Power Control in CDMA Using MOTDPC Algorithm

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Abstract—***In wireless communication systems with multiple users, the near–far effect and the co-channel interferences decrease the spectral efficiency and system performance. An efficient known method to combat these destructive effects is to properly adjust the transmit powers. A practical and efficient way for power control (PC) in cellular communication systems is the distributive power control (DPC). The aim of power control is to assign each user such transmitter power level that all users satisfy their QOS (Quality of Service) requirements by mitigating near –far effect and co-channel interference.The distributed power control algorithms has been studied and evaluated in this work. These algorithms include Distributed Power control algorithm (DPC), Fully Distributed Power Control algorithm (FDPC), Distributed Constrained Power Control algorithm (DCPC), Constrained Second Order Power Control algorithm (CSOPC), Fixed Step Distributed Power Control algorithm (FSDPC), and Multi Objective Totally Distributed Power Control Algorithm (MOTDPC). The performance of the algorithms will be observed based on the rate of convergence to the target signal-to-interference ratio, the rate of convergence of the power, and the rate of convergence of utilities. Multi Objective Totally Distributed Power Control Algorithm (MOTDPC) has been proposed as an enhancement to one of the studied algorithms based on the concept of distributed Power control algorithm. It can be observed that MOTDPC has better convergence properties than FDPC algorithm*.**

Keywords— **DPC, FDPC, DCPC, CSOPC, FSDPC, MOTDPC**

I. INTRODUCTION

In mobile communication system the Code Division Multiple Access (CDMA) plays vital role with other present techniques such as Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA). The main features of CDMA system for mobile communication applications are the widespread one-cell frequency reuse, intrinsic multipath diversity, and soft capacity limit. To efficiently apply the advantage of CDMA, it is necessary to understand effect of power control on the near-far problem, slow shadow fading and multipath fading [1]-[4]. In Frequency Division Multiple Access strategies, the focus is on the frequency dimension. Here, the total bandwidth (B) is divided into N narrowband frequency slices. So several users are allowed to communicate simultaneously by assigning the narrowband frequency slices to the users, where the Narrowband frequencies are assigned to a designated user at all time. Since the total bandwidth (B) is subdivided into N frequency slices or channels, only N users may be supported simultaneously. In TDMA all users use the whole bandwidth but in different time slots.

The CDMA is based on spread spectrum technology which makes the optimal use of available bandwidth. It allows each user to transmit over the entire frequency spectrum all the time. On the other hand GSM operates on the wedge spectrum called a carrier. This carrier is divided into a number of time slots and each user is assigned a different time slot so that until the ongoing call is finished, no other subscriber can have access to this. GSM uses both Time Division Multiple Access and Frequency Division Multiple Access for user and cell separation. More security is provided in CDMAtechnology as a unique code is provided to every user and all the conversation between two users are encoded ensuring a greater level of security for CDMA users.

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II. SYSTEM STRUCTURE

Designing a perfect radio channel in mobile communications would be practically an impossible task since the channel is stochastic in nature as the mobile terminals keep moving almost all the time with different speeds and the channel fades are unpredictable. The signals in a radio channel undergo different propagation effects like reflection, refraction, scattering and shadowing. A smooth surface reflects the signals. But, when the signals encounter sharp edges of buildings, they are refracted, while a rough surface scatters them. When these signals are obstructed by big buildings, they pass through them causing the shadowing effect. All these effects cause the channel to be lognormal, Rayleigh and Rician distributed [5]. Fig.1 shows how the signals travel in different paths from transmitter to receiver. So, the receiver receives multiple copies of the same signal with variation in time and phase.

These signals are either added constructively or destructively depending on the phase of the signals. The signals in the radio channel also undergo a path loss which depends on the distance between the transmitter and the receiver. The fading of signals is categorized as fast or multi-path fading and slow or shadow fading. The fast fading of signals is due to the rapid change of the signal amplitude and phase due to the multi-path arrival of the signal. Similarly, the slow fading of the signals is due to the shadowing effects caused by the buildings, mountains, hoardings etc.

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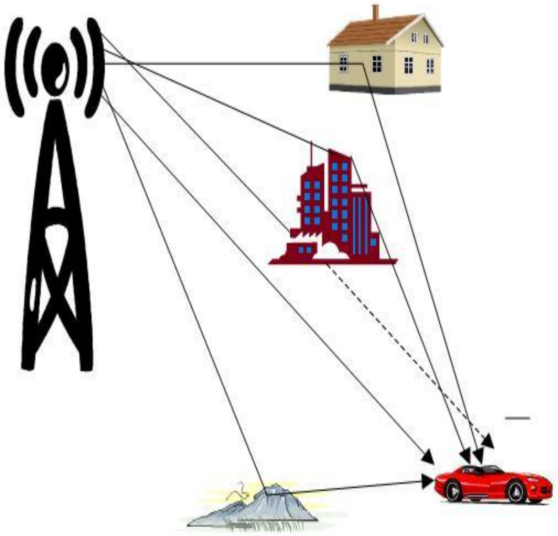

Fig.1 Multipath Propagation

III. POWER CONTROL

Power control is essential in mobile communication systems, because it can relieve the near-far problem, increase the channel capacity, improve the quality of service, decrease the biological effects of the microwaves radiation, and increase the battery life of the mobile phone. Also the future communication networks, such as the Ad hoc networks, need fast and efficient power control algorithms. The objective of the power control algorithm is to keep the transmitted power at the minimum power required to achieve the target QOS. Solving the power control problem in noisy environment, leads to a system of linear equations, the solution of which is the optimum transmitted power vector. This is called centralized power control. Centralized power control is not practical in many situations. Many algorithms exist to solve distributed power control problem, [6]-[11].

There are some techniques involved in determining the power levels. They are: Inner Loop Power Control and Outer Loop Power Control. Inner Loop Power Control is further classified into: Open Loop Power Control and Closed Loop Power Control. Open Loop Power Control is generally used in combating the Near-Far and shadowing problems. As the name itself indicates, this power control does not have feedback mechanism as the mobile itself dynamically adjusts its transmitting power. The mobile tries to estimate the signal strength on the forward pilot channel (Base to Mobile) and decides its transmitting power. If the mobile senses a large power then, the mobiles assumes that the base station is near and reduces its power level and vice versa.

Closed Loop Power Control is used in combating the fast fading effects, generally caused by multi-path fading. This mechanism is also termed as fast power control as it deals with the fast fading.

Since the forward and reverse links are considered to be highly uncorrelated, the feedback mechanism is employed in this power control. The base station estimates the signal from the mobile in the reverse channel (Mobile to Base) and compares that signal-estimate with a predetermined signal level and sends the appropriate power control command to the mobile station.

IV. POWER CONTROL ALGORITHMS

Power control algorithms use only local information for the power updating and SIR balancing. There are different types of distributed power control algorithms suited fulfilling different QOS requirements. These algorithms are iterative and, generally, each algorithm converges to the desired value after certain number of iterations. The iterations taken to converge to the desired value depend on the responsiveness of the algorithm. The system for which algorithms are considered may be CDMA,FDMA, or TDMA. This paper focuses on CDMA. Some of the power control algorithms are considered.

1) *Fully Distributed Power Control (FDPC) algorithm.*
2) *Multi Objective Totally Distributed Power Control(MOTDPC) Algorithm*

In the following sections each of the above algorithms is explained in details with all necessary properties and parameters.

1) *Fully Distributed Power Control (FDPC) algorithm*

The Power updating formulae for FDPC algorithm [12]-[15] is given by

$$p_j(k+1) = \frac{\min\{\beta,\gamma_j(k)\}}{\gamma_j(k)}, P_j(k) \qquad (1)$$

The properties of this algorithm are as follows:

a. $p_j(k+1) \le P_j(k)$ for all j and k.

b. If $\gamma_j(k) \le \beta$, then $\gamma_j(k+1) \ge \gamma_j(k)$.

c. If $\gamma_j(k) \ge \beta$, then $\gamma_j(k+1) \ge \beta$.

Property 1 states that the transmitting power sequence from each mobile station is monotonically decreasing. Properties 2 and 3 suggest that the best choice for β is the equality$\beta = \gamma^T$, therefore this algorithm does not need the normalizing procedure. So, the FDPC algorithm can be rewritten as follows:

$$p_j(k+1) = \frac{\min\{\gamma^T,\gamma_j(k)\}}{\gamma_j(k)}, P_j(k) (2)$$

Where "T" is target.

The main drawback with this algorithm is that as *k* tends to infinity, the power *p* tends to 0; that is the power levels of all the mobiles tend to zero, which is undesired for any power control algorithm.

2) *Multi Objective Totally Distributed Power Control(MOTDPC) Algorithm*

In real systems, the SIR is estimated at the base-station, and then it is compared with the target SIR. The difference is quantized (by one or two bits) and sent back to the mobile station to increase or decrease its transmitted power. If the estimated SIR is less than the target SIR, the base station asks the mobile station to step-up its transmitted power. If the estimated SIR is larger than the target SIR, the base station asks the mobile station to step down its transmitted power. The MOTDPC algorithm is described as

$$P_j(k+1) = \begin{cases} \beta P_j(k), & if \gamma_j < \gamma^T \\ \beta^{-1} P_j(k), & if \gamma_j > \gamma^T (3) \end{cases}$$

Where β>1

$$p_j(k) = \frac{\lambda 1 p_{min} + \lambda 2 \gamma_j^T}{\lambda 1 p_j(k-1) + \lambda 2[\gamma_j^T - \gamma_j(k-1)]} p_j(k-1) (4)$$

β is an adaptation factor, γ_j^T is the target SIR, P_{min} is the minimum transmitted power of each mobile station, and power vector **P**(t)=[P1(k),…PN(k)]. The main idea is to keep the transmitted power P_j (k) close to P min and at the same time to keep the SIR $\gamma_j(k)$ as close as possible to the target SIR, γ_j^T. The values of parameters λ1 and λ2 may be selected to tradeoff between the two objectives.

To modify the algorithm, the output of the quantizer can be assumed as

$$q_j(k) = \frac{d_j(k)}{\Delta_j(k)} = \pm 1` \qquad (5)$$

Where $$d(k) = \gamma_j^T - \gamma_j(k) \tag{6}$$

Therefore $$\gamma_j(k) = \gamma_j^T - q_j(k)\Delta_j(k) \tag{7}$$

By substituting the result of (7) into (4) we obtain

$$p_j(k) = \frac{\lambda 1 p_{min} + \lambda 2 \gamma_j^T}{\lambda 1 p_j(k-1) + \lambda 2[\gamma_j^T - \Delta_j(k-1) q_j(k-1)]} p_j(k-1) \tag{8}$$

Equation (7) is a function of the binary feedback q and the normalization factor Δ . From (5) we can say that Δ(k) $\gamma_j^T - \gamma_j(k)$. Since we do not know the value of $\gamma_j(k)$ we should estimate the value of Δ(k). The previous values of q(k) could be used to estimate the value of Δ(k). In the simulation we have used single value for the factor $\Delta = \frac{\gamma_j^T}{3}$

V. RESULTS AND DISCUSSIONS

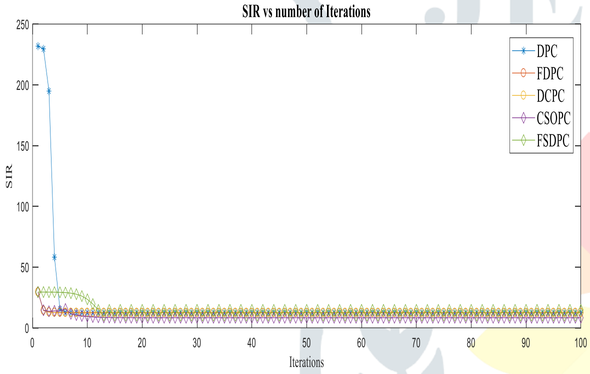

Fig 2Rate of convergence to the target SIR (100 iterations)

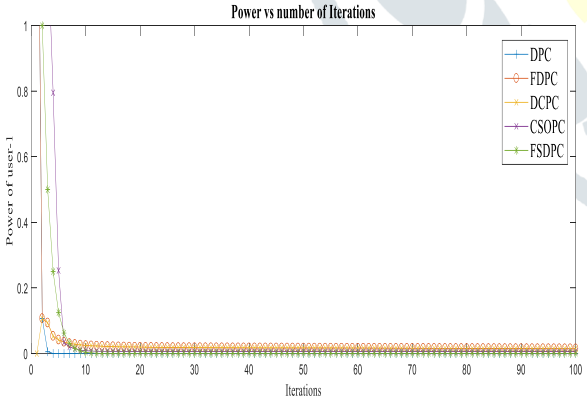

Fig.3Rate of convergence of power (100 iterations)

For brevity, the results for only user-1 are shown, i.e. the user closest to the base station, but results for all other users can be obtained similarly.

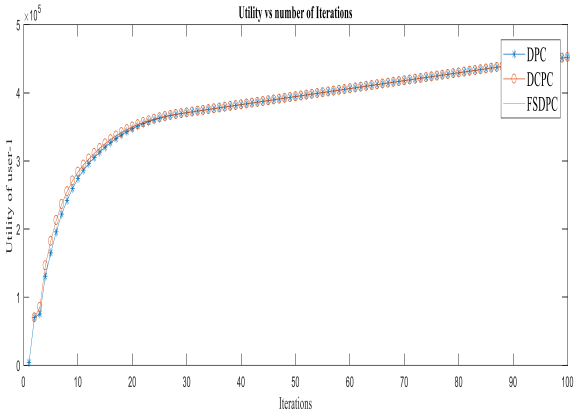

Fig.4 Rate of Convergence of Utilities (100 Iterations)

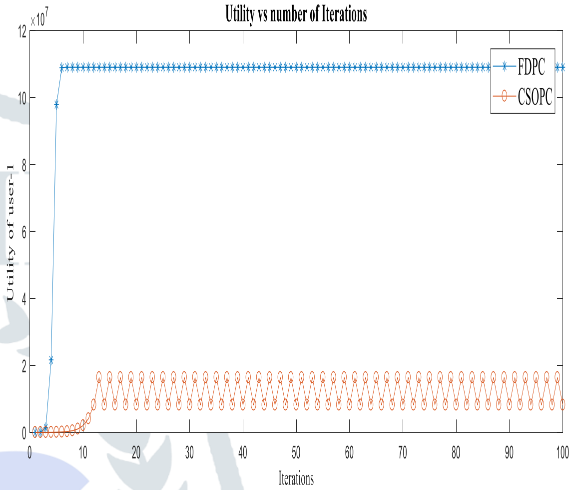

Fig.5Rate of Convergence of Utilities for FDPC and CSOPC (100 Iterations)

The rate of convergence (as the number of steps or iterations) of all algorithms to the target SIR for user-1 is shown in Fig.2 for the first 100 of iterations.

Figs.2 show that the FDPC algorithm has faster convergence to target SIR than the others algorithms, which increases the overall efficiency of the system while the FSDPC algorithm has the slowest convergence, which decreases the overall efficiency of the system. The rate of convergence (as the number of steps or iterations) of the power for user-1 is shown in Fig.3 for the first 100 iterations.

Fig.3 shows that the FDPC algorithm has faster power convergence than the others, while the DPC algorithm has the slowest convergence. It can be concluded that the FDPC algorithm will conserve the battery life time more than the other algorithms.The rate of convergence (as the number of steps or iterations) of the utilities for user-1 is shown in Fig.4 and Fig.5 for the first 100 iterations for all the power control algorithms.

Fig.4 & Fig.5shows that the FDPC algorithm has faster utility convergence than the others, while the DPC algorithm has the slowest convergence.

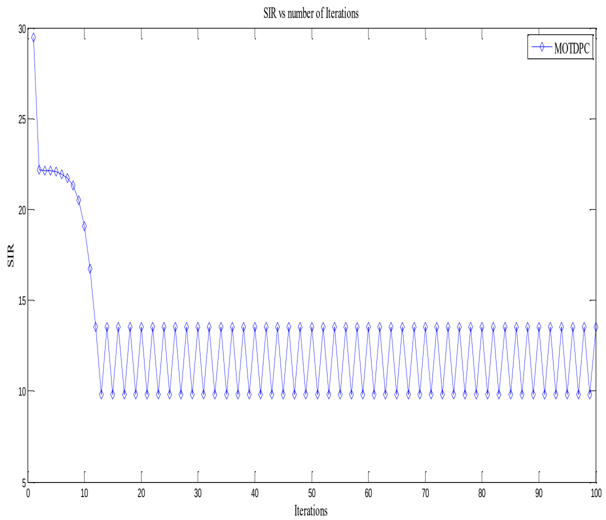

Fig .6 Rate of Convergence to target SIR for MOTDPC

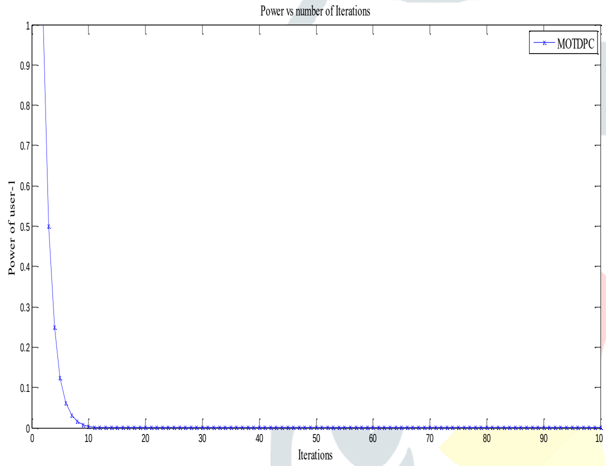

Fig .7 Rate of Convergence to target POWER for MOTDPC

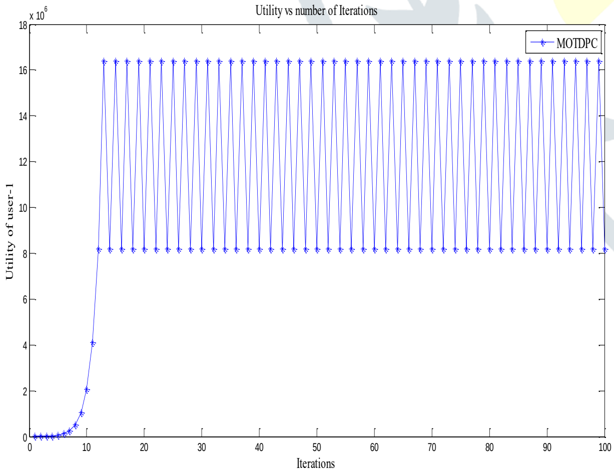

Fig .8 Rate of Convergence to target UTILITY for MOTDPC

Fig.6 to Fig.8 shows the simulated results for the proposed algorithm. It can be observed that MOTDPC converges faster than the existing techniques.

Comparative analysis of the proposed technique with the existing:

Table.1 Rate of Convergence to target SIR (12.42 DB)

S. No	Technique	No. of iterations
1	DPC	13
2	FDPC	15
3	DCPC	18
4	CSOPC	20
5	FSDPC	12
6	**MOTDPC**	**11**

Table.2 Rate of Convergence of Power

S. No	Technique	No. of iterations
1	DPC	10
2	FDPC	10
3	DCPC	15
4	CSOPC	20
5	FSDPC	20
6	**MOTDPC**	**8**

Table.3 Rate of Convergence of Utility

S. No	Technique	No. of iterations
1	DPC	25
2	FDPC	9
3	DCPC	25
4	CSOPC	12
5	FSDPC	25
6	**MOTDPC**	**8**

Table.1 gives the Rate of Convergence of various techniques to the target SIR in accordance with the number of iterations. It can be observed that MOTDPC converge at very less number of iterations.

Table.1-3 shows the comparative analysis of the proposed technique with the existing techniques in terms of Target SIR, power and Utility. It can be observed that MOTDPC has better convergence rate as it converges to the target value at very less number of iterations.

VI. CONCLUSION

Algorithms of distributed power control have been studied and proposed including DPC, FDPC, DCPC, CSOPC, FSDPC, and MOTDPC. The simulation results shows that the MOTDPC algorithm is the best one considering convergence to the target SIR, Power, Utility.

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