Scheduling Algorithm for Beyond 3G Systems based on MC-CDMA

*V. Monteiro, **A. Gameiro, ***R. Aguiar
*Instituto de Telecomunicações / **Dept. Electrónica & Telec., Aveiro-Portugal
Phone: +351 234377900, Fax: +351 234377901, e_mail: vmonteiro@av.it.pt, amg@det.ua.pt, rlaa@det.ua.pt

1. INTRODUCTION

The growing demand for wireless and mobile services has led in the recent years to considerable research towards the development and integration of technologies that allow fulfilling the long-fetched requirement of anywhere, anything, anytime communication. In particular significant effort is being devoted by the research community in the definition and development of the so called broadband component of beyond third generation (B3G) cellular systems, which aims at acting as a complementary system offering high data rates (50-100Mbps in the downlink) up to vehicular speeds [1]. For such systems Multi-Carrier CDMA appears to be as one of the most promising access technologies since it combines the benefits of OFDM and CDMA, and from the point of view of radio resource management offers the maximum flexibility since it allows to manage the network resources in the dimensions of time (time-slots), frequency (carriers), code and with multiple antennas also the space domain. In fact one of the challenges of such systems is the optimum management of the radio resources in order to satisfy the user requirements in the very adverse environment provided by the broadband mobile channel. Efficient packet scheduling schemes are required to manage users access to the resources according to the instantaneous traffic requirement and the channel condition they are experiencing.

The aim of this paper is to present a packet scheduling algorithm for an MC-CDMA based system for the broadband component of the B3G system networks [2] intended to operate in a TDD mode at 5GHz over a 50MHz bandwidth [3,4]. The priority in scheduling users is based on weighting parameters that affect the application functionality and the usage system resources. The parameters are the Predicted Reliability in transmission, the Delay that packet is experiencing in queue and the Attempted transmissions of the packet, since Automated Repeat Request (ARQ) stop and wait protocol is supposed to be included in resource management. The performance is evaluated in downlink and the minimum in terms of the physical channel definitions has been specified to allow the throughput evaluation by system level simulations.

2. SYSTEM AND ALGORITHM DESCRIPTION

In order to facilitate interoperability with TDD Third Generation cellular networks the air interface defined in the project MATRICE [2] has been designed to be as much as possible compatible with UMTS. The MC-CDMA system time-code-frequency frame is divided in 3 time slots numbered from 1 to 3 with the same duration as the UMTS time slots, in 23 groups of 32 sub-carriers each. Each data symbol is spread over one group of sub-carriers with one of the 32 spreading codes of length 32. For each time slot i and code j we can define a Resource Unit (RU) RU(i, j) as the set of symbols which are mapped over time slot i and code j, and all the sub-carriers. The time slots 1 and 2 are allocated to Downlink (DL) transmissions while the time slot 3 is allocated to Uplink (UL) transmission. In DL the spreading code 1 is reserved for the Common Pilot Channel (CPICH) which is an un-modulated channel. The spreading code 2 is reserved for the Broadcast Channel (BCH). Both CPICH and BCH are transmitted with constant power and CPICH is used by the mobile station (MS) to compute the SIR measurements to report to the Base Station (BS). For the simulations a Data Block has been defined for the QPSK modulation and for different coding rates that lead to different (Adaptive) modulation and coding schemes (AMC). Coding rate selected are 0.5, 2/3 and 0.75 that lead to block size S of 31680, 47720 and 48240 bits respectively is transmitted during the Time Transmission Interval (TTI) of 2ms.

The Dynamic Resource Allocation (DRA) unit for the downlink, which includes the scheduler, is outlined in Figure 1. IP packets arrive at the base station and are stored in queues. Before being transmitted over the air interface these bits are concatenated and the results are segmented into Radio Data Blocks specified by the PHY layer. The DRA, includes User Quality Tracking using Signal to Interference (plus Noise) Ratio (SIR) reports by each the mobile, Hybrid ARQ (HARQ) with Chase Combining. In this communication we will concentrate on the scheduling subunit.

![Figure 1: Dynamic Resource Allocation.](image)

The proposed algorithm for scheduling users is based on a prioritisation function dependent on parameters related to the QoS required by the users and Channel State Information (CSI) related parameters, in order to maximize the system throughput subject to fulfillment of the QoS requirements. When arriving at the scheduler unit, a packet gets characterized by a state, whose parameters are: Packet Time-Out; Type or Service Class; Transmission Reliability Expectation and Number of Transmissions...
attempted, where the Packet Time-Out is the remaining time for the packet deadline, after which it will be dropped if not transmitted, and the transmission reliability expectation is a function of the transmission reliability requirements for the service class the packet belongs to and the SIR from BS to mobile. In the algorithm implementation this latter function has been restricted to a ternary valued function

$$W_{t} (\text{type}, \text{SIR}) = \begin{cases} 0 & \text{if } \text{SIR} < \text{Target} \\ 1 & \text{if } \text{Target} \leq \text{SIR} \\ 2 & \text{if } \text{SIR} > \text{Target} \end{cases}$$

where the Target and Threshold values are type dependent and are adjusted so that the first condition corresponds to an unreliable transmission (for the QoS required by the service) and the third a highly reliable transmission.

The prioritization function combines weighting function related to the reliability expectation (Eq. (1)), time-out and number of retransmission attempted, and the user with the highest priority value is scheduled in the current scheduling period:

$$\text{Priority} = W_{t} (\text{type}, \text{SIR})(W_{t} (\text{type}, \text{time\_out}) + W_{t} (\text{type}, \#\text{attempTx}))$$

The delay weighting function $W_{t} (\text{type}, \text{time\_out})$ is a function that linearly increases as the time-out decreases and the maximum allowable delay depends on the service type (1-2 frames for voice, large number of frames for delay insensitive services). The function that weights the Number of Attempted Transmission function increases with number of transmissions that the packet had experienced and the slope as well as the maximum value is dependent on the type of service (maximum of 1 for voice, higher number for data).

3. PRELIMINARY RESULTS

In this section we present some illustrative results obtained by simulations with the scheduler algorithm integrated in the system Level Simulator described in [4]. The algorithm is tested for streaming service and the values of the parameters that characterize a satisfied user are measured. The QoS attributes that are used are the session average bitrate, the Block Error Rate (BIER) and the transfer delay. The performance of the presented algorithm is compared against a scheduler that simply tries to maximize the throughput [4], i.e. prioritisation made by sorting the users by the expected transmission reliability. The simulations parameters are presented in Table 1. The results are presented in Figure 5 and Table 2 for omnidirectional cells of 300 m of radius and with 25 users.

Table 1. Simulation Parameters

<table>
<thead>
<tr>
<th>Weighted Priority Scheduler parameters</th>
<th>First (best reliability and rTx) MATRICE Scheduler</th>
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<tbody>
<tr>
<td>W(\text{Type}, \text{SIR}): \text{SIR target} \Rightarrow 30% \text{Prob. of Block Success Tx} \text{Target+Threshold} \Rightarrow 95% \text{Prob. of Success Tx}</td>
<td>Timer to Prioritise Pkt retransmission 5 frames</td>
</tr>
<tr>
<td>W(\text{Type}, \text{Time-Out}): \text{Packet Time-out} = 80 ms</td>
<td>Max number of retransmissions 15</td>
</tr>
<tr>
<td>W(\text{Type}, \text{AttempTx}): \text{Max number Tx} = 16 and 3</td>
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Table 2. Satisfied users parameters results

<table>
<thead>
<tr>
<th>Unsatisfied Users</th>
<th>Priority Scheduler</th>
<th>Best Reliability User Scheduler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitrate &lt; 384 kbps</td>
<td>10.6</td>
<td>19.3</td>
</tr>
<tr>
<td>BIER &gt; 1E-1</td>
<td>10.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Transfer Delay &gt; 160 ms</td>
<td>10.0</td>
<td>17.0</td>
</tr>
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The preliminary results show that when the transfer delay (for this particular case) is one of the parameters that characterize a satisfied user, an algorithm based on the throughput maximization is no longer the most appropriate. With the presented algorithm one can get enhancements in terms of satisfied users (Table 2), with almost 50% more satisfied users compared with maximum throughput scheduler, without significant reduction in terms of overall system throughput (Figure 2). The values of the parameters of the scheduler algorithm (2) are to be optimised through simulations and the trade-offs as well as more detailed simulation results for different scenarios will be presented in the final communication.