Practical Radio Resource Management Techniques for UMTS

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ABSTRACT

The mobile communication networks are continuously expanding not only in terms of size but also in terms of traffic and services that are provided and supported. Also, the new generation mobile telecommunication platform like the UMTS which are considered to be the fundamental elements for the foreseen 4G networks with the superior broadband capabilities in data services, will further increase the demand for telecommunication resources and produce new type of traffic profiles. The need for supporting various applications and services in an broadband and complex cellular radio environment like the UMTS, is one of the main reasons for introducing much more intelligent and complex resource management techniques compared to the 2G systems. In this work we present a set of new resource management techniques for increasing the utilization of UMTS cellular networks. The capabilities and the performance of the presented techniques are highlighted through simulations.

I. INTRODUCTION

In this paper we present and analyze three novel resource management techniques for increasing the efficiency of the UMTS telecommunication platform especially during overloading periods and when new services are being introduced.

The paper is organized around six sections. Section 1 is the paper's introduction, where we present the technological background of the problem that we are dealing with as well as the structure of this document. In section 2 we present a radio resource management technique that is focusing on the ability, to control the dominance of a cell. In the subsection we present the background of the technique for UMTS networks. In section 3 we present another resource management technique that is based on the ability to reduce the cell's coverage, by tuning the sensitivity of the receiver or the admission control parameters, whenever congestion is detected. In section 4 we present another resource management technique is focusing on the ability, to control and change dynamically the broadcasted list of adjacent cells, at high telecommunication traffic situations.

II. RESOURCE MANAGEMENT BASED ON TECHNICAL CELL BREATHING

A.. Background for UMTS

In the UMTS technology, the technical cell breathing could be performed, by controlling the power of the Common Pilot Channel (CPICH), in congestion situations. First of all the CPICH power allocation is a very important task in UMTS radio planning and usually is 5 to 10% of the power of the wideband amplifier. The CPICH is a fixed rate channel of 15 kbps with spreading factor of 256, which carries the broadcasted information of Node B. There are two subtypes of CPICH the primary and the secondary. Optimum pilot power, ensures coverage with minimum interference to the adjacent cells. Excessive pilot power will easily take too large proportion of the total available transmission power, so that not enough power is left for traffic channels.

Also, it is well known that the UMTS networks are always congested due to the lack of transmission power on the wideband amplifier in the downlink direction, which is known as "downlink limited" congestion and rarely from interferences in the uplink path.

The idea of the technical "cell breathing" is to reduce the power of the CPICH for decreasing the cell's dominance. In this way we reduce the number of users that are locked in the area of the congested cell but on the other hand, we conserve enough power, from the pie of the wideband amplifier, for utilizing more WCDMA spreading codes. It is obvious that this technique is suitable for congestion in all services and especially when the congestion is caused due to limited downlink power in the wideband amplifier.

The cell reselection on UMTS is based on the criterion that the mobile station has to select the CPICH within its area which has the best E_C/I_0

$$\frac{E_c}{I_o} = \frac{P_{CPICH}/L_p}{\sum_{i=1}^{BS} P_{BSi}/L_{Pi} + I_{ACI} + N_o},$$

P_{CPICH} is the received power of best server CPICH, L_p is the link loss, I_{ACI} is the adjacent channel interferences, P_{BSi} is the total power of the i-th adjacent base station and N_0 the thermal noise.

B. Simulation Results

The following example shows the novel dynamic use of the technical cell breathing to resize congested UMTS cells. Applying cell resizing through a radio planning simulator called *"WINPROP*", we have the following results that show how powerful is this technique,.

We assume that there is an urban area, which is covered by a network with a scheme of 3/9. This means that we have 3 BTSs with 3 sectors (cells) on each, which use the same group of frequencies. Such a planning gives a very good reuse factor on the frequencies with the use of directional antennas in each sector. The $\frac{E_c}{I_o}$ level for this planning is about 4 dB.

The normal planning of the network (before applying the technique) is shown in Figure 1, where the different levels in gray scale show the dominant area of each cell.

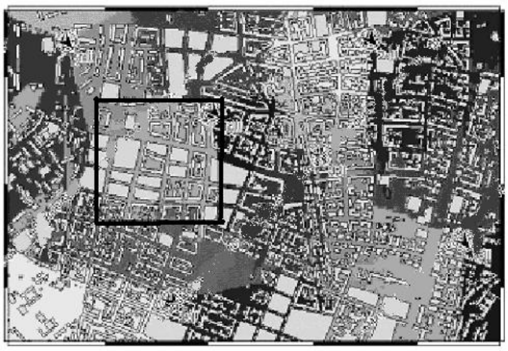

Figure 1: Initial dominance of the cell (CPICH 33 dBm)

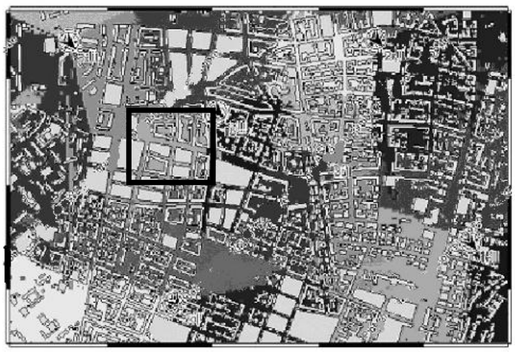

Figure 2: (CPICH 27 dBm)

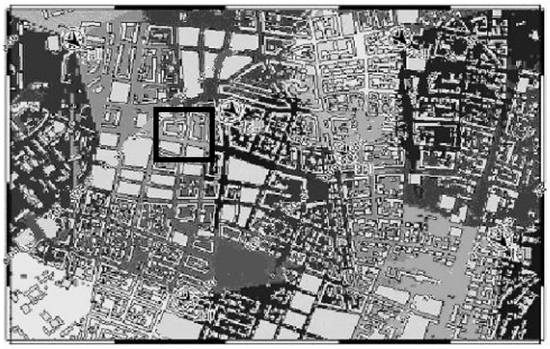

Figure 3: (CPICH 24 dBm)

Figure 4 below shows the relative reduction of the cell's area and cell size in relation to the reduction of the power that allocated to the CPICH.

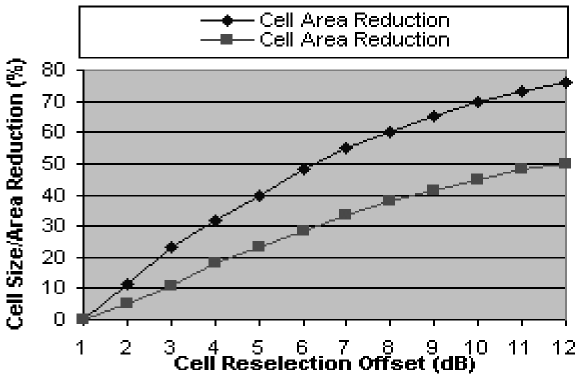

Figure 4: Relative reduction of cell size and area due to the technical cell breathing

A simulation for UMTS shows that a decrease of 6 dB in the CPICH power could provide 33% increase in traffic channels' capacity, under determined radio planning situations. Figure 5 below shows the variation on capacity of speech users only, of a UMTS cell with a 43 dBm power amplifier and 33 dBm allocated power to the CPICH, for allowed propagation losses from 135 to 167.5 dB and for 3 different power of CPICH. We assume that all users utilize only the voice service.

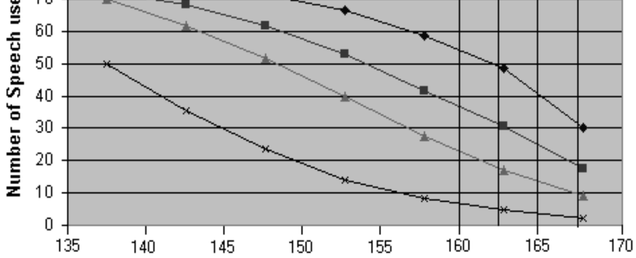

Figure 5: Relationship between allowed propagation loss and CPICH power

The above relationship is calculated from the Cost 231-Hata radio propagation formula for the urban macrocellular environment with a 25m height for the base station's antenna, a 1.5m height for the mobile station antenna and a carrier frequency of 2000 MHz.

$$L_p = A + B \cdot \log_{10} f - 13.82 \cdot \log_{10} h_b - a(h_m) +$$
$$(C - 6.55 \cdot \log_{10} h_b) \cdot \log_{10} d$$

where L_p is the path loss (dB), f is the frequency in MHz, h_b and h_m the height of the base station and the mobile antenna (meters), $a(h_m)$ is the mobile antenna gain function(dB), A=46.3 and B=33.9 for 2000MHz , C=44.9, and d is the distance in meters.

Also, the required transmitted powers to each user in the cell, P_{Ti}, could be estimated from the following expression [3]:

$$P_{Ti} \geq L_p(d_i) \frac{P_N + \chi_i + \rho \times \frac{P_{BTS}}{L_p(d_i)}}{\frac{SF_i}{(E_b/N_0)_i\, r} + \rho}$$

where: P_N is the thermal noise power, P_{BTS} is the power of the base station, $L_p(d_i)$ is the path loss at distance d_i, ρ is the orthogonal factor fixed according to the type of cellular structure considered, x_i is the inter-cell interference observed by the i-th user, E_b/N_o target, signal to noise ratio to be guaranteed, which depends on the BLER target to be achieved , r is the coding rate and SF is the spreading factor

The number of users for one service type and for a given power of the wideband amplifier is given by the following equation [2]:

$$N = \frac{P}{\frac{E_b / N_0}{W/R} \cdot v \cdot [P_{noise} \cdot L_{an} + P \cdot (1-a) + i]}$$

where P is the power of the wideband amplifier, E_b/N_0 is the ratio of the required energy per bit to spectral noise density, W is the chip rate, R is the L2 data rate, v is the service activity, P_{noise} is the background noise, L_{an} is the average downlink path loss, a is the orthogonality and *i* is the interference from the other cells in downlink.

III. RESOURCE MANAGEMENT BASED ON MINIMUM ACCESS LEVEL

A. Background for UMTS

The cell resizing by tuning the minimum access level is also applicable in the UMTS platform with two ways, that both of them reduce the coverage of the cell. Like in the two previous telecommunications platforms, the main idea for the implementation of this technique is to decrease the number of the idle and active users in a cell, in heavy congestion situations.

The two different features to achieve that is by minimizing the access level parameters by:

- tuning the Uplink Open-Loop Power Control
- tuning the Uplink Admission Control

By tuning the Uplink Open-Loop Power Control

The uplink open-loop power control function is being performed both in the MT and in the Radio Node Controller (RNC) and includes some control parameters which are being broadcasted in the cell and the received code power (RSCP) being measured by the MT on the active CPICH. Based on these measurements the MT calculates the criterion to access the cell and sets the initial power for the first PRACH, before the start of the close inner loop power control. The initial transmitted power for the preamble is calculated from the following formula:

PRACH_initial_power=CPICH_Tx_Power -CPICH_RSCP + UL_interference + UL_required_CI.

where the CPICH_Tx_Power is the power of the CPICH in dBm which is usually 5-10% of the power from the wide band amplifier, the CPICH_RSCP the received power of the CPICH, UL_required_CI is the required C/I in dB for the requested service and the UL_interference is the measured interference level that the MT receives.

By tuning the Uplink Admission Control parameters

The admission control procedure is responsible for deciding whether a new Radio Access Bearer will be accepted or rejected, depending on the interference (or load) that it adds to the existing connections. Therefore, it is responsible for deciding whether a new request for a specific service can be set-up.

In the case of the uplink, an admission control methodology based on measurements of the received interference is being considered. By utilizing this resource management technique we could control the admission of new services or users in the cell which is under congestion.

The uplink admission control decision is based on the following equation [3].

Accept a Radio Access Bearer if $n_{UL} + \Delta n \leq THR_{CAC}$

Where n_{UL} is the power of the admitted user, Δn is the increase of the wideband interference power that the admission of the new bearer would cause and THR_{CAC} is the call admission control threshold .

The increment of the network load, is estimated using the following equation:

$$\Delta\eta = (1+f) \cdot \sum_{i=1}^{k} v_i \frac{1}{\frac{W}{\left(\frac{E_b}{N_o}\right) R_b} + 1}$$

where v_i is the activity factor, f intercell factor, (E_b/N_0) the signal to noise ratio target, W is the chip rate and R_b the transmission rate of the new service.

By fine tuning the threshold parameter THR_{CAC}, the operator could manage the uplink admission control to reduce the offered telecommunication traffic in a problematic cell.

It is important to note that a more restrictive threshold setting lowers the dropping probability, while blocking probability increases. On the contrary, higher settings on the threshold could decrease the blocking probability, while increasing the dropping probability. This means that the range of the threshold is very limited.

Also by changing the (E_b/N_0) value, which is the signal to noise ratio for the target service, we could stop the allocation of such services that consume excessive radio resources.

B. Simulation Results

The effect of the implementation of this technique in a UMTS network is simulated with some concessions by utilizing the "WINPROP". Actually, at the Figure 6, we decrease the access level of the congested cell by 12 dB. In the white area around, the congested cell the MT could not access the network.

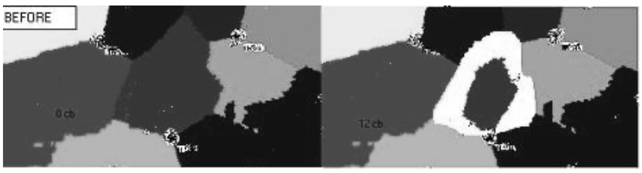

Figure 6: Reduction of the UMTS access level by 12 dB

IV. RESOURCE MANAGEMENT BY DYNAMIC MODIFICATION OF THE CELL ADJACENCY

A.. Background for UMTS

Like GSM, the UMTS has for each cell its own set of neighboring cells, that is defined in the network configuration database and which is located in the RNC. Thus a neighboring cell may be located in the same network, on the same frequency, on a different frequency or even in different telecommunication platform, like GSM frequencies.

The UMTS supports the following adjacent frequency lists:

-Intrafrequency neighbor list: The MT could monitor at least 32 cells on the same wide band carrier frequency as the serving cell.

-Interfrequency neighbor list: The MT could monitor at least 32 cells in all wide band carrier frequencies in addition to the serving cell's frequency.

-Interband neighbor list: The MT could monitor at least 32 cells in all GSM carrier frequencies that belongs to the same service operator.

Almost all vendors support the inter platform adjacency between UMTS and GSM.

In this way a MT that uses a UMTS network could see a GSM cell as a candidate base station for handover. This evolution has become quite important due to the very low UMTS base station density due to the fact that the UMTS networks are under developed.

E. Expected Results

Figure 7 shows an example, where the black cell is congested and the adjacent cells transmit (or not) after applying the technique the BCCH frequency list, so that a mobile subscriber crossing the area will consider (or not) the congested cell.

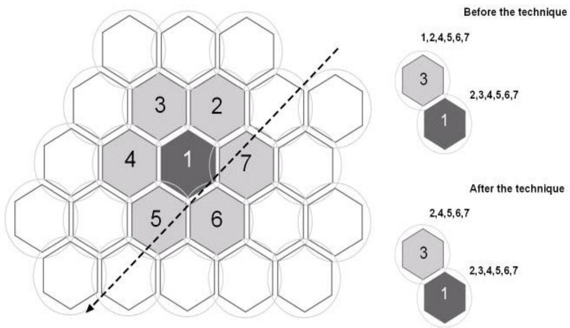

Figure 7: BCCH frequency list example

IV. RESOURCE MANAGEMENT IN CASE OF HOT SPOTS

A. Background for UMTS

Most real scenarios present certain areas with specific traffic density (the so-called hotspots) that may degrade not only transmission quality of terminals placed in that area but the whole system performance. To cope with these impairments, some studies in the literature have been carried out about how to manage non-uniformly distributed traffic environments. Some proposed solutions use embedded micro-cells in macro-cell systems to guarantee the coverage regardless of the presence of hotspots, [4-5]. Other solutions consider the possibility of inter-networking between UMTS and WLAN, [6]. However both approaches imply the deployment of new infrastructure elements.

Moreover, in many cases these hotspots appear suddenly, during some limited period in time. For instance assume a sportive event or a mass demonstration. In such situations, probably it has not sense to deploy new infrastructure and the hotspot shall be managed considering appropriate RRM strategies. In that context, we have particularly focused on the analysis of scenarios with non-uniformly distributed traffic with special attention on the impact of hotspots on the uplink admission control strategies.

In order to highlight the effects of hotspot, different traffic load distributions were analysed by varying the traffic percentage in the hotspot and its distance to the Base Station. From the obtained results, it is worth noting that hotspots placed far away from the Base Station increase remarkably the total BLER. However, this effect is solely caused by degradation of the quality of the hotspot users, since users not belonging to hotspot keep their quality approximately constant. Thus, to maintain the QoS levels for users in both the hotspot and in the rest of the cell, specific Call Admission Control (CAC) strategies, which take into account the position of the user, should be envisaged.

Such as it has been mentioned previously, the uplink call admission control is usually based in the measurement of the network load factor (η). Then, a new connection will be accepted if the estimated newest network load factor, which takes into consideration the load increase due to this new connection, is lower than a given threshold η_{max} Notice that CAC design is based on the election of a suitable maximum allowed load factor (η_{max}), which is dependant on traffic distribution. Then, taking into account the dependence with the hotspot traffic distribution of the optimal value of η_{max}, an adaptable threshold for the users in the hotspot is proposed.

To compute this adaptable threshold, first of all, the path loss statistics are used to predict probability to be below of the targeted $(E_b/N_0)_T$. From the cumulative density function of the path loses, it is possible to determine the maximum path loss L'_p not exceeded for a certain percentage of time. Once determined L'_p value an adaptive admission threshold could be found out according to the following expression:

$$\eta_{\max} = 1 - \frac{L'_p P_N}{P_{T,\max}} \frac{1}{\frac{\left(W / R_b \right)}{\left(E_b / N_0 \right)_T} + 1}$$

B. Simulation Results

The analysed scenario is composed of an isolated cell, with a hotspot placed *d* meters far from the base station which contains α% of the cell traffic. It is assumed that the rest of the traffic is homogeneously distributed around the cell.
Table 1 shows the obtained averaged BLER value in both the hotspot and the rest of the cell for two possible values of η_{max}, on fixed and other adaptable. From the table we can realize that in the case of using a single fix admission threshold value for users in both hot spot and the rest of the cell, the total perceived BLER is different even though similar load factors are seen by the different users. However, when an optimized threshold is used in the hot spot, the BLER is maintained almost constant independently if the user belongs or not to the hot spot.

	30 users		40 users	
	Cell	***Hotspot***	***Cell***	***Hotspot***
η_{max}=0,77	1,05%	1,1%	1,08%	1,7%
η_{max}=Optimized	1,05%	1,1%	1,1%	1,25%
	50 users		60 users	
	Cell	***Hotspot***	***Cell***	***Hotspot***
η_{max}=0,77	1,12%	1,75%	1,17%	2,0 %
η_{max}=Optimized	1,13%	1,3%	1,2%	1,4%

Table 1: BLER versus the number of users

However, this new and more restrictive condition applied to the users in the hot spot, limit their call admission probability such as is shown in Figure 9

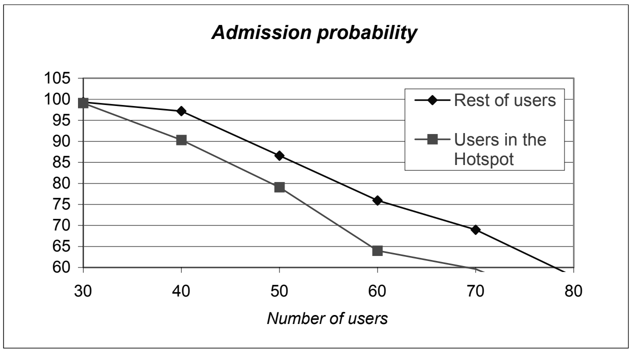

Figure 9: Admission Probability versus number of user assuming adaptive threshold in the hot spot

V. CONCLUSIONS

In this paper we presented a set of new resource management techniques that can be implemented on the UMTS cellular telecommunication platform. The correspondence RRM for the GSM-GPRS platform have been teeted on the testbed which we had developed during the activities of the IST project CAUTION. A network improvement of around 30% or even more in some experiments, in CSD and GPRS services, was achieved.
The research related to these techniques is performed under the frameworks of the activities of the CAUTION and CAUTION++ IST projects. The main evolution that is presented here is the hierarchical resource management approach that is applied over heterogeneous wireless networks. For that purpose, RRM techniques as the ones described above, should be implemented for a set of wireless networks, e.g. GPRS, UMTS, WLAN, while the resource management procedure should be coordinated in a way that allows the operator to utilize the resources of the access networks in a more efficient way.

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