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Modified Variable Step Size Power Control Algorithm for CDMA Systems

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Abstract—Power control mechanism is an important issue for Code Division Multiple Access (CDMA) systems which helps in achieving higher capacity, combating against near far effect and provides high link performance. Unless a suitable power control mechanism is developed cellular systems cannot perform better. Power control allows to minimize the transmit power while keeping the system performance above the required value. In previous research [4], variable step size for closed loop power control system has been studied and results showed an increase in convergence speed and stability by properly choosing the step size. The new algorithm presented in this paper shows that it can perform better than variable step size power control algorithm and can obtain higher stability and convergence speed for step size δ at 0.1.

Index Terms—Code Division Multiple Access (CDMA), Closed Loop Power control, Frame Error Rate (FER), Modified Variable Step Size Power Control Algorithm (MVSPCA), Near far Effect, Step Size (δ), Signal to Interference Ratio (SIR) , Variable Step Size Power Control Algorithm (VSPCA).

1 Introduction

Code Division Multiple Access (CDMA) technique provides a significant increase in capacity of cellular mobile radio systems as compared to Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) [1]. However this improvement in capacity depends on the power control of the system.

Power control in CDMA systems is a critical issue because it helps to alleviate from "near far" problem, increases capacity, improves quality of service (QoS) and prolongs the life of battery. Closed loop power control algorithms [2] are mostly in implementation, which helps to combat multipath fading. Open loop power control algorithm is used to combat against path loss and shadowing effects [3]. IS-95B and CDMA2000 uses Fixed Step Size Power Control Algorithm which updates transmits power every 1.25ms. In forward traffic channel a 20ms frame is organized into 16 time interval and each time interval consist of a power control group (PCG). Inner loop sends power control bits at a rate of 800Hz.

Transmitter adjusts their power according to the power control bits sent on the feedback channel. Speed of convergence is an important factor for a good power control algorithm and also control overhead must be less. Variable step closed loop power control algorithm [4] employ one bit for power signaling, provides stability and decrease loop delay.

Closed loop power control system consists of two systems. i) Inner closed loop and ii) Outer closed loop system [5]. Inner closed loop power control system is used to bring the estimated Signal-to-Interference Ratio (SIR) closer to the target Signal-to-Interference Ratio. Whereas Outer closed loop power control system adjusts the target SIR based upon the frame error rate (FER). Inner closed loop compares the SIR_{est} with SIR_{target} and if target SIR is greater than the estimated SIR up command is sent through feedback channel to increase the transmit power whereas, if estimated SIR is greater than the target SIR than down command is sent to decrease the transmit power. Transmit power must not exceed the maximum allowed power.

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2 System Model

Consider the uplink power control (mobile-base) in this paper. Assume the system consists of *M* base stations (BS) and each BS consists of *N* number of mobile stations (MS) out of which only U users is active at a time. Hence, Signal-to-Interference Ratio (SIR) at the j_{th} BS due to i_{th} MS is given by

$$\left(\frac{S}{I_i}\right)_i = \left(\frac{E_b R_i}{N_0 W}\right) = \frac{g_{ji} P_i}{\sum_{k \neq i}^{U} g_{jk} P_k + \eta_j} = \gamma_i \tag{1}$$

Where E_b stands for information bit-energy, N_0 is the interference power spectral density. The power transmitted by each mobile is given by P_i for $0 \le i \le U$. R_i stand for information bit rate of each mobiles and W is the chip rate of the system. g_{ji} denotes the link gain from i_{th} MS to j_{th} BS and η_i denotes the background noise. Interference in CDMA system is mainly due to intercellular interference and intracellular interference. Thus, objective of power control is to find a non-negative power vector $p = (p_1, p_2, ...p_U)$ for $0 \le i \le U$ which satisfies the maximum power constraint $\gamma_i \ge \gamma_T$ for all values of i Where γ_T is the minimum threshold SIR for the system to maintain the required voice quality and medium BER.

Zander [6] proved that the maximum achievable SIR is given by

$$SIR = \frac{1}{\lambda^{*} - 1} \qquad (2)$$

Where, λ^{*} is the largest real positive value of the link gain matrix *G* and the Eigen vector obtained for corresponding Eigen value is the maximum power vector for the system.

3 Modified Variable Step Size Power Control Scheme

This algorithm is a modified form of variable step size closed loop power control algorithm [4], which controls power adaptively rather than at fixed steps. Exponential function which has both increasing and decreasing characteristics has been used for controlling the power updates. Exponential function has already been used as power update function in most of Distributed Power Control [7], [8], [9], [10] algorithms.

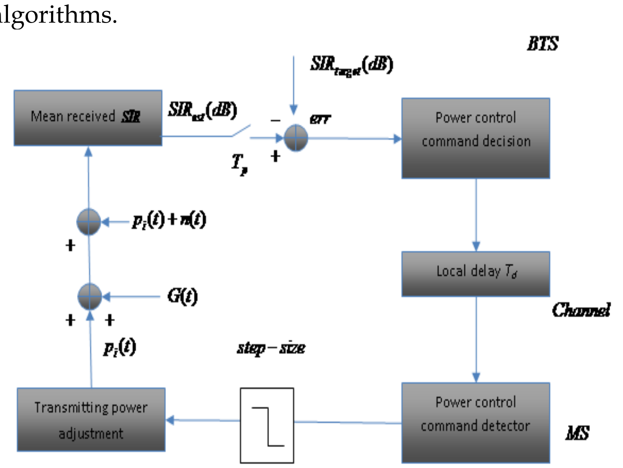

Fig. 1. Uplink power control mechanism

Fig. 1. depicts the block diagram of uplink power control mechanism studied in this paper. Power received at base station measures estimated SIR_{est} which is then compared with the target SIR_{target} to calculate error (*err*). It is then send to power control command decision block which decides power control bits and is then embedded with the traffic stream to be sent through the channel. No error protection is done for power control bits to reduce delay. Power control bits are then separated from traffic stream and are detected by power control command detector which then increments and decrements power based on the bits detected given in Table 1. After done with suitable power adjustments it is then transmitted back to the base station.

Two power control bits are used for sending power control command and mobile station updates its power based upon the received power control bits. (α, β, x, y) are the variables used in this algorithm. In the start of the algorithm all these variables are initialized to zero. Power received at base station is measured and estimated SIR_{est} is calculated which is then compared with the target SIR_{target}. If target SIR_{target} is greater power up command is generated to increase transmitter power. Transmit power is given by

$$p_i(t) = p_i(t-1) + \exp(\delta * \alpha) \qquad (3)$$

Where, $p_i(t)$ is the power of the i_{th} mobile at t_{th} iteration and δ is the step size or convergence parameter.

α is increased by one unit until the estimated SIR_{est} is greater than the target SIR_{target}. If the estimated SIR_{est} is closer to target SIR_{target} by less than 1dB then the power is increased in small steps rather than increasing it by larger steps to decrease large oscillations in received power. At this point, variable x is increased by one unit and transmit power is given by

$$p_i(t) = p_i(t-1) + \exp(-\delta * x) \qquad (4)$$

Negative step size is employed to increase or decrease power in small steps. At times, if the channel condition changes and estimated SIR_{est} is greater than target SIR_{target} than power down command is send to the mobile station to decrease transmit power. Transmit power is now given by

$$p_i(t) = p_i(t-1) - \exp(\delta * \beta) \qquad (5)$$

At this instant, α is set to zero and β is increased by one unit until the estimated SIR_{est} becomes less than the target SIR_{target}. If the estimated SIR_{est} is closer to target SIR_{target} by greater than -1dB then the power is decreased in small steps. Now y is increased by one unit and transmit power is given by

$$p_i(t) = p_i(t-1) - \exp(-\delta * y) \qquad (6)$$

Table 1 shows generation of power control bits and algorithm is given below

Table 1

Information bits and update function

Bits	Power increment/decrement
00	$\exp(\delta * \beta)$
01	$\exp(-\delta * y);$
10	$\exp(\delta * \alpha);$
11	$\exp(-\delta * x);$

It should be noted that as soon as power control bits are changed from up command to down command or vice versa the value of α and β is also changed to zero respectively and their values start increasing from zero in the next iteration.

3.1 Algorithm

Step 1. Compute received SIR. $\gamma_i(t)$

Step 2. Set α=0,β=0,x=0,y=0;

Step 3. Compare it with target SIR. γ^T. err= γ^T - $\gamma_i(t)$

Step 4. If err>0
If err<1
x=x+1;

$p_i(t+1) = p_i(t) + \exp(-\delta \ * x);$
Else
$\alpha = \alpha + 1; \beta = 0;$
$p_i(t+1) = p_i(t) + \exp(\delta \ * \alpha);$
Endif
Else
If err>-1`
$p_i(t+1) = p_i(t) - \exp(-\delta * y);$
Else
$\beta = \beta + 1; \alpha = 0;$
$p_i(t+1) = p_i(t) - \exp(\delta * \beta);$
Endif
Endif

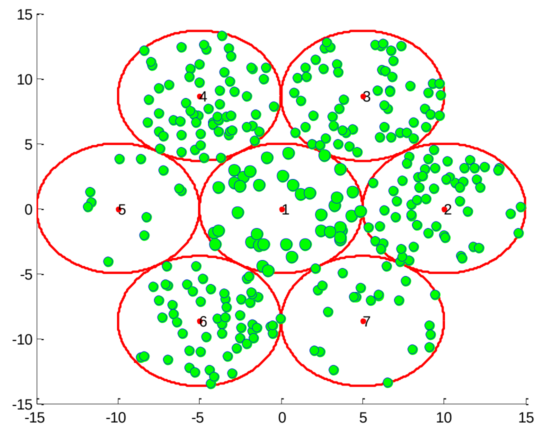

Fig. 2. Circular Cell

4 Simulation and Results

We consider a uplink (reverse link) transmission (i.e., from mobile to base station) for the entire simulation. The simulation was performed under static user condition and the propagation model consists of two components i) one component is due to multipath propagation where signal power decays with path loss component α=4. ii) The other component is due to the log normally distributed shadow effects which is a Gaussian random variable with zero mean and standard deviation of 8 dB. Hence the attenuation factor is represented by

$$g_{ij} = \frac{10^{\lambda_{ij}/10}}{d^{\alpha}} \quad (7)$$

g_{ij} is the gain between the mobile user i_{th} and the base station j_{th}. λ_{ij} is the Gaussian random variable with zero mean and standard deviation of 8 dB. d is the distance between mobile user and the base station. α is the path loss component and is assumed to be 3.64.

Though in practical environmental conditions the gain is not constant but theoretically we assume it to be constant.

We consider a circular cell of each of radius 5km with the base station at the center of the cell. The number of cells considered for simulation in this thesis is 7 and total number of users in each cell is considered to be 100. The active users in each cell are generated using a MATrix LABoratory (MATLAB) *randn()* function. The number of active users in cell 1 is fixed manually as 50. The transmit power of all the active users are assumed to be constant and fixed at 2W. Maximum power taken for the simulation equals to 3W. Small circles show the active users. The circular cell structure is shown in Fig. 2.

4.1 Convergence Performance

Convergence speed of Modified variable step size power control algorithm (MVSPCA) was found to be higher than the convergence speed of variable step size power control algorithm (VSPCA). Convergence speed of variable step size power control algorithm was measured at different values of step size whereas; step size of modified variable power control algorithm at value 0.1 gives better results. Variable step size power control algorithm shows a tradeoff between convergence and fluctuations in measured *SIR*. If chosen step size is less than convergence speed is low and fluctuations are less if step size is high than convergence is faster whereas fluctuations in measured *SIR* increase. So, step size must be chosen properly for better results.

Choosing large value of step size or convergence parameter in modified variable step size power control algorithm causes power to increase and decrease by large a amount which causes large oscillations. So convergence parameter must be chosen properly for faster convergence and less oscillation.

From above Fig. 3, Fig. 4 and Fig. 5 we can see that at larger values of step size of VSPCA convergence speed becomes almost comparable to MVSPCA, but it causes large amount of oscillations which is not desirable.

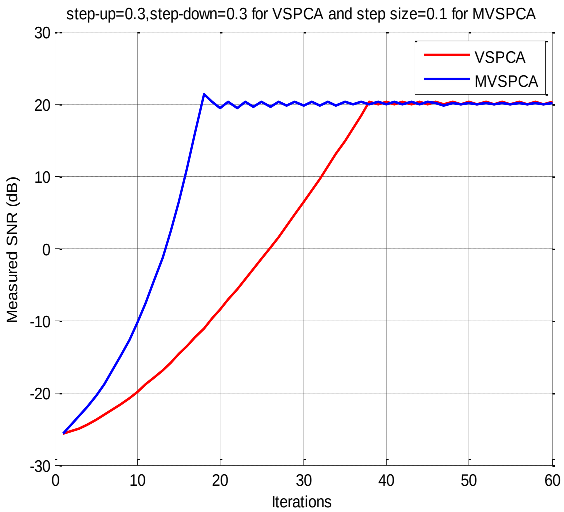

Fig. 3. Convergence speed of VSPCA for δ_{up} and $\delta_{down=}$0.3 and MVSPCA for δ=0.1

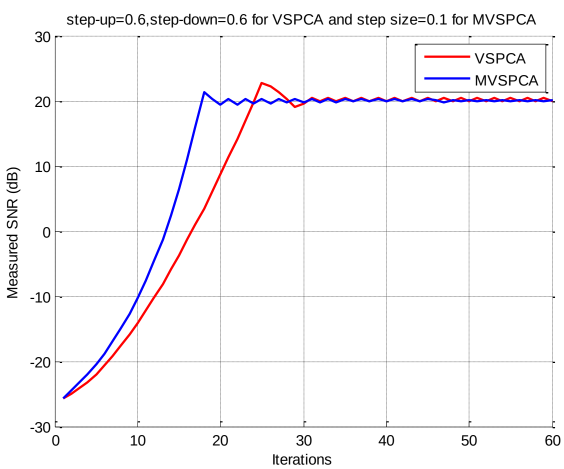

Fig. 4. Convergence speed of VSPCA for δ_{up} and $\delta_{down=}$0.6 and MVSPCA for δ=0.1

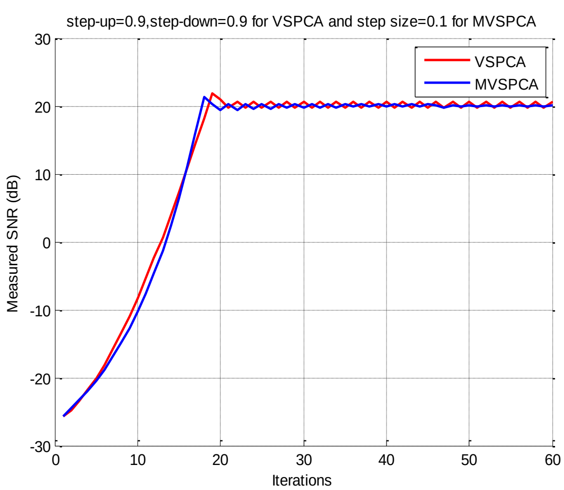

Fig. 5. Convergence speed of VSPCA for δ_{up} and $\delta_{down=}$0.9 and MVSPCA for δ=0.1

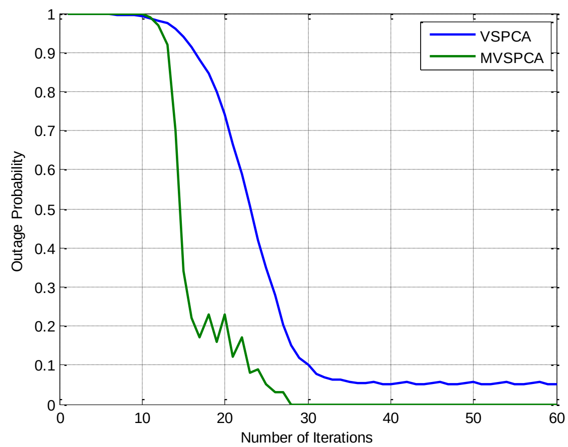

Fig. 6. Outage probability vs. Iterations

Fig. 6. shows that the outage probability drastically decreases after each iterations and the number of mobiles reaching the target *SIR* after each iteration is higher in modified variable step size power control algorithm than in variable step size power control algorithm. This algorithm has higher speed, higher robustness against loop delay and higher stability (fewer fluctuations in closed loop power control process).

5 Conclusions

This paper presents a new power control algorithm for CDMA systems which depends upon the variation of convergence parameter. The convergence speed and outage probability of modified variable step size power control algorithm outperforms that of variable step size power control algorithms. The presented algorithm increases capacity and leads to greater stability.

The presented algorithm uses two bits as power control signaling whereas variable step size power control algorithm uses single bit and more bandwidth efficient which is the major drawback of Modified variable step size power control Algorithm.

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References

[1] T. S. Rappaport. Wireless Communications: Principles and Practice IInd Edition. NJ: Upper Saddle River, Prentice-Hall, 2005

[2] C. Lee, R. Steele, "Closed loop power Control in CDMA systems", IEE proc-commun vol. 143. No. 4, August 1996

[3] A.J. Viterbi, CDMA: principles of spread spectrum communication, Addison-Wesley, 1995

[4] S. Hamed, A. Abbas, ”Variable Step Closed loop power Control in Cellular wireless CDMA systems under Multipath fading”, Islamic Azad University, Shahr_e_Rey branch, Tehran Iran, 2007

[5] L. Nuaymi, X. Lagrange, P. Godlewski, “A Power Control Algorithm for 3-G WCDMA System”, email-loutfi.nuaymi

[6] J. Zander, “Transmitter power control for co-channel interference management in cellular radio systems”, Radio Communication Systems laboratory, Dept. of Teleinformatics, Royal Institute of Technology, Electrum 207, Sweden.

[7] B. Cheng , W. Liu, C. Ma, “A Novel Power Control Algorithm for CDMA systems”, Information and Engineering University, Zhengzhon, china, @IEEE, 2005

[8] K. Dongwoo, C. Kun-Nyeong, K. Sehun, “Efficient Distributed Power Control for Cellular Mobile Systems”, August-14, 1995.

[9] A. G. Sudheer, V. Rajiv and J.G. David, “Distributed Power Control in Cellular Radio Systems”, IEEE Transactions on communications, Vol. 42 No 2/3/4, February/March/April 1994.

[10] L. Lu, S. Zhu and S. Dong, “Fast Convergence Distributed power control algorithm for WCDMA Systems”, IEE proc-commun. Vol. 150, No. 2. April 2003.