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An Approach towards Seamless Handover with Maximum Resource Utilization in Mobile Wireless Networks

Sudesh Pahal**, Brahmjit Singh[2], Ashok Arora[3]
[1,3]Manav Rachna International University, Faridabad, India
[2]NIT, Kurukshetra, India

ABSTRACT

In mobile wireless networks, a seamless handover between different communication systems has been a challenging issue. A link going down (LGD) event based on L2 layer information has been incorporated by the IEEE 802.21, media independent handover (MIH) framework. Link going down trigger allows accomplishing handover efficiently with the prior intimation of handover and enables L3 entities streamline their handover (HO) related activities. As velocity of user has a significant impact on HO initiation, predefined LGD signal strength threshold is not a good option to trigger an LGD event. To achieve seamless HO and to maximize network resources, it is necessary to make LGD threshold signal strength velocity adaptive in mobile wireless networks. In this paper, we make a comparative study of velocity adaptive handover algorithm and propose an approach to improve HO performance. We show that by triggering an LGD event, based on appropriate LGD threshold, the link failure probability and probability of false handover may be significantly decreased in mobile wireless networks.

Keywords: *Mobile wireless network, handover, MIH, 802.21, link going down trigger*

**Author for Correspondence* E-mail: pahal.sudesh@gmail.com

1. INTRODUCTION

The rapid expansion of mobile communications over the last few years allows the users to communicate without geographical coverage limitations of individual communication systems such as WLAN and WiMAX. In order to achieve interworking of Internet with wireless networks and to meet the requirement of seamless HO for real time and multimedia applications, mobility management needs careful attention. The HO performance of mobile wireless networks can be improved by using cross layer trigger-based HO mechanism as compared to the layered approach [1].

The IEEE 802.21 media independent HO (MIH) framework [2, 3] provides link layer intelligence and other useful information to the upper layers to optimize HO between heterogeneous media. The information received at the physical layer is used to make handover decision at the network layer. The role of link triggers in the initiation of HO is significant. The LGD trigger implies that a broken link is imminent. A number of methods have been proposed for generating LGD triggers [4–6]. However, most of these methods use a predefined threshold of a specific metric such as received signal strength (RSS), bit error rate (BER) and distance. Several parameters changing over time such as wireless channel conditions, the MN speed and time required for performing an HO can result in an early or late HO initiation. It is, therefore, required to devise an optimum mechanism to generate an LGD trigger. Thus, in this paper we propose an optimized method for generating the LGD trigger. The remainder of this paper is organized as follows: Section 2 describes the related work in this field. Section 3 presents the proposed system model for analyzing adaptive trigger based HO algorithms. Extensive simulation experiments are carried out to evaluate the HO performance for the conventional HO algorithms in Sec. 4. The simulation results show that the proposed method significantly enhances the HO performance. Finally, concluding remarks and future scope are mentioned in Sec. 5.

2. RELATED WORK

In recent years, researchers have focused on cross layer trigger-based HO techniques to achieve seamless HO in mobile wireless networks. In [7], authors describe the IEEE 802.21 concept and ideas to optimize HO performance. The authors in [8] show the support of IEEE 802.21 functionalities to attain seamless mobility between IEEE 802.11 and IEEE 802.16. In [9], the collection and processing of cross-layer information is done with the help of a cross-layer trigger manager in which triggers are generated by event sources/trigger producers. The authors in [10] propose a cross-layer fast HO for session initiation protocol (SIP) which performs IP address reservation and SIP session update by linklayer (LL) information. A separate database to import mobility information from all layers instead of exporting information between layers has been proposed by authors of [11].

The above mentioned cross-layer HO algorithms provide efficient methods to improve HO performance but the effect of MN's velocity is not taken into account which is an important issue to be considered. In [6], authors propose methods to set appropriate RSS threshold for the LGD trigger to improve HO performance. The authors in [12] propose an adaptive and timely fired link trigger mechanism which can be applied to IEEE 802.21 for seamless HO in heterogeneous networks. In [13] and [14], authors present a predictive HO framework which generates link trigger to finish HO procedures before link down (LD) by using neighbor network information from MIHF. In [6, 12, 13, 14], the effect of velocity on threshold signal strength and HO required time is not considered. Chi Ma [15] proposed an MIH-based VOSHM for WiMAX networks by using HO probability value to trigger LGD event. The authors in [16] present a velocity-adaptive threshold to reduce HO delay for mobile WiMAX. A straight line motion of MN is assumed by the authors of [15, 16].

Most of the above mentioned HO algorithms make use of the standard network mobility management protocol, MIP, which is simple to implement but has several shortcomings. MIP latency is composed of HO requirement detection latency and MIP registration.

Journal of Communication Engineering & Systems
Volume 2, Issue 3, December2012, Pages 1-10

The proposed hierarchical MIP and other mobility protocols [17–19] are able to reduce registration signaling delay but do not addresses the problem of HO requirement detection delay. A generic link-layer technique making use of upper layers to aid HO protocols is used in [20]. However, it does not specify any particular mechanism for obtaining link-layer triggers. Most of the existing HO algorithms implicitly assume that the HO signaling delay is constant so they give poor performance in real-life dynamic environment. Mohanty [21] presented an LGD trigger algorithm for reducing link failure probability for different HO delays. However, the HO signaling delay prediction technique used in [21] is simple but introduces extra signaling overhead to the system which may not be acceptable for some particular deployment scenario. Also, the HO decision is made irrespective of whether MN in a particular network causes network resource wastage. The mobility protocol HMIP is used which is not suitable for high-velocity applications. None of the HO algorithms gives good performance in all respects like undisrupted services and network resource utilization. Thus, there is always a tradeoff between probability of HO failure and false HO initiation.

In view of the above, in the present work we propose an optimized trigger-based HO algorithm to overcome certain limitations of the above mentioned solutions.

3. SYSTEM MODEL

Mobile wireless networks demand service continuity and minimum HO disruption or link failure time to achieve seamless HO. The timing of LGD trigger event plays an important role in achieving this goal. The LGD event is triggered by the lower layers to initiate HO procedures by upper layers so that the HO preparation can be done in advance before the link-down event occurs. The system model considered for generating LGD trigger consists of two microcells as shown in Figure 1 which shows the MN moving with a velocity 'v' away from current BS (CBS) to new BS (NBS). The distance between two BSs is D. it is assumed that target network has sufficient resources. When MN reaches the point O (the distance from the boundary is d), it is assumed that it can move in any direction with equal probability, i.e.,

$$f(\theta) = 1 \div 2\pi; -\pi < \theta < \pi \quad (1)$$

Link quality is measured by RSS obtained from the log distance path loss model [22]. The signal strengths $S_i(k)$,I = 0, 1, received by MS from BS_i at Kth sampling instant can be written as

$$S_i(k) = \eta - 10\gamma \log_{10}(kd_s) + z_i(kd_s) I = 0,1 \quad (2)$$

Sampling is done at every kd_s distance where k is an integer and k€[1, D/d_s], d_s is the sampling distance. The parameters η and γ account for the path loss and γ represents path loss exponent. In averaged signal strength measurements, fast fading component of the fading can be neglected due to its short correlation measurements. So, shadow fading

Journal of Communication Engineering & Systems
Volume 2, Issue 3, December2012, Pages 1-10

is the only fading component which is to be considered. As a result, in this work the only considered phenomenon that affects the accuracy of the time prediction is shadow fading. $z_i(k)$ is shadow fading component at kth sampling instant, which is lognormally distributed and is described (in dB) as a Gaussian distribution with zero mean and standard deviation σ.

$$Z_i(k) = \rho_i z_i(k-1) + \sigma_i \eta_i(0,1) \quad (3)$$

ρ_i is correlation coefficient of $\{Z_i(k)\}$. $\eta_i(0,1)$ are normal random variables with zero mean and unity variance.

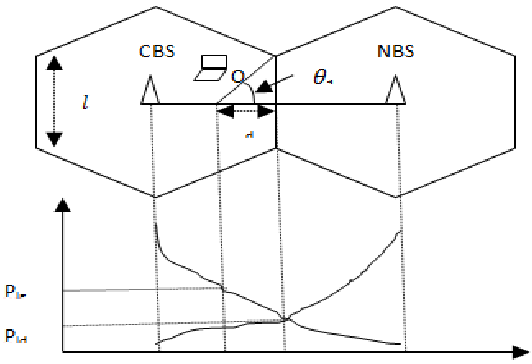

Fig. 1: A Simulation Model for HO Analysis.

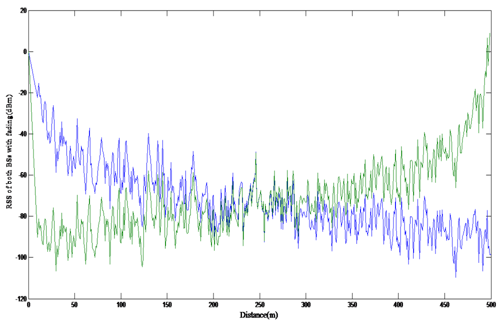

Fig. 2: The Variation of RSS with Fading Effect

The variation of received signal strength (RSS) with distance with fading is shown in Figure 2.

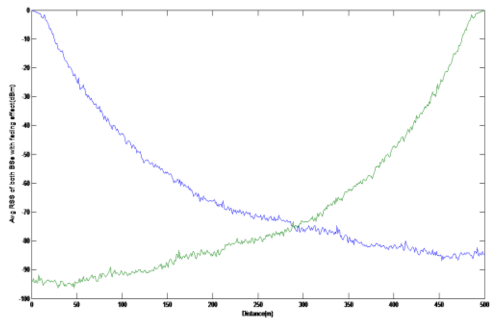

Fig. 3: The Variation of Average RSS with Fading.

The RSS at MS is averaged over N samples to reduce the fluctuations due to shadow fading. The following rectangular window is utilized for averaging

$$\overline{S_i(k)} = \frac{1}{N_w} \sum_{n=0}^{N-1} S_i(k-n) W_n \quad (4)$$

where $S_i(k)$ is the kth sample received from BS_i after averaging. W_n is the weight assigned to the sample taken at the end of $(k-n)$th interval, and $N_w = \Sigma_{n=0}^{N-1} W_n$ for a rectangular window, $W_n = 1$ for all n. P_{LD} is the link-down RSS threshold at MS below which a link-down event is said to have occurred. The link going down threshold (P_{th}) is calculated as

$$P_{th} = \alpha_{lgd} * P_{LD} \quad (5)$$

where α_{lgd} is the anticipation factor, > 1. The wireless link quality rapidly drops to minimal level with high MN speed as compared to a slow-moving MN. The LGD trigger should be fired prior to LD event by at least the time required to finish all HO procedures (π). At LGD event, the RSS is P_{th} which may be fixed or may be variable according to α_{lgd}. It should be adaptive for mobile users to achieve optimized HO performance. We can set appropriate value of α_{lgdv2} with moving speed of v_2 if given the value of v_1 and α_{lgdv1}.

$$\alpha_{lgdv2} = \frac{1}{1-\frac{v2}{v1}\left(1-\frac{1}{\alpha lgd_{v1}{}^{\frac{1}{\beta}}}\right)} \tag{6}$$

It has been evaluated experimentally by [15] that $\alpha_{lgdv1} = 1.01$ at $v_1 = 1$ m/s. So we can find α_{lgdv2} for different values of v_2 and thus P_{th1} may be written as

$$P_{th1} = \alpha_{lgdv2} * P_{LD} \tag{7}$$

By using this value of LGD threshold, the appropriate time for HO initiation and LGD trigger can be calculated. From Figure 1, it is clear that the need for HO to NBS arises only if MN's direction of motion from O is in the range where otherwise HO initiation is a false one. The probability of false HO initiation may be written as

$$P_{av} = 1 - \int_{-\theta 1}^{\theta 1} f(\theta)d\theta$$

$$= 1 -- \frac{2\theta_1}{2\pi} = 1 -- \frac{1}{\pi}\arctan\left(\frac{l}{2d}\right) \tag{8}$$

The time taken by MN to go beyond the coverage area of CBS is given by

$$t = \frac{d\sec\theta}{v} \tag{9}$$

From [16], the pdf of t is given by

$$f(t) = \begin{cases} \frac{d}{\theta 1 t\sqrt{v^2t^2-d^2}}, & \frac{d}{v} < t < \frac{\sqrt{\frac{l^2}{4}+d^2}}{v} \\ 0, & otherwise \end{cases} \tag{10}$$

The HO failure is said to occur if the time to reach the cell boundary is less than the HO signaling delay. The probability of HO failure is given by

$$p_f = \begin{cases} 1 & \tau > \frac{\sqrt{\frac{l^2}{4}+d^2}}{v} \\ p(t<\tau) & \frac{d}{v} < \tau < \frac{\sqrt{\frac{l^2}{4}+d^2}}{v} \\ 0 & \tau \le \frac{d}{v} \end{cases} \tag{11}$$

where τ HO signaling delay. $p(t < \tau)$ is the probability that $t < \tau$ and is given by

$$p(t<\tau) = \int_0^\tau f(t)dt$$

$$= \int_{\frac{d}{v}}^{\tau} \frac{d}{\pi t\sqrt{v^2t^2-d^2}}dt$$

$$\approx \frac{1}{\theta_1}\arccos\left(\frac{d}{v\tau}\right) \tag{12}$$

An efficient method to calculate P_{th} is given by Mohanty [21] which allows us to choose a desired value of HO failure probability for a particular velocity. The distance is calculated for a desired value of using the following equation.

$$d = \sqrt{\tau^2v^2 + l^2(p_f - 2 + 2\sqrt{1-p_f})} \tag{13}$$

The RSS value when the MT is at a distance *d* from the cell boundary will give LGD threshold P_{th2} and is given by

$$P_{th2} = 10\log_{10}[P_r(1-d)] \tag{14}$$

4. RESULT ANALYSIS

In this section, we present numerical results to evaluate HO performance for different velocities in mobile wireless networks. Matlab simulations are conducted to evaluate probability of HO failure and probability of false HO initiation for each of the above mentioned LGD thresholds P_{th}, P_{th1}, P_{th2}. The LGD thresholds P_{th}, P_{th1} and P_{th2} for different velocities and a signaling delay of 4 s are shown in Figure 4.

The LGD threshold P_{th1} increases linearly as velocity increases which results in decrease in P_f at higher velocities. P_{th2} is greater initially as compared to P_{th1} and results in higher values of P_a. Five thousand realizations were used to estimate the probability at each parameter setting. In the present work, we are analyzing the effect of LGD threshold RSS on probability of HO failure (P_f) and probability of false HO initiation (P_a). For numerical computation, we set the system parameters as shown in Table I.

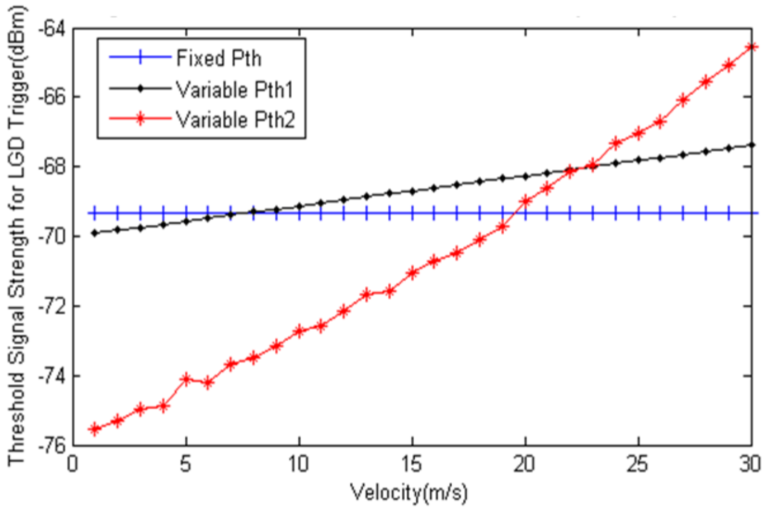

Fig. 4: The LGD Threshold variation and velocity for delay=4 s.

Table I: System Parameters for Simulation Model.

D = 500 m	Distance between two BSs
d_s = 1 m	Sampling distance
l = 250 m	Side of microcell
d_0 = 10 m	Correlation distance
η = 20 dBm	Transmitter power
V = (1–30) m/s	Velocity
τ = 2–5 s	Signaling delay
ρ = 0.35	Correlation coefficient
γ = 4	Path loss exponent
σ = 6 dB	Standard deviation of shadow fading
P_{LD} = −70 dBm	Link down signal strength

4.1. Probability of HO Failure

Figure 5(a, b, c) show the variation of probability of HO failure (P_f) with respect to velocity for τ = 2 s, τ = 4 s and τ = 5 s respectively. From observation, the P_f increases gradually with velocity in case of fixed P_{th}. The P_f is increasing slowly for higher velocities in case of P_{th1}. Due to velocity adaptive LGD threshold, the LGD trigger is sent at appropriate time. Thus, higher layers can initiate the HO procedures in such a way that just enough time is there for the successful execution of the HO. For P_{th2} the minimum desired value of P_f (taken as 0.02) remains

STM JOURNALS

constant with change in velocity; hence, it gives the optimum results independent of velocity.

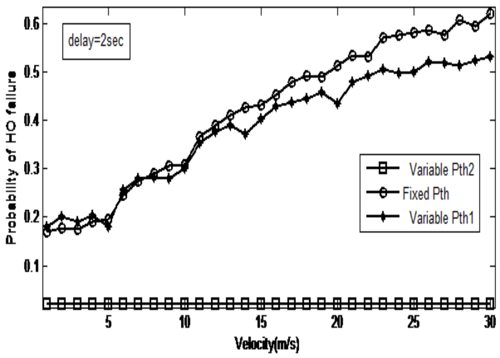

Fig. 5a: *P_f for Signaling Delay = 2 s.*

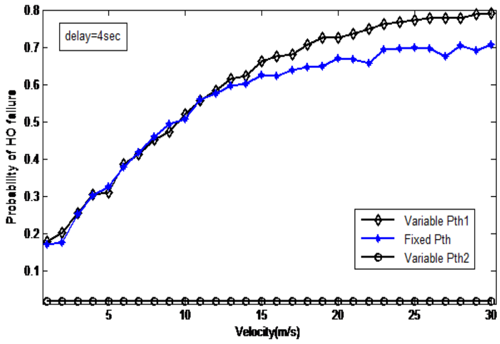

Fig. 5b: *P_f for Signaling Delay = 4 s.*

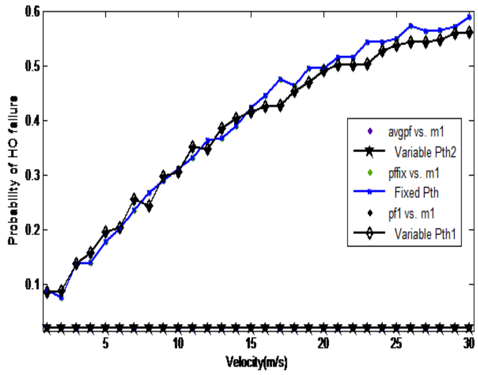

Fig. 5c: *P_f for Signaling Delay = 5 s.*

4.2. Probability of False HO Initiation

Figure 6(a, b, c) shows the variation of probability of false HO initiation (P_a) with respect to velocity for $\tau = 2$ s, $\tau = 4$ s and $\tau = 5$ s respectively. As evident, the P_a for P_{th} is almost constant for all velocities but has much greater value of P_f as compared to adaptive thresholds P_{th1} and P_{th2}. The P_a is lesser for P_{th1} as compared to P_{th2}.

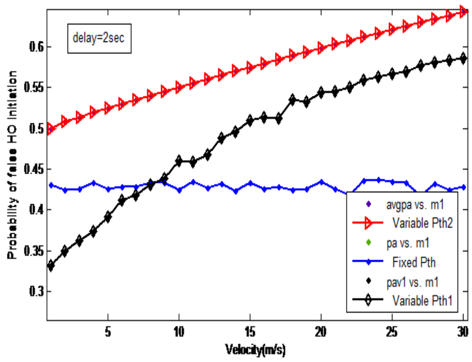

Fig. 6a: *P_a for Signaling Delay = 2 s.*

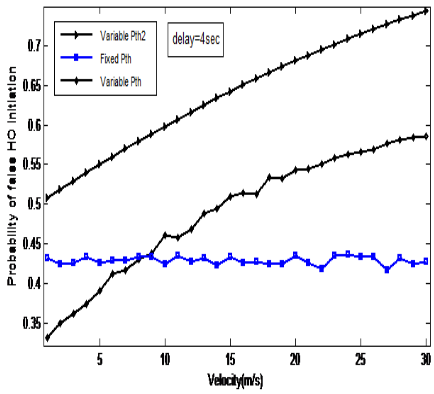

Fig. 6b: *P_a for Signaling Delay = 4 s.*

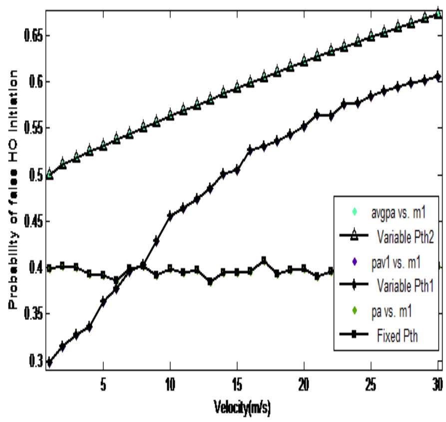

Fig. 6c: *P_a for Signaling Delay = 5 s.*

Table II illustrates the simulation results for both the probabilities for a delay of 5 s. It is clear that the P_f is minimum in case of P_{th2} but at the cost of P_a. The lower value of P_{th2} increases P_a, which results in resource wastage. Thus we predefine the probability of false HO initiation P_a (taken as 0.05) which is acceptable for microcells. Figure 7 illustrates the variation in P_f with velocity for different values of a predefined value of P_a (taken as 0.05). From Figure 7, it is clear that the P_f increases but still it is low for smaller values of velocity as compared to the case of P_{th} and P_{th1}. The value of P_a can be increased for delay-sensitive applications

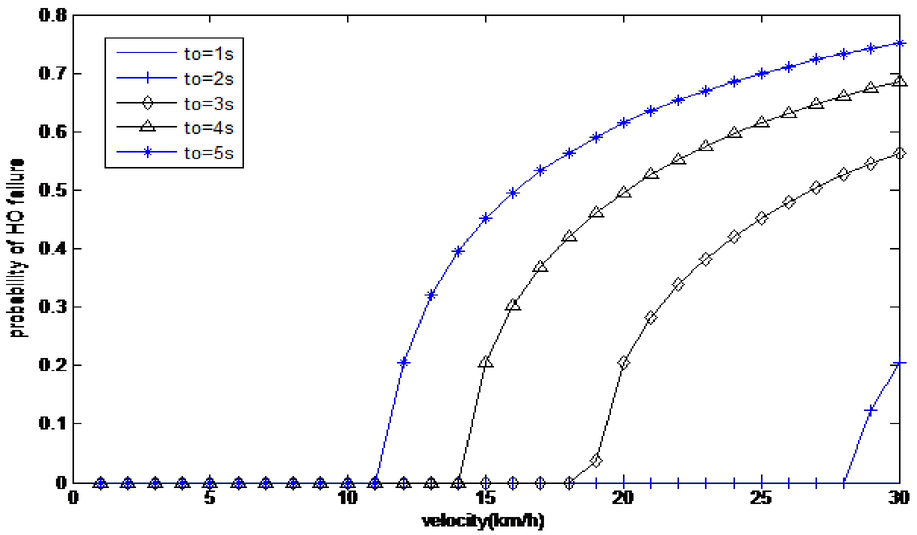

Fig. 7: *P_f vs. Velocity for Different Signaling Delays with $P_a = 0.05$.*

Table II: *Probabilities for Signaling Delay = 5 s.*

	P_f				P_a	
V	P_{th}	P_{th1}	P_{th2}	P_{th}	P_{th1}	P_{th2}
1	0.00	0.02	0.02	0.56	0.54	0.51
4	0.10	0.16	0.02	0.56	0.55	0.55
7	0.38	0.40	0.02	0.56	0.56	0.58
10	0.61	0.58	0.02	0.56	0.57	0.62
13	0.71	0.67	0.02	0.56	0.57	0.65
16	0.77	0.72	0.02	0.56	0.58	0.68
19	0.80	0.75	0.02	0.56	0.58	0.70
22	0.83	0.77	0.02	0.56	0.59	0.72
25	0.85	0.79	0.02	0.56	0.59	0.74
28	0.99	0.99	0.02	0.56	0.60	0.76

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5. CONCLUSION AND FUTURE WORK

In this paper, we have presented simulation results on the proposed HO algorithms based on the signal strength measurements. The HO performance is measured in terms of probability of HO failure (P_f) and probability of false HO initiation (P_a). It is evident from the simulation results that the HO performance is improved in terms of P_f for RSS threshold P_{th2} calculated from user defined P_f (taken as 0.02 which is acceptable for microcells) while P_f increases with velocity for velocity adaptive RSS threshold $P_{th1.}$ However, the latter gives us better results in terms of P_a as compared to P_{th2}. Thus, we can adopt the former HO algorithm (P_{th2}) to make undisrupted service requirements and latter HO algorithm (P_{th1}) for better network resource utilization.

We have proposed an optimized algorithm for handover initiation which simultaneously fulfils both requirements of undisrupted services and resource utilization. For given P_a, the value of P_f remains within the acceptable limits. For high velocity users with higher value of delay, P_f tends to increase with delay and velocity. The numerical results show that the proposed algorithm performs well for low and medium velocity users. At higher velocities, it also performs well provided the delay is around 2 s.

In future work, the mechanism could be improved in the following areas: the resource utilization and disruption can be optimized simultaneously for high velocity applications. Moreover, the interfacing among the layers needs to be focused. Other propagation and mobility models can be considered for different propagation environments and mobility of the user.

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