ADAPTIVE SIR BASED POWER CONTROL FOR CDMA SYSTEM USING FUZZY GENETIC ALGORITHM

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ABSTRACT

Towards wireless communication, efficient spectrum or radio resource management is of paramount importance due to ever increasing demands for communication services. The key allocation decisions of radio resource managements are connected with channel assignment and the transmitted powers. In DS-CDMA systems spectrum utility is not a problem. With tight power control algorithm, the system capacity in DS-CDMA systems can be enhanced. In this paper an adaptive Signal-to-Interference Ratio (SIR) feedback power control technique is described using fuzzy genetic algorithm. The SIR threshold control level of each mobile station is individually adjusted with reference to its own radio link condition. This new technique resulted in lower probability of unsuccessful transmission, less outage probability, and enhanced traffic capacity by maintaining the reliable quality of service (QoS) of the system. The proposed system is more stable when compared to the conventional systems.

INTRODUCTION

The capacity of the DS-CDMA cellular system is highly interference limited due to co-channel interference and the fading radio channel [1]. Power control is essential to reduce the interference by minimizing the effects of near far problem, co-channel interference and fading channel. Basically, Power controller algorithm falls into two categories, received power strength based and Signal to Interference Ratio (SIR) based, the later outperforming the former [2].

For any user in a cell, the interference includes noise and the total interference generated by all the other users within the desired cell and from the adjacent cells. The performance of SIR based power controller could be improved if SIR threshold (SIR_{th}) control level of each mobile station is individually adjusted with reference to its own required quality for communication.

Chang and Wang [3] proposed strength based fuzzy logic power control, which is suitable for highly dynamic and non-linear behavior of the cellular system. The value of target fixed SIR_{th} is crucial to the performance of SIR based power control [2,4]. Both [2] and [5] suggested that the performance of SIR based power controller could be improved if SIR_{th} of each mobile station is individually adjusted with reference to its own required QoS. Reference [6] described an adaptive SIR based fuzzy logic control and a dynamically tailor made SIR_{th} to control each mobile station . In [7] a new application of fuzzy logic and genetic algorithm to the strength based power control was described.

In this paper, an adaptive SIR based power control and a dynamically tailor-made SIR_{th} to control each mobile station using Fuzzy Genetic Algorithm (FGA) is suggested. FGA integrates fuzzy inference systems (FIS) with genetic algorithms (GA) to improve their advantages and strength. FGA utilizes FIS to model the knowledge base and GA to assist in initial selection and dynamic on-line adjustment of the control parameters of the algorithm. This improves the search and optimization efficiency of the FGA significantly [8]. FGA, which is particularly suitable for highly non-linear and dynamic characteristic of the cellular system, is applied for SIR based power control and SIR_{th} threshold level.

FGA POWER CONTROLLER MODEL

The closed loop uplink power controller model shown in fig.1 is used at each cell site. FGA controller mechanism is applied here to SIR_{th} control and power control of individual mobile station. For FGA controller, the inputs are the error *'e'* and error change *'de'*, and the outputs are *'dsir'* and *'dp'* , the control commands for SIR_{th} and power.
Genetic algorithm is used to design rule base, shape of the membership function and the range of each membership function in fuzzy logic. Each chromosome includes the parameters namely, the shape of the membership functions, the inputs *'e'* and *'de'*, the outputs *'dp'* and *'dsir'* and the rule base. The representation for the shape and the rule base is a number. The position of each membership function for input and output is coded by binary. Seven membership functions for inputs and

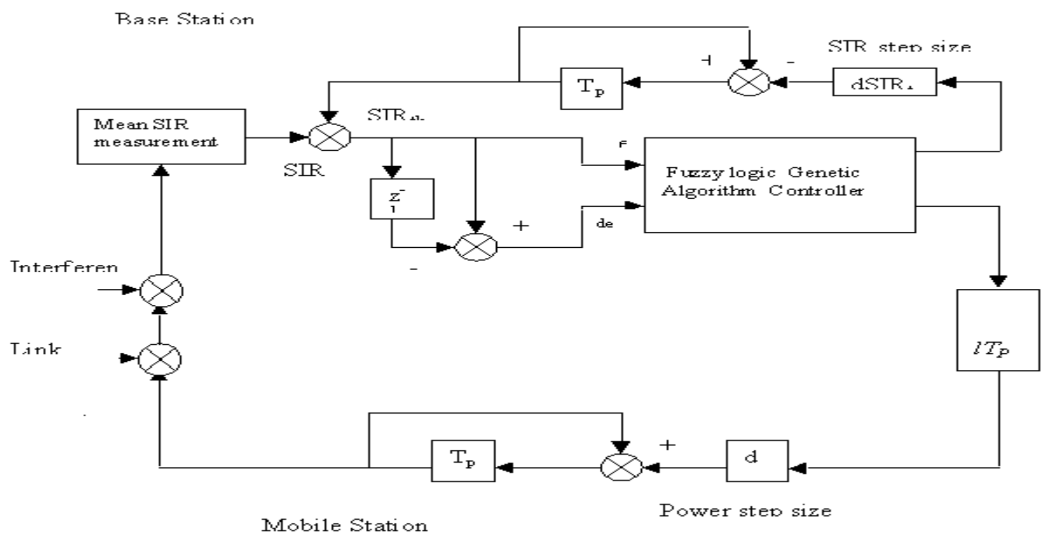


Figure 1. Power controller model

Table 1: Fuzzy Logic Rule Base

e

de

	LN	MN	SN	ZE	SP	MP	LP
LN	LN	LN	MN	MN	SN	SN	ZE
MN	LN	MN	MN	SN	SN	ZE	SP
SN	MN	MN	SN	SN	ZE	SP	SP
ZE	MN	SN	SN	ZE	SP	SP	MP
SP	SN	SN	ZE	SP	SP	MP	MP
MP	SN	ZE	SP	SP	MP	MP	LP
LP	ZE	SP	SP	MP	MP	LP	LP

outputs are used. There are 49 rules for the rule base given in table 1. Fitness function for the genetic algorithm is the minimum of Average Error (AE), which is represented as

$$AE = \frac{\text{power from the desired mobile unit} - \text{required power at the base station}}{\text{bits of information}}$$

The selection algorithm used is the Roulette wheel, which picks up the chromosome that gives the minimum *AE*. The algorithm for cross over is described in figure 2. In this, first, the chromosome parents are randomized, then cut point membership function is randomized in parent 1, which is finally crossed-over with the parent 2. The mutation algorithm is shown in figure 3.

SIR Threshold Control

Based on the input of e(k) and de(k) at the k th sampling period, the $dSIR_{th}$ at the k+1 th sampling period is

$$dSIR_{th} = FGA\{e(k), de(k)\} \quad (1)$$

where $e(k) = SIR_{th}(k) - SIR(k)$, $de(k) = e(k) - e(k-1)$ and $SIR(k)$ is the received SIR at the k^{th} sampling period. FGA is fuzzy logic and genetic function. The SIR_{th} of the mobile at the $k+1^{th}$ power control period is

$$SIR_{th}(k+1) = SIR_{th}(k) - dSIR_{th}(k+1) \quad (2)$$

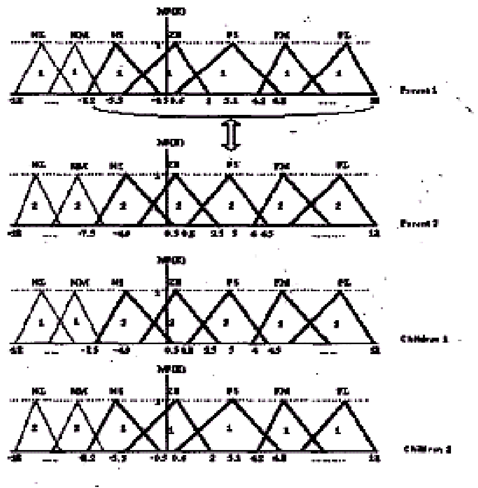


Figure 2: Crossover Algorithm

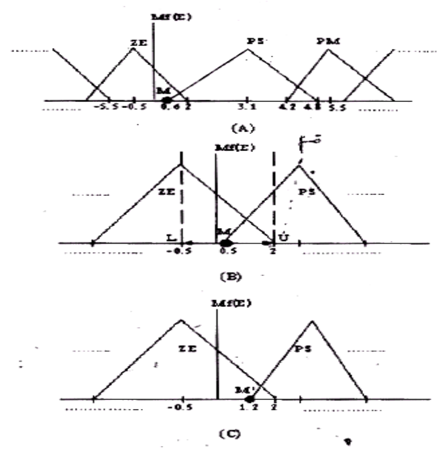


Figure 3: Mutation Algorithm

The adjustment of SIR_{th} of each user follows the variation trend of received SIR. SIR_{th} is bound between [-10 dB, -15dB] where -15dB is the minimum required SIR corresponding to BER 10^{-3} required for quality digital voice communication and -10dB is a nearly optimal SIR_{th} for SIR based power controller at low level of average interference. The SIR_{th} is adjusted at each sampling period so that it enables a quick adjustment to SIR to keep track of fast fading environment.

Power Control

Power control is performed once after each SIR_{th} adjustment. The transmitting power is controlled with reference to the newly adjusted target SIR_{th} . Therefore,

$$e_{new}(k) \;=\; SIR_{th}\,(k+1) \,-\, SIR\,(k) \tag{3}$$

$$de_{new}(k) \;=\; e_{new}\,(k) \,-\, e_{new}(k-1) \tag{4}$$

Where e_{new} (k) and de_{new} (k) are the new SIR error and SIR error change at the k^{th} sampling period respectively with reference to the new target SIR_{th} at the $k+1^{th}$ sampling period. The FGA control of power at the k^{th} sampling period is

$$dp(k+1) \;=\; FGA\,\{enew(k),\; de_{new}(k)\} \tag{5}$$

The FGA controller for both SIR_{th} and power control is the same. It simplifies the controller circuit and minimizes the hardware requirement at the base station. The transmitting power of the mobile at the $k+1^{th}$ power control period is

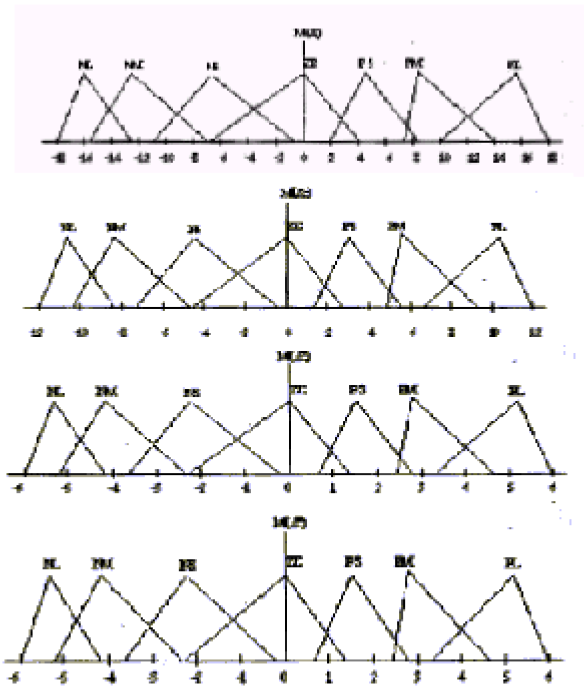
$$P(k+1) \;=\; p(k) \,+\, d\; p(k+1) \tag{6}$$

SIMULATION RESULTS

For simplicity, a single cell structure is simulated. The power control sampling rate is at least 10 times the maximum fading rate, in order to keep track of fading envelope. The outage probability is used as a criterion for measuring the system capacity. It is the probability of failing to achieve a minimum required SIR. The outage probability for a given mobile station 'i' is

$$P_0\,(i) \;=\; \mathrm{P_r}\{SIR_i \,<\, SIR_{\min}\} \tag{7}$$

The best shape of the membership function for *'e', 'de', 'dp'* and *'dsir'* are shown in figure 4. The figure 5 shows the outage probability comparison against the number of users. Though the fixed step controller, FGA power controller and FGA power controller with SIR_{th}, showed increased outage probability with increased number of users per cell, the FGA with SIR_{th}, achieved much lower probability than the other two for the same number of users. This illustrates that the value of SIR_{th} is critical to the SIR based power control. This leads to high traffic capacity with reliable QoS.



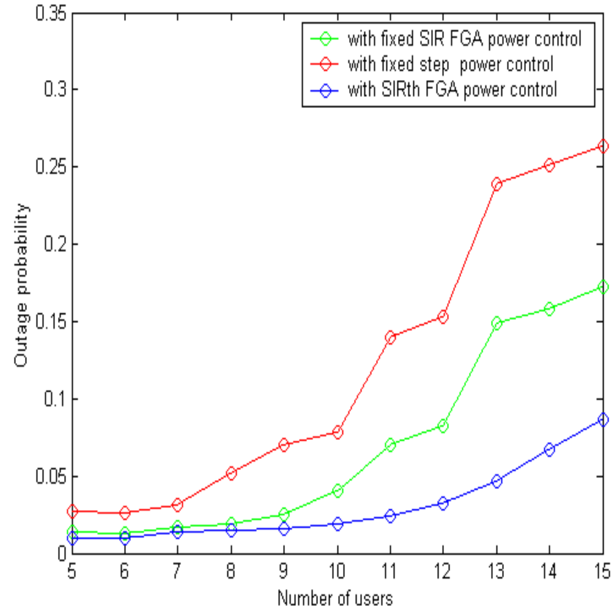


Figure 4: Best Shape of membership function **Figure 5: Comparison of outage probability**

CONCLUSION

The adaptive power control mechanism for the uplink DS-CDMA system with tailor made SIR threshold level to each mobile station using fuzzy logic and genetic algorithm is implemented. It is capable of maintaining the SIR of all the users at the optimum level. The outage probability curve for the proposed system ensures the enhanced traffic capacity and better QoS. The performance of the controller is improved by the combined effect of fuzzy logic and genetic algorithm. The proportional and integral control action introduced by the FGA controller makes the system more stable.

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