Connection Admission Control in Cellular Networks: a Discrete Time Optimal Solution

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***Abstract*—*The Connection Admission Control (CAC) problem is formulated in this paper as a discrete time optimal control problem. The control variables account for the acceptance/ rejection of new connections and forced dropping of in-progress connections. These variables are constrained to meet suitable conditions which account for the QoS requirements (Link Availability, Blocking Probability, Dropping Probability). The performance index evaluate the total throughput. At each discrete time, the problem is solved as an integer-valued linear programming one. The proposed procedure was successfully tested against suitably simulated data.*

Index Terms— Connection Admission Control- Optimal Control- Integer valued Linear Programming-QoS Requirements

A key concept of the control of the multimedia networks is that it has to satisfy Quality of Service (QoS) requirements; each connection type (e.g. voice, video, ftp, web...), hereafter referred to as *Service Class,* is characterized by its own peculiar QoS requirements. So, *resource management* procedures are becoming more and more important. By *resource management* we mean the set of procedures aiming, on the one hand, to exploit the resource (in particular, the transmission capacity) and, on the other hand, to meet all the connection QoS requirements.

The authors have focused their attention on the Connection Admission Control problem (CAC), suggesting a procedure aiming at maximizing the exploitation of the available capacity of a telecommunication network and, at the same time, assuring the respect of the QoS requirements of the various Service Classes. By Service Class we mean the set of connections characterized by the same QoS requirements; in the following, k ($k = 1, 2, ..., C$) indicates the generic Service Class. The CAC procedure is based on the modelling and optimal control methodologies. In particular, the results shown in this poster refer to the CAC procedure for an asynchronous Code Division Multiple Access (CDMA) based cellular system [1]. For instance, the proposed CAC can be applied to the uplink of the Wideband CDMA (W-CDMA) technique adopted by the Universal Mobile Telecommunications Standard (UMTS).

Main troubles of the CAC Problem, in a generic network, are related to (i) the large amount of connections that the networks have to support, each generating traffic often characterized by high burstiness (namely, the ratio between the traffic standard deviation and the traffic mean) and which is hardly predictable, (ii) the variety of the service classes QoS constraints.

Whenever a stand-by user requests a connection set-up, the CAC is in charge of deciding whether to accept or to reject the connection set-up.

If the CAC accepts a new connection, this one becomes *in progress* and remains in this status up to either its natural completion (in this case, the user decides to terminate the connection), or its forced dropping (in this case, the CAC decides to terminate the connection); whichever is the reason, whenever a connection is terminated, the corresponding user comes back in the *stand-by status*.

When a connection set up is accepted, the data that it transmits enhance the exploitation of the available bandwidth, but they produce interference (self-noise) with respect to the other in progress connections [2] [3]. In order to consider the link *available*, the above interference must be sufficiently low. A first fundamental QoS requirement is that the probability that the link is available (*link availability requirement*) does not become lower than a fixed threshold.

Moreover, if the CAC rejects a new connection, a so-called *block* occurs and the user which has attempted the connection remains in the stand-by status. In this respect, a second fundamental QoS requirement is that the probability of experiencing a block while attempting to set-up a connection (*blocking probability requirement*) does not exceed a threshold value.

Finally, situations can occur in which, in order to avoid the infringement of the link availability requirement, it is necessary to forcedly drop one or more connections. In this respect, a third fundamental QoS requirement is that the probability of experiencing a connection drop (*dropping probability requirement*) does not exceed a threshold value.

The CAC problem has been reduced and solved as a discrete time optimal control problem, subject to a set of constraints. A similar continuous time CAC problem was already discussed and solved by the authors in [4] with promising results.

As a matter of fact, the proposed controller computes the control variables which regulate the acceptance and the dropping of the connections, so that (i) a set of proper constraints, which model the QoS requirements (link availability, blocking probability and dropping probability), are respected and (ii) a proper performance index, which evaluates the exploitation degree of the available bandwidth, is maximized.In order to obtain the optimal solution, an innovative prediction approach is proposed, in which a forward interference model is used and the constraints (i) as well as the performance index (ii) are respectively expressed as probabilities and expected values over some future time interval.

At each discrete time, the problem is solved as an integer-valued linear programming one. The proposed procedure was successfully tested against suitably simulated data. In particular this approach is compared with other well known procedures [5] [6] in different traffic conditions and the results shown a considerable improvement of bandwidth exploitation.

Traffic data were generated by a specific software hereafter referred to as "Traffic Simulator" designed to represent a mobile communication network under various situations of traffic classes and intensity, number and mobility of users, geometry of cells. This software was developed within the SAILOR (Satellite Integrated UMTS Emulator) Project, supported by the European Union within the fifth framework program (Information Society Technology (IST) program). It is able to describe user mobility, traffic evolution in a network with a given number of cells and traffic classes of given types. In particular, the traffic classes considered in the software are voice, interactive, and background. In order to run, the software must be provided with the cells size, the amount of traffic in the various classes, the control policy, the simulation time.

The traffic simulator has been interfaced with a so-called CAC module implementing either the proposed CAC policy, or one of the reference CAC policies.

In the proposed CAC policy, the solution of each integer linear programming problem defined by the QoS constraints and by the performance index, is provided by a specifically devoted software package called CPLEX.

Two alternative CACs, like other similar ones described in literature, base their control policy only on the present traffic situation (ARROWS) [6] or take in account also the near past in order to compute a mean value of interference (Interference CAC)[5]. Instead, our proposed CAC policy employs a future traffic forecast, based on the present and past traffic, to estimate the traffic trend and decide on this basis the best control values. In this way it is possible to better handle the traffic and by consequence, to improve the network efficiency. In particular, in our simulations, we consider the following two classes (C=2):

- Conversational: voice call (k=1)
- Background Data: e-mail and ftp (k=2)

The Traffic Simulator was tuned so as to generate traffic according to a standard profile [8] [9]. Thus the a posteriori overall performance evaluation coincides with the total throughput. The duration of time interval $t_f - t_0$ was set equal to 1 hour, sufficiently long with respect to call and mobility dynamics. Time increments $t_{i+1} - t_i$ were set to 20 ms, sufficiently small with respect to $t_f - t_0$.The following diagrams illustrate the simulation results for background data bit rate set equal to 150 kbps and increasing conversational traffic. In particular, Fig.s 1, 2 and 3 illustrate blocked and dropped calls frequencies with their selected thresholds, for the proposed Optimal strategy, the ARROWS strategy and the Interference strategy. For figure clarity reason, the background dropped frequency is not shown: it actually is zero for ARROWS and Interference CAC's, while it is negligeable for Optimal CAC. Fig. 4 represents the a posteriori Link Availability with its selected threshold for three CAC's. Fig. 5 shows the a posteriori overall performance evaluation for the three CAC's up to their maximum allowable voice traffic. Finally, Fig. 6 describes the optimality default for the optimal CAC.

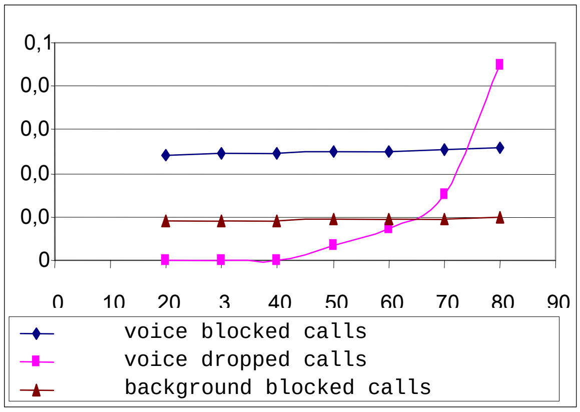

Fig.1: Optimal CAC with Background data fixed at 150 kbps

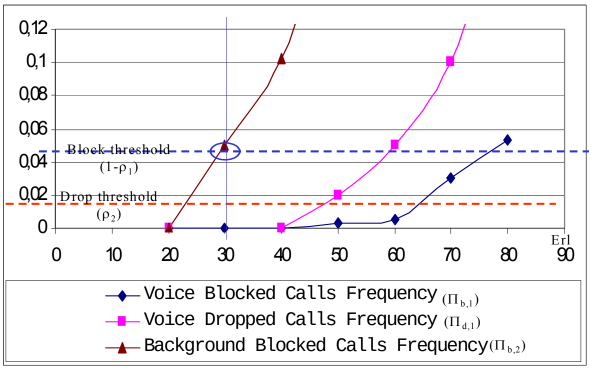

Fig. 1: Arrows CAC with Background data fixed at 150 kbps

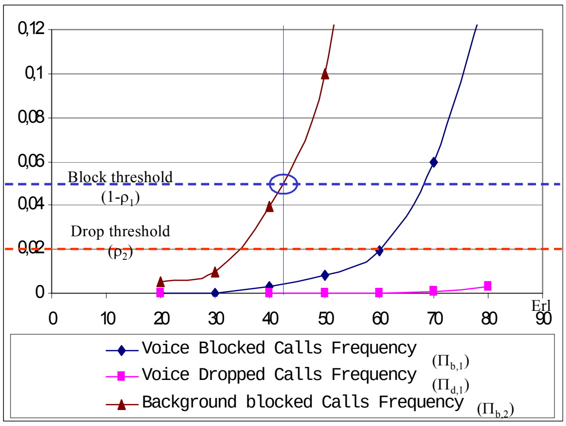

Fig. 2: Interference CAC with Background data fixed at 150 kbps

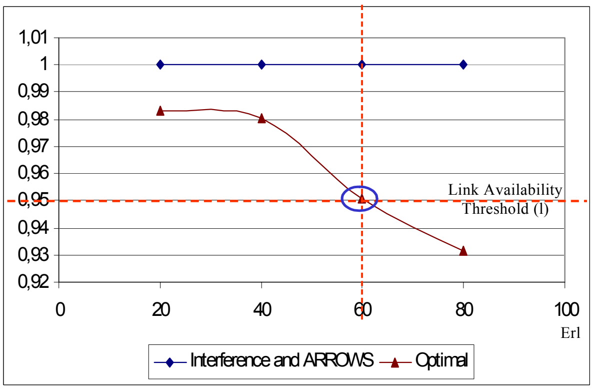

Figure V. 3: A posteriori Link Availability (L_a) with background data fixed at 150 kbps

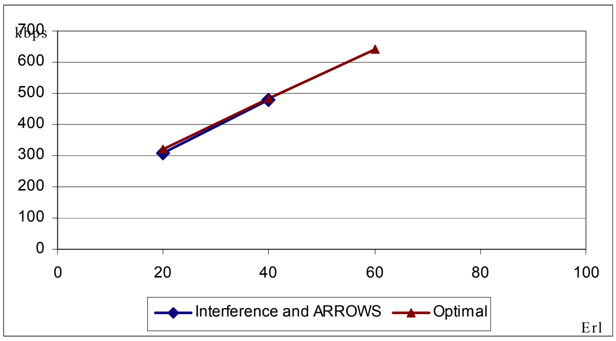

Figure 4: A posteriori Overall Performance Evaluation (J_p)

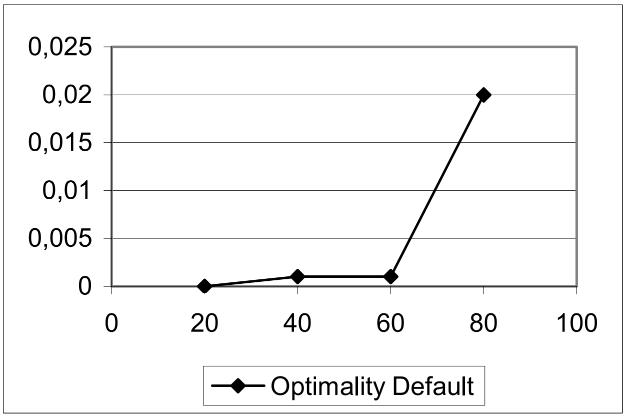

Figure 5: optimality default

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