ON DIMENSIONING UTRA-FDD DOWNLINK SHARED CHANNEL

J. Pérez-Romero, O. Sallent, R. Agustí

Universitat Politècnica de Catalunya
C/ Jordi Girona, 1 - 08034 Barcelona - Spain
E-mail : jorperez, sallent, ramon @ tsc.upc.es

Abstract - DSCH transport channel through suitable packet scheduling is the envisaged mechanism to deal with delay tolerant services in the downlink of UTRA-FDD. When operating in a mixed service scenario, where both real time and non real time traffic are present, different issues should be considered in order to guarantee some performance figures for both kinds of users. In particular, this paper shows the impact of the OVSF code tree size devoted to DSCH in terms of non real time services average packet delay. Besides, the consequences for real time traffic in terms of admission and dropping probabilities are also dealt. The completion of this research is the definition of a traffic mix region where some QoS figures are guaranteed and the corresponding DSCH dimensioning is devised.

Keywords - UTRA-FDD, DSCH, Packet scheduling, Radio Resource Management, W-CDMA.

I. INTRODUCTION

The key feature of third generation mobile systems will be the ability to deliver wideband and high bit rate multimedia services alongside the traditional radio services such as voice, messaging and slow rate data. In that context, UMTS (Universal Mobile Telecommunication System) will provide wideband mobile multimedia services for the future mass market. The broad range of services expected to be supported through these 3G networks can be divided into four Quality of Service (QoS) classes: conversational (e.g. voice), streaming (e.g. video), interactive (e.g. www browsing) and background (e.g. e-mail). However, the provision of such mobile multimedia services under QoS guarantees 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 [1][2]. Such strategies should deal with the peculiarities of the radio access technology, that in the UTRA FDD (UMTS Terrestrial Radio Access Frequency Division Duplex) mode of UMTS is based on W-CDMA (Wideband Code Division Multiple Access) [3]. One of the peculiarities of this access scheme is that it lacks from a constant value for the maximum available capacity, since it is tightly coupled to the amount of interference in the air interface. Therefore, RRM functions become crucial to manage this interference depending on the provided services. Moreover, RRM strategies are not subject of standardisation, so that they can be a differentiation issue among manufacturers and operators. Additionally, 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.

According to the 3GPP (3rd Generation Partnership Project) specifications, in the Medium Access Control (MAC) layer, logical channels are mapped to transport channels. A transport channel defines the way how traffic from logical channels is processed and sent to the physical layer. In the downlink, services can be provisioned either by means of dedicated channels (DCH) or common channels, like the DSCH (Downlink Shared CHannel) or the FACH (Forward Access CHannel), the latter normally devoted to services without QoS constraints.

This paper focuses on the DSCH transport channel dimensioning problem in a mixed services scenario. Since a part of the total OVSF (Orthogonal Variable Spreading Factor) code tree in a Node-B is reserved to the DSCH channel, and due to OVSF code scarcity, its specific dimensioning reveals to be a key issue from the network operation point of view resulting into a trade-off between real time using DCH and non real time traffic using DSCH. Particularly, if a large part of the tree is devoted to DSCH, real time users can suffer from degradations due to lack of codes, on the contrary, if the fraction of the tree devoted to DSCH is too small, non real time traffic can also suffer from excessive service delays. Several works in the literature have addressed the study of the DSCH [4-9]. However, and to the authors' knowledge, the DSCH dimensioning problem taking into account the existing traffic mix in the scenario has not been dealt so far. Under this framework, this paper studies the impact that DSCH channel allocation has over both real time and non real time users and proposes an adequate adjustment of the DSCH dimension in order to keep QoS guarantees of both types of traffic.

The paper is organized as follows. Section 2 presents the different elements involved in downlink RRM in order to provide an in depth view of the context in which DSCH operates. Then, Section 3 presents the system model and simulation scenario considered for the results presented in Section 4. Finally, Section 5 summarizes the achieved conclusions.

II. DSCH MANAGEMENT

When provisioning a downlink service with specific QoS requirements, different aspects need to be considered from the UTRAN perspective. From the point of view of transport channels selection, DCH is devoted to services with stringent transfer delay requirements, such as conversational services. In turns, DSCH is devoted to services with tolerant transfer delay requirements, such as interactive services. A DSCH channel is always associated to a low bit rate DCH channel through which physical layer control information (e.g. power control) is transmitted. DSCH transmissions are subject to a packet scheduling policy that should take into account both code availability and power allocation, as detailed in the following.

II.A.- Code Availability

In the downlink direction of UTRA FDD, simultaneous transmissions are distinguished by means of different OVSF codes, which are generated according to a tree structure as depicted in Figure 1. Such a tree has the property that two or more codes belonging to different tree branches are orthogonal, while codes belonging to the same branch do not keep orthogonality. As it can be observed, the higher the spreading factor, the higher the number of available codes in the tree (so there can be 4 orthogonal codes with SF=4, 8 with SF=8, and so on until reaching the maximum spreading factor, which is SFmax=512).

When mapping transport channels onto OVSF codes, part of the OVSF tree will be devoted to common channels and the remainder to dedicated channels. As depicted in Figure 1 the DSCH occupies a fraction of the tree. This fraction is determined by the DSCH root code, whose spreading factor SF_{root} must be fixed depending on the specific needs in terms of the provided services. The rest of the tree is occupied by DCH channels and common control channels like CPICH or P-CCPCH (each of this two requiring a code with SF=256).

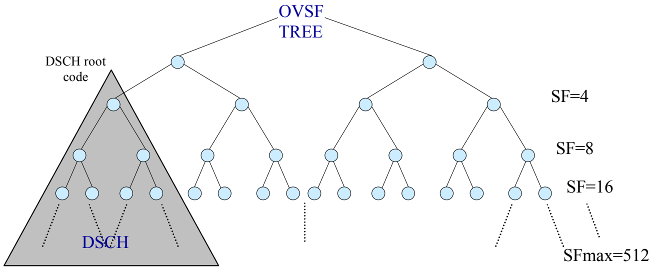

Fig. 1 OVSF code tree

Given a number of simultaneous transmissions, the code availability for all of them is guaranteed provided that the Kraft's inequality [10] is fulfilled. When taking into account DSCH, the Kraft's inequality should be modified as follows, to determine the maximum number of transmissions in DSCH channels and in the rest of channels

$$\sum_{i=1}^{N_S}\frac{1}{SF_i}\le\frac{1}{SF_{root}} \quad ; \quad \sum_{i=1}^{N_D}\frac{1}{SF_i}\le 1-\frac{1}{SF_{root}} \qquad (1)$$

where N_S is the number of allocated codes for transmissions in the DSCH, N_D is the number of allocated codes in the rest of the code tree (including DCH and common control channels). SF_i is the spreading factor being used by transmission *i*.

II.B. Power allocation

Within a W-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). Since the maximum available power at the node-B becomes a shared resource, when there are *n* users receiving simultaneously from a given cell, either in DCH or in DSCH channels, the following inequality must be satisfied:

$$P_{T,\max}\ge P_T=\frac{P_p+\sum_{i=1}^{n}\frac{(P_N+\chi_i)}{\frac{W/R_{b,i}}{\left(\frac{E_b}{N_o}\right)_i}+\rho}L_{p,i}}{1-\sum_{i=1}^{n}\frac{\rho}{\frac{W/R_{b,i}}{\left(\frac{E_b}{N_o}\right)_i}+\rho}} \qquad (2)$$

P_T being the node-B transmitted power, which must be below the maximum available power, P_{Tmax}. χ_i represent the intercell interference observed by the i-th user and $L_{p,i}$ its path loss with respect to the serving node-B, that is periodically reported. $R_{b,i}$ is the i-th user transmission rate, W the bandwidth, P_p the power devoted to common control channels and P_N the background noise. ρ is the orthogonality factor since some code orthogonality is lost due to multipath.

II.C. Packet scheduling

Taking into account the previous constraints dealing with power and code allocation, the considered packet scheduling algorithm allocates the DSCH channels to users according to the following two steps [11]:

a) Prioritization

The different users requests are ordered depending on some priority criterion that takes into account the average bit rate that the connection has received along its lifetime. The higher the bit rate the lower the priority is.

b) Resource allocation

Once requests are ordered, the next step consists in deciding whether or not they are accepted for transmission in the DSCH channel and which is the accepted Transport Format (TF) or equivalently the instantaneous bit rate. To this end, for each request, the algorithm starts from the highest possible TF and checks the following two conditions:

1st check Code availability: Kraft's inequality (1) is checked. If (1) holds, it proceeds with the 2nd check. Otherwise, it reduces TF=TF-1 and checks again (1). If TF reaches 0, the request is postponed.

2nd check Power availability: The algorithm estimates the expected transmitted power level $\widetilde{P}_T$ given by (2) with the accepted requests. If the expected transmitted power is below the maximum available power, the request is accepted. Otherwise, TF=TF-1 and the 2nd check is performed again. Finally, if TF reaches 0 the request is postponed.

III. SIMULATION MODEL

A system level simulator has been used in order to evaluate the performance of the studied downlink RRM strategies in a scenario with both real time (i.e. conversational) and non real time users (i.e. interactive). Table 1 summarises the main simulation parameters for the presented results. The mobility model and propagation models are defined in [12]. Traffic models are taken from [13]. The considered Radio Access Bearers (RABs) for both services have been selected from 3GPP TS 34.108. Specifically, the RAB for conversational service contains a single transport format that allows the transmission of 2 transport blocks of 640 bits with a Transmission Time Interval (TTI)=20ms, which requires a spreading factor SF=32. In turns, the RAB for interactive service is defined in Table 2. The physical layer characterisation is obtained through a link level simulator [14] that feeds the system level simulator with the transport block error rate (BLER) statistics for each average (E_b/N_o). This characterisation includes a detailed simulation of all the processes involved at the physical layer, such as channel estimation, antenna diversity, rate 1/3 turbo coding as well as the 1500 Hz closed loop power control. Similarly, these link level results are also used to execute the outer loop power control in the system level simulator (i.e. to compute required E_b/N_o given a BLER requirement). In the simulations a single scrambling code per cell has been assumed.

IV. RESULTS

The main performance figures that are retained to analyse the perceived QoS are the admission and dropping probabilities, together with the Packet Error Rate (PER), for conversational users and the average WWW page delay for interactive users.

Table 1
Simulation parameters

Scenario size		2.25 km x 2.25 km	
Cell radius	500 m	Cell type	Omnidirectional
Maximum transmitted power	43 dBm	Common Control Channels Power	30 dBm
DL Orthogonality factor	0.4	Thermal noise	-100 dBm
Mobile speed	3 km/h		
Propagation model (macrocellular)			
Shadowing deviation	10 dB	Shadowing decorrelation length	20 m
Handover parameters (conversational)		**Handover parameters (interactive)**	
Active Set (AS) maximum size	2	Active Set maximum size	1
Threshold to enter AS	3 dB	Replacement hysteresis	1 dB
Hysteresis to enter AS	1 dB	Time to Trigger Handover	0.5s
Replacement hysteresis	1 dB		
Time to Trigger Handover	0.5s		
Traffic model (conversational)		**Traffic model (interactive)**	
Call duration	120s (exponential)	Number of pages per session	5 (geometrical)
Offered bit rate	64 kb/s (CBR)	Reading time between pages	30 s (exponential)
Activity factor	1	Number of packets per page	25 (geometrical)
Call rate	29 calls/h/user (Poisson arrivals)	Time between packets	0.0625 s (exponential)
		Packet length	Pareto distributed (α=1.1, k=81.5 bytes, m=6000 bytes)
		Session rate	25 sessions/h/user
QoS parameters (conversational)		**QoS parameters (interactive)**	
PER (Packet Error Rate) target	2%	Average page delay	<4s
Dropping probability	<1%	Dropping probability	<1%
Dropping condition	1s below Eb/No target or lack of codes in the new cell during HO	Dropping condition	Lack of codes in the new cell during HO

Table 2

Transport formats for the interactive RAB

Service		WWW (DL)
TrCH type		DSCH
TB sizes, bit		336 (320 payload, 16 MAC/RLC header)
TFS	TF0, bits	0×336
	TF1, bits	1×336 (16 Kb/s, SF=128)
	TF2, bits	2×336 (32 Kb/s, SF=64)
	TF3, bits	4×336 (64 Kb/s, SF=32)
	TF4, bits	8×336 (128 Kb/s, SF=16)
	TF5, bits	12×336 (192 Kb/s, SF=8)
	TF6, bits	16×336 (256 Kb/s, SF=8)
TTI, ms		20

As explained in Section II, OVSF code management plays an important role in the resource allocation process. Specifically, when mixing real time and non real time traffic a trade-off arises in the suitable selection of the spreading factor of the DSCH root code SF_{root} which determines the DSCH dimension (see OVSF code tree in Figure 1). This trade-off is illustrated Figure 2 and Figure 3 that present the average page delay of interactive users and the dropping probability of conversational users for different DSCH allocations given by the value of SF_{root}. Similarly, Figure 4 and Figure 5 present the admission probability and the Packet Error Rate (PER) for conversational users. A constant conversational offered load of 40 Erlangs has been considered, while the interactive offered load has been progressively increased. The comments that can be extracted from these results are summarised in the following:

1) Packet scheduling in DSCH follows a Code Division and Time Division Multiplexing (CDM/TDM) approach, on the basis that several users may transmit at the same frame on different OVSF codes. However, once the branch defined by SF_{root} is fully occupied, the remaining users must wait for a future frame to get access to the radio interface. As a result, as Figure 2 shows, the increase in the number of interactive users in the system turns into a corresponding page delay increase. Furthermore, the lower the SF_{root} value the lower the packet delay will be for the same interactive load level because of a higher capacity of the DSCH channel.

2) DSCH allocation has an important impact over conversational traffic performance, since less OVSF codes are available for dedicated channels if SF_{root} is low. This can be observed in Figure 3 and Figure 4, where the evolution of the conversational user's dropping and admission probabilities are plotted as the interactive traffic is increased. Clearly, the lower the SF_{root} the lower the admission probability will be. On the other hand, call droppings are originated when a user must handoff a call to a cell where there are not OVSF codes available. Figure 3 shows that dropping probability is not at all negligible for high interactive loads.

3) On the other hand, and in conjunction with DSCH, interactive users require also a low bit rate DCH control channel with SF=256. As a result, the increase in the number of interactive users turns into a reduction in the number of available DCH channels for conversational users. Consequently, there is degradation in conversational users' performance in terms of both admission and dropping when interactive load increases, as shown in Fig. 3 and Fig. 4.

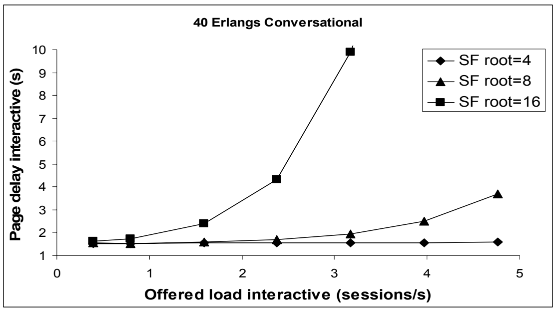

Fig. 2. Interactive page delay for different loads and SF_{root}.

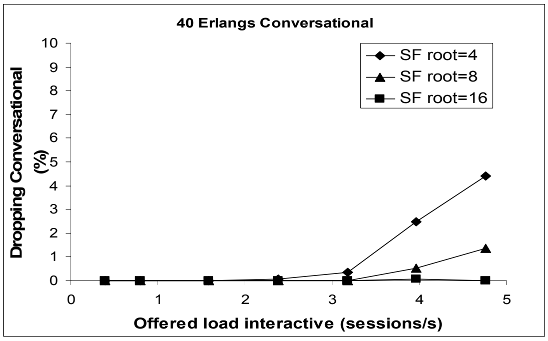

Fig. 3. Conversational users dropping probability.

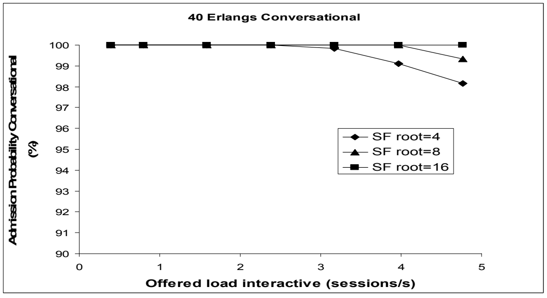

Fig. 4. Conversational users admission probability.

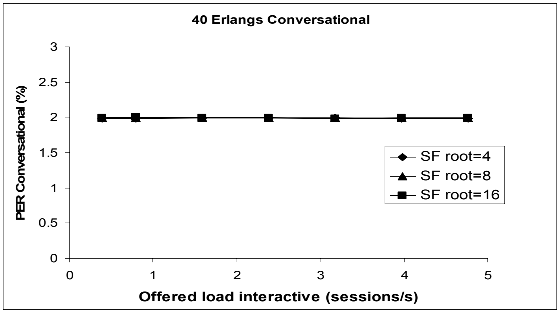

Fig. 5. Conversational PER for different interactive loads.

4) It can be noticed from Figure 5 that the conversational PER performance is assured and maintained at its target value of 2% regardless of the interactive traffic load level.

This is because the packet scheduler controls the overall interference level. Increases on the interactive load are supported by taking advantage of the TDM component of the DSCH management, thus originating an interactive packet delay increase, as reflected in Figure 2, but it does not influence on conversational traffic.

Keeping all the above in mind, and defining some performance (QoS) targets for both conversational and interactive traffic, it is possible to define a feasible region of operation for each DSCH dimensioning depending on the existing mix of conversational and interactive traffic, as shown in Figure 6. In particular, the considered QoS figures are a dropping probability lower than 1% for conversational users and an average page delay lower than 4s for interactive users. It can be observed that, as the conversational traffic increases, and for the SF_{root}=16 case, the interactive traffic is limited to no more than 2.1 sessions/s, otherwise the limited DSCH capacity does not allow to assure the target delay since interactive packets should be queued too long before getting access to the radio channel. In this case, for conversational loads higher than 80 Erlangs it would be necessary to reduce the interactive load, otherwise the conversational dropping probability could not be provided because of the OVSF code scarcity. For the SF_{root}=8 case, the supported interactive traffic when no conversational traffic is present raises up to about 5 sessions/s because more capacity is devoted to DSCH channel and facilitates the satisfaction of the interactive packet delay bound. When conversational traffic is present, it is necessary to progressively reduce interactive load, otherwise the dropping criteria can not be met. Similar conclusions can be drawn for the SF_{root}=4 case.

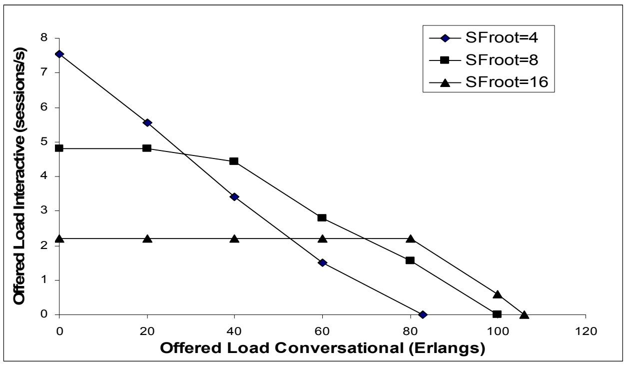

Fig. 6.Mix of conversational and interactive users regions.

IV. CONCLUSIONS

The envisaged mechanism to deal with delay tolerant services in downlink UTRA-FDD is the usage of DSCH transport channel though suitable packet scheduling. This paper has dealt with the DSCH dimensioning problem in a mixed services scenario where both real time and non real time traffic are present. Results have shown that the setting of the SF_{root} that determines the fraction of OVSF code tree occupied by the DSCH becomes a key issue to guarantee at the same time both conversational and interactive users performance. In particular, the lower the SF_{root} value the lower the interactive delay will be. However, low SF_{root} values lead to a higher call dropping rate when a user must handoff a call to a cell where there are not available OVSF codes. This trade-off results in a feasible region of operation for each DSCH dimensioning depending on the existing mix of conversational and interactive users, where specific QoS figures can be guaranteed.

ACKNOWLEDGEMENTS

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