REDUCING THE EFFECTS OF PING-PONG HANDOVER IN INTRA-LTE NETWORKS USING FUZZY LOGIC

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Abstract

Improving system performance in terms of data rate, latency, mobility and cost is the scope of Long Term Evolution (LTE) system. All IP architecture with distributed mobility management that have been implemented in LTE and the handover (HO) decision is performed by the evolved base station (eNB). The ping-pong movement in LTE is one of the most crucial problems which reduce the performance of the HO. In this paper, the impact of ping-pong handover on inter eNB handover in LTE networks is investigated. The object of the present work is to provide a method for reducing the number of ping-pong HOs in intra E-UTRA networks. A novel HO algorithm, based on keeping the old path between the source eNB and SGW/MME during the ping-pong movement and delaying the completion HO part, is presented. The ping-pong avoidance algorithm for intra E-UTRA can be a tool to reduce the number of ping-pong HOs and control the demands of the network resources. Analysis results -based on fuzzy logic technique- of the proposed algorithm showed that the probability of ping-pong HO can be reduced efficiently as the difference between the received signal strength from the target and the source (SS(target-source)) and the timer value are higher than 3dB and 1.5 sec respectively.

Keywords:
Ping-Pong avoidance, Handover, Mobility Management, Fuzzy logic, Dropped calls

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1. INTRODUCTION*:*

Long Term Evolution (LTE) is under developing to meet the increasing users' requirements and at the same time decrease the operating costs. It is under consideration to develop a new radio interface and radio network architecture that provide a high data rate, low latency, packet optimization, and improved system capacity, coverage and mobility. For an LTE system, an Orthogonal Frequency Division Multiple Access (OFDMA) and a Single Carrier Frequency Division Multiple Access (SC-FDMA) are used in downlink and uplink transmissions, respectively. Many aspects in the LTE system have been changed such as architecture, mobility and related operations comparing to that in 3G mobile networks. Changes on the radio part are performed on the eNB which involve a new radio interface based on OFDM technology and a completely different Radio Access Networks (RAN) architecture, where radio functionality is distributed into eNBs. All radio control functions such as radio resource managements and admission control are implemented in the eNB. The Evolved Universal Terrestrial Radio Access Network (E-UTRAN) consists of eNBs which provide the E-UTRA user plane and control plane protocol terminations towards the User Equipment(UE). The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by S1 interface to the Mobility Management Entity /Serving Gateway (MME/SGW). On the other hand, the changes on the core network side are mainly driven by the evolution toward having all services based on IP and the convergence of multiple access technologies under the same core network [1-3].

The handover (HO) process is being one of the most significant functionality of a mobile system, and it needs to be designed according to the distributed nature of the LTE architecture. E-UTRA mobility is the most fundamental, vital, and frequent scenario in LTE. E-UTRA should support good mobility even when the radio environment changes suddenly, e.g., when the UE enters a tunnel or in a picocell scenario. The operator should provide a special mechanism to cope with such sudden changes in the radio environment such as ping-pong and minimize its side effects.

The ping-pong HO is a very common phenomenon in the mobile networks, which can cause inefficiency, call dropping and degrading of the network performance. Coverage parameters, user location area and its movement and speed are the main considerations that can cause the ping pong. The ping-pong HO in LTE means two subsequent HOs between the source and the target eNB and vice versa. The ping-pong effect occurs due to the frequent movement of UE between the source and the target eNB, or high signal fluctuation at the common boundary of the eNBs.

Since the ping-pong HO disperses the resources between releasing and reserving, and as a result decreasing the QoS, it is essential for network operators to reduce this undesirable effect. However, the current technology does not offer a systematic and objective solution for the operators to perform a separate ping-pong HO from the general HO procedure.

The ping-pong HO has been defined as an open issue in LTE; therefore, a significant need for a mechanism that improves the HO performance during the ping-pong type of movement is required. Different research approaches tried to reduce the Ping-Pong effects in current mobile networks such as GSM and CDMA [4-8]. Limited information is available about the ping-pong HO in LTE networks [9-11]. These approaches vary from statistical analysis [12, 13] up to handover preparation based on cross-layer optimization [14,15] and complex pattern detection algorithms [16]. However, the previous mobility techniques do not distinguish between the normal movement and the ping-pong type of movement. In this work we will present a simple technique which can select whether the movement is ping-pong or it is general one via setting a timer as a first step. In the next step, the proposed algorithm suggests to delay the completion part of the HO procedure and keep the old path between the source eNB and MME/SGW for a short time – for the ping-pong type of movement-. The ping-pong HOs in LTE networks have not been addressed as a main issue in the current research so far and more research can be done to reduce the unwanted effects of the ping-pong HO and control the demand of the network resources and tackle the phenomenon. In this work we will concentrate on the effects of ping-pong on E-UTRA HO and will implement a new algorithm that can decrease these effects. Inter LTE ping-pong HO is not considered in this work but it will be main part of our future work.

A novel handover algorithm, based on keeping the old path between the source eNB and SGW/MME during the ping-pong movement and delaying the completion handover part will be presented. The proposed algorithm detects the ping-pong type of movement and selects whether the movement belongs to the general or the ping-pong type of movement. Simulation model of the proposed algorithm will be made using Matlab Fuzzy Toolbox. Also, the rate of ping-pong handover and the handover quality indicator will be considered as a pointer to check the general performance of the algorithm. This work supposed that the velocity of the User Equipment (UE) is under 70 KM/Hour- Low and Medium mobility- high user speeds will be investigated in our future work.

An overview about intra E-UTRA HO procedure according to the recent status of the specification work in 3GPP is illustrated in section 2. Section 3 explains the proposed scheme that detects the ping-pong type of movement and presents a novel HO algorithm based on keeping the old path during the ping-pong period to avoid the ping-pong HO. The analysis of the proposed algorithm using the fuzzy logic is described in section 4. Finally, conclusions and future work are presented in section 5.

2. LTE INTRA-EUTRA HANDOVER PROCEDURE

In LTE, the eNB is responsible for the accomplishment of the HO decisions without connecting the MME. The required HO information is exchanged between the eNBs via the X2 interface. The HO procedure is divided into two main steps mainly HO preparation and execution and HO completion. Figure 2 shows the intra-EUTRA HO steps with a summary of the HO procedure described in sections 2.1 and 2.2.

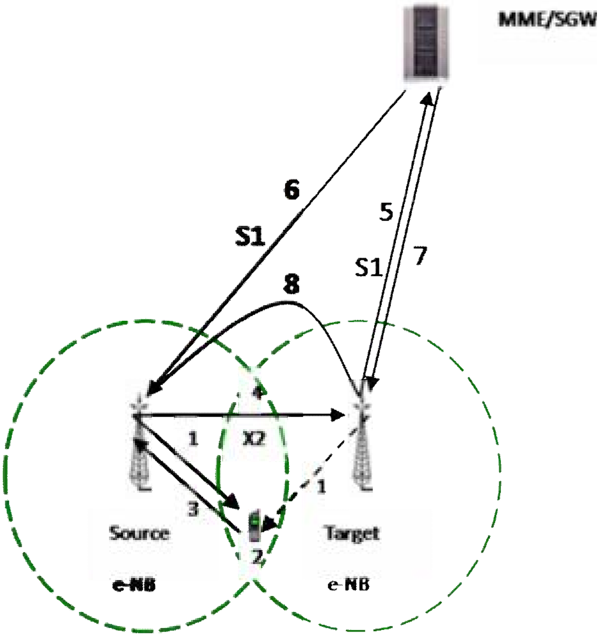

Figure 1: Summary of the different steps of preparation, execution and completion HO process which performs by eNBs. 1) Downlink HO measurements, 2) processing of downlink measurements, 3) uplink reporting, 4) HO preparation and execution via x2 interface, 5) path switch request, 6) release the old path,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

2.1 Handover preparation and execution

When the UE approaches the cell boundary it sends a measurement report to the source eNB, which decides to hand off the UE based on the measurement report and Radio Resource Management (RRM) information. The source eNB issues a HO request message to the target eNB passing necessary information to prepare the HO at the target side. The target eNB performs admission control to increase the possibility of a successful HO and to check if the resources can be approved. Then, the target eNB prepares HO with L1/L2 and sends the HO request acknowledgment to the source eNB. The source eNB generates the HO command (RRC message) with the necessary parameters towards the UE.

After receiving the HO command, UE performs synchronisation with target eNB and accesses the target cell via Random Access Channel (RACH) [7]. After UE accession, it sends the HO confirm message (Cell Radio Network Temporary Identifier (C-RNTI)) to the target eNB to indicate that the HO procedure is completed for the UE [9]. The target eNB verifies the C-RNTI sent in the HO confirm message. It has to be mentioned that all the received packets in the source eNB from the SGW should be forwarded to the target eNB which in turn begins sending them to the UE. By the end of this stage the HO preparation and execution are performed as shown in figure 2[1, 2].

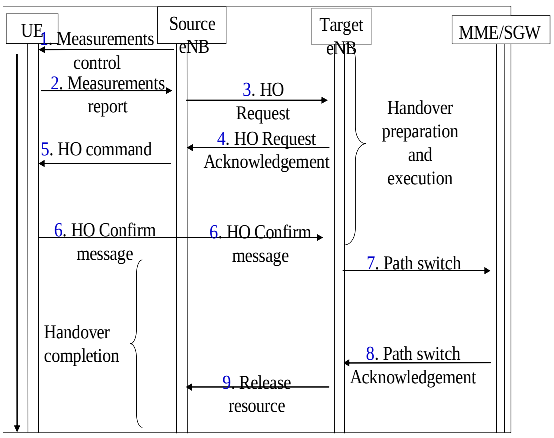

Fig. 2 Intra E-UTRA handover procedure

2.2 Handover completion

The rest of the HO procedure is to inform the MME via the S1 interface about the new changes in the wireless link. This will enable the MME to forward the packets to the target eNB and send a release resource message to the eNB. After receiving a HO confirm message from the UE, the target eNB sends a path switch message to MME to inform that the UE has changed its cell, then the MME sends a user plane update request message to the SGW. The SGW switches the downlink data path to the target eNB and sends end marker packets on the old path (MME/SGW-source eNB) to the source eNB and then it can release any U-plane resources towards the source eNB. SGW sends a user plane update response message to MME which confirms the path switch message with the path switch acknowledgement message. The target eNB sends release resource message to source eNB which then can release radio and C-plane related resources associated to the UE context. By the end of this step the HO is totally completed and the target eNB can start sending the packets received on the new direct (MME/SGW-target eNB). However, the target eNB should first deliver all forwarded packets to the UE from X2 interface before delivering any packets from S1 interface (MME/SGW-target eNB).

3. PING-PONG AVOIDANCE ALGORITHM FOR INTRA E-UTRAN ANDOVER

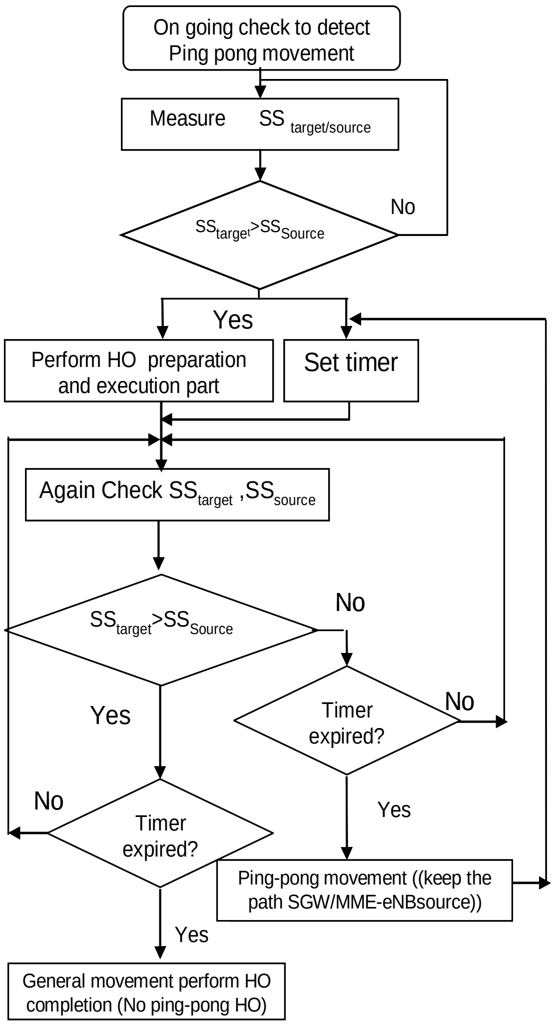

Fig. 3 proposed procedure for ping-pong avoidance in E-UTRA networks

In the proposed algorithm explained in Fig. 3, a timer is used as a guide to select whether the ongoing HO belongs to the general or the ping-pong type of movement as below.

If the received Signal Strength (SS) form the target eNB (SS-target) is stronger than that received from the source (SS-source), then the HO preparation and execution part may be performed by both the source and the target eNBs. At the same time the timer can be set. On the other hand, if the difference between the SS-target and SS-source always shows that the SS-target is sufficiently strong than the SS-source, and the timer is expired then the movement is general (no ping-pong movement). The operator in this case can immediately release the resources along the old path (MME/SGW-source eNB) and finish the completion HO part. However, if the difference between the SS-target and SS-source does not show that the SS-target is sufficiently stronger than the SS-source, then there is a ping-pong type of movement. Here, the operator can keep the old path (MME/SGW-source eNB) during the ping-pong duration and only the completion part of the HO procedure can be delayed to avoid the swinging between releasing and initiating of the paths between the MME/SGW and eNBs (Fig. 3).

4. THE ANALYSIS OF THE PROPOSED ALGORITHM

In our proposed algorithm the decision of HO completion is taken according to the difference between the received signal strength form the target eNB and the received signal strength from the source eNB SS(target-source) and the timer value.

4.1 Ping-pong Avoidance Algorithm Based on Fuzzy Logic

Fuzzy logic technique was previously used to study HO initiation and decision [17-20] but not to study HO completion or the 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 analysing 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.

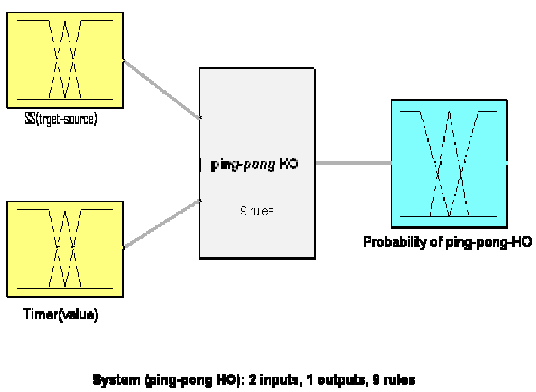

Fig. 4 Fuzzy logic system for Ping-pong Avoidance Algorithm (Matlab)

4.2 Memberships of Input Parameters

The input variables for the proposed algorithm are SS(target-source) and the timer value, where SS(target-source) refers to the difference between the received signal strength form eNB_target and the received signal strength from eNB_source (figure 4).

The first input of the proposed algorithm is the SS(target-source. SS(target-source) is assigned the linguistic values Strong, Medium, and Weak which are represented below by membership functions $A_1(x)$, $A_2(x)$ and $A_3(x)$, respectively, over the range [0,6] dB.

$$A_1(x) = \begin{Bmatrix} 0 & if & x<3 \\ x-3 & if & 3\geq x\geq 4 \\ 1 & if & x>4 \end{Bmatrix},$$

$$A_2(x) = \begin{Bmatrix} 0 & if & x<2 \\ x-2 & if & 2\geq x\geq 3 \\ 4-x & if & 3\geq x\geq 4 \\ 0 & if & x>4 \end{Bmatrix},$$

$$A_3(x) = \begin{Bmatrix} 1 & if & x<2 \\ 3-x & if & 2\geq x\geq 3 \\ 0 & if & x>3 \end{Bmatrix}$$

The degree of membership function for SS(target-source) is shown in figure 5.

The second input of the proposed algorithm is the timer value. The timer value is assigned the linguistic values as High, Medium, and Low which are represented below by membership functions $A`_1(t)$, $A`_2(t)$and $A`_3(t)$, respectively, over the interval [0-3] sec.

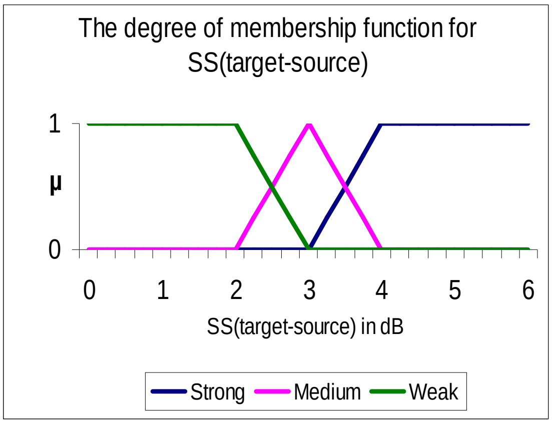

Fig. 5 The degree of membership for SS(target-source).

$$A'_1(t) = \begin{Bmatrix} 0 & if & t<1 \\ t-1 & if & 1\geq t\geq 1.5 \\ 1 & if & t>1.5 \end{Bmatrix},$$

$$A'_2(t) = \begin{Bmatrix} 0 & if & t<0.5 \\ t-0.5 & if & 0.5\geq t\geq 1.5 \\ 1.5-t & if & 1\geq t\geq 1.5 \\ 0 & if & t>1.5 \end{Bmatrix},$$

$$A'_3(t) = \begin{Bmatrix} 1 & if & t<0.5 \\ 1-t & if & 0.5\geq t\geq 1 \\ 0 & if & t>1 \end{Bmatrix}$$

The degree of membership function for timer value is shown in figure 6.

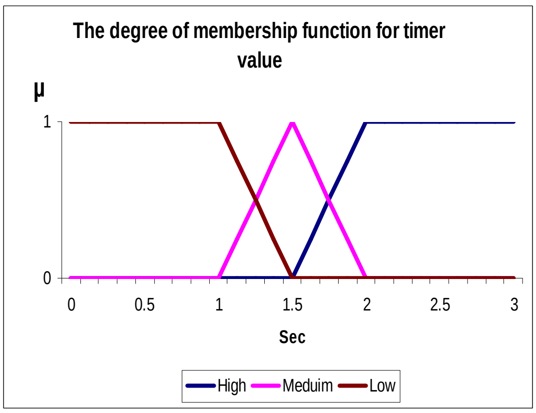

Fig. 6 The degree of membership for timer value.

4.3 Fuzzy inference

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 fuzzy rules used are presented below in table 1:

	SS(trget-source) (Fig 5)	Timer value (Fig 6)		Ping_pong_HO
If	Weak	Low	Then	High
	Weak	Medium		Medium
	Weak	High		Low
	Medium	Low		Low
	Medium	Medium		Low
	Medium	High		Low
	Strong	Low		Low
	Strong	Medium		Null
	Strong	High		Null

Table 1 Fuzzy rules used in our work

4.4 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 rule editor for simulation and evaluation. In the simulation the difference between the received signal strength form the target eNB and the received signal strength from the source eNB SS(target-source) is chosen to be in the range [0-6] dB (3GPP specifications and recommendations), and the timer value is selected to be in the interval [0-3] seconds.

The velocity of the UE in this simulation is decided to be 20 kmph. Higher speed movements are not considered in this study.

The effects of the two inputs (SS(target-source) and timer value) on the output (probability of ping-pong HO) were analysed individually and results are shown in figures 7 and 8, respectively (using our proposed algorithm and the Matlab Fuzzy Toolbox). Fig. 7 shows that the probability of ping-pong HO was efficiently reduced at high SS(target-source) values, i.e. more than 3 dB. Similarly, Fig. 8 illustrates that a timer value higher than 1.5 seconds decreases the probability of ping-pong HO to the lowest levels.

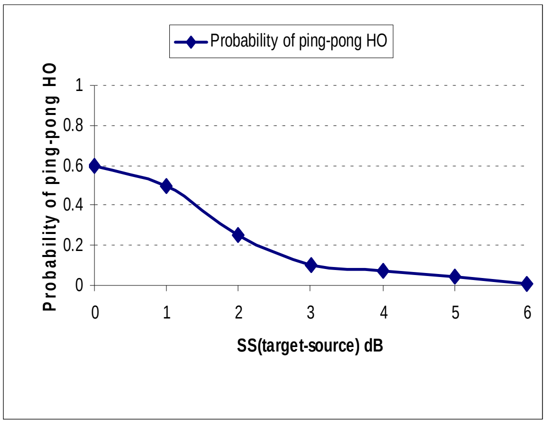

Fig. 7 Handover decision using ping-pong HO avoidance reduces the number of ping-pong HO

These results were also confirmed when the combined effect of the two inputs (SS(target-source) and timer value) on the output (probability of ping-pong HO) was further analysed as shown in Fig. 9.

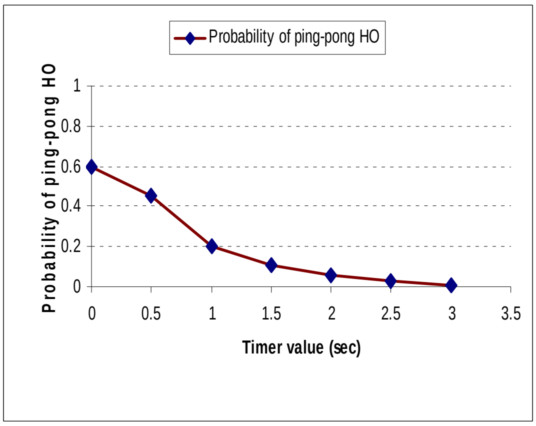

Fig. 8 Timer with high value i.e. more than 1.5 seconds the presented algorithm decreases the probability of ping-pong HO efficiently.

The ping-pong HO can be avoided if the SS(target-source) and timer value are higher than 3 dB and 1.5 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.

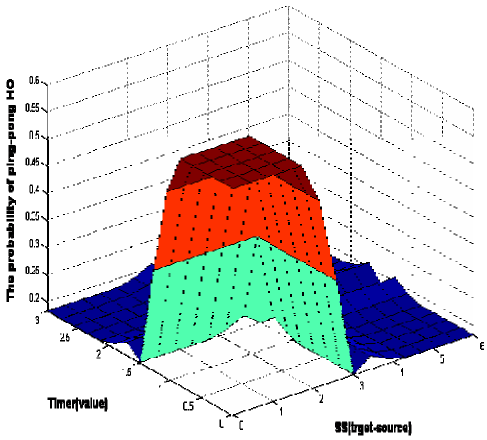

Fig. 9 Surface analysis between time value and SS(target-source).

As it appears from the figure 8, the probability of ping-pong HO is less than 0.05 for the timer value T=3 seconds. For timer value T=2 sec the probability ping-pong HO reached a good level approximately (3 %), also there is a reduction of the probability of ping-pong HO from 0.43 to 0.21 (approximately 50%) when the timer value is increased from 0.5 sec to 1 sec.

In comparison with the results obtained in [26.27], our obtained results show that the probability of the ping-pong HO in our simulation gave better results for medium and low UE velocity. Moreover, the percentage of Ping-Pong effect for the timer value 1 and 1.5 sec are within the good range and they show significant reduction in comparison with that in previous research. Moreover, our algorithm gives better results comparing to that in [28], the improvement can reach 9% reduction in the probability of ping-pong HO for low and medium mobility (less than 70 kmph).

As mentioned before, these results can be sufficient for slow and medium mobility users up to 70 kmph. However, in fast mobility user the situation can be more complicated and SS(target-source) and timer value require to be adaptive upon user speed to avoid call dropping rates. The optimal avoidance of ping-pong HO in real environment requires an accurate trade-off between SS(target-source), timer value and the velocity of the mobile user.

5. CONCLUSIONS

In this paper, the HO preparation and execution and the HO completion in E-UTRA were studied. A novel ping-pong avoidance approach to reduce the ping-pong HO in E-UTRA was presented. The presented scheme distinguished between the general and the ping-pong type of movement. In the ping-pong type of movement, only the completion part of the HO procedure can be delayed to avoid the swinging between releasing and initiating the paths between the MME/SGW and eNBs. The performance evaluation of the algorithm was obtained using fuzzy logic technique. It showed that keeping the old path in the case of ping-pong movement can reduce the probability of ping-pong HO and its undesirable effects. SS(target-source) and the timer value are used to perform the completion part of the HO procedure. Analysis results showed that the probability of ping-pong HO decreases when the SS(target-source) and timer values are higher than 3dB and 1.5 sec respectively. Therefore, this algorithm can be considered as a tool to reduce the number of unnecessary ping-pong HOs for future applications at low and medium speed movement (<70 kmph). Further work will take into account high speed movement of the UE and study the packet loss rate during ping-pong type of movement using TRIAS tool supported with NS2 simulator.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA); Overall description", June 2010.

[2] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures", Dec 2010.

[3] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA);

Physical layer; Measurements", March 2010.

[4] LARS K. RASMUSSEN, "On Ping-Pong Effects in Linear Interference Cancellation for CDMA," in Proc. IEEE 6th ISSTA (New Jersey, USA), Sept. 2000.

[5] LANDOLSI, T. and ABU-AMARA, M. "CDMA Access Channel Performance under Idle-Mode Ping-Pong Effect in Inter-MSC Handoffs," Proceedings of the IEEE International Symposium on Wireless Communication Systems, Spain, September 2006.

[6] SHUPENG, L. FANG-CHEN; C. YIFEI; TECK H., "Adaptive Frame Switching for UMTS UL-EDCH - Ping-Pong Avoidance. VTC spring 2006" 2469-2473

[7] HUAMIN, Z.; and KWAK. S, An Adaptive Hard Handoff Algorithm for Mobile Cellular Communication Systems, ETRI Journal, vol. 28, no. 5, pp. 676-679, Oct. 2006

[8] BENVENUTO, N.; SANTUCCI, F."A generalized least squares handover algorithm for wireless systems," IEEE VTC2002-Fall, pp. 1570-1574, Sept. 2002

[9] HRÖDER, A. H. UNDQVIST, and G. NUNZI. "Distributed Self-Optimization of Handover for the Long Term Evolution," IWSOS 2008, LNCS 5343, pp.281-286, 2008.

[10] ANASM, F.; CALABRESE, P.; OSTLING K.; PEDERSEN, P., Mogensen."Performance Analysis of Handover Measurements and Layer 3Filtering for UTRAN LTE," PIMRC2007

[11] HYONG, T.; YANG, Q.; JAE-HYOUNG, L.; Soon-Gi P.; Yeon-Seung S.,"A Mobility Management Technique with simple Handover Prediction for 3G LTE Systems" Vehicular Technology Conference,2007.VTC-2007 IEEE 66th,2007,pp 259-263.

[12] ROY,A.;DAS,S.K; ISRA,A, "Exploiting Information Theory for Adaptive Mobility and Resource Management in Future Cellular Networks,"IEEE Wireless Communications,2004 , pp.59-65.

[13] CHENG, C.; JAIN,R.; BERG, E.v.d.:"Location prediction for Mobile Wireless Systems",in Furht,B.(Hrsg.). Wireless Internet Handbook,CRC Press,Boca Raton ,2003 , pp.245-264.

[14] MCNAIR, J.et al., "A survey of cross-layer performance enhancements for Mobile IP networks", Computer Networks, Volume 49, Issue 2, lsevier,2005,pp.119–146.

[15] JUNG,J et al., "Mobility Prediction Handover Using User Mobility Patternand Guard Channel Assignment Scheme", LNCS, Vol.3264, 2004.

[16] POON, W.T.; CHAN, E." Traffic Management in Wireless ATM Network Using a Hierarchical Neural-Network Based Prediction Algorithm," Proceedings of the International Conference on Computers and their Applications, ICSA ,2000

[17] MANOREET D., et al., "Fuzzy Logic Based Handoff in Wireless Networks," Proceedings of IEEE VTC 2000 Spring Tokyo, Japan.

[18] CHAN, et. al. "Mobility Management Incorporating Fuzzy Logic for a Heterogeneous IP Environment," IEEE Communication Magazine, Dec. 2001.

[19] CHAN P. M. L., R. E. Sheriff, Y. F. Hu, P. Conforto, C. Tocci, "Mobility Management Incorporating Fuzzy Logic for a Heterogeneous IP Environment," IEEE Communications Magazine, Dec. 2001. pp. 42-51

[20] DANG, M.S. et al., "Fuzzy Logic Based Handoff in Wireless Networks," Proc. VTC 2000 Spring, Tokyo, Japan, 15–18 May 2000, pp. 2375–79.

[21] ZADELI, L., "Fuzzy Logic" IEEE J. Computer, Apr. 1988, pp. 83 - 93.

[22] SUGENO, M. and Yasukawa, T, "A Fuzzy-Based Approach to Qualitative Modeling," IEEE Transactions on Fuzzy Systems, Vol. 1, No. 1, Feb. 1993, pp. 7 - 3 1.

[23] BRUBAKER, D., "Fuzzy-logic system solves control problem," EDN Magazine, June 1992, pp. 121 - 127.

[24] WANG, L., “Adaptive Fuzzy Systems and Control,” Prentice Hall, Inglewood Cliffs, New Jersey 1991.
[25] ROSS, T. J.; (1995); Fuzzy Logic with Engineering Applications; McGraww-Hill Inc; New York.
[26] YANG, Y."Optimization of Handover Algorithm in 3GPP LTE" Master thesis, Stockholm, Sweden, 2009.
[27] CHENG-CHUNG L., KUMBESAN S., HUDA A., MOHD R., and RIYAJ B., “Optimised Performance Evaluation Of LTE Hard Handover Algorithm With Average RSRP Constraint” International Journal of Wireless & Mobile Networks (IJWMN) Vol. 3, No. 2, April 2012.

[28] THOMAS, J._, IRINA B., JOHN T., INGRID M., THOMAS K. _ ‘’Handover parameter optimization in LTE self-organizing networks’’; COST 2100, 10thMCM Athens, Greece VTC Fall 2011.

8. GLOSSARY:

Long Term Evolution (LTE)
Orthogonal Frequency Division multiple Access (OFDMA)
Single Carrier Frequency Division Multiple Access (SC-FDMA)
Evolved Universal Terrestrial Radio Access Network (E-UTRAN)
Radio Network Controller (RNA)
Handover (HO)
Evolved Node-B (e-NB)
Mobility Management Entity (MME)
Quality of Service (QoS)
User Equipment (UE)·

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