A Moving Direction and Historical Information Assisted Fast Handover in LTE-A

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Abstract— **Handover is one of the critical features in mobility management of Long Term Evolution Advanced (LTE-A) wireless systems. It allows the User Equipment (UE) to roam between LTE-A wireless networks. LTE-A is purely on hard handover, which may cause loss data if the handover is not fast. In this paper, an advanced technique proposed which combined between the current UE moving direction and its history information. Our proposed tracks the UE positions to discover its direction. When the UE is being near to handover area the UE starts searching in its history to return back the target cell. If the UE trajectory does not exist in its history then the UE and its serving cell start searching for target cell through using cosine function in order to select target cell. Our proposed technique is expected to increase the throughput, reduce the packet delay and loss, and reduce the frequent handovers.**

Keywords— **historical Information; eNB; LTE-A; handover; moving direction**

I. INTRODUCTION

Recently, the massive increase in using wireless technology in voice and data is clear to all because of the evolution in smartphones and telecommunication traffics. The cellular networks need to upgrade their requirements to meet the demands of data rate, coverage, capacity and Quality of Service (QoS). Therefore, in order to meet these goals the Third Generation Partnership Program (3GPP) has evolved the Long Term Evolution (LTE and LTE-Advanced) depending on the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) structure which is integrated with international mobile telecommunications (IMT-Advance) standard [1]. In E-UTRAN the 3GPP used Orthogonal Frequency-Division Multiple Access (OFDMA) mechanisms in the downlink (DL) and it used Single-Carrier Frequency Division Multiple Access (SC-FDMA) in uplink (UL) [2]. Moreover, it supported the spectrum flexibility which used both ways of duplexing which are Frequency Division Duplex (FDD) and Time Division Duplex (TDD) [3]. The first version of LTE-A was Released 10 and was launched to upgrade standard LTE by supporting new features such as carrier aggregation, advanced multiple inputs multiple outputs, coordinated multipoint and relay node [1], [4]. One of the main advantages of LTE/LTE-A is supporting the compatibility with non-3GPP system switching such as Worldwide Interoperability for Microwave access (WiMAX), WiFi, General Packet Radio Service (GPRS) and Universal Mobile Telecommunications Service (UMTS) [5]. Moreover, other advantages of LTE-A wireless networks are supporting high-speed mobility, having a wide range of coverage area, and boosting high date rates. Despite these advantages, still, there are challenges which we need to cope with such as resource allocation, seamless handover, and mobility management to support wireless technology demands.

In relation to LTE-A E-UTRAN networks, handover mechanism or handoff is one of the important features which allows the UE which is connected to the base station either to transfer to the next base station or to switch between sectors without session disconnection. This is called seamless handover as the process is fast and reliable [5]. Therefore, mobility, high QoS, security, and user's reliability will be based on seamless handover. According to LTE-A features which support the UE's speed up to 500 km/h, this will reduce the accuracy and efficiency of the wireless system and handover will be more critical [6], [7]. In addition, handover in LTE/LTE-A depends purely on hard handover (HHO) instead of soft handover that is used in Third Generation (3G) network. Using HHO means that the interruption handover time, data loss and buffering will be in User Equipment (UE) plane, and the data forwarding is within distributed controllers in handover instead of being centralized controllers in soft handover [8].

In LTE-A, the handover procedure is based on Received Signal Strength (RSS) with hysteresis value in Time To Trigger (TTT) period. Every handover process in E-UTRAN network contains three phases: information gathering, handover decision, and handover execution [7]. Moreover, the efficiency of handover procedure is based on right time and precise measurements of handover decision factors to maintain data connection when UE is being transferred from serving cell to target cell. The wrong time or bad quality of measurement factors will lead to unnecessary handover and then will cause handover failure or ping-pong effect [9]. In addition, the handover procedure needs to adapt with high UE velocity [10]. Therefore, the prediction of target cell during handover time based on the UE movement leads to a reduction in measuring neighbor cells and in unnecessary handovers. The prediction mechanism helps the UEs to take proactive handover decision in order to guarantee QoS and connection. Furthermore, the accuracy of predicting target cell for handover is based on the accuracy of mobile trajectory and cells' availability.

Several target cell prediction algorithms in handover decision are proposed in [11]–[14]. However, in [13], [14] the UE movement prediction is based on tracking the last three positions, while the authors didn't clarify how to select the UE's positions. Moreover, in [11], [12] the target cell selection is based on the probability of the UE mobility action in regular routes, and this proposed scheme cannot be implemented in a real situation.

In this paper, we propose a new handover decision technique for selecting target cell based on the UE trajectory. If the UE moves in regular routes, the target cell is selected from the UE's table. In contrary, when the UE is moving in random routes and this route is not in UE's table, the target cell selection will be based on the UE movement direction. The UE moving direction prediction is based on the location of the serving and neighbor cells, previous UE position and current UE position, and on applying cosine function to estimate candidate cells during handover time. The target cell is selected from the candidate cells through using weight adjustment function. In addition, each handover process is saved in the history table to reduce searching procedure for a target cell in future if the UE used the same route. Our scheme is different from other schemes as we used historical UE trajectory and future UE position prediction. Thus, our proposed scheme is expected to improve the system performance in LTE-A by reducing handover number and neighbor cells measurement reports. Furthermore, the reduction in handover numbers and neighbor cells measurement leads to the reduction in packet loss and packet delay while increasing the handover throughput.

The rest of the paper is organized as follows: Section II the background and related work is briefly discussed. Section III a proposed wireless availability prediction mechanism is discussed. Section IV experimental and scenario of the performance of the proposed algorithm are illustrated. Lastly, Section V concludes the paper.

II. MATERIALS AND METHODS

A. Background

In this section, the LTE-A architecture is presented firstly, and the handover procedure scenario in LTE-A is briefly discussed secondly. Next, the existing handover decision algorithms are described.

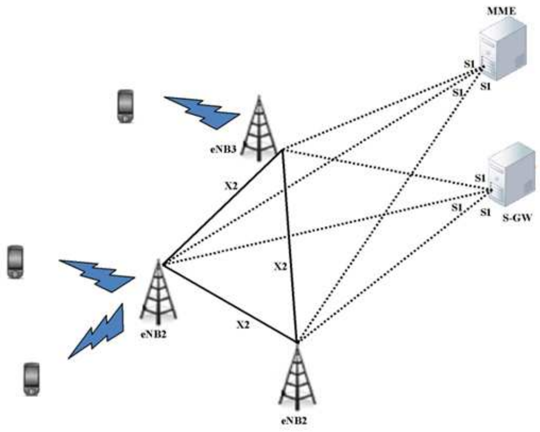

Fig. 1 LTE-A network architecture

1) *LTE-A Architecture:* As illustrated in Fig. 1, the LTE/LTE-A wireless network is divided into four main elements: Mobility Management Entity (MME), Serving Gateway (S-GW), evolved-NodeB (eNB), and User Equipment (UE) [15]. The MME is a control element which is responsible for mobility management inside radio access network, bearer management, security, paging management (mobility handling), and admission control between UE and core network [16].The S-GW is responsible for routing and forwarding functions as well as maintaining data paths between eNBs. Moreover, S-GW works as the mobility anchor for handover mechanism. The eNBs are considered the main component of LTE/LTE-A access network which are connected to MME/S-GW through S1 interface and with each other by X2 interface. Furthermore, the eNB is different from the previous wireless access in the term of distributing management and control to each eNB [17]. Therefore, the handover decisions are distributed between eNBs without the intervention of MME/S-GW, and X2 interfaces are used for exchanging messages between inter-eNBs.

2) *LTE-A Handover Procedure Scenario:* Briefly, the handover procedure in LTE-A consists of three phases. The first phase is information gathering from UEs, the UE periodically obtains Reference Signal Received Power (RSRP) values from serving eNB and neighbor eNBs during an active mode session to decide which neighbor eNB has a better signal condition for the UE switching in handover decision time [18]. In case that one of the UE's neighbors eNBs has a better value of RSRP minus hysteresis (one of handover decision parameters) than serving eNB's RSRP in Time to Trigger (TTT) period, the handover decision is triggered [19]. After that, the UE forwards measurement report message which includes candidate neighbor eNBs to its serving eNB. The second phase is handover decision, in this phase, the serving eNB selects the target eNB from the candidate eNBs list which is nominated by UE in the first phase. After that, the handover preparation to transfer to target eNB is started. In the next step, a new connection starts to be established through execution phase and all resources are transferred from serving eNB to target eNB. In addition, all Internet Protocols (IPs) and routings are lying

under mobility protocols in core network which support UEs connectivity to a multitude of eNBs [17].

3) *Handover Decision Existing Schemes:* LTE/LTE-A supports two types of handover procedures (horizontal and vertical). In horizontal handover procedure, the UE transfers from a network cell to another network cell within the same wireless technology, while in the vertical handover it transfers from a network cell to another network cell with different wireless technology. Moreover, two main types of vertical handover interoperability are supported in LTE/LTE-A wireless system. The first one is among 3GPP that is variated in radio access networks, such as between eNB and femtocells, and the second one is among non-3GPP wireless network, such as from WiMAX to LTE-A or vice versa [7], [20].

Several handover decision techniques have been proposed in the literature to keep QoS between UE and eNBs. In [12], [11], the authors used UE mobility database under the law of UE mobility action for assisting fast and seamless eNBs to select target eNB, in order to minimize the handover number and ping-pong rate in LTE/LTE-A. Therefore, they used parameters which are related to cell_id, dwell time, the number of handovers, and handover's probability of each UE pathway. However, the procedure starts when the UE is in active mode session and the measurement report is sent to serving eNB. The UE compares the current pathway with mobility pattern history to predict the target eNB, and it updates the information of mobility pattern history consequently if needed. In addition, this technique has the benefit of avoiding a ping-pong handover, reducing too early and too late handover, and reducing the cost of candidate eNB's evaluation, while the disadvantage of this technique is the cost of mobility database. Another handover technique uses the UE moving direction to predict the target eNB as well as the effect of handovers number. In [13], [14], [21], the authors suggested a handover decision technique based on tracking the last three positions of UE movements using Global Position System (GPS) to estimate UE's future position with its candidate eNBs. The candidate eNBs are selected in the same UE direction by using cosine function, and the target eNB is chosen from candidate eNBs by using a weight adjustment function. However, this technique proofed the ability to reduce the number of handovers, while it doesn't clarify how to select the last three UE's positions.

Another different technique is related to hysteresis parameter optimization. In [22], the authors proposed an adaptive hysteresis parameter value by using the cost-function algorithm. The cost-function algorithm depends on the sum of the weight of three parameters: load balance between serving eNB and target eNB, the velocity of UE, and QoS (priority of service in real time or not) respectively. Then the result of cost-function is integrated into a standard RSS-procedure. Also in [23] the authors proposed empirical criteria to modify hysteresis and TTT parameters depending on the analysis of sensitivity for each key performance indicator (KPI). The KPIs periodically monitor the sum of weight indicators of handover failure, calls drop and ping-pong performance, then match the recent indicators values with predefined threshold values. Depending on this comparison both of hysteresis and TTT parameters values will be adjusted.

Another different technique is related with Coordinated MultiPoint (CoMP). The CoMP is a new transmission technique used to reduce interference at UE location in multi-distributed eNBs. eNBs cooperated with each other to improve system performance and edge throughputs, and in the UE side, the joint processing (JP) and coordinated scheduling/beamforming (CS/CB) parameters are used to cooperate each UE with among eNBs and keep a signal connection with serving eNB [15], [24]. In [25] the authors proposed new handover technique which supports joint processing (JP) in LTE-A. The handover decision depends on four elements: serving eNB, coordinating set (CS), transmission set (TS), and measurement set (MS). The handover scenario starts when the RSRP between UE and serving eNB is lower than that of neighbor eNBs. The first filter is based on MS where the serving eNB returns back a set of neighbor eNBs which has the highest RSRP and is saved in CS. The second filter is applied to CS list to nominate TS list with the highest RSRP. Finally, the UE starts transmitting data to all eNBs in TS list, and the target eNB has the highest RSRP in TS list during standard RSS-procedure. Once handover occurs, the serving eNB informs all eNBs in TS list to cancel their current transmissions and informs the UE to connect to target eNB. The result showed the efficiency of throughput and minimized handover delay. In addition, the same authors in [26] adjusted their former work through adding a capacity indicator to JP algorithm. Also in [27], authors used the same four previous elements with the addition of target cell element. The proposed algorithm depends on both the UE velocity and RSRPs in MS, thus the CS cells list includes only one type of eNBs when the velocity of UE is high, otherwise, the CS list will include both types of neighbor cells (eNB and small). The TS cells list is selected depending on the selection of the best RSRPs from CS list, and the UE is connected to TS list cells. When handover decision occurs based on standard RSS-procedure, the serving cell will return back the target cell element, the algorithm compares the target cell element to TS list to check if the target cell element is on the list then the handover will be executed, otherwise it will be added inside TS list and then execute handover. The result showed a reduction in interference level with the maintenance of high data rates.

Another different handover scheme in CoMP reduces the handover number in [28] through using the average of coordinated eNBs' RSRPs instead of using the serving eNB's RSRP. The authors proposed that each eNB has three sectors and each CS forms common area. When the UE is at the center of CS it starts moving toward the same CS, in this case, the variation in the average RSRP is small compared to the variation in the RSRP of the serving eNB. Thus the handover will be postponed. On the other hand, when the UE moves toward different CS the conventional handover procedure is triggered.

However, our proposed algorithm must have higher handover performance by reducing both handover numbers and neighbor cells measurement report messages comparing with some of these literature reviews. Furthermore, vertical handover is out of our scope.

B. *Proposed Model*

As we mentioned above about the handover standard procedure, the handover decision trigger is based on the RSRQ and RSRP threshold values between UE and serving eNB. The UE is responsible for sending measurement report message to inform the serving eNB to trigger the handover process, then the serving eNB starts handover preparation phase. In LTE/LTE-A , the handover procedure follows three phases respectively: preparation, execution, and completion [29]. Therefore, in standard handover procedure the UE measurement report message includes the RSSs of both serving eNB and all neighbor eNBs, and then the serving eNB selects the target eNB from neighbor eNBs based on the highest RSRP. This procedure is done for each UE in each handoff process and may lead to data loss or disconnection through wasting the time of searching for candidate eNBs and selecting target eNB. Therefore, we propose a new technique to reduce searching time, handover number, and handover failure in an urban scenario. Our proposed algorithm is based on both the UE moving direction technique which avoids searching for all neighbor eNBs and its connection pattern history to predict the target eNB.

1) *Moving Direction Prediction Process:* In this work, we assume the locations of neighbor eNBs and each UE's position which are known by using GPS [30]. As the UE moves toward neighbor eNBs, and when the RSRP between UE and serving eNB is less than the threshold, two points are recalled from GPS and represented by P1, P2 to discover the future UE's direction. Where P1 is the UE previous position and P2 is the UE current position as shown in Fig. 2.

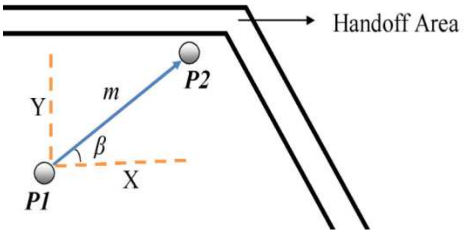

Fig. 2 UE future direction prediction

Based on Fig. 2, the *P2(X2, Y2)* position is picked up near serving eNB border where the RSRP between UE and serving eNB is less than threshold, and *P1(X1, Y1)* is traced periodically based on distance *m*, where distance *m* should be equal to threshold value to avoid *P1* and *P2* are being closer either far way from each other. *β* is the angle of UE trajectory which is used to predict the UE's future direction through analyzing the slope between the previous and current UE positions as obtained in Eq. 1.

$$\beta = \tan^{-1}\frac{Y2-Y1}{X2-X1} \tag{1}$$

In addition, to avoid wasting time and power consumption when UE sends a measurement report to its serving eNB, we apply two filters for selecting the candidate eNBs as follows:

- *Be in the range where candidate eNBs are ahead of the UE:* The range is ±60°, and each eNB is located within this range will have a probability to be included in candidate eNBs list. We chose this range value based on the fact that each eNB has three array antennas which cover 360° angle of signals coverage, as well as each array antenna, provides 120° angle. Therefore, we verified every neighbor eNB of UE through calculating the angle of *∠P1, P2, neighbor_eNB* to be in that range; otherwise, it will be ignored. This angle is calculated by Eq. 2.

$$\theta = \cos^{-1}\frac{(P3\text{-}P1).(P2\text{-}P1)}{|P3\text{-}P1|\,|P2\text{-}P1|} \tag{2}$$

where *P3(X3, Y3)* is the location of neighbor eNB, and *θ* is the angle between *P1*, *P2*, and *P3*, as shown in Fig. 3. The eNB7 verification in Fig. 3 is based on the *θ* value, if $\theta \leq |\pm 60°|$, the eNB7 is considered as candidate eNB.

- *Capacity should be less than the threshold:* The capacity will be verified for only the neighbor eNBs which fit in the range so that to be considered in the candidate eNBs list. Using the capacity will prevent wasting time and power in searching for neighbor eNB which is already busy. For the example in Fig. 4, the UE moves from *P1* to *P2* in serving eNB1, based on its direction the candidate eNBs list has (eNB2, eNB6, eNB19, eNB5, eNB4, and eNB3) if we assume the eNBs capacity is not fully loaded. As we notice that the candidate eNBs list does not have all neighbor eNBs and as a reflection, this reduces the content of measurement reports and power of UEs.

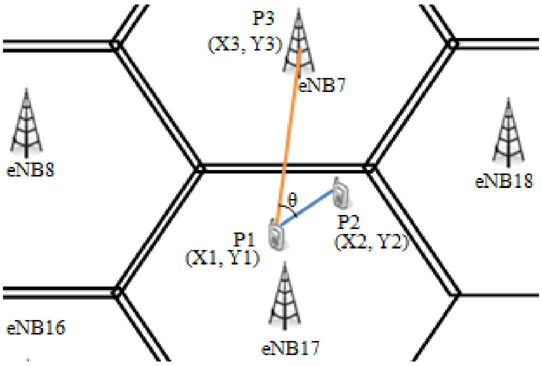

Fig. 3 Angle calculation for candidate eNBs

The next step is selecting the target eNB from candidate list by using weight adjustment. In our proposal model, the smallest *θ* and the closest distance to UE's current position from candidate eNBs list are the appropriate eNB, as well as will be a target eNB. The weight adjustment technique is shown in algorithm 1.

Algorithm 1: WeightAdjustment

```
Input $\theta_{P3}$ and $d_{P3}$
Output : W
O= 1- $\frac{\theta_{P3}}{60}$
D=1- $\frac{d_{P3}}{2r}$
W= $\gamma(D-O)+O$
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Where the θ_{P3} is the angle of eNB, d_{P3} is the distance between eNB and UE's current position (*P2*), and *W* is the weight value which is considered for selecting target eNB. We did normalization of angle and distance to be in standard unification. *O* contains the result of angle normalization and because all of candidate eNBs' angles are less than or equal to ±60°, we normalized with. *D* contains the result of distance normalization, and we normalized with eNB transmission range (*r*). γ is adopted to organize the angle offset and distance value, where $0 \le \gamma \le 1$.

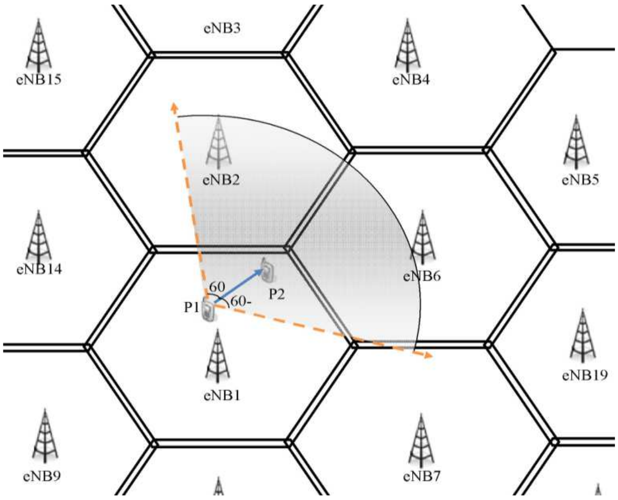


Fig. 4 Candidate eNBs area

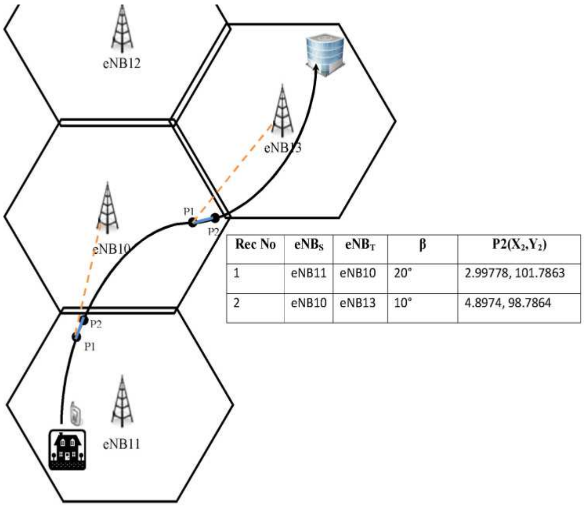
2) *Historical Connection Patterns:* According to moving direction prediction section, the searching time and measurement report consumption should be mitigated through reducing the candidate neighbor eNBs list. In this section, we will exploit the historical UE's trajectory connection patterns to select target eNB directly without applying measurement phase.

In our work, we record the information of UE's trajectory for each passing handover through moving direction prediction process. Table 1 includes the history of UE's trajectory connection patterns which consists of record number (*Rec No*), serving eNB (eNB_S), target eNB (eNB_T), UE's slope angle (β), and the UE's current position (*P2 (X2, Y2)*). Furthermore, these attributes will contribute to being a reference for future UE's movements in an urban scenario where most of the UEs are used in the same trajectories every day.

TABLE I
UE HISTORICAL CONNECTION PATTERNS

Rec No	**eNB$_S$**	**eNB$_T$**	**β**	**P2(X$_2$,Y$_2$)**
1	eNB11	eNB10	20°	2.999, 101.7

According to historical UE's connection patterns table for each passing handover, the UE records its serving eNB name, direction (β), last position in serving eNB (*P2*) and target eNB. In Fig. 5, by assuming that the UE's database is empty, the UE moves from its home to work for the first time. When UE reaches the border of its serving eNB (eNB11), the moving direction prediction process will be called. The first record in the table of Fig. 5 will be created based on the result of moving direction prediction process and the handover decision is triggered on eNB10. In eNB10 the same technique will be applied when UE moves to eNB13 and so the second record will be created in the table.



Rec No	**eNB$_S$**	**eNB$_T$**	**β**	**P2(X$_2$,Y$_2$)**
1	eNB11	eNB10	20°	2.99778, 101.7863
2	eNB10	eNB13	10°	4.8974, 98.7864

Fig. 5 Historical UE's trajectory connection database

Therefore, in the future when the UE uses the same moving direction with the same serving eNB, the target eNB is selected from the database after capacity verification. The target eNB is selected based on matching current UE's moving direction (*eNB$_S$*, *β*, *P2*) with its database to see if there is an existing record and then returning back the target eNB. The next step is verification of target eNB's capacity if its capacity is not full the UE connects directly with target eNB, otherwise, the UE applies the moving direction prediction process and updates the record of new target eNB. On the other hand, if the current UE's moving direction does not match with its database, the UE applies the moving direction prediction process and adds a new record.

That means, the UE's database is acting like a small map for each handover process, and each UE starts by matching its moving direction with its database when it arrives P2 points. If the data does not exist, it will apply the moving direction prediction process and update the database.

III. RESULTS AND DISCUSSION

In this section, we will create a scenario using Matlab R2013a and LTE-Sim simulator [31] to evaluate the performance of our algorithm based on percentages of number of handovers (NHO), packet delay (PD) ratio, throughput (TH), packet loss (PL) ratio, and average of measurement report (AMR) with various UE's speeds. The LTE-Sim simulator simulates the UL and DL scheduling approach in the multiuser/ multicell environment. In addition, Matlab 2013a will be used to draw the simulation scenario and results. The parameters in urban scenarios that will be used in the simulation are listed in table 2 based on [32]. A Macro scenario with nineteen cells with radius 1 km and thirty-seven UEs will be used of simulation as shown in Fig. 6. The system will use the carrier frequency and its value is 2GHz, bandwidth will be 5 MHz, path loss will be in the urban scenario and its equation is $128.1 + 37.6\, log_{10}(R)$. Where R is a kilometer. In addition, the UEs velocity will be in various range (3, 30, and 120 km/h), and they will be moved in constant speed with random and regular movement mobility model. The shadow fading, fast fading, and penetration loss values will be included in our simulation by LTE-Sim as default values. The TTT will be set to 1 ms.

TABLE II
SIMULATION PARAMETERS

Simulation parameters	**Value**
Frequency	2 GHz
Bandwidth	5 MHz
Noise density	-174 dBm/Hz
UE noise	9 dB
Path loss	$128.1 + 37.6\log_{10}(R)$
UEs number	37
eNBs number	19 with 3-sectored
UE speed	3, 30, 120 km/h
Radius of each eNB	1 km
TTT	1 ms
Mobility model	Random & regular move
Data Traffic	Constant bit rate

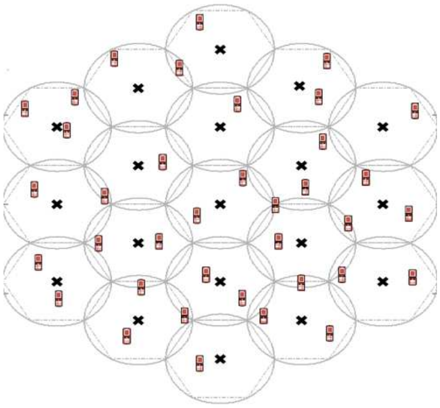


Fig. 6. Scenario environment

In standard handover, when the UEs move in LTE-A macro cells, they measure the RSRP of their serving and neighbor cells to give feedback to the serving cells by using measurement report messages. Based on the measurement report message the serving cell will select a target cell for handover. The system performance is wasted during signal measurements, and because of using HHO in LTE-A which may cause of packet drop and delay.

In our work, we will compare the performance metrics as we discussed above to standard handover procedure and [21]. The performance of handover will be measured through performance metrics as we define as follows:

$$\mathrm{NHOs} = \frac{\mathrm{H}}{\mathrm{I \; X \; T}} \qquad (3)$$

where H is the total number of handovers, I am the total number of UEs, and T is the total simulation time.

$$\mathrm{AMR} = \frac{\mathrm{R}}{\mathrm{I \; X \; T}} \qquad (4)$$

where R is the total number of measurement reports.

$$\mathrm{PL} = \frac{\mathrm{Pack_s\text{-}\,Pack_r}}{\mathrm{T}} \qquad (5)$$

where $Pack_s$ is the total number of packets that generated through simulation time and $Pack_r$ is the total number of received packets.

$$\mathrm{PD} = \frac{\sum_{\mathrm{k=1}}^{\mathrm{N}} \sum_{\mathrm{i=1}}^{\mathrm{I}} \mathrm{delay_{ki}}}{\mathrm{M}} \qquad (6)$$

where $delay_{ki}$ is the total packet delay of $\mathrm{UE_i}$ at its serving $\mathrm{eNB_{k,}}$ and M is the total number of packets that all the UEs received during simulation time. N is the total number of eNBs.

$$\mathrm{TH} = \frac{\sum_{k=1}^{N} \sum_{i=1}^{I} \mathrm{throughput_{ki}}}{\mathrm{N \; X \; I}} \qquad (7)$$

where the $throughput_{ki}$ is the total size of packet correctly received by $\mathrm{UE_i}$.

IV. CONCLUSIONS

Handover is a critical issue in LTE-A wireless network, especially in real-time applications. The presence of unnecessary measurement reports messages to select the target cell and frequent handovers reduces the system performance. In this paper, we discussed an efficient handover technique through combing between moving direction and historical information of UEs. The UE's historical information is used in regular routine route while moving direction prediction is used for the random route. Therefore, our proposal is expected to enhance the system performance through reducing both the neighbor cells measurement and unnecessary handover. Furthermore, the reduction decreases packet delay and packet loss while increasing the handover throughput.

However, our proposal is expected to improve handover performance in horizontal networks (i.e. between eNBs). Therefore, in vertical networks, the handover procedure will be more sophisticated because of the dense employment of small cells under the eNB coverage area. Thus, in our future work, we will improve the handover performance in vertical handovers such as between eNB and femtocell. We will add new input parameters with RSS to increase the handover throughput and reduce handovers number in vertical networks.

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