Call admission with joint power control and beamforming for increased system capacity in mobile cellular systems

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Abstract: Call admission control (CAC) plays a vital role to ensure the desired quality of service (QoS) and is used widely in mobile networks within joint control protocols [1-5]. A previous study [1] has proposed an efficient interactive CAC called "CICAC" based on distributed constrained power control (DCPC). In this work, we present a new interactive CAC algorithm, which is based on joint DCPC and beamforming (BF). Simulation results show that considerable improvements can be obtained compared with the previous studies.

1. Introduction

Efficient resource utilization is essential for future cellular networks. To support high QoS and appropriate control of the radio spectrum, in the future systems radio resource management will become more and more important. Power control (PC) and antenna arrays (AA) are two practical approaches to achieve such objectives to obtain the maximum system capacity [2-4]. However, many existing algorithms do not work very well without a CAC mechanism when an infeasible call is admitted. CAC, which directly control the number of users in a system, plays a very important role in cellular systems [5]. This scheme can support both grade of service (GoS), i.e. the blocking rates, QoS and the loss probability in the network. In previous studies [1], [5], [6], iteration power control based call admission algorithms have been proposed. All these algorithms are built on the distributed constrained power control (DCPC) scheme, and make the final accept/reject decision according to a CIR target which is successively compared after a number of power updating iterations. However, the results show that these algorithms need many admission iterations due to their slow convergence.

In this paper, we present a new CAC algorithm with built in joint DCPC and BF employing an appropriate AA. We considering CAC algorithm from the point of view of two perspectives: (i) Setting an effective CAC threshold to obtain the capacity and observe the power consumption, for the whole system, (ii) Comparing the proposed algorithm with other existing algorithms in admission control and probability of type II error in the network. Overall, we consider two types of errors which combine both GoS and QoS. Type I error, where a new mobile is erroneously accepted and results in an outage; type II error, where a new mobile is erroneously rejected and causes blocking.

The paper is organized as follows: Section 2 describes joint DCPC and BF in mobile networks. Section 3 presents the new CAC algorithm and discusses its operational details and finally Section 4 presents numerical results.

2. The joint DCPC and BF in mobile system

The system model studied in [4] is also adopted for our admission control algorithm in our studies presented in this paper. We consider a set of K transmitter-receiver with M antenna elements in the receivers. The channel here is slow fading. The link gain between transmitter i and receiver j denotes the received power from transmitter i to receiver j. We consider two kinds of AA in our work, a square AA with four elements and a circular AA with six elements [7].

Using an antenna array, we can get the target CIR:

$$\Gamma_i = \frac{G_{ii} P_i}{\sum_{j \neq i} G_{ij} G_{ai} (\hat{\mathbf{w}}_i, \mathbf{a}_{ji}) P_j + N_i \hat{\mathbf{w}}_i^H \hat{\mathbf{w}}_i} \tag{1}$$

Where $G_{ai}(\mathbf{w}_i, \mathbf{a}_{ji}) = \left|\mathbf{w}_i^H \mathbf{a}_{ji}\right|^2$, represent the multiplication of the antenna gain. The optimization problem of joint DCPC and BF can be defined as:

$$\min_{\mathbf{W},\mathbf{p}} \sum_{j=1}^{N} p_j \qquad \text{subject to} \quad \Gamma_i \geq \gamma_\circ, \quad i = 1,2,\ldots,N \tag{2}$$

Like DCPC, we also can get the following joint PC and AA iteration algorithm (JPCAA) [5]:

$$P_i^{n+1} = \frac{\sum_{j\neq i} G_{ij} G_{ai}(\hat{\mathbf{w}}_i, \mathbf{a}_{ji}) P_j^n + \gamma_i N_i \hat{\mathbf{w}}_i^H \hat{\mathbf{w}}_i}{G_{ii}} \qquad \text{Where } i = 1, 2, \ldots, \text{K} \tag{3}$$

In this algorithm, we assume the transmitted power of mobile j is limited by a maximum power level, that is: $P_{\mathrm{j}} \leq \mathrm{P_j^{max}}$ *f*or $1 \leq \mathrm{j} \leq \mathrm{K}$.

3. The joint interactive call admission control scheme (JICAC)

Our call admission control algorithm is built on the joint DCPC and BF scheme, as presented in section 2. The JICAC algorithm consists of the following steps:

Step (0) *(Initializing the Admission Phase)*
We assume there are K mobiles in a system when a new mobile 0 is initiated it is restricted by artificial limit $\overline{P}_0 \leq \mathrm{P_0^{max}}$ to protect ongoing calls. We set iteration time l=0 and compute,

$$\beta = \min\{\frac{P_i^{\max}}{P_i}, 1 \leq i \leq K\} \tag{4}$$

$$\overline{P_0} = \min\{P_0^{\max}, \min_{1 \leq i \leq K} \frac{\Delta i}{G_{ai}}\} \tag{5}$$

where

$$\Delta i = \beta(\frac{\Gamma_i}{\gamma_i} - 1) I_i + (\beta - 1)\eta_i \tag{6}$$

(η_i is received noise and I_i is total interference). Then set

$$P_0^l = \overline{P_0} \tag{7}$$

$$P_i^l = \beta P_i \, (1 \leq i \leq K). \tag{8}$$

Step (1) *(Testing the Initial Condition)*
If β=1, it means at least one mobile is already transmitting at its maximum, and the system will not admit any new mobiles. Reject mobile 0 and perform JPCAA (3) only for on-going mobiles.

Step (2) *(Making an admission Decision)*
Using the same scheme in [1], we can prove that during the admission phase, each of the active transmitters keeps its transmission quality, i.e. for all i {1,2,…..,K}, $\Gamma_i^l \geq \gamma_i$, for l =0,1,2,….

This leads to three kinds of decisions:
a) Accept: if $\Gamma_0^l \geq \gamma_0$, then accept mobile 0, continue JPCAA schemes.
b) Reject: if $\Gamma_0^l \leq \gamma_0$, then reject mobile 0.
c) Not-determined: for other cases, the mobiles need to go to step (3) for further check.

Step (3) (*Updating Transmitter Powers in the Admission Phase)*
Each power is updated with JPCAA rule in (4) for all mobiles {0, 1,…, K}. Set $P_0^{\max} = \overline{P_0}$, go back to step (2) for further testing with setting at "$l = l + 1$"

Comparing with the scheme developed in [4], we observe that JPCAA needs less iteration than DCPC scheme. So in our JICAC schemes, we can accelerate the admission process much faster than CICAC.

4. Results

In this work, we use the same network model employed in the previous work in [4], [7], which consist of 36 base stations distributed in a square grid in the area [0.5-6.5]*[0.5-6.5], where 400 users are randomly distributed in the area. The link gain here is modeled as: $G_{ij} = 1/d^{-\sigma}$, where d represents the distance between K^{th} base station and i^{th} mobile, and σ is a constant that models large-scale propagation loss. This is set to 4 to represent urban propagation. We assume that the target SINR=0.0304 which is equivalent to -14dB, which provides $E_b / N_0 \cong 6dB$ for a CDMA system with processing gain of 128. This target SINR results in acceptable bit error rate only in CDMA systems. However, the same methodology can be applied to TDMA and FDMA.

We firstly set CIR target = -14dB compare such three algorithms:
a) Power control with omni-directional antennas.
b) Joint DCPC with square AA.
c) Joint DCPC with circular AA.

Fig. (1) shows sum of mobile powers *vs* iterations for these algorithms, it is clear that the joint PC with circular AA algorithm requires the minimum power and less iterations for convergence, while PC with omni-directional AA need maximum power and more iterations for converge.

Fig. (2) shows the sum of powers *vs* the capacity of the system. The system capacity is 700 users if just DCPC algorithm is used; Capacity is increased to 2580 users if using square AA is employed. We get the maximum capacity of 2800 users with circular AA.

Next we compare the JICAC with previous algorithms for admission speed and probability of type II error (All the proposed algorithms are type I error free here). We execute 100,000 instances for the total number of simulation. We set $P_i^{\max}$ =1W, and noise=10^{-15} W. When $(|P_i^{l+1} - P_i^l| / P_i^l) < 10^{-8}$ for every i, we stop updating the powers. After calculating $P_i^{\max} / P_i$ and the accept/reject rate, we compare square AA based JICAC (JICAC-SAA),circular AA based JICAC (JICAC-CAA), CICAC and CICAC-AI30, plotting admission speed and probability of type II error as shown in Fig. (3) and Fig. (4).

Fig. (3) shows the admission speed of all the four algorithms. It is obviously that JICAC-SAA and JICAC-CAA needs less admission than conventional CICAC. Though CICAC-AI30 needs smaller number of iterations in Fig. (3), it has higher probability of type II error as shown in Fig. (4). It is clear that CICAC, JICAC-SAA and JICAC-CAA yield much improved result in probability of type II error, whereas, JICAC-CAA has the lowest probability of type II error amongst all the algorithms.

5. Conclusion

In this paper, we present a new interactive admission control (JICAC) scheme which is based on joint PC and BF protocols. We studied the proposed scheme using two kinds of AA. Comparison with the previous work in [4] shows that a significant improvement in system capacity using square AA and circular AA are obtained. Also a much faster admission speed and low probability of type II error are possible with the proposed scheme compared with the previous alternatives [1-5].

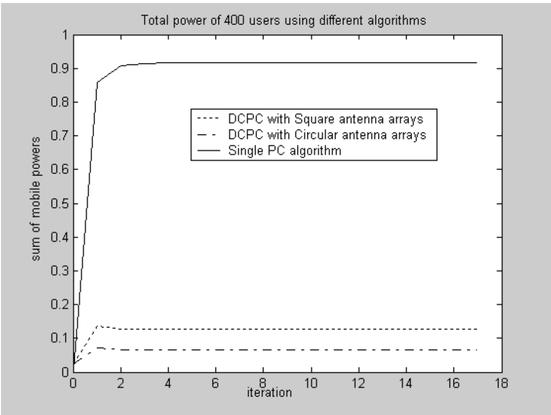

Fig. (1) Total mobile powers versus the iteration number

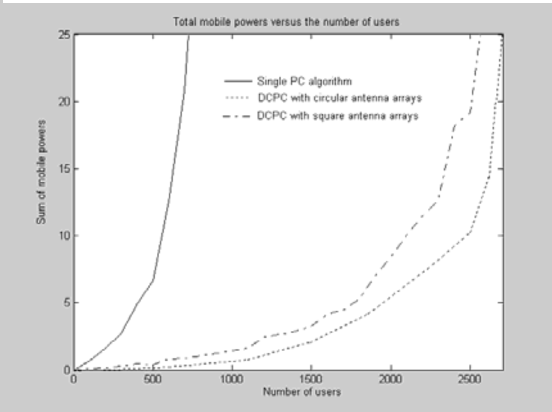

Fig. (2) Total mobile powers versus the number of users

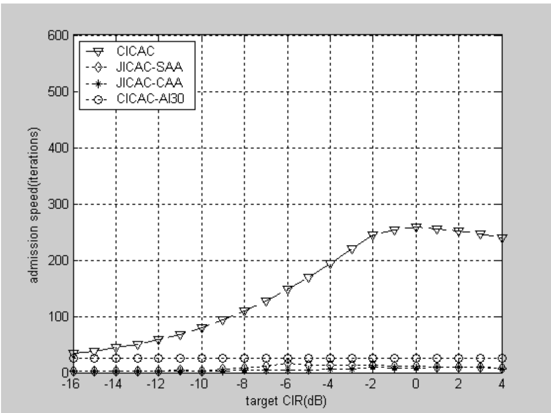

Fig. (3) Comparison of the admission speed between different schemes

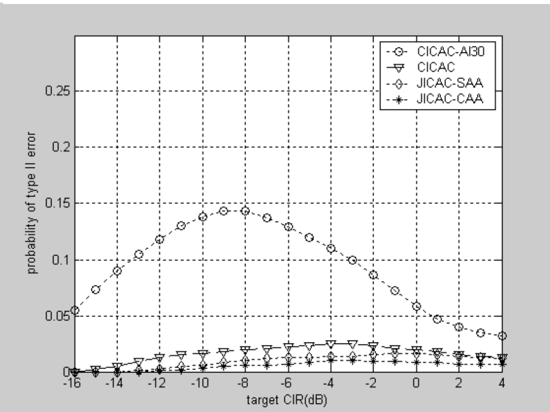

Fig. (4) Comparison of the probability of type II error between different schemes

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