On Managing Uplink Videophone and Web Browsing Traffic in UTRA W-CDMA

J. Pérez-Romero, O. Sallent, N. García, R. Agustí
Universitat Politècnica de Catalunya
C/ Jordi Girona, 1-3, 08034 Barcelona - Spain
E-mail :[jorperez, sallent, ramon @ tsc.upc.es]

Abstract— **This paper focuses on the interactions between uplink admission and congestion control strategies in UTRA W-CDMA. The proposed strategies are analysed in the framework of a representative multiservice scenario where conversational and interactive traffic are present and the presented solutions are compliant with 3GPP UTRA FDD specifications. Furthermore, the results consider a complete approach where all the Radio Resource Management strategies are taken into account, including admission, congestion, short term RRM, handover and power control feasible solutions. Therefore, obtained results allow to devise a range of guidelines for the joint design of RRM algorithms.**

I. INTRODUCTION

The broad range of services expected to be supported through 3G networks will exhibit diverse requirements in terms of Quality of Service (QoS). The provision of such mobile multimedia services will not be possible without a proper utilization of the air interface resources by means of Radio Resource Management (RRM) strategies that ensure the target QoS, the planned coverage area and offer a high system capacity. Definitively RRM strategies will play an important role in a mature UMTS scenario [1].

Taking into account the constraints imposed by the UTRAN radio interface architecture, the RRM functions are responsible of taking decisions regarding the setting of parameters such as the instantaneous bit rate, power level, code sequences, etc. RRM functions need to be consistent for both uplink and downlink, although the different nature of these links introduce some differences in the followed approach. In particular, RRM functions for the uplink include: 1) Admission control, to decide the admission or rejection of requests for set-up and reconfiguration of Radio Access Bearers (RAB), 2) Congestion control, to face situations in which the QoS guarantees are at risk due to the evolution of system dynamics (mobility aspects, increase in interference, traffic variability, etc.), 3) Short term RRM mechanisms, including a) UE-MAC algorithms, devoted to decide the suitable instantaneous Transport Format TF (or equivalently instantaneous bit rate) for a given RAB and b) Power control, whose purpose is to optimise the mobile transmitted power. To this end, power control is executed in two steps: i) Inner loop power control, responsible of adjusting the transmitted power on a fast time basis (1500 Hz) in order to reach the receiver with the required Eb/No target and ii) Outer loop power control, responsible of selecting a suitable Eb/No target depending on the BLER (BLock Error Rate) or BER (Bit Error Rate) requirement. Outer loop power control operates on a slower time basis than the inner loop power control. Finally, it must also be considered 4) Handover control, whose purpose is to optimise the cell or set of cells (i.e. the Active Set) to which the mobile is connected.

Within this context, this paper analyses the interactions between admission and congestion control algorithms. In order to attain the joint performance of both strategies, the remainder of uplink RRM strategies (i.e. short term, handover and power control feasible solutions) are also considered. Besides, the proposed strategies are studied in the framework of a representative multiservice scenario where conversational and interactive traffic are present. The presented approach will help to gain more insight into the general RRM problem and raise some interactions among different RRM strategies. Also, this proposal is compliant with 3GPP UTRA FDD specifications. The paper is organised as follows: in Section II a detailed definition of the proposed RRM strategies is provided. Section III presents the realistic simulation model that has been used for RRM evaluation and the obtained results are analysed in Section IV. Finally, Section V summarises the achieved conclusions.

II. DEFINITION OF UPLINK RRM STRATEGIES

II.A.- Admission Control

Uplink admission control is typically based on cell load factor monitoring [2]. Assuming that K users are already admitted in the system, the admission control algorithm considers the increment in the load factor that the new acceptance would originate. Therefore, the condition to be checked for the admittance of the (K+1)th request would be:

$$\eta_{UL} + \Delta\eta \le \eta_{\max} \qquad (1)$$

η_{UL} being the current estimation of the uplink cell load factor, $\Delta\eta$ being the estimated contribution demanded by the $(K+1)$th user and η_{max} the admission threshold.

II.B.- Congestion Control

For the uplink, congestion control is based on cell load factor measurements and attempts to counteract situations where this parameter reaches some limit that may cause problems to the different transmissions. The following parts are identified:

1. Congestion detection: it is assumed that the system has entered the congestion situation when the load factor remains

over a certain threshold during a certain amount of time, ΔT_{CD}, i.e. if $\eta \geq \eta_{CD}$ during a certain percentage *p* of the frames within ΔT_{CD}.

2. Congestion resolution. The congestion resolution algorithm executes a set of rules to lead the system out of the congestion status. Three steps are identified:

a. Prioritisation: Ordering the different users from lower to higher priority (i.e., from those that expect a lower grade of service to those with more stringent QoS requirements) in a prioritisation table.

b. Load reduction: Two main actions can be taken:

i. Selectively blocking new connections while in congestion

ii. Reducing the maximum transmission rate capabilities of delay-tolerant users already accepted in the network, beginning from the top of the prioritisation table.

c. Load check: After the previous actions, one would check again the conditions that triggered the congestion status. If congestion persists, one would continue with the following user in the prioritisation table. This step is carried out on a frame by frame basis. It is considered that the overload situation has been overcome if, during a certain amount of time ΔT_{CR} the load factor remains below the threshold η_{CR}, i.e. if $\eta \leq \eta_{CR}$ during a certain percentage *p* of the frames within ΔT_{CR}.

3. Congestion recovery: Once the congestion resolution phase decides that the congestion situation has been overcome, a congestion recovery algorithm is needed in order to restore to the different mobiles the transmission capabilities they had before the congestion was triggered. It is worth mentioning that such an algorithm is crucial because depending on how the recovery is carried out the system could fall again in congestion. The explored congestion recovery algorithm follows a "time scheduling" policy, restoring the former transmission capabilities on a user by user approach. This means that, until a user has not emptied his buffer, the next user is not allowed to restore the transmission capability.

II.C.- UE-MAC algorithms

This functionality is executed on a decentralized way at the MAC layer of each UE. Specifically, it is devoted to select the instantaneous Transport Format (or equivalently the instantaneous bit rate) for each RAB taking into account the expected QoS and the range of allowed transmission rates. Among the several possibilities for designing the UE-MAC algorithms, the so called Maximum Rate (MR) algorithm is considered, where the highest possible transmission rate is selected (provided that there are enough bits in the buffer waiting for transmission). It is worth mentioning that such a decentralized operation is devised in 3GPP specifications as a way to avoid the high amount of signaling that a centralized TF selection algorithm would require.

II.D.- Power Control

In UTRA FDD the UE required transmitted power and (E_b/N_o) target are set by the 1500 Hz fast closed loop power control and the outer loop power control, respectively, as explained in Section I.

II.E.- Handover

Handover procedures strongly affect the overall network performance, this being specially true in the case of the considered W-CDMA access mode because the behavior of users at the cell edge may largely influence the interference patterns. In the following, the reference algorithm defined in [3] will be retained.

III. SIMULATION MODEL

The performance of the above explained RRM algorithms has been evaluated through the use of a system level simulator that allows the support of a wide range of RABs, traffic models as well as deployment scenarios. Selected services and corresponding transport channels are selected from [4]: conversational (DCH, 64 kb/s with spreading factor SF=16) and interactive (DCH, TF0 is not transmitting, TF1 is 16 kb/s with SF=64, TF2 is 32 kb/s with SF=32, TF3 is 48 kb/s with SF=16 and TF4 is 64kb/s with SF=16). The mobility model and propagation models are defined in [5]. Traffic models are defined in [6]. The physical layer characterisation is obtained through a link level simulator that feeds the system level simulator with the transport block BLER statistics for each average (E_b/N_o) [7]. The considered scenario is summarised in Table I.

IV. RESULTS

Since RRM strategies modify the network behaviour, the methodology that has been followed in this approach begins with a higher degree of freedom (i.e. few RRM algorithms are applied) and progressively includes more constraints (i.e. more RRM mechanisms are activated) trying to identify the influence of each strategy by avoiding mixing effects.

IV.A.- UE-MAC algorithms

As a preliminary result, it is obtained that for the MR algorithm with interactive service, the source activity factor is 10%, the activity factor at the radio interface is 4% and the average spreading factor is 18. These parameters are relevant in order to set a proper load factor estimation in the admission control.

IV.B.- Congestion control

In this section some results to attain the key congestion control parameters to be taken into account are presented. To this end, no admission control is still considered. The interesting performance figures and compared policies are: 1) When the congestion status is triggered in the cell two different policies can be considered and will be compared a) Blocking new conversational requests during the congestion period and b) Not blocking new conversational requests during the congestion period; 2) Different thresholds can be used for triggering and releasing the congestion status: a) Low values (η_{CD}=0.75 and η_{CR} =0.6) and b) High values (η_{CD}=0.9 and η_{CR} =0.75); 3) Different observation periods can be considered before triggering the congestion recovery phase: a) Low values (ΔT_{CR} =0.1s or ΔT_{CR} =1s) and b) High values (ΔT_{CR} =10s) .

In all the cases, it has been assumed ΔT_{CD} =0.1s and a percentage of time *p*=90% to trigger the different events, which from previous simulations (not shown for the sake of brevity) reveal to be suitable values. The results for the different possibilities are shown in Table II. Notice that, although no admission control algorithm is considered here, admission probability is not 100% because during congestion periods all interactive requests are rejected and, depending on the considered policy, also conversational requests may be rejected.

TABLE I SIMULATION PARAMETERS

Scenario size	2.25 km x 2.25 km
Chip Rate W	3.84 Mcps
Frame duration	10 ms
BS parameters	
Cell radius	500 m
Cell type	Omnidirectional
Maximum tx power	43 dBm
Thermal noise	-106 dBm
Shadowing deviation	10 dB
Shadowing decorrelation	20 m
UE parameters	
Maximum tx power	21 dBm
Minimum tx power	-44 dBm
Thermal noise	-100 dBm
Mobile speed	50 km/h
HO parameters (convers)	
Active Set maximum size	2
AS_Th	5 dB
AS_Th_Hyst	1 dB
AS_Rep_Hyst	1 dB
Time to Trigger Handover	1 measur. period
Measurement period	0.5s
HO parameters (interac.)	
Active Set maximum size	1
AS_Rep_Hyst	1 dB
Time to Trigger Handover	1 measur. period
Measurement period	0.5s
QoS parameters (conver.)	
BLER target	1%
Eb/No target	4.57 dB
QoS parameters (interac.)	
BLER	1%
Eb/No target	4.69 dB

From Table II, it can be observed that, with respect to the no congestion control case, in this case obviously all conversational and interactive requests are accepted. Then, if the system dynamics evolves freely, the conversational BLER as well as the interactive BLER increase significantly beyond the target value. However, the impact on interactive users is almost negligible because the required retransmissions only increase the average packet delay very slightly. When congestion control policies are adopted, the expected effects are a BLER reduction for conversational users, an average packet delay increase for interactive users (because congestion control reduces the bit rate of interactive users) and, in case that requests are blocked during congestion periods, a reduction of the admission probability.

With respect to the congestion resolution period ΔT_{CR}, it can be observed that a safe congestion resolution period of ΔT_{CR}=10s severely penalizes the admission rate of interactive users. If conversational users are also blocked during the congestion period, a dramatic reduction of the conversational admission probability is also found. We note that a high value of ΔT_{CR} makes system-declared congestion situations last longer. Also a safe congestion resolution period of ΔT_{CR}=10s penalizes severely the average packet delay of interactive traffic, because transmission rate capabilities of interactive users are restricted during longer periods. At the same time, this period is able to keep the conversational BLER closer to its target value. Finally, a short congestion resolution period of ΔT_{CR}=0.1s provides higher admission rates and a lower average interactive packet delay at the expense of a higher conversational BLER, which may raise up to 1.31% in some of the analyzed cases. This BLER increase occurs because the congestion situations are not so well controlled (it can be decided after ΔT_{CR}=0.1s that the congestion has been overcome while in a short period of time the algorithm is likely to trigger again congestion).

With respect to either blocking or not conversational users during congestion periods, a significant gain is obtained in terms of conversational users admission probability if conversational users are not blocked during congestion periods. The admission probability of interactive users remains similar for both cases. Conversational BLER and interactive delay are not significantly affected by the acceptance of new conversational users during congestion periods. Therefore it is advisable not to block conversational users during congestion periods.

With respect to the congestion cell load triggering thresholds η_{CD} and η_{CR} , it can be observed that, since η_{CD}=0.9 and η_{CR}=0.75 constitute late congestion triggers compared to η_{CD}=0.75 and η_{CR}=0.6, the conversational BLER degrades more in the former case, BLER=1.31%, than in the later BLER=1.15% (i.e. when the system triggers congestion, the cell load has already remained at high values for a certain period of time and this has caused some erroneous transmissions). On the other hand, the late detection avoids some interactive users to be blocked and, consequently, in the former case a higher interactive admission probability is found. In turns, for the late detection case of η_{CD}=0.9 and η_{CR}=0.75 a lower interactive average packet delay is obtained.

This is because interactive delay is more degraded because of the congestion control actions (i.e. restricted transmission capabilities) than because of packet retransmissions due to too much load.

Additionally, other traffic mix situations have also been studied (not shown for the sake of brevity). Comments applicable to this case are similar to the ones given above.

TABLE II PERFORMANCE FIGURESFOR DIFFERENT CONGESTION CONTROL POLICIES AND PARAMETERS

3.5 sessions/s interactive 20 Erlangs conversational			**Admission Convers. (%)**	**Admission Interact. (%)**	**BLER Convers. (%)**	**BLER Interact. (%)**	**Delay Interact. (s)**
No Congestion control			100	100	2.40	5.67	0.14
η_{CD}=0.75 η_{CR} =0.6	ΔT_{CR}=0.1s	No block.	100	58	1.15	1.45	0.48
		Block.	93	57	1.14	1.47	0.47
	ΔT_{CR}=1s	No block.	100	44	1.08	1.29	1.34
		Block.	69	48	1.08	1.30	1.12
	ΔT_{CR}=10s	No block.	100	26	1.05	1.13	5.11
		Block.	42	37	1.02	1.14	3.14
η_{CD} =0.9 η_{CR}=0.75	ΔT_{CR}=0.1s	No block.	100	68	1.31	1.97	0.31
		Block.	96	68	1.31	2.00	0.29
	ΔT_{CR}=1s	No block.	100	58	1.18	1.62	0.68
		Block.	80	58	1.17	1.67	0.66
	ΔT_{CR}=10s	No block.	100	42	1.09	1.35	2.61
		Block.	52	49	1.09	1.33	1.83

IV.C.- Admission control

In order to study the mutual effects between admission and congestion control, Figure 1 to Figure 4 show the relevant performance measurements when analyzing the system under different congestion resolution thresholds (η_{CD}=0.75/η_{CR}=0.6 and η_{CD}=0.9/η_{CR}=0.75) and different admission thresholds (η_{max}=0.6 and η_{max}=0.75). In these figures the notation adm(η_{max}) has been used to indicate the admission threshold and cong(η_{CD}-η_{CR}) to indicate the congestion thresholds. Also ΔT_{CR}=1s, ΔT_{CD}=0.1s, p=90% and no blocking of conversational users have been assumed for the congestion control. Simulations include a service mix with 20 Erlangs of conversational offered load and different interactive offered loads.

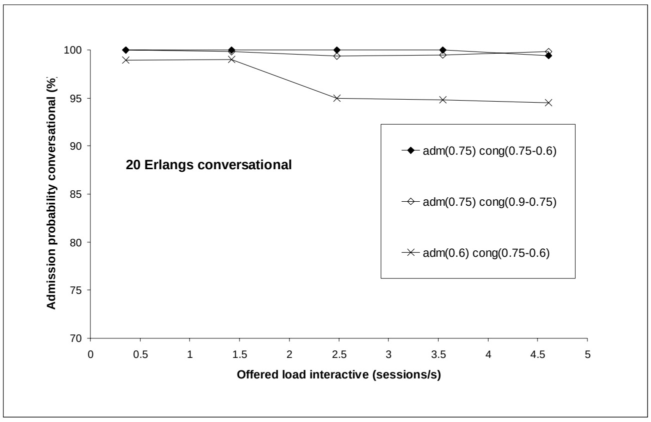

Figure 1. Conversational admission probability for different congestion and admission thresholds.

With respect to conversational users it can be observed that a late congestion activation (η_{CD}=0.9, η_{CR} =0.75) is worse than an early congestion activation (η_{CD}=0.75, η_{CR} =0.6). Notice in Figure 2 that a higher BLER is obtained in the former case. This is because real network congestion has a more direct impact on the conversational users (the load increase causes packet losses and therefore the BLER may raise up from the target value). So early congestion activation will prevent the network from affecting conversational service. With respect to admission, and since conversational users are not blocked during congestion periods, the main parameter affecting this figure is η_{max}. Clearly, Figure 1 reveals that a low value like η_{max}=0.6 leads to poor admission rates without introducing a significant improvement in terms of BLER (see Figure 1 and Figure 2).

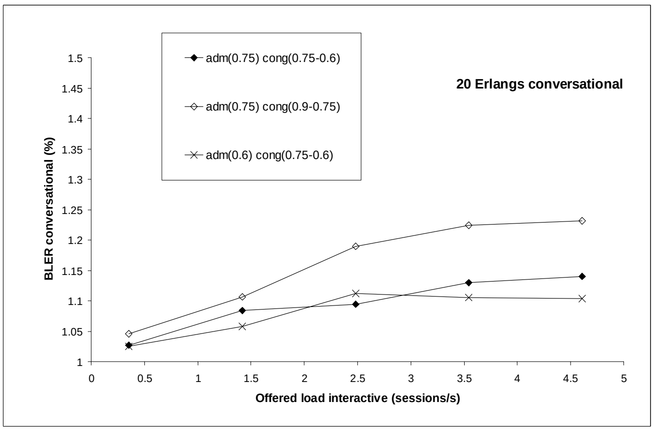

Figure 2. BLER of conversational users for different congestion and admission thresholds.

With respect to interactive users it can be observed that in the current traffic mix scenario with 20 Erlangs of conversational traffic and, since interactive users provide more flexibility to manage the radio resources, their performance is greatly dependant on the congestion control scheme. The point is that most of the interactive users rejections are due to the fact that during congestion periods no interactive requests are accepted. As a result, the interactive users performance mainly depends on how congestion situations are managed. If the congestion control thresholds are set to η_{CD}=0.75 and η_{CR} =0.6, the resulting interactive admission probability as well as the average packet delay are the same either for η_{max}=0.75 or for η_{max}=0.6, as it can be seen in Figure 3. On the contrary, if the congestion control thresholds are set to η_{CD}=0.75 and η_{CR}=0.6, since interactive admission is mostly related with congestion control, the admission probability is improved. Something similar occurs when looking at the average packet delay (see Figure 4): a late congestion activation (η_{CD}=0.9 and η_{CR} =0.75) is better than an early congestion activation (η_{CD}=0.75 and η_{CR} =0.6) for interactive users. This is because the real network congestion has a limited impact on interactive traffic (delay increases only slightly due to packet retransmissions) while declared network congestion (that is, situations where the RRM triggers congestion control mechanisms) has a strong impact on interactive traffic (RRM blocks interactive users during this period and users already in the system are forced to limited transmission capabilities with the consequent packet delay increase).

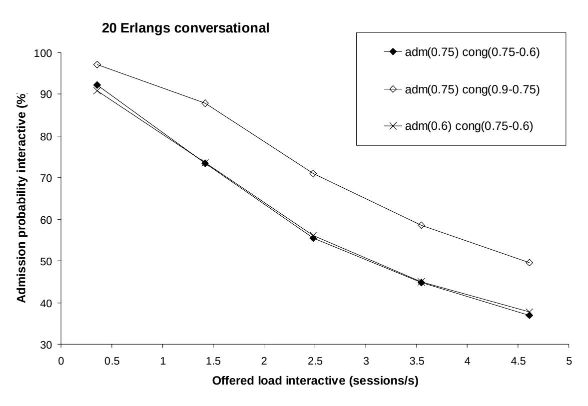

Figure 3. Interactive admission probability for different congestion and admission thresholds.

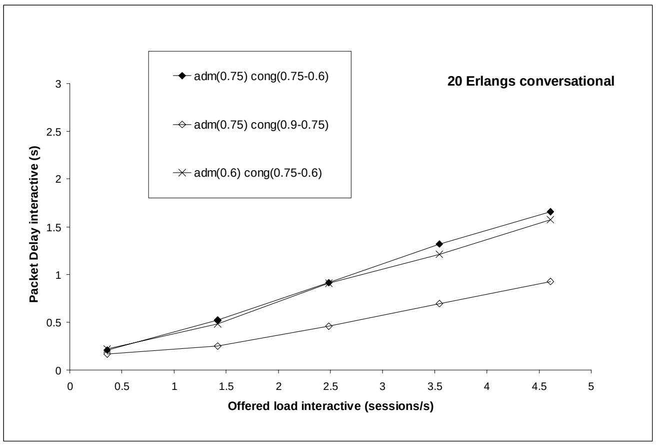

Figure 4. Average packet delay for different congestion and admission thresholds.

V. CONCLUSIONS

This paper has analysed the interactions between admission and congestion control algorithms in a W-CDMA network by providing a complete framework for RRM and proposing solutions for all the different RRM functions in the uplink direction, namely admission control, congestion control and UE-MAC algorithms and also considering connection level strategies such as handover and power control. The different strategies have been evaluated in a representative scenario where conversational and interactive users are mixed. The presented solutions are aligned with the current standardization fora (i.e. 3GPP) and have been evaluated in realistic scenarios by means of simulations. The relevant parameters that influence RRM strategies have been identified, together with the system's sensitivity to these parameters. Specifically, results have shown that, on the one hand, it is interesting not to block conversational users during congestion periods. On the other hand, with respect to the setting of admission and congestion thresholds, as well as the setting of the time to trigger the congestion recovery, it has been observed that conversational users benefit from early congestion activation mechanisms and long times to trigger recovery thus achieving a lower BLER. On the contrary, for interactive users late congestion activation and shorter triggering times improve performance in terms of delay and admission.

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