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SOLVING LTE HANDOVER PROBLEM USING A NEW FUZZY LOGIC OPTIMIZATION TECHNIQUE

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ABSTRACT

In cellular networks, the contradiction between traffic demands and network resources is very prominent, also mobile users can move inside the heterogeneous networks from cell to another cell. Aiming at solving these issues, efficient handover (HO) mechanisms are more and more concerned to enhance mobility management. In this paper a new handover optimization algorithm for long term evaluation (LTE) network based on fuzzy logic is presented, named Fuzzy Logic for LTE Handover (FLLH). It consists of finding the optimum handover margin (HOM) required for handover process and also finding appropriate time to trigger (TTT) to perform a success handover using fuzzy logic. FLLH handover optimization technique is evaluated and compared with the four well-known handover algorithms. The proposed handover optimization technique achieves minimum average number of handover per user and also have maximum throughput than the self-optimization technique.

INTRODUCTION

Nowadays, the world is heading to use high rates multimedia applications. High-speed data over cellular networks will enable a rich suite of multimedia services. LTE is the latest mobile generation that achieves the required data demand. The number of LTE subscribers worldwide is rising rapidly. LTE is provide a smooth transition towards Fourth Generation (4G) network (Dahlman, 2007). It is proposed to increase the coverage, capacity, and speed by comparing with the earlier wireless systems (Divya, 2009). Resource Block (RB) is the smallest unit for the transmission in the downlink LTE system, which contains 12 sub-carriers of 1 ms duration (Homla, 2009). Hard handover is the main type of handover in LTE. The main characteristic of the hard handover is that it has less intricacy of the LTE network architecture. However, the hard handover may have inefficient LTE performance (i.e. increasing number of handovers, decreasing throughput of the system, and maximizing system delay). Therefore, an efficient handover algorithm that can optimize the system by minimizing the number of handovers and system delay as well as maximizing the throughput of the system is required. Therefore it is important to determine optimized parameters to ensure efficiency and reliability of a handover algorithm. A new handover optimization technique based on the fuzzy logic controller to decrease the number of handovers, minimize the total delay of the system and maximize the total system throughput is proposed in this paper. This proposed algorithm is evaluated using fuzzy logic and compared with the four well known handover algorithms using optimized handover parameters under three different speeds (10, 60, 120 km/hr) scenarios. The paper is covering the following: Section II reviews on the related handover studies. Section III gives detailed descriptions of the standard well-known handover algorithms. Performance metrics which used are given in section IV. Section V investigate the proposed algorithm for LTE handover in details. Simulation results and comparison are given in section VI. Finally, the whole work is concluded in section VII.

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Related Work

There were many attempts to solve the HO problems even by self-optimization or by using fuzzy logic controller (FLC) (Shiwen, 2015 – Cheng, 2011). In (Shiwen, 2015), an enhanced self-optimization algorithm for handover among macro and femto applications on Long Term Evolution Advanced (LTE-A) networks is proposed. But it was deals with LTE-A network as an LTE network by consider that handover failure is simulated when user equipment's (UEs) are in different speeds. Also did not study the effect of the proposed algorithm on the system throughput or the system delay problems. While in (Sandrasefaran, 2014), authors propose a self-optimized downlink power allocation algorithm

to efficiently use the transmission power while minimizing the interference to other users, which utilizes the concepts of game theory and Fuzzy Logic Inference (FIS) system. The proposed algorithm is suitable for the at system architecture in LTE system, and minimizes the required information exchange among Evolved Node B (eNBs) by the usage of fuzzy logic. In (Monil, 2013), introduced a fuzzy logic based handover algorithm to avoid Ping-Pong effects. Its FIS determines the best candidate base station (BS) based on the measurements of relative speed and direction, traffic load and signal strength.
While in (Feng, 2013), a less-complexity fuzzy logic based on vertical handover decision algorithm was introduced to reduce the decision time. This algorithm was presented to minimize the fuzzy logic rules. In (Ghanem, 2012) presented a handover algorithm which keeps the old path between the serving eNB and Mobility Management Entity (MME)/Serving Gateway (SGW) during the Ping-Pong effect, and delays the handover procedure. In this algorithm, a timer was utilized to help the decision of whether the ongoing handover is a normal one or a ping-pong effect. When the signal strength difference between the target eNB and the serving eNB exceeds a certain margin, then a timer starts to work. Ping-pong problem was targeted in (Kun, 2016). FLC was used to decrease the unnecessary handover rate by using Gaussian and triangular membership functions. But did not study the effect of the proposed algorithm on the throughput and delay of system. Finally, the only paper that evaluate and optimize the performance of the well-known handover algorithms is (Cheng, 2011) but without any optimization technique, it is just self-optimization process to study the three performance metrics (average number of handover, system throughput, and system delay).

Lte Standard Algorithms

The handover process in LTE is a hard handover connection. When the mobile station (MS) moves from one BS to another BS, it becomes impossible for it to connect with both BSs (since different frequencies are used) (Mohmaed, 2013). There are two types of handover procedure in LTE for UEs in active mode which are S1-handover procedure and X2-handover procedure. The X2 handover is used when direct connectivity between source and tar- get eNBs exists. While the S1-handover procedure is done between two eNBs without the X2 interface. The 4-well known handover algorithms for LTE network to carry out the handover from source cell to target cell, are discussed as follows:

Basic LTE Handover Algorithm

This algorithm is the basic algorithm which depending on two variables, HOM and TTT. HOM is the handover margin which is a constant variable that represents the threshold of the difference in received signal strength between the serving and the target cells. HOM ensures the target cell is the most suitable cell the mobile go through handover. A TTT is the time required for satisfying the HOM condition, also it's a way to decrease the unnecessary handovers which called ping-pong handovers (Jansen, 2010). When a mobile is going away from the serving cell, the Reference Signal Received Power (RSRP) which the mobile receives from the serving cell will decay as time increases. While, the mobile will move towards the target cell, therefore the target RSRP the mobile receives will increase as time increases. A handover is triggered when the conditions in equations 1 and 2 are both satisfied (3GPP, 2009).

$$RSRP_T > RSRP_S + HOM \tag{1}$$

$$HOTrigger \geq TTT \tag{2}$$

where $RSRP_T$ and $RSRP_S$ are the RSRP received from the target cell and the serving cell, respectively and *HOTrigger* is the handover trigger timer which starts counting when the first condition gets satisfied.

Received Signal Strength based TTT Window Algorithm

This algorithm is consisting of 3 steps. It collects required information during processing step, and then performs the comparison based on this information during decision step followed by the execution step from the next equation (Anas, 2007).

$$RSS_F(nT_m) = \beta RSS(nT_m) + (1-\beta) RSS((n-1)T_m) \tag{3}$$

Where RSS_F is the filtered received signal strength measured at every handover measurement period T_m where n and $(n-1)$ is the n^{th} and $(n-1)^{th}$ time instants, respectively. β is a proposed fractional number called "forgetting factor" which can be evaluated from equation 4:

$$\beta = \frac{T_u}{T_m} \tag{4}$$

where T_u is an integer multiple of T_m. A RSS comparison will be performed through the following equation 5:

$$RSS_F(nT)_T > RSS_F(nT)_S + HOM \tag{5}$$

where *HOM* is a constant threshold value, $RSSF(nT)_T$ and $RSSF(nT)_S$ are the filtered RSS of the target cell and the filtered RSS of the serving cell at $(nT)^{th}$ interval, respectively.
This algorithm tracks the RSS value from each eNB and stores the instantaneous RSS value. Filtered RSS value at each instant is calculated using historical data (previously filtered RSS) by applying the forgetting factor variable.

Integrator Handover Algorithm

This algorithm making the handover decision by consider the historical signal strength differences. The idea of historical data is the same as the second handover algorithm has. This algorithm consists of 3 parts, RSRP difference calculation, filtered RSRP difference computation, and handover decision. The RSRP difference calculation is presented as the following equation 6 (Jansen, 2010).

$$DIF_{s-j}(t) = RSRP_T(t) - RSRP_S(t) \tag{6}$$

where $RSRP_T$ and $RSRP_S$ represent the RSRP received from the target cell and serving cell at time t, respectively. $DIF_{s-j}(t)$ is the RSRP difference of the user j at serving cell s at time t. The filtered RSRP difference computation can be evaluated from the following equation 7:

$$FDIF_{s-j}(t) = (1-\alpha) FDIF_{s-j}(t-1) + \alpha DIF_{s-j}(t) \tag{7}$$

where α is a proposed variable with constraint $0 \leq \alpha \leq 1$. $FDIF_{s-j}(t)$ is the filtered RSRP difference value of user j at serving cell s at time t, and $DIF_{s-j}(t)$ is the RSRP difference value calculated in equation 7. A filtered RSRP difference value will depend on the proportion between current RSRP difference and historical filtered RSRP difference in previous time instant by changing α variable. Once the filtered difference has been computed, the handover decision will be made if the condition in equation 8 is satisfied:

$$FDIF_{s-j}(t) > FDIF_{Threshold} \quad (8)$$

where $FDIF_{Threshold}$ is a constant value equivalent to *HOM*. If the filtered RSRP difference between any of target cell and serving cell is greater than this threshold, the handover decision will be triggered immediately. The unnecessary handovers (ping-pong) may occurs due to absence of TTT mechanism involved in this algorithm.

LTE Hard Handover Algorithm with Average RSRP Constraint

This algorithm is proposed based on basic LTE handover algorithm with an extra of average RSRP condition for more efficient handover performance. The average RSRP can be evaluated from the equation 9 (Cheng, 2011).

$$RSRP_{avgs-j} = \frac{\sum_{n=1}^{N} RSRP(nT_m)}{N} \quad (9)$$

where $RSRP_{s-j}(nT_m)$ is the RSRP received by user j from serving cell s at n^{th} handover measurement period of T_m and N is the total number of periods of duration T_m. An average RSRP of cell s received by user j ($RSRP_{avgs-j}$) can be evaluated by a sum of each n^{th} handover measurement period T_m up to N divided by N times. An average RSRP condition can give by equation 10:

$$RSRP_T(t) > RSRP_{avgs-j} \quad (10)$$

where $RSRP_T(t)$ is the current RSRP received from target cell T and $RSRP_{avgs-j}$ is the average RSRP computed from previous equation. The handover decision will be made by the same conditions of equation 1 and 2.

The concept of this algorithm is to raise the possibility of handovers to minimize unnecessary handovers. The handover decision occurs if the current RSRP of serving cell lower than the RSRP of target cell with a certain margin, also if it is higher than the average RSRP received from the serving cell for the TTT interval. In this paper, the 4 well-known handover algorithms are applied and compared together by using fuzzy logic controller.

Performance Metrics

The system performance of the four well-known handover algorithms is evaluated on the basis of average HO per UE per second, total system throughput, and total system delay. The average HO per UE per second (HO_{avg}) represents the average number of handovers occurs during a simulation. It has the following expression:

$$HO_{avg} = \frac{HO_{Total}}{J \times T} \quad (11)$$

where HO_{Total} is the total number of successful handovers and J and T are the total number of users and total simulation time, respectively.

The second metric is the cell throughput is defined as the total number of bits correctly received which by all users per second. The cell throughput is measured at the eNB. It is mathematically expressed as:

$$cell\ throughput = \frac{1}{T}\sum_{j=1}^{J}\sum_{t=1}^{T} tput_j(t) \quad (12)$$

where $tput_j(t)$ is the total size of correctly received bits of user j at time interval t, T is the total simulation time and J is the total number of users. Then the total system throughput which is the sum of the system cells throughput, is calculated. The system delay is defined as average system queuing delay. The queuing delay is defined as the time duration from the queuing packet's arrival time at the eNB buffer to current time. It can be evaluated from equation 13:

$$cell\ delay = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{J}\sum_{j=1}^{J} W_j(t) \quad (13)$$

where J is the total number of users within the cell, T is the total simulation time, and $W_j(t)$ denotes the queuing delay of user j at time t. Also the total system delay which is the sum of the system cells delay, is calculated. The final metric is the *OptimizeRatio* value which is a ratio calculated by total system throughput over the average number of handovers. *OptimizeRatio* can be computed as following:

$$OptimizeRatio_{(HOA,\,Speed)} = \frac{ST_{(HOM,\,TTT)}}{ANOH_{(HOM,\,TTT)}} \quad (14)$$

where *HOA* indicates the handover algorithm, *Speed* is the corresponding speed in each scenario. *ST* and *ANOH* are the total system throughput and the average HO per UE per second, respectively. TTT will be replaced by α or β factor when the third handover algorithm or second handover algorithm is selected.

Proposed Technique

The concept of the fuzzy logic was invented by L. A. Zadeh in 1965 (Zadeh, 1965). This invention was not well recognized until E. H. Mamdani, applied the fuzzy logic in a practical application to control an automatic steam engine in 1974 (Mamdani, 1974), which is almost ten years after the fuzzy theory was invented. The general architecture of a fuzzy system is shown in Fig. 1 (Thanachai, 2013). It consists of five components: Fuzzifier converts crisp inputs into fuzzified data, Rule base contains if-then rules; which are required by the Fuzzy Inference System (FIS), Database defines membership functions of the fuzzy sets, FIS generates aggregated fuzzified data; based on fuzzy inference methods, and Defuzzifier converts the aggregated fuzzified data into a scalar value (score). The score is then used to make the final decision. In this paper, there are 2 inputs and 4 outputs used to complete the optimization process for the LTE handover problem. The 2 inputs are the average HO per user per second and the second input is the total system throughput. While the 4 outputs are the handover margin (HOM), time-to-trigger (TTT), beta (β), and alfa (α).

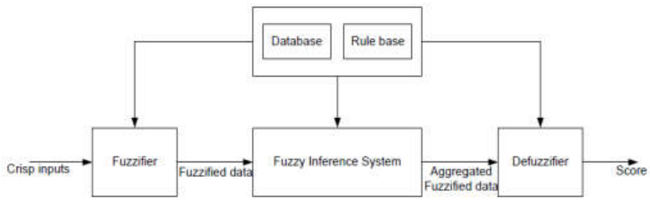

Fig. 1. Architecture of a Fuzzy System

In this paper, there are 2 inputs and 4 outputs used to complete the optimization process for the LTE handover problem. The 2 inputs are the average HO per user per second and the second input is the total system throughput. While the 4 outputs are the handover margin (HOM), time-to-trigger (TTT), beta (β), and alfa (α). The membership functions of the inputs and outputs are selected based on trial and error between many shapes (trapezoidal, triangle, and sigmoid). The proposed membership functions are shown in the following figures.

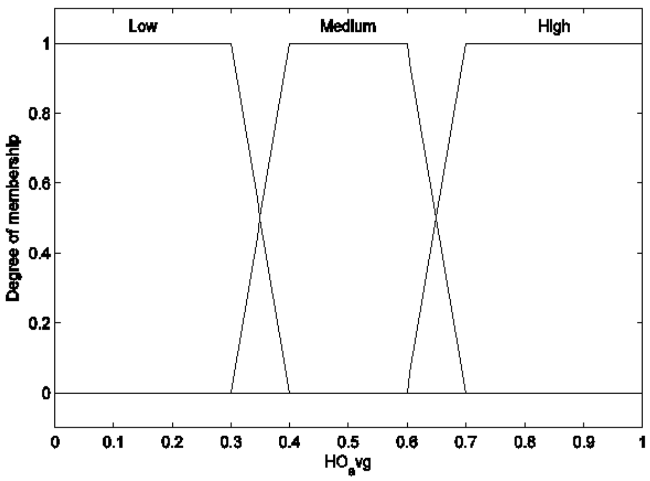

Fig. 2. Input (HO_{avg}) Membership Function

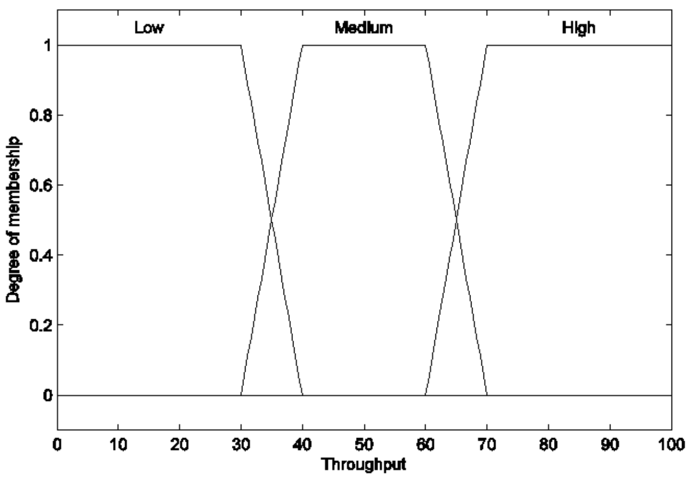

Fig. 3. Input (Throughput) Membership Function

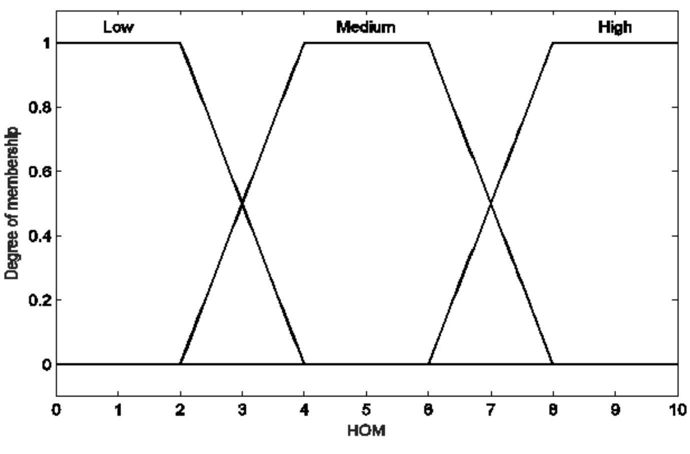

Fig. 4. Output (HOM) Membership Function

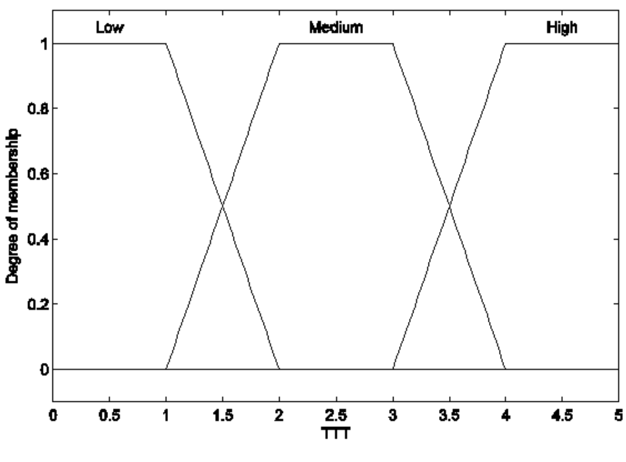

Fig. 5. Output (TTT) Membership Function

The rules which proposed to implement the optimization problem are listed in Table 1.

SIMULATION RESULTS

The optimized parameters are determined by comparing the new *OptimizeRatio* with its previous value. The highest *OptimizeRatio* value leads to a set of optimized parameters of the selected handover algorithm under a specific speed condition by maximizing the total system throughput and minimizing the unnecessary average HO per UE per second. Note that, an *ANOH* value equals to 0 is replaced to 0.5 to avoid numerical calculation error. The performance of four well-known handover algorithms are evaluated, optimized and compared. System parameters used in the simulation for downlink LTE system are given in Table 2. Table 3 records the handover parameters after optimization process for each handover algorithm for varying user speed. Table 4 shows the simulation results of HOA 1 (Basic LTE Handover Algorithm) for the standard LTE, methods presented in [4], [8], [9], [10], and fuzzy type-1 proposed in this paper. As listed in Table 4, the fuzzy type-1 proposed has better handover results when compared with all other algorithms. Fig. 8 shows the average HO per UE per second calculated for the four handover algorithms with different speed scenarios. It appears that the HOA 3 has the higher values as compared with the other three algorithms because this algorithm doesn't depend on the TTT. While the HOA 4 is the lowest curve of all algorithms due to its feature of making the handover based on the average RSRP and also it depends on the TTT. Fig. 9 shows the total system throughput for the four handover algorithms. The figure demonstrates that HOA 2 has the lowest throughput as compared with other algorithms. And also it's appear that HOA 4 has the higher system throughput because the average value of RSRP which used for handover decision has advantage that it prevents the system from making ping pong handover that make dropping in packets. The total system delay shown in Fig. 10.

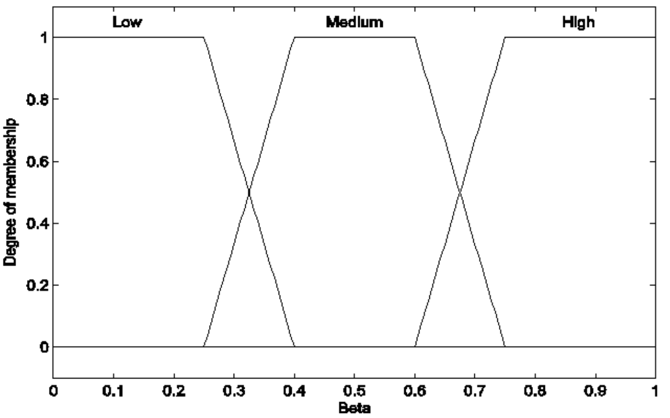

Fig. 6. Output (Beta) Membership Function

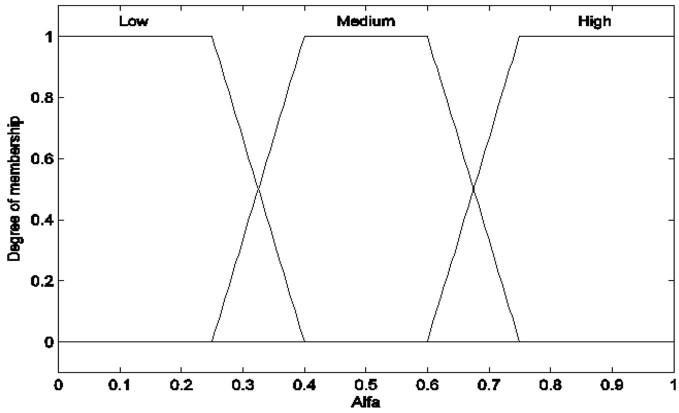

Fig. 7. Output (Alfa) Membership Function

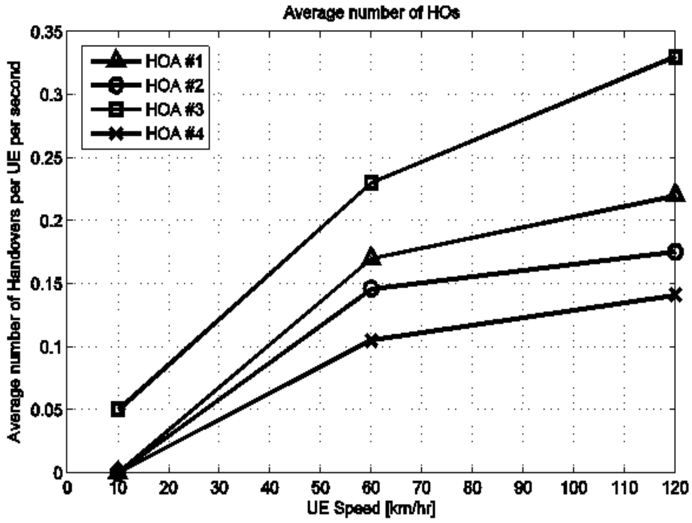

Fig. 8. Average HO per UE per second

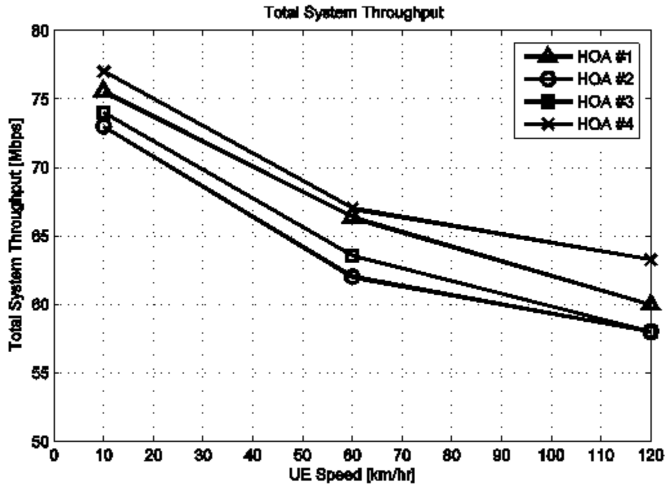

Fig. 9. Total System Throughput

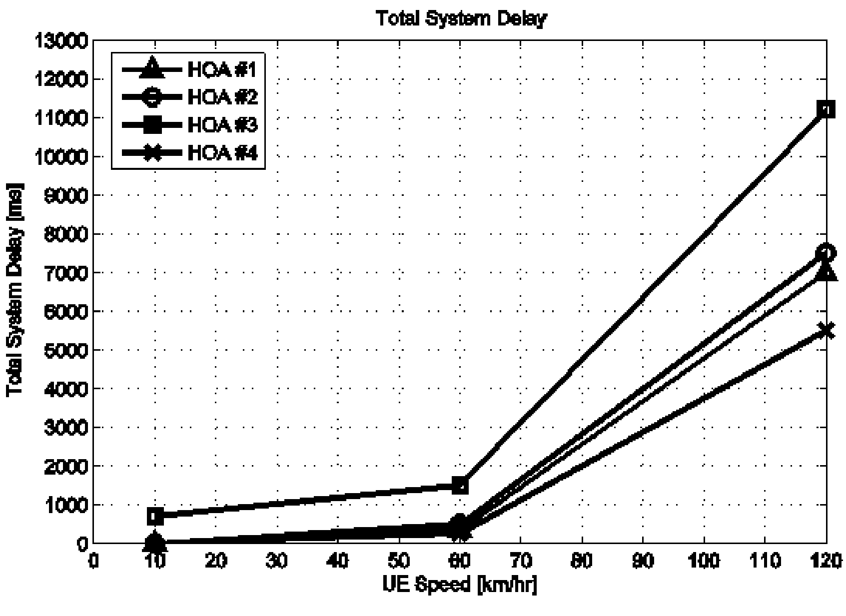

Fig. 10. Total System Delay

The handover occurs more as the speed increases so the system delay is also increases with the increase of handovers. HOA 3 has the higher system delay as compared with the other algorithms due to the absent of TTT mechanism in this algorithm, while HOA 4 still has the lowest delay because it has the minimum number of handovers and maximum system throughput.

The proposed technique can effectively reduce the average HO per UE per second for the HOA 4 up to 59% when compared with HOA 3 and decrease than the algorithm in [10] by 83.22% for HOA 4. Moreover, the total system throughput under the proposed technique for HOA 4 are 2.5%, and 5.6% higher as compared to the HOA 1, and HOA 3, respectively.

Table 1. Proposed Rules of Fuzzy for Handover Optimization

No.	Average HO	Throughput	HOM	TTT	β and α
1	H	H	H	H	H
2	H	L	H	L	L
3	L	H	L	H	H
4	L	L	L	L	L
5	M	L	M	H	H
6	M	H	M	L	L
7	L	M	H	M	M
8	H	M	L	M	M
9	M	M	M	M	M

Table 2. Simulation Parameters

Parameters	Values
Bandwidth	5MHz (25 PBR)
Frequency	2GHz
Cellular layout	Hexagonal grid, 7 cells
Number of Users	100
Handover Event	4-well known algorithms
Path Loss	Cost 231 Hata model
Shadow fading	Gaussian log-normal distribution
Multi-path	Non-frequency selective Rayleigh fading
Packet Scheduler	Round Robin
Scheduling Time (TTI)	1 ms
User's position	Uniform distributed
User's direction	Randomly choose from [0,2π], constantly at all time
Simulation time	10000 ms
TTT	{0, 1, 2, 3, 4, 5} millisecond
HOM	{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10} dB
β	{0.25, 0.5, 0.75, 1}
α	{0.25, 0.5, 0.75, 1}
UE mobility speed	Low: 10 km/h Medium: 60 km/h High: 120 km/h

Table 3. Optimized Parameters

Speed [km/hr]	HOA #1	HOA #2	HOA #3	HOA #4
10	HOM = 8 TTT = 5	HOM = 10 β = 0.25	HOM = 10 α = 0.25	HOM = 8 TTT = 5
60	HOM = 10 TTT = 4	HOM = 9 β = 0.5	HOM = 10 α = 0.25	HOM = 10 TTT = 4
120	HOM = 10 TTT = 4	HOM = 10 β = 0.25	HOM = 10 α = 0.25	HOM = 9 TTT = 5

Table 4. Simulation Results

Methods	No. of handover	No. of ping-pong
Standard LTE	13.86	3.96
[4]	--	0.57
[8]	1.18	0.18
[9]	0.74	0.05
[10]	4.68	--
Proposed Work	0.37	0.03

The proposed optimization technique succeeded to maximize the system throughput for HOA 2 more than [10] by 17%. Similarly, the proposed technique is able to maintain a lower system delay for HOA 4 when compared with the other three well-known handover algorithms (i.e. 22.4%, 29%, and 56% reductions when compared with Basic LTE Hard Handover, RSS based TTT Window and Integrator Handover Algorithm, respectively). Also fuzzy logic controller maintain an 11% lower delay for HOA 3 than [10].

Conclusion

A new handover optimization technique for LTE handover using fuzzy logic controller is proposed in this paper and is applied to optimize the handover parameters under the downlink LTE system. The performance of the proposed technique is compared with the four well-known handover algorithms under different UE speed scenarios which presented in [10].

REFERENCES

3GPP, 2009. Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); User Equipment (UE) conformance specification TS 36.509.

Anas, M., Calabrese, F. D., Mogensen, P. E., Rosa, C. and K. I. Pedersen. 2007. Performance Evaluation of Received Signal Strength Based Hard Handover for UTRAN LTE, Department of Electronic Systems, Aalborg University, Nokia Networks.

Cheng-Chung, Lin, Kumbesan Sandrasegaran, Huda Adibah Mohd Ramli, and Riyaj Basukala, 2011. Optimized Performance Evaluation of LTE Hard Handover Algorithm with Average RSRP Constraint, International Journal of Wireless & Mobile Networks (IJWMN), Vol. 3, No. 2.

Dahlman, E. 2007. LTE 3G Long Term Evolution, Expert Radio Access Technologies Ericsson Research.

Divya, R. and Hüseyin, A. 2009. 3GPP – Long Term Evolution – A Technical Study (2009).

Feng, Y., Xie, L., Chen, L., Wang, K. 2013. A low complexity fuzzy-logic control-based vertical handoff decision algorithm with rough set theory, Proceedings of international conference on wireless communications $\&$ signal processing, Hangzhou, pp. 1 – 6.

Ghanem, K., Alradwan, H., Motermawy, A., Ahmad, 2012. Reducing ping-pong handover effects in intra EUTRA networks, Proceedings of international symposium on communication systems, networks $\&$ digital signal processing, pp. 1 – 5.

Holma, H. and Toskala, A. 2009. LTE for UMTS – OFDMA and SC-FDMA Based Radio Access, John Wiley & Sons Ltd.

Jansen, T., Balan, I., Turk, J., Moerman, I., Ku, X, and T. rner 2010. Handover Parameter Optimization in LTE Self-Organizing Networks, in Vehicular Technology Conference Fall, IEEE 72nd, pp. 1-5.

Kun-Lin, Tsai, Han-Yun Liu, Yu-Wei Liu, 2016. Using fuzzy logic to reduce ping-pong handover effects in LTE networks, Soft Computing, Springer Berlin Heidelberg, pp. 1683 – 1694.

Mamdani, E. H., Assilion, S. 1974. An Experiment in Linguistic Synthesis with a Fuzzy Logic Controller, *Intl J. Man-Machine Stud* 7:1 13.

Mohamed, S. Darweesh, Hanan A. Kamal, and Mona M. El-Ghoneimy, 2013. Adaptive Mutation Particle Swarm Optimization for Dynamic Channel Assignment Problems, CiiT *International Journal of Artificial Systems and Machine Learning,* Vol. 5, No. 1.

Monil MAH, Qasim R, Rahman R.M. 2013. Speed and direction based fuzzy handover system, Proceedings of IEEE international conference on fuzzy systems, pp. 1–8.

Sandrasefaran, K., Daeinabi, A. and Ghosal, P. 2014. An enhanced inter-cell interference coordination scheme using fuzzy logic controller in lteadvanced heterogeneous networks, International Symposium on Wireless Personal Multimedia Communications, pp. 520– 525.

Shiwen Nie, Di Wu, Ming Zhao, Xinyu Gu, Lin Zhang, Liyang Lu, 2015. An Enhanced Mobility State Estimation Based Handover Optimization Algorithm in LTE-A Self-organizing Network, The 6th International Conference on

Ambient Systems, Networks and Technologies (ANT), pp. 270 – 277.

Thanachai Thumthawatworn, Anjum Pervez, and Pratit Santiprabhob, 2013. Adaptive Modular Fuzzy-based Handover Decision System for Heterogeneous Wireless Networks, *International Journal of Networks and Communications*, 3(1): pp. 25-38.

Zadeh, L. A., "*Fuzzy Sets. Intl J. Information Control*," 8:338-353, 1965.

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