논문 2008-2-8

셀룰러 네트워크의 동적채널에서 빠른 분산 전력 제어 기법의 특성에 대한 연구

A Study on the Characteristics of Fast Distributed Power Control Schemes in Cellular Network under Dynamic Channel

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Abstract

To address the convergence issue of power control algorithms, a number of algorithms have been developed hat shape the dynamics of up-link power control for cellular network. Power algorithms based on fixed point iterations can be accelerated by the use of various methods, one of the simplest being the use of Newton iterations, however, this method has the disadvantage which not only needs derivatives of the cost function but also may be weak to noisy environment. we showed performance of the power control schemes to solve the fixed point problem under static or stationary channel. They proved goof performance to solve the fixed point problem due to their predictor based optimal control and quadratic convergence rate. Here, we apply the proposed power control schemes to the problem of the dynamic channel or to dynamic time varying link gains. The rigorous simulation results demonstrated the validity of our approach.

Key Words : power control, dynamic channel, link gain, cellular network

Ⅰ. Introduction

The importance of distributed methods for power control has traditionally been fueled by the application to the uplink power control problem in cellular systems. Closed loop power control is used in wireless communication networks to compensate for fast fading, time varying channel characteristics, and to reduce mobile power consumption.

In CDMA mobile networks, transmit power control is needed to provide each user an acceptable connection by limiting the interference seen by other users. Intrinsically, centralized or distributed power control is essential and important for high capacity cellular radio networks. In recent, many

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접수일자: 2008.1.20, 수정완료일자: 2008.4.11

researchers have investigated a variety of power control algorithms from a different point of view.

Power control can be centralized or distributed. A lot of works have been performed on distributed power control(DPC) because it requires only the desired-path interference measurement made at each base, and relayed to the corresponding mobile.[1]-[4]

In the previous work[5], we showed performance of the presented the DPC algorithms(DPC-I, DPC-II) under static channel. DPC-I and DPC-II showed fast convergence rate comparing with the typical DPC. Especially DCP-II had very rapid convergence rate among them. under stationary link gain channel.

In this work, time varying nature of link gains are considered in the design and evaluation of a closed loop power control on our proposed algorithms.

II. Control Model

2.1 Interference in CDMA Systems

We consider uplink direction for a single cell CDMA system with N users, designating the transmitted power and SIR for the i th user by $p_i$and γ_i, respectively. WE denote the background(receiver) noise power within the user's bandwidth by $\eta_i := \sigma_i^2$. The interference experienced by the ith user will be designated $I_i(p_{-i})$, where subscript "-i" indicates the interference depends on the powers of all users except the ith mobile. We use a "snapshot" model, assuming that all link gains evolve slowly with respect to SIR evolution. In this problem formulation, the SIR of mobile i is at instant of time k given by

$$\gamma_i(k) = \frac{g_{ii}p_i(k)}{I_i(p_i(k))} = \frac{g_{ii}p_i(k)}{\sum_{j \neq i} g_{ij}p_j(k) + \eta_i} \tag{1}$$

where, noise power η_i is given as constant in the deterministic power control. The elements g_{ij} of the gain matrix G depends on mobile to base station distance, physical parameters, and coding reaction coefficients.

For the instant tume k, let us assume that each mobile achieves the target SIR γ^t as follows.

$$\gamma_i(k) \geqq \gamma_i^t \tag{2}$$

If we ignore fast fading, shadow fading, and interference from adjacent cells, the channel gains g_{ij} were determined according to

$$g_{ij} = \frac{A}{r_{ij}^{\alpha}} \tag{3}$$

Where, r_{ij} is the distance from a mobile station i to a base station j, and A is a constant gain and the coefficient α is usually in the range of 3 to 4 for outdoor communications.

III. The Proposed Power Control Algorithms

3.1. (Jacobi based) Distributed Power Control(DPC or J-DPC)

It was suggested that power control

algorithm can solved with Jacobi fixed point iteration in distributed way as follows.[2]

$$p_i(k+1) = \frac{\gamma_i^t}{\gamma_i(k)} p_i(k) \tag{4}$$

The above algorithm is well known as DPC(distributed power control). Here, we call it as J-DPC(Jacobi iteration based DPC)

Assuming that transmitted powers are constrained to

$$p_i^L(k) \leqq p_i(k) \leqq p_i^U \tag{5}$$

where, p_i^L and p_i^U is the minimum and maximum mobile power, respectively. Then the DPC is changed as DCPC(distributed constrained power control) as follows.

$$p_i(k+1) = \min\left(\frac{\gamma_i^t}{\gamma_i(k)} p_i(k), p_i^U\right) \tag{6}$$

The DCPC constructs a theoretical back ground of IS-95 CDMA(See Fig. 1) and W-CDMA power control algorithm. The properties of DPC(J-DPC) and DCPC were well known to have slow speed with linear rate of convergence.

3.2 The Proposed Power Control Algorithms

[DPC-I]

The power control algorithm DPC-I, which was previously suggested by us, is based on optimal control theory and it needs one-step predictor on channel variation is described as following equations.[5]

$$p_i(k+1) = p_i(k) + \alpha_i(k)(\gamma_i^t - \gamma_i(k)) \tag{7}$$

$$\beta_i(k) = \frac{g_{ii}(k)}{I_i(k)} = \frac{\gamma_i^t(k)}{p_i(k)} \tag{8}$$

$$\alpha_i(k) = \begin{cases} \frac{1}{\beta_i(k)}\left(1 - \frac{\gamma_i^t}{e_i(k)}\right) + \\ \frac{1}{\beta_i(k)}\left(1 - \frac{\gamma_i^t}{e_i(k)}\right), & \text{if} \quad e_i(k) \neq 0 \\ 0, & \text{if} \quad e_i(k) = 0 \end{cases} \tag{9}$$

$$p_i(k+1) = \begin{cases} p_i^L, & \text{if}\ \beta_i(k+1) < \frac{\gamma_i^t}{p_i^L} \\ p_i^U, & \text{if} \quad \beta_i(k+1) > \frac{\gamma_i^t}{p_i^U} \\ p_i(k) + \alpha_i(k) e_i(k), & otherwise \end{cases} \tag{10}$$

[DPC-II]

The power control algorithm DPC-II which also suggested previously by us is the accelerated version of DPC-I based on Steffensen iteration. And the iteration procedure only needs initial three power values provided by DPC-I as follows.[5]

$$p_i^s(k) = p_i(0) - \frac{(p_i(1) - p_i(0))^2}{p_i(2) - 2p_i(1) + p_i(0)} \tag{11}$$
$$k = 1, 2, \cdots$$

IV. Simulation

4.1. Simulation Environment

To demonstrate the efficacy of the algorithms developed above, we tested them in a realistic simulation in Matlab. In this section, we discuss the simulation parameters used and the simulation results.

We considered a 2-km square with base station centered at the origin and mobile locations were randomly from a uniform distribution. Power was limited to 600mW corresponding to the legal limit in the United states. Back ground thermal noise power σ_i^2 was set to 0.2mW in the simulations.

We generated random set of 20 users at default, the locations of which are uniformly distributed over a cell(See Fig.1). The initial power for each mobile is randomly chosen from the interval (0,1]mW. The target SIR(Signal to Noise Ratio) γ^t was set to 3.918. A is set to 10^{-11}, which corresponds to a path loss of 110dB at a distance of 1km.

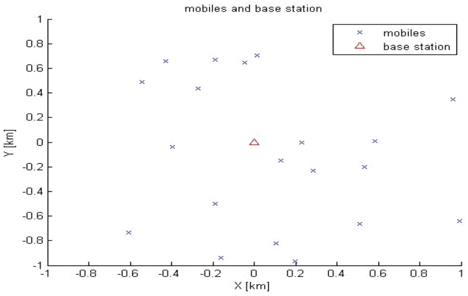
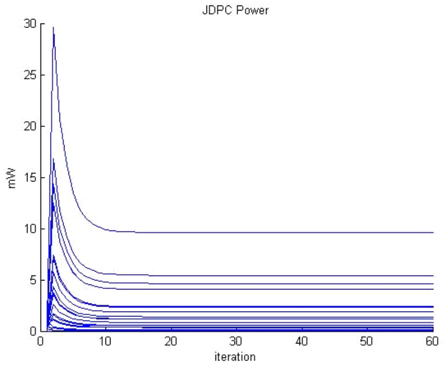


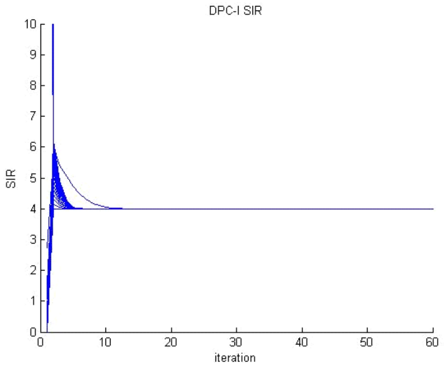
Fig. 1. A Cellular system model for simulation (One base station, uniformly distributed mobile stations)

4.2 Stationary(Quasi Static) Channel Link Gains

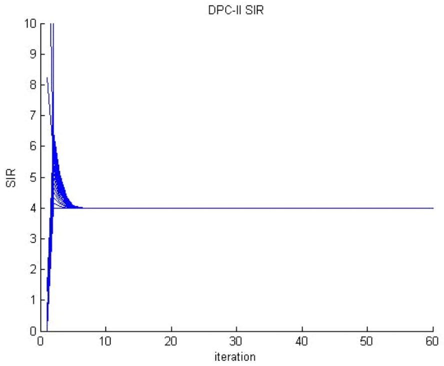
First we consider the static channel with constant link gains. The trace in Fig. 2 represents SIR and power values over the set of mobiles considered in the case of stationary channel gains. Without the sacrifice of the achieved SIR, a significant reduction in computation is observed in our power control schemes DPC-I and DPC-II comparing with the typical Jacobi iteration based DPC (or J-DPC). That is, DPC-I and DPC-II reached the equilibrium state of SIR and power faster the typical J-DPC and in converges to the solution with a few iterations. However, with the large of mobiles above thirty, the achievable SIR decreased significantly as shown in Fig. 2.



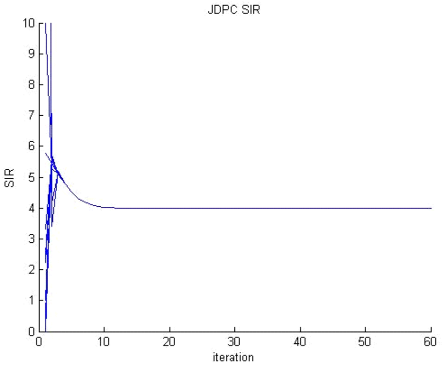
(a1) SIR of J-DPC



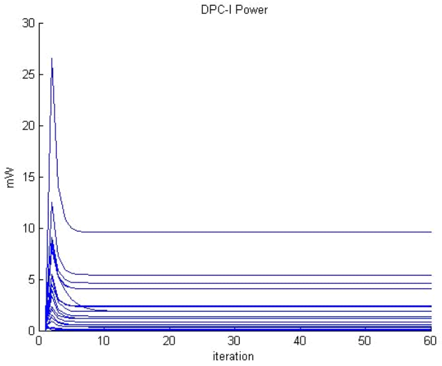
(a2) SIR of DPC-I



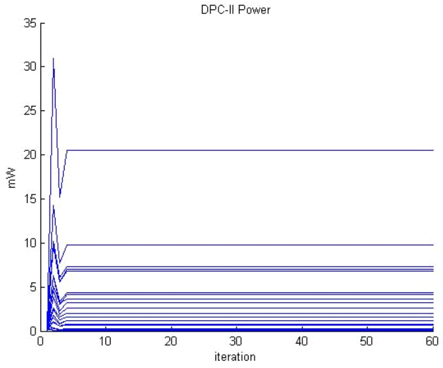
(a3) SIR of DPC-II



(b1) Power of J-DPC



(b2) Power of DPC-I

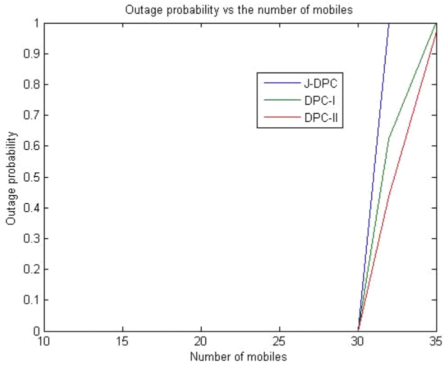


(b3) Power of DPC-II

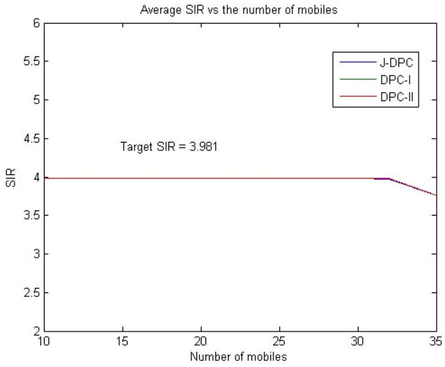
Fig. 2. Comparison of power control algorithms over iterations

That is, the number of some mobiles whose SIR fell below the minimum SIR increased suddenly. Hence, the outage probability is defined as the ratio of the number of disconnected users to the number to that of the total number of users in the system. Accordingly, dropping some of outage mobiles would be necessary to achieve the QoS in case of large users in practice.

When we increased the cell loading to 25 mobiles we found greater improvement in convergence speed, as shown in Fig. 3. However, for very heavily loaded cells, e.g. with $N \geq 30$, the accelerated methods(DPC-I, DPC-II) some times failed, however for reasonable loading they were very reliable.



(a) SIR variation



(b) Outage probabilities of mobiles.

Fig. 3. Comparison of power controls over the number of mobiles

It is noticeable that the accelerated algorithms are not so much robust as the original fixed point algorithm for very large numbers of mobiles over very heavily loaded cells.

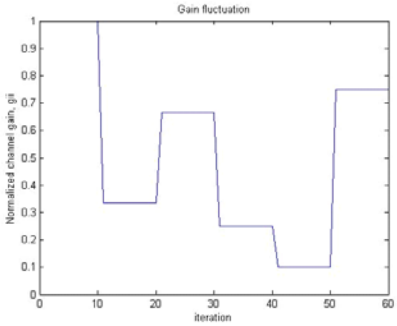
4.3 Dynamic Time Varying Channel Cases

Next we consider the dynamic channel with time varying link gains. Two cases are considered:

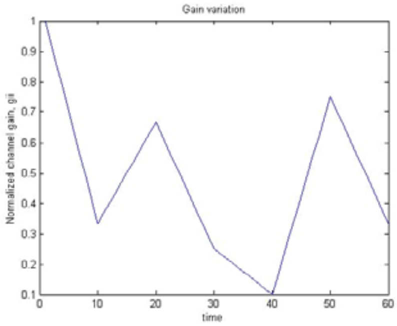
(Case 1) Channel channing sharply at certain time instants, and

(Case 2) channel changing smoothly like as shown in Fig. 4.

From the Fig. 5, it is clear that the performance of the proposed DPC-II outperforms that of J-DPC and DPC-II performance such as SIR.



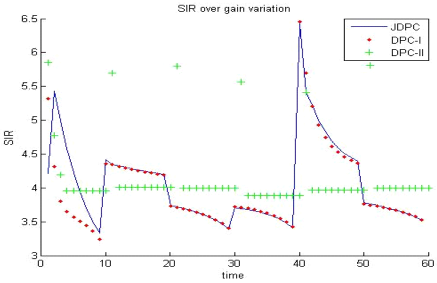
(a) Case 1



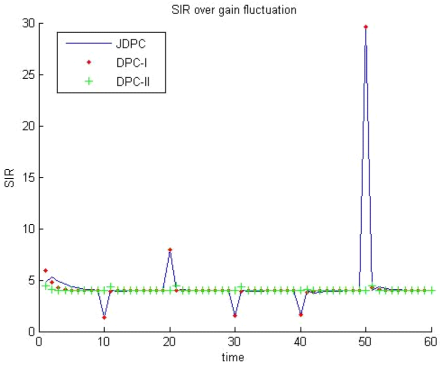
(b) Case 2

Fig. 4. Channel fluctuations in two cases

Futhermore, using the proposed scheme DPC-II, outage probability is minimized under dynamic chanel compared to DPC-I not to mention the typical J-DPC as shown in Fig. 6.



(a) SIR over time (Case 1)



(b) SIR over time (Case 2)

Fig. 5. Comparison of power control schemes over two cases of dynamic channel

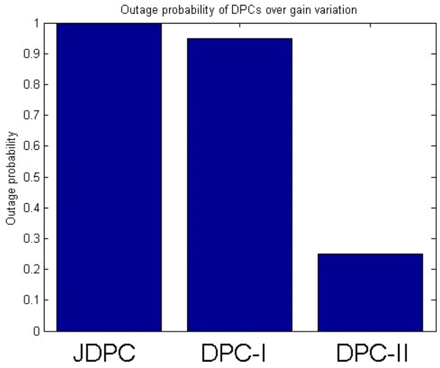


Fig. 6. Average outage probabilities in Case 2

V. Conclusion

In this paper, we investigated the properties of the proposed fast power control methods under a stationary channel with fixed link gains and two dynamic channels with varying link gains. Our simulation results indicate the proposed algorithm based on optimal control theory with one step predictor(DPC-I) and the accelerated version of it with Steffenson based iteration (DPC-II) significantly decrease the number of iterations required for convergence.

Nonetheless our further work is needed to enhance the performance of the proposed algorithms because the most acceleration based algorithms are not so robust as original fixed point algorithms. Additional study would be needed to determine why the algorithm fail and to determine limites on number of allowable mobiles or other system parameters that would prevent such failures.

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