

A Joint Scheduling/Admission Control Policy for Multimedia Services in UTRA FDD

Paolo Dini¹, Roberto Minni²

University of Rome "La Sapienza", INFO.COM Department
Via Eudossiana 18, 00184 Roma, ITALIA
E-mail: ¹paodini@infocom.uniroma1.it; ²robminni@yahoo.it

Abstract: Radio Resource Management (RRM) in 3G networks is a very challenging issue since it has to handle air interface resources in order to guarantee high capacity and QoS to different kinds of services. In particular in the terrestrial UMTS this issue is quite complex due to the soft capacity of its access technique (i.e. WCDMA).

This paper is focused on RRM issues in the uplink, where the system is limited by the interference among the active users at the Node B. An innovative solution based on a joint scheduling/admission control policy is presented in this paper. Besides an UMTS radio access simulator, fully taking into account both user movement and channel conditions, is employed to evaluate the performance of the proposed algorithm and compare it to classic solutions. Simulation results show the improvements attained by the proposed solution.

1. Introduction

Resource management is one of the most important engineering issues in modern third-generation (3G) wireless mobile communications systems where the radio spectrum is a very scarce resource. Such systems aim to provide mobile multimedia services like voice, video telephony, high-speed Internet access, mobile computing etc. For this purpose multiple traffic classes are supported, each class being characterized by its required Quality of Service (QoS) parameters (i.e. Eb/No, transfer delay, guaranteed bit rate and delay jitter). Call Admission Control (CAC) is employed to decide whether to accept or not a new service request: the goal is to admit an higher number of service requests while at the same time guaranteeing, by means of scheduling algorithms, the required QoS for every already active connection.

In this paper a novel solution based on a joint scheduling/admission control strategy is proposed for WCDMA systems and in particular for UMTS. We refer to the *uplink*, whose capacity is limited by the interference generated in the same and in the neighboring cells [1], [2].

The performance of the proposed strategy is evaluated and compared with the solutions described in [3] and [4] by using a UMTS terrestrial radio access simulator which takes into account both user mobility and channel conditions.

The paper is organised as follows. In Section 2 some classic CAC algorithms are described. Section 3 is completely devoted to the description of the joint

scheduling/admission control strategy. In Section 4 the software simulation environment and traffic models are detailed. Performance analysis is carried out in Section 5 by showing simulation results and comparing the proposed strategy with the classic solutions presented in Section 2. Some conclusions are finally drawn in Section 6.

2. Classic Call Admission Control Schemes

In WCDMA systems the classic criterion to accept a new connection is based on the Signal to Interference Ratio (SIR) featuring each existing connection after that the new one is activated. SIR depends on the power emitted by mobile users. Power Control (PC) mechanisms attempt to keep the SIR of each connection quite close to its target value [5], which in turn is fixed on the basis of QoS requirements [6].

Referring to the UMTS scenario, from [7] we assume that CAC algorithms are implemented in the RRC (Radio Resource Control) layer of RNS (Radio Network System).

Here below two typical CAC algorithms are described.

a) Interference-based CAC (ICAC) [3]

ICAC policy foresees that the RNS evaluates the total interference generated by active users in the cell and in surrounding cells. The total cell load (i.e the so-called *load factor* η , defined in [8]) is then computed and a new request is accepted if it is smaller than a given threshold η_{th} .

An observation window is employed to mediate the load factor fluctuations due to the bursty nature of the data traffic, the on/off characteristic of the speech sources and the inter-cell interference variability due to user mobility.

b) Arrows CAC (ACAC) [4]

ACAC belongs to *model-based* admission policies. In these kinds of policy the load factor is estimated by means of theoretical model; the following equation is used (according to[8]):

$$\eta = (1 + f) \sum_{i=1}^N \frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_0}\right)_i} + 1} \quad (1)$$

where N is the number of the active connections, SF_i the spreading factor of the i -th connection, v_i the activity factor of the i -th connection, $(Eb/No)_i$ is the bit energy-to-interference ratio requirement for the i -th connection, and f represents the other-cell interference fraction modeled as a fraction of the own-cell received power.

In ACAC policy an “admission with prioritisation” rule is employed: a request for a *conversational* call (referred also as *real-time* or voice traffic) can be accepted at the expense of a *data traffic* connection (referred also as *no real-time* traffic). It is assumed that some kind of “soft QoS” is provided for the active data traffic connections.

ACAC can be summarised as follows. The RNS calculates the load factor η . If it is smaller than a given threshold (η_{th}) the new request is accepted. Otherwise, if the new requested refers to a *conversational* call, the bit rates of active *no real-time* connections are properly reduced (but always kept larger than the minimum value allowed by their QoS requirements) to let the new call be admitted to the network. If bit rate reduction is not sufficient, the new call is rejected and the bit rates of existing data calls are left unchanged.

3. The Proposed Solution: Joint Scheduler CAC

In classic schemes the scheduler is the procedure in charge of allocating dynamically bandwidth for all the users accepted by the admission policy.

The new solution proposed in this paper is a joint scheduler/admission policy based on a CAC that take the decisions according to the scheduler performance. To understand the “modus operandi” of this new schema, first the particular implementation of the scheduler is depicted and then the interaction with the CAC is explained.

To provide the agreed QoS to all the connection, cell load has to keep under a prefixed value. Cell load can be considered as a sum of *real-time connection load* and *no real-time connection load*. No real-time connection load can be defined as “controllable load” since data scheduler can safely increase or reduce data connection bit rates without damaging their QoS. Whereas real-time connection load (η_{RT}) basically results “uncontrollable” because of the strict transfer delay constraints of voice traffic.

Data scheduler approach is to control the load provided by no real-time connections on the basis of the instantaneous value of real-time load in order to keep the total load factor at a target value. When real-time load increases, scheduler reduces data connection bit rate; on the contrary, when real-time load decreases, it assigns more bandwidth to no real-time connections.

This behaviour allows to shape load factor so as granting QoS requirements to every active connection and exploiting the whole system dynamics (in term of bandwidth). See Figure 1.

It has to be underlined that load shaping is possible if the amount of “uncontrollable” load is bounded.

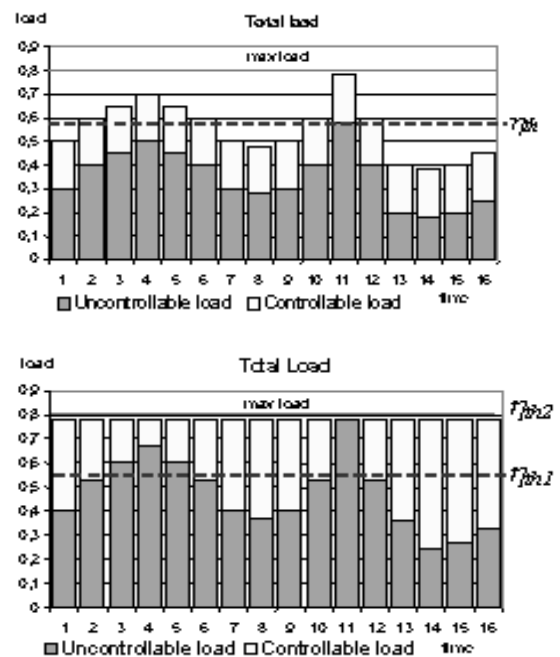


Figure 1 – Instantaneous load trend without scheduler (upperside), Instantaneous load trend with scheduler (lowerside)

Moreover the scheduler is able to provide during-time a minimum mean bit rate to data users if the number of them is not too high. In this joint admission/scheduler solution, CAC procedure aims to:

- 1) limit “uncontrollable load” by blocking new real-time connection requests
- 2) control the number of non real-time user, to guarantee them a minimum bit rate.

The operations performed are described by the flow chart in in Figure 2.

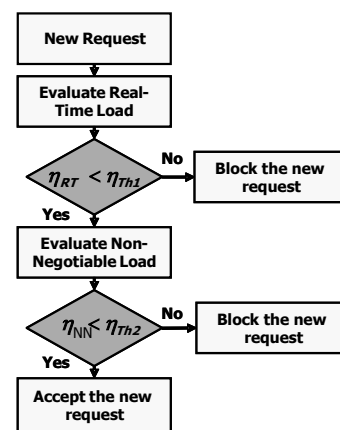


Figure 2 – Proposed call admission control algorithm flow chart

When a new connection request occurs, both conversational and data, a double-threshold comparison procedure starts.

At first, the “uncontrollable load” is evaluated according to the equation below:

$$\eta_{RT} = (1+f) \sum_{i=1}^K \frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_0}\right)_i} + 1} \quad (2).$$

where K is the number of voice active connections. If this value is bigger than a given threshold (η_{th1}) the request is blocked; data scheduler is not able to shape network load in this case. Conversely, if the value is lower than the threshold, cell load is controllable and the decision task goes on. The threshold value used in this first comparison is very conservative to take into account instantaneous fluctuations of “non-controllable” load; the same value of ACAC is employed (see Figure 1).

Then, a parameter called *not negotiable load* (η_{NN}) is computed according to the following formula:

$$\eta_{NN} = (1+f) \sum_{i=1}^K \frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_0}\right)_i} + 1} + (1+f) \sum_{i=K+1}^N \frac{1}{\frac{SF_{\max i}}{\left(\frac{E_b}{N_0}\right)_i} + 1} \quad (3)$$

where K represents the number of voice calls and N the total number of active connections.

Not negotiable load is composed by two terms: the former is the real-time load, whereas the second represents no real-time connection load considering every data connection at its minimum bit rate (i.e. at its maximum spreading factor SF_{\max}).

If η_{NN} is higher than the second threshold (η_{th2}), the new connection request is rejected. Conversely, if η_{NN} is lower than η_{th2} , the new request is accepted: there is enough bandwidth to provide, during-time, a minimum mean bit rate to data users. This second threshold is less conservative than the first one and is set according to scheduler performance; the value adopted is shown in Figure 1.

Once a new request is accepted, scheduler task is to assign dynamically the right SF according to QoS requirements and access network status.

Joint admission/scheduler behaviour can be summarized as follows: CAC limits number of connections so as allowing scheduler to control network load (i.e. load factor η); on the other hand, data scheduler provides an efficient radio resources allocation by assigning bit rates to every active connection according to their QoS requirements, so as allowing CAC to admit a greater number of connections.

4. The UMTS Terrestrial Radio Access Simulator

Traffic is not uniformly distributed within an UMTS cell, mainly due to user movement. This must be inspected to properly take into account variations of the emitted powers, due to different path losses within the cell and to PC mechanisms [5]. According to this, a realistic radio access simulator for a urban

environment, where users randomly move while producing multimedia traffic has been developed. The simulator allows to test performance of UMTS access network protocols such as *call blocking probability*, *call dropping probability*, *probability of handoff successes*, *bit rate*, *data throughput*.

Basic features of the simulator, distinguishing it from other simulators based on the classic Manhattan model ([9], [10]), are:

- the whole area is divided in pixels; within pixel all the parameters involved are constant;
- buildings and other obstacles are not necessarily rectangular in shape, as in Manhattan model;
- cells lay upon a torus surface in order to avoid border effects;
- node Bs employ omni-directional antennas with a gain of 11 dB
- mobile user terminals employ omni-directional antennas with a gain of 0 dB

The simulator is basically an event generator which, after an initialization step, manages many different processes like:

- user movement from a pixel to another (also taking into account user speed),
- request of a new connection,
- opening/closing of a connection;
- drop out of a connection;
- run of Power Control algorithms;
- run of Call Admission Control algorithms.

4.1. Propagation Model

The macro cell propagation model, valid for urban and suburban environment is employed. Path loss L is then expressed according to [11] as follows:

$$L = 128.1 + 37.6 \text{Log}(R) + \text{Log}(F) \quad (4)$$

where R is the distance (in meters) between mobile and Node B: $\text{Log}(F)$ represents the loss due to fast fading, F being a Gaussian random variable with zero mean and 10 dB standard deviation.

4.2. Mobility Model

User mobility is modeled as follows.

Each active user is featured by parameters like position within the cell and emitted power. “Pedestrian” and “Vehicular” users have been considered and described in Table 1.

	Pedestrian	Vehicular
Speed	1 – 4 km/h	5 – 50 km/h
% users	60	40

Table 1 - Active user classes

The state machines of Figure 5 have been employed to reproduce variations of user speed and direction. State transitions are controlled by different values of probability: $P(M,M)$, $P(M,S)$, $P(S,S)$, $P(S,M)$ for user speed; $P(C)$, $P(T)$ for user direction. These are properly set on the basis of the supposed environment (urban, suburban, rural, etc.).

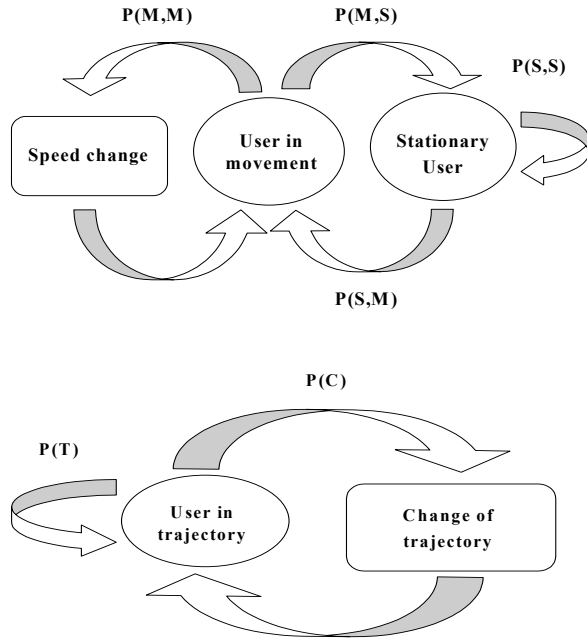


Figure 3 - State machine for user movement: Change of Speed (upper side), Change of Trajectory (lower side)

4.3. Signal to noise ratio

SIR (Signal-to-Noise ratio) after despreading is evaluated as:

$$SIR = SF \frac{P_r}{I + P_N} \quad (5)$$

where P_r is the received used signal power, P_N is the thermal noise power, SF is the spreading factor and I is the total interference produced by the other users in the cell and in the neighbouring cells.

4.4. Power Control

The transmitted power is adjusted by PC mechanism each step (assumed equal to 20 msec) to keep the SIR at the target value (SIR_{target}). The new power level for each user terminal is evaluated as:

$$P_{Updated} = P_{OLD} \frac{SIR_{target}}{SIR} \quad (6)$$

$P_{Updated}$ cannot be set larger than a maximum value featuring the mobile terminal (assumed equal to 21 dBm). Users unable to reach the SIR_{target} at the end of a PC loop are considered in "outage". If quality is equal to ($SIR_{target} - 0.5$ dB), the user is considered satisfied, otherwise the connection is dropped out.

4.5. Traffic Source Models

Three different service classes have been implemented in the simulator.

a) Conversational Service

Voice calls are generated according to a Poisson process and an exponential distribution, assuming the

typical mean call duration of 180 seconds. 50 % average activity cycle is assumed.

b) Interactive Service

The burstiness of this service is modelled as follows. A packet service session contains one or several packet calls and reading times, depending on the application. During a packet call several packets may be generated, so that the packet call constitutes a bursty sequence of packets.

Session opening time is modelled as a Poisson process; the number of packet call requests per session and the reading time are two geometrically distributed independent random variables, while the size of a packet call is a random variable which follows a Pareto distribution with cut-off.

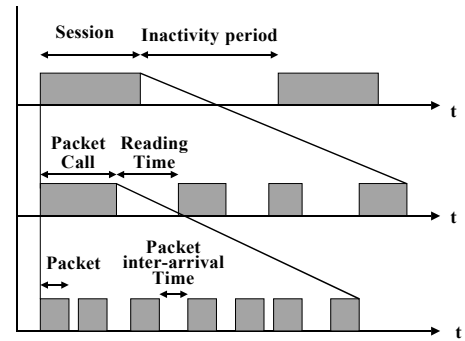


Figure 4 - Traffic model for Interactive services

c) Background Service

The model simulating file uploading or email service consists of only one packet call, whose size is a random variable with Pareto distribution with 30 Kbytes as mean value.

5. Simulation Results

In order to test the performance of the proposed strategy, hereinafter called Joint Scheduler/Call Admission Control (*JSCAC*), several computer simulations have been performed using the traffic simulator described in the previous section. The aim is to compare *JSCAC* with *ICAC* and *ACAC* performance in term of blocking probability, dropping probability, and data mean bit rate, while considering different traffic sources so as to test a truly integrated voice-data network. The case of exclusion of any admission control procedure (hereinafter referred as *No CAC*) has been also evidenced in the graphs below.

Basically two scenarios are shown in this section: the former considering only conversational services and the latter considering a mixed traffic composed by the voice and data (both interactive and background class) services.

In the conversational service scenario data scheduler functions are unessential; therefore the three considered algorithms roughly show the same trend, both in term of blocking and dropping probability, as shown in figures 5.

This scenario underlines what happens excluding the admission procedure (*No CAC*): voice blocking probability is always 0 while voice dropping

probability, as traffic grows, reaches unacceptable values. See Figure 5 (lower side).

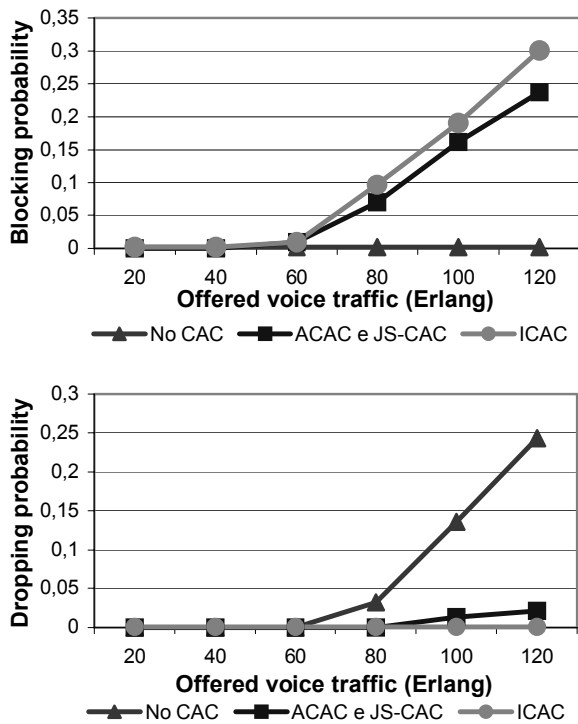


Figure 5 – Blocking (upper side) and Dropping (lower side) probability for voice traffic. Conversational service scenario

The second scenario deals with a mixed voice/data traffic situation: voice traffic and interactive traffic are set at 40 erlang and at 50 kbps respectively, while background traffic varies between 100 and 700 kbps.

Concerning voice blocking probability, both ACAC and JSCAC provide better performance than ICAC. See Figure 6 (upper side).

Referring to ACAC, the improvement in blocking probability is due to the strategy adopted: ACAC gives priority to voice users at disadvantage of the bandwidth provided to data users. Figure 7 (lower side) shows that when traffic grows, ACAC provides a lower bit rate to data user in respect to ICAC.

Referring to JSCAC, the improvement in voice blocking probability is due to a better efficiency: the load shaping allows the use of a less conservative threshold and the admittance of greater number of users.

This conclusion is strengthened observing Figure 6 (lower side): JSCAC provides a very low data blocking probability in comparison with the other two policies.

Concerning the mean bit rate, Figure 7 (upper side) shows that JS-CAC provides a mean bit rate to data users higher than the other two policies for nearly the whole traffic range. The decreasing trend is explained as follows: for low traffic value the scheduler assigns all the bandwidth to the few active users giving them high bit rate; at the growing of the traffic, the number of admitted data users increases and the amount of bandwidth available for each user is smaller.

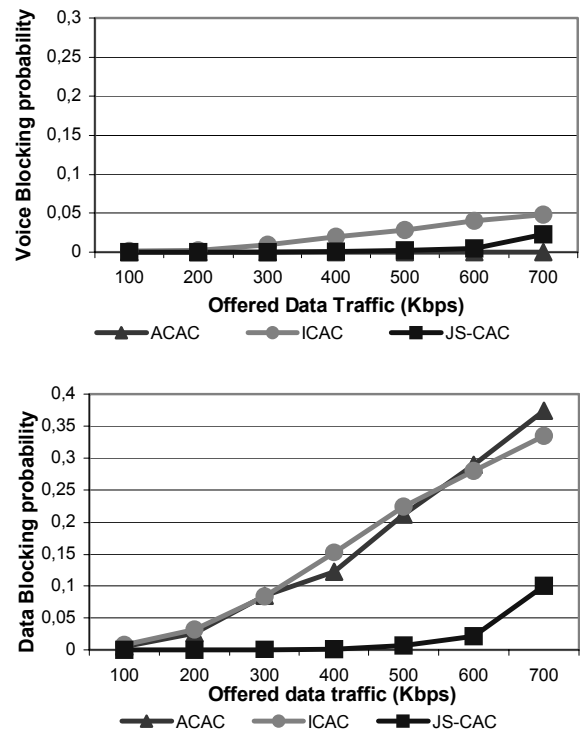


Figure 6 – Voice Blocking probability (upper side) and Data Blocking probability (lower side). Mixed traffic case

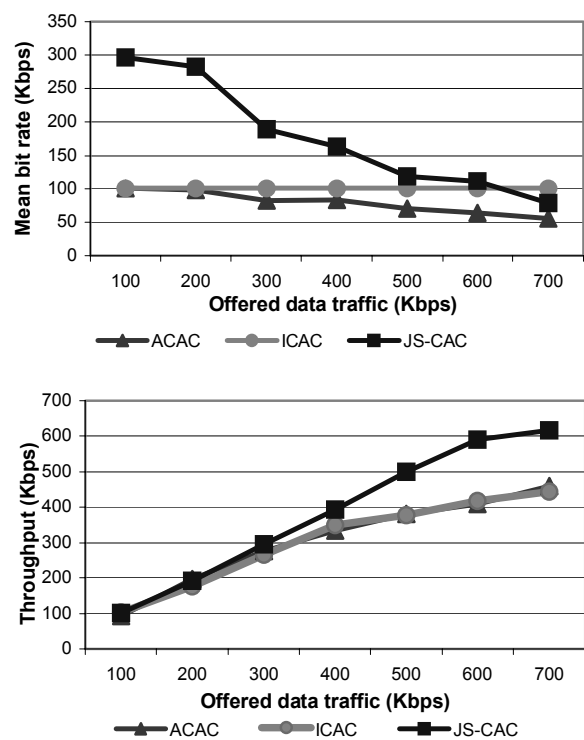


Figure 7 – Data mean bit rate (upper side) and throughput (lower side). Mixed traffic scenario. Mixed traffic case

Figure 6 (data blocking probability) and Figure 7 (mean bit rate) show that for high traffic value JS-CAC admits a higher number of users while providing the same bit rate of the other two policies.

These conclusions are strengthened by the throughput graph (Figure 7, lower side). While ICAC and ACAC have the same trends, JS-CAC provides a higher throughput for all the traffic range.

Finally, Figure 8 shows the graph of instantaneous load using ACAC and JSCAC in a mixed data-voice scenario. While in ACAC case (Figure 8, upper side) instantaneous load widely fluctuates, using JSCAC (Figure 8, lower side) the resulting trend is flat. This exploitation of load dynamic leads to a lower data blocking probability and to an increased data throughput.

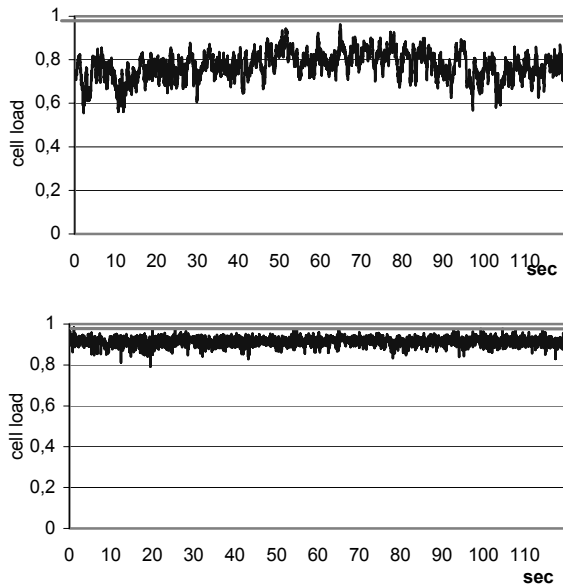


Figure 8 – Instantaneous value of load factor η for ACAC policy (upper side) and JSCAC policy (lower side). Mixed traffic case

6. Conclusions

An innovative strategy for radio resource management based on a co-operation between scheduling and call admission control procedures has been presented for WCDMA systems (mainly, UMTS). Its performance has been analysed and compared with other well-known algorithms by means of a UMTS radio access simulator. Numerical results demonstrate its ability to grant better resource exploitation in term of throughput and data mean bit rate, meanwhile maintaining a very high number of admitted connections.

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