CHAPTER 6

Miscellaneous code assignment schemes

6.1 Introduction
The chapter describes a number of code assignment schemes independent of the properties of code tree. As discussed, the WCDMA downlink has the 8 layer OVSF code tree with one code in the layer 8. Using standard Walsh procedure, starting with length one code (chip rate is same as data rate), the number of codes with length four are 4. In the current WCDMA system, only one code with length one is used. So, we can extend the size of the code tree from 8 layers to 10 layers increasing the code capacity 4 times. If we have enough vacant codes available, the code rate wastage can be minimized to zero by dividing the higher rates into smaller quantize rates. Here the code blocking can be reduced to zero.

The OVSF code tree at the UE is not utilized fully as there is single UE to use full OVSF code tree. So we can utilize the code tree at the UE for the BS. The BS code tree in this case is only used for control signals before call set up. The blocking problem does not exist at all. The time multiplexing can be used to use the capacity of single code for number of users.

6.2 Code Tree Extension
6.2.1 Description
Using standard Walsh code procedure [7], starting with single bit, the number of codes in the 1st and 2nd step are 2(two bit size) and 4(four bit size). So the number of codes with the spreading code 4 are 4([1,1,1,1], [1,1,-1,-1], [1,-1,1,-1] and [1,-1,-1,1]) respectively as shown in Figure 6.1. Therefore corresponding to the SF 4, there are 4 orthogonal codes. In WCDMA systems used so far, we uses one code out of these 4 codes in layer 8. In the proposed scheme, we use all four possible codes in layer 8. The capacity of system and the number of codes in each layer is increased 4 times. This is equivalent to using a 10 layer OVSF code tree with codes in layer 10 and 9 unused. The extension of the code tree is shown in Figure 6.1. The current WCDMA systems uses only one code (say
Figure 6.1 Illustration of OVSF code tree extension. In the current WCDMA system only one code with SF 4 (e.g. code [1,1,1,1] shown above) is used. In the proposed design, we use three additional codes with SF 4 (orthogonal to [1,1,1,1]). The codes are generated using Walsh encoding.

[1,1,1,1] in layer 8 and extend the tree till layer 1. In the proposed design, we add three more orthogonal codes ([1,-1,-1], [1,-1,1,-1] and [1,-1,-1,1]). The extension does not add complexity in UE because, for every call single code (requiring single rake combiner
as already available in present WCDMA systems) is used from any of the four code trees.

6.2.2 Flowchart and Algorithm

The flowchart of the code tree extended OVSF-CDMA scheme is shown in Figure 6.2. The algorithm is outlined below

1. Input parameters such as arrival rate, call duration and number of layers are entered.
2. For each new call, capacity check is performed to verify that whether new call can be handled by the 1st code or its children in the 8-layer OVSF code tree or not.

3. If the rate of new call is more than the available capacity of the code tree, capacity check is performed for the second code and its children. The procedure is repeated till we reach 4th code.

4. If the rate can not be handled even with the 4th code, the new call is discarded otherwise the code assignment, code blocking is done.

5. Go to the step 2.

6.2.3 Input Parameters

- The call arrival process is assumed to be Poisson with mean arrival rate, \( \lambda \) varying from 1 to 128 calls/unit time.

- The call duration is exponentially distributed with a mean value, \( 1/\mu \) is 1 units of time.

- The possible OVSF code rates considered are R, 2R, 4R and 8R corresponding to four different arrival classes.

- The total number of codes in layer 4 is 16 for all the previous schemes and is 64 for the design proposed.

6.2.4 Results

We consider event driven simulation for getting results. Simulation results are plotted for the new call blocking in the proposed extended OVSF code tree system. We compare the call blocking probability of Code tree Extended scheme named as 4-OVSF (indicating the extension by 4 times) scheme with the call blocking of random assignment (RA), leftmost code assignment (LCA), fixed set assignment (FSP) and dynamic code assignment (DCA) schemes discussed earlier. The probabilities for different class users are 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, 2R, 4R and 8R users. We consider three different distributions of arrival classes. In the first case traffic load is uniform (Figure 6.3.) for the four arrival classes. In the second case, non-real time traffic rates (higher data rates 4R and 8R) (Figure 6.4.) dominates the traffic load and in the third case real time users
(lower data rates $R$ and $2R$) (Figure 6.5.) dominates the traffic. The simulation is done
for 5000 users and result is the average of 10 simulations. Results show that the call blocking is far less in the proposed design compared to RA, LCA and FSP schemes for all types of traffic. Call blocking is even lesser than the DCA scheme except for the case of non real time calls dominating scenario.

6.3 Bandwidth Division Assignment (BDA) scheme

6.3.1 Description

In the proposed assignment scheme initially code is assigned similar to the LCA scheme. When the code tree is too fragmented causing unavailability of vacant code for higher data rates, we divide the input data rate $2^lR$ into one of 2, 4, ..., $2^{l-1}$ parallel groups of rate 1/2, 1/4, ..., 1/2^{l-1} depending upon the available capacity of the layer. If rate $2^l$ is not handled by layer l due to code blocking, we check layer l-1. If the layer l-1 has vacant capacity at least equal to $2^l$ we divide the input data rate into two groups of rate $2^{l-1}R$, each and two vacant codes from layer l-1 are assigned to it. If the vacant capacity in layer l-1 is less than $2^lR$, we go to the layer l-1 and so on till we find a layer with available capacity at least $2^lR$. So depending upon the availability of codes we can divide the rate
into smaller groups. The code blocking can be made as small as zero using the proposed assignment scheme. The number of channels required increases exponentially as we

<table>
<thead>
<tr>
<th>Rate</th>
<th>Layer</th>
<th>Number of codes required</th>
<th>Number of channels required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2(^{R/2})</td>
<td>2(^{R/2})</td>
<td>2(^{R/2})</td>
</tr>
<tr>
<td>2</td>
<td>2(^{R/2})</td>
<td>2(^{R/2})</td>
<td>2(^{R/2})</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>l-1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>l</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

divide the bandwidth from layer \( l \) down to leaf code. Table 6.1 shows the number of codes required in different layers for handling data rate 2\(^{R/2}\). The proposed bandwidth division scheme is independent of the arrival class distribution.

For illustration of assignment scheme, consider the tree shown in Figure 6.6. As explained earlier the code tree cannot handle user with data rate 8R directly. We start

<table>
<thead>
<tr>
<th>Layer</th>
<th>Bandwidth</th>
<th>SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>32 R</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>16 R</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>8 R</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>4 R</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>2 R</td>
<td>16</td>
</tr>
<tr>
<td>1</td>
<td>R</td>
<td>32</td>
</tr>
</tbody>
</table>

Figure 6.6 OVSF code tree with six layers

traversing the tree downwards till we reach to a layer whose vacant capacity is at least 8R. As we see the layer 4 has two vacant codes \( C_{3,3} \) and \( C_{3,6} \) making vacant capacity of 8
units. So the user's 8R data rate is divided into two 4R parallel rates and codes are assigned to it.

### 6.4 Zero blocking code assignment scheme

In this design, when Node B is ready for the data transmission with $i^{th}$ UE represented by $UE_i$, it generates secondary scrambling code $SC_{s,i}$ and send the same to the $UE_i$. Now, the user has both the codes of Node B, namely primary scrambling codes $SC_{p,i}$ (similar to previous scrambling codes) and secondary scrambling code. The UE acknowledge the reception of the $SC_{s,i}$. On receiving the acknowledgement, the base station will scramble data using $SC_{s,i}$ instead of $SC_{p,i}$. Hence the base station can utilize the code tree available at the $UE_i$ for the forward link transmission. So the OVSF code tree at the $UE_i$ is shared between $UE_i$ and Node B. As each channel in the cell is represented by unique scrambling code $SC_{s,i}$, there is no code blocking. The secondary scrambling code generated at the Node B should be unique for each channel in the cell. Also, as each cell has unique primary scrambling code, the secondary scrambling codes generated in a cell need not to be different in different cells. The proposed design requires extra handshaking signals for transmission of $SC_{s,i}$ and acknowledgement reception. In the previous code assignment schemes, the maximum capacity of all the channels is 512R in the downlink. In the proposed design the capacity of the channel is unlimited as far as all the channels use different secondary scrambling codes. The set of operations in forward and reverse direction for the proposed design are given below

**Forward Link**

1. **Node B** generate secondary scrambling code $SC_{s,i}$ which is having same length as the length of primary scrambling code. It passes $SC_{s,i}$ to the $UE$.
2. In response to the $SC_{s,i}$ signal $UE$ send the acknowledgement signal to the **Node B**.
3. On receiving the acknowledgement, **Node B** asks for the OVSF code tree at the $UE$.
   The code tree at the **Node B** is used only for control signals transmission.
4. The $UE$ send the OVSF code tree to the **Node B** (or **Node B** can use the second set of OVSF code tree exactly same as the OVSF code tree available with it).
5. $UE$ and **Node B** start data transmission using codes from the same OVSF code tree.

**Reverse Link**
The set of operations are similar in the reverse link except the fact that in the call initiation, the UE requests for the secondary scrambling code.

The proposed design is explained with example shown in Figure 6.7. There are five simultaneous communications in the cell under the control of single Node B. The

![Diagram](image)

**Figure 6.7 Example illustrating five UEs communicating with single Node B. Each channel uses different secondary scrambling code.**

data is scrambled using $SC_{k,i}$, $i \in [1,5]$ for channels 1,2,...,5 corresponding to $UE_i$, $i \in [1,5]$. The channelization codes $Ch_i$, $i \in [1,5]$ may be same or different.

### 6.5 Single Code Time Multiplexing (SCTM) scheme

#### 6.5.1 Description

We divide the total time frame for code in layer $m$ into $2^{m-1}$ slots, with code in layer 1 has single slot denoted by $I_{ref}$. Consider a new call arrival with non-quantized data rate in the form of $kR$, $k \neq 2^n$, $n \in [2,9]$. Choose minimum $m$ satisfying $k < 2^m$. The availability of the
code with at least \( k \) slots is checked in the layer \( m+1 \). If the vacant slots are available the time frame of the code is divided into two groups of slots \( T_{m+1}^1 \) and \( T_{m+1}^2 \), where both groups

\[
\begin{array}{cccccccccccccccc}
S1 & S2 & S3 & S4 & S5 & S6 & S7 & S8 & S9 & S10 & S11 & S12 & S13 & S14 & S15 & S16 \\
\hline
T^1_3 & & & & & & & & & & & & & & T^2_3 \\
T^1_4 & & & & & & & & & & & & & & T^2_4 \\
S1 & S2 & S3 & S4 & S5 & S6 & S7 & S8 \\
\hline
S1 & S2 & S3 & S4 \\
\hline
S1 & T_{ref} \\
\hline
\end{array}
\]

are multiple of minimum time slot \( T_{ref} \). The new call is assigned all the slots of \( T^1_{m+1} \). The slots in group \( T^2_{m+1} \) can be utilized by the other calls to come. If the vacant slots are not available, the availability of vacant slots is checked in the layer \( m+2 \). If the vacant slots are available, it is once again divided into two groups \( T^1_{m+2} \) and \( T^2_{m+2} \), where \( T^1_{m+2} = T^1_{m+1} / 2 \).

The procedure is repeated up to layer 8 till we get vacant slots.

**Optimality Criterion**

If multiple options of time slots exist in a layer, the code with the minimum number of vacant slots and greater than the slots required for the new call is chosen. This gives the maximum number of available slots for the new calls to arrive. The procedure is shown in the Figure 6.8 for a five layer system when the new call with rate 6R arrives. The number of slots in the layer 4 and 5 are 8 and 16 respectively. Slot searching is started.
from layer 4. If vacant slots are available, they are captured by the call otherwise procedure is repeated in layer 5.

6.5.2 Flowchart and Algorithm

![Flowchart](image)

Figure 6.9 Flow chart of single code time multiplexing scheme

The flowchart of single code assignment scheme is given in Figure 6.9. The algorithm is outlined below
1. Input parameters such as arrival rate, call duration and number of layers are entered.

2. Generate new call. For each new call, capacity check is performed to verify that whether new call can be handled by the code tree or not.

3. If the rate of new call is more than the available capacity of the code tree, call is discarded. Otherwise, the vacant slots are searched in the layer $m+1$ for rate $kR$, where $2^m > k$ for minimum $m$.

4. If vacant slots are available, the slots are assigned to the new call according to the optimality criteria discussed. Go to step 2.

5. If the vacant slots are not available in layer $m+1$, go to layer $m+2$. The procedure is repeated for vacant slots till layer 8.

6.6 Summary

The chapter proposes code assignment schemes independent of properties of the code tree. The code tree extension increase the capacity of code tree 4 times due to flexibility of codes in layer 8 instead of one code e.g. in present WCDMA system. The bandwidth division scheme allows the lower rate codes to be used for handling higher rate calls, a situation occurs when best effort traffic dominates the call arrival distribution. The zero blocking design is based upon the fact that the OVSF code tree at the UE is under utilized. So the UE code tree is used by the BS for handling calls. The code tree at the BS is not used for traffic transmission but is only used for control signals transmission. The time multiplexing uses single code sharing by multiple users to avoid code blocking.