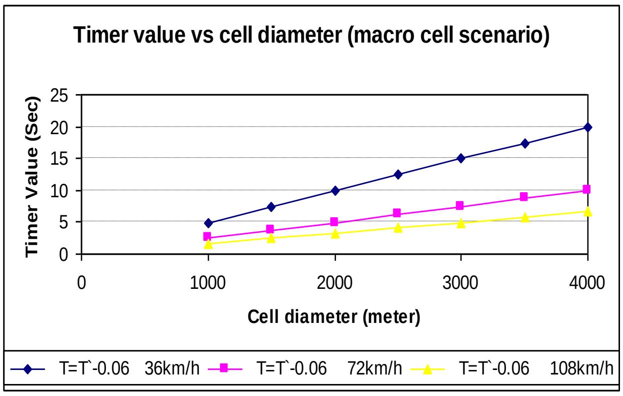

Fig.5. The effects of timer values on the cell diameter for different velocities, overall execution time is chosen to be 60 msec.

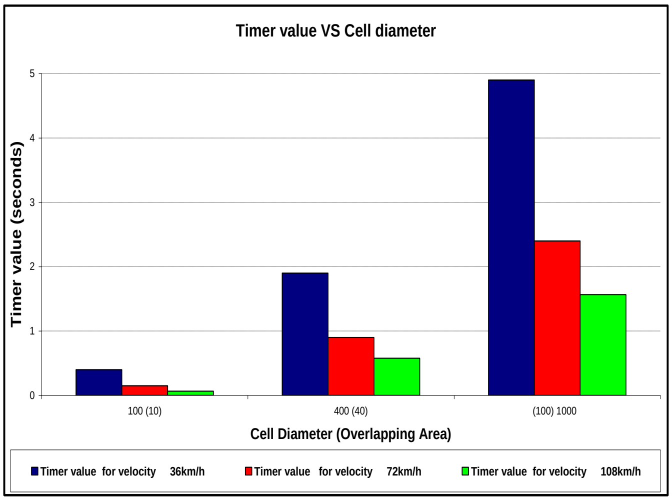

Fig. 6. The effects of velocity, cell diameter and overlapping area on the timer values

VI. PING-PONG AVOIDANCE ALGORITHM BASED ON FUZZY LOGIC

Fuzzy logic technique was previously used to study HO in different mobile networks [17-20] but not to study ping-pong HO. Fuzzy set theory allows a linguistic representation of the control and operational laws of a system in words. The main strength of fuzzy set theory is that it excels in dealing with imprecision. In the classical set theory an element is either a member of a set or it is not. Classical set theory does not allow for partial membership. This kind of logic is called bi-state logic. The fuzzy set theory allows the gradual transition from full membership to full non-membership of the set [21-25]. Thus fuzzy set theory is a generalization of classical set theory. In fuzzy set an element is related to a set by a membership function μ. The membership function usually take on a value between 0 and 1, this means μ→[0,1] where 1 is for full membership, 0 for the null-membership and values in between give the degree of membership.

There are several reasons for using fuzzy control for analyzing the ping-pong HO in E-UTRA networks in this study. The rapid changes in the radio environment require a fast response and better algorithm to follow up these changes. The ping-pong phenomenon is fuzzy since it differs from cell to cell and varies upon radio measurements and dynamic changes in the mobile environment properties. Moreover, the mobile operators are not able to completely control the ping-pong HO and they use their own experience in reducing it. The ping-pong HO could benefit from the fuzzyfication treatment of the HO input metrics and fuzzy reasoning thereon as it is explained later on this article.

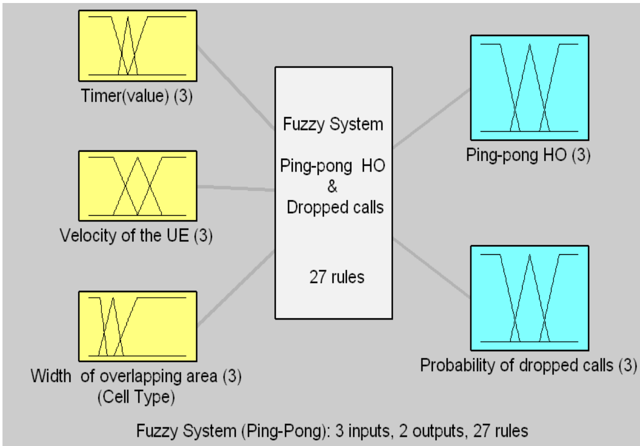

Fig. 7. Fuzzy logic system for Ping-pong Avoidance Algorithm (Matlab)

A. *Memberships of Input Parameters*

The input variables for the proposed algorithm are Timer value, velocity of UE and width of overlapping area (Fig. 7). Moreover, we will consider another input variable which is the SS (target-source) – the linguistic values are assigned as High, Medium, and Low over the interval [0-6] dB - and examine the effects of the signal strength level a long with timer value on the probability of ping-pong HO and probability of dropped alls.

The first input of the proposed algorithm is the Timer value (fig.8). Timer value is assigned the linguistic values Small, Medium, and Big which are represented below by membership functions $A_{11}(x)$, $A_{22}(x)$ and $A_{33}(x)$, respectively, over the range [0,5] Sec.

$$A_{11}(t)=\begin{cases}0 & if \quad t<1.5\\ t-1.5 & if \quad 1.5\geq t\geq 2\\ 1 & if \quad t>2\end{cases} \quad (5)$$

$$A_{22}(t)=\begin{cases}0 & if \quad t<1\\ t-1 & if \quad 1\geq t\geq 1.5\\ 2-t & if \quad 1.5\geq t\geq 2\\ 0 & if \quad t>2\end{cases} \quad (6)$$

$$A_{33}(t)=\begin{cases}1 & if \quad t<1\\ 1.5-t & if \quad 1\geq t\geq 1.5\\ 0 & if \quad t>1.5\end{cases} \quad (7)$$

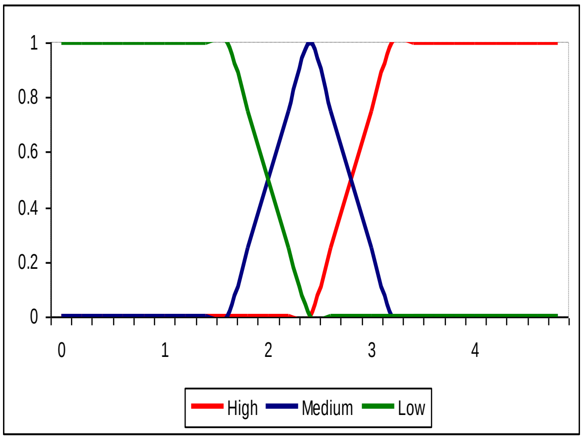

Fig.8. The degree of membership function for Timer value

The second input of the proposed algorithm is the velocity of UE. The velocity of UE is assigned the linguistic values as High, Medium, and Low over the interval [0-100] km/hour. The third input of is the width of overlapping area. The width of overlapping area is assigned the linguistic values as High, Medium, and Low over the range of [0-400] meters.

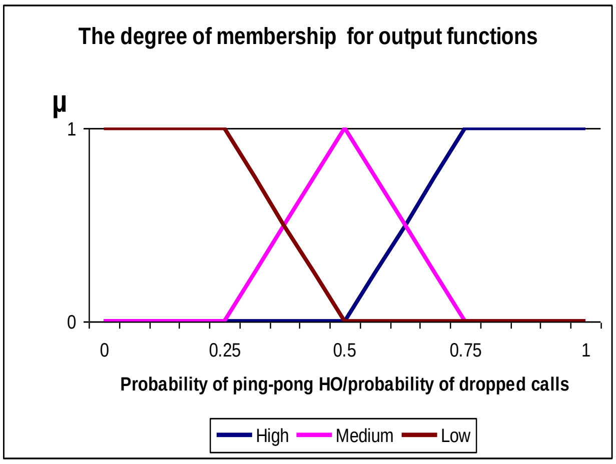

Fig. 9. The degree of membership for the output functions (Probability of dropped calls and ping-pong HO).

An output parameter refers to the probability of ping-ping HO which is defined as High, Medium and Low and the corresponding weights are taken to be 1, 0.5 and 0 respectively. A value equal to l is expressed as a definite ping-pong HO, and 0 as no ping-pong HO. The degree of membership functions for output is shown in fig. 9.

B. *Fuzzy inference*

The fuzzy rules used are presented in table (2):

TABLE II FUZZY RULES USED IN OUR WORK

If	Width of Overlapping Area	Timer value	UE_velocity	Then	Probability of dropped calls	Probability of Ping_pong HO
	Small	Low	Low		Low	High
	Small	Low	Medium		Low	High
	Small	Low	High		Medium	High
	Small	Medium	Low		Low	Low
	Small	Medium	Medium		Low	Medium
	Small	Medium	High		Medium	Medium
	Small	High	Low		Low	Low
	Small	High	Medium		Low	Medium
	Small	High	High		High	High
	Medium	Low	Low		Low	Low
	Medium	Low	Medium		Low	Low
	Medium	Low	High		Low	Low
	Medium	Medium	Low		Low	Low
	Medium	Medium	Medium		Low	Low
	Medium	Medium	High		Medium	Medium
	Medium	High	Low		Low	Medium
	Medium	High	Medium		Low	Low
	Medium	High	High		High	Medium
	Big	Low	Low		Low	Low
	Big	Low	Medium		Low	Low
	Big	Low	High		Medium	Low
	Big	Medium	Low		Low	Low
	Big	Medium	Medium		Low	Low
	Big	Medium	High		Medium	Medium
	Big	High	Low		Low	Low
	Big	High	Medium		Medium	Low
	Big	High	High		High	Medium

VII. RESULTS AND DISCUSSION

After the membership functions are determined and entered in Matlab Fuzzy Toolbox Membership Function Editor, the rules are selected and written using Matlab rules editor for simulation and evaluation. In the simulation, different parameters are chosen according to the 3GPP specifications and recommendations. Moreover, different velocities are selected to study the effect of overlapping area on the timer value for different user speeds.

The effects of the inputs functions on the output (probability of ping-pong HO) were analyzed individually and results are shown in figures 10 and 11, respectively (using Matlab Fuzzy Toolbox). Fig. 10 shows that the probability of ping-pong HO was efficiently reduced at high timer values i.e. more than 1 sec. Similarly, Fig. 11 illustrates that a timer value higher than 1.5 seconds

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decreases the probability of dropped calls rate to the lowest levels.

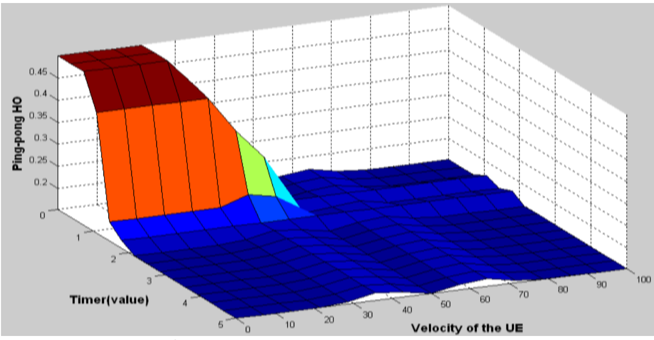

Fig. 10. Surface analysis between time value and UE velocity

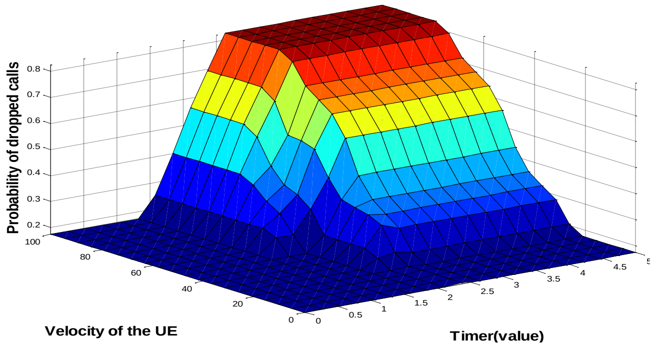

Fig. 11. Surface analysis for dropped calls rate between time value and velocity of the UE

These results were also confirmed when the combined effect of the two inputs (SS(target-source) of and timer value) on the output (probability of ping-pong HO)) were further analyzed as shown in Fig. 12. The ping-pong HO can be avoided if the SS(target-source) and timer value are higher than 3 dB and 1 sec respectively. Results also indicate that the ping-pong avoidance algorithm could significantly minimize the probability of ping-pong HO to the lowest standard. In one case where SS(target-source) is weak and the timer value is low, the probability of ping-pong HO is reduced to the medium level of 0.6 by using our algorithm.

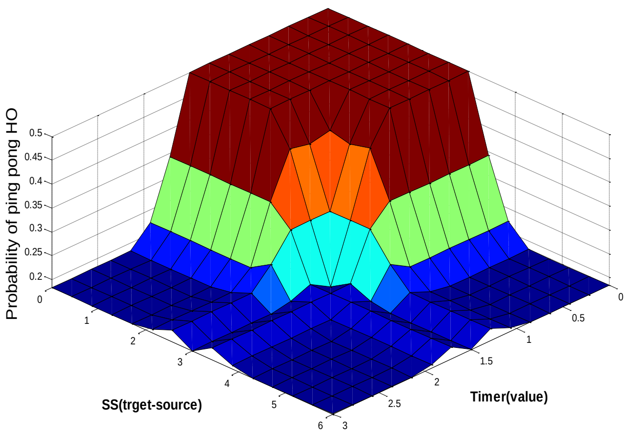

Fig. 12. Surface analysis between time value and SS(target-source).

The dropped calls rate can be reduced if the SS(target-source) and timer value are less than 4 dB and 2 sec respectively, as it can be seen from Fig. 13.

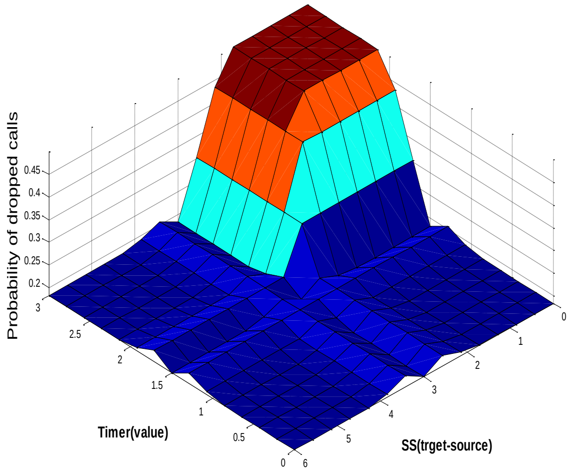

Fig. 13. Surface analysis between time value and SS(target-source).

VIII. THE EFFECTS OF OVERLAPPING AREA ON THE PROBABILITY OF DROPPED CALLS AND PING-PONG HO

Figures (14-18) show the effects of overlapping area on the probability of dropped calls and ping-pong HO. Results illustrate that the Timer values should not exceed 1.5 sec to keep the probability of dropped calls at lowest rates and reduce the ping-pong HO at the same time. For high speed user velocities the timer value should kept less than 1 sec to keep the dropped calls rates very low as it can be seen in Fig. 18.

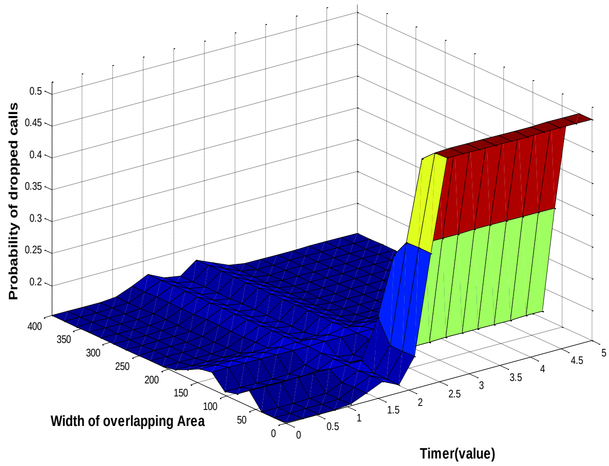

Fig. 14. Surface analysis for dropped calls rate between time value and the width of overlapping area for low velocity (25 km/h)

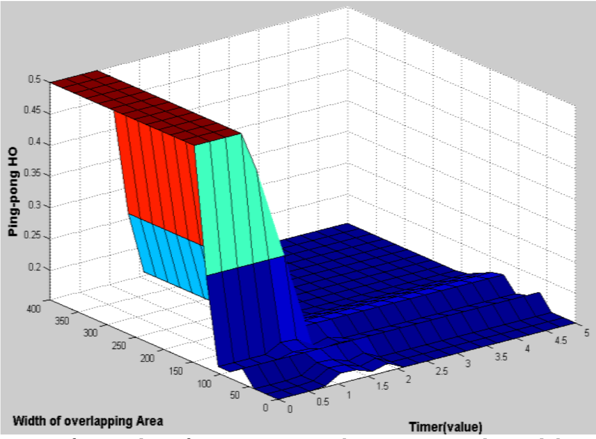

Fig. 15. Surface analysis for ping-pong HO between time value and the width of overlapping area for low velocity (25 km/h)

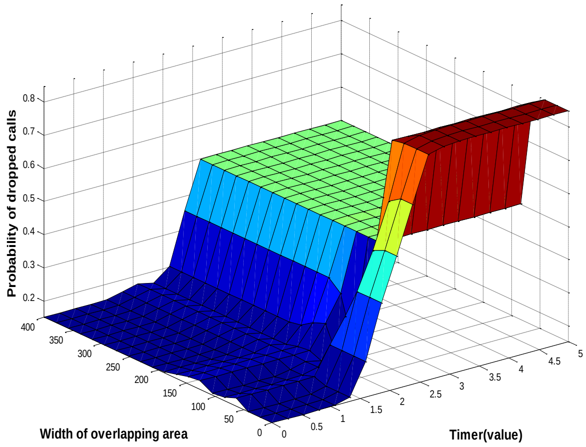

Fig. 16. Surface analysis for dropped calls rate between time value and the width of overlapping area for medium velocity (50 km/h)

Moreover, results can be sufficient for slow and medium mobility users up to 50 kmph. However, in fast mobility user, the situation can be more complicated and timer value requires to be adaptive upon user speed and the width of overlapping area, in order to avoid call dropping rates and reduce the ping-pong HO rates. The optimal avoidance of ping-pong HO in real environment needs an accurate trade-off between SS(target-source), timer value, width of overlapping area and the velocity of the mobile user.

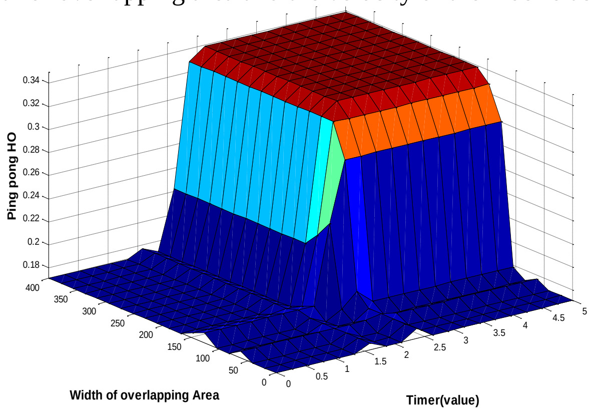

Fig. 17. Surface analysis for ping-pong HO between time value and the width of overlapping area for medium velocity (50 km/h)

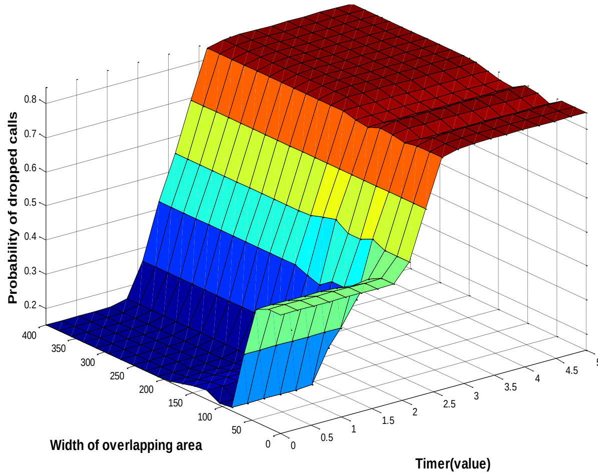

Fig. 18. Surface analysis for dropped calls rate between time value and the width of overlapping area for high velocity (100 km/h)

IX. CONCLUSIONS

In this paper, the effects of overlapping area on the ping-pong HO in intra E-UTRA were studied. A novel ping-pong avoidance approach – based on adaptive timer value- to reduce the ping-pong HO in E-UTRA was presented. The presented scheme uses only timer value to delay the completion part only of the HO procedure as a trial to reduce the ping-pong HO rates and at the same time keep the probability of dropped calls at a low rate. The performance evaluation of the suggested algorithm was obtained using fuzzy logic technique. Results showed that the width of overlapping area play significant role in selecting the optimal timer value to reduce the ping-pong HO rates. For high speed velocity the timer value should be kept less than 1 sec to prevent the probability of dropped calls and avoid the undesirable effects of ping-pong HO. Further work will consider the effects of overlapping area in LTE advanced and heterogeneous networks.

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