An Adaptive Algorithm for Call Admission Control in Wireless Networks

Yi Zhang and Derong Liu
Department of Electrical and Computer Engineering
University of Illinois
Chicago, IL 60607

Abstract–In the present paper, we develop an adaptive algorithm for call admission control in wireless networks. The algorithm is built upon the concept of guard channels and it uses an adaptation algorithm to search automatically the optimal number of guard channels to be reserved at each base station. The quality of service parameters used in our study are the new call blocking probability and the handoff call blocking probability. Our simulation studies are performed for comparisons of the present algorithm with static guard channel policy. Simulation results show that our algorithm guarantees that the handoff blocking rate is below its given threshold and at the same time, minimizes the new call blocking rate.

I. INTRODUCTION

Call admission control (CAC) schemes are critical to the success of future generations of wireless networks. On one hand, CAC schemes provide the users with access to a wireless network for services. On the other hand, they are the decision making part of the network carriers with the objectives of providing services to users with guaranteed quality and at the same time, achieving as much as possible resource utilization. It is therefore conceivable that CAC policy is one of the critical design considerations in any wireless networks.

The design of modern wireless networks is based on a cellular architecture that allows efficient use of the limited available spectrum. The cellular architecture consists of a backbone network with fixed base stations interconnected through a fixed network (usually wired) and of mobile units that communicate with the base stations via wireless links. The geographic area within which mobile units can communicate with a particular base station is referred to as a cell. Neighboring cells overlap with each other, thus ensuring continuity of communications when the users move from one cell to another. The mobile units communicate with each other, as well as with other networks, through the base stations and the backbone network. A set of channels (frequency bands or codes) is allocated to each base station.

When a mobile user wants to communicate with another user or a base station, it must first obtain a channel (or code) from one of the base stations that hears it (the best). If a channel is available, it is granted to the user. In the case that all the channels are busy, the new call is blocked. This kind of blocking is called *new call blocking*. The user releases the channel under either of the following scenarios: (i) The user completes the call; (ii) The user moves to another cell before the call is completed. The procedure of moving from one cell to another, while a call is in progress, is called *handoff*. While performing handoff, the mobile unit requires that the base station in the cell that it moves into will allocate it a channel. If no channel is available in the new cell, the handoff call is blocked. This kind of blocking is called *handoff blocking*. The motivation for many studies on the new call and handoff blocking is that the quality of service (QoS) in cellular networks is mainly determined by these two blocking probabilities. The first determines the fraction of new calls that are blocked, while the second is closely related to the fraction of admitted calls that terminate prematurely due to dropout.

CAC in wireless networks has been studied by many researchers. Some of the existing results utilize optimization techniques in deriving CAC algorithms. The techniques used include, among others, descent search [1], linear programming [8], and value iteration [21]. The objective of the optimizations in these algorithms is to optimize certain QoS measures (e.g., to minimize the call blocking prob-

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abilities). Other existing results determine call admission policies through resource allocation; resource allocation is performed based on certain estimates or measurements of channel characteristics such as traffic rates [4], signal-to-interference ratios [14], resource requirements [13], and overload probabilities [15].

In the present paper, we will develop an adaptive algorithm for CAC in wireless networks. Our algorithm is built upon the concept of guard channels, and it will impose a hard constraint on the handoff call blocking probability. Our approach will be able to achieve optimal performance (i.e., maximum resource utilization with guaranteed QoS) and will have the ability to adapt automatically to changes in traffic conditions.

II. AN ADAPTIVE CALL ADMISSION CONTROL ALGORITHM

Because of the limited bandwidth of wireless channels and the quality requirements of different users, the admission requests of new call arrivals may not be all accepted. Efficient policies for admitting traffic into a wireless networks must be developed so that the blocking rates are minimized. It has been pointed out by many researchers [1], [4], [6], [8], [9], [10], [15], [21] that call admission policy can have a significant impact on the performance of a network and that a simple, fixed policy will usually lead to poor performance. As a result, much research has been devoted to CAC for wireless networks in recent years.

Part of the CAC policy will have to deal with handoff calls. Handoff calls to a cell from neighboring cells should be considered to have higher priority than new call arrivals and must be dealt with immediately. This is because an abrupt, premature termination of an on-going conversation will definitely upset the caller more than a rejection of the call in the first place. Guard channel policy [2], [3], [5], [11], [12], [16]–[20], [23] can be used to solve this problem; it reserves a subset of channels, codes, or bandwidth allocated to a given cell for handoff calls. Clearly, increasing the number of guard channels will reduce the handoff blocking rate and at the same time, it may increase the new call blocking rate. It is therefore very important to choose the right number of guard channels so that handoff blocking rate is guaranteed to be under the desired threshold and the sacrifice to new call blocking rate is kept at minimum. In this case, for any given desired threshold of handoff blocking probability, we want to determine the minimum possible number of guard channels to be kept at each base station in a wireless network.

The principle idea of the present CAC algorithm is as follows. The total number of available channels or codes (denoted by C) will be divided into two parts: One part (denoted by C_A) is used for handling admitted calls and the other part (denoted by C_H) is reserved for handling handoff calls. In this case, $C = C_A + C_H$ and C_H indicates the number of guard channels or guard codes. A new call request will be granted for admission if the total number of on-going calls (including handoff calls from other cells) is less than the threshold C_A. A handoff call request will be granted for admission if the total number of on-going calls in the cell is less than the total capacity C. This part of the CAC algorithm can be illustrated as follows:

P_A = number of on-going calls.
D_N = number of rejected new calls.
D_H = number of rejected handoff calls.

```
If handoff call request
  {
  If $P_A < C$, then $P_A = P_A + 1$ and grant
      admission.
  Otherwise, $D_H = D_H + 1$ and reject.
  }
If new call request
  {
  If $P_A < C_A$, then $P_A = P_A + 1$ and grant
      admission.
  Otherwise, $D_N = D_N + 1$ and reject.
  }
If a call is completed or handoffed to another cell
  {
  $P_A = P_A - 1$.
  }
```

We note that the number of guard channels has been considered to be one of the key design parameters which have tremendous effects on the performance of wireless networks [2], [3], [5], [11], [12], [16]–[20], [23]. In our approach, the number of guard channels of a wireless network at each base station will be determined through optimizing certain performance goal with service quality constraints. When a base station experiences high handoff call blocking rate, we will increase the number of guard channels until the handoff blocking rate drops to below its threshold. When a base station does not get to use a significant portion of the guard channels over a period of time, we can gradually decrease the number of guard channels until most of the guard channels are used frequently. By doing this, we may get the handoff blocking rate close to its threshold. However, we need to keep it below the threshold all the time. We propose the following algorithm for determining *adaptively* the number of guard channel C_H.

τ = time period for updating the measurements.

H = total number of handoff calls into the present cell (including both rejected and admitted) in the past τ seconds.

D_H = number of rejected handoff calls in the past τ seconds.

T_H = threshold for handoff call blocking probability.

```
If a handoff call is dropped and
    $D_H/H \ge \alpha_u T_H$ then
    $C_H = \min\{C_H + 1, C_{\max}\}$,
    where $\alpha_u$ is a threshold chosen
    as, e.g., 0.9.
If $D_H/H \le \alpha_d T_H$ for $N$ consecutive
    handoff calls, then
    $C_H = \max\{C_H - 1, C_{\min}\}$, where $\alpha_d$ is
    another threshold chosen as,
    e.g., 0.6, and $N$ is an integer
    chosen as, e.g., 10.
```

This algorithm has the following important features.

- It adjusts the number of guard channels C_H adaptively according to the dropping rate of handoff calls in time period τ; and
- It tries to make sure that the handoff call blocking rate is below the given threshold T_H and it also tries to reduce the new call blocking rate by decrementing C_H when it is observed to be more than needed.

We note that the present algorithm will only increase the number of guard channels when a handoff call is dropped under the condition that $D_H/H \ge \alpha_u T_H$, and we will only decrease the number of guard channels after a number of consecutive handoff calls under the condition that $D_H/H \le \alpha_d T_H$. α_u and α_d are usually chosen to be less than 1. By choosing $\alpha_u < 1$, our algorithm will most likely keep the handoff call blocking rate below its given threshold. An algorithm in a similar spirit has been applied in [17] for adaptive bandwidth reservation where the increase and the decrease in the reserved bandwidth are both done as soon as the threshold conditions for the monitored dropping probabilities are satisfied. We note that the present algorithm will wait for N consecutive handoff calls under the condition that $D_H/H \le \alpha_d T_H$ before increasing the number of guard channels, where N is larger than 1. Same idea can be applied to the algorithm in [17] to improve its performance. In particular, by waiting for N consecutive handoff calls under certain condition before increasing the number of guard channels, we will keep the system performance from oscillating.

One design parameter left untouched thus far is the time period τ, which indicates the total time for updating all the measurements used in our algorithm. We note that it must be long enough in order to have a meaningful evaluation and decision making. If τ is too small, the system will response to changes too often and certain measurements (e.g., call blocking rates) may not be accurate, which may result in oscillations in system performance. On the other hand, if τ is too large, the system may not response fast enough and thus may not perform to its best possible. Generally speaking, we can choose τ to be proportional to $1/T_H$ (T_H is the threshold for handoff blocking probability) or proportional to the inverse of any other QoS parameters. This is based on the observation that, for example, when T_H is small, we need a longer time period τ so that the calculated handoff blocking rate D_H/H is more accurate. In our simulation studies in the next section, we will choose τ as 2 hours (7200 seconds). Our experiments with larger τ (e.g., 10 hours) did not show any major improvements in system performance.

III. SIMULATION RESULTS

In the present simulation study, we consider a base station (or a cell) with a total of $C = 50$ interference-free channels. We assume that the new call arrivals are modeled by a Poisson process with mean λ and handoff calls are modeled by a Poisson process with mean γ, respectively. Channel holding times of both types of calls are assumed to follow an exponential distribution with mean $1/\mu$. In the simulation, we assume that $\lambda/\gamma = 5/1$ and $1/\mu = 180$ seconds. The threshold for handoff dropping probability is 0.01. The time period for updating all the measurement τ is chosen to be 2 hours. We change adap-

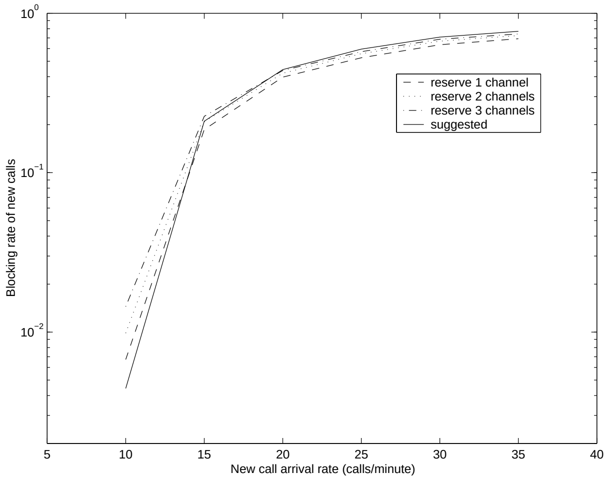

Fig. 1. New call blocking rate.

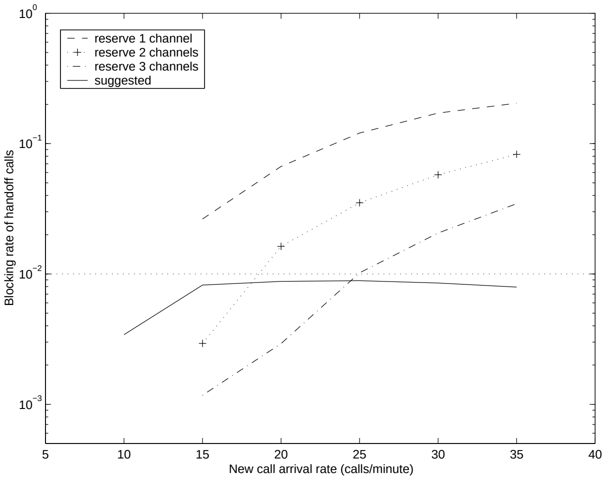

Fig. 2. Handoff call blocking rate.

tively the number of guard channels according to the estimated D_H/H in this period. The total simulation period is chosen to be 10 hours.

In Figures 1 and 2, we compare the present (suggested) algorithm with the static guard channel policy. Using the static guard channel policy, we reserve 1, 2, and 3 guard channels, respectively. Our simulations are run for call arrival rates from 10 calls/minute to 35 calls/minute. The new call blocking rate and handoff call blocking rate are both estimated based on the measurement in the total simulation period. From the figures, we can see that when the traffic load is low, the present algorithm has the lowest new call blocking rate, which means that the present algorithm makes more room for new calls while keeping the handoff call blocking rate below its threshold. When the traffic load is high, the present algorithm guarantees the blocking rate of handoff calls to be always below the given threshold. We also note that, comparing the present algorithm with fixed guard channel policies, the percentage of decrease in the blocking rate of handoff calls is greater than the percentage of increase in the blocking rate of new calls. For example (cf. Figure 1), at new call arrival rate of 25 calls/minute, the proposed scheme shows the blocking rate (59.57%) of new calls to be 13.2% higher than the policy with 1 guard channel (52.61%), 6.8% higher than the policy with 2 guard channels (55.81%), and 3.7% higher than the policy with 3 guard channels (57.44%). On the other hand (cf. Figure 2), at new call arrival rate of 25 calls/minute, the proposed scheme achieves blocking rate of handoff calls (0.887%) to be 12.6 times lower than the policy with 1 guard channel (12%), 2.9 times lower than the policy with 2 guard channels (3.52%), and 14.8% lower than the policy with 3 guard channels (1.02%). We note that our experiments are conducted with very heavy offered traffic load resulting in a high new call blocking rate. Our purpose here is to compare different admission algorithms for new call and handoff call blocking rates.

The results of Figures 1 and 2 show that the present algorithm can adapt to changes in traffic conditions such as changes in the call arrival rate and can achieve optimal performance in terms of guaranteeing handoff call blocking threshold and minimizing the new call blocking rate at the same time.

Figure 3 shows a typical sequence of the numbers of guard channels during the total simulation period when the call arrival rate is 20 calls/minute. We can see clearly from Figure 3 the need for adaptively changing the number of guard channels. If we were to use a fixed number of guard channels, the CAC policy will be conservative at certain time periods and will be overly tight at other time periods.

IV. CONCLUSIONS

In this paper, we developed an adaptive call admission control algorithm based on the concept of guard channels. We assumed the fact that handoff calls have higher priority than new calls. Our adaptive algorithm can search automatically the optimal number of guard channels to be reserved at a base station, and it can also adapt to changes in traffic conditions such as changes in the call arrival rate. We note that changes in traffic conditions are inevitable

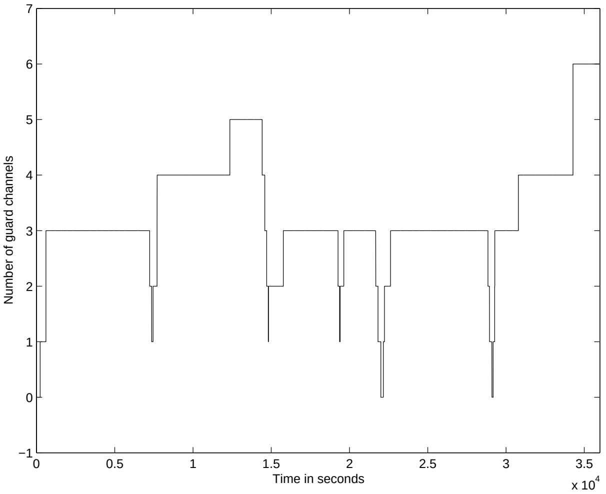

Fig. 3. guard channel C_H at new call arrive rate of 20 calls/minute.

in reality. Thus, fixed CAC policies such as fixed guard channel policies are less preferable in applications. We showed in the present paper that a simple adaptation algorithm can be used to automatically determine the optimal number of guard channels to be reserved at a base station under changing traffic conditions. Our simulation results showed that when traffic condition changes, fixed guard channel policy will suffer either from higher new call blocking rate (when the traffic load is low) or from higher handoff call blocking rate (when the traffic load is high).

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