UPLINK RRM FOR CONVERSATIONAL AND INTERACTIVE SERVICES IN UTRA-FDD

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Abstract The definition and assessment of suitable Radio Resource Management (RRM) strategies able to provide a required QoS in the framework of the UTRA segment of UMTS is a key issue for achieving the expectations created on 3G technology. This paper evaluates specific algorithms for the admission control of a new connection and UE-MAC strategies for the dynamic management of the transmission parameters. Conversational and interactive-like services are studied. Results reveal that the behaviour of the different proposed UE-MAC algorithms in the uplink has an impact on the admission phase and, consequently, they should be taken into account for a proper admission control algorithm design.

1. INTRODUCTION

W-CDMA access networks, such as the considered in UTRA-FDD proposal [1], provide an inherent flexibility to handle the provision of future 3G mobile multimedia services. 3G will offer an optimization of capacity in the air interface by means of efficient algorithms for Radio Resource and QoS Management. RRM entity is responsible for utilization of the air interface resources and covers power control, handover, admission control, congestion control and packet scheduling [2]. These functionalities are very important in the framework of 3G systems because the system relies on them to guarantee a certain target QoS, to maintain the planned coverage area and to offer a high capacity. RRM functions are crucial because in W-CDMA based systems there is not a constant value for the maximum available capacity, since it is tightly coupled to the amount of interference in the air interface. Moreover, RRM functions can be implemented in many different ways, this having an impact on the overall system efficiency and on the operator infrastructure cost, so that definitively RRM strategies will play an important role in a mature UMTS scenario. Additionally, RRM strategies are not subject of standardisation, so that they can be a differentiation issue among manufacturers and operators.

To cope with a certain QoS a bearer service with clearly defined characteristics and functionality must be set up from the source to the destination of the service, maybe including not only the UMTS network but also external networks. Within the UMTS bearer service, the role of the Radio Bearer Service is to cover all the aspects of the radio interface transport and this will be the focus of the present paper.

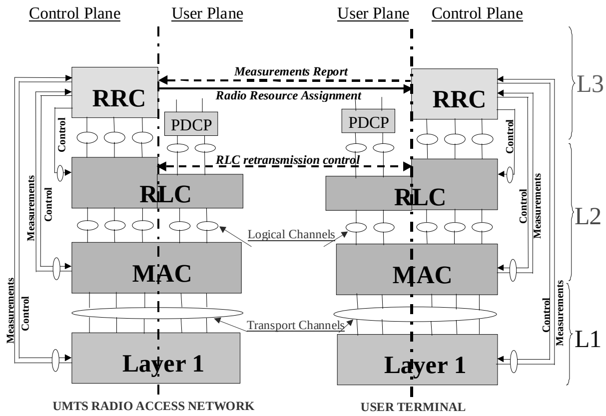

Figure 1. UTRA radio interface protocol stack.

The radio interface of the UTRA is layered into three protocol layers: the Physical Layer (L1), the Data link Layer (L2) and the Network Layer (L3). Additionally, the layer 2 is split into two sub-layers, the Radio Link Control (RLC) and the Medium Access Control (MAC). On the other hand, the RLC and layer 3 protocols are partitioned in two planes, namely the User plane and the Control plane. In the Control plane, Layer 3 is partitioned into sublayers where only the lowest sublayer, denoted as Radio Resource Control (RRC), terminates in the UTRAN, as Figure 1 shows.

Connections between RRC and MAC as well as RRC and L1 provide local inter-layer control services and allow the RRC to control the configuration of the lower layers. In the MAC layer, logical channels are mapped to transport channels. A transport channel defines the way in which traffic from logical channels is processed and sent to the physical layer. The smallest entity of traffic that can be transmitted through a transport channel is a Transport Block (TB). Once in a certain period of time, called Transmission Time Interval (TTI), a given number of TB will be delivered to the physical layer in order to introduce some coding characteristics, interleaving and rate matching to the radio frame. The set of specific attributes are referred as the Transport Format (TF) of the considered transport channel. Note that the different number of TB transmitted in a TTI indicates that different bit rates are associated to different TF. As the UE may have more than one transport channel simultaneously, the Transport Format Combination (TFC) refers to the selected combination of TF. The network assigns a list of allowed TFC to be used by the UE in what is referred as Transport Format Combination Set (TFCS).

It is worth mentioning that for the optimisation of the radio interface utilisation, RRM functions should consider the differences among the different services, not only in terms of QoS requirements but also in terms of the nature of the offered traffic, bit rates, etc. The RRM functions include:

1. Admission control: it controls requests for setup and reconfiguration of radio bearers.
2. Congestion control: it faces situations in which the system has reached a congestion status and therefore the QoS guarantees are at risk due to the evolution of system dynamics (mobility aspects, increase in interference, etc.).
3. Mechanisms for the management of transmission parameters: are devoted to decide the suitable radio transmission parameters for each connection (i.e. TF, target quality, power, etc.).
4. Code management: for the downlink it is devoted to manage the OVSF code tree used to allocate physical channel orthogonality among different users.

Within the UMTS architecture, RRM algorithms will be carried out in the Radio Network Controller (RNC). Decisions taken by RRM algorithms are executed through Radio Bearer Control Procedures (a subset of Radio Resource Control Procedures) such as [3]:

1. Radio Bearer Set-up.
2. Physical Channel Reconfiguration.
3. Transport Channel Reconfiguration.

3GPP has provided a high degree of flexibility to carry out the RRM functions, so that the parameters that can be managed are mainly:

1. TFCS (Transport Format Combination Set), which is network controlled and used for Admission Control and Congestion Control.
2. TFC (Transport Format Combination), which in the case of the uplink is controlled by the UE-MAC
3. Power, as the fundamental physical parameter that must be set according to a certain quality target (defined in terms of a SIRtarget) and taking into consideration the spreading factor used and the impact of all other users in the system and their respective quality targets.
4. OVSF (Orthogonal Variable Spreading Factor) code

In the above framework, this paper focuses on the admission control and the mechanisms for the management of transmission parameters for conversational and interactive services carried out at UE-MAC in the uplink direction. It is worth mentioning that the problem of QoS provisioning for multimedia traffic has gained interest in the literature in recent years, as the problem arises in the context of 2.5G and 3G systems and is not present in 2G systems. Thus, Naghshineh and Acampora [4] introduced resource sharing schemes for QoS guarantee to different service classes in microcellular networks. Akyildiz et al. [5] proposed the so-called WISPER protocol, scheduling the transmissions according to their BER requirements. Das et al. [6] developed a general framework for QoS provisioning by combining call admission control, channel reservation, bandwidth reservation and bandwidth compaction. Lately, Dixit et al. [7] among others have discussed the evolution scenarios from 2G to 3G networks and the QoS network architecture proposal by 3GPP for UMTS. For the decentralized uplink RRM component, proposals such as the ones presented in [8] could be adapted to the UTRA-FDD framework. In this respect, few studies aligned to the 3GPP specifications are available in the open literature [9-11]. For the admission control several schemes have been suggested for the uplink [12, 13] under different conditions and at a lower extent for the downlink [14]. More recently, Ho et al. [15] have built mathematical models for various call admission schemes and have proposed an effective linear programming technique for searching a better admission control scheme. The admission approach presented in this paper is innovative in the sense that the admission procedure in the uplink is related to the decentralised algorithm applied at UE-MAC level and the relevance to take this fact into account is pointed out.

The rest of the paper is organised as follows. Section 2 details the uplink RRM approach by proposing two different UE-MAC algorithms and a statistical-based admission control strategy. Section 3 details the simulation model used to evaluate the strategies through system level simulation in Section 4, where some basic assumptions concerning congestion control are introduced. Finally, Section 5 summarises the obtained results.

2. UPLINK RRM

RRM strategies have to be applied in a consistent way to both uplink and downlink. Focusing in the uplink direction, centralized solutions (i.e. RRM algorithms located at the RNC) may provide better performance compared to a distributed solution (i.e. RRM algorithms located at the UE) because much more RRM relevant information related to all users involved in the process may be available at the RNC. In return, executing decisions taken by RRM algorithms would be much more costly in terms of control signalling because in this case UE must be informed about how to operate. Consequently, strategies face with the performance/complexity trade-off, which usually finds a good solution in an intermediate state where both centralized and decentralized components are present. 3GPP approach for the uplink could be included in this category, as it can be divided in two parts:

1. Centralized component (located at RNC). Admission and congestion control are carried out.
2. Decentralized part (located at UE-MAC). This algorithm autonomously decides a TF (or TFC if combination of RABs exists) within the allowed TFCS for each TTI, and thus operates at a “short” term in order to take full advantage of the time varying conditions.

The expected effects of applying RRM strategies can be better explained by comparison with the situation where there is not a tight control of the use of radio resources, for example in a W-CDMA packet network in the uplink direction such as the ones considered in [16, 17]. The typical uplink behavior of such a network expressed in terms of throughput and delay is shown in Figure 2. Two regions can be distinguished: in region A the offered load is low and the interference is also low, so that packets are correctly transmitted, whereas in region B the offered load is high and the interference is also high, so that packets are incorrectly transmitted and the throughput decreases at the time that delay increases due to retransmissions. This behaviour is due to the lack of coordination among mobile terminals. Despite in strict sense the W-CDMA networks considered in [16, 17] are inherently unstable due to the random access mechanism, in practice the system operation point may provide a controlled performance.

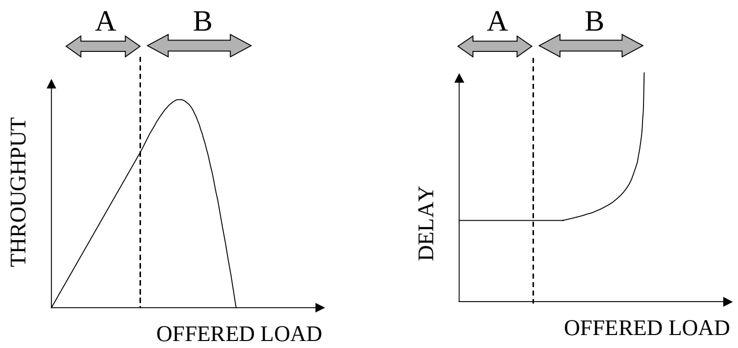

Figure 2. Operation with no RRM (i.e. S-ALOHA W-CDMA network).

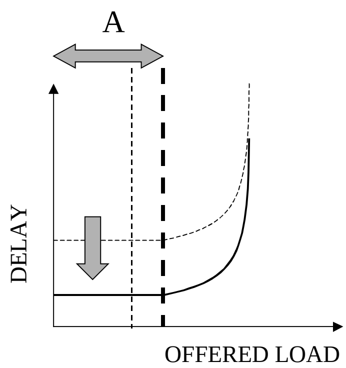

Figure 3. Operation when RRM strategies are applied to a W-CDMA network.

In case of applying RRM, the purpose of admission and congestion control would be to keep the system operation point in the region A, otherwise the system becomes unstable and no QoS can be guaranteed. Smart admission and congestion control strategies will shift region A at some extent to the right side, so the system capacity is increased. Additionally, the performance achieved under region A is dependant on the access mechanism and in some cases it could happen that the system operation is access-limited instead of the more efficient case, which is interference-limited. A suitable UE-MAC strategy should try to take full advantage of the load conditions by pushing the system into a interference-limited situation, which in turns provides a performance improvement in terms of delay (see Figure 3) because active users could transmit at a higher rate. The challenge is to achieve a good balance between improving the performance (for example in terms of decreasing the delay under low load situations by increasing the transmission rate) and maintaining the interference level manageable by the congestion and admission control algorithms. Moreover, RRM can control and exchange the gain levels between capacity and delay: if desired the admission region can be extended at the expense of some reduction in the delay gain or the reverse, the delay gain can be increased at the expense of some reduction in the admission region.

2.1. Admission control

Within a CDMA cell, all users share the common bandwidth and each new connection increases the interference level of other connections, affecting their quality expressed in terms of a certain (E_b/N_o). For n users transmitting simultaneously at a given cell, the following inequality must be satisfied [18]:

$$\frac{P_i \times SF_i}{P_N + \chi + [P_R - P_i]} \geq \left(\frac{E_b}{N_o}\right)_i \qquad i=1..n \qquad (1)$$

$$P_R = \sum_{i=1}^{n} P_i \qquad (2)$$

where P_i is the k-th user received power at the base station, SF_i is the i-th user spreading factor, P_N is the thermal noise power, χ is the intercell interference and $(E_b/N_o)_i$ stands for the i-th user requirement. P_R is the total received own-cell power at the base station. Implicitly in the above inequalities a certain received power level is assumed in each case:

$$P_i \geq \frac{P_N + \chi + P_R}{\dfrac{SF_i}{\left(\dfrac{E_b}{N_o}\right)_i} + 1} \qquad i=1..n \qquad (3)$$

Adding all n inequalities it holds:

$$\sum_{i=1}^{n} P_i = P_R \geq \sum_{i=1}^{n} \frac{P_N + \chi + P_R}{\dfrac{SF_i}{\left(\dfrac{E_b}{N_o}\right)_i} + 1} \qquad (4)$$

$$P_R \geq \frac{(P_N+\chi)\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1}}{1-\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1}} \Rightarrow P_R = \frac{(P_N+\chi)\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1}}{1-\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1}} \quad (5)$$

Claiming in (5) for the inherent positivity of P_R (i.e. $P_R>0$) leads to:

$$\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1} < 1 \quad (6)$$

Claiming in (5) for the inherent positivity of χ (i.e. $\chi>0$) leads to:

$$\left(1+\frac{P_N}{P_R}\right)\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1} < 1 \quad (7)$$

Claiming in (5) for the inherent positivity of P_N (i.e. $P_N>0$) leads to:

$$\left(1+\frac{\chi}{P_R}\right)\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1} < 1 \quad (8)$$

The later expression is commonly known as the load factor [19]. The load factor measures the theoretical spectral efficiency of a W-CDMA cell:

$$\eta = \left(1+\frac{\chi}{P_R}\right)\sum_{i=1}^{n}\frac{1}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1} = \frac{P_R+\chi}{P_R+\chi+P_N} \quad (9)$$

Notice that η<1 is equivalent to claim that P_N>0 and so η<1 is the same expression as (8). Introducing the definition of the load factor η, (3) can be expressed as:

$$P_i \geq \frac{(P_N + \chi + P_R)}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i} + 1} = \frac{P_N \frac{1}{1-\eta}}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i} + 1} \qquad i=1..n \tag{10}$$

where it can be observed that as the load factor increases the power demands also increase. Consequently, and due to the limited power available at mobile terminals and also for efficiency reasons the cell load factor must be controlled. Admission control is one of the RRM strategies devoted to achieve such an objective.

The admission control procedure is used to decide whether to accept or reject a new connection depending on the interference (or load) it adds to the existing connections. Therefore, it is responsible for deciding whether a new RAB (Radio Access Bearer) can be set-up and which is its allowed TFCS. Admission control principles make use of the load factor and the estimate of the load increase that the establishment of the bearer request would cause in the radio network. From the implementation point of view, admission control policies can be divided into modeling-based and measurement-based policies [20]. In case the air interface load estimation is based on measurements and assuming that *K* users are already admitted in the system, the *(K+1)*th request should verify:

$$\eta + \Delta\eta \leq \eta_{\max} \text{ with } \eta = \frac{P_R + \chi}{P_R + \chi + P_N} \text{ and } \Delta\eta = \frac{1 + \frac{\chi}{P_R}}{\frac{SF_{K+1}}{v_{K+1} \cdot \left(\frac{E_b}{N_o}\right)_{K+1}} + 1} \tag{11}$$

v_{K+1} being the activity factor of the *(K+1)*th traffic source. In the case of the voice service this factor is typically set to 0.67. For interactive services, like www surfing, this factor should be estimated on a service by service basis.

Capacity and coverage are closely related in W-CDMA networks, and therefore both must be considered simultaneously. In the measurement based approach η_{max} is obtained from radio network planning so that coverage can be maintained. The coverage problem is directly related to the power availability, so that the power demands deriving from the system load level should be in accordance with the planned coverage. So, it must be satisfied that the required transmitted power will be lower than P_{Tmax} allowed and high enough to be able to get the required *(Eb/No)* target even at the cell edge:

$$P_{T,i} = L_p(d_i)\frac{(P_N + \chi + P_R)}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1} = L_p(d_i)\frac{P_N \frac{1}{1-\eta}}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1} \quad \text{i=1..n} \tag{12}$$

$$P_{T,máx} = L_p(R)\frac{P_N \frac{1}{1-\eta_{\max}}}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i}+1} \quad \text{i=1..n} \tag{13}$$

$P_{T,i}$ being the power transmitted by the i-th user, $L_p(d_i)$ the path loss (including shadowing effects) at distance d_i R the cell radii and η_{max} the maximum allowable load factor for assuring coverage. The term $1/(1-\eta)$ is known as the interference margin.

In case the air interface load is estimated in statistical terms it is the cell throughput which is maintained and cell breathing effects may arise due to the fact that intercell interference can not be directly and precisely included. For the statistical-based approach and assuming that K users are already admitted in the system, the *(K+1)*th request should verify:

$$(1+f)\sum_{i=1}^{K}\frac{1}{\frac{SF_i}{v_i\cdot\left(\frac{E_b}{N_o}\right)_i}+1} + (1+f)\frac{1}{\frac{SF_{K+1}}{v_{K+1}\cdot\left(\frac{E_b}{N_o}\right)_{K+1}}+1} \le \eta_{\max} \tag{14}$$

where other-cell interference power is modeled as a fraction of the own-cell received power ($\chi = f \times P_R$). According to (14) different admission strategies arise by balancing the following parameters:

- The spreading factor: by setting SF_i as an estimated average value the user will adopt along its connection time the assumed load will be closer to the real situation at the expense of relying on the statistical traffic multiplexing. In turns, considering SF_i as the lowest SF in the defined RAB covers the worst case at the expense of overestimating the impact of every individual user and, consequently, reducing the capacity.
- The activity factor of the traffic source: by setting v_i <1 the admission procedure can be closer to the real situation of discontinuous activity (typical in interactive-like services) at the expense of relying on the statistical traffic multiplexing. In turns, v_i =1 covers the worst case at the

expense of overestimating the impact of every individual user and, consequently, reducing the capacity.

- The overall load level: by setting η_{max} the admission procedure allows for some protection against traffic multiplexing situations above the average (for example having more active connections than the expected average number, or having more users making use of low SF than the expected number).

2.2. UE-MAC strategy

For the conversational service, the UE-MAC strategy is straightforward because the service is of constant bit rate nature, so that the UE will transmit at every frame at the same bit rate. For interactive-like services (e.g. WWW browsing), two specific algorithms are proposed:

2.2.1. Maximum Rate (MR) algorithm

It consists on selecting the TF that allows the highest transmission bit rate according to the amount of bits L_b to be transmitted. Thus, the number of transport blocks to be transmitted in a TTI would be:

$$numTB = \min\left(TB\max, \left\lceil \frac{L_b}{TBsize} \right\rceil \right) \qquad (15)$$

TBmax being the maximum number of Transport Blocks that can be transmitted per TTI and *TBsize* being the number of bits per Transport Block.

2.2.2. Service credit (SCr) algorithm

When a certain mean bit rate should be guaranteed, a new possibility arises that makes use of the "service credit" (SCr) concept. The SCr of a connection accounts for the difference between the obtained bit rate (measured in TB per TTI) and the expected bit rate for this connection. Essentially, if SCr < 0 the connection has obtained a higher bit rate than expected, if SCr > 0 the connection has obtained a lower bit rate than expected. At the beginning of the connection: SCr(0)=0. In each TTI, the SCr for a connection should be updated as follows:

$$SCr(n) = SCr(n-1) + (Guaranteed\_rate / TB\_size) - Transmitted\_TB(n-1) \qquad (16)$$

where *SCr(n)* is the Service Credit for TTI=*n*, *SCr(n-1)* is the Service Credit in the previous TTI, *Guaranteed_rate* is the number of bits per TTI that would be transmitted at the guaranteed bit rate, *TB_size* is the number of bits of the Transport Block for the considered RAB, *Transmitted_TB(n-1)* is the number of successfully transmitted Transport Blocks in the previous TTI.

The quotient *Guaranteed_rate/TB_size* reflects the mean number of transport blocks that should be transmitted per TTI in order to keep the guaranteed mean bit rate. As a result, *SCr(n)* is a measure of the number of Transport Blocks that the connection should transmit in the current TTI to keep the guaranteed bit rate. For example, if *TB_size*=240 bits, *Guaranteed_rate*=24 Kb/s, and TTI=20 ms, the UE adds 2 service credits each TTI.

Then, assume that in the buffer there are L_b bits, the number Transport Blocks to be transmitted in the current TTI=n would be:

$$numTB = min\left(\left\lceil \frac{L_b}{TBsize} \right\rceil, SCr(n), TBmax\right) \tag{17}$$

Once *numTB* is calculated, the determination of TF is straightforward.

3.- SYSTEM MODEL

The radio access bearer considered for supporting the interactive service has a maximum bit rate of 64 Kbps in the uplink and an associated 3.4 Kbps signalling radio bearer [21]. The radio access bearer selected for videophone service has a constant bit rate of 64 Kbps when transmitting [21]. TB error rate target is 0.5%. Possible transport formats are detailed in Table 1.

Table 1. Transport formats for the considered RABs.

Service		WWW	VIDEOPHONE
TrCH type		DCH	DCH
TB sizes, bit		336 (320 payload, 16 MAC/RLC header)	640
TFS	TF0, bits	0×336	0×640
	TF1, bits	1×336 (16 Kb/s, SF=64)	2×640 (64 Kb/s, SF=16)
	TF2, bits	2×336 (32 Kb/s, SF=32)	-
	TF3, bits	3×336 (48 Kb/s, SF=16)	-
	TF4, bits	4×336 (64 Kb/s, SF=16)	-
TTI, ms		20	20

The interactive traffic model considers the generation of activity periods (i.e. pages for www browsing), where several information packets are generated, and a certain thinking time between them, reflecting the service interactivity. The specific parameters are: average thinking time between pages 30 s, average number of packet arrivals per page: 25, number of bytes per packet: average 366 bytes, maximum 6000 bytes (truncated Pareto distribution), time between packet arrivals: average 0.125 s, exponential distribution. The videophone traffic model is a constant bit rate source of 64 Kbps with average duration 120s. As the interest of the present paper in what admission control concerns is on the statistical terms in (11), the simulation model includes a cell with radii 0.5 km and intercell interference is represented by f=0.6. Physical layer performance, including the rate 1/3 turbo code effect and the 1500 Hz closed loop power control, is taken from [22] to feed the system level simulator presented here with BLER (BLock Error Rate) statistics. The mobility model and propagation models are defined in [23], taking a mobile speed of 50 km/h and a standard deviation for shadowing fading of 10 dB.

4.- RESULTS

As a previous result and for a better understanding of the admission control phase, several figures regarding UE-MAC algorithms should be detailed. One important measurement to understand the behaviour of the different UE-MAC strategies is the transport format distribution used. Referring to Table 1, UE-MAC has the freedom to choose among TF0 (when the buffer is empty or when SCr<0), TF1, TF2, TF3 and TF4. For SCr24 (see Figure 4, SCrX standing for a service credit strategy with a guaranteed rate X Kb/s) it can be observed that most of the time TF1 and TF2 are used because the UE buffer queues several packets and so it tends to transmit the information at 24 Kb/s. In turns, in the periods that the UE buffer is empty the UE is gaining service credits and, when a new packet arrives the transmission rate is increased over the guaranteed one (i.e. TF3 and TF4 are used). For MR strategy, as it chooses the TF according to the buffer occupancy and tries to transmit the information as fast as possible, most of the time TF4 is being used (see Figure 2). Additionally, Table 2 shows the average delay performance for both MR and SCr strategies. It can be seen that MR provides a lower delay because the strategy tends to maximise the transmission rate according to the buffer occupancy.

Table 2. Average delay performance for UE-MAC algorithms.

UE-MAC strategy	Average packet delay (s)
SCr24	0.54
MR	0.12

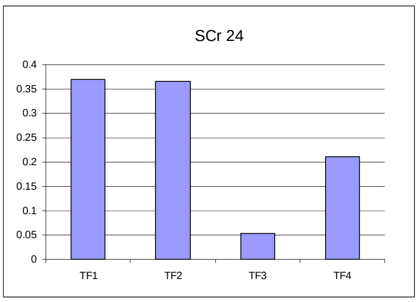

Figure 4. TF distribution for SCr.

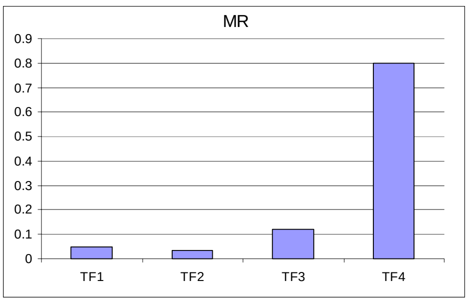

Figure 5. TF distribution for MR.

According to (13), Figure 6 plots the maximum cell radii for a 95% coverage probability as a function of the load factor for the considered services with a σ=10 dB shadow fading and unity antenna gains. Thus, for a cell range of 500m, the load factor must be below 75%.

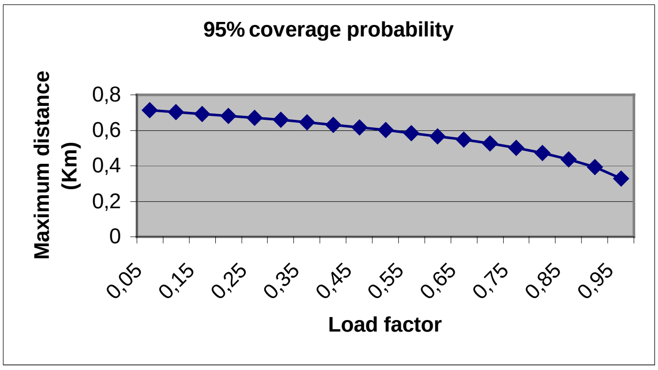

Figure 6. Cell range for different load factors.

Admission probabilities for videophone service with η_{max} =0.75 are shown in Table 3. Since videophone is of constant bit rate nature, the admission procedure is quite easy to handle. For 15 users in the cell, the system is still below the planned load factor, all users can be admitted and the performance is good, as shown in Figure 7 and Figure 8. In particular, Figure 7 shows the power limitation probability (i.e. the probability that the required transmitted power is above the maximum value) and Figure 8 the TB error rate also as a function of the distance to the cell site. If the offered load is above the planned load factor, as it is the case for 30 users, the admission procedure is able to assure the system stability, planned coverage and planned quality by rejecting connection requests. Figures 7 and 8 show a little increase in the power limitation probability as well as the TB error rate due to the increase in the load factor. In turns, Figure 9 shows the load factor distribution in the system.

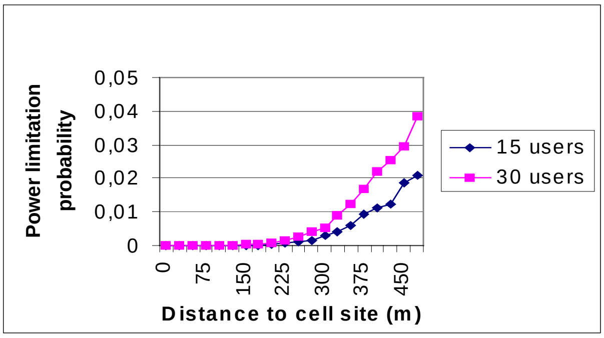

Figure 7. Dynamic power limitation probability.

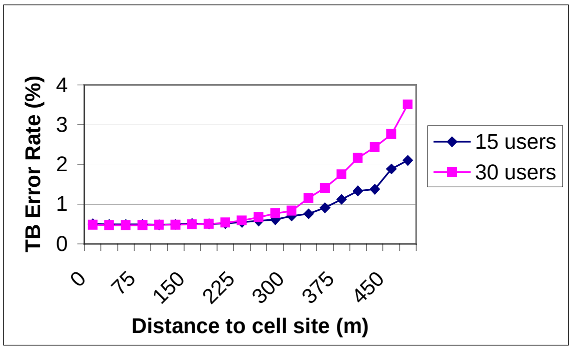

Figure 8. Transport Block error rate.

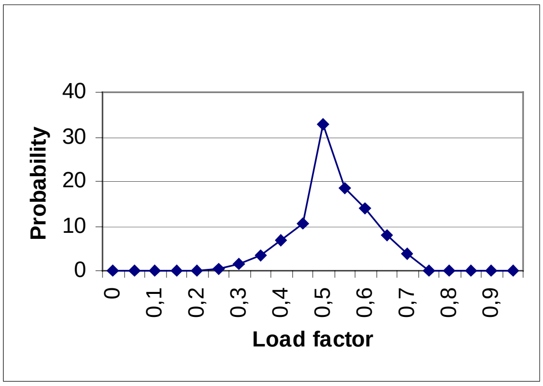

Figure 9. Load factor distribution for 20 videophone users.

Table 3. Admission probabilities for videophone service.

Number of videophone users	Admission probability
15	1
20	0.98
25	0.79
30	0.59

For the interactive service the situation is not so easy to handle because of two dynamic issues affecting the system behaviour that are difficult to predict: the statistical traffic multiplexing (the interactive service is of discontinuous nature and, consequently, the number of simultaneous users in a given frame in principle is not known in advance) and the TF used in uplink transmissions (it is decided in a decentralized way by UE-MAC and, consequently, the set of SF used by simultaneous users in a given frame in principle is not known in advance). Table 4 shows the admission probabilities for different values of the admission TF (equivalent to SF) and $\eta_{\max}$ for both MR and SCr strategies. The activity factor is assumed to be the average value coming from the traffic model. The criterion for considering the system under a congested situation is when (18) holds for more than 90 out of 100 consecutive frames, revealing that the CDMA capacity has been overcome. Note that depending on the specific congestion detection and congestion resolution algorithms, the system could continue operating under normal conditions or not and the interest of the present criterion is only for establishing a basis for comparison purposes since we are not dealing with congestion control algorithms in this paper.

$$(1+f)\sum_{i=1}^{n}\frac{1}{\dfrac{SF_i}{\left(\dfrac{E_b}{N_o}\right)_i}+1}>\eta_{th} \tag{18}$$

Table 4. Admission probabilities for different cases.

Number of www users	Admission probability TF2 $\eta_{\max}$ =0.75		Admission probability TF4 $\eta_{\max}$ =0.75		Admission probability TF4 $\eta_{\max}$ =0.9	
	MR	SCr	MR	SCr	MR	SCr
450	1	1	0.98	0.98	1	1
500	Cong.	1	0.93	0.91	1	1
550	Cong.	1	0.84	0.82	Cong.	0.98
600	Cong.	Cong.	0.76	0.74	Cong.	0.93

It can be observed from Table 4 that for a proper admission procedure the characteristics of the decentralized algorithm being applied at UE-MAC layer should be taken into account. For example, if TF2 and $\eta_{\max}$ =0.75 are considered in the admission phase for MR strategy, and since the dynamic behavior of this algorithm tends to use TF4 in most cases, the system enters in congestion with 500 users because the admission is too soft. In turns, for SCr the TF considered for admission purposes is much better adjusted to the real dynamic value, so that admission allows for more than 550 users to enter in the system while maintaining a controlled performance. On the other hand, if TF4 is considered for admission purposes, congestion is avoided because from the transmission rate point of view the worst case is considered and from the traffic multiplexing point of view $\eta_{\max}$ =0.75 is low enough to absorb traffic fluctuations without causing congestion. Nevertheless, for SCr strategy this is not so suitable because the admission is too strict. It is worth noting that the value for $\eta_{\max}$ eventually allows for a softer or stricter admission as shown in the example in Table 4, where increasing the value up to $\eta_{\max}$ =0.9

improves the percentage of admitted users for SCr strategy compared to the TF4 and η_{max} =0.75 case. For this later case, Figure 10 plots the statistical load factor distribution, showing that it tends to be quite low because of the still strict admission procedure. For 550 www users, 2% of the requests are already rejected (see Table 4) while the performance in the system is still very good. As a matter of fact, Figure 11 shows that the power limitation probability as a function of the distance to the cell site (i.e., the probability that a given user requires more power than the maximum allowed for achieving the target Eb/No) is within the coverage probability design even at the cell edge. Also, Figure 12 plots the average packet delay again as a function of the distance to the cell site, and reveals that no performance degradations are observed as one moves far from the cell site.

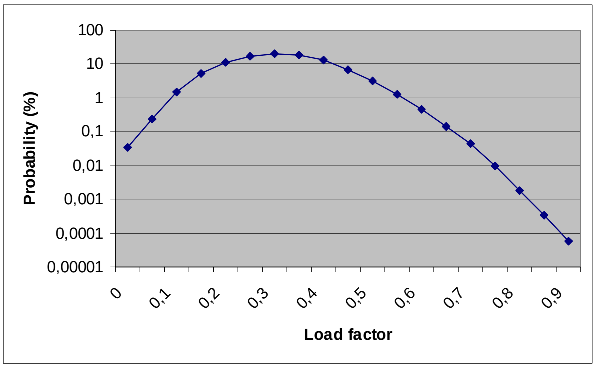

Figure 10. Load factor distribution for 550www, SCr, admission TF4 η_{max} =0.9.

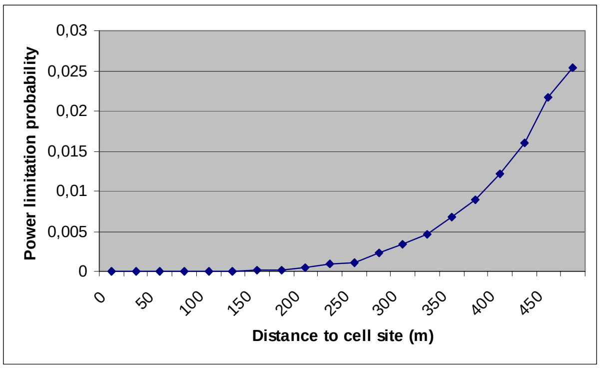

Figure 11. Power limitation probability for 550www, SCr, admission TF4 η_{max} =0.9.

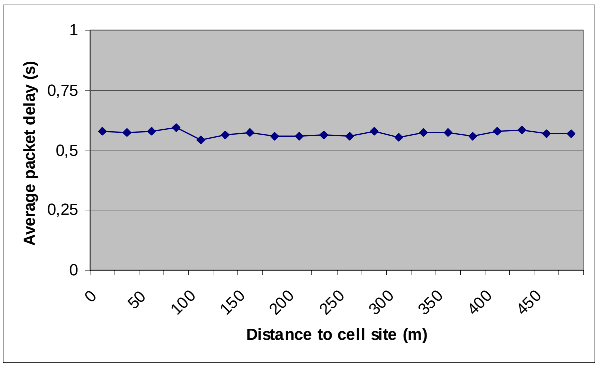

Figure 12. Average packet delay for 550www, SCr, admission TF4 η_{max} =0.9.

5. CONCLUSIONS

3G will offer different QoS guarantees and an optimization of capacity in the air interface by means of efficient RRM algorithms, which should consider the differences among the different services, not only in terms of QoS requirements but also in terms of the nature of the offered traffic, bit rates, etc. In the framework of UTRA-FDD, this paper has focused on the admission control and the mechanisms for the management of transmission parameters for conversational and interactive services in uplink direction. Results for UE-MAC strategies show that for SCr strategy most of the time TF1 and TF2 are used while for MR strategy most of the time TF4 is used This different behaviour of the UE-MAC algorithms impacts on the admission control process, which should take this fact into account for avoiding either too strict or too soft policies.

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