Handover Optimization and User Mobility Prediction in LTE Femtocells Network

Mahmoud Mandour*, Fayez Gebali*, Ashraf D. Elbayoumy†, Gamal M. Abdel Hamid†, Amr Abdelaziz†
*Department of Electrical and Computer Engineering, University of Victoria, Canada.
{mmandour, fayez}@uvic.ca
†Department of Communications, Military Technical College, Cairo, Egypt.
adiaa@afmic.com - gmabrouk@hotmail.com - abdelaziz.7@osu.edu

***Abstract*—Mobility prediction in cellular networks helps in reducing the number of unnecessary handovers (HO). The deployment of large number of femtocells renders the challenge of reducing the number of unnecessary users' handovers challenge of great importance. Femtocells achieve higher data rate and extend the coverage area in cellular networks. Deploying a huge number of femtocells results in more frequent initiation of an HO procedure. In this paper, a novel algorithm based on the Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ) and some User Equipment (UE) parameters like moving direction and the position inside the femtocell used as HO decision criteria. The goal of the proposed algorithm is to nominate the most proper target femtocell among many candidates and to eliminate the redundant HO in femtocell based cellular networks. Toward this goal, the results show the proposed algorithm will increase/decrease the HO success/failure probability, respectively.**

***Index Terms*—Femtocell, Handover, RSRP, RSRQ, UE parameters.**

I. Introduction

The 3rd Generation Partnership Project (3GPP) is a communion between groups of telecommunications standards associations, have been innovated for of (2G, 3G, 4G, and 5G) cellular networks, to meet the aims of high-speed data communications networks. LTE and LTE Advanced (LTE-A) technologies are the most tremendous technologies for future deployment of cellular networks and wireless communication system. Basically, LTE/LTE-A supports different kinds of deployment cells in the cellular network (i.e. Macro, Micro, Pico or Femtocell), where used to circulate the coverage area depending on the area. However, (Macrocell) is the largest coverage area and used for outdoor subscribers or UEs, it is known as (eNB) in the LTE networks. So, whenever the coverage of macrocell starts decrease imply that (microcells to femtocells) founded. Actually, those are used to increase the capacity and coverage for the indoor subscribers [1].

In mobile communication, it is renowned that the indoor mobile users are the origin of most networks traffic. In modern buildings, service providers hardly trying to provide high-quality service on-the-go for indoor subscribers, but many users facing problems with poor indoor connectivity due to the signal attenuation [2].

In mobile communication, HO technique can be defined as allowing the connected UE's with Evolved Node-B (eNB) to be handed-off to the next eNB without any disconnection [3].

Femtocells are known as either Femtocell Access Point (FAP) or Home Evolved Node-B (HeNB). FAP's, are supposed to be deployed especially (e.g. in offices, schools, universities and in shopping malls .. etc). The FAPs is connected to the service provider's backbone via a wired line such as Digital Subscriber Line (DSL) or optical fiber.

There are many driving factors behind deploying LTE and LTE-A networks. One of the most important is boosting cellular network capacity by shrinking the cell size. So, the need for a technology such as FAPs is mandatory to achieve high capacity, high data rates, signal quality, and low latency for multimedia services indoor or in shadowed areas. Also, to increase throughput in areas with a high density of users, and to offload a large amount of capacity from the network [4].

Recently, many studies aimed to help in users mobility prediction. It can be classified into two schemes. One of them depends on user mobility history and the other one on user current movements. The first one, looking for a certain pattern during the user mobility in the network and creating a user mobility profile. Naturally, this approach has a complicity in mobility management, analysis, and user data updates. So, it has to pay an extra high cost for that. This can also handle a sudden repetitive user movement. On the other hand, the second prediction approach depends on user current movement data as user speed and moving direction without considering mobility history. This one has to pay a lower cost than the user mobility history approach [5].

Overall, the paper is arranged as follows: we describe the related work in Section II. In Section III, we illustrate the LTE based femtocells network architecture and properties. The details of modeling the system and all the assumptions of the proposed algorithm discussed in Section IV. Finally, the result of the study and network performance evaluation presented in Section V, and in Section VI the conclusion of the work.

II. Related Works

Recent studies aimed to improve the HO performance by alleviating the unnecessary handovers and the probability of dropped calls, reducing the HO delay and reserve in advance radio resources by predicting the next handed-over target cell. Predicting the next location of the UE is one of the most important techniques used to reduce the latency and delay in resource allocation. Mobility prediction detects the identity of the target cell for resource reservation before starting the actual handover procedure [5].

In [6], a tentative study was done to create a list with a minimum number of neighbor femtocells to start the femtocell-to-femtocell HO in a dense homogeneous network. The proposed method count on the RSRP and the operating frequency of each femtocell are then defined. So, any femtocell that uses a frequency as the serving femtocell is rejected.

As presented in [7], the authors propose a new mechanism for femtocell-to-femtocell handover to enhance the performance of femtocell based cellular networks. The result shows the proposed scheme has decreased the failure rate of handover also reduce the femtocell neighbor list compared with the traditional scheme which is based on (RSSI) the received signal strength indicator only.

The authors in [8], have proposed a prediction scheme based on the history of UE mobility. The network will recognize the UE whom visit the cell frequently, and then track and records the movement data. Using this information and the position of the user, the network can find a route of the user and the RSRP is considered. This technique minimizes the number of HO's in LTE systems.

The work in [9], propose a prediction technique based on the Markov Chain. This method using the path prediction to predict the target cell for the users. Position and velocity of the users are the main factors helps to expect the heading next cell for the user. In this technique, the author assumed that UE can send its location to the serving cell. Simultaneously; the serving cell is able to keep a database of the network coverage. Based on Markov Process, the UE movement can be predicted.

In [10], the authors use the UE mobility history that provides frequent position and time spend on particular places. Then, using the time as an input to the transition probability matrix. After that, this matrix used to predict the UE movement by Markov Chain equations.

In [11], a position-based path prediction scheme are used. Using a Markov Chain, the user movement has been predicted before the proper handover strategies are done.

III. Handover Decision

Basically, The HO procedure can be divided into four parts [12]:

1) Obtaining Measurement Reports from neighbor FAPs to the serving cell.
2) Appropriate Target FAP Selection.
3) HO Decision.
4) HO Execution and Completion.

Handover decision is one of the most challenging parts in the HO call flow. The proposed algorithm concerning the HO decision based on some common system metrics included in the measurement report. The proposed algorithm based on some main parameters as:

1) RSRQ... Reference Signal Received Quality.
2) RSRP... Reference Signal Received Power.

Both are used to choose the best target cell for the UE. The RSRQ provides more readings about the interference level at the location. Furthermore, RSRQ is more favorable than RSRP for the dense HeNB's network, where the interference level is high. In the LTE network, every 200 ms the measurement report should update these parameters on the reference signal RSRP/RSRQ [13].

IV. System Model and Proposed Algorithm

Basically, we should discuss how the conventional (classical) HO occurred. The classical HO scheme for wireless and mobile networks show up two styles of threshold area in the coverage of the cell. The handover threshold and the exit threshold can be imagined as two different hexagons with an irregular radius around the cell core. The inner hexagon with small radius refers to exit threshold hexagon, and the outer hexagon with larger radius refers to the handover threshold hexagon [13].

Nevertheless; the outer threshold hexagon is the beginning of the HO process. So, for complete a successful mobility, any UE has to end the handover process before finishing the handover threshold hexagon area. If the UE is not handed-over efficiently before this threshold area, the UE call will be blocked (i.e. dropped) [14].

We consider the proposed system shown in figure 1, as a homogeneous cellular network consists of many merged indoor FAPs and some UE's are moving randomly inside the network. Inside the network, every UE has a unique ID and its neighbors will depend on the serving cell type (corner/edge).

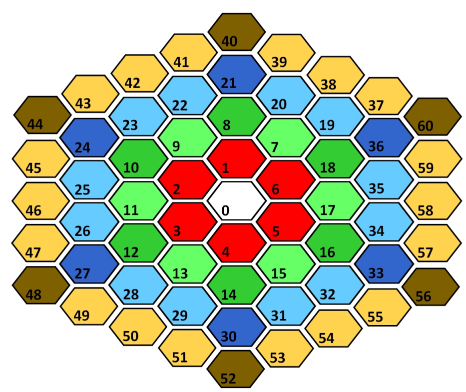

Fig. 1. Geometry of hexagonal grid for cellular-femtocell network.

Figure 1 shows the architecture of the cellular-femtocell network, which has rings around the central hexagon. The darker tone represents as Corner Hexagon, and the lighter tone represents as Edge Hexagon.

In network modeling, we employ the following schema:

1) We assume 60 FAPs, the numbering sequence follows a "spiral" path such that the numbers of hexagons per ring are multiple of 6, e.g. first ring 1-6, second ring 7-18, third ring 19-36, and the last ring 37-60.
2) Two FAPs can be adjacent by being neighbors along the spiral-ling path indicated above, in which case their IDs are also consecutive. In this spiral-ling counting pattern,

we call the FAPs such as 7, 19, 37, ... (gate cells) where the path jumps to an outer larger circular ring.

3) We assumed that we have 6-directions rounded counterclockwise with the first ring (R=1) which labeled as direct 1 for cell ID 1 to the direct 6 for cell ID 6.
4) The main direction is known as the Top direction which has the IDs of (1, 8, 21, 40, .. etc).
5) In figure 1, all hexagons were labeled using a single non-negative integer ID, $0 \leq ID \in Z$; or, equivalently, using the ring number R, $0 \leq R \in Z$, and the user site within the ring S, $0 \leq S \in Z$, where

$$ID = \begin{cases} 0, & R = 0 \\ 3R(R-1) + 1 + S, & R \geq 1 \end{cases} \tag{1}$$

or inversely,

$$R = \begin{cases} 0, & ID = 0 \\ \lfloor ((3 + \sqrt{(}12 * ID - 3))/6) \rfloor, & ID \geq 1 \end{cases} \tag{2}$$

where, $\lfloor \rfloor$ denote rounding towards zero, and

$$S = ID - 3R(R-1) - 1 \tag{3}$$

6) Each hexagon is divided into two different regions, the Core region where (P=0) and the HO region where (P=1).
7) At $t = ts$, when a moving UE located in the Core region that implies the serving cell and target cell will be the same. Only the UE position will change from Core to HO region.
8) A special case at ring $R = 0$, there is only one corner hexagon (the white hexagon in the center). It has six hexagons neighbors are located in ring $R = 1$.
9) At ring $R = 1$ is kind of special because it consists of only corner hexagons, but it turns out the same rules to handle this ring as well as all outer rings just fine.
10) All rings except ring $R = 0$ has $(R - 1)$ edge hexagons between consecutive corner hexagons. Particularly, each outer ring has one more edge hexagon between corner hexagons: which allows compensating the P indexing along the ring and in any other rings.
11) UE located inside any ring, where R = (0) to $(R - 1)$ have 6-neighbors, but in the proposed solution we decrease them to only 3-neighbors based on other parameters as UE position inside the source cell (Core region/HO region) hexagon and its direction of movement.
12) As shown in figure 1, if the user located in the outer ring, first we have to check the station type (will be discussed in Algorithm 1) either (corner/edge).
13) Whenever UE moving towards the boundaries (outer ring) in any direction inside the network (i.e. Not Valid destination cell) which located in the outer ring, the moving direction will be laterally inverted, such as mirror-like reflection. The outer ring acts Specular Reflection and no HO has done in this case.
14) All characteristics with general forms of the proposed hexagonal FAPs network are listed in the table (I).

Algorithm 1 Pseudo code for assigning station types.

```
Input: ID, R, S, Total Femtocells, Corner, Edge
Output: Station Type
Total Femtocells ← N % Initialization step
if ID = 0 then
    R ← 0;
    ID.Corner ← 1;
    ID.Edge ← 0;
else if ID = 1 : 6 then
    R ← 1;
    ID.Corner ← 1;
    ID.Edge ← 0;
else if ID = 7 : Total Femtocells then
    R ← floor((3 + sqrt(12 * ID − 3))/6);
    S ← ID − 3 * R * (R − 1) − 1;
    modulo ← mod(S, R);
end if
while modulo do
    if modulo = R − 1 then
        ID.Corner ← 1;
        ID.Edge ← 0;
    else
        ID.Corner ← 0;
        ID.Edge ← 1;
    end if
end while
return Station Type
```

Algorithm 1 shows the proposed pseudo-code for the algorithm to minimize target FAP by assign station type in the network. We define the input parameters as (ID, R, S, N, Corner, and Edge), an output parameter is the Station Type.

For the user being served by outer edge cell, it has 4-neighbors and only 3-neighbors for the one being served by an outer corner cell. After knowing the station type from Algorithm 1, we need to investigate the UE's mobility inside the network and find-out a schema to know the neighbor cells. Mobility Checker will be described in flow-chart to illustrate when the UE needs HO or not.

Figure 2 shows how the proposed Mobility Checker flow chart works. Basically, start with checking the UE position inside the serving cell either in the Core region or HO region.

After that, the Mobility checker starts based on the values of (α) and (β). (α) is the transition probability of any UE moves inside the serving cell from the Core region to HO region. (β) is the transition probability of any UE moves inside the serving cell from the HO region outgoing to the next core region in the target cell.

The first case, if UE located in the Core region (P=0), then after that we need to check the mobility (α) if UE is moving or not. So, the moving UE will change its position forward to HO region in the same serving cell at ($\alpha > 0$) and for the stationary UE will stay at the Core region where ($\alpha = 0$).

For the second case, when UE located in HO region (P=1), the algorithm checks the mobility (β). Here, the stationary UE will stay as is in HO region ($\beta = 0$) but for the moving one

TABLE I
CHARACTERISTICS OF HEXAGONAL FEMTOCELLS.

Ring	#edge cells per sector	#cells on ring	Start ID	End ID	Top Corner ID
0	0	1	0	0	0
1	0	6	1	6	1
2	1	12	7	18	8
3	2	18	19	36	21
4	3	24	37	60	40
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
R	$R-1$	$6R$	$3R(R-1)+1$	$3R(R+1)$	$R(3R-2)$

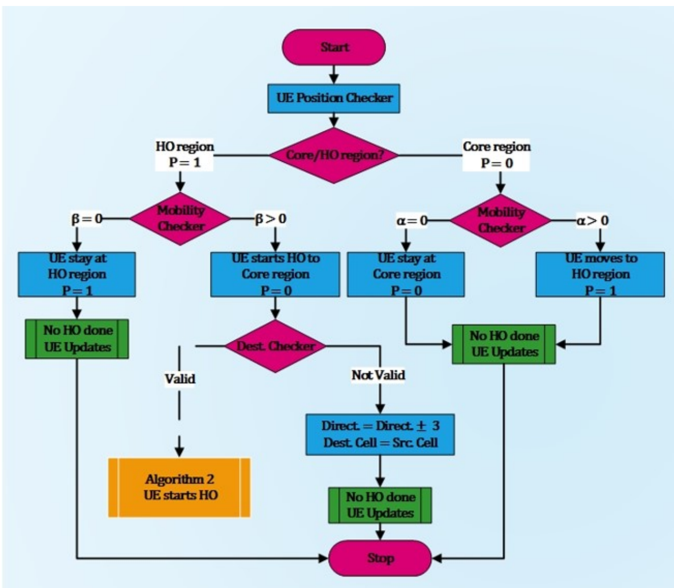

Fig. 2. Mobility Checker Flow Control Procedure for femtocells network.

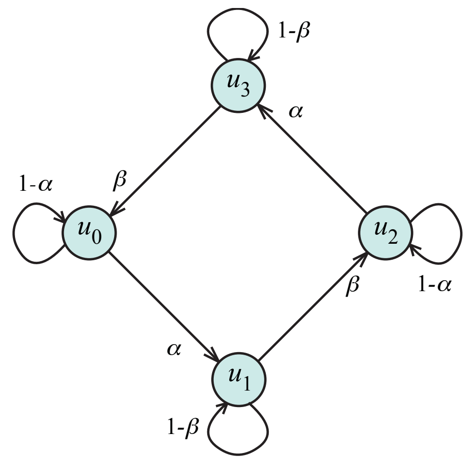

Fig. 3. Markov chain state transition diagram for femtocell system.

$(\beta > 0)$ will be prepared to start the HO process as well as in algorithm 2 to finalize the HO procedure.

Mobility prediction helps to discover which cell will be the next appropriate target cell to finish the HO procedure.

The basis of the proposed HO scheme it to enhance the performance of the LTE FAPs network and optimizing the HO process. Since the number of users in the queue depends on its immediate past state of the queue only, the system can be modeled using Markov chain Models [15].

In this paper, the predictor uses the transition probability matrix **H**, where the values of **H** are derived from the Markov Chains state diagram and the highlighted circles illustrate the different states being studied.

Our model described as a set of different states (u_0, u_1, u_2, u_3). A set of transitions; where every single transition represents a movement from one state to another state.

Figure 3 shows the state transition diagram for the FAP system, where the transition probabilities α and β based on the UE's mobility among the network.

The transition probability matrix **H** is developed from Markov Chain state diagram. In the proposed scenario, the UE will have one assigned probabilities in every two neighbor FAPs.

Now, we have UE moving from state to the next state where, (u_0) and (u_2) represents the (Core region) of serving and target HeNB's, respectively. (u_1, u_3) represents the merged edges (HO regions) between two neighbor serving/target HeNB's (i.e. the two FAPs under investigation). Every column represents the serving HeNB, while the row represents the target HeNB.

$$\mathbf{H} = \begin{bmatrix} (1-\alpha) & 0 & 0 & \beta \\ \alpha & (1-\beta) & 0 & 0 \\ 0 & \beta & (1-\alpha) & 0 \\ 0 & 0 & \alpha & (1-\beta) \end{bmatrix} \quad (4)$$

Basically, α and β are selected to ensure a positive column-stochastic matrix. It means that the summation of each column is equal to 1, means the summation of (α) and ($1-\alpha$) is equal to 1; and the same concept for the other columns.

We apply these matrix equations to MATLAB to solve it as:

$$\begin{aligned} u_0 &= (1-\alpha)u_0 + \beta u_3 && (5) \\ u_1 &= \alpha u_0 + (1-\beta)u_1 && (6) \\ u_2 &= \beta u_1 + (1-\alpha)u_2 && (7) \\ 1 &= u_0 + u_1 + u_2 + u_3 && (8) \end{aligned}$$

By using the Symbolic Math Toolbox, we get:

$$\begin{aligned} u_0 &= (\beta/\alpha)u_3 && (9) \\ u_1 &= (\alpha/\beta)u_0 && (10) \\ u_2 &= (\beta/\alpha)u_1 && (11) \\ u_3 &= (\alpha/\beta)u_2 && (12) \end{aligned}$$

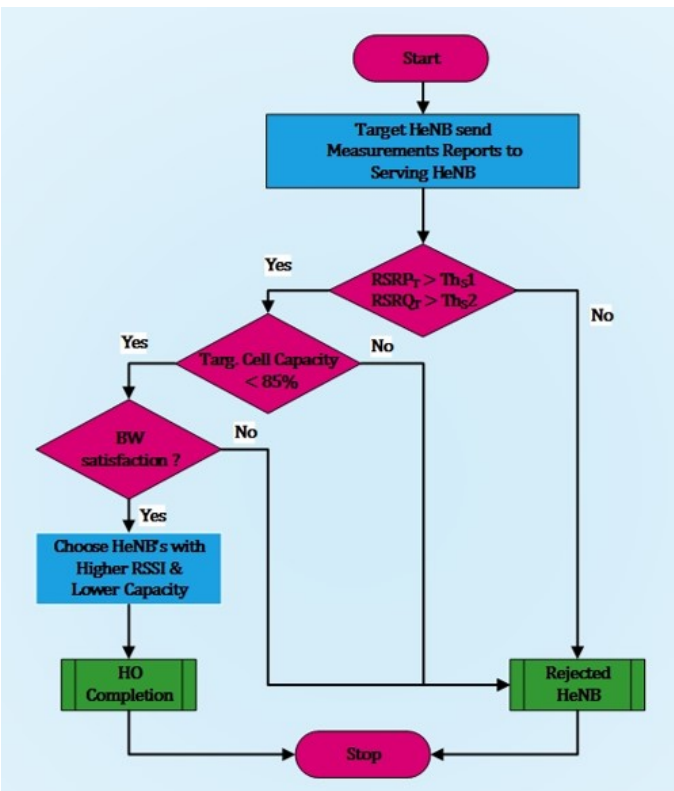

Fig. 4. Handover Decision Procedure for femtocells network.

Figure 4 shows how HO decision phase has done. Starting with the information comes from the Measurement Reports from neighbor FAPs to the serving cell.

Toward the paper aim, we have three steps to nominate the most proper target FAP among many candidates and to eliminate the redundant HO in the proposed cellular network. First, if the (RSRP and RSRQ) of the target cell > thresholds of serving cell it will pass to the second filter; if not, the target cell will be rejected. Then, if the target cell load Capacity < Cell threshold Capacity (assumed 85%) it will pass to the third filter; if not, the target cell will be rejected. The last filter examines the available BW of the target cell.

The pseudo code in Algorithm 2 shows in steps how to arrange all survived target cells according to the higher RSRP/RSRQ, lower load Capacity and BW requirements of the UE are satisfied.

Algorithm 2 Pseudo code for reducing the target FAPs.

Input: $RSRP_T, RSRQ_T, Th_S1, Th_S2, Th_C, P, Cell\ Capacity, BW, HO\ Decision$
Output: $HO\ Completion$

```
RSRP_T, RSRQ_T ← Signal measurements
if RSRP_T > Th_S1 then
    P ← 1 , FAP Selection step
else
    Rejected FAP
end if
if RSRQ_T > Th_S2 then
    P ← 1 , FAP Selection step
else
    Rejected FAP
end if
if Cell Capacity < Th_C then
    P ← 0 , FAP Selection step
else
    P ← 1 , ”Rejected Cell”
end if
if BW ← OK then
    Seclect best FAP
    HO Decision ← 1
else
    Seclect next FAP
    HO Decision ← 1
end if
return  HO Completion
```

Now, UE authorized to access one of the survived target FAP which has the higher signal strength and its load capacity would not exceed 85% of UEs connected of the maximum number of allowed UEs.

By applying this concept, the source FAP can easily select the appropriate target FAP and can achieve our goal of avoiding more number of unsuccessful HO.

V. Performance Analysis

In this section, the performance of the proposed network is analyzed using MATLAB simulation tool. We evaluate the performance for the proposed algorithms in terms of user mobility in HO region with Success/Failure HO probability.

Hence, the proposed algorithm based on some HO decision metrics such as the level of the received signal strength from the target FAPs. Also, we add another feature of network weighty to give flexibility to the service provider for HO decision based on the capacity of FAP to minimize the effect of ping-pong compared with the traditional scheme.

Figure 5 shows a comparison between the proposed and the traditional schemes, the traditional mechanism has a little bit higher HO failure rate than the proposed one, because it based on the received signal strength only. However, the proposed

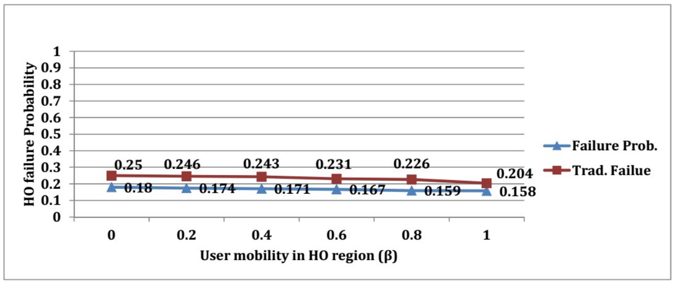

Fig. 5. HO failure Probability.

mechanism reduces the HO failure probability because it considers different factors such as signal strength, cell capacity, and the BW availability.

Note that, by deploying a large number of FAPs in the network, it will not make the HO failure probability rise. So, the HO failure rate of the proposed scheme will decrease as long as increasing the number of deployed FAPs.

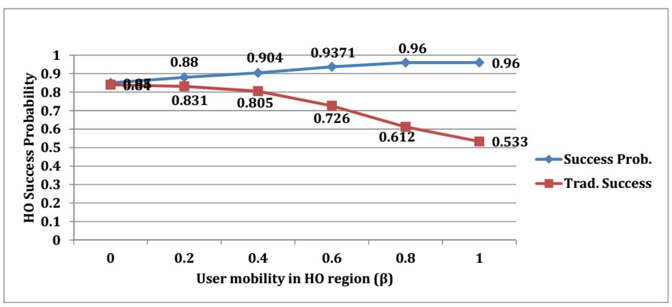

Fig. 6. HO Success Probability.

Figure 6 shows the HO success probability for the survived target FAPs increased, consequently we are using only the survived target FAPs for HO process.

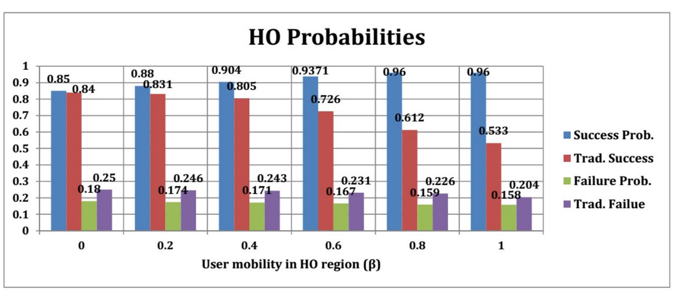

Fig. 7. All HO Probability.

VI. Conclusion

In this paper, the simulation result shows up some advantages of the new proposed HO mechanism as eliminating the unnecessary HO and ensure the load balance of the target FAP and the entire network. Also, the serving cell takes into consideration the real capacity of the available survived target FAP. Note that, if the target FAP has a heavy UE capacity state around the threshold, the serving FAP will give up and will choose the next lighter load cell for the HO process. Finally, this mechanism can lighten the over-charge of resources usage by using the BW resources of selected target FAP only.

The results demonstrate that using the proposed scheme to predict the best target FAP for HO, cause a better performance compared to the traditional procedure. Also, it improves the QoS in the entire network by decreasing the failure probability rate and reducing the effect of ping-pong with an almost stable level.

References

[1] R. Ahmad, E. A. Sundararajan, and N. E. Othman, "Handover in lte-advanced wireless networks: state of art and survey of decision algorithm," *Springer Telecommun Syst*, vol. 66, no. 16, Mar. 2017.

[2] S. H. S. Ariffin, E. A. Sundararajan, N. N. N. A. Malik, and N. E. Ghazali, "Mobility prediction via markov model in lte femtocell," *International Journal of Computer Applications*, vol. 65, no. 18, Mar. 2013.

[3] A. M. Miyim, M. Ismail, and R. Nordin, "Vertical handover solutions over lte-advanced wireless networks: An overview," *Springer Wireless Pers Commun*, vol. 52, no. 30, Mar. 2014.

[4] A. Ulvan, R. Bestak, and M. Ulvan, "Handover procedure and decision strategy in lte-based femtocell network," *Springer Telecommun Syst*, vol. 52, no. 9, Sep. 2011.

[5] T. V. T. Duong and D. Q. Tran, "An effective approach for mobility prediction in wireless network based on temporal weighted mobility rule," *International Journal of Computer Science and Telecommunications*, vol. 3, Feb. 2012.

[6] M. Z. Chowdhury, B. M. Trung, and Y. M. Jan, "Neighbor cell list optimization for femtocell-to-femtocell handover in dense femtocellular networks," in *IEEE Third International Conference on Ubiquitous and Future Networks (ICUFN)*, no. 15, Jun. 2011.

[7] H. SI, Y. WANG, J. YUAN, and X. SHAN, "Mobility prediction in cellular network using hidden markov model," in *IEEE 7th IEEE Consumer Communications and Networking Conference*, no. 9, Jan. 2010.

[8] H. Ge, X. Wen, W. Zheng, Z. Lu, and B. Wang, "A history-based handover prediction for lte systems," in *IEEE International Symposium on Computer Network and Multimedia Technology*, Jan. 2009, p. 1–4.

[9] A. Ulvan, M. Ulvan, and R. Bestak, "The enhancement of handover strategy by mobility prediction in broadband wireless access," in *NAEC Networking and Electronic Commerce Research Conference*, vol. 55, no. 6, Oct. 2009.

[10] Z. H., W. X., W. B., Z. W., and Y. Sun, "A novel handover mechanism between femtocell and macrocell for lte based networks," in *Second international conference on communication software and networks*, vol. ICCSN'10, no. 228–231, Jul. 2010.

[11] K. T., Y. Q., L. J., P. S., and Y. Shin, "A mobility management technique with simple handover prediction for 3g lte systems," in *IEEE 66th vehicular technology conference*, vol. VTC-2007, no. 259–263, Mar. 2007.

[12] P. G., S. B., R. S., S. X., and K. S., "A novel approach for mobility management in lte femtocells," *IJWMN International Journal of Wireless and Mobile Networks*, vol. 6, no. 5, Oct. 2014.

[13] Y. Kirsal, E. Ever, A. Kocyigit, O. Gemikonakli, and G. Mapp, "Analytical modelling of a new handover algorithm for improve allocation of resources in highly mobile environments," *Springer The Journal of Supercomputing*, vol. 71, no. 1, Oct. 2015.

[14] Y. K. Ever, Y. Kirsal, E. Ever, and O. Gemikonakli, "Analytical modelling and performability evaluation of multi-channel wlans with global failures," *International Journal of Computers Communications and Control*, vol. 10, no. 1, Aug. 2015.

[15] F. Gebali, *Analysis of Computer Networks, Second Edition*. New York: Springer, 2015.