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Performance Evaluation of Signal Strength and Residual Time based Vertical Handover in Heterogeneous Wireless Networks

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Abstract: In most of the wireless networks, signal strength is considered as the basic criteria to initiate handover. In future generation heterogeneous wireless systems, the vertical handover between different types of networks take place to satisfy demands of users. The location and velocity of mobile terminal is expected to be available in most of the modern systems. The time to reach boundary of serving cell named as Residual time is calculated using this information. The proposed mechanism makes use of signal strength and residual time to initiate handover. The threshold for residual time and hysteresis margin is determined to optimize vertical handover performance for different velocities. Simulation results show that the proposed mechanism improves handover efficiency in terms of handover rate and probability of call interruption.

Keywords: Heterogeneous wireless networks; Handover; WiMAX; LTE; Handover Rate;

I. INTRODUCTION

In recent years, heterogeneous wireless networks are supposed to establish numerous networks of different types like WiFi (Wireless Fidelity), WiMAX (Worldwide Interoperability for Microwave Access) and LTE (Long Term Evolution) to provide users with promising applications. These networks are designed independently and vary widely in terms of their service parameters like throughput, coverage area, access delay etc. Some of these networks are complimentary to each other while others are competitive. The rapid increase of access technologies demands interoperability and better mobility management techniques to fulfill the requirements of users.

Mobility management is comprised of location management and handover management. The previous one tracks and maintains the exact location of mobile terminals for successful information delivery. This information is maintained when they are powered on, powered off or even when they move from one place to another. On the other hand, Handover is a process responsible for managing seamless transitions between existing networks whenever required. It deals with active transfer of mobile terminals from the control of a Base Station (BS) to the control of another BS in a different cell. Handovers are broadly divided into two categories: Horizontal handovers and Vertical handovers. Horizontal handovers are between two different cells with homogeneous networks (of same type) while vertical handovers take place between two cells of heterogeneous networks (of different type). Due to enclosure of different technologies in heterogeneous networks, the vertical handover is a challenging task and require great attention. The associated networks differ in various aspects such as operating frequency, bandwidth, modulation techniques etc. For vertical handovers, the mobile terminal has to perform handover between different systems thus it should be able to operate in multimode. The regular monitoring of the signal received from different networks is a prerequisite. The absolute or relative value of the Received Signal Strength (RSS) estimates the requirement of handover. However, in some situations, RSS based handover decision results in poor performance due to its random nature and increasing demands of users. It can cause early or late initiation of handovers. Early initiated handovers may result in wastage of network resources while an ongoing call may be interrupted in case of late handovers. Therefore, we aim to device a mechanism which would be effective to find appropriate time to trigger initiation of handover in different propagation environments and different velocity applications. Most of the modern mobile terminals are equipped with location detection device such as Global Positioning System (GPS) which can provide information about distance of mobile from BS and velocity of mobile user. This information can be used to compute residual time to reach boundary of serving cell. In this paper, we propose a signal strength and residual time based vertical handover mechanism for heterogeneous wireless networks.

The rest of the paper is organized as follows: Section II provides related work to the vertical handovers in the literature. Section III describes System model considered in this paper. The proposed handover mechanism based on signal strength and residual time measurements is discussed in Section IV. The Matlab simulation results are analyzed in Section V. This paper is summarized and concluded in Section VI.

II. RELATED WORK

A number of research works have been done on handover algorithm in wireless networks. The handover performance is affected by the time at which handover trigger is generated [1]. The authors in [2] investigate the impact of Layer 2 triggering time on the signaling cost, packet delivery cost, total overhead cost, and buffer space. Various criteria can be used to initiate handover such as signal strength, bit error rate, distance, data rate etc. In literature, the most common criterion considered for handover is absolute or relative signal strength [3-5]. Bit error rate in conjunction with signal strength is used in [6] to minimize average handover delay and handover rate. The authors in [7] consider interference along with data rate, RSS as criteria to decide handover initiation. The signal strength with data rate is considered in [8]. The distance between mobile station and BS is also to be considered as important factor to initiate handover. It can reduce number of handovers by selecting appropriate handover parameters [9]. Hysteresis margin and absolute threshold are determined to optimize the handover performance in [10]. Some of the researchers propose a variable hysteresis margin instead of fixed hysteresis to improve handover performance. The authors in [11] and [12] have utilized the location of mobile to find optimum hysteresis margin. The above discussed algorithms have ignored velocity of Mobile Node (MN) while designing handover algorithm. Some authors like [13] have shown impact of mobile user's velocity on handover performance in wireless networks. Velocity adaptive threshold signal strength is proposed in [13].The hysteresis margin between RSS of two networks should be adaptive [14]. The hysteresis is made dependent upon path loss exponent and user velocity to eliminate call quality degradation [14]. Mohanty [15] calculated the threshold signal strength for handover in accordance to the predefined probability of failure. The information about RSS and speed of user is used to predict travelling time in WLAN [16]. The travelling time and RSS are considered as handover parameters responsible for handover initiation in [16].

Looking into the widespread access of broadband to support many multimedia applications, interoperability between different networks seems to be essential. As discussed above, location information has been used as handover criteria. With this idea, utilizing distance and velocity for making handover decision may be a good proposition for enhancing handover performance in velocity varying environments in heterogeneous networks. Moreover efficient handover algorithms are needed to be employed to make best utilization of serving and candidate network resources. Keeping this in mind, optimum thresholds for parameters like hysteresis and time to trigger are chosen for different velocities of mobile.

III. SYSTEM MODEL

We consider network configuration as shown in Fig. 1 for performance evaluation of proposed handover algorithm. It consists of WiMAX and LTE cells adjacent to each other with a distance 'D' between two BSs. The BS is assumed to be located at the center of its associated cell. The mobile user is assumed to be travelling in a straight line with velocity 'v' from serving cell to neighboring cell.

The wireless network planning requires a suitable propagation model according to the environment surrounding mobile station. The RSS is affected by path loss, shadow fading and multipath fading during propagation as given by equation

$$S_i\,(d)=P_t + G_t - L_t - PL_i\,(d) + G_r - L_r + \varphi_i \qquad (1)$$

Where P_t is transmitter power, G_t and G_r are antenna gain of transmitter and receiver respectively. L_t and L_r are losses due to transmitter and receiver antenna respectively. $PL_i(d)$ denote path loss whereas φ_i is for shadow fading component and can be modeled as Gaussian process with zero mean and σ_i standard deviation [17].

$$\varphi_i(d) = \rho\, \varphi_i\,(d-1) + \sigma_i \qquad W(0,1) \qquad (2)$$

Where ρ is correlation coefficient, σ_i is standard deviation of shadow fading and W(0,1) represents truncated normal random variable. Multipath fading is neglected at high frequencies as it is averaged out due to much shorter correlation distance as compared to shadow fading.

The path loss evaluation can be done by deterministic or empirical models. The former calculates RSS at a particular location using detailed geometric information on terrain profile, location and dimensions of building etc. On the other hand, empirical models predict mean path loss as a function of various parameters e.g. distance, frequency, antenna height etc.

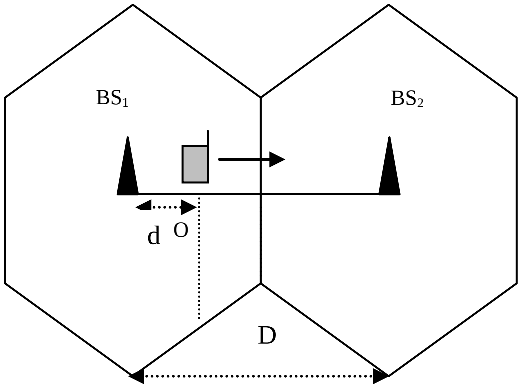

Fig. 1 Network Model

In this paper, we consider Erceg empirical propagation model [18] for suburban areas, recommended by IEEE 802.16 standard to calculate path loss due to its suitability for high frequencies [19].

The path loss increases with distance from serving BS according to equation 3.

$$PL_i(d)= X+10n\log_{10}(d_i/d_0)+PL_f+PL_{hms}+PL_{\theta ms} \quad (3)$$

Parameter X represents free space path loss and is given by

$$X = 20\log_{1o} \quad (4)$$

The term n represents path loss exponent, is defined as

$$n = a – bh_b + \quad (5)$$

$$PL_f = 6 \log \quad (6)$$

$$PL_{hms} = -20\log \quad (7)$$

$$PL_{qms} = 0.64 \ln \qquad + 0.54 \quad (8)$$

Where f_i is the carrier frequency and is the BS antenna height in meters. The parameters a, b and c for suburban areas are given in Table 1. PL_f, PL_{hms}, PL_{qms} are correction factors corresponding to frequency f, MN height , and MN antenna directivity q. PL_{qms} is often referred to as the antenna-gain reduction factor and accounts for the fact that the angular scattering is reduced owing to the directivity of the antenna.

The received signals $S_1(d)$ and $S_2(d)$ are smoothed using an exponential window function in order to reduce the fluctuations due to shadow fading. The signal obtained after smoothing is given in [20], can be represented as

$$= \qquad \frac{1}{d_1}\sum \quad (9)$$

Where $S_i(d)$ is the d^{th} sample received from BS_i before averaging. W_n is the weight assigned to the sample taken at the end of $(d-n)^{th}$ interval, and d_1 is the smoothing filter period.

For an exponential window, the impulse response of the filter is given by

$$W_n = (1/d_1) \exp(-d/d_1) \quad (10)$$

The Residual Time (RT) is a function of distance of mobile user from serving BS and velocity of mobile user. The estimated distance, at a distance‘d’ from BS_1, is computed as $d_e(d) = d+ n_d$ and the velocity of mobile user is estimated as $v_e(d) = v + n_v$.

Where n_d and n_v represents distance and velocity measurement errors respectively. These are considered as independent white gaussian processes having zero mean and variance σ_d^2 and σ_v^2 respectively. RT at a distance d from BS_1 for a serving cell of radius R_1, is given by

$$RT(d) = (R_1 - d_e(d)) / v_e(d) \quad (11)$$

IV. PROPOSED HANDOVER ALGORITHM

The entire process of vertical handover is broadly divided into three phases: handover initiation phase, target network selection phase and handover execution phase. First two phases are collectively responsible for a handover decision. In this paper, we are focused on taking a decision about handover initiation. It includes monitoring of signal strength of serving cell and target cell, checking conditions for handover initiation and to conclude about handover initiation. The handover initiation event is triggered followed by execution phase if the conditions given below are satisfied. The proposed vertical handover algorithm performs a handover from BS_1 to BS_2 if both of the following conditions are met:

1) The difference between averaged RSS from the BS_2 and BS_1 is greater than hysteresis margin H (dB).
2) The RT to reach boundary of BS_1 is less than threshold time (T_{th}).

Similarly, handover from BS_2 to BS_1 will occur

3) if the difference between averaged RSS from the BS_1 and BS_2 is greater than hysteresis margin H (dB).
4) if the RT to reach boundary of BS_2 is less than threshold time (T_{th}).

where H and T_{th} are hysteresis margin and time threshold settings. Typical values of these thresholds are set for optimizing handover process and will be discussed in next section. The velocity of the mobile user is considered within a range of (10-100) m/s. The thresholds for hysteresis and time are obtained for different velocities.

To show relative improvement in performance by the proposed handover algorithm as compared to traditional handover algorithm, simulation results are obtained for proposed as well as traditional handover algorithm. According to traditional handover algorithm, the handover is triggered at a point where signal strength of target cell exceeds the signal strength of serving cell by H. This type of algorithm can cause excessive number of handovers and ping pong effect due to fluctuations in RSS. The mobile user will go on switching from one network to another which will enhance switching load associated with handover process. This motivates us for this research and to get better handover performance.

V. RESULT ANALYSIS

The performance metrics considered to evaluate performance of proposed mechanism are handover rate (h_n) and Position of first handover (h_p). Handover rate is defined as the average number of handovers experienced by mobile while travelling from one cell to another cell. The position of first handover is denoted by first cross-over point on mobile trajectory where the conditions for handover (defined in above section) are satisfied. Another metric, the probability of call interruption P_i is defined as the probability that the ongoing service is disrupted due to unavailablity of sufficient signal strength from either of the BSs. This situation may occur when the signal strength from serving BS drops below threshold and target BS is not able to provide sufficient signal strength.

In this section, we evaluate handover rate (h_n) and position of first handover (h_p) as the mobile user moves with different velocities along a straight line trajectory between two BSs. The variation in h_n and h_p with hysteresis is also studied. These two metrics are contradictory to each other thus the optimum point for handover is considered where a tradeoff between h_n and h_p exists (intersection point).

In order to avoid handovers at early stages for a diverse range of velocities, the residual time is also considered as a handover criteria. The residual time is calculated with the help of location and velocity information of mobile as discussed in Section III. For numerical computation, the typical values of system parameters falling in the range of practical interest have been chosen as shown in Table 1. Based on the MATLAB simulation results, following observations are made:

For traditional RSS based handover mechanism, keeping RSS threshold for BS_1 and BS_2 = -107 dBm , h_n and h_p are computed for different values of hysteresis margin (Fig. 2). The intersection point of two curves gives optimum handover point. The handover rate is found to be 5 and h_p equals to 4600m which is too early when compared with boundary of serving cell, leading into undesired high handover rate. In contrary to the RSS based method, the handover is not allowed to take place early in proposed handover mechanism as there is constraint of residual time. The residual time should be less than threshold time (T_{th}) which makes handover to take place in the vicinity of boundary of cell. The following observations have been made through simulation results.

For mobile users moving with low velocity (10-30m/s), the optimum handover point is obtained for hysteresis margin H=6 dB. The optimum point for handover is independent of T_{th} because the intersection point is obtained at same position for different values of T_{th} [Fig. 3]. The handover rate is approximately 3.5 and first handover position is 5130 m which is nearer to boundary of current cell as compared to traditional method.

For users moving with medium velocity (40-70 m/s), the curves for h_n and h_p are drawn for different values of H and T_{th} [Fig. 4]. Three intersection points are obtained corresponding to T_{th} = (5, 6, 7) seconds. The handover Point (T_{th}=6s, H=8dB) is corresponding to least handover rate therefore can be considered as optimum handover point. The handover rate is equal to 3 and h_p = 4850 m which is earlier than low velocity scenario discussed in above paragraph.

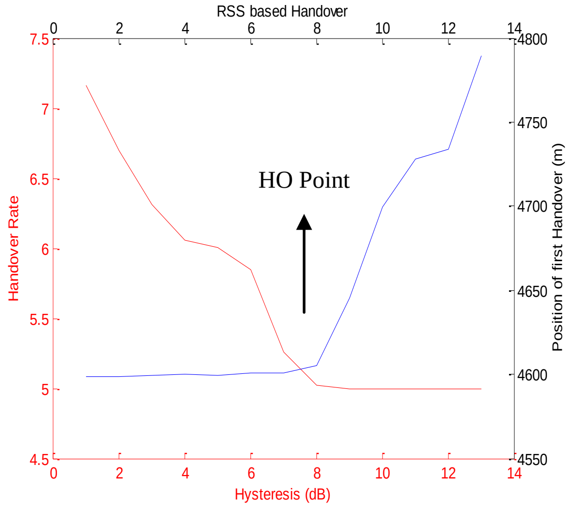

Fig. 2. Handover rate and Position of first handover versus Hysteresis margin for RSS based handover mechanism

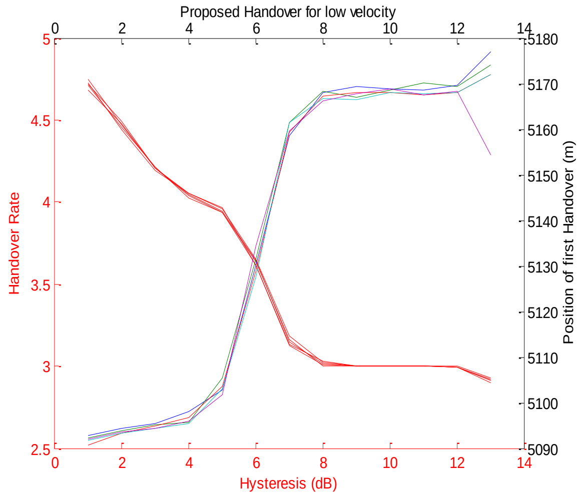

Fig. 3. Handover rate and Position of first handover versus Hysteresis margin for proposed handover mechanism for low velocity users

For high velocity scenario (80-100 m/s), two intersection points are obtained. Point 1 is corresponding to H=5 dB and T_{th}=3 s while point 2 is corresponding to H=11dB and T_{th}= (4-7)s . For point 2, the handover rate is equal to 2.8 which is lesser than point 1 (3.2) and h_p = 4890m which is comparable to point 1(4900m) m. Thus it is taken as optimum handover point as shown in Fig 5.

As velocity increases, the mobile is expected to reach boundary of serving cell earlier thus position of first handover h_p is to be shifted towards left to the boundary of serving cell to avoid call interruption.

The probability of call interruption P_i increases as H increases as the signal strength preceived from target BS relative to serving BS should exceed by H which may not be available at the time of link down. However, a lesser value of H will increase handover rate as the condition for handover may get satisfied too early. Therefore in order to have a trade off between the two metrics, H should not be too low or too high. The graphs for P_i with respect to H for low, medium and high velocities are plotted (Fig 6a, 6b, 6c). The probability of call interruption increases gradually with hystereses margin in signal strength based handover because handover point will get shifted towards left of serving cell boundary for increasing H. In proposed method, there is a constraint of residual time threshold which will avoid shifting of handover point away from boundary. In addition, the residual time is dependent upon velocity of user which helps to maintain the handover performance irrespective of variations in velocity whereas the situation gets worse in traditional method with increase in velocity. This shows significant improvement in handover performance for the proposed method in terms of P_i as velocity increases. It is evident that P_i is much lesser in proposed mechanism for all values of H when compared with traditional signal strength based algorithm.

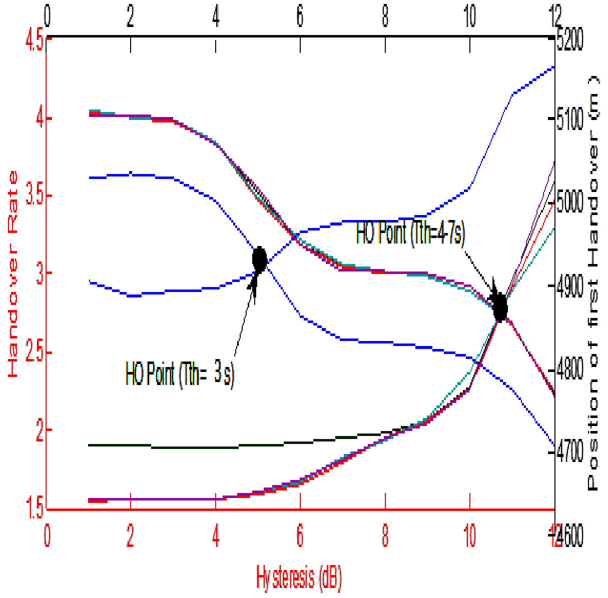

Figure 5. Handover rate and Position of first handover versus Hysteresis margin for proposed handover mechanism for high velocity users

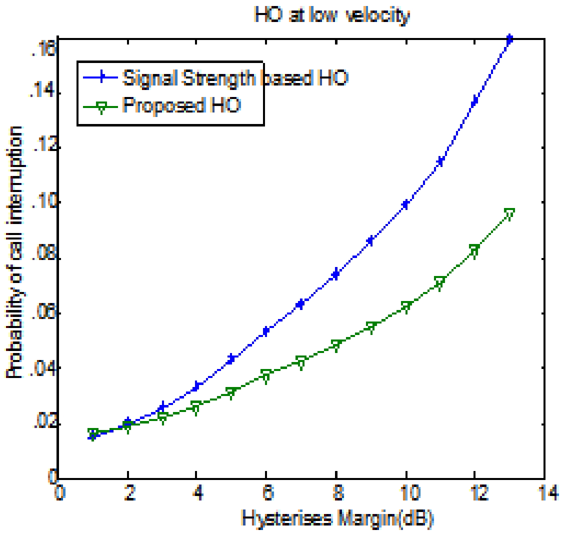

Figure 6a. Probability of call interruption versus hysteresis margin for low velocity

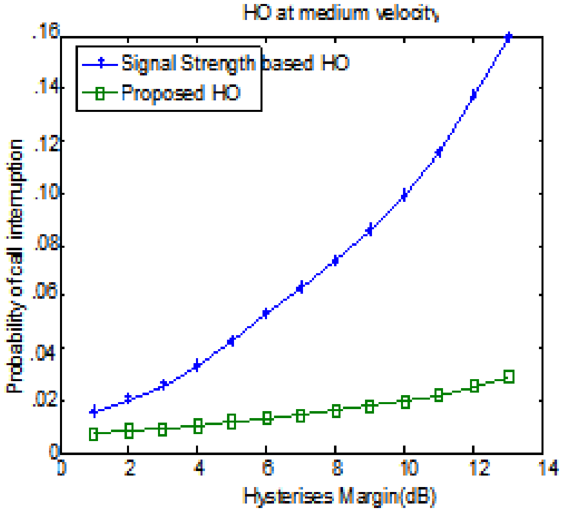

Figure 6b. Probability of call interruption versus hysteresis margin for medium velocity

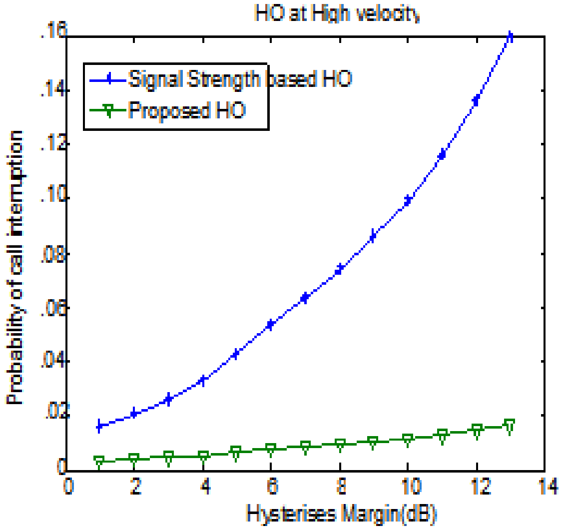

Figure 6c. Probability of call interruption versus hysteresis margin for high velocity

TABLE 1 SIMULATION PARAMETERS

R1=5000m	Radius of WiMAX cell	L_t= 3 dB	Transmitter antenna loss
R2 =5000m	Radius of LTE cell	G_r= 0 dB	Receiver antenna gain
d_0=100m	Correlation distance	L_r= 8 dB	Receiver antenna loss
Pt =43dBm	Transmitter power	σ_i =8 dB	Standard deviation of shadow fading
=(10-100)m/s	Velocity of user	h_b= 50 meter	Base station antenna height
$q = 10$	MS antenna directivity	h_m= 2 meter	Mobile station antenna height
ρ_i =0.95	Correlation coefficient	f_1 = 3500 MHz	Carrier Frequency of WiMAX
G_t= 18 dB	Transmitter antenna gain	f_2 = 2500 MHz	Carrier Frequency of LTE
d_1 =10	Smoothing filter period	$S_{th1} = S_{th2} = -107$ dB	Threshold Signal Strength
σ_d = 10 meters	Standard Deviation of distance	σ_v =10 m/s	Standard Deviation of velocity
a = 3.6	b(m^{-1}) = 0.005	c(m) = 20	D=10000 m

VI. CONCLUSION

In this paper, we proposed signal strength and residual time based vertical handover mechamism for heterogeneous networks. The performance evaluation for the proposed mechanism and traditional signal strength based handover is done using simulation in Matlab. The results obtained in this paper lead to the conclusion that number of handovers and position of handover can be optimized by tuning threshold values of hysteresis margin and residual time for different velocities of mobile user. A reduced handover rate is obtained which will decrease signalling load. In addition, a lesser probability of call interruption results to seamless communication. The proposed handover mechanism is well suited for high velocity applications.

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