Distributed Admission Control for Power-Constrained Cellular Wireless Systems

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***Abstract*— In the literature distributed call admission control (CAC) schemes exist in which, an infeasible call is rejected early and incurs only a small disturbance to existing calls, while a feasible call is admitted and the system converges to the Pareto optimal power assignment. However, these schemes exist only for unconstrained systems (systems that have no constraint on maximum transmitted power level). In practical systems, a power constraint exists in both uplink and downlink. In this paper we propose a method by which an incoming call whose inclusion in the system can force one of the existing calls to violate the maximum power constraint, is rejected. This method can be used at call admission stage in practical systems which are power constrained. Simulation results have been provided.**

I. INTRODUCTION

Call admission control (CAC) is classically based on signal to interference plus noise ratio (SINR) estimates [1],[2] and threshold comparisons [3]. SINR-based CAC schemes [1],[2] can lead to outage i.e. dropping of an existing call and in a recent work [4], lower bound of SINR threshold ($SINR_{th\_lb}$) has been determined that keeps outage probability below a maximum value. Receiver-power-based call admission control (RPCAC) scheme in [3] is based on threshold comparisons, but it is a heuristic and is not optimal [5]. A scheme is said to be optimal if it never admits any infeasible user and at the same time no other scheme can admit more calls in the system [5]. Transmitter-power-based call admission control (TPCAC) scheme proposed in [3] is for a constrained system and is also optimal, but it is not distributed. Distributed power control with active link protection (DPC-ALP) proposed in [6], is not optimal [5],[7] and it resolves the constrained case by transmitting a distress signal and so it is not distributed as well. Two schemes noninteractive admission control (N-IAC) and interactive admission control (IAC) have been proposed in [7] for constrained systems. Although noninteractive scheme is distributed but it is based on threshold comparisons and is not optimal. The interactive scheme is optimal but it is not distributed.

In cellular wireless communication systems, transmitted power is regulated to provide each user an acceptable connection by limiting the interference caused by the other users and a user can obtain feedback information by monitoring the interference induced on its receiver by the other users. This feedback turns out to be sufficient for making admission decisions in optimal distributed manner in [5]. However, the schemes given in [5], fail for constrained systems.

In this paper, we propose two optimal distributed CAC schemes for constrained systems, by introducing a method by which an incoming call is rejected if its inclusion in the system can force any of the existing calls to hit the power constraint.

II. SYSTEM MODEL

We denote the downlink transmitted power of the i^{th} base station communicating with the i^{th} terminal by P_i. The gain on the radio link from base station of user j to user i is denoted by G_{ij}. Let η_i denote the receiver noise at the i^{th} terminal and γ_i be the desired SIR threshold of the i^{th} terminal. Then to maintain the downlink connection for the i^{th} terminal we require that

$$SIR_i = \frac{G_{ii}p_i}{\sum_{j\neq i} G_{ij}p_j + \eta_i} \geq \gamma_i \qquad (1)$$

We consider that the transmitted powers are regulated by the well-known distributed power control algorithm given in [10].

$$P_i(k+1) = \frac{\gamma_i}{SIR_i(k)} P_i(k), \qquad (2)$$

where $P_i(k)$ and $SIR_i(k)$ denote the power and SIR respectively for user i at the k^{th} iteration. It has been shown in [11],[12] that if a pareto optimal solution exists the algorithm converges to it. However, without an effective CAC algorithm, this algorithm diverges.

We assume that n users are in service and a new $(n+1)^{th}$ user is trying to get admission into the system. It has been proved in [5] that $(n+1)^{th}$ user is admissible if and only if $\Delta_{n+1} = 1 - F^T_{n+1,.}(I_n - F_n)^{-1}F_{.,n+1} > 0$. Further in [5], two CAC schemes have been proposed to measure Δ_{n+1} in a distributive manner and hence, to take the admissibility decision. The basic idea is that the $(n+1)^{th}$ user measures the total interference power received by it when it arrives into the network and its base station starts transmitting to it a fixed power level. The downlinks of the existing calls increase their power according to (2), in order to overcome the interference produced by the new user. In Δ-CAC scheme [5],

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when the power control algorithm converges, $(n+1)^{th}$ user again measures interference received on it and then decides (by computing Δ_{n+1} in a distributive manner) that if the system will become infeasible after its admission. But Δ-CAC scheme takes a large time in making the decision of admitting a call and to overcome this R-CAC scheme has been given in [5]. R-CAC scheme is based on the condition that the power control algorithm should be monotonic and optimal [5]. In R-CAC scheme $(n+1)^{th}$ user measures its received interference after every iteration and if the interference reaches certain value then the call is rejected. So in R-CAC scheme, there is no need to wait for the convergence of power control algorithm for making the admission decision and hence it works faster than Δ-CAC scheme.

For constrained systems even when $\Delta_{n+1} > 0$, the optimal unconstrained power assignment may have some user exceeding its corresponding power constraint and hence, CAC schemes given in [5] fail in the constrained case. In the next section, we propose a method to let the incoming call know that whether, any existing call can hit the power constraint due to its inclusion in the system.

III. OPTIMALLY DISTRIBUTED CAC SCHEMES FOR POWER CONSTRAINED SYSTEMS

We propose a method such that, whenever an existing call hits the power constraint it decreases its transmit power level and the incoming call obtains this information by monitoring the interference received on it and hence, the incoming call determines distributively that whether an existing call can hit the power constraint due to its inclusion in the system. The equation for the interference received at the incoming call m_{n+1} is

$$R_{n+1} = [G_{n+1,1}, G_{n+1,2}, ..., G_{n+1,n}][p_1, p_2, ..., p_n]^T \quad (3)$$

If any call hits the constraint it decreases its power by some percent (let's say c) of the power constraint. As in [3], [5] and [8] effects from fading in the performance of the system has not been taken into account. Now, if the rest of the existing users (those who have not hit the constraint) keep their power fix, the new interference received at the incoming call (assuming that i^{th} existing call has hit the constraint) will be

$$R_{n+1} = [G_{n+1,1}, G_{n+1,2}, ..., G_{n+1,n}][p_1, p_2, .., p_i - cp_i, ., p_n]^T \quad (4)$$

The incoming call by measuring the sudden decrease in received interference can know distributively, that if any existing call has hit the power constraint. The point to be noted is that even if more than one call hit the constraint at the same time then they all decrease their power by the fix amount because the incoming call has to be rejected in case of more than one existing calls hitting the constraint at the same time.

The proportion in which powers are decreased (as taken to be c percent above) should be decided according to the standard in which we are implementing the algorithm, keeping in mind that the decrease in power should be large enough so that the change in the interference due to it becomes visible and at the same time it should not be very large, as it will degrade the QoS of the existing call. Now, by using our method we propose two schemes namely, Scheme A and Scheme B.

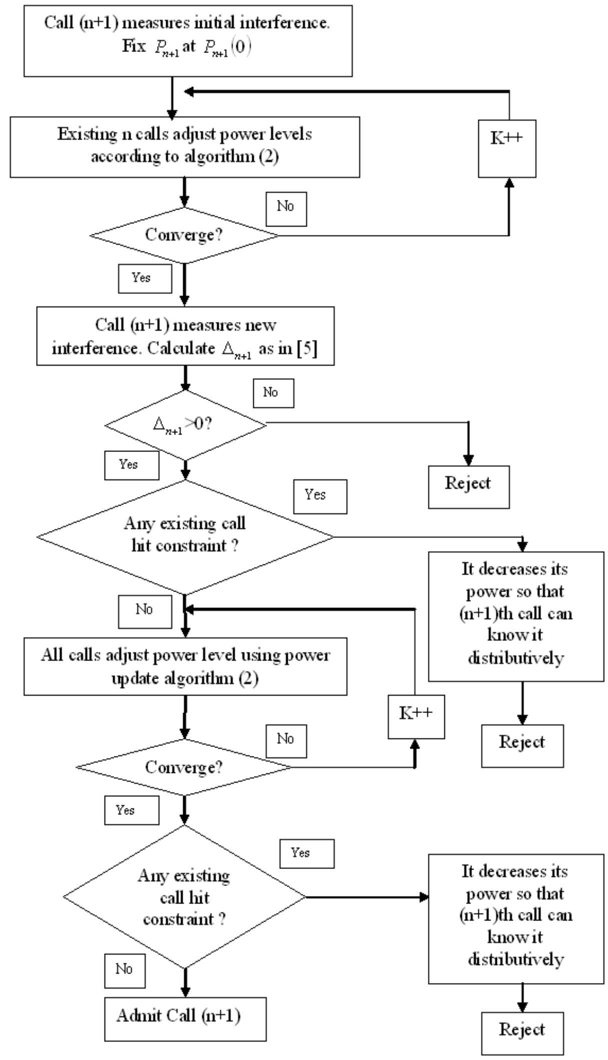

Fig. 1. Scheme A: Based on modification in Δ-CAC scheme

A. Scheme A: Based on Modification in Δ-CAC Scheme

We use our method of determining that whether any existing call can hit the power constraint due to the admission of the incoming call, in the Δ-CAC scheme given in [5] and we have the following distributed CAC algorithm for power constrained systems (flowchart is given in Fig. 1.) :-

1) Incoming call m_{n+1} measures the initial received interference on it and its base station starts transmitting to m_{n+1} in a fixed proportion to it.

2) The downlinks of the existing calls increase their power according to the power control algorithm given in (2).

3) Afer the convergence of the power control algorithm, incoming call measures interference received on it and on that

basis calculates Δ_{n+1} as in [5] and if $\Delta_{n+1} < 0$, the new call is rejected.

4) Otherwise, if any existing call hits the power constraint it will decrease its power by a fixed amount (c percent) after a brief time after the convergence of power control algorithm and the incoming call measures again the received interference on it and if it detects a decrease in the interference, the new call is rejected. It should be noted, that brief time has been given to ensure that the other users(those who have not hit the power constraint) keep their power constant while the user who has hit the constraint decrease its power.

5) Otherwise, (n+1) calls update their power according to the power control algorithm given in (2). Now, it is possible that any existing call hit the power constraint during this update of powers and so after the convergence of the algorithm the incoming call again measures interference on it. Now, if any existing call hits power constraint, then after a brief time after the convergence of power control algorithm it decreases its power by a fixed amount (c percent) and the new call will know and it will be rejected if the power constraint is hit due to it.

In using our method in the Δ-CAC scheme, it happens that if any existing call hits the power constraint than, it has to operate below threshold QoS till the power control algorithm converges. To overcome this problem, we next proposed Scheme B which is based on the modification in R-CAC scheme.

B. Scheme B: Based on Modification in R-CAC Scheme

Our proposed scheme based on the modification in R-CAC scheme is better as compared to the previous scheme as in this scheme the new call is rejected as soon as any existing call hits the power constraint and the existing call does not need to operate below the threshold QoS. Based on the modification in R-CAC scheme, we have the following improved distributed CAC algorithm for power constrained systems (flowchart is given in Fig. 2.) :-

1) Incoming call m_{n+1} measures the initial received interference ($R_{n+1}^{initial}$) on it and its base station starts transmitting to m_{n+1} in a fixed proportion to it.

2) The downlinks of the existing calls increase their power according to the power control algorithm given in (2).

3) During the process of iteration incoming call measures the received interference on it and if it reaches a certain value ($2R_{n+1}^{initial}$) as in [5], then the new call is rejected. Otherwise, if any existing call hits the power constraint it will decrease its power by a fixed amount (c percent) after a brief time and the incoming call measures again the received interference on it and if it detects a decrease in the interference, the new call is rejected.

4) Otherwise, after the convergence of the power control algorithm, (n+1) calls update their power according to the power control algorithm given in (2). Again, during the process of iteration the new call measures the interference received on it and decides distributively that if any existing call has hit the power constraint. The new call will be rejected if the power constraint is hit due to it.

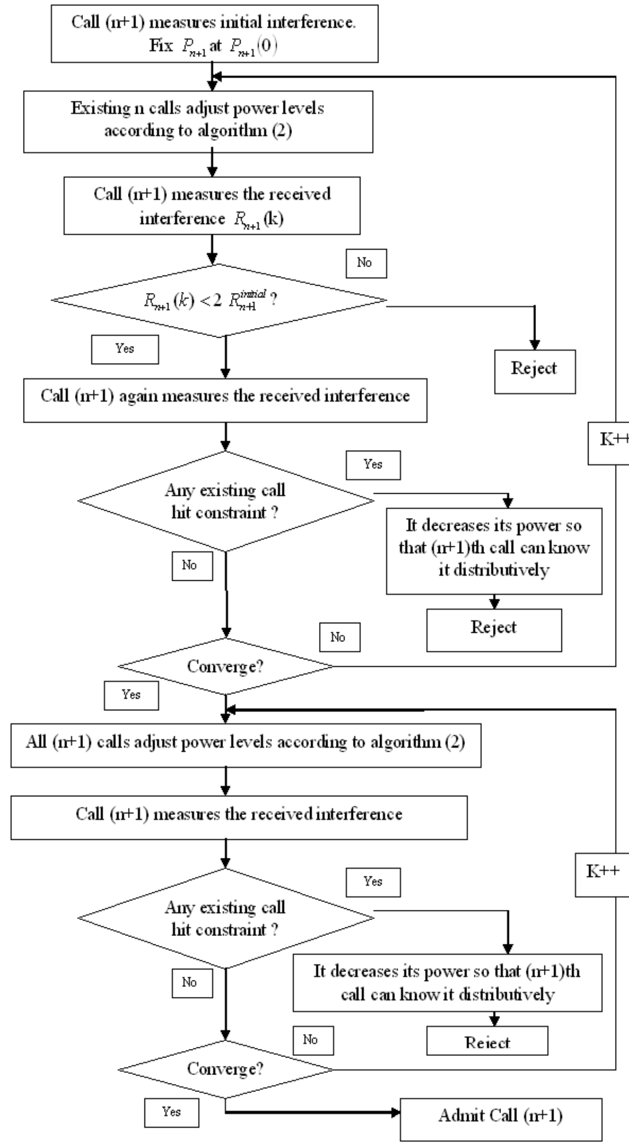

Fig. 2. Scheme B: Based on modification in R-CAC scheme

IV. SIMULATION RESULTS

We consider a 1-dimensional cellular system consisting of 37 cells. The locations of the calls are assumed to be uniformly distributed over the cell area. Base stations are assumed to be located at the center of the cell and are assumed to use omnidirectional antennas. As in [3], [5], and [8] effects from fast fading has been assumed to be averaged out in power measurements or by diversity. The link gain G_{ij} is modeled as

$$G_{ij} = \frac{A_{ij}}{d_{ij}^4} \tag{5}$$

where d_{ij} is the distance between call in the cell i and the base station in cell j, and the attenuation factor A_{ij} models the

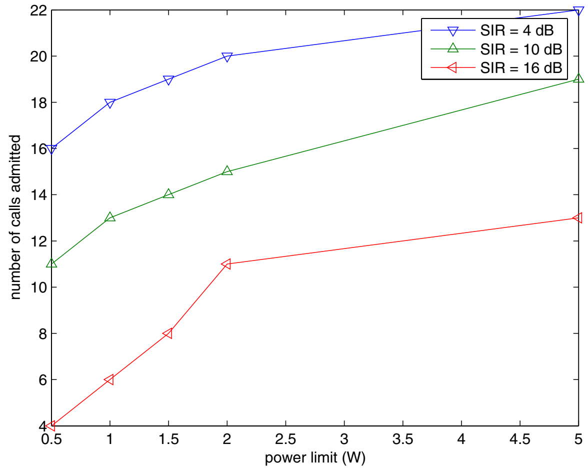

Fig. 3. Number of calls admitted versus power constraint for our proposed schemes

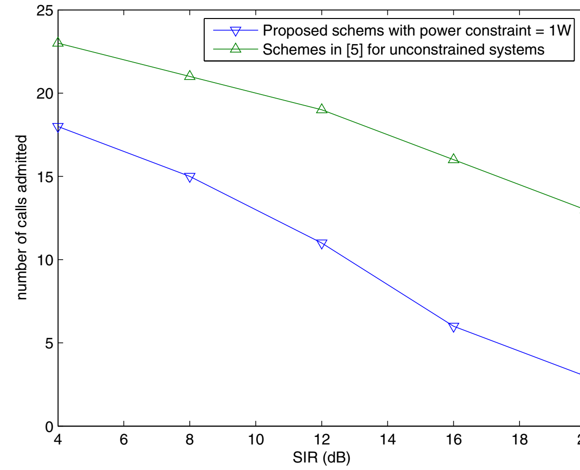

Fig. 4. Comparison of Number of calls admitted versus SIR threshold for our proposed schemes and schemes in [5]

power variation due to shadowing. As in [5], [9], and [10], we assume all A_{ij} to be identically independent and log-normally distributed random variables with 0 dB expectation and 8 dB log-variance. c percent has been taken to be 2.5 percent and the brief time has been taken to be 0.2 iteration.

It should be noted that, we can not compare our results to any of the existing schemes as the CAC schemes given in [5] are distributed, but they for unconstrained systems. TPCAC [3], DPC-ALP [6] and IAC [7] schemes are for constrained systems but are not distributed. Further, RPCAC [3], SINR-based CAC schemes [1],[2] and N-IAC [7] CAC schemes are heuristic and they result in divergence of power control algorithm [5].

We run simulations of our proposed schemes and provide plots of the number of users that can be admitted in the system versus limit on the power constraint for various values of SIR threshold 4, 10 and 16 dB in Fig. 3. Both proposed schemes (Scheme A and Scheme B) admit same number of calls. We can see from the plots given in Fig. 3 that as the limit on the power constraint decreases, the number of calls that can be admitted into the system decreases as more existing calls hit the power constraint.

Further, we provide comparison plots for CAC schemes given in [5] for unconstrained systems and our schemes with power constraint taken to be 1 W, in Fig. 4 to show that the schemes given in [5] admit calls, which will let the existing calls hit the power constraint in the practical systems which are power constrained. Our schemes, rejects these calls in the call admission stage itself. It should be noted that as in our case, both the CAC schemes (Δ-CAC and R-CAC) proposed in [5] admit same number of calls.

V. Conclusions

We have proposed a method by which an incoming call can determine in a distributive fashion that whether an existing call can hit the power constraint due to its inclusion in the system. We have applied our method to propose two optimal distributed CAC schemes for power constrained systems. Simulation results have been given to demonstrate the performance of our schemes.

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