Optimization of Handover Problem Using Q-Learning for LTE Network

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***Abstract*—In this work, Q-learning technique on level of optimization is used to improve the performance of handover parameters such as handover margin (HOM) and time to trigger (TTT) and evaluated in terms of total system delay, average number of handover and system throughput in purpose to provide long term evolution (LTE) technology seamless and fast handover from one cell to another, knowing that optimization is based on Q-learning technique which achieves minimum average number of handover per user and also have maximum throughput than the literature work of optimization using fuzzy logic optimization.**

Keywords—Q-Learning, Handover, LTE, HOM, TTT, Optimization.

I. INTRODUCTION

Long Term Evolution (LTE) is 3GPP latest radio access technology. Its main purpose is to increase capacity and speed [1] for these purposes orthogonal frequency division multiple access (OFDMA) is the type of multiple access technique used in the downlink, while the uplink works by single-carrier frequency division multiple access (SC-FDMA) [2] to increase the system speed and capacity.

A physical resource block (PRB) is the smallest transmission unit, containing 12 sub-carriers with a total bandwidth of 180kHz and duration of 1ms [3]. The equivalent to a base station in the LTE network is the evolved-NodeB (eNB) [4].

To prevent the call from being dropped, the power received by the user from the serving station must not decrease below a certain value, so the user equipment should connect to a new station with a better received power.

In this presented work, a Q-learning handover optimization technique is proposed to minimize the number of handovers and maximize the total system throughput under different speeds.

The paper is covering the following: Section II gives descriptions of the several of handover algorithms and performance metrics which used. Section III investigates the proposed optimization algorithm for LTE handover problem in details. Simulation results and comparison are given in section IV. Finally, the whole work is concluded in section V.

II. STANDARD LTE HANDOVER ALGORITHMS

In this paper, the standard handover algorithms (HAO) which used to carry out the handover from source cell to target cell, are applied, compared together, and compared with the algorithms presented in [5-6].

The standard handover algorithms for LTE network are:

- **HOA #1**: *LTE Hard Handover Algorithm [6].*
- **HOA #2**: *Received Signal Strength based TTT Window Algorithm [7].*
- **HOA #3**: *Integrator Handover Algorithm [6].*
- **HOA #4**: *LTE Hard Handover Algorithm with Average RSRP Constraint [3].*

The following conditions must occur for the handover procedure: the reference signal received power (RSRP) of the target base station must be greater than that of the serving base station by a certain margin (HOM) for a duration greater than or equal the time to trigger (TTT) as shown in Fig. 1.

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 [7].

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

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

Where $RSRP_T$ and $RSRP_S$ are the RSRP received from the target and the serving cell, respectively and $HOTr$ is the handover timer which starts counting when the first condition is satisfied.

In this paper, the standard handover algorithms are applied and compared together with the proposed technique. The main parameters to optimize in the basic LTE handover algorithm are HOM and TTT, while in the received signal strength based TTT window algorithm, we optimize HOM and beta (β) which replaces the TTT of the basic LTE handover algorithm, while in the integrator handover algorithm, the parameter TTT is replaced by alfa (α). In the fourth algorithm, we optimize the same parameters of the basic LTE algorithm.

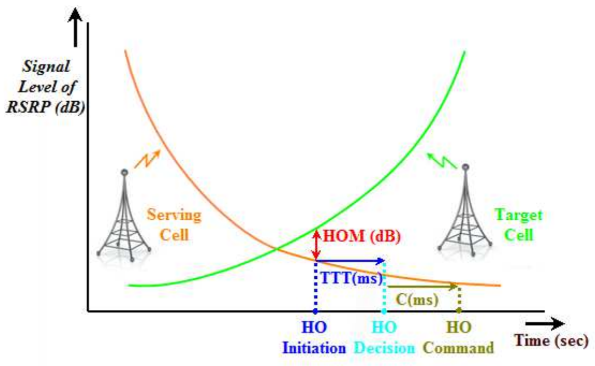

Fig. 1: Handover decision based on HOM and TTT [8]

The LTE handover algorithms will be evaluated on the following metrics [5].

The average number of handovers per second per UE is he first metric.

$$HO_{avg} = \frac{HO_{Total}}{J \times T} \quad (3)$$

Where J is the total number of users and T is the total simulation time and HO_{avg} is the average handovers per second per UE and HO_{Total} is the total number of successful handovers.

The system throughput is defined as the rate of successful messages delivered by all users per second. The cell throughput is measured at the eNB and is mathematically expressed as:

$$cell\ throughput = \frac{1}{T}\sum_{j=1}^{J}\sum_{t=1}^{T} tput_j(t) \quad (4)$$

where T is the total simulation time, J is the total number of users, and $tput_j(t)$ is the total size of the correctly received bits of user j at interval t.

The third metric is the system delay which is the average queuing delay of the system. It can be expressed as follows:

$$cell\ delay = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{J}\sum_{j=1}^{J} W_j(t) \quad (5)$$

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.

III. Q-LEARNING OPTIMIZATION TECHNIQUE

Q-Learning is a model which can solve problems without requiring a model for maximizing or objective function. It can come with an optimal action selection that Markov decision process (MDP) gives. It models the environment around it to certain states and actions. One of the states (S) is defined to be the goal state (agent's main goal) which required to minimize or maximize. The agent makes random actions which are assigned different rewards and the action that reaches the goal state has the largest reward.

The learning technique calculates a Q value for this action using the reward value assigned to it and updates this value in the action's corresponding index in the Q matrix [9]. Thereafter, the agent can reach the goal state guided by this Q-matrix whatever initial state is chosen [10].

In our problem we want to find the HOM and TTT to provide the best performance (maximum throughput and minimum system delay and average numbers of handover) we can acquire. However, there is no direct relation between the performance metrics and the system parameter that we can use for optimization. So, the handover optimization problem is modeled as MDP to achieve our goal state (S) which is the best performance can be acquired, and the actions (A) would be the different combinations of HOM and TTT.

Each HOM and TTT combination defined in the range mentioned in 3GPP release [11]. The performance metrics are calculated and used to get the reward value.

At the end, the maximum Q-value in the matrix corresponds to the HOM and TTT provides the best performance which can acquire. The proposed algorithm is applied for the 3 velocities (10, 60, 120 Km/hr) [12]. The learning rate β used was equal to 0.5.

The proposed Q-Learning optimizing technique as follows:

For each velocity, initialize a Q-matrix of zeros. For every HOA, each HOM and TTT, simulate the overall system, then calculate total system throughput, total system delay and the average handover per second for all UEs.

After that, calculate the reward function using $r = -(w_1 * HOav + w_2 * System\ Througput - w_3 * System\ Delay)$ and update the Q-value corresponding to the current HOM and TTT values using $Q(HOM, TTT, V) = (1 - \beta) * Q(HOM, TTT, V) + \beta * r$. Finally, choose the maximum Q-value out of the Q-matrix at each velocity.

The weights of the reward function parameters w_1, w_2 and w_3 were 0.175, 0.65 and 0.175 respectively.

IV. SIMULATION RESULTS

The evaluation for the performance of the 4 well-known LTE handover algorithms is optimized and compared according to the System parameters used in the simulation for downlink LTE system are given in Table 1.

Table 1. Simulation Parameters

Parameters	Values
Bandwidth	5MHz (25 PBR)
Frequency	2GHz
Cellular layout	Hexagonal grid, 7 cells
Number of Users	100
Handover Event	Hard handover algorithm (A3 event)
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 2 shows a summarized result of the optimized parameters by Q-learning technique for each handover algorithm for varying user speed.

Table 3 shows the simulation results for the standard LTE, methods presented in [4], [5], [13], [14] and Q-learning proposed in this paper. As listed in Table 3, the handover optimization algorithm proposed in this paper has the better results when compared with other algorithms.

Table 2. Optimized Parameters using Q-learning

Speed [km/hr]	HOA #1	HOA #2	HOA #3	HOA #4
10	HOM = 8 TTT = 3	HOM = 8 β = 0.5	HOM = 9 α = 0.25	HOM = 7 TTT = 4
60	HOM = 8 TTT = 3	HOM = 9 β = 0.5	HOM = 8 α = 0.5	HOM = 9 TTT = 4
120	HOM = 6 TTT = 3	HOM = 9 β = 0.25	HOM = 10 α = 0.25	HOM = 9 TTT = 5

Table 3. Simulation Results

Methods	No. of handover	No. of ping-pong
Standard LTE	13.86	3.96
Ref. [4]	1.68	--
Ref. [5]	0.37	0.03
Ref. [13]	--	0.57
Ref. [14]	0.74	0.05
Proposed Work	0.22	0.015

Fig. 2 shows the average number of HO per UE per second calculated 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 also it depends on the TTT.

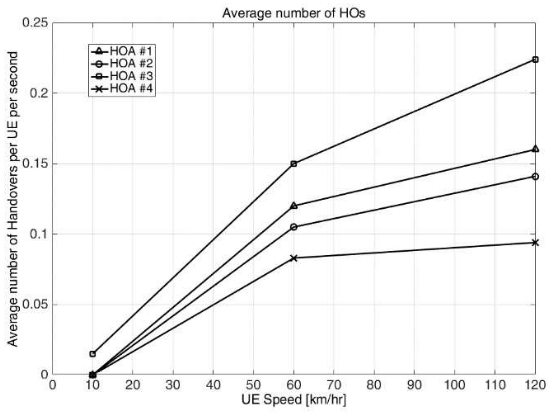

Fig. 2: Average number of HO per UE per second

Fig. 3 shows the total system throughput. The figure demonstrates that HOA #2 has the lowest throughput as compared with other algorithms. Also, it appears that HOA #4 has the higher system throughput because the average value of RSRP which used for handover decision which prevents the system from the ping-pong.

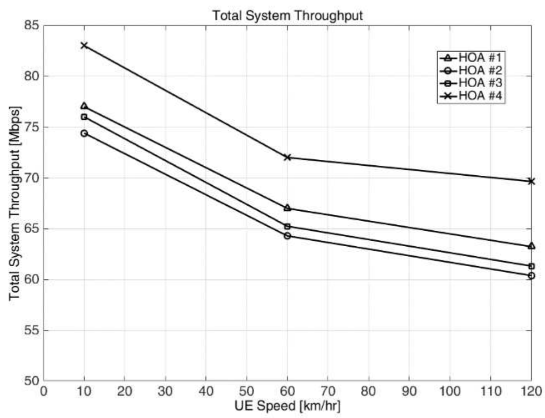

Fig. 3: Total System Throughput

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

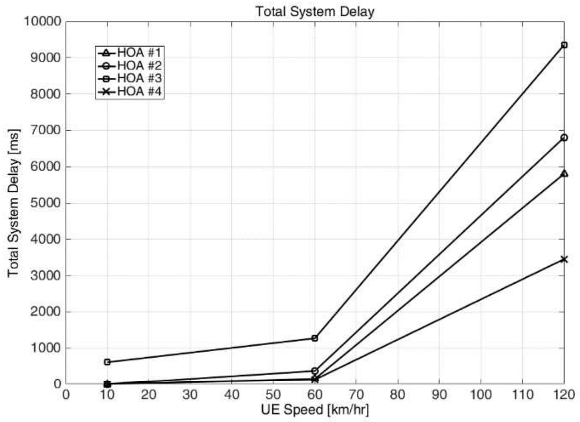

Fig. 4: Total System Delay

The proposed optimization technique which presented in this paper, achieves the best performance according to the performance metrics in the HOA #4 less than the other algorithms.

V. CONCLUSION

In this work, we have presented a proposed technique based on Q-learning that learns the best HOM and TTT values. 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, gives minimum number of handovers, maximum throughput, and minimum delay when it is compared with previous work.

ACKNOWLEDGMENT

This work was partially funded by ONE Lab at Zewail City of Science and Technology, Egypt and Cairo University, Egypt.

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