The Analysis of the Reservation Strategy in The OVSF Tree for The WCDMA Systems

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Abstract

The Orthogonal Variable Spreading Factor channelization codes are widely used to provide the variable data rate and support different bandwidth requirements for users in the WCDMA system. The code assignment has the significant impact on the code utilization and code blocking probability. The code assignment strategies are unfair for the large bandwidth requests. To improve the fairness in the code assignment, we reserve a part of bandwidth in the OVSF tree to reduce the blocking probability of the larger bandwidth request. The performance of the proposed scheme is simulated by programs to verify the outperformance.

Keywords: Orthogonal Variable Spreading Factor (OVSF), Wideband Division Multiple Access (WCDMA), Code Assignment, Code Reassignment.

1. Introduction

In the Third Generation (3G) wireless systems, it is expected that a majority of the traffic will carry bursted data, which is drastically different from the voice traffic carried in the existing second generation wireless system. The radio interface is implemented by the technology of Wideband Code Division Multiple Access (W-CDMA). To access variable multimedia applications, the system supports flexible transmission rates for different users. Such flexibility can be achieved by the orthogonal variable spreading factor (OVSF) as the channelization codes. The Multirate Code CDMA (MC-CDMA) system needs multiple transceiver units to provide the high data rates for the mobile users complexity [1][2][3][4][5]. The OVSF-CDMA system only needs a single transceiver unit. The hardwire complexity is less than that of the MC-CDMA system. Therefore, we proposed our schemes based on the OVSF-CDMA system.

In this paper, we proposed a scheme to assign and reassign codes in OVSF code tree. This scheme is to reserve a part of bandwidth in the OVSF tree. The reserved bandwidth is reserved for the large bandwidth request. Using this scheme, we can balance the code blocking probability of the large bandwidth requests. The experimental results show that our code assignment strategy is fairer than other schemes in terms of code blocking.

To support higher speed and multirate data services in 3G mobile communication systems, two approaches are proposed in International Mobile Telecommunication 2000 (IMT-2000) with W-CDMA: the variable-length spreading and multicode techniques. The variable-length spreading CDMA employs multiple spreading factors for multirate transmissions, while multicode CDMA allocates multiple codes for the high rate channel assignment. Channelization and scrambling are the basic operations in the W-CDMA. Channelization transforms every data symbol into a number of chips. The number of chips of per data symbol is called the spreading factor (SF). Orthogonal variable spreading factor (OVSF) [6][7] codes are employed as the channelization codes in W-CDMA to preserve orthogonality among different downlink channels. Scrambling employs scrambling codes in the downlink channels for users to recognize their own base stations and also to preserve mutual randomness among users of different cells.

In 3GPP specification, OVSF codes can be represented as a binary code tree. OVSF codes are used as the channelization codes in the UMTS terrestrial radio access (UTRA). These OVSF codes can be represented by a code tree. Each layer corresponds to a particular spreading factor, so all codes in the same layer can support the same data rate. The data rate a code can support is called its capacity. Let each leaf node in layer K has the minimum data rate 1R. Then, the capacity of the codes in layer (K-1), (K-2),…, 1 and 0 are 2R, 4R,…, 2K-1R and 2KR respectively. For example, in Figure 1, there is a 4 layer OVSF code tree, SF in layer 0 is 1, SF in layer 1 is 2,…, SF in layer 3 is 8, the bandwidth capacities are 8R, 4R, 2R, 1R, respectively. The total amount of the bandwidth in this OVSF code tree is 8R. The number of codes at each level is equal to the value of SF.

In OVSF code tree, all lower layer codes spanned from a higher layer code are defined as descendant codes. All high layer codes linking a particular code to the root code are called its ancestor codes. Two sibling codes are those generated from their immediate ancestor code. The lowest-layer codes are called leaf codes, or simply leaves. Note that all codes in each layer are mutually orthogonal. Furthermore, any two codes of different layers are also orthogonal except for the case when one of the two codes is the mother code of the other.

There are different kinds of codes in OVSF tree. In Figure 1, this is an OVSF code with its bandwidth is 8R, there are 4 busy codes, 1R、1R、2R、1R (from left to right, $C_{8,1}$、$C_{8,2}$、$C_{4,2}$、$C_{8,7}$), respectively, with the total bandwidth is 5R. The remaining assignable codes are 2R、1R (left to right , $C_{4,3}$、$C_{8,8}$), respectively, with total bandwidth is 3R. It means that we can assign one code 2R and one code 1R, or three codes 1R to user requirements.

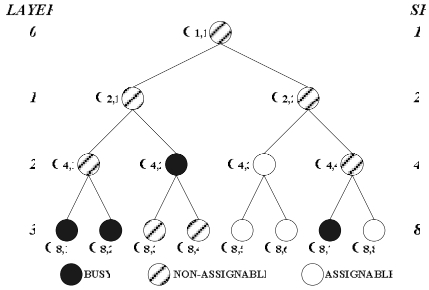


Figure 1 The OVSF Codes

The OVSF code blocking is defined as the condition that a new call cannot be supported although the system has excess capacity to support the rate requirement of the call. After the call requests are provided and served in the system, an OVSF code tree may become too fragmented to support the newly arrival calls even if there are sufficient spaces in the code tree. This is referred to as the external fragmentation problem. Solutions of the code blocking require intelligent code assignment and code reassignment strategies. The code assignment is the algorithm how to assign the code to a new call in the code tree to avoid the tree becoming too fragmented. The code reassignment is the algorithm how to rearrange the available code when a new call arrives and finds no proper place in the OVSF tree to accommodate the requests but the remaining capacity in the system is sufficient. Code reassignment involves the system performance cost. Therefore, the frequency of the code reassignment should be minimized. The problem is very similar to the traditional memory management in the Operating System design.

2. The Code Assignment and Reservation Scheme

When a call requesting arrives, we need to find a code in the OVSF tree to serve the call. Assuming that no code reassignment will be conducted, we discuss three strategies as follows [9][10][11][12]:

1. Random Assignment: Consider Figure 2. Suppose a new call arriving requesting a rate 2R, by the random strategy, any of the codes $C_{16,2}$、$C_{16,5}$、$C_{16,7}$、$C_{16,15}$ may be chosen to serve the new call.
2. Leftmost Assignment: In Figure 2. Suppose a new call arriving requesting a rate 2R, by the leftmost strategy, remaining codes are $C_{16,2}$、$C_{16,5}$、$C_{16,7}$、$C_{16,15}$, and $C_{16,2}$ will be chosen.
3. Crowded-First Assignment: In Figure 2. Suppose a new call arriving requesting a rate 2R and the remaining codes are $C_{16,2}$、$C_{16,5}$、$C_{16,7}$、$C_{16,15}$, by the crowded-first strategy, the codes' ancestors are compared. $C_{8,1}$, $C_{8,3}$, $C_{8,4}$, $C_{8,8}$, and both $C_{8,1}$, $C_{8,8}$ will be fully occupied if $C_{16,1}$ and $C_{16,15}$ are chosen, respectively. So, we further compare their ancestors, $C_{4,1}$, $C_{4,4}$,the comparison is tied again. After comparing one level up, we found that $C_{2,2}$ is more crowded than $C_{2,1}$, then $C_{16,15}$ will be selected to serve the new call.

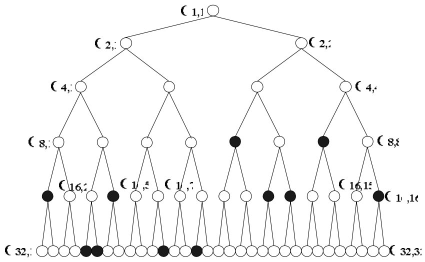


Figure 2 A Example of the Code Assignment in the OVSF Tree

When the code tree is used for a while, it is inevitable that the tree become fragmented. To provide the assignment of the large bandwidth requests, code reassignment can be conducted to squeeze a large-enough space for the new call. The solutions are very similar to the traditional memory management in the Operation System. Code reassignment may incur costs in the system. Dynamic Code Assignment (DCA) [8] is proposed to find a branch in the code tree which can be vacated with the minimum cost (minimum-cost branch).

In Figure 3, we assume a new call arrived with requesting a rate of 8R. Code $C_{4,4}$ is the minimum-cost branch because it contains only two busy codes, $C_{8,8}$ and $C_{16,13}$. When reassigning $C_{8,8}$, another reassignment will be triggered. In this period, $C_{8,2}$ is selected as the minimum-cost branch because it contains only one busy code $C_{32,8}$. Based on the crowded-first strategy, $C_{32,8}$ will be replaced by $C_{32,12}$. Then, $C_{8,8}$ can be replaced by $C_{8,2}$. Finally, $C_{16,13}$ will be replaced by $C_{16,9}$. Now, $C_{4,1}$ is vacated to accommodate the new 8R-call. In this example, the chain reaction occurs when the DCA is triggered.

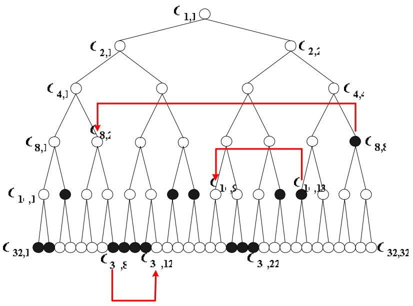


Figure 3 A Example of the Code Reassignment

Random assignment and left-most assignment can assign codes easily. They also cause code blocking easily. Crowded-first assignment can retain larger continuous bandwidth, but its computation time is more complexity than the random and left-most assignments for the recursive computation. Code reassignment DCA solves code blocking, but the costs are large for the chain reaction.

To reduce the code blocking of the large bandwidth requests, reservation scheme is the easy way. Figure 4 shows our scheme to reserve one subtree in the OVSF tree to support large bandwidth requests. The algorithm of the reservation scheme is very simple. We extract a subtree from the OVSF tree to be the partition of the reserved OVSF subtree. The partition excluding the extracting subtree is the non-reserved OVSF tree. The 1R, 2R, 4R, and 8R requests can be assigned to the non-reserved OVSF tree. If the requests are rejected in the non-reserved OVSF tree, 4R and 8R requests can be assigned to the reserved OVSF subtree.

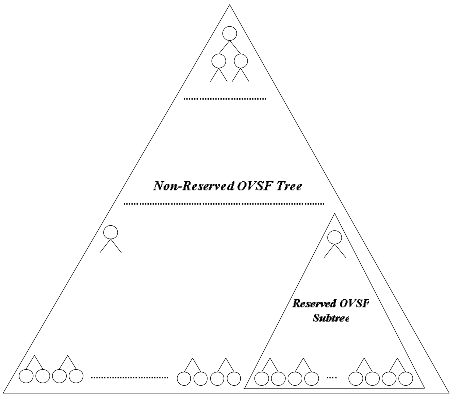
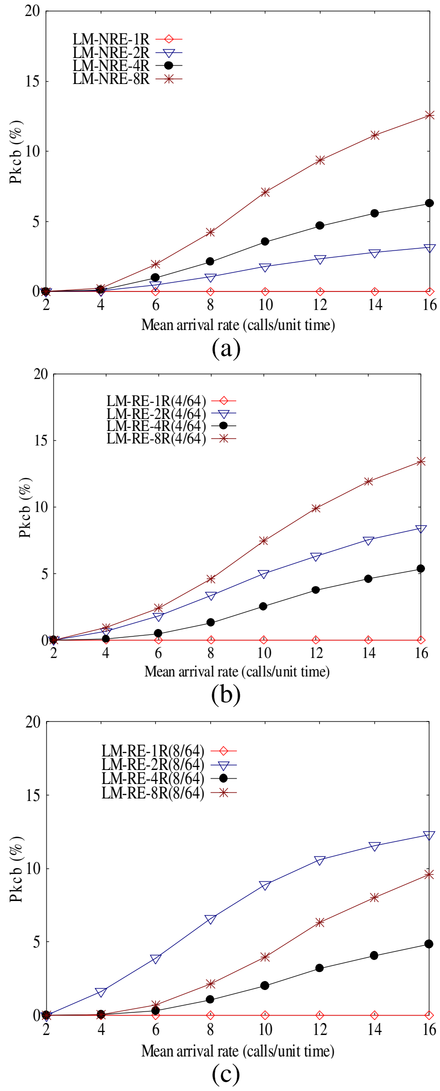


Figure 4 The Reserve OVSF Code Assignment and Reassignment

3. The Simulation Results and Analysis

We have implemented a simulator to evaluate the performance of the proposed strategies. New calls arrived in a Poisson distribution. Each call might request a rate of 1R, 2R, 4R, and 8R. Call duration is exponentially distributed with a mean of 4. The traffic pattern used here is 1R:2R:4R:8R=1:1:1:1. Figure 5 shows the requests 1R, 2R, 4R, 8R with Left-Most Assignment and reserved bandwidth scheme. The total capacity of the system is 64R. If we use non-reserved scheme, the code blocking (P_{kcb}) of the request 8R is larger than other requests as shown in Figure 5 (a). That is because 8R request is more difficult to obtain the continuous bandwidth. We also compare the sizes of the reserved OVSF trees with 4R and 8R. The code blocking of the large bandwidth requests (4R and 8R requests) are reduced as shown in Figure 5 (b) and (c).



(a)

(b)

(c)

Figure 5 (SF=64) Left-Most Assignment with (a) Non-Reserved Scheme (b) Reserved 4R Scheme (c) Reserved 8R Scheme

Figure 6 shows the code blocking probability of the 4R request with left-most assignment and with different reserved capacity. If we reserve more bandwidth, and the code blocking will decrease.

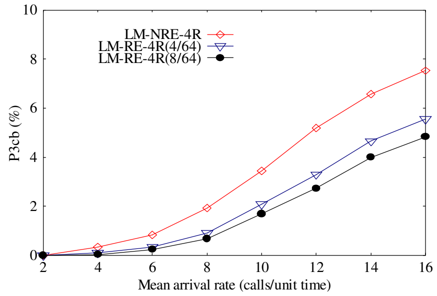


Figure 6 (SF=64) The Comparisons in the 4R Requests with Reserved Schemes

Figure 7 shows the 8R requests with left-most assignment with different reserved capacity. If we reserve more bandwidth, and the code blocking of the 8R requests will decrease. Because reserved 4R is not enough for the 8R request, the code blocking of the LM-RE-8R(4/64) is larger than the code blocking of the LM-NRE-8R.

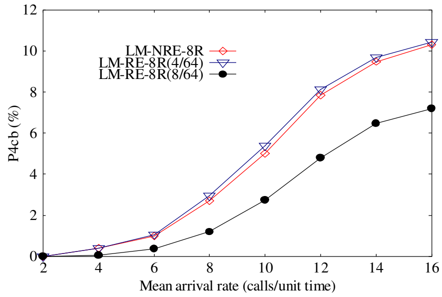
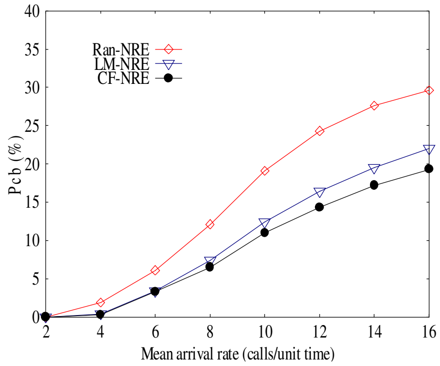
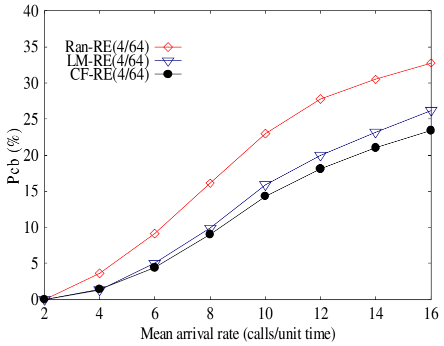


Figure 7 (SF=64) The Comparisons in 8R Requests with Reserved Schemes

Figure 8 shows the total code blocking with different reserved capacity and different reserved bandwidth scheme. If we reserve more bandwidth, and the code blocking should be increased. The code blocking of random assignment is larger than left-most assignment and crowded-first assignment. The results are coincide with the previous studies.



(a)



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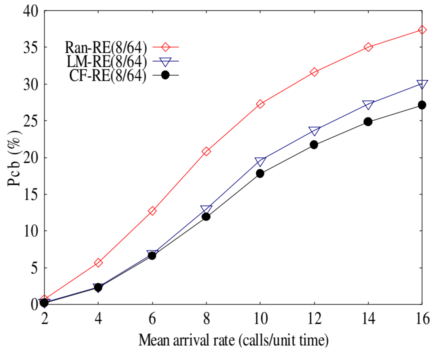


(c)

Figure 8 (SF=64) Three Kinds of OVSF Assignment with (a) Non-Reserved Scheme (b) Reserved 4R Scheme (c) Reserved 8R Scheme

Figure 9 shows the code blocking with left-most assignment with different reserved capacities. If we reserve more bandwidth, and the code blocking will increase. The code blocking of reserved bandwidth 8R scheme is larger than reserved bandwidth 4R scheme and non-reserved bandwidth scheme.

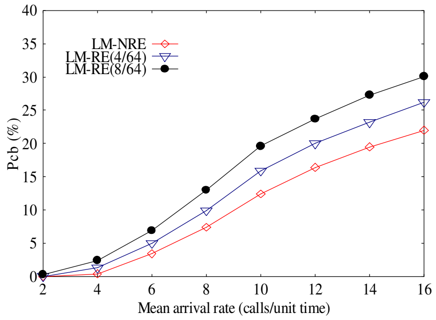


Figure 9 (SF=64) Reserved Schemes with Left-Most Assignment

Figure 10 shows the number of reassigned codes comparisons with different assignment methods and different reserved capacities. If we reserve more bandwidth, the number of reassigned codes will be increased.

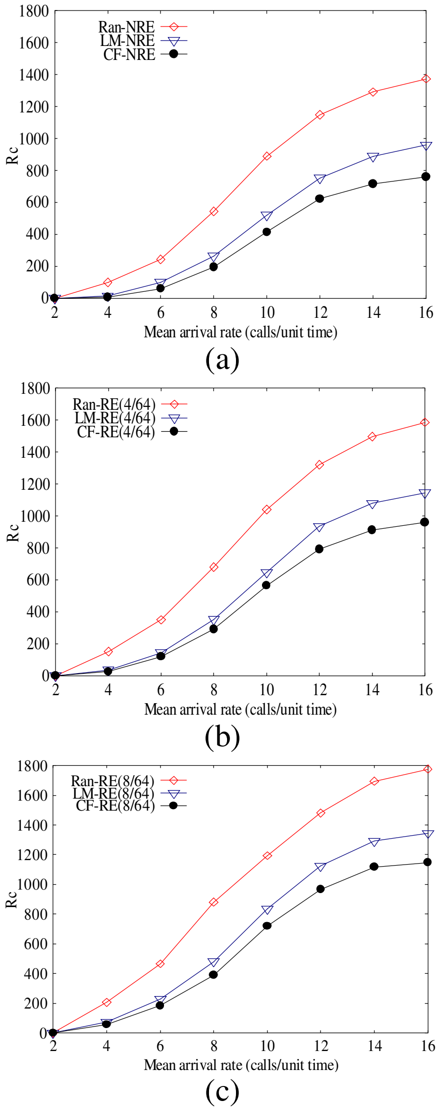


Figure 10 (SF=64) The Number of Reassigned Codes Comparisons with (a) Non-Reserved Scheme (b) Reserved 4R Scheme (c) Reserved 8R Scheme

Figure 11 shows the number of reassigned codes comparisons with left-most assignment and different reserved capacities. If we reserve more bandwidth, the number of reassigned codes will be increased.

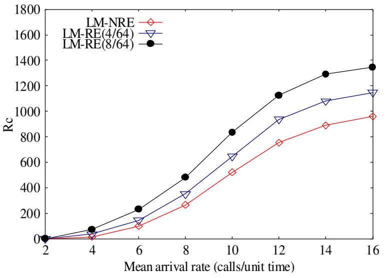


Figure 11 The Number of Reassigned Codes Comparisons with Left-Most Assignment (SF = 64)

Figure 12 and Figure 13 show the reject call rate with left-most assignment and different reserved capacities. The results show that if we reserve more bandwidth, the reject call rate will be increased.

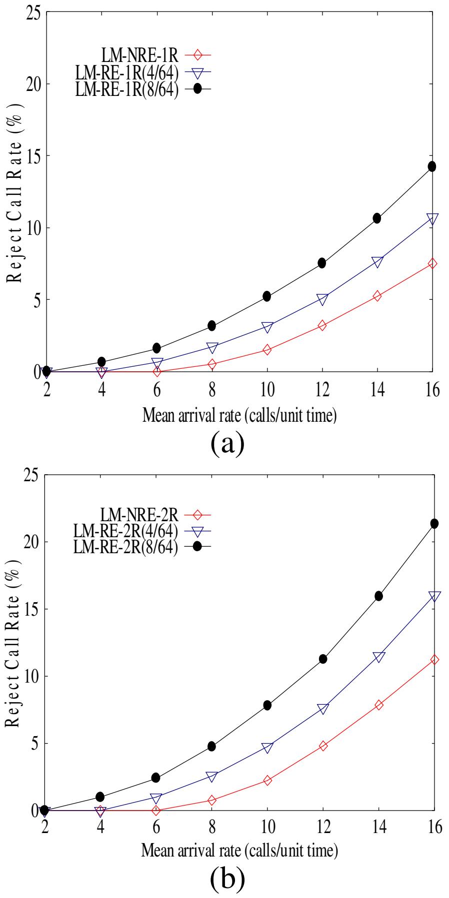
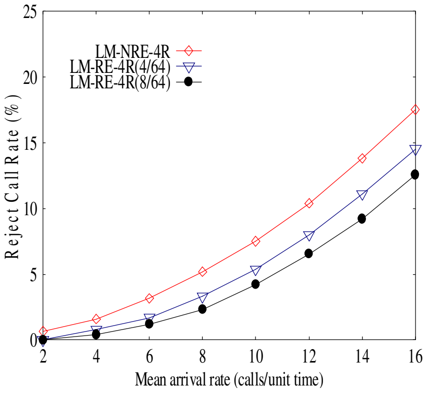
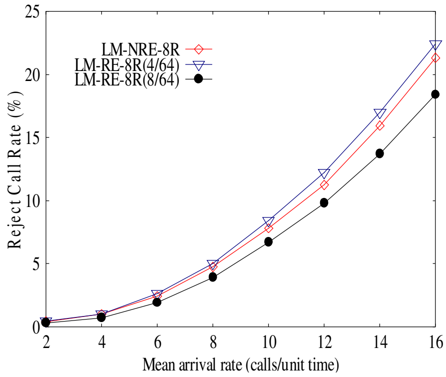


Figure 12 (SF=64) Reserved Schemes with (a) 1R Reject Call Rate (b) 2R Reject Call Rate



(a)



(b)

Figure 13 (SF=64) Reserved Schemes with (a) 4R Reject Call Rate (b) 8R Reject Call Rate

4. Conclusions

Many works in the literature have been intensively investigated for the code assignment and code reassignment schemes. Our proposal is to reserve a part of bandwidth in the OVSF tree to reduce the blocking probability of the large bandwidth requests. The simulation results also show that the reservation scheme can reduce the code blocking of the large bandwidth requests. But the strategy is also harmful for the other kinds of the requests. That is, the system will sacrifice the low bandwidth request. The future work is how to arrange the reserved subtree to increase the fairness of the call requests.

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