Performance of Soft Handover Algorithm in Varied Propagation Environments

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Abstract—CDMA cellular networks support soft handover, which guarantees the continuity of wireless services and enhanced communication quality. Cellular networks support multimedia services under varied propagation environmental conditions. In this paper, we have shown the effect of characteristic parameters of the cellular environments on the soft handover performance. We consider path loss exponent, standard deviation of shadow fading and correlation coefficient of shadow fading as the characteristic parameters of the radio propagation environment. A very useful statistical measure for characterizing the performance of mobile radio system is the probability of outage. It is shown through numerical results that above parameters have decisive effect on the probability of outage and hence the overall performance of the soft handover algorithm.

Keywords—CDMA, Correlation coefficient, Path loss exponent, Probability of outage, Soft handover.

I. INTRODUCTION

MOBILITY Mobility management is a great challenge in current and future radio access networks. In third generation (3G) networks user experienced quality of service (QoS) under the movement of User Equipment (UE) from one mobile cell to another cell has been improved by implementing soft handover (SHO). Soft handover makes it possible to have connections on several base stations (BS) simultaneously. Code-Division Multiple Access (CDMA) based cellular standards support soft handover, which makes smooth transition and enhanced communication quality. Soft handover offers multiple radio links to operate in parallel. The User Equipment (UE) near the cell boundary is connected with more than one Base Station (BS). Consequently, in soft handover UE is able to get benefit from macrodiversity. Soft handover can, therefore, enhance both the QoS and the capacity of CDMA based cellular networks [1-2].

Soft handover problem has been treated in literature for performance evaluation of the algorithms using both analytical and simulation methods [3-10]. An analytical model has been proposed in [11] to evaluate cell assignment probabilities to compute outage probability, macrodiversity gain, and signaling load.

Soft handover is associated with active set and its size. The inclusion and drop of a particular BS in/from the active set is determined by the initiation trigger utilized for soft handover algorithm. Initiation trigger include, received pilot signal strength, Carrier to Interference ratio, Bit-Error-Rate, Energy per bit to noise power density. In the present work, we consider received pilot signal strength as the initiation trigger. It is easily measurable quantity and directly related to the quality of the communication link between UE and BS and the most commonly used criterion for handover initiation trigger. In the present work, we have utilized received pilot signal strength as the initiation trigger. Due to the random nature of the received signal at UE, there are frequent inclusion and drop of BSs in the active set, which is the set of all the BSs with which an UE is communicating. Outage of all BS(s) from the active set causes handoff failure and termination of call. Communication quality is represented by the outage probability and this has been considered as the metric for performance evaluation of the soft handover algorithm. It is directly related to performance of handover process and is required to be minimized.

In this paper, we report the effect of radio propagation parameters on the outage probability. Path loss exponent, standard deviation of shadow fading and correlation coefficient of shadow fades have been utilized as the characteristic parameters of the radio propagation environment.

The rest of the paper is organized as follows. Section II describes the system model used for computer simulation; Soft handover algorithm follows cellular layout and radio propagation assumptions. It is followed by description of soft handover algorithm in section III. Numerical results are obtained, plotted and discussed in section IV. Finally, conclusions are drawn in section V.

II. THE SYSTEM MODEL

For the sake of simplicity, a basic system consisting of two BSs separated by a distance of D is considered in this paper [3-6]. Both of the BS(s) are assumed to be located in the center of the respective cell and operating at the equal transmitting power as depicted in Fig. 1. Hexagonal geometry of the cell has been considered. The UE moves from one cell to another along a straight line trajectory with constant speed.
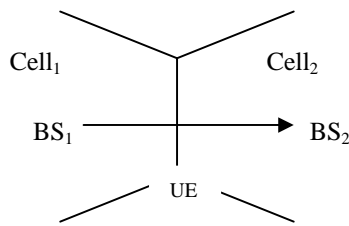
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Fig. 1 Cellular configuration

Received Signal Strength (RSS) at UE is affected by three components as follows:
(i) Path loss attenuation with respect to distance.
(ii) Shadow fading.
(iii) Fast fading.

Path loss is the deterministic component of RSS, which can be evaluated by outdoor propagation path loss models [12-13]. Shadowing is caused due to the obstruction of the line of sight path between transmitter and receiver by buildings, hills, trees and foliage. Multipath fading is due to multipath reflection of a transmitted wave by objects such as houses, buildings, other man made structures, or natural objects such as forests surrounding the UE. It is neglected for handover initiation trigger due to its short correlation distance relative to that of shadow fading. The UE measures RSS from each BS. The measured value of RSS (in dB) is the sum of two terms, one due to path loss and the other due to lognormal shadow fading. The propagation attenuation is generally modeled as the product of the ηth power of distance and a log normal component representing shadow fading losses [12]. These represent slowly varying variations even for users in motion and apply to both reverse and forward links. For UE at a distance 'd' from BS_i, attenuation is proportional to

$$\alpha(d,\zeta) = d^{\eta} 10^{\frac{\zeta}{10}} \qquad (1)$$

where ζ is the dB attenuation due to shadowing, with zero mean and standard deviation σ. Alternatively, the losses in dB are

$$\alpha(d,\zeta)[dB] = 10\eta \log d + \zeta \qquad (2)$$

where η (eta) is path loss exponent. where d represents BS to UE separation in kilometers . The autocorrelation function between two adjacent shadow fading samples is described by a negative exponential function as given in [14]. Let d_i denote the distance between the UE and BS_i, i=1, 2. Therefore, if the transmitted power of BS is P_t, the signal strength from BS_i, denoted S_i,(d) i=1, 2, can be written as

$$S_i(d) = P_t - \alpha(d_i,\zeta) \qquad (3)$$

The measurements are averaged using a rectangular averaging window to alleviate the effect of shadow fading according to the following formula [15]

$$\hat{S}_i(k) = \frac{1}{N_w}\sum_{n=0}^{N-1} S_i(k-n)W_n \quad i=1,2 \qquad (4)$$

where; $\hat{S}_i$ is the averaged signal strength and S_i is the signal strength before averaging process. W_n is the weight assigned to the sample taken at the end of $(k-n)^{th}$ interval. N is the number of samples in the averaging window

$N_w = \sum_{n=0}^{N-1} W_n$. In the case of rectangular window $W_n = 1$ for all n.

The size of averaging window should be selected judiciously as larger size of the window may not detect the need of handover initiation trigger at right time. On the other hand, smaller window may cause ping-pong effect, which is not desirable. In this work, first of all we have determined the optimum value of the size of averaging window for given system parameters and then the effect of propagation parameters is analyzed for that typical setting of averaging window size.

Shadow fading in the present work is modeled as follows:

$$\zeta(k) = \rho\zeta(k-1) + \sigma_i\sqrt{(1-\rho^2)}W(0,1) \qquad (5)$$

where ρ (rho) is correlation coefficient, σ is standard deviation of shadow fading and $W(0,1)$ represents truncated normal random variable.

III. SOFT HANDOVER ALGORITHM

The active set is defined as the set of BSs to which the mobile user is simultaneously connected. A soft handover algorithm is performed to maintain the user's active set. For the description of the algorithm, the following parameters are needed.
- HYST: Hysteresis for adding and dropping threshold;
- S_{min}: Minimum acceptable signal strength to maintain the call;

Active set is updated in following manner:

- If $\hat{S}_1(d)$ and $\hat{S}_2(d)$ are greater than S_{min} and absolute difference of $\hat{S}_1(d)$ and $\hat{S}_2(d)$ is greater than HYST, Active set consist of either BS_1 or BS_2.

- If $\hat{S}_1(d)$ and $\hat{S}_2(d)$ are greater than S_{min} and absolute difference of $\hat{S}_1(d)$ and $\hat{S}_2(d)$ is less than HYST, Active set consist of BS_1 and BS_2.

- If $\hat{S}_1(d)$ and $\hat{S}_2(d)$ are less than S_{min}, Active set consist of neither BS_1 nor BS_2. UE will have no connection with BS1 and BS_2. This state of the communication between BS and UE is referred as outage.

- For other than above conditions, Active set consist of either BS_1 or BS_2.

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Where $\hat{S}_1(d)$ and $\hat{S}_2(d)$ is the averaged signal strengths from BS_1 and BS_2 respectively.

Since received signal at distance d is a random variable, analytically Q – function or error function (erf) may be used to determine the probability of outage. The probability of outage (P_o) at distance d is given by

$$P_o(d) = Q\left(\frac{\hat{S}_{best}(d) - S_{min}}{\sigma}\right) \qquad (6)$$

where $\hat{S}_{best}(d)$ is the largest signal strength among available averaged signals from the BSs at distance d.

IV. RESULTS AND DISCUSSION

In this section, outage probability has been computed as the function of different system parameters and characteristic parameters of radio propagation environment. Numerical results for this performance metric are obtained via computer simulation for the system parameters indicated in Table I. System simulation is performed in Matlab 7.0. To obtain probability of outage for each system parameter setting, 10000 runs of the simulation program are performed.

TABLE I
SYSTEM PARAMETERS FOR SYSTEM SIMULATION

D = 2000 m	Distance between two adjacent BSs
S_{min}=-90dBm	Minimum acceptable signal to maintain the call
d_s = 1m	Sampling distance
P_t = 30dBm	Base station transmitter power

As depicted in Fig. 2a & 2b, there is decisive effect of sample size of the averaging window (N) on the probability of outage. It decreases sharply in the initial stage of the sample size. As N is increased, probability of outage decreases.

It indicates that for the given system parameters, mean probability of outage for N=20 is less than 0.1%, which is more than sufficient for seamless communication. Moreover, more averaging may lead to the failure of the detection of handover at right time and at right place. This situation is not desirable, particularly in microcellular systems where path loss characteristics are not gentle. In the light of the above discussion, for all the results reported henceforth the sample size N = 20 has been assumed.

Fig. 3a & 3b shows the variation of probability of outage with respect to path loss exponent. A large increase in probability of outage is observed with the increase of path loss exponent. The reason for this result is attributed to the fact that with greater value of path loss exponent, RSS will decrease faster and its probability of becoming less than required minimum value for maintaining call will be more. With higher value of path loss exponent, there will be sharp fall-off in the RSS. As a result, probability of outage will be more with increased value of path loss exponent. In such cases, QoS can be increased by increasing transmitter power.

Fig. 4a & 4b shows the probability of outage as a function of standard deviation of shadow fading. Greater value of standard deviation causes increased value of probability of outage. It is because higher the standard deviation more will be the random variation in the RSS, which leads to increased probability of outage.

Finally, Fig. 5a & 5b depicts the variation of probability of outage with respect to correlation coefficient of shadow fading. This plot shows that, as ρ is increased, probability of outage decreases rapidly. This is an interesting result and should be taken into consideration while designing handover algorithm for propagation environment with different values of correlation in shadow fades. Correlation coefficient is the measurement of the similarity between consecutive sample values. Increase in correlation coefficient reduces the randomness and hence will lead to reduced probability of outage.

From the above discussion, it is clear that radio propagation environment has decisive effect on the probability of outage in soft handover procedure. As probability of outage is the indication of termination of call, it becomes essential to reduce the probability of outage of the BSs in the active set. From the numerical results, inference may be drawn that a given set of handover design parameters may not yield optimum results in the entire cellular network. Propagation conditions may be different at different places and, therefore, handover design parameters should be adaptive in response to the changing environmental conditions of the radio propagation environment.
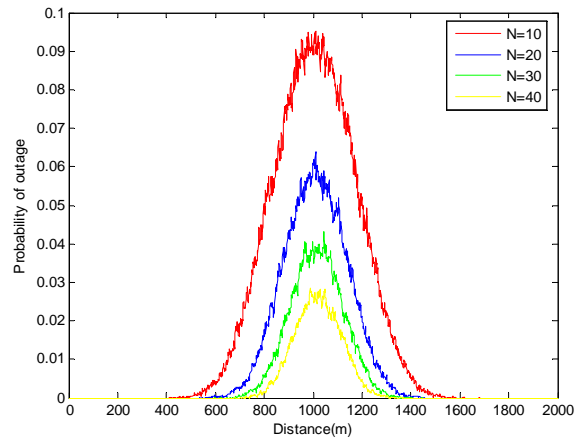

Fig. 2a Effect of window size on Probability of outage for given $\rho = 0.5, \sigma = 8dB, \eta = 3.6$

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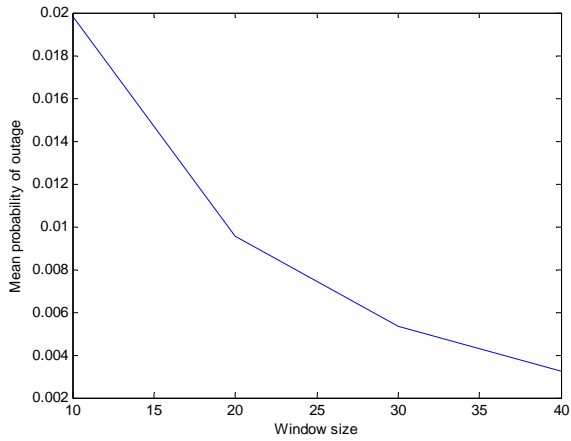Vol:2, No:9, 2008

Fig. 2b Effect of window size on Probability of outage for
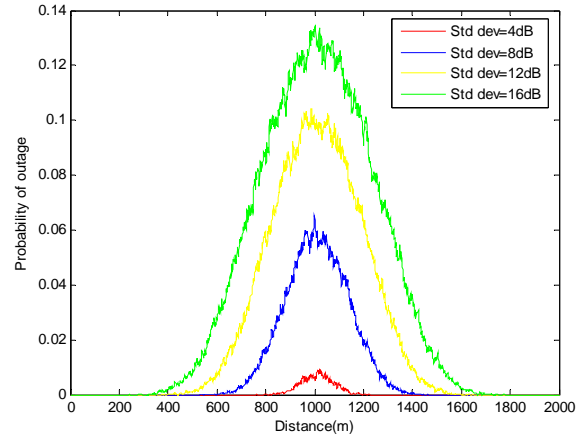given $\rho = 0.5, \sigma = 8dB, \eta = 3.6$

Fig. 4a Effect of standard deviation on probability of outage for
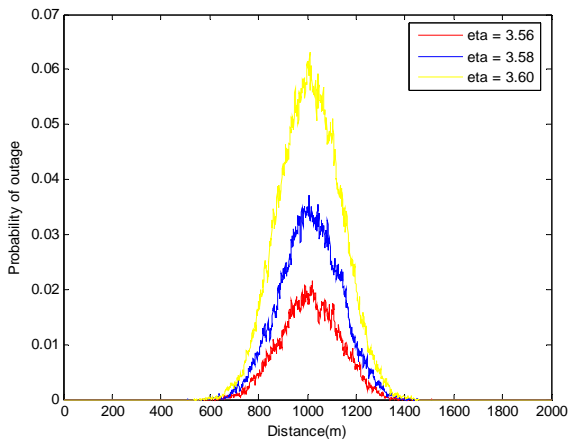given $\eta = 3.6, \rho = 0.5, N = 20$

Fig. 3a Effect of path loss exponent (eta) on probability of outage for
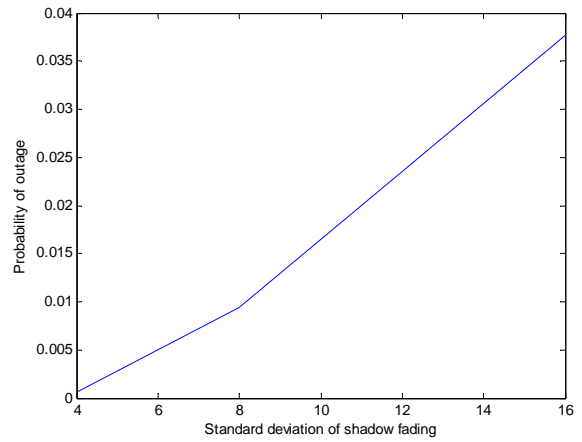given $\rho = 0.5, \sigma = 8dB, N = 20$

Fig. 4b Effect of standard deviation on probability of outage for
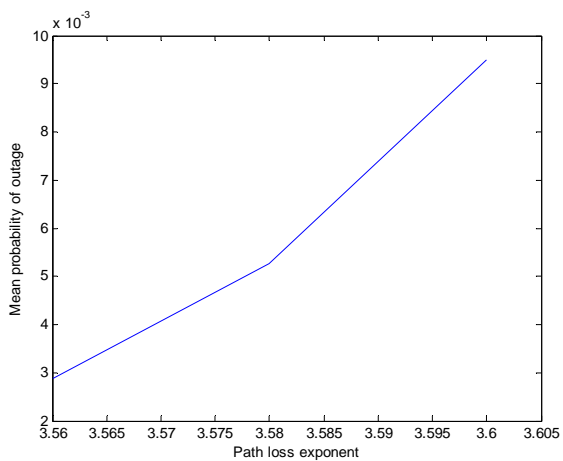given $\eta = 3.6, \rho = 0.5, N = 20$

Fig. 3b Effect of path loss exponent (eta) on probability of outage for
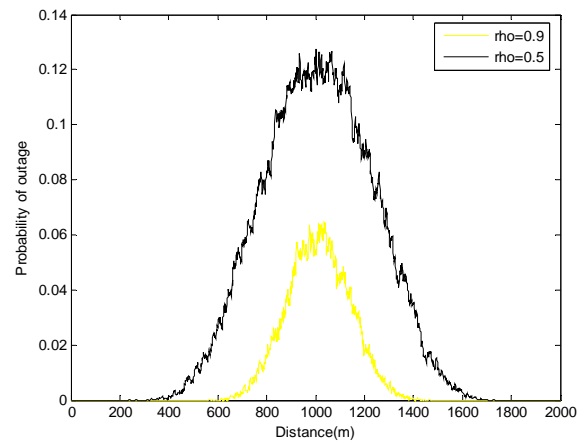given $\rho = 0.5, \sigma = 8dB, N = 20$

Fig. 5a Effect of Correlation coefficient (rho) on probability of
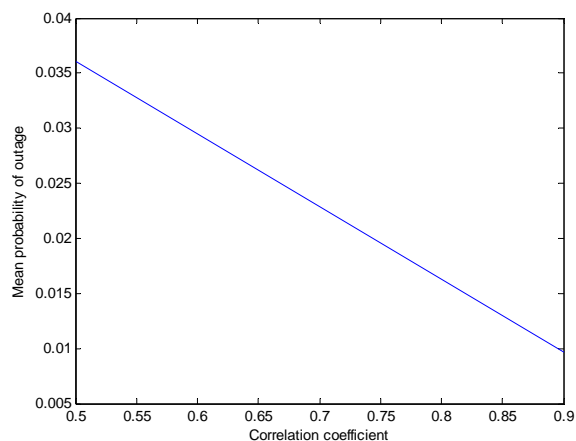outage for given $\eta = 3.6, \sigma = 8dB, N = 20$.

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Fig. 5b Effect of Correlation coefficient (rho) on probability of outage for given $\eta = 3.6, \sigma = 8dB, N = 20$.

V. CONCLUSION

In this paper, effect of radio propagation parameters on soft handover performance have been reported, which was measured in terms of probability of outage. Path loss exponent, standard deviation of shadow fading and correlation coefficient were considered as the characteristic parameters of the propagation environment. Simulation results show that probability of outage decreases with increased size of averaging window, smaller value of path loss exponent and large value of correlation coefficient. But greater standard deviation of shadow fading causes higher value of probability of outage. This study may be useful while designing stable soft handover algorithms in varied propagation environmental conditions. The work may be extended by considering other performance metric of soft handover algorithm like soft handover region.

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