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Performance of Space Time Trellis Codes for Channel with Nakagami Fading Channel Model

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ABSTRACT : Space-time trellis codes provide both diversity gain and coding gain. There are two different design criteria proposed for space-time trellis codes (STTCs), namely the rank and determinant criteria (RDC) and the Euclidean distance design criteria (EDC). In this paper, we present the performance of STTCs over Nakagami fading channels. Our results show that the STTCs designed for Rayleigh fading channels and Recian fading channels are also suitable for Nakagami fading channels. Nakagami fading channel models are considered more versatile than other channel models. Gong *et al.* presented the performance of the STTCs over Nakagami fading channels. In this paper, we also present the performance of the STTCs designed using the EDC over Nakagami fading channels.

I. INTRODUCTION

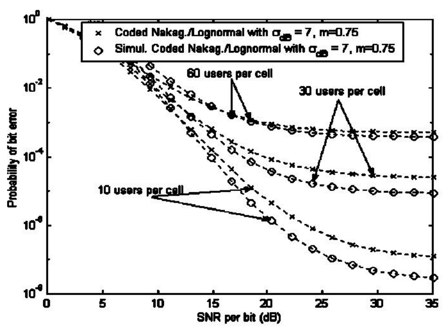
The performance of the forward channel of a DS-CDMAcellular system becomes increasingly more important as we transition from a system that carries principally voice traffic to one that supports data traffic at high data rates. The forward signal traveling through the mobile radio channel is subject to reflection, diffraction, and scattering. Raleigh fading channels are typically used to model the small-scale propagation effects on the forward signal [1]. Large-scale propagation models incorporate shadowing effects on path loss using a lognormal random variable [2]. Furthermore, the key-limiting factor on DS-CDMA performance is the co- channel interference. Convolution encoding with soft- decision decoding, antenna sectoring, and power control will be employed to overcome interference in 3G systems [3]. Investigations into the performance of the cellular DS-CDMA forward channel [4]-[5] have considered a subset of these channel conditions and/or performance enhancing techniques. Similarly, analysis of the reverse channel [6] -[8] has not considered the combined effects of the channel in conjunction with forward error correction and soft-decision decoding. In this paper we extend the analysis in [10] to the forward channel in a Nakagami-fading and lognormal- shadowing environment to develop the upper bound on the probability of bit error for a DS-CDMA cellular system Employing convolution encoding with soft-decision decoding, antenna sectoring, and power control.

II. CHANNEL MODEL

In this paper, the DS-CDMA cellular forward channel is modeled as undergoing slow-flat Nakagami fading and lognormal shadowing. We model the cells in our CDMA system as hexagons using a basic seven-cell cluster with a base station located in the center of each cell. The forward signal $S_i(t)$ is transmitted by base station in each cell. It includes the traffic for all active channels in the cell. The power spectrum of this traffic has been spread by a factor of N and then BPSK modulated. The composite signal $S_0(t)$ transmitted from the base station in the center cell is given by The transmit power in user channel k is given by $P_{t,k}$ and there are K active channels in the center cell. The information signal consisting of a binary bit stream for the k^{th} user is represented as $b_k(t)$. The orthogonal Walsh function for the kth user channel in the center cell is represented as $w_k(t)$. The PN spreading code for the center cell is represented as $c(t)$ and the carrier frequency is f_c. The forward signal is attenuated as a function of distance to the mobile and affected by slow-flat Nakagami fading and lognormal shadowing. The total signal received by a mobile user in the center cell is comprised of the forward signal sent from the user's base station, interference from the six adjacent base stations, and Additive White Gaussian Noise (AWGN) n ?t ?defined by where R and R_i represent the Nakagami fading effects on the envelope of the forward signals. The lognormal shadowing is represented in the random variable P_k.

A. Coded Probability of Bit Error P

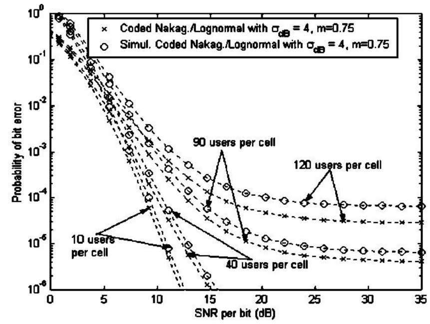
In order to improve the performance of the DS-CDMA cellular system operating in the Nakagami-lognormal channel, we institute forward error correction in the form of convolutional codes. We use an (n, k) encoder and the code rate is given by $R_{cc} = k/n$. The coded bits are spread, To decode the information bit stream, we use the Viterbi algorithm with soft-decision decoding. In [10], we analyzed the performance of the coded system in a manner similar to that in [1], in which the Viterbi algorithm was applied to an additive white Gaussian noise channel with soft-decision or simulate the integral in (9) using Monte Carlo methods. In square-lognormal random variable. Using the approximation or Monte Carlo simulations, we can determine the probability of first-event error for a path that is distance *d* from the all-zero path and that merges with the all-zero path at node *B*. For a given convolutional code, there are many such paths of differing distances that coul dmerge with the all-zero path at node *B*. Accordingly, we can calculate an upper bound on the probability of bit error Peusing the total number of information bit errors that is associated with selecting a path of distance *d* from the all zero path [11], we approximated *Zd* as a multiplicative Nakagami. Accordingly, we have developed a probability of error *Pe* the coded DS-CDMA cellular system in the Nakagami-lognormal channel for a mobile user in the worst-case position within the cell. As an example, we examine the performance of the DS-CDMA system using the first five terms of the union bound in The analytical model in [11] and the simulated model for the bit error probability agree well, especially in the practical range of signal-to-noise ratio per bit of 10 to 15 dB shows the more users can be accommodated in the practical range of SNR per bit of 10 to 15 dB.



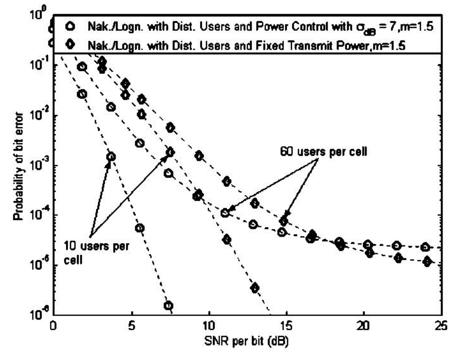
Probability of bit error for Nakagami fading

B. Incorporating User Distribution

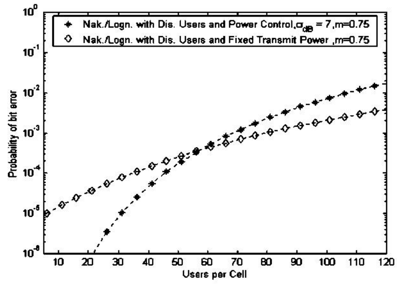
In Section III, we analyzed the performance of the forward channel in a DS-CDMA cellular system by assuming that our intended mobile user was situated in the outer corner of the hexagonal cell. We can obtain a more realistic view of typical performance of the forward channel by assuming that the users are randomly distributed within the cell according to a specified probability distribution. The position of the intended mobile in the cell is represented by a random variable, which we incorporate into a revised probability of bit error.



To simplify our analysis, we will replace our hexagonal cells with overlapping circular cells. The overlap accounts for soft-handoff of mobile users between cells. We take the center base station to be the origin of a polar coordinate system. Accordingly, the position of our intended mobile In order to incorporate user distribution into our performance analysis of the forward forward channel by assuming that the users are randomly distributed within the cell according toa specified probability distribution. The position of the intended mobile in the cell is represented by a random variable, which we incorporate into a revised probability of bit error. To simplify our analysis, we will replace our hexagonal cells with overlapping circular cells. The overlap accounts for soft-handoff of mobile users between cells. We take the center base station to be the origin of a polar coordinate system. Accordingly, the position of our intended mobile user in the center cell is represented by The randomization of the distances complicates the use of the Hata model in predicting path loss In order to incorporate user distribution into our performance analysis of the forward channel we require a joint probability density function in terms of that represents a user's position within the cell We define a user density as the normalized number of users per unit of area at The upper bound on the probability of bit error is given by (10) using the first-event error probability as defined in (12) and (13). Furthermore, we can implement antenna sectoring, which simply reduces the number of sectored users in cell *i* to where *S* is the number of sectors. Implementing Power Control The goal in our power-controlled system is to ensure that the power received by all mobile users is at the target power level *P* by adjusting the transmit power in each channel, *k*, with the power control factor *Fk* We can relate the target power received to the baseline transmit power *Pt* by an attenuation factor as *P* = *Pt*/*a*, where *P*, *Pt* and *a* are constant for all users in all cells. When the mobile user receives thein formation signal, the actual power received is measured and reported back to the base station for adjustment. At the point the mobile user measures his received power and reports it to the base station, it is no longer a random variable as described by (3), rather it is a realization of the random variable, which is known precisely and represented in our analysis as follows: With perfect power control, the power received by intended mobile is simply *P*. Accordingly, by adjusting the power factor to achieve the target power received by all users; we have defeated the lognormal shadowing effect on the information signal. The power received from the adjacent cells, however, is a random variable based upon user distribution and lognormal shadowing. The first-event error probability for the power-controlled system is given by the upper bound on the probability of bit error is given by (10) using the first-event error probability as defined in (12) and (13). Furthermore, we can implement antenna sectoring, which simply reduces the number of sectored users in cell *B*. Implementing Power Control The goal in our power-controlled system is to ensure that the power received by all mobile users is at the target power level *P* by adjusting the transmit power in each channel, *k*, power received to the baseline transmit power *Pt* by an attenuation factor as $P = Pt/a$, where *P*, *Pt*, and *a* are constant for all users in all cells. When the mobile user receives the information signal, the actual power received is measured and reported back to the base station for adjustment. At the point the mobile user measures his received power and reports it tot by (3), rather it is a realization of the random variable, which his known precisely and represented in our analysis as follows :he base station, it is no longer a random variable as described where *dk* is the user's actual distance to the base station, and *xk* is the shadowing experienced by the user. Accordingly, in We can calculate an upper bound on the probability of bit error numerically using (16) and (17) in (10). Compares the probability of bit error for a cellular system using forward power control with the fixed-power results develop. We see that the interference floor for the power-controlled system is actually higher than the interference floor for the fixed-power system. In order to explain this, let us examine the isolated co-channel interference contribution received power for all users is equal in the power-controlled system, we adjusted the power in the forward channel to overcome level *P* the base station must adjust the power factor such that lognormal shadowing effects. By doing so, we have in effect increased the expected value of the co-channel fixed-power system. This extra factor of $E\{X\}$ is a result of randomizing the transmit power in the forward channel. Probability of bit error for DS-CDMA with Nakagami fading ($m = 1.5$) and lognormal shadowing (dB = 7) applying forward power control and linear user distribution with 60º sectoring and FEC using a rate ½ convolution encoder with $v = 8$.



In spite of the increased co-channel interference, the performance of the power-controlled system is far superior to that of the fixed-power system for lognormal shadowing environments of dB < 6 with 120-degree antenna sectoring as shown in [10] for a Raleigh fading channel ($m = 1$). Under these circumstances, the benefits eliminating the lognormal shadowing from the intended signal outweigh the increased co-channel interference. Consequently, we can achieve a probability of bit error of less than 10-3 without entering the interference-limited region of operation. As showing [10], the power-controlledsy stem can accommodate as many as 100 users per cell using 120 degree sectoring for dB < 6 for $m = 1$. For dB = 6, the power-controlled system can accommodate up to 80 users using 120 degree sectoring and still achieve the desired probability of bit error of 10^{-3}. In designing a system with power control that operates in more intense lognormal shadowing environments (dB > 6), we must ensure that our system is not working in the interference-limited region. For example, for $m = 0.75$, if we expect our system to work in the *SNR* = 15 dB range, the system could accommodate up to roughly 50 users per cell in dB = 7 shadowing environment using 60-degree sectoring. Adding more users would degrade performance due to operating in the interference-limited region as indicated in Probability of bit error for DS-CDMA with Nakagami fading ($m = 0.75$) and lognormal shadowing ? dB 7 ? versus users per cell using linear user distribution with 60 sectoring and FEC ?R_{cc} 12 and = 8? with *SNR* = 15 dB. The use of sectoring to alleviate the co-channel interference in support of power control only works up to a point. For a shadowing environment of dB = 9 and heavy fading $m = 0.75$, for example, the 6-sector system can accommodate up to roughly 10 users prior to becoming interference-limited at *SNR* 20 dB. Accordingly, implementing power control in such environments demands some additional method of interference mitigation for the system to be viable.



III. CONCLUSIONS

In this paper we presented the performance analysis of the Space-time trellis codes can achieve the best tradeoff among bandwidth efficiency, diversity gain, constellation size and trellis complexity. In this paper, some optimum low rate space-time trellis codes are proposed. Performance analysis and simulation show that the low rate space-time trellis codes outperform space-time block codes concatenated with convolution code at the same bandwidth efficiency, and are more suitable for the power limited wireless communication system. CDMA forward channel operating in a Nakagami-faded and lognormal-shadowed environment. We have incorporated forward error correction in the form of convolution encoding with soft-decision decoding. We examined the performance of the system for the worst-case scenario with the mobile users at the edge of the cell, and accounting for a distributed user scenario. We added power-control to the forward channel, and found that performance and system capacity are greatly enhanced with careful implementation of power control.

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