CHAPTER III

RECEIVED SIGNAL STRENGTH PLUS RESIDUAL TIME DRIVEN HANDOVER ALGORITHM

3.1   INTRODUCTION

Looking into the widespread access of broadband to support many multimedia applications, interoperability between different networks seems to be essential. As discussed in literature survey, location information has been used as handover criteria. With this idea, utilizing distance and velocity for making a handover decision may be a good proposition for enhancing handover performance in velocity varying environments in heterogeneous networks. In this chapter, we have proposed a signal strength plus residual time driven handover mechanism in which time required by mobile user to reach the boundary of the serving cell is also considered as an important handover decision parameter. The time to reach the boundary of serving cell, referred to as Residual Time ($\overline{T}$), is determined using the information about the location and velocity of the mobile user.

It is desirable to minimize handover rate and probability of call interruption in order to maintain seamless mobility and to make the best utilization of the network resources. Keeping this in mind, optimum threshold values of hysteresis and residual time are chosen for different velocities of MN. Performance evaluation is performed for the proposed handover mechanism which assumes signal strength, hysteresis margin and residual time as criteria to initiate handover. Simulation results show that the proposed mechanism improves handover efficiency in terms of handover rate and probability of call interruption.

3.2   SYSTEM MODEL

We consider the network configuration shown in Fig. 3.1 for performance evaluation and for estimating threshold parameters for RSS plus residual time based handover algorithm.
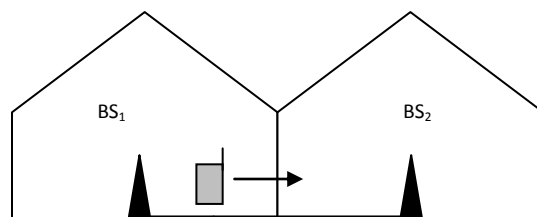
Fig.3.1. Network model

It is assumed to be comprised of WiMAX and LTE cells adjacent to each other with a distance 'D' between two BSs. Each 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 (BS$_1$) to the neighboring cell(BS$_2$). The wireless network planning requires a suitable propagation model according to the environment surrounding the MN. The signal strength received at a distance 'd' is affected by path loss, shadow fading and multipath fading during propagation as given by

$$S_i \ (d) \ = \ P_t + G_t - L_t - PL_i \ (d) + G_r - L_r + \varphi_i \qquad (3.1)$$

where P_t is the transmitter power, G_t and G_r are the antenna gains of transmitter and receiver respectively. L_t and L_r are the losses due to transmitter and receiver antenna respectively. $PL_i(d)$ denote path loss for ith BS at distance 'd' whereas the term φ_i is the representation of shadow fading component and modeled as a Gaussian process with zero mean and σ_i standard deviation.

$$\varphi_i(d) \ = \ \rho \ \varphi_i \ (d-1) + \sigma_i \ \sqrt{1 - \rho^2} \ W(0,1) \qquad (3.2)$$

where ρ is the correlation coefficient, σ_i is the standard deviation of shadow fading and W(0,1) represents a normal random variable with zero mean and unity variance. Multipath fading is neglected at high frequencies as it is averaged out due to much shorter correlation distance as compared to shadow fading. As a result, the only considered phenomenon that affects the accuracy of the measurement is shadow fading. The path loss can be evaluated by deterministic or empirical models. The former calculates signal strength 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, such as distance, frequency, antenna height, etc. Here, Erceg empirical propagation model [128] is considered to calculate path loss as recommended by IEEE 802.16e standard due to its suitability for high frequencies [129].

The model is defined for three different terrain types A, B and C. Terrain type A is suitable for rural areas with moderate to heavy tree density. Terrain type C is a flat terrain, suitable for urban areas with light tree density. Terrain B is in between, suitable for suburban areas. The path loss increases with distance from serving BS according to Eqn 3.3.

$$PL_i(d) = X + 10n\log_{10}(d_i/d_0) + PL_f + PL_{hms} + PL_{qms} \tag{3.3}$$

Parameter X represents the free space path loss and is given by

$$X = 20\log_{10}\frac{4\pi d_0}{\lambda} \tag{3.4}$$

The term n represents path loss exponent, defined as

$$n = a - bh_b + \frac{c}{h_b} \tag{3.5}$$

$$PL_f = 6\log\frac{f_i}{1900} \tag{3.6}$$

$$PL_{hms} = -10.8\log\left(\frac{h_m}{2}\right) \qquad \text{for type A and B} \tag{3.7}$$

$$PL_{hms} = -20\log\left(\frac{h_m}{2}\right) \qquad \text{for type C} \tag{3.8}$$

$$PL_{qms} = 0.64\ln\left(\frac{q}{360}\right) + 0.54\left(\ln\left(\frac{q}{360}\right)\right)^2 \tag{3.9}$$

where f_i is the carrier frequency and h_b is the BS antenna height in meters. The parameters a, b and c for terrain categories, A, B and C are given in Table 3.1 and account for path loss exponent. PL_f, PL_{hms} and PL_{qms} are correction factors corresponding to frequency f, MN's height h_m, and MN antenna angular direction q respectively. 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 direction of the antenna. The variation of RSS with distance conidering the effect of fading in rural, suburban and urban areas is shown in Fig. 3.2. The RSS at a particular distance is decreasing as we move from urban (light tree density) to rural area (heavy tree density) [128]. The signal strength received from BS_1 and BS_2, termed as $S_1(d)$ and

Table 3.1. Model parameters [128]

Model Parameter	Terrain Type A	Terrain Type B	Terrain Type C
a	4.6	4.0	3.6
$b(m^{-1})$	0.0075	0.0065	0.005
c(m)	12.6	17.1	20

$S_2(d)$ respectively, are smoothed in order to reduce fluctuations due to shadow fading as shown in Fig. 3.3. The signal obtained after smoothing is given by

$$\overline{S_1(d)} \;=\; \frac{1}{d_1} \sum_{n=0}^{d} S_i(d-n)W_n \tag{3.10}$$

where $S_i(d)$ is the dth 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 a rectangular window, $W_n = 1$ for all n. For the present scenario, averaging is performed using an exponential window function whose impulse response is given by

$$W_n \;=\; (1/d_1)\,\exp(-d/d_1) \tag{3.11}$$

The residual time is a function of distance of mobile user from serving BS and velocity of MN. The estimated distance at a distance 'd' from BS_1 is computed as $d_e(d) = d + n_d$ and the velocity of the mobile user is estimated as $v_e(d) = v + n_v$, where n_d and n_v represent distance measurement error and velocity measurement error respectively. These are considered as independent white Gaussian processes having zero mean and variance σ_d^2 and σ_v^2 respectively.

The radius of the serving cell, R_1 can be represented as the distance between BS and boundary of the cell. The residual time at a distance 'd' from BS_1 is given by

$$\overline{T}(d) = (R_1 - d_e(d)) / v_e(d) \tag{3.12}$$
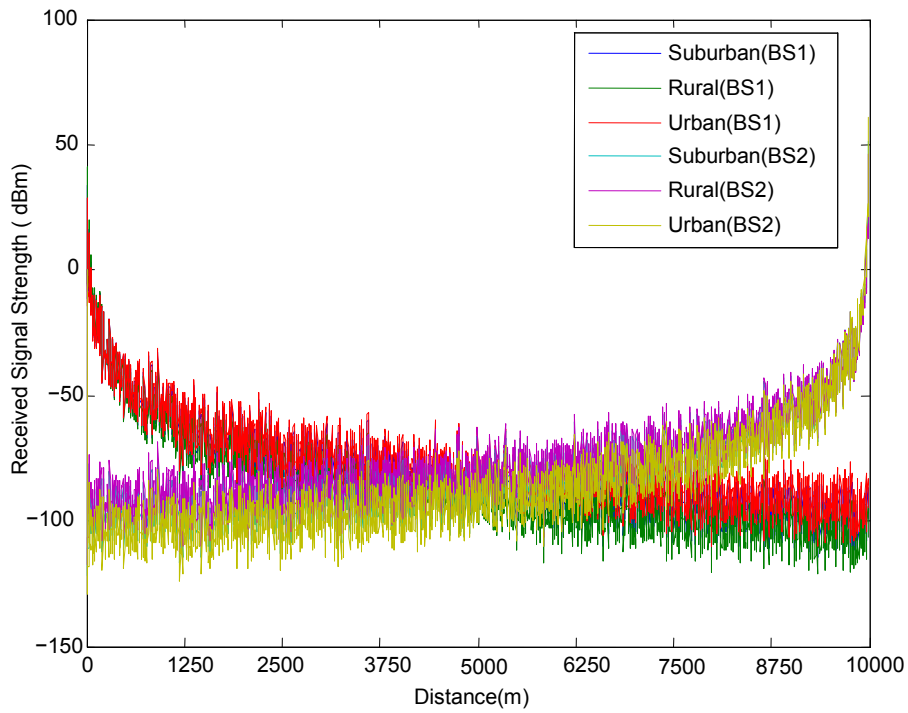
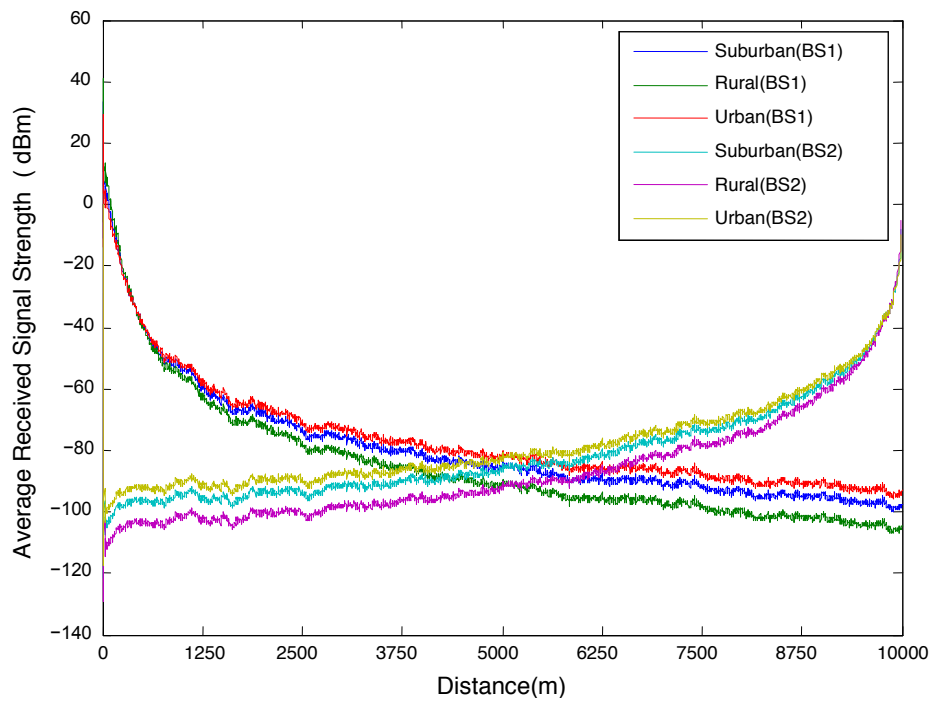Fig. 3.2 Received signal strength versus distance

Fig. 3.3 Average received signal strength versus distance

3.3 STEPS FOR SIGNAL STRENGTH PLUS RESIDUAL TIME BASED HANDOVER ALGORITHM

As the focus is on the handover initiation decision in this section, the conditions for handover initiation are defined explicitly. For this purpose, the signal strength received from serving cell and the target cell are monitored continuously. The proposed handover algorithm performs handover from BS_1 to BS_2 if both of the following conditions are met:

1) If the difference between average RSS from the BS_2 and BS_1 is greater than hysteresis margin H (dB).

2) If the residual time to reach the boundary of BS_1 is less than the threshold time (T_{th}).

Similarly, handover from BS_2 to BS_1 will occur when

3) If the difference between average RSS from the BS_1 and BS_2 is greater than hysteresis margin H (dB).

4) If the residual time to reach the boundary of BS_2 is less than the threshold time (T_{th}).

The parameters H and T_{th} are hysteresis margin and time threshold settings respectively. Typical values of these thresholds are tuned to improve the handover performance and will be discussed in the next section. The velocity of the mobile user is considered within a range of (1−100) m/s. The threshold for hysteresis and residual time are obtained for different velocities.

To show relative improvement in performance by the proposed handover algorithm as compared to the conventional RSS based handover algorithm, simulation results are obtained for both algorithms. According to the RSS based handover algorithm, the handover is triggered at a point where the signal strength of target cell exceeds the signal strength of serving cell by hysteresis margin H. This type of algorithm may cause the excessive number of handovers and ping-pong effect may also occur due to fluctuations in RSS. The MN may go on switching from one network to another which may enhance signaling load associated with handover process. This motivates us for this research to provide mobile users an alternate with improved handover performance.

3.4   ANALYSIS OF THE RESULTS

To evaluate the performance of the proposed handover algorithm and to estimate suitable threshold parameters, simulation results are obtained for both proposed algorithm and conventional algorithm. The handover rate (h_n) and position of first handover (h_p) are the performance metrics that are investigated. Handover rate is defined as the average number of handovers experienced by MN while travelling through a trajectory from one cell to another. The position of first handover is denoted by the first crossover point on mobile trajectory where the conditions for handover, defined in the above section, are satisfied. The probability of call interruption P_i is defined as the probability that the call is interrupted due to unavailability of sufficient signal strength from either of the BSs. This situation may occur when the signal strength received from serving BS drops below the predefined threshold, but TBS is not able to provide sufficient signal strength.

In this section, the number of handovers and position of first handover is evaluated as mobile user moves with different values of velocity along a straight line trajectory between two BSs. Alongwith this, an attempt is made to find the variation of h_n and h_p with hysteresis margin. As these two metrics are contradictory to each other so a trade off is achieved by considering intersection point as the handover point.

In order to avoid handover at early stages, the residual time is also considered as a handover criteria. The residual time is calculated with the help of information about the location and velocity of mobile user as discussed in Section 3.2. For numerical computation, the typical values of system parameters falling in the range of practical interest have been chosen as shown in Table 3.2. Based on the results obtained through computer simulation, the following observations are made:

For conventional 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 as shown in Fig. 3.4. The position of the first handover is found to be 4600m which is too early when compared with boundary of serving cell, resulting into high handover rate of 5. In contrary to the RSS based method, the handover is not allowed to take place early in proposed handover mechanism as there is a certain constraint of residual time. The residual time should be less than

the threshold time (T_{th}) which makes handover to take place in the vicinity of the boundary of the cell. The following observations have been made through simulation results.

For mobile users moving with low velocity (1−30m/s), the handover point corresponding to hysteresis margin H = 6 dB can be considered as the appropriate handover point as shown from Fig. 3.5. It is clear from the figuren that the intersection point is obtained at the nearly same position for different values of T_{th}. It, therefore, may be concluded that the handover point obtained through the proposed algorithm is independent of the T_{th} for low velocity scenario. The handover rate is approximately 3.5 and the first handover position is 5130 m which is nearer to the boundary of the current cell as compared to the conventional method discussed in the above paragraph.

Table 3.2 Simulation parameters

Radius of WiMAX cell	R_1 = 5000m	Transmitter antenna loss	L_t = 3 dB
Radius of LTE cell	R_2 = 5000m	Receiver antenna gain	G_r = 0 dB
Correlation distance	d_0 = 100m	Receiver antenna loss	L_r = 8 dB
Transmitter power	P_t = 43dBm	Standard deviation of shadow fading	σ_i = 8 dB
Velocity	v = (1−100)m/s	Base station antenna height	h_b = 50 m
MN antenna angular direction in degrees	q = 10	Mobile station antenna height	h_m = 2 m
Correlation coefficient	ρ_i = 0.95	Carrier frequency of WiMAX	f_1 = 3500 MHz
Transmitter antenna gain	G_t = 18 dB	Carrier frequency of LTE	f_2 = 2500 MHz
Smoothing filter period	d_l = 10ms	Threshold signal strength	S_{th1} = S_{th2} = − 107dB
Standard deviation of distance	σ_d = 10 m	Standard deviation of velocity	σ_v = 10 m/s
		Distance between two BSs	D = 10000 m

For users moving with medium velocity (30−70 m/s), the graphs are drawn for h_n and h_p with different values of H and T_{th} in Fig. 3.6. Three intersection points are obtained corresponding to T_{th} = (5, 6 and 7) seconds. The handover Point (T_{th} = 6s, H= 8dB) is corresponding to the least handover rate, therefore can be considered as an optimum handover

point. The handover rate is equal to 3 and h_p is equal to 4850 m which is earlier than low velocity scenario discussed in the above paragraph.

For high velocity scenario (70−100 m/s), two intersection points are obtained. The handover 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 is observed to be 4890m which is comparable to point 1(4900m). Thus, it is considered as an optimum handover point as shown in Fig. 3.7.

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

The probability of call interruption P_i increases with increase in H. This is due to the fact that the signal strength received from TBS relative to serving BS should always exceed by H which may not be available at the time of LD in case of high values of H. However, a lesser value of H will increase the 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 obtained for P_i with respect to H at low, medium and high velocity are shown in Fig. 3.8(a−c). The probability of call interruption increases gradually with hysteresis margin in case of signal strength based handover because the handover point will get shifted towards left of the serving cell boundary for high values of H. In the proposed method, there is a constraint of residual time threshold which will avoid shifting of handover point away from the boundary. In addition, the residual time is dependent upon the velocity of the user which helps to maintain the handover performance irrespective of the variation in velocity whereas the situation gets worse in conventional method with the increase in velocity. This shows significant improvement in handover performance of the proposed method in terms of P_i for a wide range of velocity. It is evident from the graphical results that P_i is reduced in the proposed mechanism for all values of H when compared with conventional signal strength based algorithm.
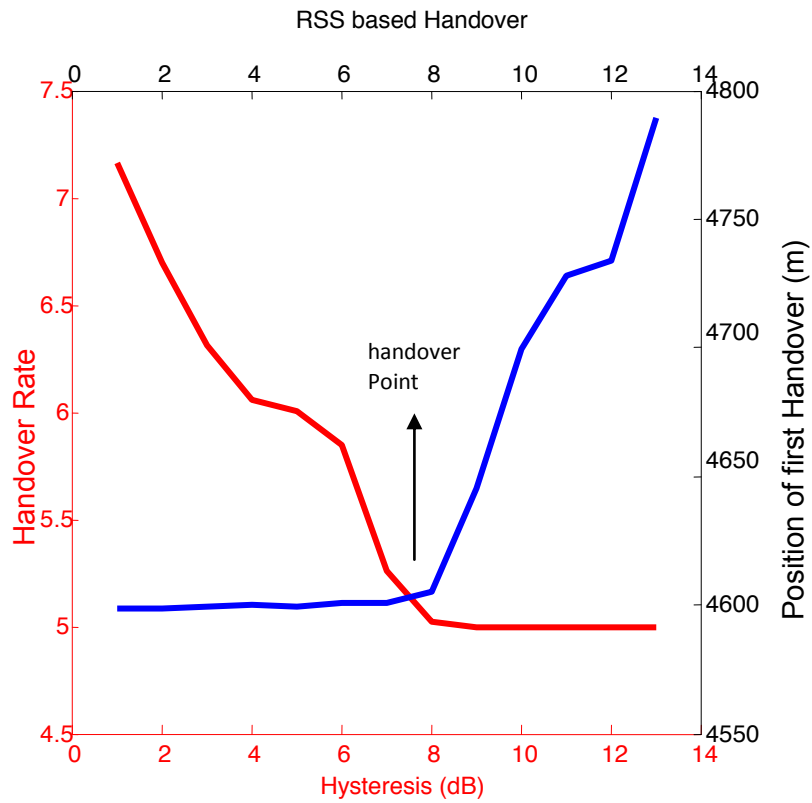
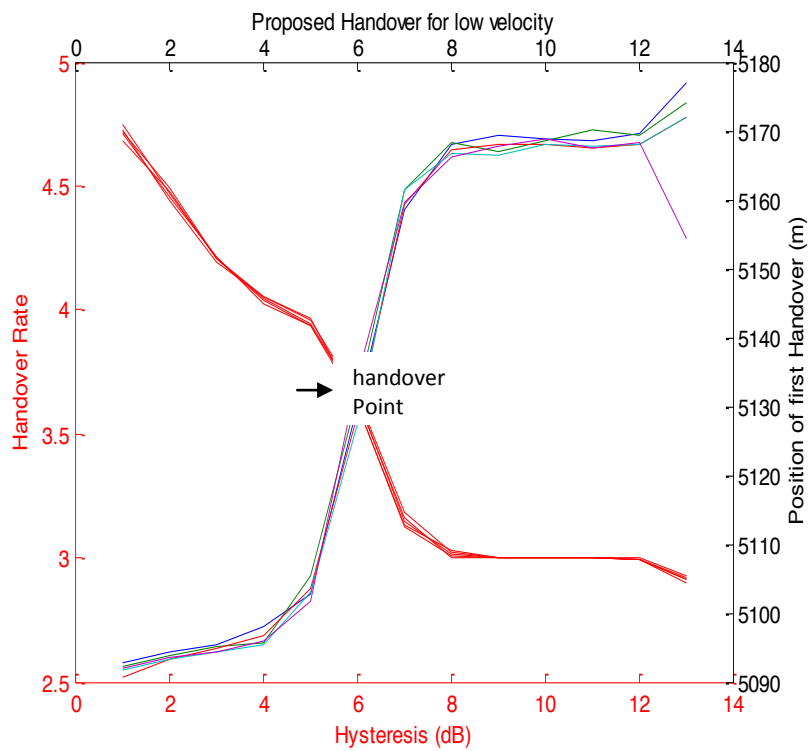Fig. 3.4 Handover point for RSS based handover mechanism

Fig.3.5 Handover point for proposed handover mechanism for low velocity users
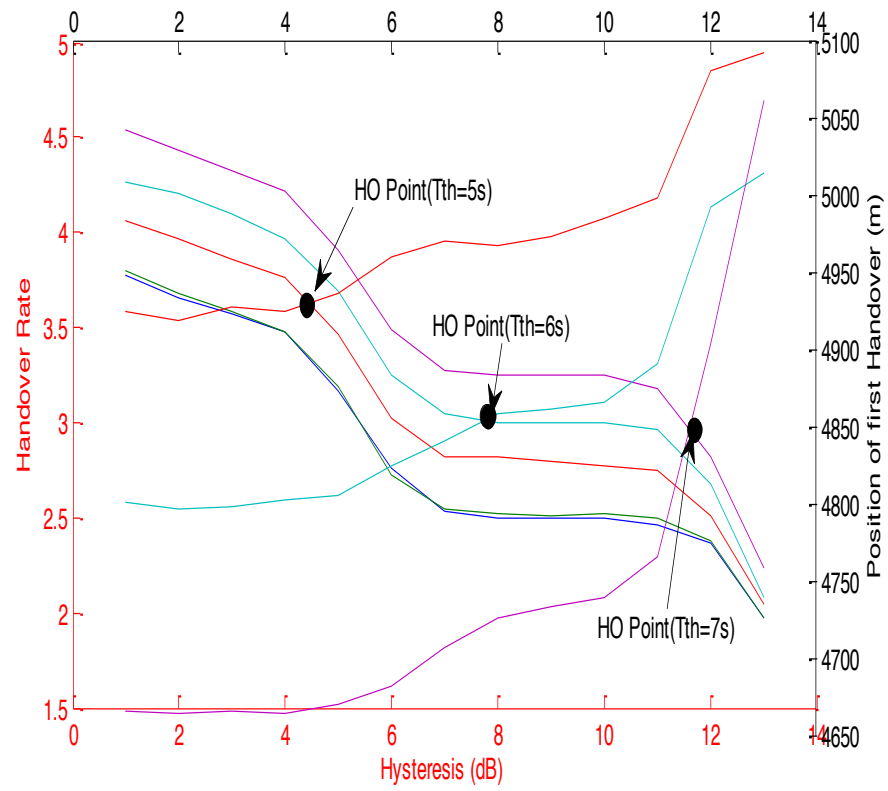

Fig.3.6 Handover point for proposed handover mechanism for medium velocity users
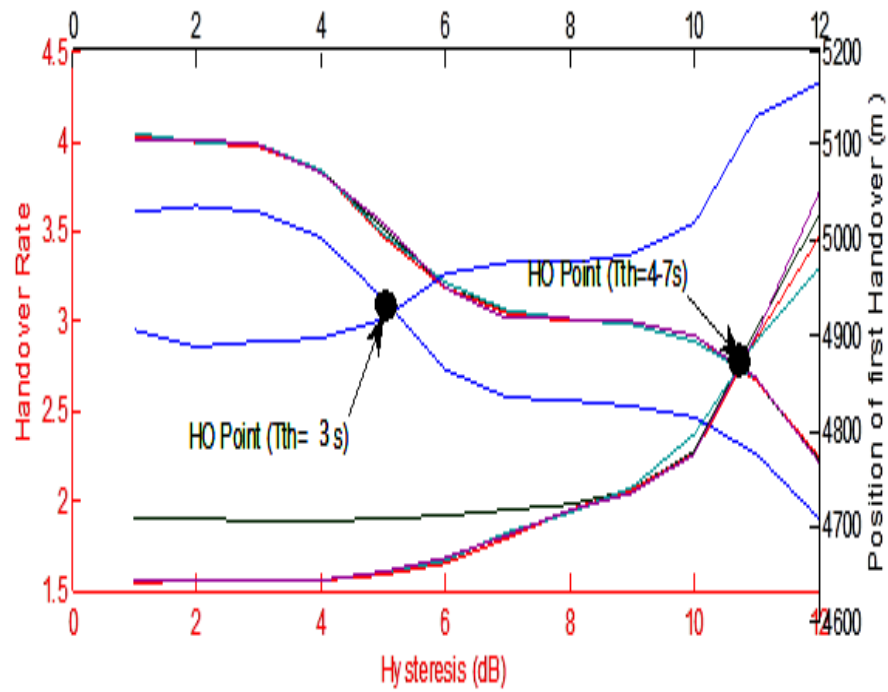
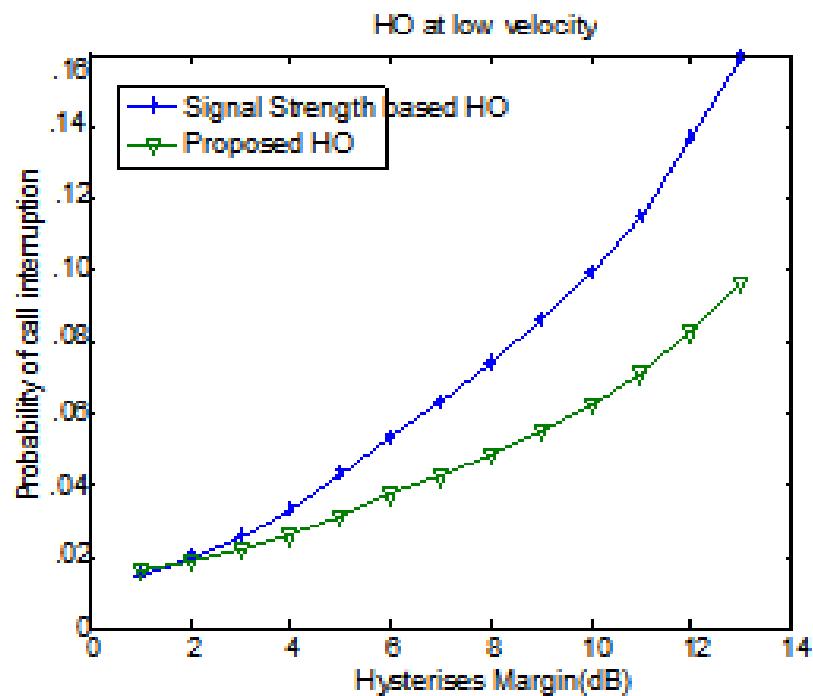Fig.3.7 Handover point for proposed handover mechanism for high velocity users

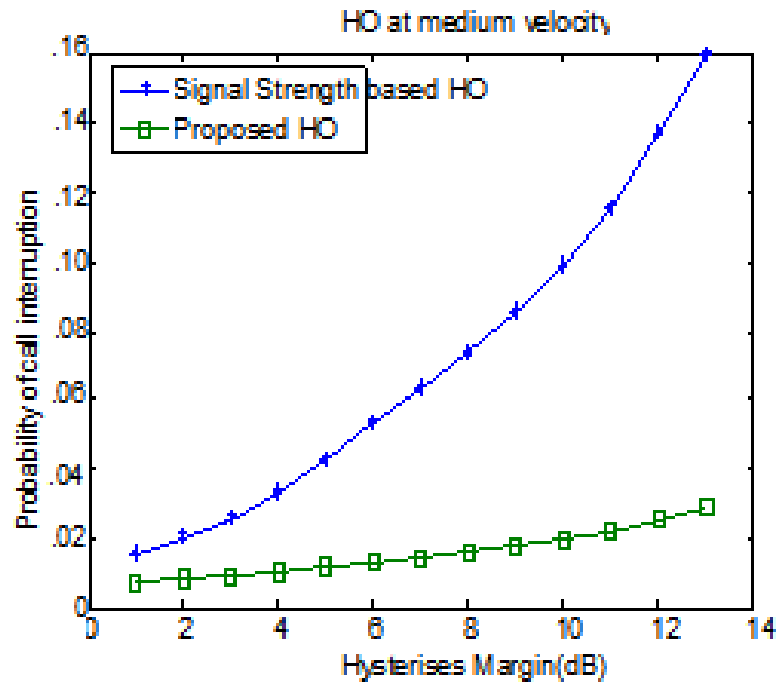Fig.3.8a Probability of call interruption for low velocity users

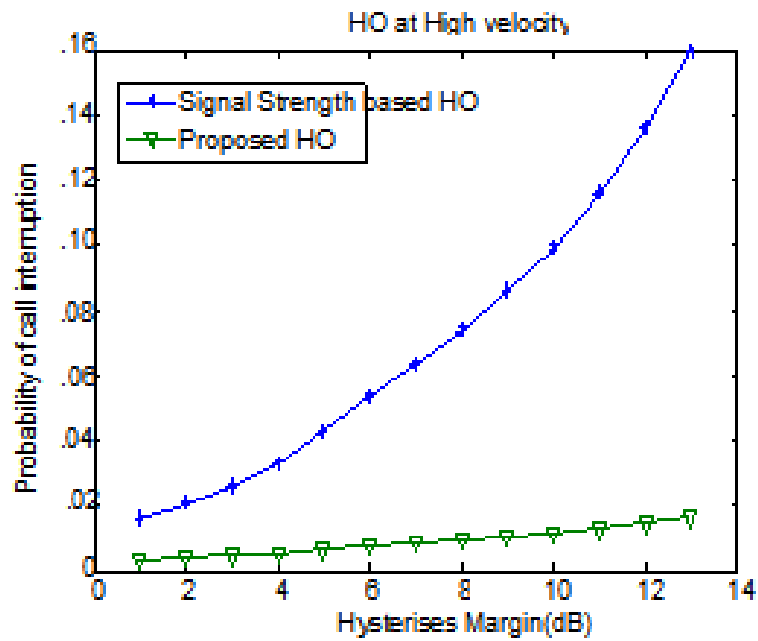Fig.3.8b Probability of call interruption for medium velocity users

Fig.3.8c Probability of call interruption for high velocity users

3.5   SUMMARY

In this chapter, we have proposed signal strength and residual time based vertical handover mechanism for heterogeneous networks. The performance evaluation of the proposed mechanism and conventional signal strength based handover is carried over using simulation in Matlab (version 7.10). The results obtained in this chapter lead to the conclusion that the number of handovers and position of handover can be optimized by tuning threshold values of hysteresis margin and residual time. The handover rate obtained in the proposed method is 30% lesser than conventional methods which decreases overall signalling load on the network. In addition, the probability of call interruption is reduced by 80% approaching to seamless communication. The proposed handover mechanism is well suited for the higher mobility scenario.