ISSN 2229-5518

# NovelType-2 Fuzzy Logic Optimization Technique for LTE HandoverProblem

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**Abstract**—Wireless cellular networks requires more intelligent and adaptive handover decision mechanisms to fulfil the user's expectations in terms of seamless mobility over extensive area and maximum throughput. In this paper a new handover optimization technique for long term evolution (LTE) network based on type-2 fuzzy logic optimization is presented, named Fuzzy Logic Type-2 for LTE Handover (FL2LH). FL2LH picks the best hysteresis (handover margin - HOM) and Time-To-Trigger (TTT) combination for the current network status. Another enhanced mobility handover technique based on updating TTT by user speed is applied to fine the optimum handover parameters. These both new handover evaluated and compared with the four well-known handover algorithms by using the optimum handover parameters under three different speeds (10, 60, 120 km/hr) scenarios.

## 1 INTRODUCTION

LTE is a new radio technology established to provide a smooth transition towards Fourth Generation (4G) network [1]. It is designed to increase the coverage, capacity, and speed more than the earlier wireless systems [2]. LTE can provide up to 300Mbit/s downlink data rate communication and high speed user's service quality can also be guaranteed [3].

Handover is the key whichensures that the users move seamlesslybetween the cells while still being connected. Handover success rate is a key indicator of user satisfaction, it is required that this procedure happens as fast and as seamlessly as possible.In currently mobile networks, handover (HO) optimization is done manually over a long time, e.g. days or weeks, on a need basis only. This technique is time consuming and may not be sufficient as often as needed. By introducing an optimizationtechnique that will tune the parameters of the HO process, the overall network performance is improved. The main objects are minimizing the number of HOs that are initiated but not successful to completion (ping-pong) and calls being dropped [4].

The main challengesfacing the suggested algorithms is finding the minimum handover rate and maximum throughput with minimum delay. This proposedtechniques is


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## 2LITERATURE REVIEW

There were many attempts to solve the HO problems even by self-optimization or by using Fuzzy Logic Controller (FLC) [5-12]. Ping-pong problem was targeted in [5]. FLC was used to decrease the unnecessary handover rate by using Gaussian and triangular membership functions. The effect of the proposed algorithm on the throughput and delay of system was not studied.

In the work presented in [6], an enhanced self-optimization algorithm for handover among macro and femto applications on Long Term Evolution Advanced (LTE-A) networks is proposed and it was deals with LTE-A network as an LTE network by considering that handover failure is simulated when user equipment's (UEs) are in different speeds which is not the real case. Another weakness point is that it did not study how the proposed algorithm effect on the system throughput or the system delay problems.While in [7], a FLC based handover algorithm was introduced to avoid ping-pong effects. Its success todetermine the best candidate base station (BS) based on the measurements of relative speed and direction, traffic load, and signal strength.

While in [8], a less-complexity FLC based on vertical handoff decision algorithm was introduced to reduce the decision time. This algorithm based on rough set theory, was presented to minimize the number of rules, select core parameters for FLC and then estimate the value of access network candidacy.

The work in [9] presented a handover algorithm which keeps the old path between the serving eNB and Serving Gateway (SGW) during the Ping-Pong effect, and delays the handover procedure. In this algorithm, a timer was used to decidewhether the ongoing handover is a normal HO 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.

The only paper that evaluate the performance of the four well-known handover algorithms is [10], but without using optimization technique, it is only a self-optimization process to study the three performance metrics (average number of handover, system throughput, and system delay).

The study in[11]based on a technique using HOM and TTT which were varied in each iteration depending on the number of times thatthe UE crosses a boundary during two successive calls. Ping-Pongs rate and the number of HOs in the network decreased with different speeds of the users. But this work did not study how the proposed algorithm effect on the throughput or the Radio Link Failure (RLF)problems.

While the work in [12],a new handover optimization algorithm for LTE network based on FLC is presented. It consists of finding the optimum HOM required for handover process and also finding appropriate TTT to perform a success handover using FLC. The suggested handover optimization technique is evaluated for the four well-known handover algorithms and it successes to achieve minimum average number of handover per user and also have maximum throughput than the self-optimization technique.

In this paper, type-2 fuzzy logic is applied for the first time on the handover problem for LTE network to minimize the handover rate, maximize the throughput, and minimize the system delay.

The main contribution of this paper is as follows: Type-2 fuzzy logic optimization technique is applied to optimize the HO problem for LTE network. Another contribution is that the UE speed and all LTE handover algorithms are considered under threedifferent speeds (10, 60, 120 km/hr) scenarios. The developed technique proves it's robustness to the changes of the user's speed and superiority over previous work.

## 3LTE HANDOVER ALGORITHMS

The LTE handover procedure is completely hard handover. When the UE moves from one BS to another BS, so it's impossible for it to connect with both BSs.

Thehandoverparameters are HOM and TTT. HOM is the difference in the received signal strength between the target and theserving cells. HOM ensures that the target cell is the most suitable cell for the mobile to go through handover. A TTT is the time required for satisfying HOM condition. Also it'sa way to decrease the Ping-Pong handovers [13].

Choosing the HOM and TTTvalues is critical for the HO optimization in LTE. For example, long TTT increases HO failure because the signal strength may become too low before the HO event is triggered, while short TTT decreases HO failure, but leads to more ping-pongs.

The 4-well known handover algorithms for LTE network which used to carry out the handover from source cell to target cell [10], are discussed in the following section:

### 3.1 BasicLTE Handover Algorithm

The LTE basic handover algorithm, is the basic algorithm consisting of two variables, HOM and TTT.

When a mobile is going away from the serving cell, the Reference Signal Received Power (RSRP) which received by mobile from the serving cell will decay as time increases. While, the mobile will go towards the target cell, therefore the target RSRP that received by mobile will increase with time. A handover is triggered when the following conditions are satisfied together[14].

$$RSRP_T > RSRP_S + HOM \quad (1)$$

$$HOTrigger \geq TTT \quad (2)$$

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 is satisfied.

$HOM$ is measured in dB. $TTT$ is measured in msec. Consequently, it is required to search for the optimum values of HOM and TTT to minimize the HO rate and maximize the system throughput.

### 3.2 Received Signal Strength based TTT Window Algorithm

This algorithm is consist of 3 steps. It collects the required information during the processing step, and then performs the comparison based on this information during the decision step followed by the execution step. The handover is based on eq.(3) [15].

$$RSS_F(nT_m) = \beta RSS(nT_m) + (1-\beta) RSS((n-1)T_m) \quad (3)$$

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 instant, respectively. $\beta$ is a fractional number called "forgetting factor" which can be expressed as follows:

$$\beta = \frac{T_u}{T_m} \quad (4)$$

where $T_u$ is an integer multiple of $T_m$. A RSS comparison is performed based on the following equation:

$$RSS_F(nT)_T > RSS_F(nT)_S + HOM \quad (5)$$

where $HOM$ is a constant threshold value, $RSSF(nT)_T$ and $RSSF(nT)_S$ are the filtered RSS of the target cell and the serving cell at $(nT)^{th}$ interval, respectively.

This algorithm tracks the RSS value from each eNB and stores the instantaneous RSS value.

### 3.3 Integrator Handover Algorithm

This algorithm making the handover decision by considering the historical signal strength differences. The idea of historical data is the same as the second algorithm. This algorithm consists of 3 parts, RSRP difference calculation, filtered RSRP difference computation, and handover decision. The RSRP difference calculation is presented as following [13].

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

where $RSRP_T(t)$ and $RSRP_S(t)$ 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 written as following:

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

Where $\alpha$ is a proposed variable with constraint $0 \le \alpha \le 1$. $FDIF_{s\_j}(t)$ 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 the previous equation. A filtered RSRP difference value depends on the current RSRP difference and the historical filtered RSRP difference by changing $\alpha$ variable. Once the filtered difference has been computed, the handover decision occurs if the condition in eq.8 is satisfied:

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

Where $FDIF_{Threshold}$ is equivalent to HOM. If the last condition number (8) is satisfied, the handover decision will be triggered immediately. The ping-pong may occurs due to absence of TTT mechanism involved in this algorithm.

### 3.4 LTE Hard Handover Algorithm with Average RSRP Constraint

This algorithm is based on LTE basic handover algorithm with average RSRP condition for more efficient handover performance. The average RSRP can be calculated as following in eq.9 [10].

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

where $RSRP(nTm)$ is the RSRP received by user $j$ from serving cell $s$ at $n^{th}$ 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 calculated by summation of each $n^{th}$of $T_m$ up to $N$ divided by $N$ times. The average RSRP constraint can be expressed as following:

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

where $RSRP_{avgs_j}$is the average RSRP computed from equation (9). The handover decision will occurswhen the same conditions of equations 1 and 2 are satisfied.

The idea of this algorithm is to minimize the Ping-Pong. 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 higher than the average RSRP for the time-to-trigger interval.

In this paper, the four handover algorithms are applied and compared together with the proposed technique FL2LH. The main parameters to optimize in the basic LTE handover algorithm are HOM and TTT, in received signal strength based TTT window algorithm, we optimize HOM and bets ($\beta$) which replaces the TTT of the basic LTE handover algorithm, while in theintegrator handover algorithm, the parameter TTT is replaced by alfa ($\alpha$).In the fourth algorithm, we optimize the same parameters of the basic LTE algorithm. Two different cases are considered where the TTT is user speed independent and when it is user speed dependent to fully simulate the real scenarios.

## 4PERFORMANCE METRICS

The system performance is evaluated for the handover algorithms on the basis of average handovers per UE per second, total system throughput, and total system delay.

The average handovers 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, respectively and $J$ and $T$ are the total number of users and total simulation time, respectively.

The second metric is the cell throughput which is the total number of bitswhich correctly received by all users per second. 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 the average system queuing delay which is defined as the time duration from the queuing packet's arrival time at the eNB buffer to current time. It can be expressed as follows:

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

where $J$ is the total number of users within the cell, $T$ represents the total simulation time, and $W_j(t)$ denotes the queuing delay of user $j$ at time $t$. Also the sum of the system cells delay, is calculated.

The final metric is the *OptimizeRatio* which is a ratio between the total throughput and the average number of handovers. *OptimizeRatio* can be computed as follows:

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

where *HOA* indicates the handover algorithm, Speed is the corresponding UE speed in each scenario. *ST* and *ANOH* are the total system throughput and the average number of handover per UE per second, respectively. TTT will be replaced by $\alpha$ or $\beta$ factor when Integrator Handover Algorithm or Received Signal Strength based TTT Window Algorithm is selected.

## 5PROPOSED TECHNIQUE

In this presented work, an enhanced mobility handover algorithm is applied to find the optimum handover parameters based on the user speed. In handover process, TTT is affected by UE speed. When UE have a high speed, it will go for a longer distance and more severe degradation of signal quality during TTT.The value of this TTT is the original value configured in cell, which cause too late handover. Thus it is necessary to set a lower TTT value for high speed UEs according to the following equation [6].

$$TTT_{new} = \mu * TTT \quad (15)$$

where $\mu$ is a scaling factor (Cauchy random number) with the scale parameter of 1 which come from the standard Cauchy distribution, with the probability density function [16]:

$$f\ (x\,;0,1) = \frac{1}{\pi(1+x^2)} \quad (16)$$

The μ factor is generated according to UE speed to make the TTT suitable for the handover process and ensure the success of HO.

As it will be shown in the results that for low speed users the $\mu$ factor is around 1 so there is no need to change the TTT value. While for high speed users the $\mu$ factor will be around 0.2 to optimize the TTT for successful HO process.

The handover algorithms will be optimized and comparedin this paper by using Type-2 fuzzy logic technique which applied for the first time on the LTE handover problem.

Fuzzy Inference Systems (FIS) have been broadly used for a wide range of engineering applications. FIS is successfully applied in control and decision making systems [17]. Most of FIS used are based on Type-1 model [18], but lately, Type-2 model has been developed to be a next step to design and have more capability to model real-world things.

The knowledge that's used to construct the rules in a Fuzzy Logic System (FLS) is uncertain. These uncertainty data are translated into uncertain membership functions. Type-1 FLS, is unable to directly handle theseuncertainty. While type-2 FLS, can handle theuncertainty[19].

FIS is based on logical rules which work with fuzzy input, when rules are evaluated, the individual results form together what is known as the fuzzy output, then a numerical value must be passed through a process of defuzzification. Type-2 FIS basic structure includes four components as shown in Fig. 1 [17]. Mamdani FLC is used in this paper.

1. Fuzzifier: Converts inputs (real values) to fuzzy values.
2. Inference System: Applies a fuzzy reasoning mechanism to obtain a fuzzy output.
3. Defuzzifier: The Defuzzificator reduces one output to specific values; or it can be as a type reducer which transforms a type-2 fuzzy set into a type-1 fuzzy set.
4. Knowledge base: Contains set of fuzzy rules, and the membership functions which are known as data base.

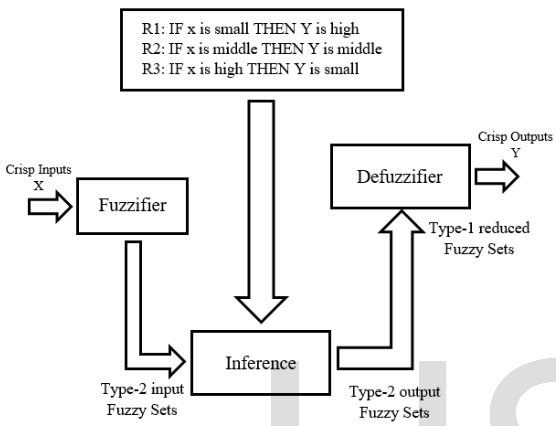


Fig.1.Architecture of a Type-2 Fuzzy System



In this presented work, there are 2 inputs and 4 outputs used to complete the optimization process for the LTE handover problem by applying the type-2 fuzzy flow according to Fig. 1. The 2 inputs are $HO_{avg}$ and the total system throughput. While the 4 outputs are HOM, TTT, beta ($\beta$), and alfa ($\alpha$).Fig. 2 shows the inputs and outputs of the FLC used.

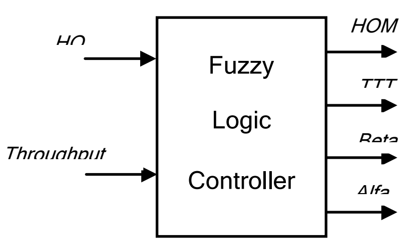


Fig. 2. FLC inputs and outputs

The inputs to the proposed FLC are $HO_{avg}$ and Throughput.$HO_{avg}$ range is from 0 to 1. It consists of three fuzzy sets which are "Low", "Medium", and "High"as shown in Fig. 3. Below 0.4 and above 0.6 are considered Low and High respectively. Throughput range if from 0 % to 100%. Its membership function also consists of three fuzzy sets which are "Low", "Medium", and "High" as shown in Fig. 2. The fuzzy outputs areHOM, TTT, beta, and alfa. HOM range is from 0 dB to 10 dBas shown in Fig. 4, to limit the instability which maybe occurs from wide changes in the HOM.TTT starts from 0 to 5 msec and it has three fuzzy sets which are "Low", "Medium", and "High" as shown in Fig. 4. Beta and alfa have the same range from 0 to 1 as shown in Fig. 5.

A lot of experimental workhave been carried out on many membership functions (trapezoidal, triangle, and sigmoid) to select the best membership function and the best fuzzy sets for both input and output.The selected membership functions which gives the best results for the handover problem in LTE are shown in the following figures.

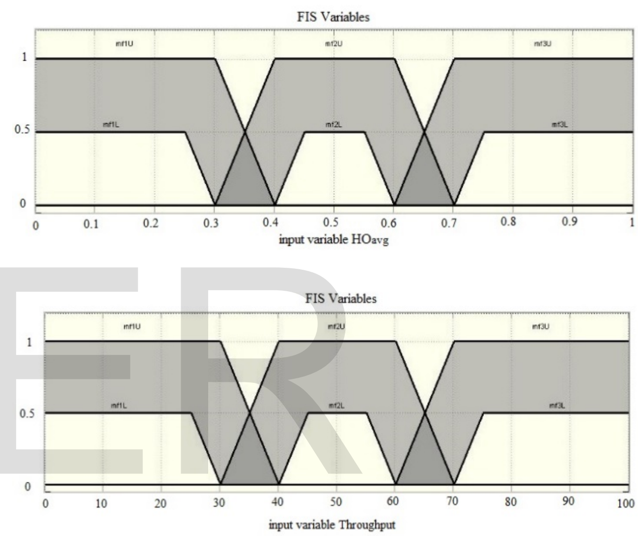


Fig.3.Inputs Membership Functions

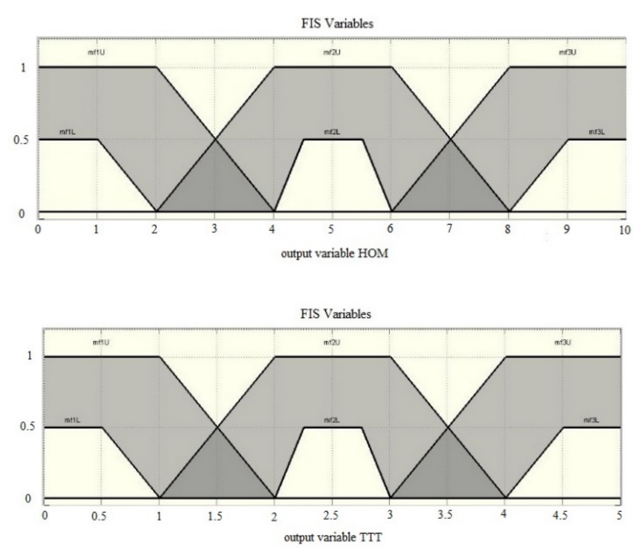


Fig.4.Outputs (HOM & TTT) Membership Functions

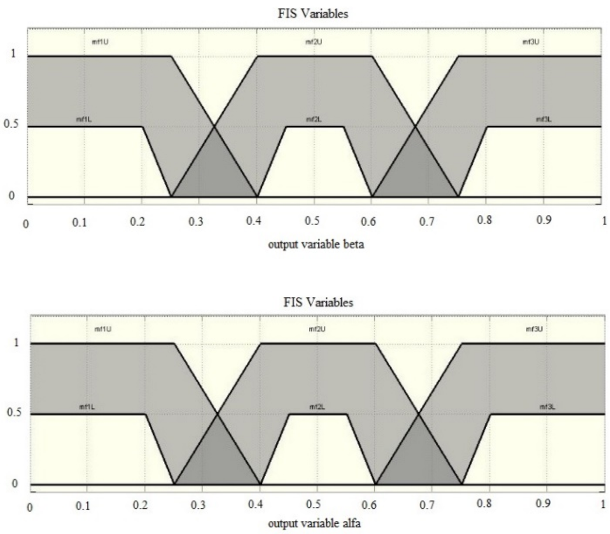


Fig. 5.Outputs (Beta & Alfa) Membership Functions

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

TABLE 1

Proposed Rules of Fuzzy for Handover Optimization

| No. | Average HO | Throughput | HOM | TTT | $\beta$ and $\alpha$ |
|---|---|---|---|---|---|
| 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 |

The action of the output is taken based on the selected membership functions according to the inputs ($HO_{avg}$, Throughput) which are connected together by the conjunction "and". At the end, there is one output from the FLC, which is different according to the LTE HO algorithm which selected.

Algorithm 1 shows how type-2 fuzzy enhanced technique is implemented.

**Algorithm 1**Type-2 Fuzzy Enhanced Technique

**Inputs**: {$HO_{avg}$, Throughput}
**Outputs**: {HOM, TTT, $\beta$,$\alpha$}
1: **Monitor** signal strength of serving and target eNB in the cell.
2: **IF**target eNB signal strength >serving eNB signal strength
3: **Trigger** handover procedure
4: **Select** the LTE HO Algorithm
5: **Calculate** the $HO_{avg}$, Throughput for the LTE Network
6: **Test** UE speed
7: **Generate** a Cauchy random number based on the UE speedto update TTT according to equation 15.
8: **Fuzzification**: converts the inputs to fuzzy values.
9: **Calculate** the degree of truth for each input based on the membership functions.
10: **Inference**: select the new values of outputs based on the rule base and the membership functions of the output.
11: **Update** HOM, $\beta$, and $\alpha$ by the new values.
12: **Defuzzification**: transforms the outputs fuzzy values to crisp values.
13: **Repeat** steps from 8 to 12 during the simulation time

To study the effectiveness of FL2LH algorithm, MATLAB fuzzy toolbox has been used. The simulation results of the four well known handover algorithms under FL2LH are summarized in the following section.

## 6SIMULATION RESULTS

The performance of the handover algorithms which are the average number of handovers, system throughput, and system delay are evaluated, optimized according to the proposed technique FL2LH and compared with previous work.

System parameters used in the simulation for downlink LTE system are summarized in Table 2. They are chosen in compliance with the 3GPP specifications [20].

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 | Log-normal shadowing |
| 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} msec |
| 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<br>Medium: 60 km/h<br>High: 120 km/h |

The optimization parameters are determined by comparing the new *OptimizeRatio* with its previous value. The highest value leads to the 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.

In this paper, there are 2 different cases used for the handover in LTE to improve the performance metrics, and go near the realistic model for the LTE network.In the first case, the HO is independent on the UE speed, which is the default case but it is not the real case. The second caseis applied by making anenhancement for the handover process to be dependent on the UE speed.

### 6.1 Results of TTT User Speed IndependentCase

In this section, the results of the first caseby applying type-2 fuzzy logic technique, is presented. Table 3 shows the optimized parameters for each handover algorithm for different user speed.

Table 3

Optimized Parameters

| Speed [km/hr] | HOA #1 | HOA #2 | HOA #3 | HOA #4 |
|---|---|---|---|---|
| 10 | HOM = 9<br>TTT = 5 | HOM = 8<br>$\beta = 0.25$ | HOM = 10<br>$\alpha = 0.25$ | HOM = 8<br>TTT = 5 |
| 60 | HOM = 9<br>TTT = 4 | HOM = 9<br>$\beta = 0.5$ | HOM = 8<br>$\alpha = 0.25$ | HOM = 9<br>TTT = 4 |
| 120 | HOM = 9<br>TTT = 3 | HOM = 10<br>$\beta = 0.25$ | HOM = 10<br>$\alpha = 0.25$ | HOM = 9<br>TTT = 3 |

Table 4 shows the simulation results of HOA #1 (LTE Basic Handover Algorithm) for the standard LTE, methods presented in [5], [6], [9], [10], [12], and fuzzy type-2 proposed in this paper. As listed in Table 4, the proposed fuzzy type-2 has better handover results when compared with all other algorithms.

TABLE 4

Simulation Results

| Methods | No. of handover | No. of ping-pong |
|---|---|---|
| Standard LTE | 13.86 | 3.96 |
| [5] | 0.74 | 0.05 |
| [6] | -- | 0.57 |
| [9] | 1.18 | 0.18 |
| [10] | 1.68 | -- |
| [12] | 0.37 | 0.03 |
| FL2LH | 0.32 | 0.02 |

Fig.6 shows the average number of HO per UE per second calculated for the four handover algorithms with different speed scenarios. It appears that the HOA #4 is the lower curve within all algorithms due to its feature of making the handover based on the average value of RSRP and also it depends on the TTT. While the HOA #3 has the higher values as compared with the other three algorithms because this algorithm doesn't depend on the TTT.

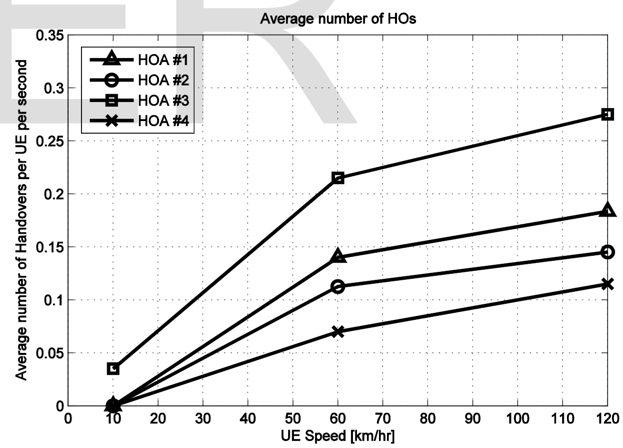


Fig. 6.Average number of HO per UE per second

Fig.7 shows the total system throughput for the four handover algorithms with FL2LH. The figure demonstrates 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 ping-pong and the dropping in packets. Also, HOA #2 has the lowest throughput as compared with other algorithms.

ISSN 2229-5518

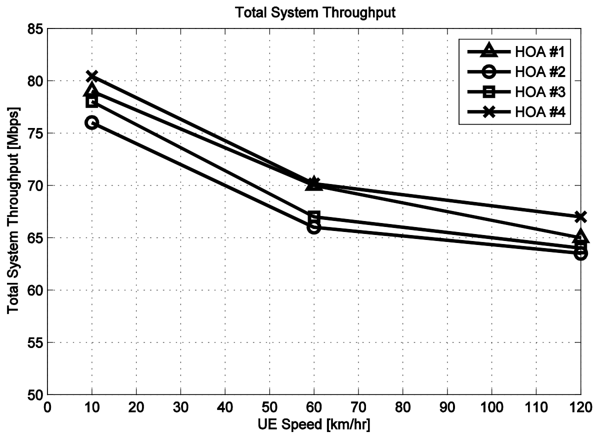


Fig. 7.Total System Throughput

The total system delay is presented in Fig. 8. The handover rate goes higher as the speed increases so the system delay is also increases.HOA #4 has the lower delay because ithas the minimum number of handovers and maximum system throughput. Still HOA #3 has the higher system delay as compared with the other algorithms due to the absent of TTT mechanism in this algorithm.

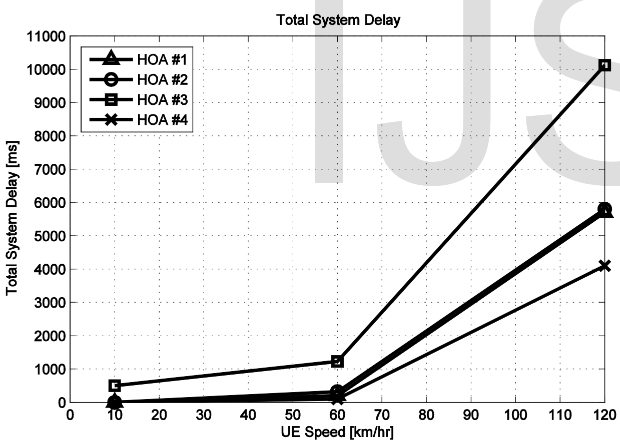


Fig. 8. Total System Delay

It is shown via MATLAB computer simulation that the FL2LH technique, which applied for the first time for the LTE handover problem, can effectively reduce the average number of handovers per UE per second for the HOA #4 up to 83% when compared with Integrator Handover Algorithm (HOA #3) and lower than the algorithm presented in [10] by 88.5%. Moreover, the total system throughput with the proposed technique for HOA #4 are 2.3%, and 4.6% higher as compared to the LTE Basic Handover, and Integrator Handover Algorithms, respectively. The work in this paper,succeeded to increase the system throughput for HOA #2 more than [10] by 31%. Similarly, it is able to maintain a lower system delay for HOA #4 when compared with the other three well-known handover algorithms (i.e. 31%, 32.3%, and 64% reductions when compared with LTE Basic Handover, RSS based TTT Window and Integrator Handover Algorithms, respectively). Also FL2LH maintains a 30% lower delay for HOA #3 than the technique which is applied in [10].

### 6.2 Results of TTT User Speed Dependent Case

In this part, case 2 which is depending on the UE speed is applied and the results are shown below.

Table 5 shows the optimized parameters for each handover algorithm by adjusting TTT as a function of UE speed.

TABLE 5

Optimized Parameters

| Speed [km/hr] | $\mu_{optimum}$ | HOA #1 | HOA #2 | HOA #3 | HOA #4 |
|---|---|---|---|---|---|
| 10 | 0.9532 | HOM=5 | HOM=8 $\beta = 0.25$ | HOM=10 $\alpha = 0.25$ | HOM=9 |
| 60 | 0.5337 | HOM=8 | HOM=9 $\beta = 0.5$ | HOM=8 $\alpha = 0.25$ | HOM=10 |
| 120 | 0.1992 | HOM=10 | HOM=10 $\beta = 0.25$ | HOM=10 $\alpha = 0.25$ | HOM=10 |

Table 6 shows the simulation results of HOA #1 for the standard LTE, methods presented in [6], [12], and fuzzy type-2 (FL2LH) proposed in this paper. As listed in Table 6, FL2LH has better handover results when compared with all other algorithms. It reduces the number of handovers by 60% than the work in [12] and succeededto make the number of ping-pong near to zero.

TABLE 6

Simulation Results

| Methods | No. of handover | No. of ping-pong |
|---|---|---|
| Standard LTE | 13.86 | 3.96 |
| [6] | -- | 0.35 |
| [12] | 0.37 | 0.03 |

| | | |
|---|---|---|
| FL2LH - TTT | 0.15 | 0.02 |

Fig. 9 shows the average number of HO per UE per second calculated for the four handover algorithms with different speed scenarios. It appears that the HOA #4 is the lower curve within all algorithms and it succeeded to reach zero number of handovers at high speed, due to its concept of making the handover not only based on the RSRP of the target cell but also based on the average RSRP.

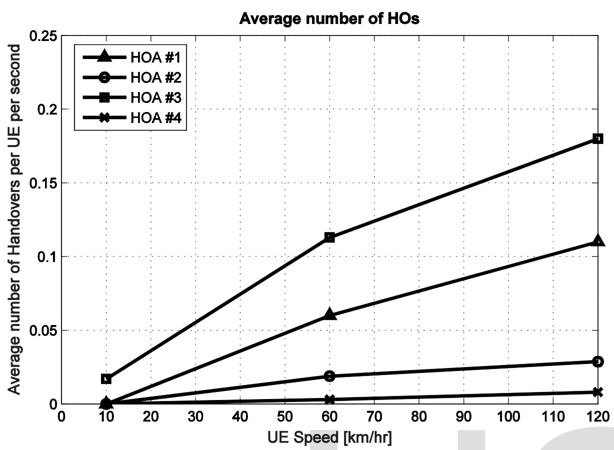


Fig. 9. Average number of HO per UE per second

Fig. 10illustrates the total system throughput for the four handover algorithms. The figure demonstrates that HOA #4 has the higher system throughput as thedropping in packets is very low due to existing of average RSRP in the handover action. Also, HOA #4 has higherthroughput than the independent case.

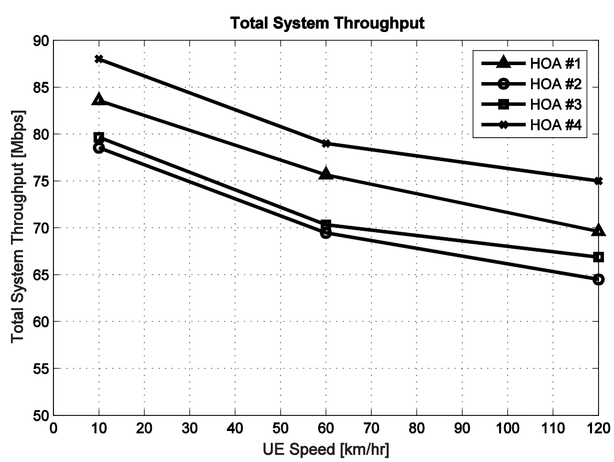


Fig. 10. Total System Throughput

The total system delay is described in Fig. 11. The handover depends on the user speed so the system delay increases with the increment of handovers. It appears that the minimum number of HO and maximum system throughput achieves by HOA #4. Also HOA #4 hasthe lower delay compared with other algorithms.Similar to case one, HOA #3 has the highest system delay and this is due to theabsence of TTT concept.

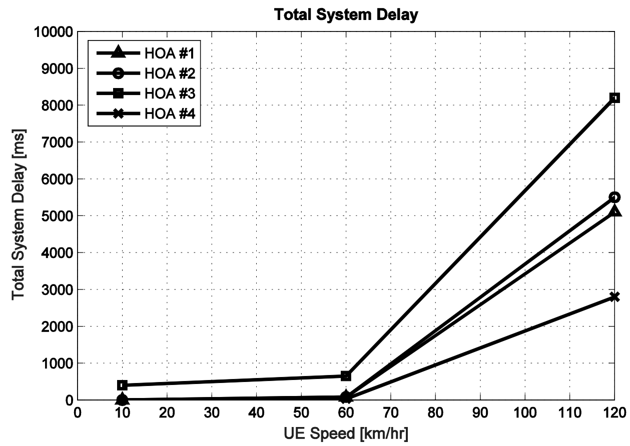


Fig. 11. Total System Delay

## 7CONCLUSION

The novelty in this paper is applying FL2LH for the first time on the handover problem in LTE network, taking into consideration both HOM and TTT as the main factors in selecting this algorithm. Moreover, the algorithm used an enhanced technique by selecting TTT based on UE speed which made it more realistic to be applied.

The results of the proposed technique were compared with the four well-known handover algorithms under different UE speed scenarios. It gives better results than other studies like fuzzy type-1 or self-optimization methods. Also, the enhanced technique which based on TTT scaling gives minimum number of handovers, maximum throughput, and minimum delay when it is compared with previous work.

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