# Uplink Call Admission Control Techniques for Multimedia Packet Transmission in UMTS WCDMA System

Angela Hernández Solana[1], Antonio Valdovinos Bardají[1], Fernando Casadevall Palacio[2]
[1] Electronics Engineering and Communications Dpt. University of Zaragoza. (Spain) anhersol@posta.unizar.es
[2] Signal Theory and Communications Dpt. Polytechnic University of Catalonia (UPC); Barcelona (Spain)

***Abstract-*** *The third generation cellular network, UMTS, provides large opportunities to offer multimedia applications and services that meet end to end quality of service (QoS) requirements, in a more efficient way, considering packet data transmission mode. However, this requires to design an efficient flow control and call admission control (CAC). Design of CAC has special difficulties given that capacity in CDMA varies according with the number of active users and the level of interference. Taking into account the stochastic nature of multimedia traffic and the changes in the available capacity in the CDMA system, an effective capacity request is derived and used to characterize the resources required by each mobile user in order to meet its respective QoS requirements. These requirements are expressed in terms of rate and delay constraints in addition to the signal to interference ratio. After setting an effective capacity threshold for the system, a linear approximation is used to find the total amount of resources required by all the mobile users already admitted in the system and the new connection request. Packet transmission is considered for both real time and non real time services while a centralized demand assignment algorithm has been implemented in order to provide QoS in the packet level. Computer simulation results are given to demonstrate the performance of the proposed method.*

## I. INTRODUCTION

The connection admission control (CAC) for mobile communications is one of the most important engineering issues in order to guarantee system efficiency and quality of service (QoS) to connection oriented services. In interference limited CDMA systems, good interference handling by radio resource allocation schemes plays an important role to enhance the performance and to increase the system capacity. In this way, CAC indirectly controls interference by limiting the number of users in the system in order that the negotiated signal to interference ratio values can be achieved by each existing connection. Whereas, in a packet time scale, the medium access control/flow control balances the system interference and arranges transmissions on a frame to frame basis by scheduling users according with their QoS requirements in terms of the maximum allowed delay, rate and bit error rate. In any case, coordination between CAC and flow control is required to meet QoS and consequently the results obtained from packet level have to be taken into account in order to infer an efficient method for CAC.

The flexibility of CDMA access in addition to the packet transmission mode improves system efficiency but increases the complexity of the CAC. Given that in CDMA capacity varies due to changes in the interference the design of CAC has associated two main design problems: a) to set an effective CAC threshold to guarantee the QoS for an integration of various service types, and b) to achieve the maximum efficiency in the sense of resources usage. In fact, CAC really operates at two different levels: the first one characterized by the “packet level” constraints such as packet loss, delay jitter or average delay and the second one that allows the system capacity to be shared among the various traffic types and/or to protect the handoff connections from the new connections. Several research studies have addressed these issues by means of static and dynamic prioritization and sharing scheme, associated with static or adaptive reserve of resources.

The problem of setting an effective CAC threshold has been addressed before in quite a lot of works [4][5][6][11]. In general, two CAC styles can be found in these references: CAC that derive an average cell capacity based on the allowed number of active connections and CAC based on the transmitted power or the total interference level. [4] presents useful expressions for system capacity evaluation. However, since the erlang capacity is calculated based only on blocking rate, the communication quality is not guaranteed and its relation with erlang capacity is left unclear. A distribution function of interference is determined in order to evaluate the blocking probability. [4] shows that the mean and variance of other-cell interference can be approximated by the intracell interference multiplied by a constant coefficient *f*. In [5] expressions of the QoS (packet loss) and GoS (grade of service) as functions of traffic intensity and CAC thresholds have been derived although only a type of service is considered. In [6], an effective capacity (rate), taking into account the stochastic nature of traffic and the delay requirements in a multimedia scenario, is used to characterize the resources required by multimedia services. The proposed method, though useful, has been shown to be conservative. In [11] an interference-based CAC strategy is proposed. A new user is not admitted by the uplink CAC if the new resulting total interference level is higher than a threshold value. This threshold is the same as the maximum uplink noise rise and can be set by radio network planning. Although this method could guarantee the signal to interference ratio for all admitted connections, packet level quality constraints in terms of delay requirements are not assured.

Note that the most capacity analysis concentrate simply on transmission characteristics and do not consider the real time operation of the system under stochastically varying traffic load. On the other hand, none of the previous references consider specific MAC protocols in order to provide differentiated QoS in the packet level. We have introduced this specific factor. Computer simulation results obtained from packet level have been evaluated in order to infer an effective capacity threshold. In particular, our study has been associated to the Wideband Code Division Multiple Access (WCDMA) uplink defined in Universal Mobile Telecommunication System (UMTS) terrestrial radio access (UTRA) and limited to the uplink. Transmissions of real-time and non real-time services have been performed in packetized form over the physical data channel (DPDCH) where a centralized demand assignment protocol has been implemented to integrate services with QoS. Note that this proposal differs from packet transmission modes defined for the moment in UTRA (short infrequent packet on RACH and short number of successive frames on Common Packet Channels (CPCH) [1]). However, we have considered the mentioned alternative in order to transmit large or frequent data packets without content for a code. In this case, each MS, which has packets waiting to transmit, setups a dedicated code using an initial Random Access request, wherein the type and traffic parameters are specified. Then, the network evaluates the request and decides if the necessary resources can be provided to the MS in order to support its QoS. Once the dedicated channel (code) is assigned, the MS is not allowed to start the transmission, it needs to wait that the base station (BS) specifies the times in which it can transmit. Both MS transmitted powers and transmission rates may be considered as controllable resources by the network. Thus, the scheduling disciplines at BS, in coordination with a minimum transmitted power criterion, are responsible for arranging packet transmissions within their specified rate requirements and delay tolerances, being channel conditions of individual users in mind. The purpose of the minimum power control criterion is to meet the Bit Error Rate (BER) of simultaneously transmitted packets, assigning an optimum level to the transmitted power from all the MS's in such a way that interference caused to other cells is minimized and thus throughput is maximized. Besides, the level of interference at BS is always maintained under a threshold while MS output powers are constrained. Several scheduling strategies based on static and dynamic priorities have been considered and proved to perform differentiate QoS. A detailed description of the protocol and the scheduling strategies can be found in [2]. However, some assumptions about power assignment are reviewed in section II in order to support the analysis of the effective user capacities and the threshold system capacity.

Once the effective CAC threshold is set, we evaluate the performance of a variable channel reservation CAC policy based on the estimated position and movement of mobiles stations (MS's). This estimation is performed considering measurements reported by the MS. Computer simulation results demonstrate the efficiency of the proposed CAC threshold in a multimedia scenario and also the effective handoff priority provided by the proposed distributed-adaptive CAC policy.

## II. Call Admission Threshold

The set of requirements associated with a MS i located in a cell k: maximum delay and delay jitter, minimum rate $r_{i,k}$ and maximum bit (BER) or block (BLER) error rates, can be mapped into an equivalent $(E_b/No)_{i,k}$ constraint denoted by $\gamma_i$:

$$\left(\frac{E_b}{N_o}\right)_{i,k} = \frac{W}{r_{i,k}} \frac{P_{i,k} h_{i,k}}{I_{\text{int},k} + I_{ext,k} + \eta_o W} \geq \gamma_i \quad i = 1..N \tag{1}$$

with $I_{ext,k} = \sum_{\forall k' \neq k} \sum_{\forall l} P_{l,k'} h_{l,k}$, $I_{\text{int},k} = \sum_{\forall i} P_{i,k} h_{i,k}$

where $E_b$ is the bit energy, $N_o$ the total interference density received at the BS, $\eta_o$ the thermal noise spectral density, $I_{int,k.}$ and $I_{ext,k}$ the intracell and intercell interference respectively, $P_{i,k}$ the transmitted power associated to the MS i located in cell k, $h_{i,k}$ the path loss between MS i and the BS k, N the number of users in the cell k and W the available bandwidth in the cell (chip rate). It has been shown that, considering that power output constraints are applied to MS, $0 < P_{i,k} < p_{i,k,\max}$, the power control problem in a cell is feasible if and only if [3]:

$$\sum_{j=1}^{N} C_j = \sum_{j=1}^{N} 1 \Big/ \left(\frac{W}{r_{j,k}\gamma_j} + 1\right) \leq \frac{1-\eta(t)}{(1+f(t))} = C_{\max}(t) \tag{2}$$

$$\eta(t) = \frac{\eta_o W}{min_j \left[ p_{j,k,max} h_{j,k}(t) \left( \frac{W}{r_{j,k}\gamma_j} + 1 \right) \right]}, \quad f(t) = \frac{I_{ext,k}(t)}{I_{\text{int},k}(t)}$$

We consider $C_{max}(t)$ is the maximum available capacity in the cell, $C_i$ the consumed capacity by a MS and $\eta(t)$ is the reserved capacity needed to guaranty the power constraints to MS's in a frame. A minimum value of parameter $\eta$ equal to 0.1 is considered in order to limit the maximum total power received at the BS $I_{total,k}$.

If condition (2) is achieved for a set of rates and $E_b/N_o$ values, then the power can be obtained using (3).

$$P_i(t) = \frac{\eta_o W}{\hat{h}_{i,k}(t) \left( \frac{W}{r_{i,k}\gamma_i} + 1 \right) C_{res}(t)} \quad \text{with } C_{res}(t) = 1 - (1+f(t)) \sum_{j=1}^{N} C_j \tag{3}$$

Note that in a certain frame, where $N_{sch}$ is the number of scheduled users, the relation (4) is satisfied.

$$C_{max}(t) - \sum_{i=1}^{Nsch} C_i = \frac{C_{res}(t)}{1+f(t)} - \frac{\eta(t)}{1+f(t)} \geq 0 \tag{4}$$

The ratio between inter and intracell interference *f(t)*, and the channel condition should be known in order to achieve the minimum transmitted power criterion with accuracy. Ratio *f(t)* is estimated from the ratio measured in the previous frame. Taking into account condition (2), scheduling at the BS arranges transmissions of MS's according to algorithms related with delay and rate requirements. MS's which can not meet Eb/No requirements are delayed although could be in contact with the base through the Dedicated Control Channel (DPCCH) (to perform closed power control). Unused resources (power and instant of transmission) are assigned to the rest of the users. Note that the waste of capacity associated to DPCCH must be added in (2). In addition to the scheduling strategies based on delay and rate requirements, we have considered a channel–state dependent scheduling algorithm based on the required value of parameter $\eta$ [2]. MS's which require a high value of $\eta$ could be delayed in order to provide permits to more users.

Once we have described theoretical expressions for capacity in the packet level time scale, we will explain the development of the effective CAC. In our case, unlike [4][5][6], the scheduler limits the number of MS's transmitting in a frame, thus, a priori, every MS having permit to transmit must reach its Eb/No constraints (condition (2) is satisfied). So, only imperfections in the estimation of ratio *f(t)* could prevent it, given that almost perfect channel estimation could be assumed thanks to DPCCH. Thus, users can only not satisfy their QoS constraints related with delay constraints. Real time services drop packets that exceed delay constraints, so a specific drop probability constraint is imposed as QoS criterion.

On the other hand, simulation results show that initial capacity $C_{max}(t)$ maintains the same statistical distribution, which has been shown to correspond to a gamma distribution, with the same mean an variance independently of the number of active users in the system, being only dependent of the propagation parameters, closed power control inaccuracy and the spatial distribution of MS's within the cell. However, in order to perform CAC, we use an alternative measure of the capacity (5), more dependent of current active users, which provide a more accurate bound.

$$C_{ini}(t) = 1 - \eta(t) - f(t)\sum_{i=1}^{Nsch} C_i(t) \tag{5}$$

Simulations show that $C_{ini}(t)$ can be characterized by a F-distribution, given that the product of *f(t)* and $\sum_{i=1}^{Nsch} C_i(t)$ can be modeled as a product of Gamma distributions. This distribution is maintained considering either one type of traffic or an integration of real time and non real time services. However, for the moment, in order to simplify the analysis, we will only consider real time services, and only one type of traffic.

Note that if there are $N_i$ MS's admitted in a cell, the probability of $k_i$ active users may be expressed as a binomial distribution (6), where $\rho_i$ is the activity factor associated to class i MS's. Distribution of active users is not the same as distribution of scheduled users. However, while $N_i$ is below the CAC threshold (characterized by the maximum number of MS allowed, $N_{max,i}$) they could be considered equal, which simplifies the parameters of the F-distribution associated to $C_{ini}$.

$$P_{u,i}(k_i) = \binom{N_i}{k_i} \rho_i^{k_i} (1-\rho_i)^{N_i - k_i} \tag{6}$$

Considering the distribution of the available capacity $C_{ini}$, the delay probability can be calculated as the fraction of all active users that can not transmit due to the absence of available capacity in frame. (7):

$$P_{delay} = \frac{\sum_{k_i=0}^{N_i} P_{u,i}(k_i) \left( \sum_{j=0}^{k_i} \left( \int_0^{jC_i} p_{Cini}(m)dm \right) \right)}{\sum_{k_i=0}^{N_i} k_i P_{u.i}(k_i)} \tag{7}$$

($p_{Cini}$ is the pdf. of $C_{ini}$.)

If we assume no delay tolerance, the maximum number of allowed users, considering a threshold to the $P_{delay}$, represents an admission region bound, given that in fact, in this case, $P_{delay}$ is equal to the dropping probability. However, this assumption is very conservative given that we can assume some tolerance to the delay to almost any real time service.

Instead of $C_i$, an effective capacity, $C_{i,ef}$ (introducing the delay influence) must be derived in order to provide a more accurate result. Probability $\varepsilon_i$ is the probability that delay associated to packets of any connection k belonging to class i exceed delay requirements. So, if we are able to obtain the delay distribution of the individual sources, the capacity of the system in terms of number of MS's ($N_{max}$) can be calculated as (8) and, in addition, the effective capacity associated to MS of class i as (9):

$$N_{max} = max(Ni \mid \forall_{k=0:N_i} \ \Pr[delay_k > Dmax_k] \leq \varepsilon_i) \tag{8}$$

$$C_{i,ef} = E[C_{max}] / N_{max} \tag{9}$$

where $E[C_{max}]$ is the mean of the capacity $C_{max}$, estimated in a period of time. To obtain $N_{max}$, we need to compute the delay distribution for individual sources considering their BLER and service rate requirements, the variable wireless capacity and the error control scheme (selective repeat algorithm is implemented). To consider all these factors together in a single analytical model seems inaccessible, so we have made the analysis in two steps. The probability that delay does not exceed delay requirements is computed as the probability that capacity assigned to the individual connections, in a time interval equal to delay tolerance $Dmax_k$ counted from the instant of the packet arrival to the queue ($t_a$), is higher than the capacity required to transmit all packets waiting in the queue when packet arrives, $q_k(t_a)$ (10).

$$\begin{aligned}\Pr\lfloor delay_{k,i} > Dmax_{k,i} \rfloor &= \\ &= 1 - \Pr(C_{asig,k\in\{N_i\}}(t_a, t_a + Dmax_k) \geq q_k(t_a) * C_i) \\ &= 1 - \sum_{n_q} \Pr\left[C_{asig,k\in\{N_i\}}(t_a, t_a + Dmax) \geq n_q * C_i / q_k(t_a) = n_q\right] \Pr(q_k(t_a) = n_q)\end{aligned} \tag{10}$$

The probability (11)

$$\Pr\lfloor C_{asig,k\in\{N_i\}}(t_a, t_a + Dmax) \geq n_q * C_i / q_k(t_a) = n_q \rfloor \tag{11}$$

is calculated using a model that includes the selective repeat scheme, the capacity assigned to a connection calculated depending on the delay probability calculated in (7), $P_d$, and the error probability related to the Eb/No requirement, $P_e$. Calculus of $P_e$ includes the effects of the little deviations in the Eb/No due to errors in the estimation of ratio *f(t)* and channel conditions (they have been statistically modeled). This model considers that all packets waiting to transmit must receive service within their specific delay requirement.

On the other hand, the probability of queue occupation when a packet arrives is calculated from an analytical model that considers the evolution in the queue occupation when the source doesn't generate traffic and when the source is in active state (remember that traffic is assumed to be bursty). The interaction between sources and the changes in the assigned capacity due to changes in traffic distributions are included. Delay tolerance of users is only represented by the maximum size allowed to the queue and no additional considerations are taken into account. A detailed description of the analytical models for queue and delay distribution can be found in [14].

The extension for an integration of several real time users with different BLER and rate requirement is immediate considering the effective capacity computed separately for each type of traffic. So, a linear approximation can be used to find the total resources required by all the MS's. When an integration of real time services with different delay requirements is considered, linear approximation has been shown to be also valid. However, it could be necessary, in some cases, to define a little reserve of capacity in order to prevent little deviations from the linear approximation. Note that the effective capacity associated to non real time services is calculated considering their mean bit rate in capacity $C_i$. In a first instance, we can consider a conventional CAC that allows a new user into the radio access network if condition (12) is satisfied.

$$\sum_{i\in cell} C_{i,ef} + C_{new,ef} < E[C_{max}] \qquad (12)$$

where $C_{new,\,ef}$ is the effective capacity of the new user.

## III. Call Admission Control Techniques

We have considered an adaptive CAC policy to evaluate the performance of the proposed CAC threshold. In order to protect handoff calls we perform variable resource reservations for handoff calls depending on the MS mobility behavior and we compare the results with a complete sharing approach.

Call admission decision is performed in a distributed manner near to that used in [12][13] for fixed capacity systems. Each BS makes an admission decision by exchanging state information with the adjacent cells periodically. BS's estimate the future MS handoffs using information of power and quality measurements reported by each MS. We assume that the power measurements will come from the current and adjacent cells. The control system knows which of the adjacent cells are potential candidates to handoff, especially when channel degradation becomes important. A MS placed in a degradation area, defined in the limits of the cell, has high probability to handoff within a time interval. Using information about the evolution in the power levels received by a MS in this region, it could be possible to predict in some cases the direction of movement of the MS and prevent in some cases unnecessary resource reservation.

Therefore, when a MS i is predicted to handoff, an indication of a capacity reserve equal to $C_{i,ef}$ is sent to the predicted destination in order to pre-allocate resources for the expected handoff. Reserves are interchanged periodically between cells. A reservation may be no longer required and cancelled. A handoff call, with effective capacity $C_{new\_handoff,ef}$, is accepted if:

$$\sum_{i\in cell} C_{i,ef} + C_{new\_handoff,ef} < E[C_{max}] \qquad (13)$$

whereas a new call is only admitted if:

$$\sum_{i\in cell} C_{i,ef} + C_{new,ef} + \sum_{j\in adj\_cells} C_{j,pr\_adj\_handoff} < E[C_{max}] \qquad (14)$$

where $C_{j,pr\_adj\_handoff}$ is the reserve of capacity associated to the MS's from the adjacent cells.

Note that handoff requests are treated equally independently whether specific MS had made a reservation or not. All the reserved capacity at any instant is used in a complete shared way to serve handoff requests. After a successfully handoff, the reserve of capacity, if available, is decreased in the corresponding $C_{i,ef}$.

## IV. Simulation Model and Results

We propose a cellular system model composed by 19 hexagonal cells (radius=2Km). Wrap-around technique is used to avoid border effect. Only interference from the first-tier of adjacent cells is considered. Macrocell propagation model proposed in [7] is adopted for path loss. Log-normally distributed shadowing with standard deviation of $\sigma = 8dB$ is added according with the model proposed in [8]. Additionally, a multi-path fading environment proposed in [9] is considered. 11dB antenna gain and thermal noise power of –103dBm are assumed [7]. MS's have a maximum output power of 27 dBm according with class 2 defined in [9], and move with a speed between 25 to 50Km/h. Initial localization is selected randomly (uniform distribution). MS can change its direction of movement within an angle of $\pm\pi/6$ each 1s and $2\pi$ each 20s.

Two kind of traffic sources: Real Time Services (Class I.1 and Class I.2 data services with delay constraints of 300 ms 150ms respectively) and Non-real Time Services (Class II - Data services with non-delay constraints) are considered. Convolutional coding rate ½ together with a retransmission scheme (ARQ) are used to achieve BLER=$10^{-2}$ in both cases. Real-time sessions are based on Packet Calls with a number of packets exponentially distributed with mean 35 packets (Class I.1) and 40 packets (Class I.2), while a service of 36kps (transport block of 360bits and real transmission rate of 120kbps) is assumed. Average inter-packet arrival time is 10ms, while packet call inter arrival time is exponentially distributed with mean 1s. On the other hand we assume that each user generates a single connection/call and connection/calls arrive to the system according to a Poisson process of intensity $\lambda$. Call length is exponentially distributed with mean 180s and a user leaves the system as soon as the call ends. Non-real time traffic sources are based on the model presented in [10]. 32Kbps data rate services have been considered.

We present some results in order to assess the performance of the connection admission control. Fig 1 compares the dropping probabilities computed with models (7) (Pr_delay_model) and (10) (Pr_drop_model) and simulations results when only class I.1 MS's are considered. Delay probability is far from dropping probability obtained in the simulation. However, the dropping probability calculated when delay tolerance is included in the model is very close to those obtained in the simulation. Similar results are obtained for Class I.2. Fig. 2 shows call admission limits when an integration of class I.1 and class I.2 and a dropping probability of 1% is considered as quality criterion (in this figure handoff has not been considered in simulations). In Fig. 4,5,6,7 computer simulations show, for the same combination of MS, the efficiency of the proposed CAC method both considering homogeneous (Fig. 4 and 6(a)) and heterogeneous traffic distributions in cells (Fig 5, 6(b) and 7) and mobility between cells.

Dropping probability is always maintained under quality constraints (Fig. 6a and 6b). On the other hand, variable reservation (Fig. 4 and 5) provides good results (handoff rate is near to $\lambda/4$.).

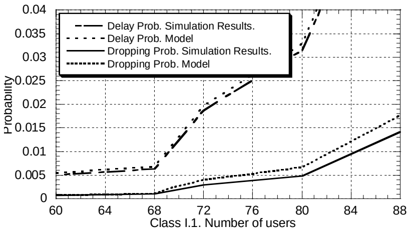


Fig. 1. Delay and packet dropping probability

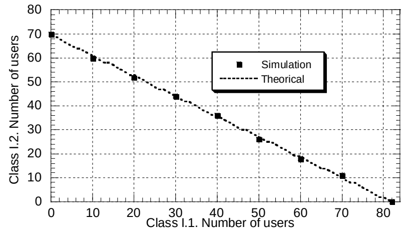


Fig. 2. CAC limits. Integration class I.1 and I.2.

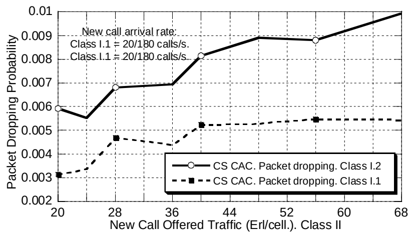


Fig. 3. Packet dropping probability considering an integration of real time and non real time services.

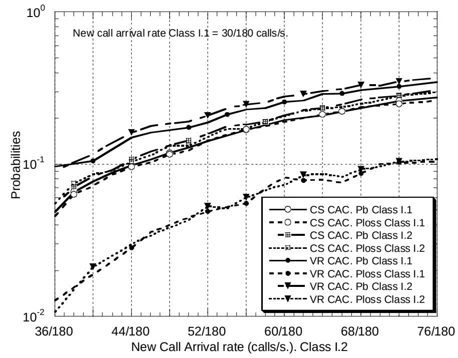


Fig. 4. CS vs VR CAC. New call blocking and handoff dropping probability vs. offered traffic.

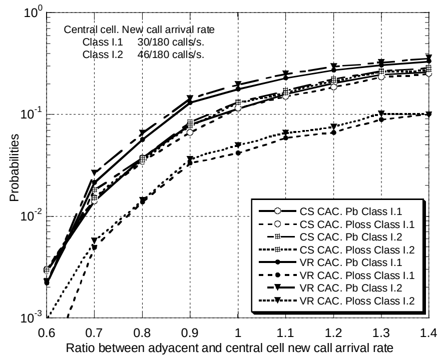


Fig. 5. CS vs VR CAC. New call blocking and handoff dropping probability considering heterogeneous traffic distribution in cells.

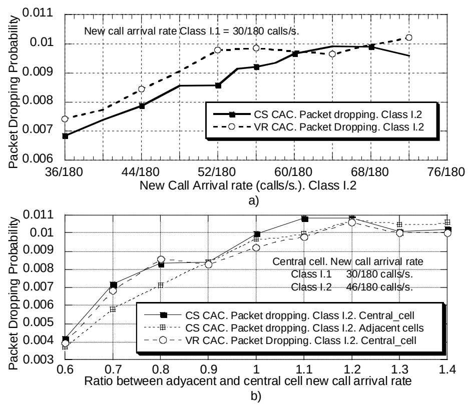


Fig. 6. CS vs VR CAC. Packet dropping probability considering homogeneous (a) and heterogeneous (b) traffic distribution in cells.

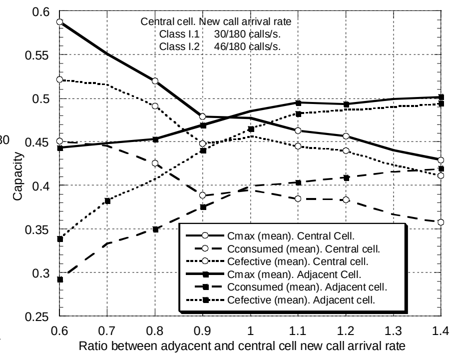


Fig .7. Distributions of available and consumed capacity considering heterogeneous traffic distribution in cells.

Fig. 7 shows the evolution of the available and consumed capacity in addition to the effective capacity computed when a heterogeneous traffic distribution is considered. Note that although Cmax capacity is different in cells, dropping probability (Fig. 6b) changes according with values shown in Fig. 7.

Similar results are obtained when an integration of real and no real time traffic is assumed (Fig. 3 shows dropping probability).

Although results are not shown here, the evaluation of the interference levels shows that an interference-based CAC in the way of [11] results in an underestimation of the capacity. Interference threshold must be set according with delay requirements of MS and adapted to take into account the time variations on traffic sources distributions.

## V. CONCLUSIONS

In this paper, we have evaluated the performance of a CAC method for the W-CDMA reverse link, where packet transmission has been considered for real time and non real time services. A centralized demand assignment protocol has been implemented in the packet level in order to provide QoS. Results obtained from packet level provide useful information in order to induce capacity bound. Delay constraints associated to individual traffic classes are considered in order to set an accurate threshold of CAC. The results show that the proposed CAC threshold guarantee a safe admission both considering uniform or non-uniform traffic distributions in cells, given that packet dropping probability is always maintained under the QoS constraints. On the other hand, the proposed variable reservation policy guarantees QoS and GoS.

## VI. ACKNOWLEDGMENTS

This work has been supported by the grants CICYT TIC2001-2481 and TIC2001-2222 from the Ministry of Science and Technology of Spanish Government and FEDER.

## VII. REFERENCES


[1] 3GPP TS 25.321 " MAC Protocol Specification",v.3.6, Dec. 2000.

[2] A. Hernández Solana, A. Valdovinos Bardají, F. Casadevall Palacio, "Performance Analysis of Packet Scheduling Strategies for Multimedia Traffic in WCDMA", Proc. IEEE VTC'2002 Spring.

[3] A. Sampath, S. Kumar and J. M. Holtzman, "Power Control and Resource Management for a Multimedia CDMA Wireless System", Proc. IEEE PIMRC'95.

[4] A. M. Viterbi and A. J. Viterbi, "Erlang Capacity of a power controlled CDMA system", IEEE JSAC, vol. 11, no. 3, Aug. 1993, pp. 892-900.

[5] Y. Ishikawa, N. Umeda, "Capacity Design and Performance of Call Admission Control in Cellular CDMA Systems", IEEE JSAC, vol. 15, no 8. Oct. 1997, pp 1627-1635.

[6] J. Q. J. Chak, W. Zhuang,, "Capacity Analysis for Connection Admission Control in Indoor Multimedia CDMA Wireless Communications". Wireless Personal Communications 12, 2000, pp. 269-282, Kluwer.

[7] 3GPP TS 25.942 "RF System Scenarios". v.3.1.0., Jun. 2001.

[8] A. J. Viterbi, A. M. Viterbi, "Soft handoff extends CDMA cell coverage and increases reverse link capacity", IEEE JSAC, vol. 12, no 8, Oct. 1994, pp. 1281-1287.

[9] 3GPP TS 25.101 " UTRA (UE) FDD; Radio Transmission and Reception", v.3.5.0, Mar. 2001.

[10] "Universal Mobile Telecommunications System (UMTS). Selection procedures for the choice of radio transmission technologies of the UMTS", UMTS Technical Report 30.03, v..3.2.0. Apr. 1998.

[11] H. Holma, A. Toskala, "WCDMA for UMTS. Radio Access For Third Generation Mobile Communications", John Wiley &Sons, 2000, pp. 215.

[12] M. Naghshineh, M. Schwartz, "Distributed Call Admission Control in Mobile/Wireless Networks", IEEE JSAC. vol. 14., no4, May 1996, pp. 711-717.

[13] M. Oliver Riera, "Admission Control Strategy Based on Variable Reservation For a Wireless Multi-Media Network.", Proc. WPMC'99.

[14] A. Hernández Solana, A. Valdovinos Bardají, F. Casadevall Palacio, "Capacity Analysis and Call Admission Techniques for CDMA Packet Transmission Systems", Proc. IEEE MWCN'2002.