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Analysis of Trajectory Path Impacts on VHO Algorithms in Integrated Heterogeneous Networks

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Abstract

With the development of wireless communication technologies, the next generation of wireless communication systems is expected to be the convergence of different wireless networks with diverse applications. This paper investigates the analysis of a vertical handoff decision algorithm that enables access network selection at an E-UE of interest. A performance study using a new integration model of 3GPP Long Term Evaluation (LTE) network and Wireless Local Area Networks (WLANs) shows that the proposed vertical handoff decision algorithm is able to determine when a handoff is required and selects the best access network. We evaluate the performance of proposed network model as the E-UE of interest is moved in the integrated heterogeneous environment of WLAN and LTE cellular wireless networks. We evaluate the number of handoffs, throughput and decision delay by using proposed VHO algorithms with hysteresis and dwell timer approaches.

Keywords: *Vertical handoff, WLAN, LTE Network, Received signal strength, Heterogeneous network, Standard deviation, E-UE of interest*

1. Introduction

The impact of wireless communication is all around the world and its usage is rapidly increasing [1][2]. Providing the stabilized and error free communication at various areas and levels is the main challenge faced by communication networks and the level of its users should be increasing time-to-time. An efficient and stable communication system should be required for increasing the value and status of networks. The current changing private and professional lifestyles have created a growing demand for communications. A heterogeneous network can be defined as a network which comprises of two or more different access network technologies [3]. The key feature of such an integrated heterogeneous network is to support a seamless vertical handoff. Traditional handoff refers [4] to transition of on-going call or data session from network to another network. If these two networks belong to same wireless access, then it is called as horizontal handoff. In contrast, if both networks are of two different types of wireless networks then it is called as vertical handoff.

The integration of LTE Network and WLAN are given renaissance for the modern way of communication system. WLANs are operated in unlicensed frequency band with data rates up to100Mbps [5], within the radius of 100m. A few latest techniques like IEEE 802.11n, 802.11ac and 802.11ad will provide data rates in terms of Gbps. The only disadvantage with WLANs is its poor coverage area. A lot of research work is going on improving the coverage area of WLAN. On the other hand, cellular networks like 3G, 4G will provide less data rates, but the coverage area of these networks is very large. That's why the integration of WLAN in cellular networks is unavoidable and, in a world, hungry for mobile devices capable of

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simultaneously handling High Definition (HD) streaming video, Voice over IP (VoIP) calls, web page delivery, fast data transfers and other multimedia facilities of user will be full filled. The authors of [6] propose an ultra-dense network which provides good data rates and network throughputs, but inter-cell interference and handover counts also increased with it. In [7], the author considered integration of heterogeneous network with macro and small base station to analyse the handoffs rates for different vehicular speeds. In [8], a similar heterogeneous ultra-dense network is proposed to obtain optimum coverage in terms of minimal Radio Link Failure (RLF) rates. A multi-level thresholds handoff algorithm is proposed in [9]. The performance results obtained, shows that an 8-level threshold algorithm operates better than a single threshold algorithm in terms of forced termination and call blocking probabilities. Fuzzy-logic theory based Quantitative Decision Algorithm (FQDA) is proposed by considering RSS, bandwidth and monetary cost [10]. A Combined SINR based Vertical Handoff algorithm (CSVH) with combined effects of both SINR from WLAN and WCDMA have been considered in [11]. In [12], a reliable method to accommodate the movement by measuring the received signal strengths to the base stations and from the user has been considered. The received signal strength decreases when the distance from the base station increases. In order to avoid excessive handoffs, dwell timer and hysteresis margin is used. The total Handoff delay is the sum of the average signal delay and the hysteresis delay [13]. In small cell base station deployment, frequent handoffs resulted due to fast moving users and may cause packet delays/losses and increase network load also [14]. The authors in [15], analysed Handover failure probability with different handover conditions for high speed train scenario in LTE-LTE network.

In this paper, we consider Received Signal Strength (RSS) based VHO algorithm by considering two wireless systems in concern: LTE cellular network and WLAN. To assess VHO algorithms, we lay out analytical framework to evaluate the proposed VHO algorithms in which the E-UE of interest is moved in a trajectory path from LTE cellular network coverage area through WLAN coverage. In order to elucidate, we put forward two VHO based decision algorithms, hysteresis and dwell timer algorithms with hysteresis margin (H) =4dB, dwell timer = 5sec in order to lower the number of handoffs and to avoid the ping pong effect. We contemplate the main performance evaluation metrics like the number of handoffs, handoff delay and throughput. The effect of the standard deviation of shadow fading (σ_{dB}) and non-negligible effect of velocity of the E-UE on the performance has also been investigated.

The remainder of this paper is organized as follows: in section 2, the network model is discussed in detail. Section 3 describes assumptions used in this paper and handover algorithms to obtain performance evaluation criteria of our proposed model. In section 4, numerical results are presented. This paper is concluded in section 5.

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2. Network model

In our proposed system model, we consider two heterogeneous networks i.e., WLAN coverage area within the LTE cellular network and assume that the E-UE of interest is moving from point A to point B, in a circular path through WLAN coverage area as shown in [Figure 1].

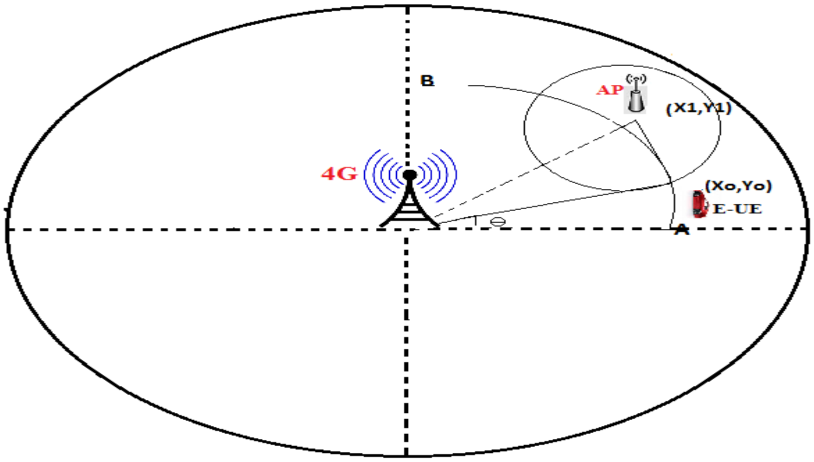

Figure 1. The system model

While the E-UE of interest is moving from LTE cellular network to WLAN coverage area, the user will face only one vertical handoff. But in practical scenario signal fluctuates more and more at E-UE of interest because of shadow fading effect. Due to this we will observe two different types of vertical handoffs i.e., upward (a vertical handoff from WLAN to LTE cellular network) and downward (a vertical handoff from LTE cellular network to WLAN). So, we have evaluated the performance of proposed network model in terms of the average number of vertical handoffs, through put and decision delay as a function of the standard deviation of shadow fading, velocity and radius of circular path in which the E-UE of interest is moved. The figure represents the overall scenario in which WLAN is surrounded by LTE cellular network. In our system model, initially, the E-UE is connected to LTE cellular. As it moves towards the AP of WLAN, received signal strength increases gradually. After some time, the signal strength increases even above LTE cellular. At that point it detaches from LTE cellular and start accessing WLAN making handoff. If WLAN signal strength is much enough, it accesses the WLAN even though LTE cellular is present. Thus, continuous connectivity to internet is maintained. Similarly, when the E-UE starts receiving higher signal strength from LTE cellular than the RSS from WLAN it switches to former making handoff again. At any instant let us say that the E-UE of interest is at M(x_0, y_0) and AP of WLAN is fixed at A(x_1, y_1). Then we can express the distances from the figure as follows,

$$\left.\begin{aligned} x_0 &= R*cos(\phi) \\ y_0 &= R*sin(\phi) \end{aligned}\right\} \quad co\ ordinates\, of\ AP \tag{1}$$

$$\left.\begin{aligned} x_1 &= R*cos(\theta) \\ y_1 &= R*sin(\theta) \end{aligned}\right\} \quad co\ ordinates\, of\ MT \tag{2}$$

The received signal strength from the AP at the E-UE of interest is a function of the distance between E-UE and AP and the relation is given by

$$D = R*\sqrt{(cos(\phi)-cos(\theta))^2+(sin(\varphi)-sin(\theta))^2} \tag{3}$$

In LTE cellular network, channel and time slots are allocated to a E-UE beforehand by its BS, so it can be assumed that the bandwidth is constant when the E-UE moves within hundreds of meters. In 802.11 WLAN systems, the data rate is chosen based on achievable RSS to meet a certain link quality, so the bandwidth is dynamic. By considering path loss and shadow fading, the received power at a distance 'd' from the AP is given by:

$$P_w(d) = \mu_{RSS}(d) + S(\sigma, d) \tag{4}$$

where $\mu_{rss}(d)$ is the average signal strength and $S(\sigma, d)$ represents shadowing effect. The shadowing follows log normal distribution with zero-mean and standard deviation σ_{dB}.

The average signal strength $\mu_{rss}(d)$ can be expressed as

$$\mu_{RSS}(d) = K - P_L(d) \tag{5}$$

where K is the parameter that include the transmitted power and transmitting/receiving antenna gain and $P_L(d)$ is the path loss. The PL is represented as [16]:

$$PL(d) = 32.5 + 20 \log F + 10 * n_I \log d \tag{6}$$

The average signal strength $\mu_{rss}(d)$ of the AP can be expressed as

$$\mu_{rss1} = K_1 - K_2 \log d; \tag{7}$$

Now the probability that E-UE receiver can translate the data correctly can be represented as [17]

$$Pr[P_w(d) > S_R] = 1 - Q\left(\frac{S_R - \mu_{RSS}(d)}{\sigma}\right) \tag{8}$$

where Q(•) is Q-function.

The data rates in the WLAN are as below [18].

$$DR_W[\mu_{RSS}(d)] = \begin{cases} r_1, \mu_{RSS}(d) \in (-\infty, S_1) \\ r_2, \mu_{RSS}(d) \in (S_1, S_2) \\ \vdots \\ r_m, \mu_{RSS}(d) \in (S_{m-1}, \infty) \end{cases}, r_1 < r_2 < \cdots < r_m \tag{9}$$

where $S_1, S_2, \cdots, S_{m-1}$ *are receiver sensitivity values required for different level of data rate from* r_2 *to* r_m.

The bandwidths in WLAN can be represented as [19]

$$B_W(d) = Pr[P_w(d) > S_R] * DR_W[\mu_{RSS}(d)] \tag{10}$$

3. Simulation model

In this section, we analyse and evaluate the performance of proposed model after briefly describing the movement mode of E-UE of interest. We assume that the E-UE of interest is moving in a circular path through the WLAN coverage area with a constant velocity v (m/s) in the LTE cellular network. The received signal strength at the E-UE of interest is sampled with sampling duration of T_s (0.1s) and sampling distance kd_s from the AP. Here k is an integer (0, 1, 2...) indicating the sampling instants and d_s indicates sampling distance $(= v.T_s)$. At k-th instant the received signal strength from the AP is given by

$$P_w(kd_s) = \mu_{RSS}(kd_s) + S(\sigma, kd_s) \tag{11}$$

Now we analyze metrics - the decision delay, throughput and the number of handoffs as performance evaluation metrics.

3.1. Decision delay

Only one VHO should occur at the position where $\mu_{RSS}(d)$ of WLAN equal to P_{3G} of LTE cellular network in an ideal case. Let us consider the sampling instance corresponding to such position as optimum handoff instant ($k_{O_{HO}}$). But in practical scenario, because of shadowing fading term S(σ,d), E-UE will face more than one VHO (back-and-forth) during the movement. Let us denote that the first and last handoffs occur at $k_{f_{HO}}$ and $k_{l_{HO}}$ sampling instant respectively. The decision delay is defined as mean of first and last handoff decision delay as follows,

$$D = T_s * \left(\frac{E(k_{l_{HO}}) + E(k_{f_{HO}})}{2} - k_{O_{HO}}\right) \tag{12}$$

3.2. Total number of handoffs

The total number of upward and downward handoffs referred to as the number of VHOs when the E-UE of interest moves out of or into the WLAN. The expected number of VHOs in our network model is computed as

$$\overline{N_{\text{VHO}}} = E\{N_{VHO}\} = \sum_{k=0}^{h} P_{VHO}(k) \tag{13}$$

where $P_{VHO}(k)$ is the probability that a VHO should occur at the *k*-th sampling instant.

3.3. Throughput

While the E-UE of interest is moving through the WLAN in the LTE cellular network, it experiences several data rates based on received sensitivity. We can evaluate average throughput in the distance D with [20],

$$\overline{R_{avg}} = \frac{1}{D}\int_0^D R(kd_S)dx \tag{14}$$

where $R(kd_s)$ is the instantaneous data rate at the *k*-the instant.

3.4. Hysteresis based VHO-algorithm

A vertical handoff is initiated from X-th network to Y-th network at k-th instant if the RSS of other network (AP or BS) exceeds that of the current network's (BS or AP) RSS value by hysteresis margin (H). i.e.,

$$RSS_Y(k) > RSS_X(k) + H \tag{15}$$

3.5. Dwell timer based VHO-algorithm

A counter of predefined threshold is started when the RSS from another network (BS/AP) exceeds the RSS from the current network (AP/BS) in this algorithm [14]. Here RSS means the equivalent RSS converted from the bandwidth of the corresponding network. If this condition continues till the counter is expired, a vertical handoff is initiated. i.e., the condition for vertical handoff from X-th network to Y-th network at k-th instant is,

for $l=k-N+1: k$

$$RSS_X(l) < RSS_Y(l) \tag{16}$$

end;

Here we assume that the E-UE is connected to X-th network at (k-N)-th instant. And N is the equivalent sampling instant corresponding to dwell timer value in seconds. RSS_X and RSS_Y are decision parameters from X and Y networks respectively.

4. Results & discussion

The following values are choosen for the simulation purpose. The standard deviation of shadow fading is σ_{dB} =8dB, the velocity is v=2 m/s, the sampling time is T_s =0.1s, the bandwidth of LTE is 2.4 Mbps and the receiving sensitivity is S_R=-94dBm.According to the description of the Orinoco Gold(Hermes) 802.11b wireless card in [18], we prescribe that

$$DR_w(\mu_{RSS}(d)) = \begin{cases} 1Mbps, \mu_{RSS}(d) \in (-\infty, -91dBm) \\ 2Mbps, \mu_{RSS}(d) \in [-91dBm, -87dBm) \\ 5.5Mbps, \mu_{RSS}(d) \in [-87dBm, -82dBm) \\ 11Mbps, \mu_{RSS}(d) \in [-82dBm, \infty) \end{cases} \tag{17}$$

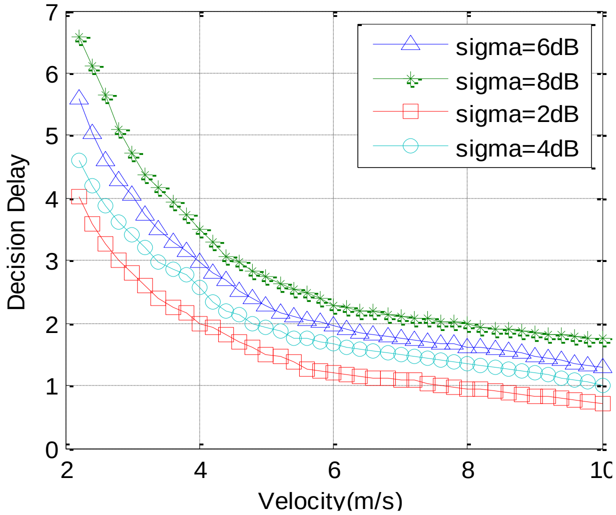

Figure 2. The decision delay vs. velocity (m/s) for different values of the standard deviation of shadow fading by using dwell timer based VHO algorithm

[Figure 2]. shows decision delay as a function of the velocity of E-UE of ineterest for diffret values of sigma based on dwell timer algorithm. From the figure it is clear that decision delay lessens with the increase in velocity of E-UE. With the velocity of E-UE of inerest, sampling distance increases and lesser time is needed to overcome this distance. Hence the decision delay is less for greater velocities of E-UE. The legends in the figure represent the decision delay experienced by E-UE with the standard deviation of shadow fading (sigma)=2dB, 4dB, 6dB and 8dB respectively. As the sigma increases the RSS fluctuates more and more at the E-UE of interest result in more number of handoffs. Hence the decision delay is more for larger value of sigma.

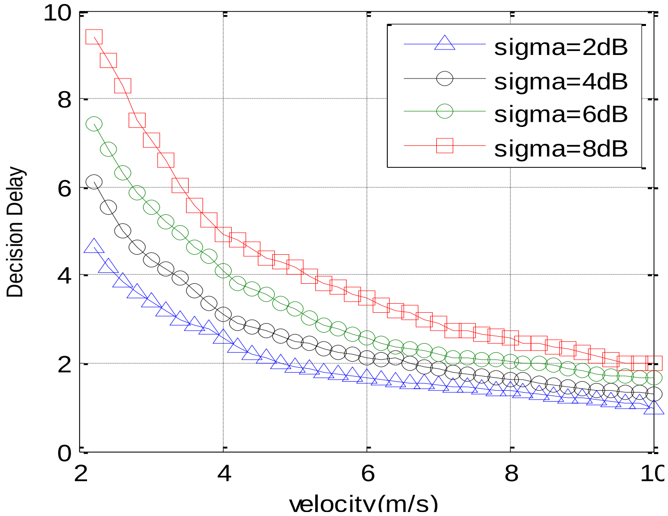

Figure 3. The decision delay vs. velocity (m/s) for different values of the standard deviation of shadow fading by using dwell timer based VHO algorithm

In [Figure 3]., the decision delay is shown as a function of the velocity of E-UE of interest for hysteresis based handoff algorithm. In [Figure 4]. the decision delay is shown for different values of the standard deviation of shadow fading (σ_{dB}) as the velocity of E-UE of interest increases from 2 m/s to 10 m/s. As the velocity of the E-UE of interest increases from 2 m/s to 10 m/s, handoff decision delay decreases rapidly. With increasing velocity, sampling distance increases and hence RSS increases rapidly with respect to time which makes lesser sampling points between $k_{f_{ho}}$ and $k_{l_{ho}}$, so it takes less decision delay. On the other hand, as the standard deviation of shadow fading increases, the distance between first and last handoff sampling points increases which causes more handoff delay for larger sigma values.

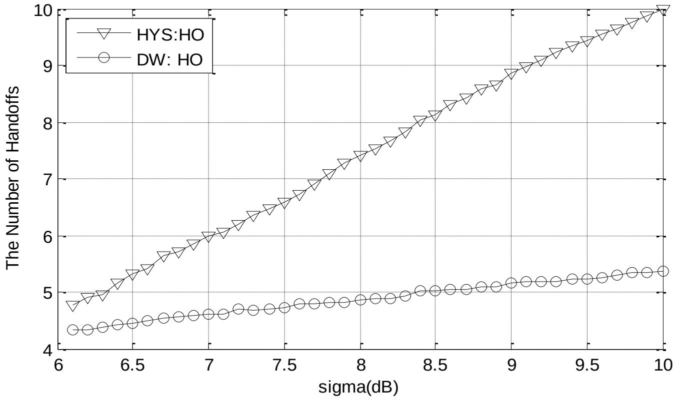

Figure 4. The Number of handoffs vs. the standard deviation of shadowing for v=2 m/s

In [Figure 4]., shows the total number of handoffs vs the standard deviation of shadow fading for hysteresis as well as dwell timer VHO algorithms. The total number of handoffs increases with the standard deviation of shadow fading. Because the RSS fluctuates more and more at the E-UE of interest as the standard deviation shadow fading increases which will increase the total number of handoffs. This can be controlled by using hysteresis margin. A minimum of 2 dB of hysteresis margin value will be necessary to reduce unnecessary handoffs and it should not high such that user call will not drop due to hysteresis value.

We observe less number of handoffs in case of dwell timer VHO algorithm as compared to hysteresis algorithm and the decision delay experienced by the E-UE is less with dwell timer algorithm as compared to hysteresys algorithm. Handoff condition needs to be satisfied in entire dwell duration in order to initiate a handoff in case of dwell timer is the reason for having less number of handoffs. Hence the number of handoffs observed and decision delay experienced by the E-UE of interest are less in dwell timer algorithm comparing to the hysteresis VHO algorithm.

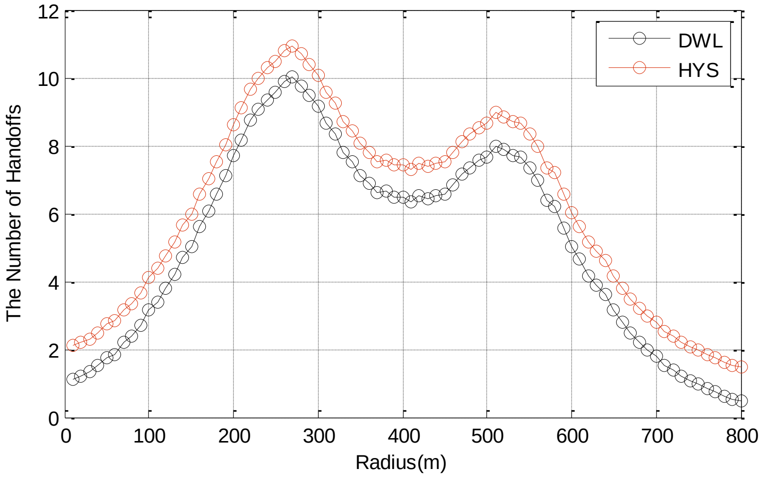

Figure 5. The Number of handoffs vs Radius(m) for v=2 m/s

In [Figure 5], the total number of handoffs is shown as a function of the radius of circular path in which the E-UE of interest is moving. The total number of handoffs are monotonically increasing upto R=300m and afterwards upto 400m the total number of handoffs decreases. Upto 300m the E-UE of interest is roaming at the edges of the coverage area where the effect of the stadard deviation of shadow fading is more as the received signal strength is weak. Hence more number of handffs are observed. As we increase the radius further, the effective distance between AP and E-UE start decreasing. thence the stronger will be the RSS and lesser the number of handoffs. Again from the 400m by increasing radius, more number of handoffs are noticed similarly upto 500m. If we increase the radius of circular path further, then one can observe nonmonotonic handoffs. Because the E-UE of interest is moved through the edges of WLAN coverage area.

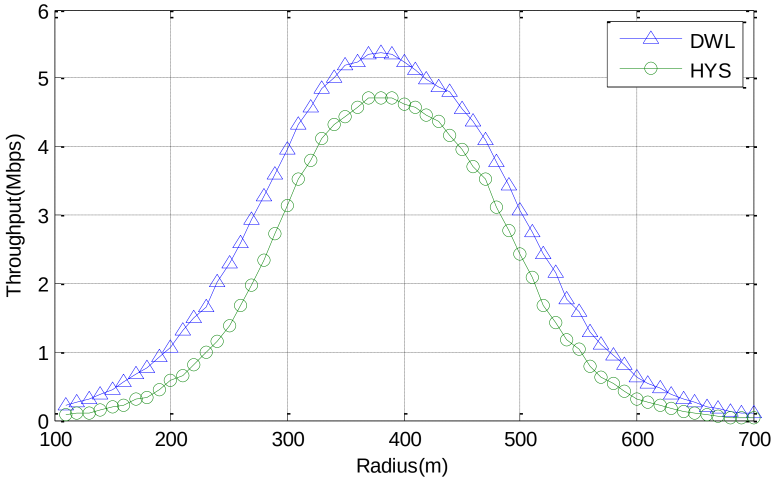

Figure 6. Throughput(Mbps) vs radius(m) for hysteresis and dwell timer algorithm

In [Figure 6]., how the throughput is varied according to the Radius(m) of circular path inwhich the E-UE of interest is moving. We can observe that as the radius of the circular path increases, offered throughput to the user will monotonically increase upto 400m. Because the effective distance between the E-UE of interest and AP decreases. Further increase in circular path radius will lower the throughput for both dwell timer and hysteresis algorithms at the E-UE of interest. As we increase the radius of circular path in which the E-UE of interest is moving, the effective distance between the E-UE and AP is decreases upto 400m. Hence it will get stronger signal and more data rates. Beyond 400m, increase in radius i.e., indirectly moving the the E-UE of interest away from the AP results in weak RSS at the E-UE of ineterest and that increases the number of handoffs. Hence throughput will decrease with radius of circular path.

5. Conclusion

In this paper, we consider different trajectory of movement of a E-UE of interest in our proposed network model. We contemplate a proposed simulation model to record the performance based on two VHO algorithms. In the integrated network model of LTE cellular network and WLAN, we evaluate the the performance of proposed network model in terms of number of handoffs, throughput and decision delay. The effect of shadowfading, the velocity of E-UE of interest and trajectory path on the number of handoffs, decision delay and throughput are estimated using dwell timer, and hysteresis VHO algorithms. It is noticed that the dwell timer algorithm restricts the frequent occurrence of handoffs as compared to that of hysteresis algorithm and produces less decision delay with a hike in throughput.

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