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유전 알고리즘을 이용한 CDMA 셀룰러 시스템의 성능 개선

Performance Enhancement of CDMA Cellular System Using Genetic Algorithm

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요 약 본 연구에서는 차세대 CDMA 셀룰러 네트워크의 성능향상을 위한 멀티 데이터 전송 레이트 조절과 전력제어 문제를 결합한 문제를 제시하고 유전 알고리즘 접근에 기반한 새로운 해법을 제안하였다. 본 연구에서 제안한 알고리즘으로 많은 사용자를 보다 빨리 서비스 할 수 있고 SIR 제한값을 고려하면서 최적의 해를 얻을 수 있었다. 이 연구에서는 CDMA 셀룰러 네트워크의 데이터 전송 레이트를 최대화하는 적합도 문제와 가능한 모바일의 수를 최대화하는 적합도 문제 두 개를 고려하였으나 이 들을 결합한 문제나 다른 것 들에 대한 적합도 함수도 충분히 장착이 가능하다. 시뮬레이션 결과는 접근 방식의 유효성과 타당성을 보여준다.

Abstract In this work, we present a novel genetic approach to solve the problem of combining power control and data rate transmission adjustment for the performance enhancement of the next generation CDMA system. We obtained the optimal solution of multi rate and power control problem by compromising slightly on SIR limit values. The proposed algorithm was able to handle many more users with comparable or faster convergent service. While this paper considered two kinds of fitness function such as maximizing the total transmission data rate and maximizing the acceptable mobiles of CDMA cellular network, the evaluation function combining these two cases or others can be also easily implemented. The simulation results showed the effectiveness and validity of our approach.

Key Word : cellular network, multi-rate transmission, genetic algorithm

Ⅰ. Introduction

Up/down link traffic portions are getting more dominant in cellular CDMA cellular networks. It will be thus very important to achieve high data rate capability in CDMA system. Most of the optimum resource allocation problems were solved in order to achieve the maximum CDMA capacity. That is, there works have been devoted to solve power and/or rate allocation problem which is aimed to increase network throughput [1-4]. In fact, the rate transmission control and power control are closely related each other in practice. Most of all conventional power control methods, however, deal only with fixed data rate during the power control process and has focused on finding a power assignment that maximizes the minimum carrier-to-interference ratio and transmission rate of each user, which is known and fixed. Moreover, their works on this topic have inherent limitation by assuming that CIR(Carrier to Interference Ratio) and transmission rate are continuous functions.

However, it should be emphasized here that the transmission rate is not continues but it is distinct in

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practice such as DS-CDMA and EDGE(Enhanced Data rates GSM Evolution) cellular system. For these reasons, it is not so easy to develop efficient data rate control in CDMA due to maximum transmit power control constraints and the researches combining them are believed to yet immature in spite of its importance[5].

In this work, we consider the problem of combining power control and data rate transmission adjustment to increase cellular network capacity. The formulated problem to solve belongs to a kind of NP hard problem, which implies that any well-known exact algorithm will run exponentially in time as the size of problem instance grows. Moreover the design parameters contain mixed variables such as distinct variables including continuous real ones. GA(Genetic Algorithm) is an adaptive procedure that finds solutions to problems by genetic process based on natural selection [6]. They are iterative search algorithms with various applications [7].

The main idea of the proposed scheme is divided into two parts: The first one is in applying GA to the distinct variables such as multi rate data transmission. The binary genetic representation is believed to be very effective in these variables. The second one is in utilizing our previously suggested power controller. Our power control algorithm has very rapid convergent rate comparing with the representative distributed power controller suggested by others.

The remainder of the paper is organized follows. In section 2, we introduce the system model. We formulated the optimization problem and present a genetic solution procedure in section 3. Simulation condition and experimental results are discussed in section 4. We finally conclude our remarks in section 5.

II. System Description

2.1 System Model

Consider the uplink for a single cell CDMA in which N mobiles are active in the system. We use a "snapshot" model, assuming that link gains evolve slowly with respect to the SIR evolution. That is, we consider that stationary link gain between a base station i and a mobile j and ot os given by g_{ij}[8]. Without a loss of a generality, we will assume that mobile j is communicating with base station i. We denote the background(receiver) noise power within the user's bandwidth. In the deterministic formulation of the power control problem for wireless networks, the noise power is treated as constant. In a CDMA system, many mobiles will communicate with the same base station. The current SIR $\nu_i(k)$ at the base station i is given by

$$\nu_i(k) = \frac{q_i(k)}{I_i(k)} = \frac{W}{R}\frac{g_{ii}P_i(k)}{\sum_{j=1,j\neq i}^{N} g_{ij}P_j(k) + \nu_i} \quad i = 1,2, \cdots N \tag{1}$$

In the above, k denotes an instant time, $q_i(k)$in the numerator part is the power received from transmitter i and $I_i(k)$ is the received interference plus noise power at receiver i and the quantity ν_i is the thermal noise variance at receiver i. R_i is the transmission rate from the mobile i and W is the total spread spectrum bandwidth occupied by CDMA.

For the instant time k, let us assume that each mobile should achieve the target SIR ν^t as follows.

$$\nu_i(k) \geq \nu^t \qquad i=1,2, \cdots N \tag{2}$$

2.2 Distributed Power Control in Uplink Case

Let us define a N by N matrix $H = [h_{ij}]$ such that

$$h_{ij} = \frac{\nu^t g_{ij}}{g_{ii}} \quad \text{for } i \neq j \tag{3}$$
$$= 0 \quad \text{for } i = j$$

Additionally, let us define a vector $b = [b_i]$ such that

$$b_i = \gamma^t \frac{\sigma_i^2}{g_{ii}} \quad (4)$$

Converting Eq.(1) into a matrix form, we have the following linear algebraic eqations of power control problem.

$$Ap = b \quad (5)$$

where, $A = I - H$ and $p = [p_i]$ denotes the power vector.

A suitable power control algorithm should converge to the solutions in a quick and distributive way, while feasible system should support as many users possible. It was suggested that Eq.(5) can be solved with Jacobi fixed point iterations[7], which leads to the following algorithm.

$$p_i(k+1) = (I - A)p_i(k) + b \quad (6)$$

$$p(k+1) = \frac{\nu^t}{\nu_i(k)} p_i(k) \quad (7)$$

where, SIR $\nu_i(k)$ is given by Eq.(1) at the base i. A nice feature of the algorithm in Eq.(10), which is called DPC(Distributed Power Control) algorithm, is that only the information about the current mobile power and the current SIR is sufficient to update the mobile power. Assuming that the transmitted powers are constrained to

$$0 \leq p_i(k) \leq p_i^U \quad (8)$$

where, p_i^U describes the maximum mobile power. Then algorithm Eq.(7) is modified into the following DCPC(Distributed Constrained Power Control) algorithm[7].

$$p_i(k+1) = \min\left(\frac{\nu^t}{\nu_i} p_i(k), p_i^U\right) \quad (9)$$

The DCPC provides a theoretical background of IS-95 and W-CDMA power control and convergence properties of this algorithm were studied in [9].

2.3 Transmission Rate

If a non-negative power vector p is within the maximum criteria Eq.(8) as well as the single quantity requirement Eq.(2), it is called effective. Let E be the set of all effective power vectors for the considered system, then the shape of E typically depends on transmission bit rate $R = \{R_1, R_2, \cdots, R_N\}$. If the effective power vector is nonzero, then the corresponding R is called admissible to the system[9]. On the contrary, every power control convergies to an effective power if the given(fixed) transmission is admissible. In practical systems, the feasible transmission modes are often discrete and finite; the number of link adaptation schemes, code rates and the processing gains. Therefore, we consider here that each user can choose transmission out of K possible rates such that $R_i \in \{r_i^1, r_i^2, \cdots r_i^K\}$.

III. Genetic Algorithm

3.1 Chromosome and Fitness

Genetic scheme not only combines survival of the fittest, genetic operations, random but structured searches but also performs parallel evaluation of solutions in the search space. GA has been well applied to a variety of problems such as NP-hard problems and mixed integer problems[6][7].

In our work, transmission rates of mobiles consist of an individual as a potential solution for the adjustment problem. In order to represent a transmission rate level value of a user, we transform transmission rate of a user into binary numbers or strings which can inherently satisfy the discrete constraint condition.

We design the chrome C_i of a user i such that $C_i = b_1 b_2 \cdots b_L$, where $b_1 b_2 \cdots b_L$ is the binary coding representation of an instant transmission rate R_i of a user i with L bits. Thus the bits of transmission rate per each mobile terminal constitute one chromosome of an individual. Therefore, if the number of mobiles is M, there are M groups of population. The evaluation function of GA determines the fitness of potential solutions, which can be denoted generally as follows. The following evaluation function is used in order to support systems as many mobiles as possible as follows[6][7].

$$\text{Fitness} = \max f(\cdot) \tag{9}$$

where, $f(\cdot)$ is the evaluation function to be maximized. In this work, we selected it as the number of supported mobiles constraints at first, and we considered it as the total data rate at second while satisfying the SIR threshold in Eq.(2).

3.2 Overall Procedure

The overall procedure of the proposed algorithms is as follows.

[Step 1] (*Initialization*): Start with complete set of active mobile N, and initial power vector $p(0)$, and initial transmission rate vector $R(0)$. Set the parameters of GA.

[Step 2] (*Termination Criteria*): For every mobiles do Steps 2-4 until any predefines condition is satisfied.

[Step 3](*Evaluation*): Calculate the fitness of the population.

[Step 4] (*Evolution*): Evolve the population by manipulating chromosomes using GA operations while maintaining the elite chromosome. Go to Step 2.

IV. Simulation

4.1 Test condition

The main purpose of the experiments is to investigate how much system capacity can be increased and how many extra effort is needed in combining power control and multi rate adjustment using genetic algorithm. We considered a 2km square cell with base station centered at the origin mobile locations were chosen randomly from a uniform distribution[10]. Power was limited to 600mW corresponding to the legal limit in the United States. Back ground receiver noise power within the user's bandwidth of $2\text{x}10^{-13}mW$ was used in the simulations. We generated random set of 30 users, locations of which are uniformly distributed over a cell. The initial power of each mobile is randomly chosen from the interval [0,1]mW. The target SIR(Signal to Interference Ratio) was set to 3.918. The channel gains was determined according to

$$g_{ij} = \frac{A}{r_{ij}} \tag{10}$$

where r_{ij} is the distance from a mobile station i to a base station j, and A is 10^{-11} corresponds to a path loss of 110dB ar a distance of 1km We ignored fast fading, shadow fading and interference from adjacent cellsl We here consider IS-95 example, where spreading bandwith is 1.2288 Mcps. Data rate R_i can be one value of IS-95 rate set 1200, 1800, 2400, 4800, 7200, 9600bps per each mobile user.

We selected population size of GA as 100, crossover rate as 0.8, mutation rate as 0.1, termination criteria as 200 generations, which are typical in GA[6][7]. The length L of a chrome is set to 3, which is believed enough to encode the transmission rate R_i of a mobile user in IS-95 CDMA. Thus the chromosome of an individual represents the total rate of mobiles. Fig. 1 shows the cellular system of our simulation model, which consists one base station and multiple mobile stations.

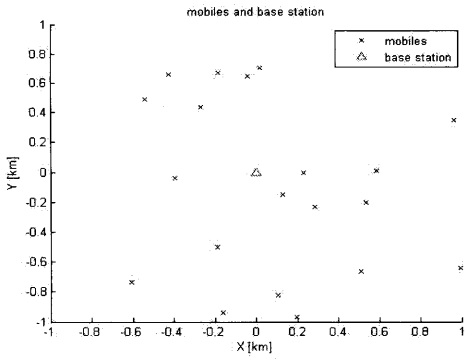

Fig. 1. A cellular system model for simulation (One base station, uniformly distributed mobile stations)

4.2 Maximizing the Total Data Rate

First, the evaluation function in Eq.(10) was set to maximize the total data rate of the mobiles as possible satisfying the SIR threshold constraints.

$$Fit = \max \sum_{i=1}^{N} R_i \tag{11}$$

where, R_i is the transmission data rate of a mobile i and N is the number of mobiles. Fig.2 shows the sum of the data rate of mobiles satisfying the constraints over generations, which shows the data rate increase over generations. Fig.3 shows the portion of unacceptable mobiles, or outage probability, decreases over 120 generations and Fig. 4 shows average power over generations.

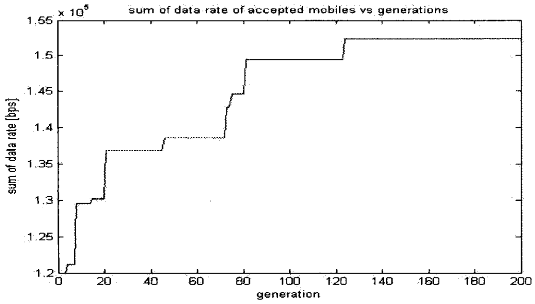

Fig. 2. Sum of data rate of mobiles over generations

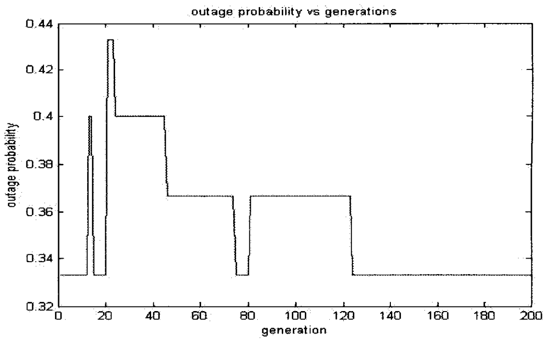

Fig. 3. Outage probability over generations

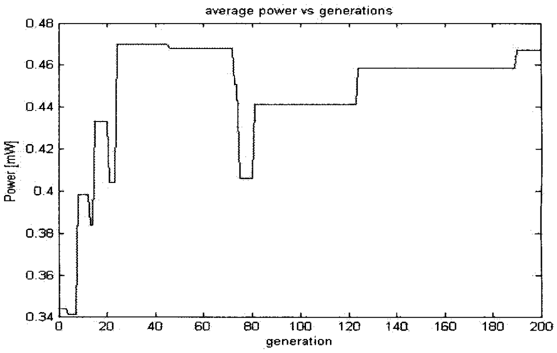

Fig. 4. Average power over generations

4.3 Maximizing the Number of Supporting Mobiles

Second, we set the evaluation function in Eq.(10) to support the cellular system as many mobiles as possible satisfying the SIR threshold constraint as follows.

$$Fit = \max S \tag{12}$$

Where, S is number of the acceptable mobiles, which do not violate the power and SIR constraints. Fig.5 shows the number of acceptable mobiles satisfying the constraints over generations. From the figure, it is observed that fitness function of the elite chromosome stably converges to the maximum after 60 generations. In other words, it means that the portion of unacceptable mobiles was minimized, or outage probability decreased as shown like Fig.6. Fig.7 and

Fig.8 show variation of average power and average transmission rate of the cellular network, respectively.

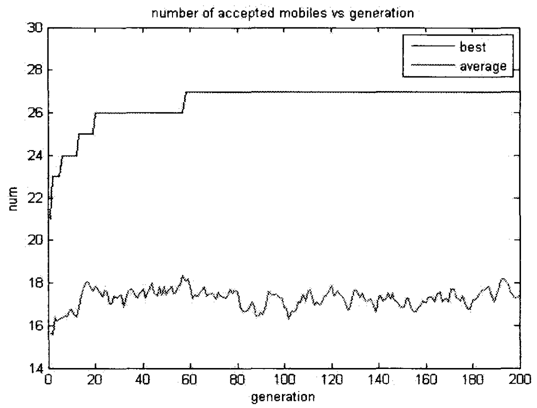

Fig. 5. Fitness variation over generations

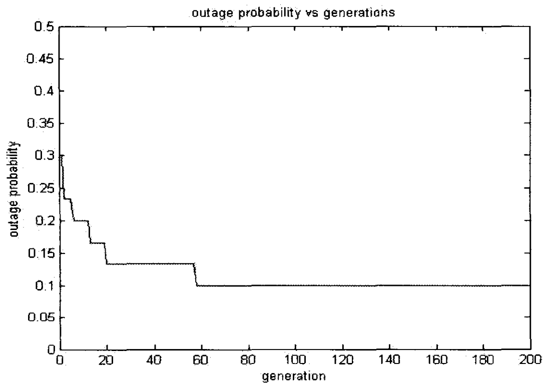

Fig. 6. Outage probability

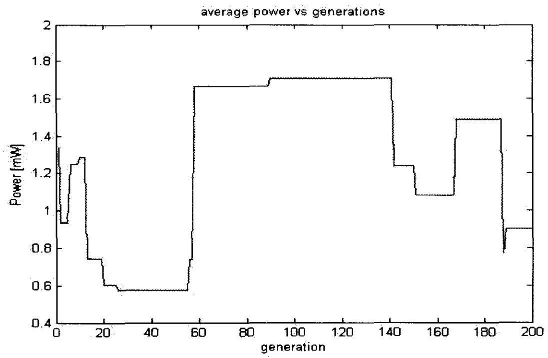

Fig. 7. Average power over generations

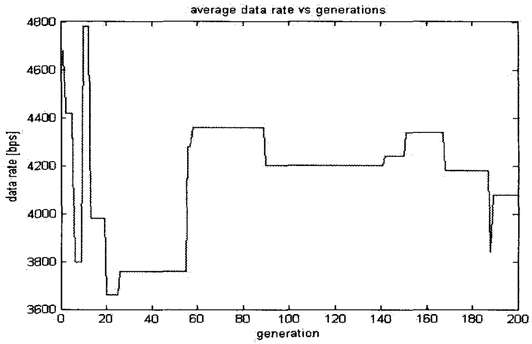

Fig. 8. Average data rate over generations

V. Conclusion

In this work, we firstly presented genetic solution algorithm based approach to solve the proposed combined problem of multi data rate adjustment and power control using genetic algorithm in CDMA cellular network.

The formulated problem contains the design parameters with mixed variables such as distinct variables including real ones. Moreover, it belongs to a kind of NP hard problem, which implies that any well-known exact algorithm will run exponentially in time as the size of problem instance grows. For this reason, it is difficult to solve the problem using conventional optimization methods. Here, we firstly proposed genetic algorithm based solution approach to this problem, which mimics natural evolution. Our work can be potentially extended to power control of ad-hoc networks for ubiquitous communication system.

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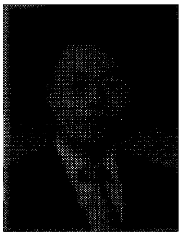

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