Fixed Thresholds for Power Allocation and Management in WCDMA Mixed Services Scenarios

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Abstract— **In this contribution we evaluate the utilization of fixed thresholds for allocation and management of downlink dedicated channels (DCH) transmission power in WCDMA mixed service scenarios. We have made use of system-level dynamic simulation approach. We assess modified versions of the call admission control (CAC) and the power control (PC) algorithms. The system performance is evaluated taking into consideration the quality of service (QoS) experienced by connected users and the utilization of available power resources.**

I. Introduction

The WCDMA radio access technology emerges as the primary air interface for the 3G systems. The downlink (DL) of WCDMA cellular systems is essentially interference limited. Moreover, the transmission power resources which are made available in the base station antenna are scarce and must be shared among control, signaling and traffic channels. If no restriction is imposed over the maximum transmission power that is allowed per DL traffic channel (except the serving BS runs out of power resources) some users can demand excessive transmission power values and the network can be rapidly driven into an situation of power resources unavailability compromising the acceptance of new connections or the quality of calls already established [1, 2].

The call admission control (CAC) is in charge of deciding the acceptance or refusal of new connections. Further, the power control (PC) algorithm dynamically sets the transmission power at the admission moment and during the call. In this contribution, we evaluate two modified versions of the default CAC and PC algorithms by imposing upper limits to the maximum transmission power which can be achieved per DL dedicated channel. We consider multiple fixed thresholds for conversational and data service class users aiming to identify tradeoffs between system capacity and user satisfaction.

The reminder of this contribution is organized as follows: in section II, we identify the methodology that we utilized to conduct these investigations. In section III, we characterize the proposed solution. In section IV, we define the test scenarios, identify the performance indicators and evaluate the performance results. In section V, we finish this article by addressing key issues observed throughout these investigations.

II. System-Level Dynamic Simulation Modeling

For the investigations, we have used a dynamic network simulation tool named $WIDE_{SIM}$ (WCDMA Downlink Dynamic System-Level Simulator). This computational tool allows us to investigate and validate intrinsic WCDMA network features by emulating the WCDMA network behavior.

We assess conversational traffic class (12.2 kbps) operating in a single-code transmission scheme. Connections are initiated following a Poisson process and call durations are exponentially distributed. The ON-OFF traffic pattern modeled in the simulator is based on. We also model data service classes transmitting at 64 kbps [3].

A number of users are generated over the network and properly moved according to [3]. The deployment model comprises a vehicular environment served by tri-sectored cell sites with hexagonal sectors and a UMTS typical antenna radiation pattern. An homogeneous cellular area consisting of 16 cell sites is considered. To avoid border effects in interference calculation, a wrap-around technique is utilized.

Distance attenuation is calculated in accordance with [3]. A Gaussian distributed distance correlated shadowing is utilized following [4]. Multipath fading is modelled as independent Rayleigh processes imposed over the channel profile [3]. The receiver corresponds to a RAKE receiver with pre-determined number of fingers, which are capable of resolving an amount of paths, and optimally combining the signals from the respective paths using Maximum Ratio Combining (MRC) [5].

III. Solution Conception

In this section, we present concisely the simulation modelling of the proposed solutions (modified versions of the CAC and PC functionalities restricted by transmission power upper limits). The utilization of fixed thresholds for allocation and management of the downlink dedicated channels transmission power is performed in two distinct moments: at the admission moment by means of the call admission control with restriction and during the call by means of the constrained power control adjustments.

The fixed thresholds are estimated in the network link budget stage and corresponds to the transmission power required by a user located at the cell border. The threshold value depends on the propagation environment (channel profile), mobility profile and traffic profile (UMTS service

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class). We determine each transmission power limit by performing the joint evaluation of coverage and capacity of each UMTS service class (conversational and interactive service classes) [6].

The proposed solution is implemented by using fixed thresholds as upper limits to the dedicated channel transmission power. In fact, we propose a modified version of the CAC algorithm named CAC with restriction and a modified version of the PC algorithm named constrained power control (based on the default PC procedure, up-down algorithm defined in specifications [3]).

A. Call Admission Control and Initial Transmission Power Allocation

The CAC decides whether a new connection will be accepted or refused. The decision criterion is based on the initial transmission power which is allocated according to the open loop power control (see equation 1).

The transmission power which is assigned by the s^{th} sector to the m^{th} user at the admission moment or during the handover procedure is determined by using the equation 1.

$$P_{s,m}^{DCH} = \frac{\Gamma_m}{\varsigma_m}\left[\frac{P_s^{CPICH}}{\xi_s^{CPICH}} - \bar{\alpha}\left(P_s^{CCH} + P_s^{DCH}\right)\right] \quad (1)$$

The transmission power value, $P_{s,m}^{DCH}$, assigned by the s^{th} sector to the m^{th} user depends on:

- the quality requirement of the user m^{th} service class, Γ_m;
- the interference perceived by the s^{th} sector, where the m^{th} user intends to connect, ξ_s^{CPICH};
- the CPICH transmission power of the s^{th} sector, P_s^{CPICH};
- the transmission power resources of the s^{th} sector and the propagation environment profile, $\bar{\alpha}\left(P_s^{CCH} + P_s^{DCH}\right)$.

The algorithm 1 presented by the following flowchart illustrates the CAC procedure. According to the proposed CAC with restriction the transmission power required by the incoming call is compared to the previously specified transmission power upper limit.

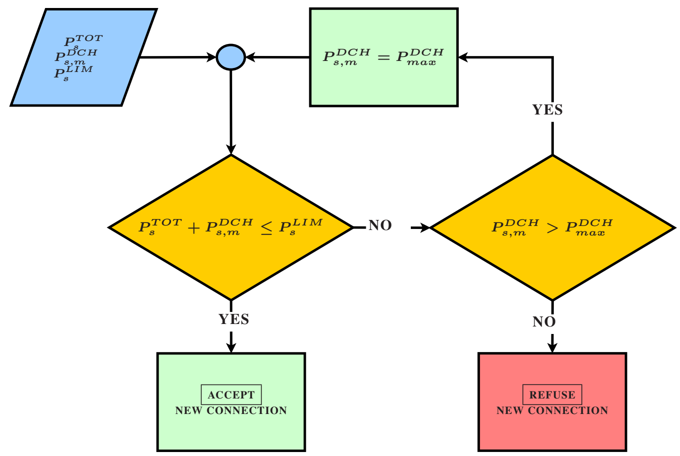
B. Transmission Power Control

Traditionally, the downlink transmission power resources are shared among the users in accordance with their demands, i.e., in response to the perceived effects of the wireless channel impairment as well as the experienced interference level [1, 2].

The power control algorithm dynamically adjusts the transmission power of all DCH users. Notice that according to the default procedure no restriction is imposed over the maximum transmission power which can be achieved per traffic channel. Therefore, some users can demand higher power values propagating more interference into the air interface while other users do not have sufficient power resources to fulfil their quality requirements.

Differently, by using transmission power upper limits, it is possible to reduce the interference profile in the air interface

Algorithm 1 Call Admission Control with Transmission Power Upper Limits.



[7-10]. These investigations aim to capture the impact of the fixed thresholds over the system dynamics.

The constrained power control algorithm updates the dedicated channel transmission power following the equation 2.

$$P_{s,m}^{DCH}(k) = min\{P_{max}^{DCH},\ P_{s,m}^{DCH}(k-1) + \Delta P\} \quad (2)$$

where $P_{s,m}^{DCH}(k)$ denotes the next transmission power value, $P_{s,m}^{DCH}(k-1)$ is the transmission power at the previous instant and ΔP is the channel power update step. **P_{max}^{DCH} is the maximum transmission power that is allowed per traffic channel.** The transmission power upper limit is set sufficiently higher in order to avoid coverage effects and guarantee the contracted QoS.

IV. Performance Results

In this section we carry out a feasibility study into improve the downlink performance of WCDMA networks by employing the fixed thresholds strategy. We focus on the system performance and resultant interoperability with the default radio resource management functionalities.

Table I summarizes the main configuration parameters of the simulated scenarios. These parameters identify the default configuration of the network.

The efficiency and applicability of the proposed solution is decided by taking into consideration the guarantee of the service requirements (blocking probability, frame erasure probability and contracted data rate) and utilization of the available power resources. In this way, we evaluate the blocking probability and 95th percentile of the frame erasure probability for the conversational service class users. For the data service class users, we evaluate the assurance of the contracted data rate. We also evaluate the 95th percentile of the total transmission power resources which are utilized per sector.

TABLE I Configuration Parameters of the Simulation Environment

Parameter	Value
Simulation Environment	
Cellular Grid	torus grid - wrap-around technique
Cellular Radius	0.9 km (link budget)
Pedestrian mobility class	speed of 3 km/h
Conversational service class	transmission rate of 12.2 kbps
Large-scale fading	Okumura-Hata propagation model & spatial correlated shadowing
Small-scale fading	vehicular test environment
open-loop power control for the conversational service class	
$(E_b/N_0)_{12.2\ kbps}$	6.5 dB, for the conversational service class on the forward link
open-loop power control for the interactive class	
$(E_b/N_0)_{64\ kbps}$	5.5 dB, for the interactive service class with 64 kbps on the forward link
$(E_b/N_0)_{144\ kbps}$	5.0 dB, for the interactive service class with 144 kbps on the forward link
closed-loop power control	
Frequency	1500 Hz
Operation mode	operation mode 0 (zero)
Step	1 dB
soft handover process of the mobility control	
AS length	one sector
Reporting Time	one TTI
Filtering window	four frames
Quality Requirements for the conversational service class	
Blocking Probability	less than 2%
Frame Erasure Probability	less than 2%
Quality Requirements for the interactive service class	
Accepted Throughput	50% of the contracted data rate

Intending to assess the system performance we defined two distinct test scenarios: the reference scenario and scenario with transmission power limits. The reference scenario corresponds to the default radio network configuration (see table I). The scenario with transmission power limits corresponds to an extension of the reference scenario where multiple fixed thresholds are imposed over the dedicated channel transmission power. We consider Mixed Service Scenarios (combined evaluation of the conversational and interactive service classes).

The system performance is evaluated taking into consideration the quality of service experienced by connected users and the utilization of power resources. Regarding the QoS we evaluate both the frame erasure probability (FEP) and the blocking probability which must be lower than 2% for the conversational users. For the data users, the actual data rate must be at least 50% of the contracted data rate (144 kbps). We also assess the utilization of power resources evaluating the 95^{th} percentile of the utilized base station power resources and the 95^{th} percentile of the transmission power achieved per traffic channel during the call.

The Mixed service scenario is composed of 75% of conversational service class users transmitting at 12.2 kbps and 25% of interactive service class users transmitting at 144 kbps. The main idea is to restrict the power resources available to the NRT (best-effort) services, by using fixed thresholds, in order to release extra power resources to the RT (conversational) users. Notice that, NRT users (high data rate users) demand the highest transmission power levels.

In this way, we begin the system evaluation by assessing the utilization of transmission power resources at the base station antenna. In figure 1 we compare the Mixed Reference Scenario and the Mixed Scenario with power limits of 2-fold and 3-fold the required transmission power at cell border. The reference scenario presents the highest transmission power utilization, since in this test scenario there is no restriction over the transmission power of data users. The scenario with power limits presents a utilization of the power resources lower than that achieved in the reference scenario without fixed thresholds.

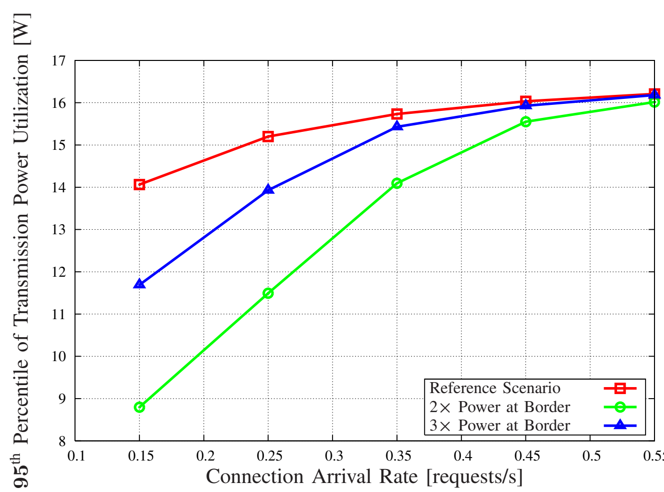


Fig. 1 Utilization of transmission power resources per cell sector in mixed service scenarios.

From figures 2 and 3, we can assess the network capacity in the mixed service scenario. On the one hand, the FEP values in mixed service scenarios without power limits are lower than that observed in mixed service scenarios with power thresholds. However, the achieved FEP values remains lower than the QoS requirement, which must be at most 2%. On the other hand, the blocking probability of mixed test scenarios with power thresholds is lower than that obtained without power limits.

In this way, it was possible to reduce the blocking probability of RT users and increase system capacity by using the extra transmission power resources released by NRT users, whose DCH transmission power were restricted by the power thresholds.

Both the blocking probability and FEP of voice users in mixed service scenarios with power thresholds are mainly decreased because there exist more power available to be transmitted in order to compensate for the channel impairments and interference profile. From figure 4 we can confirm this assertion, since in mixed scenarios with power

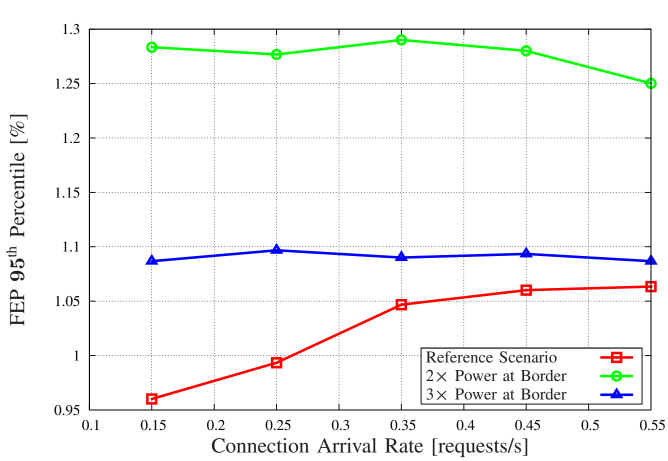


Fig. 2 Frame Erasure Probability for the conversational service class users transmitting at 12.2 kbps in mixed service scenarios.

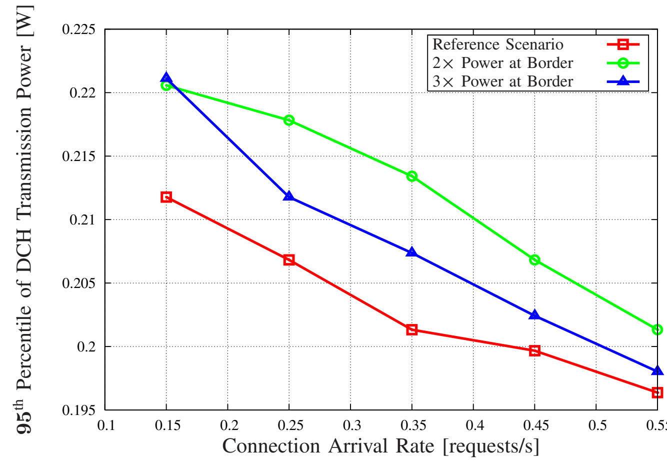


Fig. 4 Transmission power per dedicated traffic channel for the conversational service class users transmitting at 12.2 kbps during the call in mixed service scenarios.

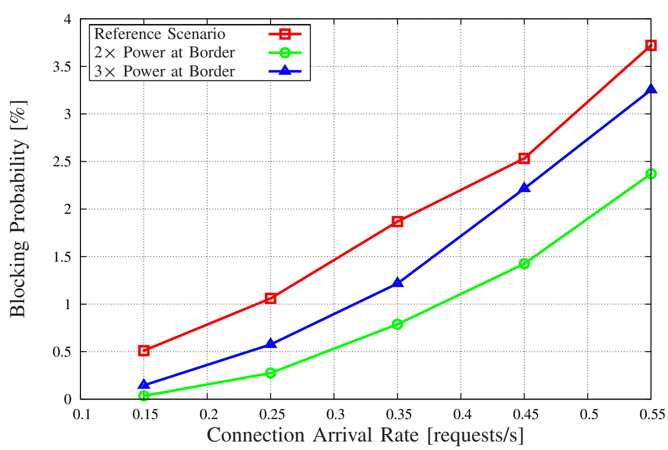


Fig. 3 Blocking Probability for the conversational service class users transmitting at 12.2 kbps in mixed service scenarios.

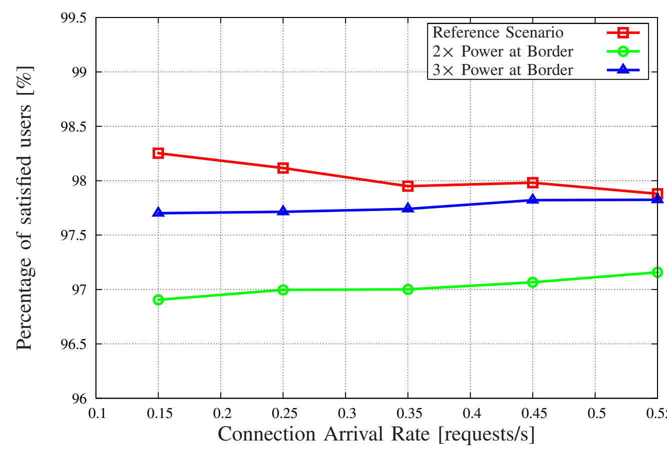


Fig. 5 Percentage of satisfied users for the conversational service class users transmitting at 12.2 kbps in mixed service scenarios.

thresholds the transmission power per traffic channel is increased.

Figures 5 and 6 present the percentage of satisfied users in the mixed service scenarios for the voice and data service classes, respectively. As can be seen from these figures, the higher the transmission power upper limit the higher the amount of satisfied users. This fact mainly happens because there is more power to be transmitted throughout the traffic channel in order to compensate for channel effects and interference level.

Notice that the QoS requirements, i.e., at least 2% of blocking probability and FEP for voice users and at least 50% of the contracted data rate for the data service class users, are guaranteed. Additionally, the minimum amount of 95% of satisfied users for both service classes is also assured although the NRT users are restricted by the transmission power limits.

V. Conclusion

In this article we evaluated the applicability of fixed thresholds for allocation and management of the downlink power resources. This solution was evaluated taking into consideration the utilization of power resources and assurance of contracted quality requirements.

For the conversational service class in mixed service scenarios the percentage of satisfied users is increased with the elevation of the transmission power limits, because higher power levels can compensate for more severe channel impairments and the interference profile (higher values of frame erasure probability). However, higher power thresholds also increase the blocking probability.

For the NRT users in mixed service scenarios special attention is needed: the power thresholds can be insufficient to compensate for the channel degradation effects and

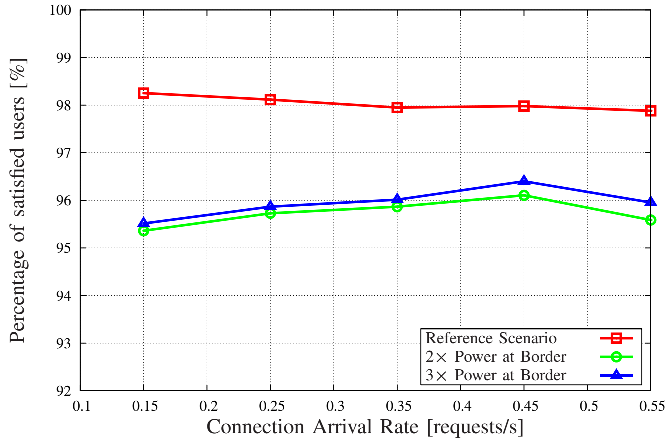


Fig. 6 Percentage of satisfied users for the data service class users transmitting at 144 kbps in mixed service scenarios.

interference. Additionally, the queue time of best-effort users can be increased (time waiting in forced delay).

On the other hand, imposing upper limits to the maximum transmission power of data users in mixed service scenarios can release extra power resource to RT users. This scheme can be a good approach to improve system performance by benefiting conversational users without hardly harming best-effort users.

In summary, the utilization of fixed thresholds constitute a simple solution to improve system performance and increase system capacity, since the power resources are better shared among the users (balancing the interference profile). However, it is necessary to finely tune the upper limits in order to improve the achieved gains, and avoid collateral degradation effects.

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