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CDMA Power Control Using Optimization Techniques- A Review

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Abstract— In this paper power control techniques for code division multiple access (CDMA) system is presented. For CDMA system Power control is the most important system requirement. To function effectively, there is a need to control the power. If power control is not implemented many problems such as the near-far effect will start to dominate and consequently will lower the capacity of the CDMA system. However, when the power control in CDMA systems is applied, it allows multiple users to share resources of the system equally between themselves, leading to increased capacity. With appropriate power control, capacity of CDMA system is high in comparison to frequency division multiple access (FDMA) and time division multiple access (TDMA).For power control in CDMA system optimization algorithms i.e. genetic algorithm & particle swarm algorithm can be used which determines a suitable power vector [1], [2]. These power vector or power levels are determined at the base station and told to mobile units to adjust their transmitting power in accordance to these levels. So a detailed discussion about CDMA system power control is given here.

Keywords— CDMA, TDMA, FDMA, GAME, PSO, TPC,QOS etc.

1.INTRODUCTION

In CDMA system users access the complete bandwidth available [3]. In Frequency Division Multiple Access or FDMA strategies, the focus is on the frequency dimension. The total bandwidth (B) is divided into N narrowband frequency bands. So several users are allowed to communicate simultaneously by assigning the narrowband frequency bands to the different users, where the narrow band frequencies are assigned to a designated user at all time. Since the total bandwidth (B) is subdivided into N frequency bands or channels, only N users can be supported simultaneously. In TDMA all users use the whole bandwidth but in different time slots. Unlike FDMA/TDMA the users in CDMA are isolated by codes rather than frequency slots or time slots. Each user is identifying via orthogonal codes. Sixty four Walsh functions are used to identify forward link channels and 64 long PN codes are used for identification of reverse link channels user. Due to this frequency reuse in CDMA system is very high which enhances the spectral efficiency. There is no limit on number of users in CDMA system. Each time a user is added, noise level for another mobile unit increases. So CDMA system has soft capacity which is more than any other multiple access schemes. In reality it is hard to maintain the orthogonal nature of the codes, thus this added with the multipath propagation and synchronization problem will result in interference. In FDMA and TDMA access schemes the number of available frequencies and time slots are the factors which limits the number of users. When the number of users is more than available frequencies and time slots then blocking occurs. In CDMA blocking occurs when the interference tolerance limit is exceeded. Therefore in CDMA the level of interference is the limiting factor.

2.Power control

With appropriate power control, CDMA offers high capacity in comparison to FDMA and TDMA. Since in CDMA systems there is no need of secluding of time or frequency slots among users, the central mechanism for resource allocation and interference management is power control [5]. So power control is a significant design problem in CDMA systems. Each user changes its access to the resources by adapting its transmitting power to the changing channel and interference conditions. Therefore power control also known, as Transmit Power Control (TPC) is a significant design problem in CDMA systems. Power control encompasses the techniques and algorithms used to manage the transmitted power of base stations and mobiles. Power control helps in reducing co-channel interference, increasing the cell capacity by decreasing interference and prolonging the battery life by using a minimum transmitter power. In CDMA systems power control insures distribution of resources among users. If power control is not implemented, all mobiles will transmit signal with the same power without taking into consideration the fading and the distance from the base station, so mobiles close to the base station will cause a high level of interference to the mobiles that are far away from the base station. This problem is known as the near-far effect [4]. The near far problem is shown in Fig 1:-

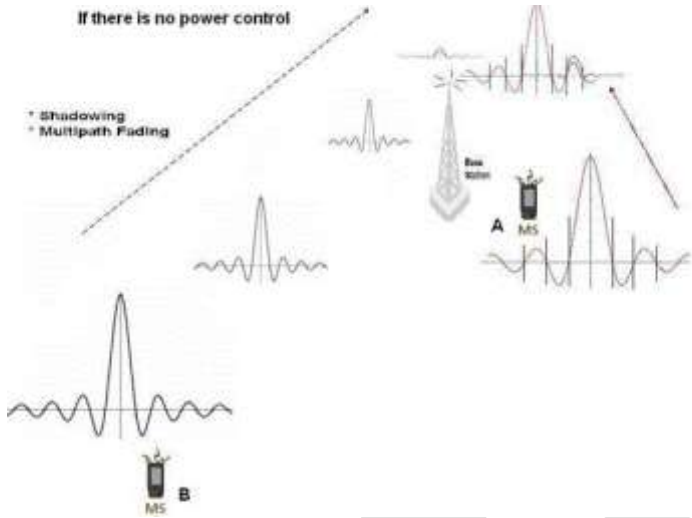

Fig.1 Near-Far problem when power control is not used [1].

In the reverse link (mobile to base station) it is necessary to use power control for solving the near far problem. The near-far problem can be avoided using power control mechanism. This is shown in Fig.2.

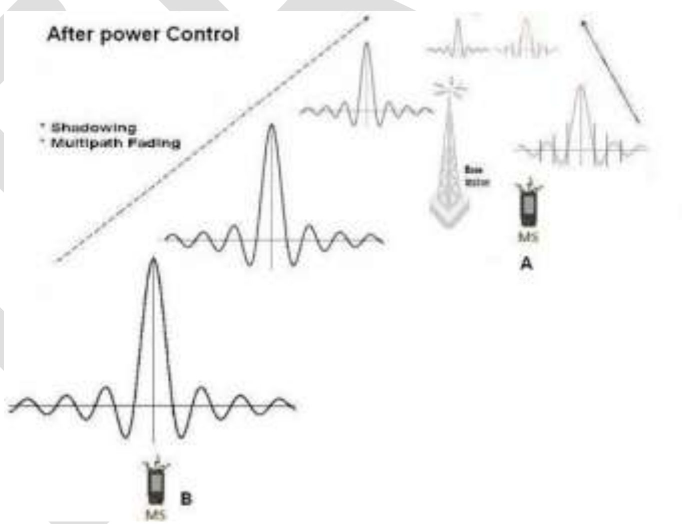

Fig.2 Power control overcomes near-far problem [1].

2.1 Main objectives of power control:-

1. To minimize the transmitting power from the mobile units in order to increase the battery lifetime.

2. To ensure that a certain quality of service parameter (QOS) is satisfied. This is done by making the value of

$\frac{E_b}{N_o}$ of the received signals from all mobile units exceed a certain threshold $(\frac{E_b}{N_o})_{th}$.If the received $\frac{E_b}{N_o}$ from a certain unit is lower than this threshold, this unit is out of service.
E_b is the energy per bit and N_o is the noise power spectral density..

3. Minimize the near-far effect. This is done by trying to make the received signal levels from mobile units very close to each other. The objective of the power control is to limit the transmitting power on forward link & reverse link. Due to non-coherent detection at the base station reverse link power control is more important as compared to forward link power control. Reverse link power control is essential for CDMA system and it is enforced by IS-95 standard.

2.2 Reverse Link Power Control

Reverse link power control mechanism is used to control the power on access and reverse traffic channels. It is used for establishing a link while originating a call. The reverse link power control includes open-loop power control (also called as autonomous power control) and the closed loop power control. The closed loop power control also includes inner-loop power control and outer- loop power control.

2.2.1 Reverse Link open loop Power Control

In this method base station is not involved. This method is based on the principle that mobile station closer to the base station needs to transmit less power as compared to a mobile which is far away from the base station or in deep fading condition. The mobile adjusts its power based on the power received in the 1.23 MHz band i.e. power in pilot, paging, sync and traffic channels. The key rule is that a mobile transmits in inverse proportion to what it receives. If the received power is low the mobile transmits high power and on receiving high power it transmits low power value.

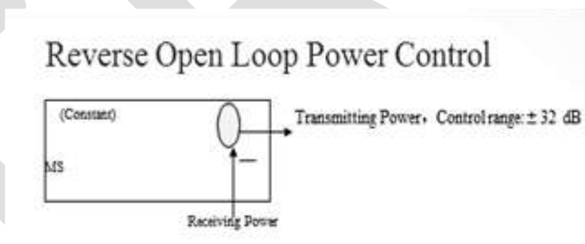

Fig. 4. Reverse open loop power control [13]

2.2.2 Reverse Link closed loop Power Control

In this method base station is involved. Base station sends the power control bits to the mobile station for power adjustment. A power control sub channel continuously transmits on the forward traffic channel. This sub channel runs at 800 power control bits per second. So a power control bit 0 or 1 is transmitted in every 1.25 ms. A'0' indicate that mobile should increase its mean output power level while '1' indicates that it should decrease its mean output power. The response time of this method is very low (1.25 ms) as compared to open loop power control (30ms) to counter deep fading condition.

The reverse link closed loop power control has two parts-inner loop power control and outer-loop power control. The inner loop power control keeps the mobile as close to its target $\frac{E_b}{I_t}$ as possible, but outer loop power control adjusts the base station $\frac{E_b}{I_t}$ for a given mobile. E_b is the energy per bit and I_t is the total interference.

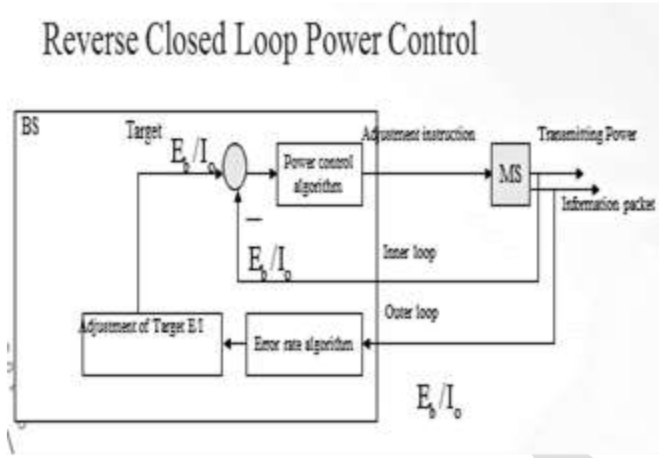

Fig. 3. Reverse closed loop power control [13]

3. Power control using optimization algorithms

Most of the practical Power control algorithms present today require high number of iteration in order to reach zero probability of Outage. The main aim of this paper is to represent idea of genetic algorithm and particle swarm algorithm power for control. The power control algorithm based on genetic algorithm was proposed by M. Moustafa *et.al* (Oct. 2000) [1] and based on particle swarm algorithm was proposed by Hassan M. Elkamchouchi Hassan *et.al* in 24th National radio science conference (NRSC 2007) [2].

3.1 Genetic Algorithm for Mobiles Equilibrium (GAME)

In a CDMA network, resource allocation is critical in order to provide suitable QOS for each user and achieve channel efficiency. Many QOS measures, including bit error rate, depend on the $\frac{E_b}{N_o}$ given by [1]:

$$\left(\frac{E_b}{N_o}\right)_i = \frac{G_{bi} P_i / R_i}{\left(\sum_{j \neq i}^{M} G_{bi} P_j + \eta\right)/W}$$

Where W is the total spread spectrum bandwidth occupied by the CDMA signals. G_{bi} denote the link gain between the base station 'b' and mobile user 'i'.η denotes the thermal noise contained in W and M is number of mobile users. P_i is the transmitted power by ith mobile which is limited by a power level $0 \le P_i \le P_{max}$ for $1 \le I \le M$. R_i is the information bit rate transmitted by ith mobile user. GAME uses a fix value for R_i(transmission rate of ith user)=15.5 kbps.

When any user increases its transmission power then its $\frac{E_b}{N_o}$ value increases but increases interference to others using CDMA i.e. decrease in $\frac{E_b}{N_o}$ of other mobile user. So power control means directly controlling the QOS that is specified as a pre specified $\frac{E_b}{N_o}$. It can also be stated in terms of probability that $\frac{E_b}{N_o}$ falls below $(\frac{\mathrm{Eb}}{\mathrm{No}})_{th}$(Outage probability). Thus, the objective here is to find an non-negative power vector P = [p1, p2, ... , pM] which maximizes the function F proposed as

$$F = \left(\frac{1}{M}\sum_{i=1}^{M} w_p\, F_i^E\, F_i^P + w_H F^H\right.$$

Where F_i^H is a threshold function defined for ith user depending on $\frac{E_b}{N_o}$ value.

$$F_i^H = \begin{cases} 1 & \left(\frac{E_b}{N_o}\right)_i \ge \left(\frac{\mathrm{Eb}}{\mathrm{No}}\right)_{th} \\ 0 & otherwise \end{cases}$$

Here F_i^H maximize the average QOS. Minimization of mobile power is also essential objective. Since low transmitting power means long battery life & less interference to other user, F_i^P is the part which uses minimum power and punishes high power transmitting mobiles.

$$F_i^p = 1 - \frac{P_i}{P_{max}}$$

The author has to ensure that received powers from all mobiles are in narrow range so that near-far problem can be reduced. The received power P_i^r is the product of link gain G_{bi} and P_i^r.

F^H, proposed in the fitness function penalize the solution whose received power components divergence is far away from its mean value.

$$F^H = \begin{cases} 1 - 5\left(\frac{\sigma_{p^r}}{p^{-r}}\right) & \sigma_{p^r} \leq 0.2p^{-r} \\ 0 & otherwise \end{cases}$$

Here p^{-r} is the average received power level and σ_{p^r} is the standard deviation.

w_P and w_H are the non-negative weights indicating the relative importance of an objective over the another. For example if the objective is to minimize the transmitting power then w_P would be the highest value.

GAME is a steady state GA which stops evolution after a timeout period [1]. The inputs are current power level from different users. Additional information like $(\frac{\text{Eb}}{\text{No}})_{th}$ maximum power level P_{max} and the link gains G are also required. In GAME method initial population of chromosomes is formed by encoding the power levels from mobiles. The chromosome is a string of N bits and it encodes power level of M mobile users. If each mobile power is encoded using q bits then N=q×M. the fitness function is used to evaluate these chromosomes. The cycle of evolution and reproduction works up to a stopping criterion. The base station transmits the new power vector to the users. In the meantime, the new solution is being used to initialize the input vectors at the next control period. The assumption for GAME method was that the base is situated at the center of cell. It was only for single cell with radius of unit distance. The users are distributed uniformly over the cell area. The loss model used is distance loss model. The link gain is $G_{ij} = A_{ij} \times D_{ij}$.

A_{ij} is the variation in the received signal due to shadow fading, and assumed to be independent and log normally distributed with a mean of 0 dB and a standard deviation of 8 dB.

The variable D_{ij} is the large scale propagation loss. Let d_{ij} is the distance between transmitter j and receiver I then it is assumed that in decibels

$$10\log D_{ij} = \begin{cases} -127.0 - 25 log d_{ij} & d_{ij} < 1 \\ -127.0 - 35 log d_{ij} & 1 \leq d_{ij} \leq 3 \\ -135.5 - 80 log d_{ij} & 3 \leq d_{ij} \end{cases}$$

This model uses three different path loss slopes ant for the 1 unit distance interception assumes -127.0 dB. The required QOS target or $(\frac{\text{Eb}}{\text{No}})_{th}$ is 5 dB and P_{max} is 1 watt. The transmission rate is fixed as 15.5 kbps and the thermal noise density is -174dbm/Hz.

4. Particle Swarm Optimization (PSO) Algorithm

Particle Swarm Optimization (PSO) is a method for global optimization [5] and it is different from other well-known Evolutionary Algorithms. As in Evolutionary Algorithms, a population of potential solutions is used to probe the search space, but no operators are applied on the population to generate new solutions. In PSO, each individual particle, of the population, called swarm, adjusts its trajectory toward its own previous best position, and toward the previous best position attained by any member of its topological neighborhood. In the global variant of PSO, the whole swarm is considered as the neighborhood. Thus, global sharing of information takes place and the particles profit from the discoveries and previous experience of all other companions during the search for promising regions of the landscape. For example, in the single-objective minimization case, such regions possess lower function values than others, visited previously. In the local variant of PSO, the neighborhood of each particle in the swarm is restricted to a certain number of other particles but the movement rules for each particle are the same in the two variants. The basic algorithm of PSO has two different versions. The first version is the one where the particles are represented by binary strings and the other is the one where the particles are represented by real numbers in n dimensional space where n is the dimension of the optimization problem under consideration. First, the author describes the basic algorithm of PSO in real number problems. The Pseudo-code for this algorithm is:

For i=1 to number of individuals

If G ($\overline{x_i}$)$>$G($\overline{p_i}$) then do // G() evaluates fitness

For d=1 to dimensions

p_{id}=x_{id} //p_{id} is best so far

Next d

End do

g=i // arbitrary

For j=indices of neighbors

If G($\overline{x_i}$)$>$G($\overline{p_g}$) then g=j // g is index of best performer

Next j

For d= 1 to dimensions

v_{id}(t)= v_{id}(t-1)+φ_1(p_{id}-x_{id} (t-1))+ φ_2(p_{gd}-x_{id}(t-1))

$v_{id} \in (-V_{min} , +V_{max})$

x_{id}(t)= x_{id}(t-1)+ v_{id}(t)

Next d

Next i

Here x_i is the position of particle i, v_i is the velocity of particle i, φ_1 is a random number that gives the size of the step towards personal best, φ_2 is a random number that gives the size of the step towards global best (the best particle in the neighborhood) and G is the fitness function which we are trying to minimize.

For the binary PSO, the component value of x_i , p_i and p_g are restricted to the set {0, 1}. The velocity v_i is interpreted as a probability to change a bit from 0 to 1, or from 1 to 0 when updating the position of particles.

Therefore, the velocity vector remains continuous-valued but the value of the velocity needs to be mapped from any real value to a probability in the range [0, 1]. This is done by using a sigmoid function to squash velocities into a [0, 1] range. Finally, the equation for updating positions is replaced by the probabilistic update equation:

$$x_{id} = \begin{cases} 0 & if\ \rho_{id}\,(t-1) \geq sig(v_{id}(t)) \\ 1 & \rho_{id}\,(t-1) \leq sig(v_{id}(t)) \end{cases}$$

$\overline{\rho(t)}$ is a vector representing random numbers, drawn from a uniform distribution between 0 and 1.

4.1 PSO-based Algorithm for Power Control Problem

In PSO based method the author uses basic binary PSO technique. The PSO algorithm is used to maximize a fitness function that takes into consideration all the objectives of the power control problem.

In PSO-based algorithm, every particle in the swarm should represent a power vector containing power values to be transmitted by all mobile units in order to be evaluated and enhanced by the algorithm. The particle representation in swarm is similar to the chromosome representation of the power vector in GAME method with q = 15 bits which gives a good resolution of tuning the power of the mobile units. If P_{max} =1 watt then the resolution by which user can be tune the power of the unit is$\frac{1}{2^{15}} = 3.051758 \times 10^{-5}$ watts (approx. 30.5 μW). It may be seen that this method of representation of the power vector inherently satisfies the maximum power constraint as we always assign the value of P_{max} to the string of 15 ones.

In this method first the author tried to use the same fitness function of GAME method. That fitness function gave good results in terms of minimization the transmitted power from the mobile units and making the value of $\frac{E_b}{N_o}$ of the received signals from all mobile units exceed
$(\frac{\mathrm{Eb}}{\mathrm{No}})_{th}$ but this function failed to fulfill the objective of the minimization of the near-far effect. This is because of the method it used to handle this objective. The parameter F^H gives credit to solutions which have received power values close to each other but the problem here is that this parameter is set to zero for all solutions whose received power components divergence is far away from its mean value. Assume two solutions, the first has $\sigma_{p^r} = 0.3p^{-r}$ and the second has $\sigma_{p^r} = 3p^{-r}$. The first solution is better than the second one but the F^H parameter is set to zero for both cases. This leads to the result that the second solution is not encouraged updating itself towards the first solution in order to minimize the near-far effect. So to solve that in PSO use a new fitness function which the author want to maximize is described as below

$$F = \left(\frac{1}{M}\sum_{i=1}^{M} w_p\, F_i^E\, F_i^P + w_H F^H\right) + \frac{w_s}{\sigma_{p^r}}$$

The first term of fitness function is same as in GAME method but the second term gives credit to solution with small standard deviation of received power distribution. This term is not zero for all particles and gives good result in minimization of near far problem. w_s is priority weight which indicates the relative importance of near-far problem objective over other objective. To check the effectiveness of the PSO algorithm, the author first initialized the particles of the swarm to using random bits. But his is not the real case, because in a real system the mobiles' power is updated from the power values in the last frame. After that the author applied PSO algorithm with the proposed fitness function to these randomly initialized particles [2]. The procedure of proposed algorithm is shown in Fig.5.

4.2 Treating Updated Distances and Fading Conditions

In order to work in a real system, the algorithm must react to the updates that are done on the mobile users 'positions and the fading conditions of the environment. In a real system, the power control information changes in every frame period of 10 ms and thus it takes into consideration the updates in the system. To simulate these updates, we assumed that users will move with a maximum velocity of 5 km/hr. and that the fading in each link may change from a frame to another as long as it follows the same probability distribution. Using these assumptions, we can calculate the new positions of the users and the new values for fading every frame period of 10 ms. The author calculate the new link gain for all mobile users and then apply our PSO algorithm. Of course, the best solution found so far from a previous run is being used to initialize the input vectors at the next control period because we expect that the new solution after the updates is not far away from the old solution before the updates in the search space. This procedure is described in Fig. 6.

5. CONCLUSION

- **Comparison of GAME & PSO method**

  - Regarding the average transmitting power for the mobile units, PSO algorithm reached solutions with much smaller values of transmitting power to serve the same number of users. The author says that the resulting values of PSO algorithm are about 65% on average from those of GA algorithm [1]. This means that PSO algorithm was much better in searching the search space when we fixed the maximum number of iterations.
  - Regarding the average received $\frac{E_b}{N_o}$ the author found that the results obtained by GA algorithm are slightly better than those obtained by PSO algorithm [1]. This was an expected result because the solutions of GA algorithm used greater values for transmitting power and thus they probably will achieve better average received $\frac{E_b}{N_o}$. In spite of the fact that GA results are better than PSO results, the results for both algorithms are too close to each other.
  - Regarding the outage probability, both algorithms achieved zero outage for small number of users. As the number of users increases, the outage probability appears. In general, the solutions of GA algorithm had outage probability greater than the solutions of PSO algorithm.

REFERENCES:

[1] M. Moustafa, I. Habib and M. Naghshineh, "Genetic Algorithm for mobiles equilibrium", in Proceedings of MILCOM 2000: 21st Century Military Communications Conference, vol. 1, pp. 70–74, Oct. 2000.

[2] Hassan M. Elkamchouchi , Hassan M. Elragal ,Mina A. Makar "power control in cdma system using Particle swarm optimization" 24th national radio science conference (NRSC 2007)

[3] R. Esmailzadeh and M. Nakagawa , "TDD-CDMA for Wireless Communications" Artech House, 2003.

[4] Juha Korhonen "Introduction to 3G Mobile Communications" Artech House, 2003.

[5] Abdurazak Mudesir "Power Control Algorithm in CDMA systems" International University Bremen

[6] J. Kennedy and R.C. Eberhart, "Particle swarm optimization", in Proceedings of IEEE International

Conference on Neural Networks, Piscataway, USA, pp. 1942–1948, 1995.

[7] J. Kennedy and R. C. Eberhart " Swarm Intelligence" San Francisco: Morgan Kaufmann Publishers, 2001.

[8] M. G. Omran, "Particle swarm optimization methods for pattern recognition and image processing", Ph.D.dissertation, University of Pretoria, Pretoria, South Africa, Nov. 2004.

[9] C.U. Saraydar, N. Mandayam and D. Goodman, "Pareto efficiency of pricing-based power control in wireless data networks" in: *WCNC* (1999).

[10] C.W. Sung and W.S. Wong, Power control for multirate multimedia CDMA systems, in: *Proc. of IEEE INFOCOM*, Vol. 2 (1999)

[11] A.J. Viterbi, "CDMA Principles of Spread Spectrum Communication" (Addison-Wesley, Reading, MA, 1995).

[12] R.D. Yates, A framework for uplink power control in cellular radio systems, IEEE Journal on Selected Areas

[13] Abdurazak Mudesir, " Power Control Algorithm in CDMA systems,"submitted as a Guided research in International University Bremen