DYNAMIC FUTURE CODE ALLOCATION SCHEME FOR DSCH IN WCDMA SYSTEMS

NISHANT YADAV
Mobility and Intelligent Networks Division
Hughes Software Systems
Plot 17, Sector 18, Electronic City
Gurgaon 122015, Haryana
INDIA

Abstract : -Third generation wireless system is based on the WCDMA (Wide band Code Division Multiple Access) access technique. In this technique all the users share the same bandwidth simultaneously but with different codes. System transmits from base station to multiple user terminals or from user terminal to base station. WCDMA uses Orthogonal Variable Spreading Factor (OVSF) codes. Each user terminal data is being spread by different code chosen from the set of orthogonal codes. Each receiver in the user terminal or base station correlate for its intended data by de-spreading the signal using its particular one of the orthogonal codes. The paper describes a method of selecting spreading codes for multiple users at a particular scheduled time in future. According to the proposal, dynamic future code allocation is done for DSCH which keeps the transmission power as constant as possible and number of user terminals can share the same code tree and gain from statistical multiplexing.

1. Introduction

WCDMA is 3G standard, aiming at providing high speed wireless data services with different Quality of Services (QoS) guarantees.

In WCDMA there are three types of transport channels that can be used to transmit packet data. They are the common, dedicated and shared transport channel. The transport channel for a packet data is selected based on the resource requirement of the bearer, amount of data, the load of the common and the shared channels, the interference levels in the air interface , and the radio performance capability of the different transport channels. The channel selection is done by the packet scheduling algorithm, which is typically controlled by RNC (Radio Network Controller).

The common channels are typically used to carry signalling messages, and low volumes of low bitrate data. The common channels have a low setup time, but do not have a feedback channel. Thus, only open loop power control can be used. Dedicated channels has fast power control, can carry high bit rate data but as setup time for DCH (Dedicated Channel)is longer it it not efficient to setup and release it frequently. For bursty traffic, where the inactivity periods are long, it would not be optimal to keep the downlink code reserved for long period. DSCH is the downlink time shared channel with effective power control and fast scheduling but without soft handover. It is defined to support flexible multiplexing of bursty data traffic in WCDMA. Each user terminal assigned for the DSCH operation is assumed first to setup an associated DCH, which takes care of the power control and indication of transmission on the DSCH for the particular terminal. Control information for DSCH which denotes the data rate and code details is transmitted in DPCCH (Dedicated Ohysical Control Channel) slightly ahead in time than the intended arrival time of data.

2. Channelization Codes

For a Direct-Sequence CDMA (DS-CDMA) system, orthogonal variable spreading factor (OVSF) codes preserve the orthogonality among various channels used. DS-CDMA provides two relevant transmission modes, multi-code (MC-CDMA) and single-code (OVSF-CDMA), by employing various spreading factors. For MC-CDMA, multiple transceivers are equipped with each user' device and thus more hardware complexity is introduced. In OVSF-CDMA, each user device, however, only requires a single transceiver and accordingly the hardware implementation costs are lessened. Although OVSF-CDMA does not need the support of sophisticated hardware, it severely suffers from *code blocking*, i.e., a new call cannot be served although the system can provide the acquired transmission rate. Compared with MC-CDMA, OVSF-CDMA greatly increases the call blocking rates for those new calls with higher data transmission rates since codes providing higher transmission rates are severely fragmented. OVSF-CDMA may thus inefficiently utilize the whole OVSF codes.

The channelization codes of UMTS are based on the OVSF technique, to distinguish various physical channels. An OVSF code allows the spreading factor to be varied among different spreading codes with different coding lengths. FIG 1 presents an OVSF code tree.

There is one tree of channelization code for every scrambling code. In FIG 1, each node in the code tree represents a particular transmission rate, which denotes a *code*. In the code tree each code is represented as C SF, code_number, where *SF* is the spreading factor and the code number is ranging from 1 to *SF*. For OVSF codes, a code *x* can be allocated by/ to a user terminal if and only if the following two conditions are held. (1) No user terminal occupies the codes, which are on the path from the code *x* to the root in the code tree, and (2) any codes appearing in the sub-tree of the code *x* is not allocated. Accordingly, only one code can be assigned to a user terminal in the path from the root to any given leaf.

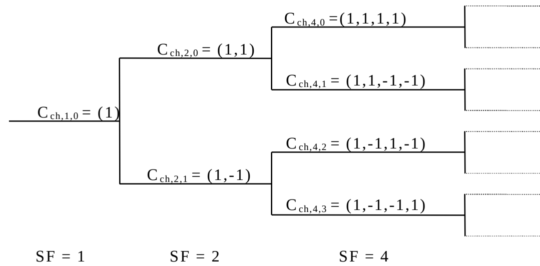

FIG 1

3. DSCH Code Allocation

Downlink Shared Channel is defined to support flexible multiplexing of bursty data traffic in WCDMA. Codes assigned to users are shared in time. Time means SFN (System Frame Number) of a cell which changes every radio frame interval of 10 ms. Unlike in DCH, codes in DSCH are not blocked for long period of inactivity but same code can be assigned to different users at different time. Thus, a subtree from the channelisation code tree is allocated to each user terminal. Different user terminal subtree can overlap. In case codes overlap, care has to be taken that any particular time instant, one code can is assigned to one user only.

At any particular time instant, one code can be used by one user only. Code(s) can be selected dynamically at every schedule time for single or multiple users, which depends upon user whose TTI has expired and availability of codes. This approach has two major drawbacks. First, if higher priority user terminals are selected repeatedly, this may lead to starvation of low priority user terminal as they may never get scheduled. Secondly, if at any particular instant all the data of a high priority user is not scheduled for transmission, multiple iterations for scheduling the user terminal and selection of code has to be done to meet the QoS requirements of this high priority user. This leads to operational inefficiency, taking into consideration large number of users, transport channels and cells supported by Radio Network Controller (RNC). The performance of the DSCH is effected by the delay profile, resource sharing policy, rate adaptation and power control strategy.

4. Dynamic Future Code Allocation Scheme

We propose an improved system and method of managing assignments of spreading codes, for DSCH, to multiple users, based upon the link interference, according to variable data rates requested by the user and priority of user terminals. The proposed approach aims at improving throughput and delay performance of user terminal while ensuring fair service to all the users. This results in an improved utilization of the available frequency spectrum and maintains constant power.

User(s) are selected based on a user defined priority and instantaneous data rate, selecting optimal time ahead in future and allocating codes in future for multiple users at multiple scheduled time.

DSCH is a Bandwidth on Demand type of resource that is allocated to a user terminal after considering following factors:

(1) Priority of user terminal
(2) Data rate / Amount of data pending to be sent on the DSCH
(3) Number of user terminal getting affected due to the code allocation
(4) Multi code capability of the user terminal
(5) TTI (Transmission Time Interval) boundary of the channel(s).

DSCH is a cell resource and all the user terminal in the same cell compete for the DSCH resources. A cell has limited number of PDSCH (OVSF code) and in any given Radio Frame Interval (RFI), at most these many user terminal can be allocated DSCH to send data in a given RFI. Number of PDSCH at any particular time instant in a cell is controlled by code allocation scheme.

The present scheme selects the best possible OVSF code for a user terminal to maximize the throughput and reliability of traffic transferred over the PDSCH.

In the DSCH allocation the principle is to maintain the transmission power as constant as possible, even if the link condition of the target terminal changes for each scheduling period. The present algorithm defines the selection of user terminal and code for that user terminal in future. Following parameters are defined:

1. ‘user priority’ which may take into consideration the quality of radio propagation from the base station and also the Quality of Service requirements that can be met for the particular user. This code selection algorithm is based on the priority of user terminal whose code selection is under consideration and also other user terminal present in the cell. This can be changed dynamically.
2. ‘Data rate’ which at any particular instant defines the instantaneous data rate of a user terminal. It also takes into consideration the data which is queued up and was not sent due to non availability of code for selected time instant. This can be changed dynamically.
3. ‘Dsch offset’ which defines the number of frames ahead when TFCI(2) is to be signaled to the user terminal than the actual data is transmitted, on the air interface
4. ‘Eligible CTFC’s ’ which defines maximum number of CTFC’s, which can be considered for a particular user terminal at any given time instant. If code(s) are not available at the given instant for the best possible CTFC, codes corresponding to other eligible CTFC(s) will be considered for allocation.
5. ‘Future SFN’ which defines the time ahead till when codes can be allocated.
6. ‘Total User priority’ is defined as a combination of ‘user priority’ as defined by the user and the current ‘data rate’ of the user. This combined priority of the user keeps on changing dynamically based on the current rate, movement of user

terminal in the cell, and code assignment

This scheme does not restrict the definition and dynamic behavior of 'user priority' but give the flexibility to the user to change it according to the needs. Present algorithm remains unaffected with the change in criterions taken into consideration for defining the 'user priority'.

Depending upon the user defined parameter, Future SFN- for future code allocation, state of every node in the OVSF tree is maintained for every SFN, from present SFN till (SFN + Future SFN).

FIG 2 describes the main units and flow of the present algorithm. Below is he detailed description of every unit.

(1) This unit describes the selection of user terminal whose data has to be transmitted first. User terminal with highest 'Total User priority' will be serviced first. In case of multiple terminals with same priority data rate is taken into consideration. After a particular user U(n), is selected its relative priority within the 'same' priority user will change as some of its data has been selected for future transmission. Actual transmission of data is done at the scheduled time.

(2) This unit selects the CTFC set denoted by C(n). CTFC selection is based on maximum data rate that can be achieved for the particular user terminal based upon the available data on all the DSCH(s) for the user terminal U(n) selected in (1) and the possible user defined data rates possible. Each selected element in C(n) gives a code set T(n1) from which code selection is to be done.

(3) This unit selects the future SFN, T1 which is based upon TTI, 'Future SFN' and dsch offset before which signalling of the codes has to be done on DPCCH

(4) This unit selects the code X(n1) from T(n1) for the particular data rate selected in (2). It determine the particular SF from which selection has to be done. Selection of any code X will result in shadowing of all the codes in subtree and all the parent codes. Selection of similar codes at the same SF is done based upon number of other user terminals whose allocation will get effected without effecting the QoS requirements of the concerned user. This ensures that all the codes are allocated in the most efficient manner. For example in Figure 5, if a code at SF=16 is to be allocated to user terminal 3, C ch, 16, 3doesn't effect any user, but C ch, 16, 2 effects user terminal 2 also, though both codes will give same data rate to user 1. Thus C ch, 16, 3 will be selected for user terminal 3. If no codes are free, at the selected time, T1 in (3) (for example in figure 5 if at SF=16, all codes for user 1 are shadowed), (3) is repeated to select the second possible time T2, ahead when the allocation can be done.

If for all the possible time instant that can be selected by (3) for any given user terminal, code cannot be allocated for a particular CTFC, (2) is repeated to select the next best CTFC in C(n) (may be at SF=32 in figure 7). This will continue till either the code is selected or 'Eligible CTFC's 'is done. Any particular code selection X(n1) for U(n) at any time instant T1 will block the code from T1 to T2 where T2-T1= (TTI/ 10) -1 of DSCH for that user. In case of multiple DSCH with different TTI for a user, this code selection is done every 10 msec. So at any particular time T1, code will be blocked for 10 msec only. In case of same TTI this code can be selected and blocked for the entire TTI. 'Future SFN' determines number of iterations (5) and 'Eligible CTFC's ' will determine number of iterations (6) as shown in figure (3).

If the selected code X(n) does not result in all the data of the selected user terminal to be scheduled, this user terminal has to be scheduled ahead in time, again, with the processing repeating as defined in (4) and (5). This is to ensure that data of high priority user are scheduled in time.

As the present algorithm is blocking codes in future, if the link condition changes and it becomes bad for certain high priority user which have been scheduled in future, priority of this user will change accordingly. This is reflected in the selected code list by appropriately reselecting the codes for the users in the list.

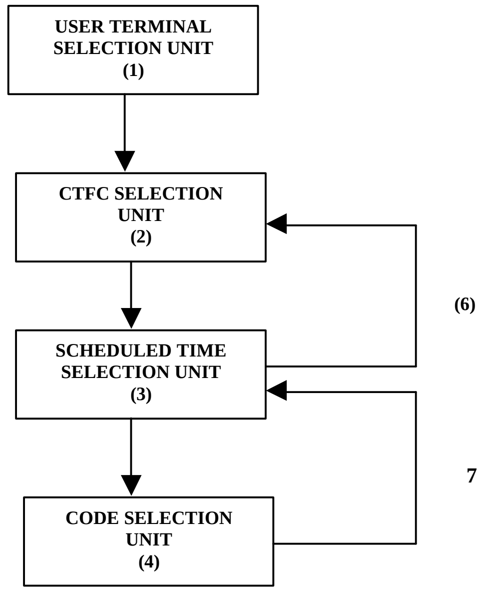

FIG 2

Present algorithm takes into consideration future code allocation upto certain user defined time, ‘Future SFN’. This parameter needs to be adjusted accordingly based upon the future blocking required and characteristics of system usage.

To demonstrate the future code allocation algorithm of the present scheme let us take an example:

Assume user terminal1 is selected for data to be transferred using DSCH services. A CCTrCH for the user terminal 1 consists of transport blocks available for DSCH transport channels DSCH1 and DSCH2. Let TTI for DSCH1 be 80ms and DSCH2 be 20ms. Possible Transport Format Combinations (TFC) to form CCTrCH are described in FIG 3.

User terminal 3 has four 20-byte packets and two 10-byte packets to be sent over DSCH1 and DSCH2 respectively.

Now following steps are applied in sequence to perform future code allocation:

(1) Select the set of CTFC to send maximum possible data for the user terminal. Every CTFC has a list of associated OVSF codes. In the above example CTFC #1 is chosen for 20ms and CTFC #2 is selected for next 60ms.
(2) A best possible code from the list of codes associated with the selected CTFC is selected for the user terminal. The code(s) selected provides maximum reliability and affects code allocation for minimum number of user terminal. Similar selection of code(s) is performed for every CTFC in the CTFC set. So a code C#1 for CTFC #1 a code C#2 for CTFC #2 is selected.
(3) Select a SFN, SFNX such that SFNX and SFNX + 1 has code C#1 and C#2 free and SFNX + 3 to SFNX + 7 has code C#1 free. How much ahead in time the allocation can be done depends upon user defined parameter. This is one of the factor governing the performance of the system

	DSCH 1 (No. TBN x TB Size)	DSCH 2 (No. TBN x TB Size)
CTFC #1	4 x 20	2 x 10
CTFC #2	4 x 20	0 x 10
CTFC #3	0 x 20	2 x 10
CTFC #4	0 x 20	0 x 10

FIG 3

The present algorithm takes into consideration following factors while selecting a code for a CTFC.After a CTFC has been selected, a code needs to be selected for that CTFC. Figure 5 shows the subtree with codes for user terminal 3 and user terminal 4.

Consider a case where codes associated with a CTFC of user terminal 3 are C(8,1), C(16,2), C(16,3), C(32, 5), C(32, 6), C(32, 7) . Codes associated with a CTFC of user terminal 4 are C(8, 0), C(16,0), C(16,1), C(16,2), C(32, 1), C(32, 2), C(32, 3), C(32, 4) and C(32, 5). While choosing a code for CTFC of user terminal1 for SF=16 it is desirable that C(16, 3) is chosen because their allocation will not block any code of CTFC of user terminal 4 though both of the codes will be providing the same data rate.

User Terminal/ Total user priority	TTI	DSCH data (TBS * TBN)	CTFC selected	Available codes
UT1/ 1	20	100 * 80	100 * 20	C ch 64,8
UT2/ 2	10	100 * 40	100 * 20	C ch 64,8
UT3/ 3	10	200 * 20	200 * 20	C ch 32, 6
UT4/ 4	80	400 * 40	400 * 20	C ch 16, 1

FIG 4

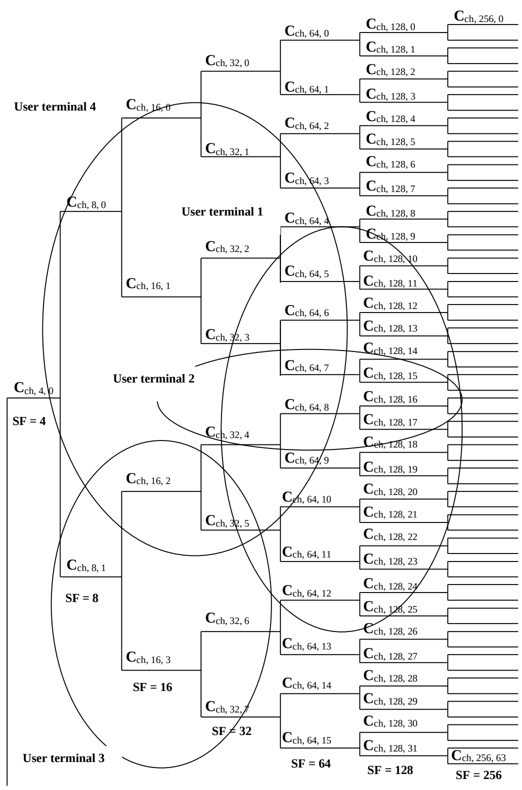

FIG 5

In case assignment of code C(16, 3) does not meet the data rate requirement of user terminal at the scheduled time, more codes will be allocated to this terminal in future. After meeting the requirement of user terminal 3 within the given code constraints codes of user terminal 4 are allocated in time ahead of user terminal 3. Efficiency of the present algorithm can be enhanced by appropriately defining the time in future till which code allocation can be done.

FIG 5 describes example which allocates the codes to 4 different user terminals at any selected time instant, SFN=1 as denoted in FIG 6. Available codes are the codes selected which are free. After C ch 64,8 has been allocated to UT1, this code is not available till SFN=8. If the same code is to be used for UT2 it can be allocated from SFN=9 till SFN=10. Similarly codes are assigned for UT3 and UT4. Note that in the given example CTFC selected and SF does not depict actual data rate of the user.

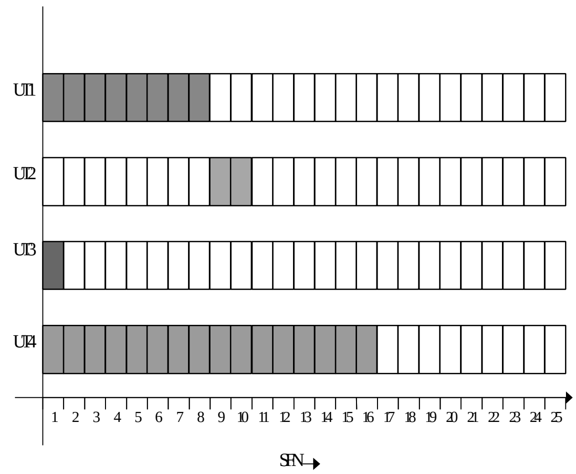

FIG 6

5. Conclusion

DSCH is a cell resource and all the user terminal in the same cell compete for the DSCH resources. A cell has limited number of PDSCH (OVSF code) and in any given Radio Frame Interval (RFI), at most these many user terminal can be allocated DSCH to send data in a given RFI. The performance of the DSCH is effected by the delay profile, resource sharing policy, rate adaptation and power control strategy. The given scheme manages future assignments of spreading codes from sub tree assigned to user terminal taking into consideration user priority and data rate wherein maximum number of users requirement can be met at any given scheduled time. Efficiency of the present algorithm can be enhanced by appropriately defining the time in future till which code allocation can be done.

References:

[1] 3GPP TS 23.321, " *Medium Access Control (MAC) protocol specification*

[2] 3GPP TS 25.213, *"Spreading and Modulation (FDD)"*