European Journal of Control (2008)1:62–75
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DOI:10.3166/EJC.14.62–75

European
Journal of
Control

Admission Control in UMTS Networks based on Approximate Dynamic Programming

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This paper presents a Connection Admission Control (CAC) algorithm for Universal Mobile Telecommunications System (UMTS) networks based on an Approximate Dynamic Programming (ADP) approach. To deal with the non-stationary environment due to the time-varying statistical characteristics of the offered traffic, the admission policy has to be computed periodically based on on-line measurements. If standard algorithms are used, the optimal policy computation is excessively time-consuming to be performed on-line. Thus, an ADP approach for the computation of a sub-optimal admission policy is proposed. The ADP approach is based (i) on the reduction of the policy space, and (ii) on an approximated state-space aggregation. Theoretical results and numerical simulations show the effectiveness of the proposed approach, which is currently being implemented in a real UMTS testbed.

Keywords: Approximate Dynamic Programming (ADP), Connection Admission Control (CAC), Markov Decision Process (MDP), Universal Mobile Telecommunications System (UMTS).

1. Introduction[1]

This document presents a Connection Admission Control (CAC) strategy for wide-code division multiple access (WCDMA) networks based on an Approximate Dynamic Programming (ADP) approach. CAC consists in refusing a new connection if the addition of its traffic would lead to an unacceptable degradation of that or previously accepted traffic.

The admission control problem has been successfully described as a Markov Decision Process (MDP), based on the fact the decision to accept or reject a call impacts on whether future calls will be accepted or not (see [1]). As shown in Section 2, Dynamic Programming (DP) algorithms can be used to compute the optimal admission policy once the CAC problem is represented as a MDP.

Two problems arises when DP algorithms are proposed for the implementation in real networks: (i) the "curse of dimensionality", which is the exponential growth of the state dimension as the number of links increases [3]; (ii) the stationary hypothesis underlying the MDP, which is not realistic due to non-stationary traffic characteristics.

With regard to the curse of dimensionality, the WCDMA scenario is not incompatible for a DP approach since, from the CAC viewpoint, each cell (a cell identifies a group of terminals transmitting to/receiving from the same base station) is almost independent of each other−the inter-cell interference is usually modelled by a pre-defined constant (see Section 3). Thus, the WCDMA CAC problem is essentially a single-link problem, and the dimension of the

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[1] This work was supported by the EuQoS project ([6]), funded under the European Commission IST (Information Society Technologies) 6th Framework Programme, coordinated by

Received 12 August 2006; Accepted 9 November 2007
Recommended by J. Lunze, A.J. Van der Schaft

state space remains tractable [22,5]. Moreover, the single-link case is meaningful also for multi-link networks: in fact, the multi-link case can be reduced to the single-link case by assuming the link independency approximation [21,23,18].

As regards the latter problem, i.e., the non-stationary environment, it requires the admission policy to be update periodically, based on on-line measures of traffic statistics. Thus, even if we are considering a single-link case, the policy computation cost becomes critical. Therefore, a novel ADP algorithm specifically tailored for the admission control problem in communication networks is proposed.

ADP approaches are used to fast compute sub-optimal policies by introducing some approximations in the model–for instance by performing state aggregation or by reducing the policy space (see [2] for a survey on ADP and comprehensive references).

1.1. Related Work

A significant number of MDP-based admission control algorithms were proposed in the literature, both for terrestrial and wireless networks.

In all terrestrial networks, the above-mentioned link independency hypothesis is assumed. For instance, in [21] the CAC problem in optical networks is dealt with: the problem is formulated as a single link MDP and solved via the *value iteration algorithm* [7]. In [23], the *policy iteration algorithm* [7] is used to compute the optimal admission policy in ATM (Asynchronous Transfer Mode) terrestrial networks. Other examples can be found in [28,13,10]. Also MDP-based CAC for CDMA networks have been analyzed in the literature: for example, in [22], the multi-service admission control problem with fairness guarantees is solved by formulating the MDP problem as a Linear Programming (LP) one (as described in [7,27]); in [31], the DP approach is aimed at maximizing the revenue; in [24] and in [34], the average data throughput is maximized under a blocking probability constraint; in [4], a fairness constraint is introduced in the LP, which enforces the difference between the blocking probabilities of different classes to be lower than a certain value; other examples can be found in [13,5,20].

In [15] the single link problem is modelled as a MDP, and a state grouping technique is developed; the technique is based on the concept of bandwidth quantization [18] and is used to evaluate "product-form" policies [14]; even if well-known policies, such as the *greedy* (or *complete-sharing*) one[2], have product-form distributions, this is not generally true for all the policies (see [18] for some examples). The novelties proposed in this paper are (i) that the proposed state space reduction technique is based on an ADP approach and is not limited to product-form policies, and (ii) that the state aggregation is used within a policy computation (and not only evaluation) algorithm tailored to an on-line implementation.

1.2. Paper Outline

The paper is organized as follows: Section 2 presents the proposed CAC approach; Section 3 describes the Universal Mobile Telecommunications System (UMTS) scenario and the CAC role; Section 4 shows numerical simulation results; finally, in Section 5 the conclusions are drawn and on-going and future work is outlined.

2. MDP Connection Admission Control

Let us consider a single link in a generic network supporting C classes of service, each one requiring a load share $\Delta L^{(c)}$, $c = 1, \ldots, C$. The maximum link load is denoted with η_{MAX}. The network can be represented by a discrete-time system, whose state is the number of on-going connections of each class. Under the assumption that each on-going connection is compliant with its declared parameters, the controller has a perfect knowledge of the state, since, at time t, the load $\eta(t)$ is given by $\sum_{c=1}^{C} \Delta L^{(c)} n^{(c)}(t)$, where $n^{(c)}(t)$ is the number of connections of service class c, on-going at time t.

Let us define the state $x(t)$ at time t as follows:

$$x(t) = \left(n^{(1)}(t), n^{(2)}(t), \ldots, n^{(c)}(t)\right). \qquad (1)$$

The system is sampled with sample time γ, defined in Section 2.1, and has the following dynamics:

$$x(t+1) = f(x(t), u(t), z(t)), \qquad (2)$$

where $u(t)$ is the control action of the CAC controller and the disturbance $z(t)$ represents the connection attempt and terminations, characterized as follows:

(i) for each class c, connection attempts are distributed according to a Poisson process with mean arrival frequency $\lambda^{(c)}$;
(ii) the connection holding time of class c is exponentially distributed with mean termination frequency $\mu^{(c)}$.

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[2] Under the *greedy* policy, a connection is accepted unless the maximum link bandwidth is exceeded.