Performance Analysis of Adaptive Power Control Based On Signal to Interference Ratio (SIR) Using Fuzzy Genetic for WCDMA

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***Abstract*-The number of active users in a cell in the WCDMA system is very limited and influenced by co-channel interference and fading radio channels. Power control is needed to reduce interference by reducing the effects of near-far problem, co-channel interference and fading channels. WCDMA system is required power control that works fast and precisely because radio channels are changing randomly. Fuzzy Genetic Algorithm (FGA) gives the correct solution to the dynamic decision making problem under non-linear conditions, based on simple rules. This paper presents application of adaptive SIR based power control using the FGA on uplink WCDMA system, and compared to fixed step size method using computer simulation. The results confirmed that use of FGA on the SIR-based Power Control for WCDMA systems increases the number of active users while maintaining QoS standards. This is shown by the decline in value of outage probability compared to fixed step methods. Average outage probability at fixed power control step is 0.270036 while the FGA power control is 0.18465.**

Keywords-Power Control, SIR, Fuzzy, Genetic Algorithm, WCDMA

I. INTRODUCTION

WCDMA system capacity is affected by the co-channel interference and fading radio channel [1]. Power control (PC) reduces interference by reducing the effects of near-far problem, co-channel interference and fading channels.

Power control mechanism based on Signal to Interference Ratio (SIR) is better than PC mechanism based on received power strength [2]. Inner closed-loop PC keeps received SIR in accordance with the targets, by sending a feedback signal to the MS (Mobile Station). Target SIR is determined by the outer-loop PC. WCDMA system commonly uses fixed simple step-PC to minimize the PC signaling schemes, which does not require the complex of the PC command and historical measurements [3].

Chang and Wang [4] proposed an adaptive SIR based fuzzy logic control and a dynamically tailor made *SIRth* to control each mobile station. F.Herrera confirmed that genetic algorithm capable to improve the performance of fuzzy system [5]. However, there is no study on application of fuzzy genetic algorithm in power control mechanism based on SIR.

This research was aimed to implement adaptive SIR based power control to control the mobile station transmit power using the Fuzzy Genetic Algorithm (FGA). FGA combines fuzzy inference system (FIS) with genetic algorithm (GA). FGA uses the FIS to model the knowledge base and uses the GA to optimize the control parameters in the FIS.

II. FGA POWER CONTROL MODEL

WCDMA is the air interface of UMTS, WCDMA uses DS-CDMA technology with a chip rate of 3.84 MCPs and 5 MHz of carrier bandwidth. WCDMA supports multimedia services such as high-speed data, video and traffic with different Quality of Service. WCDMA using frequency reuse 1, which means that every cell uses the same carrier frequency.

In the uplink path, the signal from each user propagates through the different channels so that the level of reception quality at the node B (Base Transceiver Station) will be different also. Signal reception quality level affects the QoS. Power control on uplink channels maintains signal reception quality level that meets the QoS service requested by way of controlling the mobile station transmit power. Transmit power will be optimal for a service and minimum interference to other users.

WCDMA uses closed loop power control which is a combination of outer and inner closed loop power control. Inner closed loop power control adjusts the transmit power to maintain the Signal to Interference Ratio (SIR) received in accordance with the target. Correction of the inner loop is done 1500 updates per second. SIR target is set based on the Block Error Rate (BLER) or Bit Error Rate (BER).[3]

Fuzzy Inference System (FIS) is the process of mapping from input to output using fuzzy logic. This mapping then provides a basis from which decisions can be made. Consisting of fuzzification, rule evaluation and defuzzification.[6]

Genetic Algorithm (GA) are search algorithms based on the mechanism of natural selection and natural genetics. GA begins with a series of initial solutions (chromosomes), called the population. These populations will evolve into different populations through a series of iterations. At the end of the iteration, the GA returns the best member of the population as a solution to the problem. At each iteration (generation), the evolutionary process that occurs is as follows:

Two members of the population (the parent) is selected based on a population distribution. The two members are then combined through a crossover operator to produce children (offspring). With low probability, this child will change by mutation operator. If the child is suitable for this population, a replacement scheme is applied to select the members of the population to be replaced by the child. This process is repeated until a certain condition is achieved, for example, until a certain number of iterations.[7]

2.1 WCDMA System Model

Power control will be modeled on the uplink WCDMA system based on the SIR. Power control process in Node B. The signal sent by the MS, through the channel and received at the Node B. Channel used is Rayleigh fading with Jakes model.

Fuzzy Genetic Algorithm applied to the power control to make decisions based on SIR error and delta SIR error. SIR error is the difference between the target SIR with the received SIR, the received SIR measured at Node B after the despreading process.

The result of the decision of the FGA is sent back to the user (MS) as a PC command to decrease or increase the MS transmit power. In this simulation a user is controlled and the other users have function as interferer.

WCDMA system parameters used in this study are as follows:

Table 1. Parameters of WCDMA system

Parameters	Value
Number of users	1-15
Carrier frequency	2 GHz
Doppler spread	f_d = 70, 120, 200 Hz, (v_{user} = 38, 65, 108 km/h)
Processing gain	128
Chip rate	3.84 Mcps
Power control period	0.667 ms (*update* power rate = 1500 Hz)
Data rate (voice)	Rb = 120 kbps (symbol rate = 60 ksps)
Power control step size (fixed step size method)	Δp = 1 dB

Consisting of sender and receiver blocks. Block of sender is in figure 1. The sent data is uniformly distributed and randomly generated. BPSK mapper is used to form the binary data into data symbols according to the BPSK symbol constellation. BPSK mapper convertes serial data to parallel. The number of bits on each branch corresponds to the type of mapping signals or the type of modulation used.

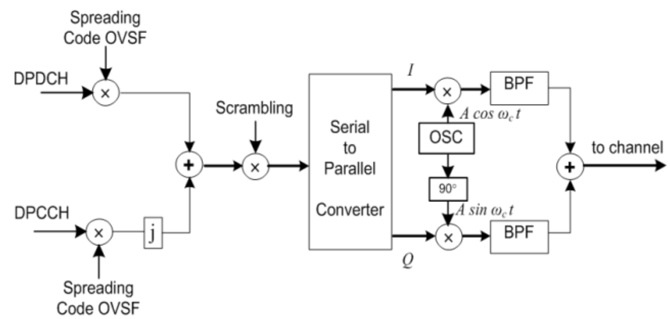

Figure 1. Block diagram of WCDMA transmitter

Spreading code is used to spread the data signal so that it will have a chip rate of 3.84 Mcps. Its use different canalization code, called OVSF code (Orthogonal Variable Spreading Factor). Each user data bits (1 and -1) as a representation of the base band signal is then multiplicated with Walsh-Hadamard code. The process of spreading data is done in time domain so that every bit of data is multiplied by only one element of Walsh-Hadamard codes as OVSF codes. Walsh codes can be generated by following recursive matrix operation:

$$H_n = \begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & -H_{n-1} \end{bmatrix} \quad (1)$$

In the uplink direction, there are two choices of scrambling, the short scrambling code and long scrambling code. This simulation used the long scrambling code. Long codes are Gold codes formed from two long scrambling sequences $c_{long,1,n}$ and $c_{long,2,\ n}$. While x and y are two m-sequences of binary sequence, x sequence is built using polynomial $X^{25} + X^3 + 1$ and y sequences are built using the polynomial $X^{25} + X^3 + X^2 + X + 1$.

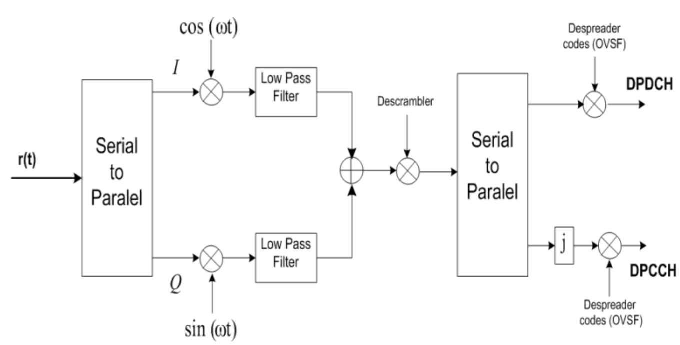

Figure 2. WCDMA Receiver Block Diagram

The function of BPSK demapper is to change the symbol-stream into the bit-stream based on the received frequency complex domain in accordance with the constellation of modulation used. Demapper scheme according to the signal mapper that is used in the receiver. Block of receiver is in figure 2.

Signal is demodulated using a sinusoidal signal with 90^0 shift phase to achieve the desired QPSK demodulation. Signal filter is a root-raised cosine (RRC) with roll-off α = 0.22 in the frequency domain. Received signal at the demodulator input from all users K :

$$s(k) = \sum_k \left[\sqrt{E_c(k)} \sum_{n=-\infty}^{\infty} x_n(k) c_n{}^I(k) h(t - nTc) \cos(f_c + \theta_{k)}) + \sqrt{E_c(k)} \sum_{n=-\infty}^{\infty} x_n(k) c_n{}^Q(k) h(t - nTc) \sin(f_c + \theta_{k)}) \right] \quad (2)$$

$\sqrt{E_c(k)}$ is the chip energy of the k-th user, $c_n{}^I(k)$ and $c_n{}^Q(k)$ are the inphase and quadrature spreading sequence, $x_n(k)$ is a binary symbol and *fc* is the carrier frequency.

2.2 Channel Propagation

AWGN noise modeled as a Gaussian random distribution pattern with the average value is zero, the standard deviation (σ) = 1, power spectral density = No / 2 (W / Hz).[8]

Rayleigh fading signal is generated by Jakes model. In this channel model, a_c and a_s that is a Gaussian random variable with mean zero and variance σ^2, is determined by:

$$a_c = \frac{2}{N_0}\left(\sum_{n=1}^{N_0} \cos\beta_n \cos\omega_n t + \sqrt{2}\cos\alpha\cos\omega_d t\right) \quad (3)$$

$$a_s = \frac{2}{N_0+1}\left(\sum_{n=1}^{N_0} \cos\beta_n \cos\omega_n t + \sqrt{2}\sin\alpha\cos\omega_d t\right) \quad (4)$$

$$a = \sqrt{\frac{(a_c)^2 + (a_s)^2}{2}} \quad (5)$$

$$\omega_n = \omega_d\left(\cos\frac{2\pi n}{N_1}\right), \qquad n = 1, 2, ..., N_0 \quad (6)$$

N_0 is a low frequency oscillator with frequency ω_n.

$$N_1 = 2(2.N_0 + 1) \quad (7)$$

$$N_0 = \frac{1}{2}\left(\frac{N_1}{2} - 1\right) \quad (8)$$

$$\beta_n = \frac{\pi . n}{N_0} \quad (9)$$

$$\alpha = \frac{\pi}{4} \quad (10)$$

$$\omega_d = 2\pi . f_d \quad (11)$$

ω_d is the Doppler shift.

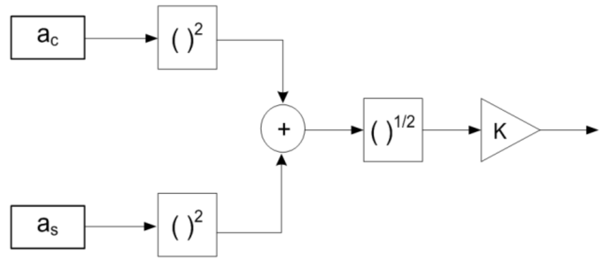

Figure 3. Rayleigh distributed coefficients generator

Coefficients a_i *(t)* is a variable rayleigh (channel gain) generated from two Gaussian random variables (a_c and a_s) with zero mean and variance σ^2. Generators coefficients *a(t)* rayleigh distributed made with Jakes method.

2.3 Modeling of Power Control Mechanism

In FGA controller, the inputs are the error *'e'* and the error change *'de'*, while the output is *'dp'*, which is a control command for power control. Error is the difference between the target SIR with the received SIR, while the delta error is the difference between SIR error now with the previous error.[9]

Genetic algorithms are used to optimize the value of the width of the fuzzy membership functions. Each chromosome contains information on coverage of the membership function for 'error', 'error change' and 'dp'. This experiment use seven membership functions for input and output. So there are 49 rules for the rule base (Table 2). Fitness function for genetic algorithm is the minimum value of SIR error RMSE.

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{[SIRtarget - SIRreceived\ (i)]^2}{n}} \quad (12)$$

$SIR_{received}$ is the SIR value received from mobile users after application of power control, SIR_{target} is the SIR threshold value.

Table 2. Fuzzy Logic Based Rules

de	*e*						
	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

The transmitted power is controlled by the reference target, SIR_{th}.

$$e(k) = SIR_{th}(k) - SIR(k) \quad (13)$$
$$de(k) = e(k) - e(k\text{-}1) \quad (14)$$
$$dp(k+1) = FGA\ \{e(k), de(k)\} \quad (15)$$

Outage probability is used as a criteria for measuring the capacity of the system (the ability to accommodate the number of active users).[10]

$$P_o(i) = P_r\ \{SIR_i < SIR_{min}\} \quad (16)$$

III. RESULT AND DISCUSSION

On the analysis of WCDMA Uplink SIR based power control using a Fuzzy Genetic Algorithm, Fuzzy is used for classification and decision making, while the GA is used for optimization of fuzzy membership function. This paper compares the performance of FGA Power Control to Fixed Step Control Power, based on these parameters : outage probability, processing time and convergence time. This research also study the effect of fading rate on the performance of power control.

In this simulation assumed that open-loop power control works perfectly, so the influence of near-far effect can be overcomed completely. The purpose of power control in this simulation is to reduce the effects of fading. Uplink channel used in this simulation is a Rayleigh fading channel using Jakes model. In the simulation of multi-user, one user is controlled and the others as interferer.

Genetic algorithm is used for optimization of Fuzzy Control System by adjust the width of fuzzy membership functions with the fixed form of membership function. Genetic algorithm attributes here are three chromosomes $[X_1\ X_2\ X_3]$, each variable serves to adjust the width of fuzzy membership functions of *error*, *delta error* and *deltap* (each variable is composed of 5 bits). The population size is 15, cross over is 0.6, the probability of mutation is 0.07, and the maximum number of generation is 80.

3.1 Relationship between Total Outage User with Outage Probability

Outage probability is the probability of SIR below the minimum SIR (SIR_{min}).

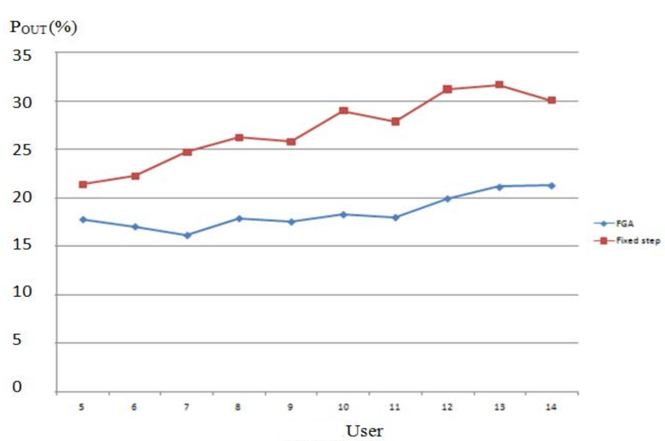

Figure 4. Graph outage probability (P_{out}) vs the number of users

Figure 4 shows that increasing the number of active users make the outage probability also increases, and the outage probability of SIR FGA power control is smaller than outage probability of SIR Fixed step power control. Average outage probability at fixed step power control is 0.270036, while the average of outage probability on FGA power control is 0.18465.

3.2 The Effect of Fading Rate for BER

Effect of fading rate (fdTp) for BER on using fixed step power control and FGA power control can be seen in figure 5

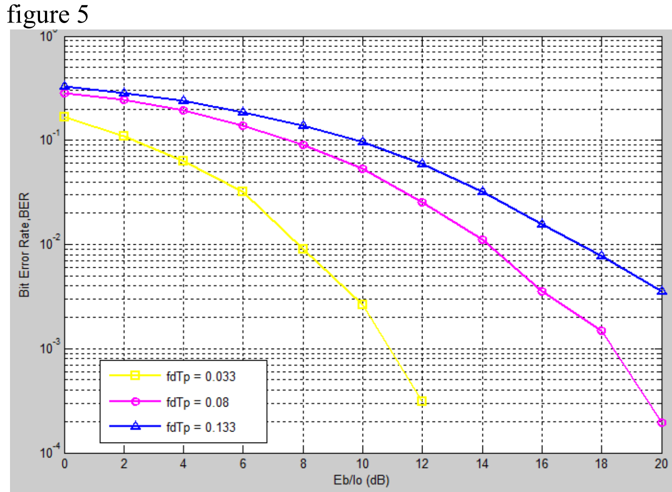

Figure 5. Effect of fdTp for power control

The graph shows that the value fdTp has an effect for the performance of power control. To achieve the same BER, power control with a smaller value fdTp requires smaller the level of Eb/Io.

3.3 Convergence and Processing Time Analysis

The time needed to reach SIR_{target} by both power control can be seen in Figure 6.

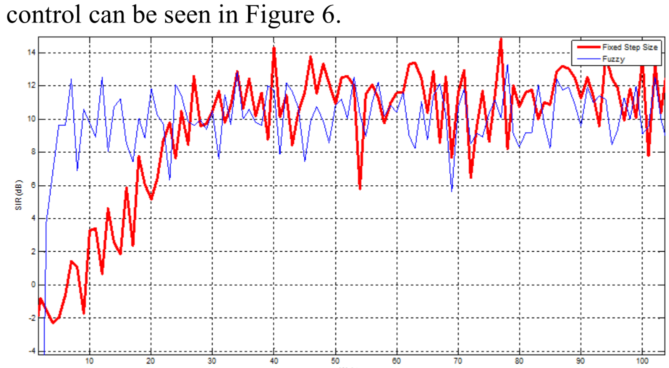

Figure 6 Time to reach SIR_{target}

To achieve SIR_{target}, FGA power control requires 7 units of time, Fixed step power control need 27 units of time. One unit of time equal to the power control period (0.667 ms). This is because the stepsize on FGA power control can be larger than the fixed step power control.

IV. CONCLUSION

Performance FGA power control is influenced by its membership function. Application of Fuzzy Genetic Algorithm on the SIR-based Power Control in WCDMA Uplink able to provide improved performance compared with fixed power control step in terms of outage probability and convergence time to reach SIR target.

Outage probability of FGA power control is 0.18465, while the average outage probability at fixed step power control is 0.270036. To achieve SIR target, FGA power control requires 7 units of time, and fixed step power control need 27 units of time. One unit of time equal to the power control period (0.667 ms).

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