Computers and Electrical Engineering 37 (2011) 601–613

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Learning automata based dynamic guard channel algorithms ☆

Hamid Beigy [a,*], M.R. Meybodi [b]

[a] Department of Computer Engineering, Sharif University of Technology, Tehran, Iran
[b] Department of Computer Engineering, Amirkabir University of Technology, Tehran, Iran

ARTICLE INFO

Article history:
Received 14 November 2009
Received in revised form 28 March 2011
Accepted 4 April 2011
Available online 14 May 2011

ABSTRACT

In this paper, we first propose two learning automata based decentralized dynamic guard channel algorithms for cellular mobile networks. These algorithms use learning automata to adjust the number of guard channels to be assigned to cells of network. Then, we introduce a new model for nonstationary environments under which the proposed algorithms work and study their steady state behavior when they use L_{R-I} learning algorithm. It is also shown that a learning automaton operating under the proposed nonstationary environment equalizes its penalty strengths. Computer simulations have been conducted to show the effectiveness of the proposed algorithms. The simulation results show that the performances of the proposed algorithms are close to the performance of guard channel algorithm that knows all the traffic parameters.

1. Introduction

In the last decade, there is an increase in the popularity of mobile computing systems, which results in an increase for channel (bandwidth) demands. Since the number of channels allocated for this purpose is limited, cellular networks are introduced, in which the service area is partitioned into regions called *cells*. Every cell is serviced by a server called *base station*. When a mobile station moves across the cell boundary while using channels, handoff is required. If an idle channel is available in the destination cell, then the call is resumed; otherwise the call is dropped. The dropping probability of handoff calls (B_h) and the blocking probability of new calls (B_n) are important quality of service (QoS) measures of the cellular networks. Since the disconnection in the middle of a call is highly undesirable, dropping of handoff calls is more serious than blocking of new calls. Blocking more new calls generally improves the dropping probability of handoff calls and admitting more new calls generally improves the blocking probability of new calls. In order to control these QoS measures, *call admission control algorithms* are introduced, which determine whether a new call should be admitted or blocked. Both blocking probability of new calls and dropping probability of handoff calls are affected by call admission control algorithms. Several call admission algorithms have been proposed in the literature. *Fractional channel algorithm* accepts new calls with a certain probability that depends on the current channel occupancy and accepts handoff calls as long as channels are available [1]. A restricted version of this algorithm is *uniform fractional channel algorithm* (UFC), which accepts new calls with probability of π independent of channel occupancy [2]. It is shown that there is an optimal π^*, which minimizes the blocking probability of new calls with the constraint on the dropping probability of handoff calls. An algorithm for finding π^* and conditions for which the uniform fractional guard channel performs better than guard channel is given in [2]. Another restricted version of fractional channel algorithm is called *guard channel algorithm*, which reserves a subset

☆ Reviews processed and proposed for publication by Associate Editor Dr. Gill Rafael Tsouri.

* Corresponding author. Tel.: +9821 66164624.
E-mail addresses: beigy@ce.sharif.edu (H. Beigy), mmeybodi@aut.ac.ir (M.R. Meybodi).

0045-7906/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compeleceng.2011.04.003

of channels allocated to a cell, called *guard channels*, for handoff calls (say $C - T$ channels) [3–5], where $0 \leqslant T \leqslant C$ is a threshold and C is the number of channels allocated to the cell. Whenever the channel occupancy exceeds the threshold T, the algorithm rejects new calls until the channel occupancy goes below the threshold. The guard channel algorithm accepts handoff calls as long as channels are available. As the number of guard channels increases, the dropping probability of handoff calls will be reduced while the blocking probability of new calls will be increased [4]. It has been shown that there is an optimal threshold T^* in which the blocking probability of new calls is minimized subject to the constraint on the dropping probability of handoff calls [1]. Algorithms for finding T^* are given in [1,4,5]. If only the dropping probability of handoff calls is considered, the guard channel algorithm gives very good performance, but the blocking probability of new calls is degraded to a great extent. In order to have more control on both the dropping probability of handoff calls and the blocking probability of new calls, *limited fractional guard channel algorithm* (LFG) is proposed [1]. This algorithm, which reserves non-integral number of guard channels for handoff calls, uses an additional parameter π and operates the same as the guard channel algorithm except when T channels are occupied in the cell, in which case new calls are accepted with probability π. It has been shown that there is an optimal pair (T^*, π^*), which minimizes the blocking probability of new calls subject to the constraint on the dropping probability of handoff calls [1]. An algorithm for finding the optimal parameters is given in [1].

All of the above mentioned algorithms are useful when the input traffic is a stationary process with known parameters. Since the parameters of input traffic are unknown and possibly time varying, adaptive versions of these algorithms need to be used. In [6], two adaptive uniform fractional channel algorithm based on learning automata are introduced in which the parameter of uniform fractional guard channel algorithm is adjusted according to the traffic condition. In [7,8], dynamic guard channel algorithms are proposed in which the number of guard channels in any particular cell is adjusted based on the number of ongoing calls in neighboring cells. For more information about the call admission algorithms in cellular mobile networks, the readers may refer to [9].

In other hand learning automata are simple agents that have many desirable features such as they can be used without any priori information about the underlying application with large amount of uncertainty, require a very little and simple feedback from their environment, are very simple in structure and can be implemented easily in software or hardware, and require a few mathematical operations at each iteration so they can be used in real-time applications. Learning automata are also very useful in multi-agent and distributed systems with limited intercommunication and incomplete information and unlike traditional hill-climbing algorithms, hill-climbing in learning automata is done in expected sense in a probability space. Optimization algorithms based on learning automata do not need the objective function to be an analytical function of adjustable parameters. Learning automata have flexibility and analytical tractability needed for most applications. These features make learning automata as a useful tool for finding the near optimal number of guard channels.

In this paper, we first propose two learning automata based adaptive and autonomous call admission control algorithms. These algorithms only use the current channel occupancy of the given cell and dynamically adjust the number of guard channels for that cell. The proposed algorithms adapt the number of guard channels in such a way that the blocking probability of the new calls is minimized subject to the constraint on the dropping probability of the handoff calls. Since the learning automaton starts its learning without any priori knowledge about its environment, the proposed algorithms do not need any a priori information about input traffic and can adapt itself to the varying traffic. One of the most important advantages of the proposed algorithms is that no status information will be exchanged among the neighboring cells, although addition of such information increases the performance of the call admission algorithm [10,11]. The simulation results show that the performances of the proposed algorithms are close to the performance of guard channel algorithm that knows all traffic parameters. In this paper, we also formulated the nonstationary environment under which the proposed algorithms work and then study their behavior when they use L_{R-I} learning algorithm. It is also shown that a learning automaton operating under the proposed nonstationary environment equalizes its penalty strengths.

The rest of this paper is organized as follows. Guard channel algorithm and learning automata are given in Sections 2 and 3, respectively. The proposed adaptive call admission control algorithms are given in Section 4. The simulation results are given in Section 5 and Section 6 concludes the paper.

2. Basics in guard channel algorithm

In this section, we briefly describe the guard channel algorithm and compute its blocking performance. We assume that any given cell has a limited number of full duplex channels, C, in its channel pool. The guard channel algorithm, which is depicted algorithmically in Algorithm 1, reserves a subset of channels allocated to a particular cell for handoff calls (say $C - T$ channels) [3], where $0 \leqslant T \leqslant C$ is a threshold. These $C - T$ channels are called *guard channels*. Whenever the channel occupancy exceeds threshold T, guard channel algorithm rejects new calls until the channel occupancy goes below T. The guard channel algorithm accepts handoff calls as long as channels are available.