A New Method for Minimizing the Unnecessary Handover in High-Speed Scenario

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***Abstract*— The application of Wireless Local Area Network (WLAN) is limited to indoor or pedestrian walking speed environment because the small WLAN coverage will lead to the growth of unnecessary handover rate in high-speed scenario. The previously proposed traveling distance prediction based handover methods assumed mobile terminal (MT) travels at a constant speed is impractical as most of the MTs may not be traveling at constant speed in real environment. These methods have poor performance in case of acceleration because MT will leave the network earlier than the estimated time. In this paper, a new traveling distance prediction based handover scheme that is aware of MT's speed changes is proposed to overcome the limitation of the existing methods. The proposed scheme is adapted to the MT velocity and acceleration or deceleration rate. The numerical result shows that the performance of the proposed scheme is better than the existing handover methods in high-speed scenario. It keeps the probability of unnecessary handover within the user acceptable level in high-speed scenario.**

Keywords—WLAN; high-speed scenario; velocity; unnecessary handover; vertical handover.

I. INTRODUCTION

The next generation wireless technology will be focused on ubiquitous access over heterogeneous wireless technologies [1]. The network service is no longer restricted by particular wireless technology. To achieve this, an efficient seamless handover mechanism to switch the mobile terminal (MT) amongst the different wireless technologies is needed to ensure that the MT is continuously connected to the most appropriate network at anywhere.

The existing wireless technologies can be divided into two groups; Third Generation Partnership Project (3GPP) and non-3GPP. Interoperation between 3GPP (2G, 3G and 4G cellular network) and non-3GPP (WLAN, WiMAX, etc.) network candidates is called vertical handover. It can be achieved by using the Media Independent Handover (MIH) [2]. MIH provides information services to discover the neighboring network information, even service to report the link quality and command service to control and manage the network selection [2].

Horizontal handover process is much straightforward contrasted with vertical handover process since it just includes a solitary system. MT can choose the best Base Station (BS) by comparing the measured Received Signal Strength (RSS) of different BSs. The horizontal handover is necessary if the RSS of existing connected BS drops below the predefined RSS threshold and the targeted BS RSS value is greater than predefined RSS threshold and RSS of the existing connected BS.

WLAN is the most preferable amongst the heterogeneous wireless networks because of its high bandwidth capacity and low access cost. However, the WLAN application is always restricted to the indoor or low speed environment. This is because the small WLAN coverage leads to high number of unnecessary handovers, especially in high-speed scenario. Unnecessary handover occurs when traveling time within WLAN coverage (t) is less than the total handover latency enter (T_i) to and leave (T_o) from WLAN cell ($t < (T_i+T_o)$) where MT does not get any benefit from WLAN cell. High number of unnecessary handovers will interrupt the connection and also induce call drop.

In this paper, a new traveling time prediction based handover method is proposed for minimizing the number of unnecessary handovers to WLAN in high-speed scenario.

II. RELATED WORKS

Authors in [3] proposed a RSS threshold based handover plan to permit MTs access to WLAN and 3G arrange in consistent way. This scheme made two RSS thresholds. The first threshold is 3G→WLAN threshold and the second one is WLAN→3G threshold. MT initiates handover from 3G network to WLAN if measured WLAN RSS value is greater than 3G→WLAN threshold. When currently attached AP's RSS signal drops below the WLAN→3G threshold, MT performs handover to 3G network. The weaknesses of this scheme are high handover rate and ping-pong impact because of the fluctuation of RSS value caused by channel fading, MT portability, and shadowing [4].

Authors in [5] proposed a dynamic RSS threshold in view of the MT's speed and handover latency to limit the likelihood of handover disappointment from WLAN to 3G systems. In this scheme, MT handovers to WLAN whenever the WLAN is available because it assumed handover failure probability from 3G to WLAN is zero as WLAN cell is covered by 3G cellular network. The primary drawback of this scheme is execution corrupts when the MT's traveling time inside the WLAN coverage is not as much as the handover latency.

The speed based vertical handover algorithm [6-8] defined a speed threshold for WLAN. The MT performs handover to WLAN if and only if the traveling speed is lower than the predefined threshold. The authors in [6-8] defined WLAN speed threshold at 5 m/s and below. In [9, 10], authors presented a Fuzzy based handover algorithm

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with the If-Else rule, "If MT speed is low then WLAN-reject is low; otherwise WLAN-reject is high". The application of WLAN is restricted to low traveling speed or indoor environment such as shopping complex, hospital, airport and home. In fact, the coverage radius of WLAN is more than 50 meters at outdoor environment. For example, IEEE 802.11n coverage radius is up to 100 meters.

Authors in [11] presented a dwell timer based scheme for vertical handover between WLAN and cellular networks to reduce the number of unnecessary handovers. MT will initiate dwell timer after MT first detects the measured RSS value is less than the predefined RSS threshold. MT compares the measured WLAN RSS value with the predefined RSS threshold consecutively until predefined dwell time period expired. If measured RSS is always less than the predefined RSS threshold during the dwell time period, MN initiates the handover to cellular network. Otherwise, it will persist with WLAN. The fixed dwell timer proposed in [11] had successfully reduced the number of unnecessary handovers. However, in high-speed scenario, time taken by MT to cross the WLAN coverage might less than the predefined dwell timer. Therefore, there will be high number of handover failures and unnecessary handovers in high-speed scenario.

For reducing the number of unnecessary handovers, authors in [12] and [13] presented the handover necessity estimation methods. Figure 1 shows the scenario of traveling distance prediction in WLAN. These methods trigger handover to WLAN if and only if the estimated traveling distance (*l*) is greater than the distance threshold (*L*). The traveling distance (*l*) from P_{In} to P_{Out} is given as

$$l = \frac{r^2 - s^2 + d^2}{d} \tag{1}$$

where *r* is the radius of WLAN coverage, *s* is the distance between P_s and AP, and *d* is distance between P_{In} and P_s. The value of *d* can be determined by

$$d = v_{P_{In}}(t_{P_s} - t_{P_{In}}) \tag{2}$$

where v_{PIn} represents MT's velocity at point P_{In}, t_{P_s} is time at point P_s, $t_{P_{In}}$ is time MT pass through P_{In}. The distance threshold with acceptable probability of unnecessary handover (*L*) presented by [12, 13] is expressed in Equation (3).

$$L = 2r\sin\left(\sin^{-1}\left(\frac{l_{th}}{2r}\right) - \frac{\pi P_u}{2}\right) \tag{3}$$

where P_u is the predefined tolerable or acceptable probability of unnecessary handover and l_{th} is distance threshold. The l_{th} can be calculated by multiplying MT speed $v_{P_{In}}$ with total handover time, $T_t + T_o$. *L* is equal to l_{th} if $P_u = 0$. The probability of unnecessary handover of [12, 13] is as expressed in Equation (4).

$$P_r = \frac{2}{\pi}\left[\sin^{-1}\left(\frac{l_{th}}{2r}\right) - \sin^{-1}\left(\frac{L}{2r}\right)\right] \tag{4}$$

This method maintains the probability of unnecessary handovers within the predefined tolerance. However, this method assumes that MT travels at a constant speed. This assumption is impractical as the speed of MT may not be constant in the real environment. This method will have poor performance if MT accelerates, because MT will leave the WLAN coverage earlier than the estimated time. Therefore, a new prediction method which is aware of MT speed changes is proposed in this work to overcome the limitation of existing methods.

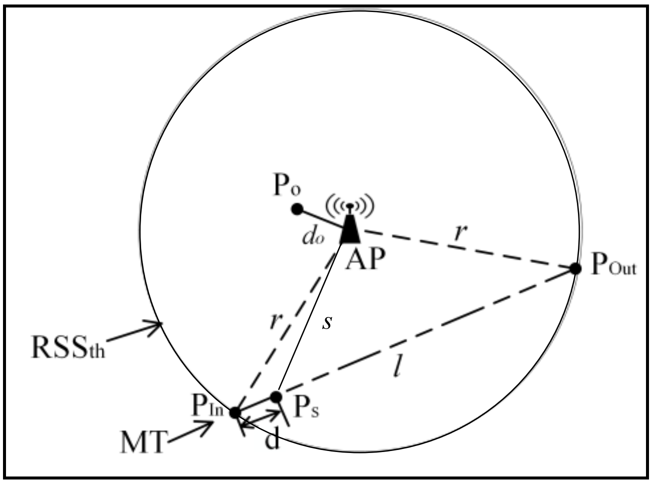

Fig. 1. Traveling distance prediction in WLAN coverage [12].

I. PROPOSED METHOD

The proposed method is the extension of Yan et al. [12] and Hussain et al. [13] methods. In dynamic speed, the distance *d* can be determined by using the kinematic equation [14] where the distance is equal to average speed multiply with time interval. It is given as

$$d = \left|\frac{v_{P_s} + v_{P_{In}}}{2}(t_{P_s} - t_{P_{In}})\right| \tag{5}$$

where v_{P_s} and $v_{P_{In}}$ denotes measured MT velocities at P_s and P_{In}, respectively. The MT velocity can be measured by using the velocity estimation technique that is presented in [15]. By substituting (5) into (1), the distance *l* can be estimated by using Equation (6).

$$l = \frac{r^2 - s^2 + \left(\frac{v_{P_s} + v_{P_{In}}}{2}(t_{P_s} - t_{P_{In}})\right)^2}{\frac{v_{P_s} + v_{P_{In}}}{2}(t_{P_s} - t_{P_{In}})} \tag{6}$$

The *r* and *s* values can be determined by using log-distance path loss model [16]. The distance *r* is calculated by using Equation (7).

$$RSS_{th} = P_{TX} - PL_0 - 10n\log\frac{r}{d_0} + \varepsilon$$
$$\log\frac{r}{d_0} = \frac{P_{TX} - PL_0 - RSS_{th} + \varepsilon}{10n}$$
$$r = d_0 * 10^{\left(\frac{P_{TX} - PL_0 - RSS_{th} + \varepsilon}{10n}\right)} \tag{7}$$

where d_0 is the reference distance, P_{TX} represents AP transmit power, PL_o is the power loss at P_o, RSS_{th} denotes measured received signal strength (RSS) at point P_{In}, n is the path loss exponent (usually 2 to 4 depending on transmission environment), and ε is a zero-mean Gaussian random variable caused by shadow fading. Doppler shift effect in high speed environment can be mitigated by using the Doppler frequency offset estimation and compensation algorithm [17, 18]. The s value can be calculated by replacing RSS_{th} in (7) with the measured RSS at point P_s.

To alleviate the shadowing effect, MT takes numerous RSS samples and the arithmetic mean is evaluated. RSS_{th} is given by Equation (8).

$$RSS_{th} = \frac{1}{z}\sum_{i=0}^{i=z} RSS_i \tag{8}$$

The sample size, z is adjusted based on the MT's velocity. It is expressed as

$$z = \left\lceil \frac{\gamma}{T_s} \right\rceil \tag{9}$$

where T_s is RSS sampling time and γ is total sampling period given by Expression (10).

$$\gamma = K * T_m \ , \qquad K \in \{0.1, 0.2, \dots, 0.9\} \tag{10}$$

In the proposed method, MT updates the RSS measurement periodically at time interval of T_m which is given by $\frac{D}{v}$ second, where D is a fixed distance of 1 m. The higher the velocity is, the smaller the T_m period and sample size. The maximum value of z is limited to 20 samples to avoid excessive sampling while MT travels at low speed.

Referring to the kinematic equation [14], the relationship between distance, speed, acceleration and time is given as

$$l' = \frac{\alpha\tau^2}{2} + v_i\tau \tag{11}$$

where l' is traveling distance, v_i is initial speed, τ is traveling time and α denotes acceleration or deceleration rate. The α value can be determined by using Equation (12).

$$\alpha = \frac{v_{P_s} - v_{P_{In}}}{|t_{P_s} - t_{P_{In}}|} \tag{12}$$

If $v_{P_s} = v_{P_{In}}$, it mean that MT is traveling at a constant speed. MT is accelerating if $v_{P_s} > v_{P_{In}}$ and decelerating if $v_{P_s} < v_{P_{In}}$.

Referring to Equation (11), assuming $l' = l$, $v_i = v_{P_{In}}$, $\tau = T_i + T_o$ and α is given by Equation (12), the l_{th} of the proposed method (l_{th_p}) can be determined by using Equation (13).

$$l_{th\_p} = \frac{(v_{P_s} - v_{P_{In}})(T_i + T_o)^2}{2|t_{P_s} - t_{P_{In}}|} + v_{P_{In}}(T_i + T_o) \tag{13}$$

Then substituting (13) into (3), the L of the proposed method (L_p) is given by Equation (14).

$$L_p = 2r\sin\left(\sin^{-1}\left(\frac{(v_{P_s} - v_{P_{In}})(T_i + T_o)^2 + 2v_{P_{In}}(T_i + T_o)|t_{P_s} - t_{P_{In}}|}{4r|t_{P_s} - t_{P_{In}}|}\right) - \frac{\pi P_u}{2}\right)$$

$$L_p = 2r\sin\left(\sin^{-1}\left(\frac{\alpha(T_i + T_o)^2 + 2v_{P_{In}}(T_i + T_o)}{4r}\right) - \frac{\pi P_u}{2}\right) \tag{14}$$

L_p is adjusted dynamically to the MT's velocity and acceleration or deceleration rate. MT triggers handover to WLAN if and only if the estimated traveling distance l is greater than the distance threshold L_p.

Figure 2 shows the correlation between acceleration, velocity and distance threshold L_p with setting of WLAN coverage radius, r = 100 m, total handover time, $T_i + T_o = 2$ seconds, and acceptable probability of unnecessary handover, $P_u = 0$. The higher the MT acceleration rate or velocity is, the greater the distance threshold L_p. However, the distance threshold introduced by [12] and [13] methods is fixed where L is equal to L_p ($a=0$) all the time even though the MT accelerates, because these methods do not account for the changes of velocity and MT is assumed travel at the constant velocity.

The probability of unnecessary handover of the proposed method (P_{r_p}) can be calculated by replacing l_{th} and L in Equation (4) with l_{th_p} and L_p, respectively, yields;

$$P_{r\_p} = \frac{2}{\pi}\left[\sin^{-1}\left(\frac{l_{th\_p}}{2r}\right) - \sin^{-1}\left(\frac{L_p}{2r}\right)\right] \tag{15}$$

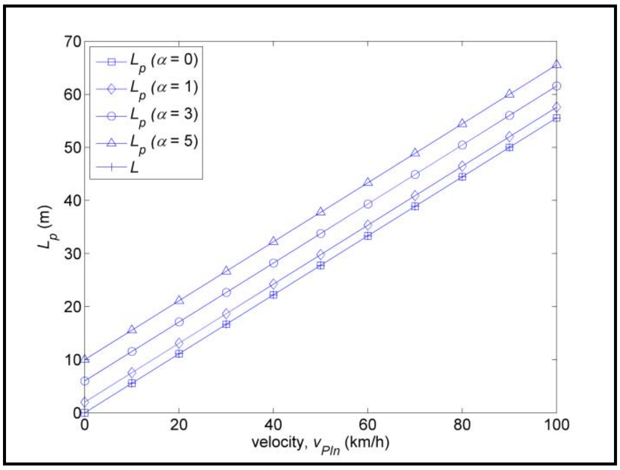

Fig. 2. The correlation between the acceleration rate, velocity and distance threshold L_p (r = 100m, $T_i + T_o$ = 2 sec, P_u = 0).

II. PERFORMANCE ANALYSIS AND DISCUSSION

The performance of the proposed method is compared against the approaches in [12] and [13]. In this experiment, the deceleration scenario is omitted because it provides MTs longer traveling time within WLAN coverage and has no impact on unnecessary handover. The simulation parameters are listed in Table 1.

Table 1 Simulation parameters used in the experiment.

Parameter	Value
α	0, 1, 3, 5 m/s²
v_{PIn}	10 to 100 km/h
r	100 m [12, 13]
P_u	0.02 or 2% [12, 13]
$T_i + T_o$	2 s [12, 13]

Figure 3 shows the probability of unnecessary handover of Yan et al. [12], Hussain et al. [13] and the proposed methods. As shown in Figure 3, Yan et al. [12] and Hussain et al. [13] methods keep the probability of unnecessary handover within the predefined tolerable value (P_u) at constant speed ($\alpha = 0$). However, the unnecessary handover probability is up to 35%, 100%, and 165% higher than P_u at the acceleration rate of 1m/s², 3m/s², and 5m/s², respectively. The higher the MT acceleration rate is, the higher the unnecessary handover probability for Yan et al. [12] and Hussain et al. [13] methods because MT takes shorter time to cross the WLAN coverage.

In Figure 3, it can be seen that at the acceleration rate (α) of 1m/s², 3m/s², and 5m/s², the proposed method retains the probability of unnecessary handover within the predefined tolerable value (P_u), which is 0.02. The numerical result shows that the proposed method outperforms R. Hussain et al. [13] and Y. Xiaohuan et al. [12] methods.

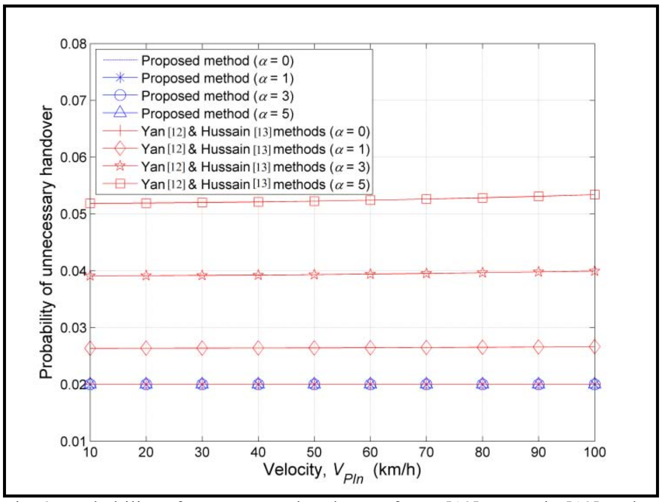

Fig. 3. Probability of unnecessary handover of Yan [12], Hussain [13] and proposed methods ($P_u = 0.02$).

III. Conclusion

This paper presented a traveling distance prediction method to keep the probability of unnecessary handover within the predefined tolerable value (P_u) while optimizing the connection time to WLAN in high-speed scenario. The proposed method overcomes the limitation of previous methods which assume the MT traveling in a fixed velocity. The performance of the proposed method is better than the previous methods.

Acknowledgment

This research is supported by Ministry of Education Malaysia and University Malaysia Sabah, Geran Penyelidikan UMS (SBK0364-2017).

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