Performance of Movement Direction Distance-Based Vertical Handover Algorithm Under Various Femtocell Distributions in HetNet

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***Abstract*-The LTE-A networks system depends solely on the Hard HandOver (HHO) to allow the user to migrate among the cells. The HHO procedure depends mainly on the Received Signal Strength (RSS) along with the hysteresis parameters to trigger the procedure. However, the scenario still produces high handover probability and throughput degradation due to the severe interference when high density of the femtocells has been deployed. In this paper, new multi-criteria handover decision parameters are proposed to support the handover decision in both the dense macro-cell and the femtocell environment. The User Equipment (UE) moving direction and the distance between the UE and the femtocells are selected to assist handover decision in heterogeneous network. The proposed Movement Direction Distance-Based Vertical Handover Decision (MDD-VHD) algorithm has been simulated and evaluated under three femtocells distribution scenarios. The simulation results show that ratios of the packet delay and loss are improved as the femtocell deployment is distributed from the middle towards cell-edge by 85% and 60% respectively.**

Keywords-- LTE-A; HetNet; femtocell; handover

I. INTRODUCTION

In the last two decades, an obvious increase in the demand for wireless telecommunications was observed. This saw an exponential rise in the use of smart equipment devices. The Cisco Visual Network Index (VNI) global mobile data traffic forecast showed a tremendous rate of increase in broadband traffic up until the year 2020 [1]. One of the solutions is the interoperability between the homogenous and the heterogeneous networks (HetNets). The Third Generation Partnership Program (3GPP) had released the Long Term Evolution (LTE) and the (LTE-Advanced) as new radio access wireless networks so as to meet these objectives. The new radio access technology supports small cells (femtocells) in the HetNet [2], [3]. Therefore, better indoor/outdoor coverage in the LTE-A can be achieved. Hence, because LTE-A technology must support high-speed mobility, mobility improvement is an essential feature of the network. The femtocells are low-powered nodes and cover of a small coverage range (30 – 40 meters) [4].

Moreover, due to the small coverage area, a huge number of femtocells is deployed in evolved NodeBs (eNBs). Moreover, the number of users which is supported by each femtocells is limited and grouped into three groups (open, close, and hybrid) according to femtocells constraint policies [5]. Furthermore, the LTE-A wireless network uses the HHO procedure for devices roaming between the eNB and femtocell networks. Therefore, the handover process between the (eNB and femto) cells remains a dilemma. The seamless handover becomes more complicated, especially that the HHO decision is based only on the RSS parameter along with hysteresis threshold, as clarified in Fig. 1.

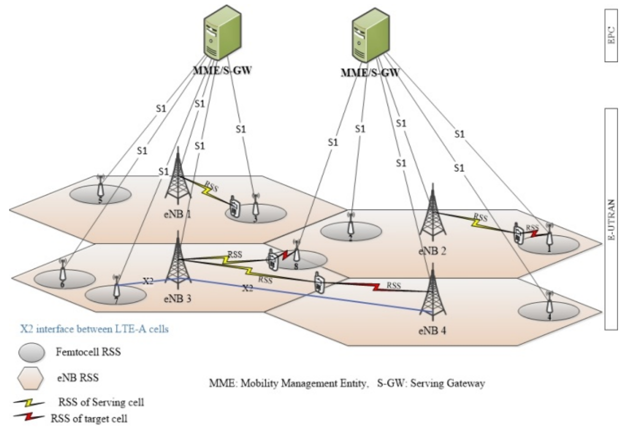

Fig. 1. LTE-A system architecture with the handover technique

The HHO procedure is carried out in three primary stages: collection of information, decision, and execution respectively [6]. In the first stage, data associated with wireless network cells and UEs is gathered for the handover starting process. Subsequently, this data is utilized to assess the candidate wireless cells in the decision stage. After selecting the target network cell in the previous stage, a new connection is built up in the execution stage. Then, all the resources are forwarded from the old network cell (serving cell) to the new network cell (target cell) in the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN). Moreover, all Internet Protocols (IPs) and routings will be categorized under mobility protocols in the Evolved Packet Core (EPC). However, the long searching time needed for nominating and selecting the target cell for handover minimizes the efficiency of this type of handover.

The aforementioned LTE-A HetNet will increase the efficiency of the wireless network system. However, the mobility management in HetNet system is difficult, i.e when the UE is in the active session within the density of femtocells, it is necessary to search for and identify the cell to permit the UE to recognize the femtocell which is in proximity [5]. Therefore, the performance of the handover decision is based on the specific time and the accurate measurement of handover decision parameters. Thus, both the density of femtocells in a certain area and the UE velocity pose new challenges. Therefore, in LTE-A wireless networks; the handover decision in the standard procedure must be updated using several input parameters along with the RSS.

The paper is structured as follows: in Section II, the related work is briefly explained, while a proposed mechanism for wireless accessibility prediction is discussed in Section III. Section IV shows the scenario and results of the proposed algorithm performance. Finally, Section V concludes the work.

II. RELATED WORK

This section includes studies on the femtocell networks and handover types that are related to femto and eNB cells.

A. Femtocell

The femtocells provide better service in indoor areas and can be deployed even by enterprises or users (unplanned) to handle the traffic for a Closed Subscriber Group (CSG) [7]. The femtocells are low-powered nodes and they are prepared with omnidirectional antennas of a small coverage range. Moreover, they can connect to the EPC within user's broadband connection. Femtocells have three types of policies; these are open access which supports the access to all users, closed access which supports the access to users whom are in CSG group and hybrid access which support the access to all users with the priority given to the users in CSG.

B. Vertical handover

There are three handover scenarios among eNB and indoor cells (femtocells) as illustrate as follows:

- Hand-in: this scenario of handover occurs when the UE moves from the eNB to femtocell coverage area, as the UE has to choose the best femtocell out of an enormous number of femtocells.
- Inter-femtocells: this scenario of handover is similar to the hand-in procedure, but different in which the UE selects the best femtocell for handover from a large number of femtocells.
- Hand-out: this scenario of handover triggers when the UE goes from the femtocell to eNB coverage rang. In this case, the handover scenario is not too difficult compared to the Hand-in because there is only one target eNB for the UE to handoff to.

A wide variety of algorithms have been proposed to handle the handovers using additional parameters in [8-13]. In [8]–[10], the authors modified the RSS-procedure in the standard handover for the sake of avoiding the existence of asymmetric power among eNB and femtocells. In [8], the authors suggested a new RSS-procedure for the hand-in handover. The main idea of this algorithm is to detect the ideal arrangement factor by integrating the RSS of the source eNB with the RSS of the target femtocell, so as to conclude a reasonable handover criterion. However, this technique introduced good results in terms of minimizing the asymmetry in power; increasing the computational complexity and then reducing the system performance. In [9], the authors reduced the computational complexity by considering the contrast/variation in the transmission power among the eNB and femtocell cells. The main attribute of the algorithm is based on the integration of the RSS and path loss factors in the source eNB and target femtocell. The results showed a decrease in handovers number and an improvement in the use of femtocell compared to [8]. Conversely, the traffic circumstance in the femtocells was not taken into account in both proposals. Therefore, the authors suggested a new handover decision algorithm in [10], according to/considering the traffic circumstance and propagation elements. The key feature of the algorithm is to integrate the RSS with the traffic influence (i.e estimated service time) of the source eNB and target femtocell cells. Moreover, with respect to researches on movement prediction, in [11], the authors used history of the UE mobility and cells location to improve the handover decision performance, by reducing the handovers number. The algorithm works by predicting how long the UE stays in the femtocell range in order to prevent temporary femtocell visitors.

Another technique was proposed in [13] and [12] for enhancing the 3GPP standard handover by reducing the number of candidate cells in dense femtocells scenario. In [13], the authors suggested an effective signaling measurement and cell searching processes for hand-in decision. The proposed procedure includes a location-based management of the neighbor eNB in order to exclude the cells that are out of range. Once the UE path has been calculated using the previous measurement consequences, all the nearby femtocells to UE position are selected to be part of the neighbor eNB list. The subsequent part of the proposed outline is the handover decision assisted by femtocell, which confirms that the UE handover is seamless. However, in both sections of the algorithm, the eNB and femtocell cells are required to maintain the UE path or monitor the uplink signal that are derived from the UEs by using additional wireless interfaces of the eNB and femtocell cells. On the contrary, in [12], the authors used a Self-Organizing Network (SON) technique which depends on the structure of the network in order to reduce the list of neighbor femtocells in a femtocell density topology.

III. PROPOSED MODEL

The conventional handover decision that is only based on the transmission power (RSS) is not sufficient for the two-tier wireless network. Consequently, extra input parameters are needed along with the RSS. Therefore, our proposed MDD-VHD algorithm includes additional parameters with RSS.

The UE will knows its speed from using the GPS technology [14] and the Queue positions of UE are saved in the UE cache. Moreover, the MDD-VHD algorithm is based on three main factors:

- The UE speed: to prevent high-speed UEs from connecting to femtocells. We suppose that the maximum speed of UE that is needed to hand-off to femtocells is 30 km/h [15].
- The distance between the current UE location and femtocell site: to impose the UE to be handed-off to the femtocell that is located in front of the present UE position.
- The UE trajectory: to expect the future UE movement for the sake of selecting the appropriate target cell.

In our proposal model, all femocells modes are open access and they admit any UE handover request. Moreover, The Distance among the present UE location and femtocells' sites can be determined as follows. Firstly, we add the scanned distance periodically along with the RSS in the UE signaling measurements. Since the UE goes toward to femtocells, and while UE signaling measurement catches the distance (*d*) among UE current position and femtocell site is less than the predetermined value, the UE send the measurement report message the serving cell to start handover process, as illustrated in Fig.2.

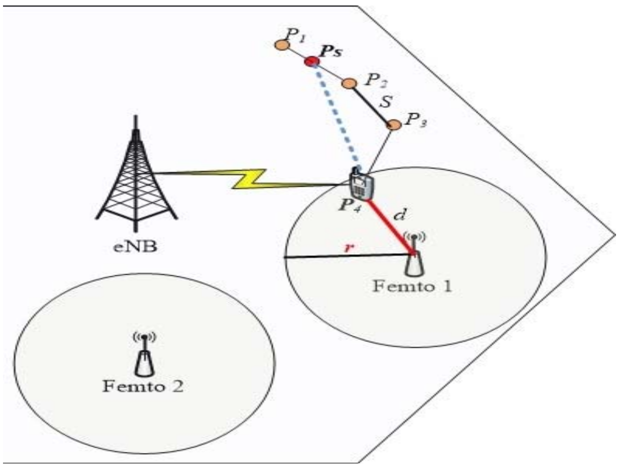

Fig. 2. The femtocells and eNB deployment scenario

Based on Fig. 2, the UE goes from P1 to P4 and upon its access to P4, the UE signaling measurement catches the d which is among the current location of theUE and the location of femto1 and is less than the predefined value, as so the UE hands-off to femto1. Be aware that the d should be less than (r), where r is the radius of the femtocell.

Secondly, to predict the future UE position we should know the previous UE mobility. Therefore, the polynomial function is used in/by each UE in order to draw its own trajectory [16]. Based on Fig. 2, P_1, P_2, P_3, and P_4 are considered in expecting the next UE position. In addition, each UE site involves both x and y coordinates that are gained from GPS in each *S* threshold. The Queue (*Q*) is used to track the last four locations of UE, and the future position of the UE is based on the polynomial equation calculation for these four locations.

The polynomial function *f(x)* generates 4 locations and each location is stored in the UE memory as (x_i, y_i), where i is from 1 to 4. The polynomial function in Equation (1) is used:

$$f(x) = a_0 x^j + a_1 x^{j-1} + a_2 x^{j-2} + \ldots + a_j \quad (1)$$

where *j* is the current UE location and $a_0 \neq 0$. Therefore, for estimating the future UE direction as linear prediction, we suppose a location (*Ps*). The *Ps* location involves *x* and *y* coordinates, where *x* coordinate is located between $P_1(x)$ and $P_2(x)$. The $Ps(y)$ is gained from the polynomial function outcome. Thereafter, investigation of the UE pathway will be based on the linear prediction among $Ps(x,y)$ and the present UE location $Q\text{-}last(x_4,y_4)$, as shown in Fig. 3, when the UE goes from Cell2 to Cell1.

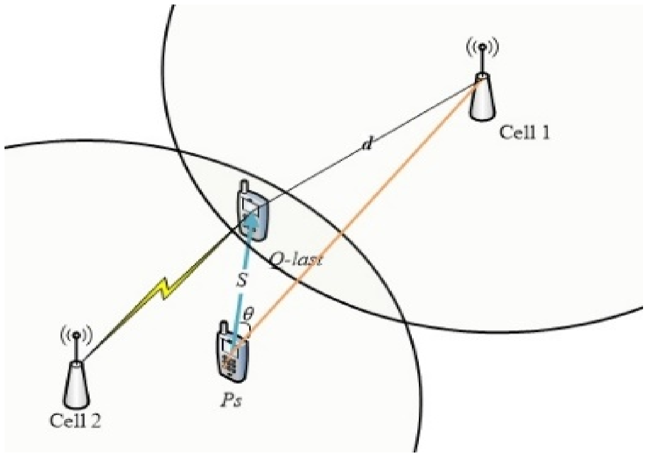

Fig. 3. UE pathway and candidate cells collection

Moreover, the angle, θ, between P_2, P_1, and *C* of the candidate cell can be determined by the Equation 2.

$$\theta = \cos^{-1} \frac{(C-P_1).(P_2-P_1)}{|C-P_1|\,|P_2-P_1|} \quad (2)$$

where $C(x,y)$ is the position of each neighbor cell. In addition, the *weightAdjustment* algorithm will be used for choosing the target cell from the candidate cell list as shown in Algorithm 1.

Algorithm 1: WeightAdjustment

1:Input θ_c and d_c
2:Output: W
3: A_norm= 1- $\frac{\theta_c}{\alpha}$
4: D_norm=1- $\frac{d_c}{r}$
5: W= A_norm + D_norm

where θ_c is the angle of eNB, dc is the distance among eNB and UE's present position (P_2), and W is the summation value, which is considered for selecting the target cell. Moreover, normalization was also performed for both the angle and the distance, so that both would be according to standard unification. α is the angle value that is used for normalization. *A_norm* contains the outcome of the angle normalization and because all the candidate cells angles are less than or equal to |± α °|, this angle (α) was used for the normalization process. *D_norm* contains the outcome of distance normalization, and this was normalized using the cell transmission range (r) to increase the angle priority, as the distance of all nominee cell list is less or equal to r.

Furthermore, our proposal model is executed in three types of handover scenarios: the hand-in, inter-femtocells, and hand-out as illustrated in Fig. 4.

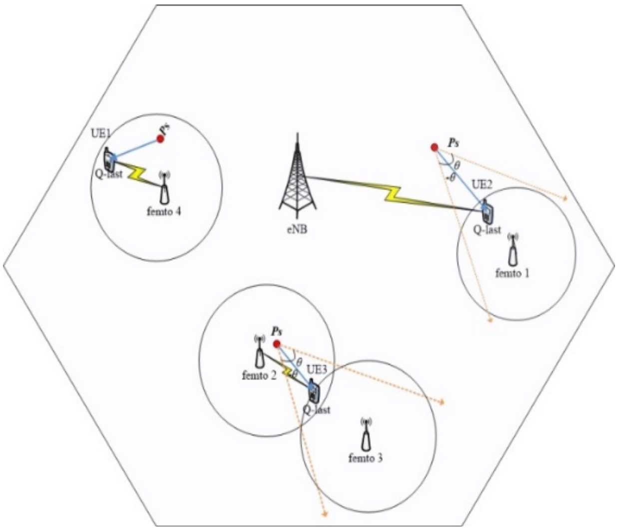

Fig. 4. The three types of handover procedure

In the hand-in scenario, the handover is triggered on the basis of the distance (d) among the present UE position and location of the neighbor femtocells. If there is a femtocell that meets the distance condition, the UE sends a message to its serving eNB. Thereafter, each neighbor femtocell is investigated by the serving eNB based on the UE trajectory. The investigation, in Fig. 4, is based on the θ cost; if θ is ≤ |α|, the neighbor femtocell will be counted in the list of the candidate cells. Therefore, the list of the candidate cells will contain (femto1) based on UE2 direction in Fig. 4. Subsequently, the serving eNB will choose femto1 from the list of candidate cells based on the *WeightAdjustment*. Thereafter, the handover process occurs.

In the inter-femtocell handover scenario, the handover is triggered when two conditions are met regarding distance (d). The distance (d) which is among the UE location and serving femtocell site should exceed the predefined value, and the distance (d) which is among the present UE location and neighbor femtocells site should be less than the threshold value. Then, the aforementioned procedure in hand-in handover will be applied. Based on Fig 4, the serving femtocell (femto2) will select the target cell (femto3), where θ =|α| as shown in UE3 in Fig. 4, and the UE3 will be handed off to femto3.

In the hand-out scenario, handover is triggered when the UE goes toward the femtocell and the distance (d) which is among the present UE location and its serving femtocell site is less than the predefined value. Furthermore, if the UE did not find a neighbor femtocell that is close to its position during the control phase of the measurement, the UE will reconnect to its serving eNB. For this reason, a variable, named (BS_s), is used in our algorithm to preserve the eNB-ID which belongs to each UE. This variable is stored in the memory of every UE. Based on Fig 4, UE1 will send a message to its serving femtocell (femto4), which contains the BSs value, so that to hand off to the main eNB.

The proposed MDD-VHD scheme is presented in Fig. 5.

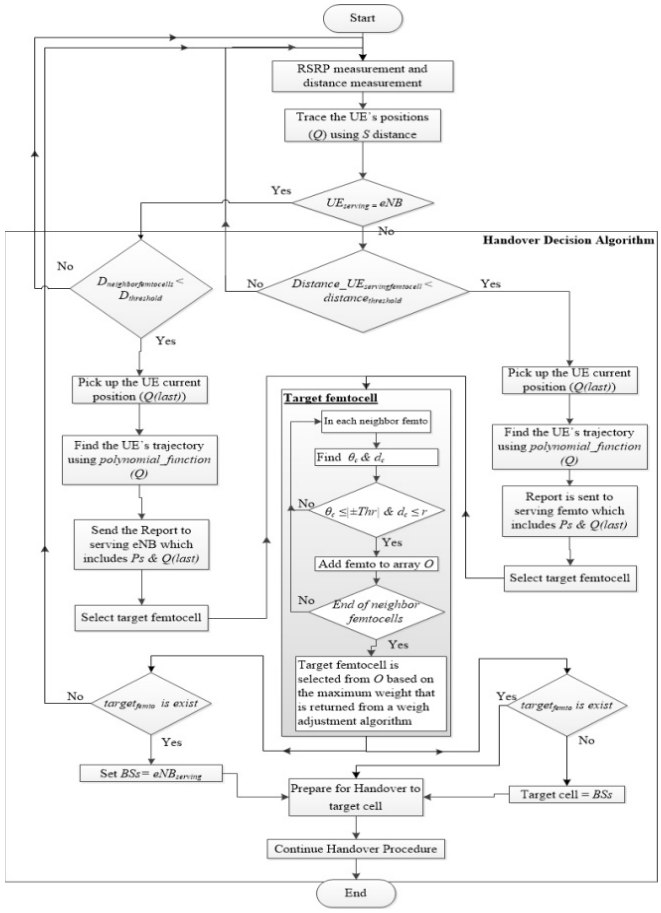

Fig. 5. MDD-VHD algorithm

IV. SIMULATION AND RESULTS

The LTE-Sim simulator is used for evaluating the performance of the proposed scheme. Moreover, the performance metrics that are used in the evaluation are: the packet delay ratio and packet loss ratio for various femtocells number in three distributed scenarios. Furthermore, the full defined analysis of MDD-VHD algorithm in standard femtocells distribution is highlighted in [17]. Packet delay and packet loss ratios are defined as follows:

- Packet delay ratio is given in Equation (3):

$$\text{Packet delay ratio} = \frac{\sum_{k=1}^{N} \sum_{i=1}^{M} delay_{k,i}}{E} \qquad (3)$$

where $delay_{ki}$ is the total packet delay of UE_i at its serving $cell_k$, and E is the total number of packets that all of the UEs received during simulation time. N is the total number of femtocells and U is the total number of UEs.

- Packet loss ratio

This metric evaluates real-time service because retransmission is not applicable. The invalid packets are defined as the ones arriving at their destination with a delay of more than 100 ms, as per Equation (4).

$$\text{Packet loss ratio} = \frac{Pack_s - Pack_r}{T} \tag{4}$$

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

The eNB scenario involves one cell with a radius of 1 km. The number of femtocells is randomly distributed into three scenarios (close, middle, and the edge) from the eNB tower and has incremental values of 20, 40, 60 and 80, as exposed in Fig. 6. Moreover, UE speeds are configured as 25 km/h while UEs number is configured as 20 and they start moving from the eNB tower location. Table I shows the parameters in/of urban scenarios that are used in the simulation.

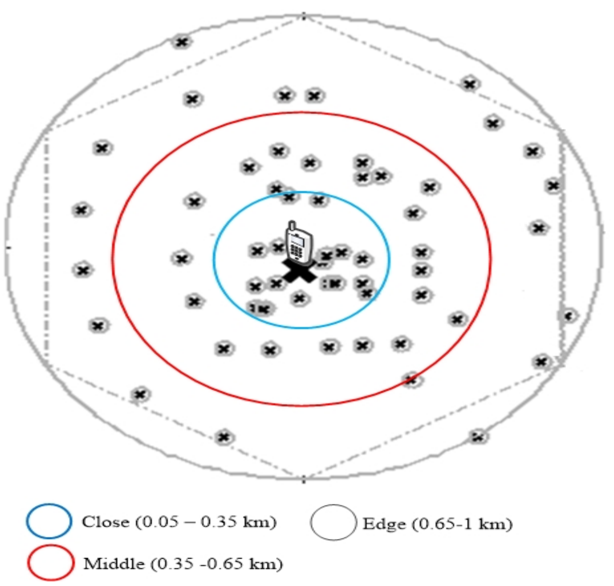

Fig. 6. MDD-VHD topology

Figs. 7 and 8 show the comparison of ratios of packet delay and packet loss in the proposed algorithm in femtocells distribution scenarios. Moreover, both Figures show that the lowest packet delay and loss ratios are when the density of femtocells is in the middle while the highest is when the femtocell density is at the edge. This is because the UE starts moving from the eNB tower location and the density of femtocells when concentrated closed to eNB tower affects the packet loss by increasing both the handovers number and interference. Furthermore, when femocells are distributed at the edge, the packet loss increases because of the weakness of RSS among the UE and its serving eNB while UE executes hand-out handover and the density of femtocells is less than their density when distributed in the middle.

TABLE 1: THE PARAMETERS OF SIMULATION

Parameter	Values
Environment	eNB, femtocell, (Urban zone)
Bandwidth	5 MHz
eNB Frequency	2 GHz
Femtocell Transmit Power	21.5 dBm
eNB Transmit Power	43 dBm
Radius of femtocell	30 meters
Radius of eNB	1 km
Resource Block	180 kHz
Noise density	-174 dBm/Hz
Subcarrier spacing	15 kHz
eNB Path loss	$128.1 + 37.6 \log_{10}(R)$
femtocell Path loss	$127 + 30 \log_{10}(R)$
femtocell layout	20, 40, 60 and 80
eNB layout	1 eNB
UE speed	25 km/h
Number of UEs	20
Mobility model	Random direction
Data Traffic	Constant bit rate
θ for femtocell searching	[25], experimental value
TTI/TTT	0.8 s / 0.1 s
Simulation time	140 s

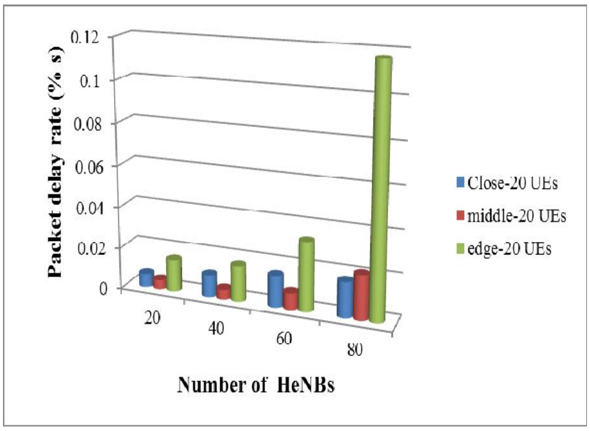

Fig. 7. Comparison of packet delay ratio

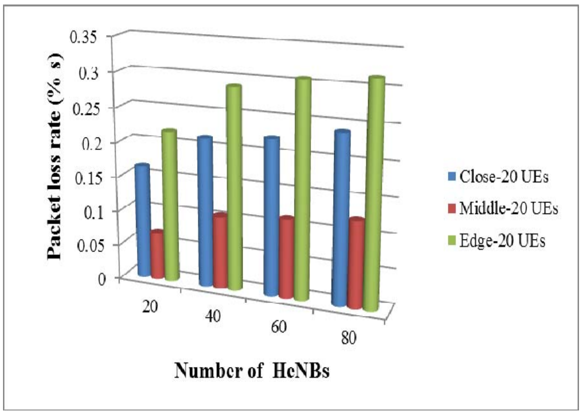

Fig. 8. Comparison of packet loss ratio

V. CONCLUSION

The MDD-VHD algorithm is been developed by considering additional metrics; distance, UE velocity and UE movement and direction. The algorithm then been executed and analyzed under three femtocell deployment scenarios based on packet delay and packet loss ratios. In conclusion, the proposed method outperformed the conventional method but best suit for middle scenario.

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