Acquisition-based Capacity of a DS/CDMA System with Imperfect Power Control in a Nakagami Fading Channel

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Abstract — The capacity of a DS/CDMA system can be determined by the performance of PN synchronization and power control which are the most challenging problems for desirable performance. The acquisition-based capacity is defined and estimated for a DS/CDMA system with imperfect power control in a Nakagami fading channel. The imperfect power control decreases acquisition-based capacity substantially when the standard deviation of received power is above 1dB.

I. INTRODUCTION
A critical aspect of a receiver in a direct-sequence/code-division-multiple-access (DS/CDMA) system is synchronization of the incoming PN sequence and the locally generated PN sequence [1]. PN synchronization is usually done in two stages: PN acquisition and PN tracking. Mainly the acquisition time determines the code synchronization time, so it should be as short as possible for rapid initial link setup and smooth handoffs in a mobile environment. The reverse link of CDMA system is typically designed to be asynchronous, and an asynchronous CDMA system is vulnerable to the "near-far problem" in which very strong undesired signal swamp out a weaker, desired signal. A solution to the near-far problem is the use of power control, which attempts to ensure that all signals from the mobiles within a given cell arrive at the base station of that cell with equal power. The primary use of power control is to maximize the total user capacity, and an additional benefit is to minimize consumption of transmitted power of a portable unit. In this paper, the acquisition-based capacity is defined and estimated for a DS/CDMA system in an m-Nakagami fading channel. The imperfection of power control system is modeled as logarithm standard deviation of the lognormal power distribution of the received signal. Since the imperfect power control affects PN acquisition performance, the imperfect power control has an influence on acquisition-based capacity of a CDMA system [2].

II. SYSTEM MODEL
A serial and a parallel matched-filter (MF) acquisition schemes are considered for the estimation of acquisition-based capacity. These acquisition schemes have two modes of operation: a search mode and a verification mode. A more flexible way to model fading is the use of m-Nakagami fading model, which fits measurements in a variety of scenarios by simply adjusting m [3]. Specifically, it becomes Rayleigh for m = 1, or one-sided Gaussian for m = 0.5. It can be also used for approximating Rician and lognormal distributions. Since it p.d.f. of MAI and self interference is difficult to obtain, the effect of AWGN, MAI, and fading is in incorporated into analysis of acquisition performance by increasing variance of interference using Gaussian approximations.

III. ACQUISITION-BASED CAPACITY
The previous definitions of a CDMA capacity is mainly based on BER(bit error probability) or outage probabilities. Since the PN acquisition performance in the presence of MAI may pose a limit to the DS/CDMA capacity [4], we define the DS/CDMA capacity based on PN acquisition performance and estimate it by simulation. The acquisition-based capacity is defined as follows:

\[ C_{acq} = \max K, \quad \text{for } T_{acq} \leq \bar{T}_{acq} \]

where \( T_{acq} \) is the maximum allowable mean acquisition time and \( K \) is the number of active users. \( \bar{T}_{acq} \) is defined by

\[ \bar{T}_{acq} = \max \bar{T}_{acq}, \quad \text{for } \bar{P}_d \leq P_d \text{ and } \bar{P}_f \leq P_f \]

where \( \bar{P}_d \) and \( \bar{P}_f \) are detection and false alarm probabilities, and \( P_d \) and \( P_f \) are allowable minimum detection and allowable maximum false alarm probabilities. Since \( P_d \) and \( P_f \) determines \( T_{acq} \), \( T_{acq} \) is a random variable depending on propagation environments (fading, shadowing, etc.) and MAI.

IV. SIMULATION RESULTS AND DISCUSSIONS
Assuming that both reverse and forward links suffer from identical shadowing, the mobile user estimates signal strength by measuring pilot signal and controls its transmission power. For simulation results, phase adjustment parameter \( \alpha = 1/2 \), penalty factor = \( 10^8 \) (chips), PN code length = \( 2^{15} - 1 \) (chips), and chip rate = 1.2288 Mcps were assumed. The acquisition-based capacity vs. processing gain will be shown for a serial and a parallel MF acquisition schemes with power control error as a parameter. From Monte-Carlo simulation results, for both a serial and a parallel MF acquisition schemes, the power control error decreases the acquisition-based capacity substantially when the standard deviation of received power is above 1 dB. Therefore, the power control must be accurate within 1 dB, and be fast enough to compensate for fading effect as well as shadowing effect. The considerations in this paper can be applied to the reverse link design of a DS/CDMA system.

REFERENCES

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