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OVSF code groups and reduction in call blocking for WCDMA systems

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Compact code assignment (CCA) scheme for wideband CDMA (WCDMA) system has been proposed using Orthogonal Variable Spreading Factor (OVSF) channelization codes. In WCDMA systems, each User Equipment (UE) is given an OVSF code tree. In CCA scheme, the codes in OVSF code tree are divided into groups and the new call is handled by most congested group. The CCA scheme assigns code to the incoming call in the most compact form such that the available capacity after code assignment is least fragmented. This increases call handling capability of the OVSF-CDMA system. Simulation results show that proposed assignment scheme provide performance improvement in terms of reducing new call blocking probability.

Keywords: WCDMA, OVSF codes, Spreading factor (SF), Code blocking, Code (channel) assignment, Code (channel) reassignment

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1 Introduction

WCDMA[1, 2] uses OVSF codes as channelization codes for data spreading in both reverse link and forward link. In WCDMA each of the UE (User Equipment) and Node B is provided a unique scrambling code and set of channelization codes. The product of the scrambling code and channelization code should be unique for interference free data transmission. In the reverse link transmission all the UEs are distinguished by their unique scrambling codes. Therefore each user can use the complete set of channelization codes. Unlike reverse link, in the forward link transmission, data are carried by the same Node B to the number of UEs. In this case, the same scrambling code is used to carry data through different channels. To fulfill the unique product requirement in the forward link, one needs a channelization code orthogonal to all those channelization codes which are engaged in data transmission. So, for the UEs under the control of single Node B, same channelization code cannot be used. Hence the OVSF channelization code management becomes important in the forward link of OVSF-CDMA system.

For OVSF code tree[3], the codes in different layers have different SFs which make multirate transmission possible. The code is chosen from a layer to make product of data rate and SF constant for all the input traffic classes. In the OVSF code tree, all the codes in one layer are orthogonal to each other. A code is not orthogonal to its ancestors and descendants. In general, to provide variable rate transmission in WCDMA, there are two approaches. In the first approach, all the codes in the system are orthogonal having same SF equal to 512. This is called OCSF (Orthogonal Constant Spreading Factor) CDMA. In OCSF-CDMA, to handle traffic class with smaller data rate, more codes are combined to make product of data rate and code SF same. The approach has the limitation that each UE require a number of transceiver units equal to the maximum number of codes used. This increases the transceiver complexity.

In the second approach called OVSF-CDMA[2] a single code tree is used. The code tree consists of number of codes with different SFs. The code to be used depends upon the rate of incoming user. Only single transceiver unit is required in OVSF-CDMA. In this case when a code is used, all of its ancestors and descendants are blocked from assignment, because they are not orthogonal. This increases the code blocking (to be discussed later) leading to new call blocking. The code blocking is due to internal and external fragmentation[4] of codes. The external fragmentation is because of the scattering of the vacant codes in the code tree. The internal fragmentation is due to quantized nature of the rate handling capability of the OVSF code tree. Data rates in the form of 2^nR are known as quantized data rates. Both, internal and external fragmentation can be reduced by applying assignment and reassignment strategies[5-9]. The remainder of the paper is organized as follows.

Section 2 reviews the background of OVSF-CDMA. Section 3 describes the proposed compact code assignment scheme. Section 4 describes simulation results showing performance improvement using CCA scheme. The conclusions are given in Section 5.

2 Review of OVSF-CDMA

2.1 OVSF code tree

The WCDMA standard defines a 8-layer *OVSF* code tree in the forward link. The SFs from layers 1 to 8 are 512, 256, 128, 64, 32, 16, 8, and 4, respectively. The corresponding data rates handled are R, $2R$, $4R$, $8R$, $16R$, $32R$, $64R$ and $128R$ (where R is the basic data rate 7.5 kbps).

The OVSF code tree is generated using the Walsh code procedure explained in Ref. 7. For input code A the two children are $[A, A]$ and $[A,–A]$. In the second step assume $[A, A]$ as B and $[A,–A]$ as C. The code B and C further generate children $\{[B, B], [B,–B]\}$ and $\{[C, C], [C,–C]\}$, respectively. The procedure is repeated eight times to generate 8 layer OVSF code tree as in WCDMA system. Figure 1 shows an OVSF code tree with the SF varying from 1 to 8. It can handle four different data rates R, $2R$, $4R$ and $8R$. As explained earlier, in the OVSF scheme a code can be given to the coming user if, all descendents and ancestors of the code from root to leaf are free. Accordingly, only one code can be assigned to a UE in the path from the root to leaf. The code with the relatively smaller SF is used for user with relatively higher data rate, so that the overall bandwidth (data rate × SF) of the system is same.

2.2 Code/Call blocking

As explained earlier, code blocking is the major drawback of OVSF-CDMA system. In Fig.2, code tree with four layers is considered. The maximum capacity of the code tree is $8R$. In the code tree two codes with SF 4 (for data rate $2R$) and 8 (for data rate R) are occupied. So, the capacity used for the OVSF code tree is $3R$. The remaining capacity of the code tree is $8R – 3R = 5R$. If a new call with data rate $4R$ arrives, code from the third layer is required. The code tree is not able to provide code for the new call, because both the codes corresponding to $4R$ capacity are blocked. So, this is a situation where a new call can not be supported even if the system has enough capacity to handle it. This is called code (call) blocking and can be avoided using efficient assignment and reassignment schemes.

2.3 Assignment and reassignment schemes

The assignment and reassignment schemes are used to optimize the performance of the OVSF-CDMA

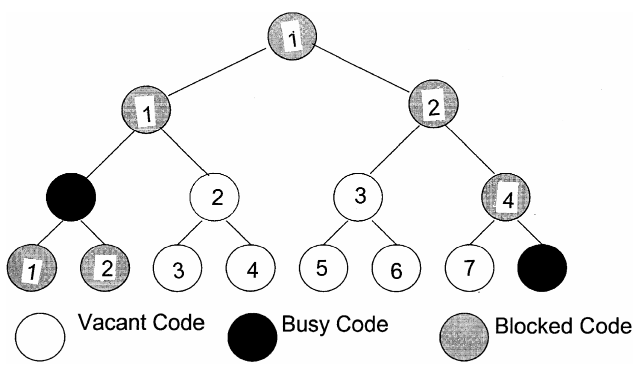
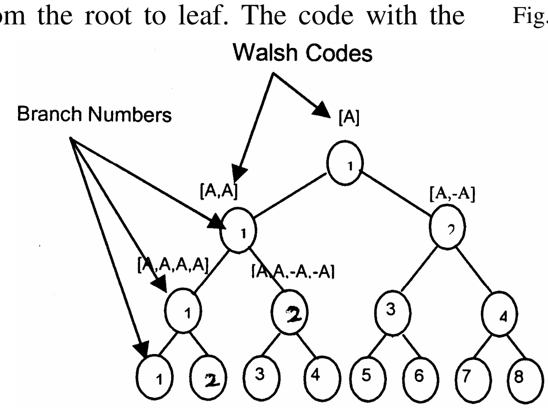


Fig.2 — Four layer code tree with two assigned codes



Layer	Spreading Factor	Data Rate
4	1	8*R*
3	2	4*R*
2	4	2*R*
1	8	1*R*

Fig.1 — A four layer OVSF code tree

system. In random assignment (RA)[5], the incoming user picks vacant code from appropriate layer randomly. In leftmost code assignment (LCA)[5] scheme, the code usage in the code tree starts from left. In the fixed code partitioning (FCP)[6], the code tree is divided into a number of sub trees according to the traffic distribution. The RA, LCA and FCP schemes suffer from large blocking probability and smaller throughput. In dynamic code assignment (DCA)[7] scheme, the blocking probability is reduced using reassignments based on the cost function. The code blocking can be reduced up to 25% using DCA scheme. The DCA scheme requires extra information to be transmitted to inform the receiver about code reassignments adding complexity in transmission. The adaptive assignment scheme (ADA)[8] does code reservation adaptive to the distribution of input traffic classes. The performance comparison of some of these schemes is given in Ref. 9.

3 Compact code assignment (CCA) scheme

Consider an OVSF-CDMA system with code tree having eight layers. Consider that the possible SF in layer 1 to 8 (considering forward link transmission) is $2^7, 2^6,\ldots,2^0$ (128,64…1). One can intentionally use SFs $2^7, 2^6, \ldots, 2^0$ instead of $2^9, 2^8, \ldots 2^2$ (512, 256,…, 4) for mathematical simplicity. The code in layer l, where $l \in [1,8]$ is represented by $C_{l,n}$, where n varies from 1, 2, …., 2^{8-l}. The maximum capacity of each layer and the system is 2^7R. The number of codes in layer l is 2^{8-l}. The SF in layer l is 2^{8-l}. The data rate handled by the code in the layer l is $2^{8-l}R$. There are in total 8 different arrival classes of users corresponding to eight SFs in the OVSF-CDMA system. In the proposed scheme, one can divide the leaves (128 codes in layer 1) into 8×2^m, $m \in [0,4]$ groups. The number of codes in each layer for 8 groups (corresponding to $n = 0$) is given in Table 1. Higher the value of n, more is the number of groups making code tree compact for assignment of low data rates. The division is performed to make the code assignment most compact. When a new call arrives with the code requirement from any of the layers 1 to 5, the most compact group is chosen for code assignment. For a code $C_{5,n}$, the code group contains codes given in Eq. (1).

Table 1 — Illustration of number of codes in each group, where the number of groups is 8

Layer	No. of codes in each group	Maximum used capacity
1	16	16R
2	8	16R
3	4	16R
4	2	16R
5	1	16R

$C_{4,2n-1}$, $C_{4,2n}$ in layer 4
$C_{3,4n-3},\ldots, C_{3,4n}$ in layer 3
$C_{2,8n-7},\ldots, C_{2,8n}$ in layer 2
$C_{1,16n-15},\ldots, C_{1,16n}$ in layer 1 … (1)

The algorithm for assignment scheme considering 8 groups in layer 5 is given below:

- For a new call requiring code from layer l, $l \in [1,5]$, possible vacant codes are listed.
- For each vacant code, find the group to which the code belongs. Find the neighbour capacity (NCP) for the vacant code in its associated group. Neighbour capacity for code $C_{l,n}$ is defined as sum of capacities of all the busy descendants of parent of the code $C_{l,n}$ in layer 5.
- Pick the code from the most congested code group (group with highest neighbour capacity). If two or more codes from same or different groups have the same neighbour capacity, any of them can be used for assignment.

The above procedure leads to the minimum external fragmentation of the remaining capacity, which makes the code assignment most compact. The higher data rates (e.g. rates corresponding to layer 6, 7 and 8 in 8 code groups) are treated like leftmost code assignment scheme. The flowchart of the CCA scheme is shown in Fig. 3. The proposed assignment scheme is explained with the example shown in Fig. 4. The total number of groups is assumed to be 8, so that each group has 16 leaves. Five layers have been considered in the OVSF-CDMA system consisting of 3 trees of capacity 16R each. Assume the status of the code tree before the arrival of new call as shown in Fig. 4. If a new user with the requirement of layer 3 code arrives, there are large numbers of vacant code alternatives. The codes $C_{3,2}$, $C_{3,3}$ and $C_{3,4}$ belongs to the same group with neighbour capacity of 2R each. The neighbour capacity of $C_{3,7}$ and $C_{3,8}$ is 4R each. Similarly the neighbour capacity of $C_{3,10}$ and $C_{3,11}$ is 6R. The neighbour capacity of $C_{3,10}$ and $C_{3,11}$ is maximum and any of the two can be assigned to the incoming call.

4 Results

Event driven simulation has been considered for getting results. The call arrival process is assumed to be Poisson with mean arrival rate, λ varying from 1 to 128 calls/unit time. The call duration is exponentially distributed with a mean value, 1/μ is 1 units of time. The possible OVSF code rates considered are *R*, 2*R*, 4*R* and 8*R*, corresponding to four different arrival classes. Total number of code groups considered is 16 to make maximum capacity 128*R* (equal to the capacity of WCDMA systems). Simulation results are presented to show the new call blocking probability of the proposed CCA scheme. The new call blocking (P_B) is defined as

$$P_B(\%) = \frac{\text{Number of calls blocked}}{\text{Total number of calls}} \qquad \ldots (2)$$

The blocking probability of CCA scheme is compared with the blocking probability of random assignment (RA), leftmost code assignment (LCA) and fixed code partitioning (FCP) schemes discussed earlier. The probability distribution is denoted by (p_1, p_2, p_3, p_4), where p_1, p_2, p_3 and p_4 are the probabilities of arrival rate *R*, 2*R*, 4*R* and 8*R* users. Traffic load is defined as product of arrival rate and call duration. Three traffic arrival distributions are considered. In the first case, all the four classes have uniform distribution (Fig. 5). In the second case, the probability of arrival of real time calls (*R*, 2*R* for simulation results) is more compared to non-real time

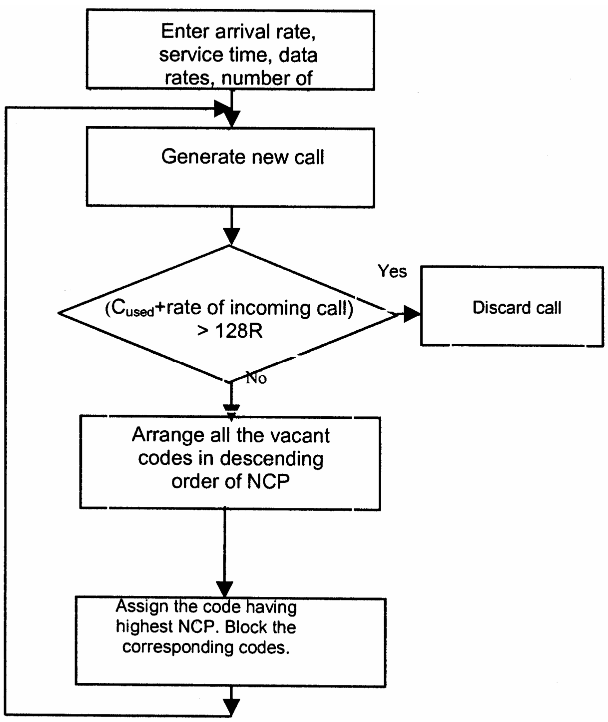


Fig.3 — Flowchart of compact code assignment (CCA) scheme

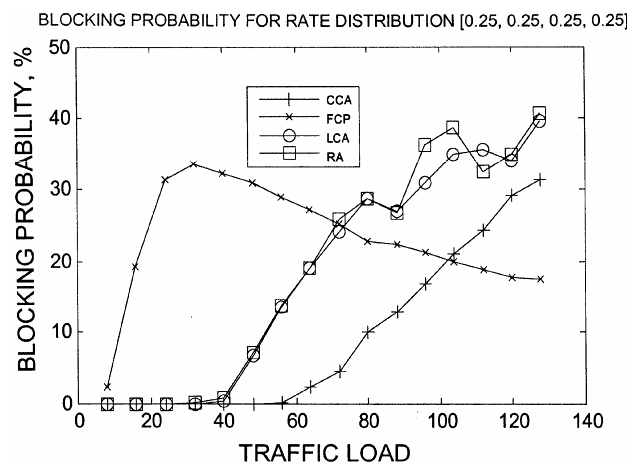


Fig. 5 — Blocking probability versus traffic load for uniform distribution

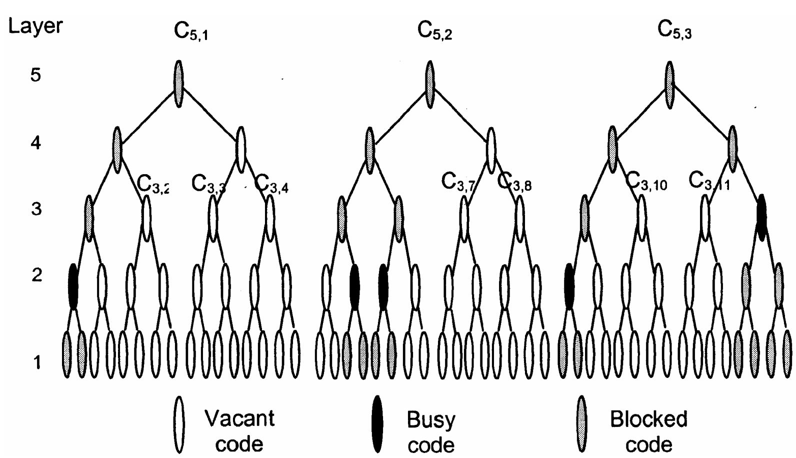


Fig.4 — Illustration of compact code assignment (CCA) scheme

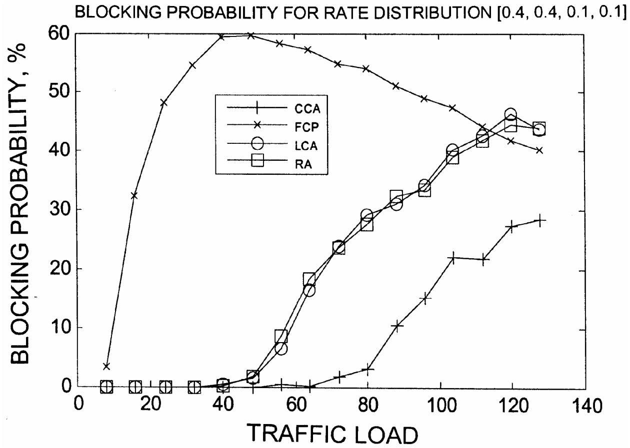


Fig. 6 — Blocking probability versus traffic load for more real time calls

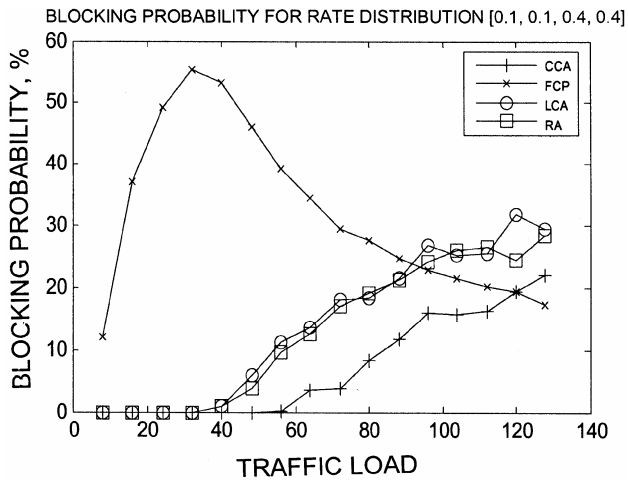


Fig. 7 — Blocking probability versus traffic load for more non-real time calls

calls (Fig. 6). In the third case (Fig. 7), non-real time calls (4*R*, 8*R* for simulation results) dominate the traffic. The simulation is done for 5000 users and the result is the average of 10 simulations. Results show that, for all kinds of traffic the compact code assignment scheme provides reduction in new call blocking, leading to the improved system throughput. The FCP scheme gives performance comparable to CCA for higher loads but for all types of load, the CCA scheme, on the average is superior to FCP scheme.

5 Conclusion

A compact code assignment (CCA) scheme is proposed for the efficient use of OVSF codes in 3G and beyond WCDMA wireless communication systems. The benefit of the proposed CCA scheme is that it assigns the code to new incoming call in such a way that the remaining capacity of the system is least fragmented making the assignment scheme most compact. This leads to improved performance of the OVSF-CDMA system. The event-driven simulation was performed to demonstrate the results. Results show that the CCA scheme can outperform the schemes that do not consider the code assignment on the basis of code groups.

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