CDMA 셀룰라 시스템에서 변동 경감 요소를 가지는 제한적 분산 전력제어

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Distributed Constrained Power Control with Non stationary Relaxation Factor in CDMA Cellular systems

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Abstract

The current paper proposes fast distributed constrained power control (FDCPC) with a non stationary relaxation factor as the next power update for CDMA cellular power control systems. A review is also given of unconstrained control algorithms: distributed power control (DPC), unconstrained second order power control (USOPC), and DPC with a stationary relaxation factor (DPCSRF). To improve the performance of outage probability convergence, DCPC with a non stationary relaxation factor (FDCPC) is proposed. Under constrained conditions, the convergence rate of FDCPC is shown to outperform that of DCPC and constrained second order power control(CSOPC).

Keywords : CDMA, SIR, Relaxation Factor, DCPC, CSOPC

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1. Introduction

The purpose of power control in CDMA cellular systems is to obtain an acceptable SIR for all users and maximize the system capacity. In addition, the near far problem has to be solved through calculating the optimum transmission power according to the user locations. Various distributed power control (DPC) algorithms have already been developed that enable the power level of each mobile to be adjusted to make a connection using only local measurements. Since the most important performance measure of DPC is the convergence rate of the outage probability, the goal of the current study is to present a method with a faster convergence rate than conventional algorithms as an aspect of outage probability.

[1] presents a framework for uplink power control in cellular radio systems, while [2] introduces a distributed power control algorithm based on a more general model, where the algorithm calculates the transmission power required for each mobile that can accommodate all users with an acceptable SIR and produces a fixed point convergence. Grandhi *et al.* [3] propose distributed constrained power control (DCPC), which has become one of the most frequently referenced algorithms in recent studies. Meanwhile, [4] describes a second-order constrained power control (CSOPC) algorithm that updates the transmission power using the current and past power. CSOPC has been shown to be more effective, including the ability to converge within a lower iteration number, than the DPC algorithm in [2]. El-Osery *et al.* [5] review various power control methods, including earlier referenced studies, then present a state space equation that applies modern control theory and design the controller using linear quadratic control (LQ). LQ power control has a faster convergence time and higher CDMA channel capacity than CSOPC [5].

In contrast, the current paper proposes fast distributed constrained power control (FDCPC) with a non stationary relaxation factor as the next power update for CDMA cellular power control systems. A review is also presented of unconstrained control algorithms: DPC, USOPC, and DPCSRF. To improve the performance of outage probability convergence, DCPC with a non stationary relaxation factor (FDCPC) is proposed. Under constrained conditions, the convergence rate of FDCPC is shown to outperform that of DCPC and CSOPC.

The following sections provide a review of DPC, USOPC, and DPCSRF as unconstrained control algorithms. The convergence of each algorithm is also analyzed using the characteristics of iterative linear matrices. Next, the case of transmission power constraints is briefly reviewed and fast distributed constrained power control (FDCPC) is proposed. Section 4 presents simulation results for comparison with other power control algorithms and discusses the performance of FDCPC.

2. System Description of DPC and Convergence Analysis

2.1 Distributed Power Control(DPC)

For a CDMA cellular system, it is normally assumed that Q mobiles in a cell share the same channel at a given instance and the received SIR for each mobile in the cell is unaffected by the received signal power from mobiles in other adjacent cells. Here, only the uplink power control case is considered, and it is assumed that the signal of mobile i is received correctly if the SIR at base k is not less than a given target SIR value r^*. In order to make a connection with the minimal transmission power in distributed power control, the SIR for mobile i should satisfy the following SIR constraint (1).

$$s_i = \frac{g_{ki} p_i}{\sum_{j=1, j\neq i}^{Q} g_{kj} p_j + n_i} \geq \gamma^* \quad (1)$$

where,

p_i : transmission power of mobile i

g_{kj} : link gain from mobile j to base k

n_i : receiver noise at base k

s_i : SIR of mobile i

r^* : desired SIR value.

Based on constraint (1), distributed power control applies an iterative method to adjust the power levels of each transmitted signal, using only local measurements. For the ideal situation, it is assumed that constraint (1) is the same as (2).

$$s_i = \frac{g_{ki} p_i}{I_i} = \gamma^*, \quad I_i = \sum_{j=0, j\neq i}^{Q} g_{kj} p_j + n_i \quad (2)$$

Here, the $Q \times Q$ matrix $H = [h_{ij}]$ is defined such that $h_{ij} = \gamma^* g_{kj} / g_{ki}$ for $i \neq j$ and $h_{ij} = 0$ for $i = j$, and the vector $\eta = (\gamma^* n_i / g_{ki})$ has the length Q. Using the predefined matrices, (2) can be converted into a matrix form as follows :

$$AP = \eta \quad (3)$$

where $A = I - H$ and $P = (p_i)$ is the power vector of length Q.

To solve (3), the general iterative method can be considered as follows :

$$P(n+1) = M^{-1} N P(n) + M^{-1} \eta, \quad n = 0, 1, \cdots \quad (4)$$

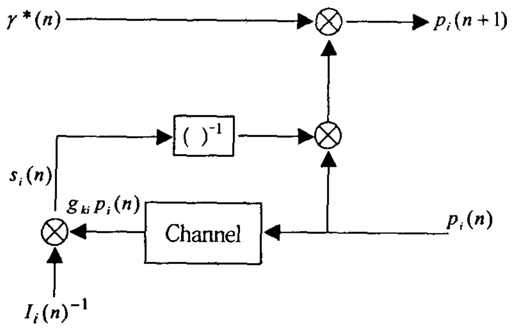
where M and N are matrices of an appropriate size such that $P^* = M^{-1} N P^* + M^{-1} \eta$; vector $P(n) = (p_i(n))$ power level at iteration n. Based on the appropriate selection of M and N, the above iterative method can converge, i.e.,

$$\lim_{n \to \infty} P(n) = P^* \quad (5)$$

When applying (4) to (2), (4) can be written as a set of linear equations that can be iteratively solved for P[3]. Through some manipulations, for each mobile i, (4) becomes

$$p_i(n+1) = \frac{\gamma^*}{s_i(n)} p_i(n), \quad n = 0, 1 \quad (6)$$

where $S_i(n)$ denotes the received SIR of mobile i at iteration n. Thus, as seen above, applying the DPC algorithm enables the next transmission power of mobile i to be iteratively calculated using the current power and received SIR. This is the distributed power control (DPC) algorithm and a control block diagram of DPC is shown in <Figure. 1>.



〈Fig. 1〉 Control block diagram of DPC for mobile i

2.2 DPC with stationary relaxation factor (DPCSRF)

As seen in (6), the DPC algorithm uses the ratio between the desired SIR (r^*) and the measured SIR ($S_i(n)$) to obtain the next optimum transmission power. However, the proposed method computes the next transmission power using the error between r^* and $S_i(n)$. Thus, the power update equation of DPC with a stationary relaxation factor (DPCSRF) can be written as follows :

$$p_i(n+1) = p_i(n) + u_i(n), \quad n = 0,\ 1 \tag{7}$$

The control input $u_i(n)$ of (7) is defined as

$$u_i(n) = k_i e_i(n) \tag{8}$$

where k_i is the state feedback control gain, and $e_i(n)$ can be described as follows :

$$\begin{aligned} e_i(n) &= (\gamma^* - s_i(n)) I_i(n) / g_{ki}(n) \\ &= (\gamma^* - s_i(n)) p_i(n) / s_i(n) \end{aligned} \tag{9}$$

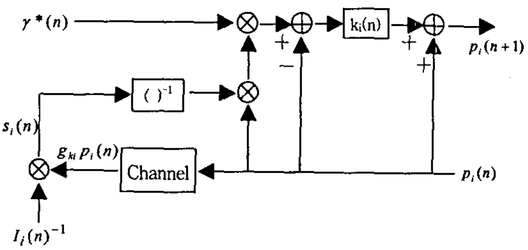
where $s_i(n)$ is the measured SIR. Now, (8) can be rewritten as (10).

$$u_i(n) = k_i \{ \frac{\gamma^*}{s_i(n)} p_i(n) - p_i(n) \} \tag{10}$$

Thus, the calculation of the next transmission power is performed as follows :

$$\begin{aligned} p_i(n+1) &= p_i(n) + k_i \left(\frac{\gamma^*}{s_i(n)} p_i(n) - p_i(n) \right) \\ &= \left(1 - k_i + k_i \frac{\gamma^*}{s_i(n)} \right) p_i(n) \end{aligned} \tag{11}$$

Notice that, if $k_i = 1$ in (11)~(11) is the same as the next power update equation (6) of DPC.



〈Figure. 2〉 Control block diagram of DPC SRF for mobile i

To show the convergence of DPC SRF, the DPC SRF system should be converted the form of a general iterative equation in (11). If we assume $\eta = 0$, (11) can be changed to the form of general iterative equation in (4) as,

$$\begin{aligned} P(n+1) &= (I - kI + kH)\, P(n) \\ &= (kI)((kI)^{-1}(I - kI + kH))\, P(n) \\ &= M^{-1} N P(n) \end{aligned} \tag{12}$$

Here, the matrices M and N for the proposed algorithm are defined as follows :

$$M^{-1} = kI,\ N = (kI)^{-1}(I - kI + kH) \tag{13}$$

where k is the relaxation factor. Hereafter, it is assumed that k_i is the same as an appropriate constant k for all mobiles, $0 \le k \le 2$ in this section. Therefore, the convergence of DPC with a relaxation factor can be verified using the successive overrelaxation iterative method (SOR) as in [4]. Applying (12) to (4), (11) can be rewritten as (14).

$$p_i(n+1) = k \frac{\gamma^*}{s_i(n)} p_i(n) + (1-k) p_i(n) \tag{14}$$

In the distributed power control (DPC), for the case $k=1$, the spectral radius of DPC satisfy $\rho(M^{-1}N)_{k=1}=\alpha\gamma^*<1$. Here, $\alpha=\sqrt{\frac{g_{12}g_{21}}{g_{11}g_{22}}}$. For convergence, the spectral radius for k should be satisfied with the condition $\rho(M^{-1}N)_k<1$. Here, $\rho(M^{-1}N)_k=\max|\lambda_i(M^{-1}N)_k|$ and λ_i is i th eigenvalue of $M^{-1}N$.

Proposition 1 : In the distributed power control (DPC) system, the spectral radius when $k=1$ has the smallest value, $\rho(M^{-1}N)_{k=1}=\alpha\gamma^*<1$ and $\alpha\gamma^*<\rho(M^{-1}N)_{k\neq 1}$ when $M^{-1}=kI$, $N=\frac{1}{k}(I-kI-kH)$ in (4) and $0\le k\le 2$.

Proof : For simplicity, let's find the spectral radius of the DPC system, $\rho(M^{-1}N)$, and assume that it only has two mobiles, as in [4]. The eigenvalues of the iteration matrix, $M^{-1}N$, are

$$\lambda=(1-k)\pm k\alpha\gamma^* \quad (15)$$

(a) When $0\le k\le 1$,

$$|(1-k)-k\alpha\gamma^*|\le|(1-k)+k\alpha\gamma^*| \quad (16)$$

is always satisfied. the right hand side in (16) is the spectral radius when $0\le k\le 1$. The following equation is always satisfied for k.

$$|(1-k)+k\alpha\gamma^*|\ge\alpha\gamma^* \quad (17)$$

Thus $k=1$ is the largest universal relaxation constant in this interval.

(b) When $1\le k\le 2$,

$$|(1-k)-k\alpha\gamma^*|\ge|(1-k)+k\alpha\gamma^*| \quad (18)$$

is always satisfied. the left hand side in (18) is the spectral radius when $1\le k\le 2$. Therefore, it is satisfied with $\rho(M^{-1}N)_k=|(1-k)-k\alpha\gamma^*|$ and the following equation is always satisfied for k.

$$|(1-k)-k\alpha\gamma^*|\ge\alpha\gamma^* \quad (19)$$

Therefore, the spectral radius when $k=1$ has the smallest value, $\alpha\gamma^*<1$ and $\alpha\gamma^*<\rho(M^{-1}N)_{k\neq 1}$ when $0\le k\le 2$. ■

2.3 Unconstrained second order power control(USOPC)

USOPC is based on the same framework as the general iterative method (4), as with DPC, yet it has a second order iterative form given by

$$p_i(n+1)=k_i\frac{\gamma^*}{s_i(n)}p_i(n)+(1-k_i)p_i(n-1),\quad n=1,2,\cdots,l \quad (20)$$

where $p_i(0)$ and $p_i(1)$ are arbitrarily chosen and relaxation factor k_i is a stationary relaxiation factor. Equation (20) determines the next transmission power using both the current power and the past power with the weight $1-k_i$. Thus, if $k_i=1$ is satisfied, (20) can be rewritten as (6).

The convergence analysis of USOPC in [4] is performed using the same method as in proposition 1 and the iterative matrices are

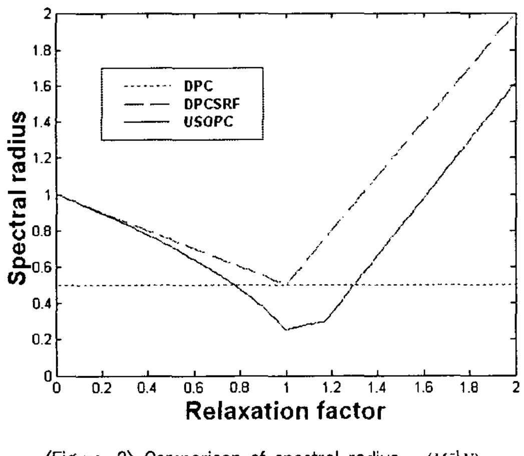
$$M^{-1}=k\left(I-k\begin{bmatrix}0&0\\H&0\end{bmatrix}\right)^{-1} \text{ and } N=\frac{1}{k}\left((1-k)I-k\begin{bmatrix}0&H\\0&0\end{bmatrix}\right).$$

Thus the eigenvalues of USOPC are

$$\lambda=(1-k)+0.5\cdot k\alpha\gamma^*\left\{k\alpha\gamma^*\pm\sqrt{k^2\alpha^2\gamma^{*2}-4(1-k)}\right\} \text{ and}$$
$$\lambda=(1-k)+0.5\cdot k\alpha\gamma^*\left\{k\alpha\gamma^*\pm\sqrt{k^2\alpha^2\gamma^{*2}+4(1-k)}\right\}. \quad (21)$$

Plus, the spectral radius when $k=1$ is $\rho(M^{-1}N)_{k=1}=(\alpha\gamma^*)^2$. When $0\le k\le 2$, theoretical proof of the existence of k satisfying the condition $\rho(M^{-1}N)_k<\rho(M^{-1}N)_{k=1}=(\alpha\gamma^*)^2<1$ is very difficult because of the nonlinearity of the eigenvalues in (21). Thus, a numerical example is used to verify that all the eigenvalues of USOPC in (21) are calculated as a function of the relaxation factor when $\alpha\gamma^*=0.5$.

<Figure. 3> displays the comparison of the spectral radius according to the stationary relaxation factor. The rate of convergence of DPC is defined as a constant value (0.5), and DPCSRF and USOPC vary according to the relaxation factor as the graphs indicate. The graphs show that DPCSRF has the smallest spectral radius when $k=1$, and the value is greater than DPC elsewhere. However, in the case of USOPC, the spectral radius is smaller than DPC near $k=1$. This is due to the fact that the eigenvalue of UOSPC is in the form of a square of k, as shown in (21). Therefore, as mentioned in [4], USOPC has a faster rate of convergence than DPC under unconstrained conditions. However, it is not necessarily applied in an identical manner when there are non-stationary relaxation factor and power constraint.



<Figure. 3> Comparison of spectral radius, $\rho(M^{-1}N)$

2.4 DCPC and CSOPC

DCPC(distributed constrained power control) [3] and CSOPC(constrained second order power control) [4] refer to DPC and USOPC with constraints, respectively. Since the transmission power of a mobile is limited, the following power constraint is considered :

$$0\le p_i\le \bar{p}_i \qquad (22)$$

where $\bar{P}i$ is the maximum allowable transmission power level of each mobile. It has been proven that by simultaneously considering the constraint and non stationary relaxation factor, CSOPC has a faster rate of conversion than conventional DCPC. However, the next section introduces a simpler case of FDCPC which considers the constraint and non stationary relaxation factor, proves its convergence and compares its performance with existing methods.

3. DCPC with non-stationary relaxation factor (FDCPC)

If constraint (22) is considered during a power update, (6) is changed as follows :

$$p_i(n+1)=\min\left\{\bar{p}_i,\frac{\gamma^*}{s_i(n)}p_i(n)\right\},\quad n=0,1 \qquad (23)$$

As such, Eq. (23) represents distributed constrained power control (DCPC), however, its convertgence rate is no longer the fastest algorithm because of constraint (22), as the convergence rate does not depend on the spectral radius any more. Yet, since power constraints are unavoidable in practical application, a method is needed to improve the convergence rate of DCPC.

Here, a non stationary relaxation factor is applied to state the feedback gain $k_i(n)$ in (11), like $\omega_i(n)$ in[4]. The relaxation factor in an iterative method is applied as a non increasing sequence satisfying $1 < k_i(n) \le 2$, $\lim_{n\to\infty} k_i(n) = 1$ and can be described as (24).

$$k_i(n) = 1 + \frac{1}{a^n}, \quad n = 1, 2 \tag{24}$$

where, a is the constant that satisfies $1 < a$. Now, the equation for DCPC with a non-stationary relaxation factor (FDCPC) can be rewritten in a constraint form as follows :

$$p_i(n+1) = \min\left\{\overline{p}_i, p_i(n) + k_i(n)\left(\frac{\gamma^*}{s_i(n)} p_i(n) - p_i(n)\right)\right\} \tag{25}$$

To show the convergence of FDCPC, let's define a vector norm for a given positive definite diagonal matrix W with an appropriate size as follows :

$$\|V\|_\infty^W = \|W \cdot V\|_\infty = \max_i \left|\sum_j \omega_{ij} v_j\right| \tag{26}$$

Lemma 1 : If the system is feasible, there exists a positive definite diagonal matrix W and a number $\hat{k} > 1$ such that $\|(M^{-1}N)_k\|_\infty^W < 1$ for $1 < k < \hat{k}$.

Proof : Let $T_{\hat{k}} = |(M^{-1}N)|$, where $|\ |$ is an element wise absolute value operator. Since $T_{\hat{k}}$ is an irreducible nonnegative matrix, Perron Frobenius Theorem[7] guarantees that there exists a positive vector $E = (c_i)$ such that $T_{\hat{k}} E = \rho(T_{\hat{k}}) E$. Let us choose a matrix $W = diag\{1/c_i\}$. Clearly

$$\|(M^{-1}N)_{\hat{k}}\|_\infty^W \le \|T_{\hat{k}}\|_\infty^W = \rho(T_{\hat{k}}) \tag{27}$$

By [8, Theorem 4 5.9], $\rho(T_{\hat{k}}) < 1$ if $1 < \hat{k} \le 2/(1+\rho(H))$ From the definition of matrix in (26), it is clear that if we decrease the absolute value of any element in the matrix, then the corresponding norm cannot increase and thus $\|(M^{-1}N)_k\|_\infty^W < 1$ for $1 < k < \hat{k}$ must hold. This concludes the proof. ■

Theorem 1: In FDCPC, if the system is feasible, the power vector $p(n)$ converges to P^*.

Proof : As we showed in (12), FDCPC power update equation (25) can be described as a form of general iterative equation like as (28).

$$P(n+1) = (M^{-1}N)_{k(n)} \cdot P(n) + (M^{-1})_{k(n)} \eta \tag{28}$$

Here, $M^{-1} = k(n)I$, $N = (k(n)I)^{-1}(I - k(n)I - k(n)H)$. The feedback gain $k(n)$ in FDCPC is decreasing sequence like as (24), $\lim_{n\to\infty} k(n) = 1$. Let's define a constrained form of (25) as follows:

$$T(P(n)) = \min\left\{\overline{P}, (M^{-1}N)_{k(n)} \cdot P(n) + (M^{-1})_{k(n)} \eta\right\} \tag{29}$$

Then, it is clear $P^* = (M^{-1}N)_{k(n)} \cdot P^* + (M^{-1}N)_{k(n)} \eta$

for any n. Thus, for a given positive definite diagonal matrix W, we have

$$\|T(P(n)) - P^*\|_\infty^W \le \|(M^{-1}N)_{k(n)}(P(n) - P^*)\|_\infty^W \le \|(M^{-1}N)_{k(n)}\|_\infty^W \cdot \|P(n) - P^*\|_\infty^W \tag{30}$$

Repeating the iteration (30), it can be rewritten to (31).

$$\|T(P(n)) - P^*\|_\infty^W \le \prod_{i=0}^{n} \|(M^{-1}N)_{k(i)}\|_\infty^W \|P(0) - P^*\|_\infty^W \tag{31}$$

By Lemma 1, we can choose a positive definite diagonal matrix W and a number $\hat{k} > 1$ such that $\|(M^{-1}N)_{k(n)}\|_\infty^W < 1$ for $1 < k(n) < \hat{k}$. Since $k(n)$ is a decreasing sequence and $\lim_{n\to\infty} k(n) = 1$, it is guaranteed that there exists a number N_1 such that $1 < k(n) < \hat{k}$ for all $N_1 < n$. In this case,

$$\lim_{n\to\infty} \prod_{i=0}^{n} \|(M^{-1}N)_{k(i)}\|_\infty^W = 0 \tag{32}$$

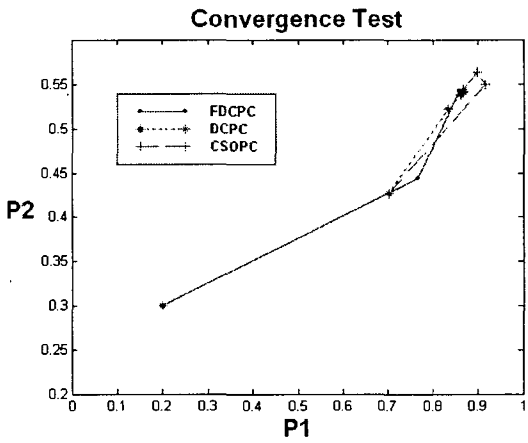
Thus the power vector P converges to P^* in FDCPC. ■

Furthermore, using lemma 2 and theorem 2 in reference [4], it can be proven that FDCPC converges faster than DCPC. The details of the proof procedure are not discussed here.

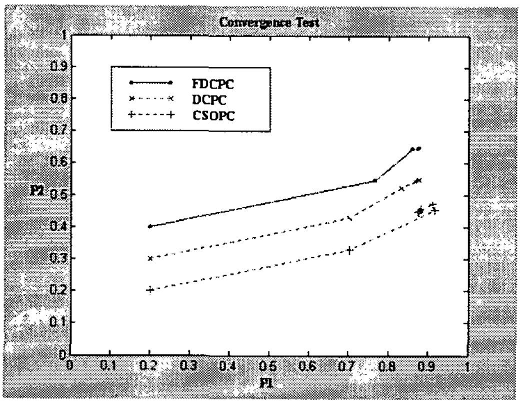
As iteration progresses, the convergence pattern according to the non stationary relaxation factor that converges to 1, manifests itself very differently from CSOPC. In comparison to CSOPC, advantages are displayed in terms of the rate of convergence and outage performance. As it will be explained in chapter 4, examining the result of convergence of SIR reveals that CSOPC converges in the increasing direction from a value less than the desired SIR, whereas FDCPC converges in the decreasing direction from a value greater than the desired SIR, signifying that CSOPC and FDCPC are fundamentally different.

<Figure. 4> shows a convergence test example of FDCPC and CSOPC with a non stationary relaxation factor, and the simulation was performed based on the parameters mentioned in chapter 4.

It displays the results of a simulation test conducted under identical conditions for 5 mobiles simultaneously converging in a single cell. Transmission gain for each mobile was G = 1e 11*[0.0095 0.0152 0.03264 0.00712 0.04538] with the initial transmission power set at $p_1(0) = 0.2$, $p_2(0) = 0.3$, $p_3(0) = 0.02$, $p_4(0) = 0.0075$, $p_5(0) = 0.03$. <Figure. 4> displays the power of mobile 1 and 2 converging to the power level for acquiring the desired SIR according to the number of iteration. Mobiles 3, 4 and 5 display similar results.



〈Figure. 4(a)〉 Convergence test example



⟨Figure. 4(b)⟩ Distinguished line presentation of an example identical to fig.4(a)

Conditions in <Figure. 4> are extracted from the actual simulation described in chapter 4. FDCPC only needs 3 steps to converge, while DCPC needs 4~5 steps and CSOPC needs 5~6 steps due to fluctuation. Thus, the convergence rate of the proposed FDCPC is the fastest in <Figure. 4>. Although the graphs in <Figure. 4(b)> are indicated as 0.1 apart from the p_2 axis because the approach for each step in <Figure. 4(a)> is not displayed properly, it signifies that the start and end points are identical.

4. Simulation

4.1 Simulation environment and parameters

The distributed power control simulation was performed based on the IS-95 system [6], and the environment and parameters were as follows :

- Based on a 7 cell model, the choice of the number of mobiles and allocation of the mobiles in each cell were random. Here the number of mobiles in each cell was determined as 10.
- The generation of path loss was based on available models. Here, it was assumed that the link gain g_{ki} was d^{-4}, where d (meter) was the distance between the mobile station and the base station. Other propagation models [6] were not considered.
- The desired SIR was set at 8dB and the same desired SIR was applied to all mobiles in a cell
- The bit rate, R_b, was 9600 bits per second and the radio channel bandwidth, B_c, was 1.2288 MHz
- Receiver noise, $n_i = n = 10^{-12}$
- The maximum transmission power for each mobile was 1 Watt.

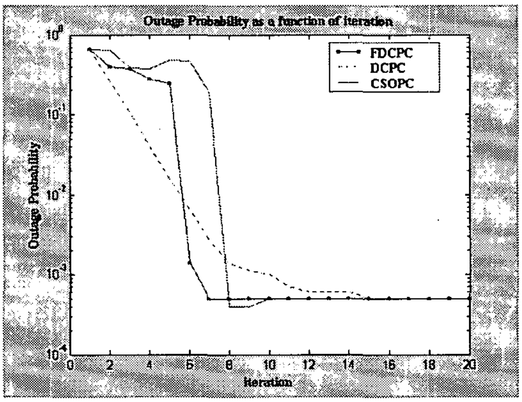
4.2 Results

The distributed power control simulation was performed based on the IS 95 system [6] and a seven cell configuration, plus the initial power of each mobile was selected as a uniformly distributed random number within the interval [0, 1]. DCPC and CSOPC were used as reference algorithms and the outage probability value was accumulated for 10,000 randomly selected instants, as in [4]. The outage probability for each iteration was computed over 10,000 instants based on counting the number of unsupported mobiles for the iteration.

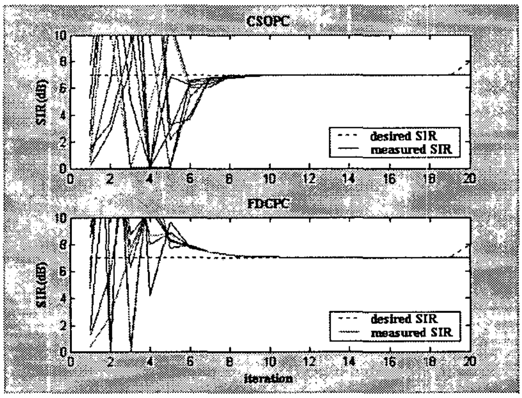
<Figure. 5> shows the simulation results for the outage probability as a function of the

iterations. The outage probability of DCPC took 15 iteration steps until it approached a fixed outage probability (5×10^{-4}), which was slower than the other algorithms. Initially, DCPC converged faster than the other algorithms, yet became slower as it approached a fixed outage probability. CSOPC required 10 iteration steps to converge, which was faster than DCPC. However, the increase in the outage probability from iteration 6 to 7 was caused by the dynamics of second order power control. Finally, FDCPC only needed 7 iteration steps to converge to a fixed outage probability, plus the convergence rate of FDCPC was the fastest. In addition, the problem of the increased outage probability from iteration 6 to 7 with CSOPC was greatly improved with FDCPC.

<Fig. 6> shows the convergence shape of the SIR example to explain the difference in the convergence between CSOPC and FDCPC. The number of mobiles in a cell was set at 10. An increasing type convergence shape was exhibited for CSOPC from under the desired SIR when approaching the desired SIR (from iteration step 6 to 8). As such, since the probability of unsupported mobiles was high even though the SIR of each mobile was converging to the desired SIR, the outage probability of CSOPC near the desired SIR remained high. In contrast, a decreasing type convergence shape was exhibited for FDCPC from over the desired SIR when approaching the desired SIR (from iteration step 5 to 8). As such, since most mobiles satisfied the desired SIR, even though the start rate of convergence was slower than that of CSOPC, the outage probability of FDCPC near the desired SIR abruptly decreased to a very low value. This improvement was possible due to the non-stationary relaxation factor and outage decision method.



⟨Figure. 5⟩ Outage probability as a function of iteration



⟨Figure. 6⟩ Convergence shape of SIR

5. Conclusion

The current study presented fast distributed constrained power control (FDCPC) with a non stationary relaxation factor as the next power update for CDMA cellular power control systems. Under unconstrained conditions, a convergence analysis showed theoretically that the convergence rate of DPC was the fastest. Yet, consideration of constrained control algorithms showed that the DCPC was no longer the fastest due to transmission power constraints. And outage probability performance of CSOPC is also better than DCPC. Thus to improve the performance of outage probability and SIR convergence rate, DCPC with a non-stationary relaxation factor (FDCPC) was proposed. Under constrained conditions, simulation results demonstrated that FDCPC converged the fastest as an aspect of outage probability, which was made possible by the non stationary relaxation factor and outage decision method. As a future work, considering various initial conditions (mobile position, number of mobiles, transmission power), we will evaluate the SIR convergence rate with performance index like as mean square error.

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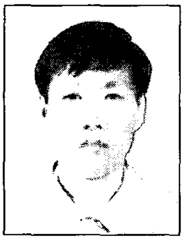

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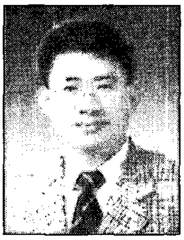

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