Scrambling Code Planning for WCDMA System

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Abstract:
For a WCDMA system, frequency planning is not required for a WCDMA system, but scrambling code planning for neighborhood cells is necessary. With scrambling code planning, the reuse distance between adjacent cells using the same scrambling code can be determined and different cells can be distinguished. The planning method based on scrambling code groups can be adopted for mobile station to quickly search cells. One principle for scrambling code planning is that overlapping cells in a network cannot use the same primary scrambling codes.

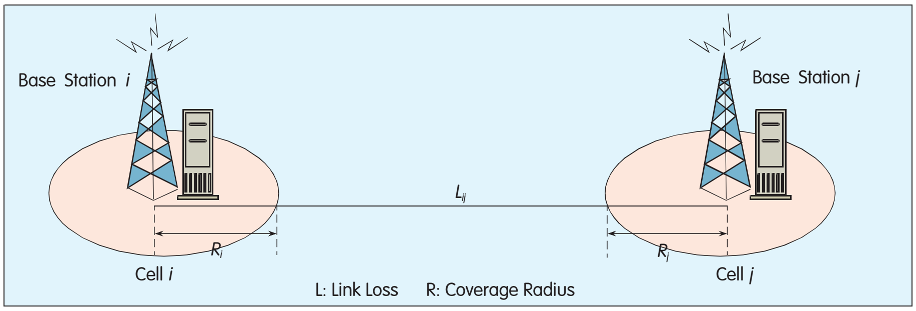
Global System for Mobile Communication (GSM) mainly adopts wireless access modes like time division and frequency division multiple access. As for planning engineers, frequency planning is very important, since it is concerned directly with the network performance. However, Wideband Code Division Multiplex Access (WCDMA) systems mainly adopt code division multiple access mode, a kind of multiplexing of the same frequency. Hence unlike GSM networks, frequency planning is no longer needed in WCDMA networks.

In WCDMA networks, scrambling code planning is necessary. The uplink scrambling codes are used to distinguish different mobile users, and the scrambling code sequences used could be classified into short and long scrambling codes. The number of scrambling codes in the uplink is about several million, hence there is no need to plan the code resources for the uplink direction. While in the downlink, scrambling codes are used to distinguish different cells, and the scrambling code sequences only contain long codes, which adopt the same gold series link the uplink with a total number of $2^{18}-1$. In order to shorten the time for mobile stations searching for cells, downlink Primary Scrambling Codes (PSC) are restricted to 512, which fall into 64 groups, with one PSC allocated for one cell. The commonly said scrambling code planning refers to the downlink scrambling code planning, which is done by network planning softwares.

1 Theory of Scrambling Code Planning

The scrambling code planning in WCDMA systems resembles frequency planning in Global System Mobile (GSM) systems, mainly to allocate PSC to cells.

In WCDMA systems, there are 512 PSCs in the downlink, with one PSC allocated to one cell as an identification parameter. When cells exceed 512, a duplicate PSC could be allocated to another cell, as long as the distance between the cells using the same PSC is large enough. Therefore the signal received at the other cell is below the threshold level. The main idea for scrambling code planning is to determine the minimum propagation distance between two cells using the same scrambling code, namely the reuse distance. The detailed calculations are



▲Figure 1. Reuse distance of two cells using the same scrambling code.

as follows:

As shown in Figure 1, for the convenience of analysis, it is assumed that the transmission power of each cell's base station is equal and the noise can be ignored. Cell *i* and Cell *j* use the same scrambling code. The link loss between the two cells is L_{ij}. The coverage radius of the two cells is R_i and R_j respectively.

To avoid fuzzy interferences of scrambling code owing to the allocation of the same scrambling code to two cells, the distance between the two cells should be sufficiently large. Therefore, the wireless transmission signals from the remote cell with same scrambling code is much smaller than wireless signals from local cell. Hence the following inequation needs to be established:

$$10\log(L_{ij}-\max(R_i,R_j))^{\alpha}-10\log(\max(R_i,R_j))^{\alpha}\geqslant PG_{dB} \quad (1)$$

Here, α is the path loss exponent, PG_{dB} is processing gain (dB in units). The first item in the above inequation is the minimum path loss from remote Cell *j*. The second item is the maximum path loss of local Cell *i*. From the inequation (1), the requirement for L_{ij} is rewritten as follows in inequation (2):

$$L_{ij}\geqslant\max(R_i,R_j)\times(1+10^{PG_{dB}/10\alpha}) \quad (2)$$

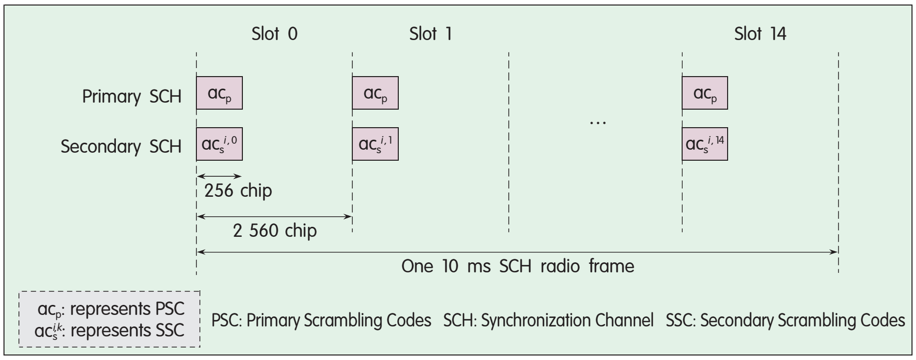
Inequation (2) depicts the reuse distance that satisfies the scrambling code planning. The objective of scrambling code planning is to determine the multiplex pattern of the scrambling code space. Substituting $\max(R_i, R_j)$ with R_{max}, and let K denotes the number of cells in the multiplexing collection, the reuse distance between cells $L=R_{min}\sqrt{3K}$. Here R_{min} is the radius of the cell with the minimum coverage area. Then the minimum number of multiplex cells that satisfies the scrambling code planning is shown in inequation (3):

$$K\geqslant\frac{R^2_{max}}{3R^2_{min}}\cdot(1+10^{PG_{dB}/10\alpha})^2 \quad (3)$$

Take the 12.2 Kb/s AMR voice service as an example, PG_{dB}=24 dB, the path loss component α=3, R_{max}/R_{min}=3, then it could be calculated that the multiplex cell number $K\geqslant160$. If 3 cells are to be planned, $3K$=480, i.e. the multiplexing collection contains 480 scrambling codes and 512−480=32 marginal scrambling codes are left available.

Since scrambling codes could be used to distinguish cells, with applicable scenarios like initial access to network, cell reselection and handover of mobile stations, the scrambling code allocation is very important in system planning.

While under actual cases, owing to such factors like wireless propagation environment and irregular distribution of base station locations, it is rather difficult to determine the effect of scrambling code planning. Therefore, scrambling code planning is usually carried out using network-planning software. Scrambling code planning implemented by software usually adopts the above shown cell reuse distance calculation method, to implement automatic scrambling code allocation. However, the principles for scrambling code planning is determined by network planning engineers.



▲Figure 2. Structure of synchronization channel.

2 Principles of Scrambling Code Planning

2.1 Cell Search Procedure

A total number of $2^{18}-1$ scrambling codes could be generated from an 18-bit shift register. Since too many scrambling codes will lead to too long search time for mobile stations and complex designs for systems, only 8 192 scrambling codes were chosen in the 3GPP specification. These scrambling codes are divided into 512 collections, each collection with 1 PSC and 15 Secondary Scrambling Codes (SSC). Each cell uses one of the PSCs. These 512 PSCs are further divided into 64 groups, each group containing 8 PSCs.

The objective of scrambling code planning is to help mobile stations finish such tasks as cell searching, identification and synchronization quickly and correctly. Therefore, the cell search procedure should be briefly covered here. Commonly, terminals will search cells without any previously known information and should take 3 steps of slot synchronization, frame synchronization, and PSC capture. Therein the slot and frame synchronization concerns with Primary Synchronization Channel (P-SCH) and Secondary Synchronization Channel (S-SCH).

The 10 ms radio frame of P-SCH and S-SCH is divided into 15 slots, each with 2 560 chips. The structure of the radio frame for the synchronization channel is shown in Figure 2.

P-SCH contains one PSC of 256 chips long, and for certain cells within the system PSC is the same and is transmitted in each slot, which is denoted as ac_p in Figure 2. In S-SCH the SSC with 15 sequences, each of 256 chips long, is transmitted repeatedly and propagates parallel with P-SCH. The SSC is denoted as $ac_s^{i,k}$ in Figure 2, here i=0, 1…63 being the serial number of the scrambling code groups, and k=0, 1, 2…14 being the slot number. SSC is a code chosen from 16 different codes of 256 chips long. The sequence sent in S-SCH means the group that the downlink scrambling code of current cell belongs.

The first step in cell searching is slot synchronization. Since all cells have the same PSC and the terminals know the chip sequence in advance, only a matching filter of better performance should be used to detect and capture the PSC. Therefore, to the slot boundary of each physical channel will be determined.

▼Table 1. PSC planning example

Code Group	Macro Cell				Micro Cell		Indoor Coverage	
$Group_0$	SC_0	SC_1	SC_2	SC_3	SC_4	SC_5	SC_6	SC_7
$Group_1$	SC_8	SC_9	SC_{10}	SC_{11}	SC_{12}	SC_{13}	SC_{14}	SC_{15}
$Group_2$	SC_{16}	SC_{17}	SC_{18}	SC_{19}	SC_{20}	SC_{21}	SC_{22}	SC_{23}
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
$Group_{63}$	SC_{505}	SC_{506}	SC_{507}	SC_{508}	SC_{509}	SC_{510}	SC_{511}	SC_{512}

SC: Scrambling Code

The second step is frame synchronization. The SSC is also 256-chip long, and is sent through S-SCH together with PSC at the beginning of each slot. Each slot has one SSC. The difference is, SSC contains 16 different chip sequences, and these SSCs are arranged into 64 different combinations. Each combination is 15 SSC words long and is used within one radio frame. It should be noted that the same SSC might occur several times in a single combination and one combination corresponds to a group of PSC. Hence, it is possible to determine to which group the PSC current cell is using belongs.

Based on the determination of scrambling code group from the foregoing two steps, the matching PSC of current cell is determined from 8 candidate PSCs, and the capture of PSC is over.

2.2 Scrambling Code Planning Method

The principle of scrambling code planning is that overlapping cells in the network cannot have the same PSC. From the above analysis, scrambling code planning could be implemented based on scrambling code group or all different scrambling codes. The planning based on all different scrambling codes is to allocate 512 PSCs to each cell only meeting the requirement of reuse distance. While planning based on scrambling code groups is to allocate a various scrambling code group to each base station, and in different sectors of base station, PSC is selected and allocated from the eight PSCs within the scrambling code group.

From the search procedure, it is known that the difference of these two allocation methods is that in planning based on scrambling code group, PSC and SSC sequence of different sectors in base station are the same. In planning based on all different scrambling codes, scrambling codes of different sectors in base station belong to different groups, PSC sequences are the same, but SSC sequences are different. Therefore, planning based on scrambling code groups are more convenient and simpler than planning based on all different scrambling codes, and will be more efficient and flexible for mobile stations to search cells. By this means, usual scrambling code planning is carried out based on PSC groups. After determining the planning principles, reuse distance of scrambling code group should be considered. This is done by computing Carrier-to-interference Ratio (C/I) of the signals.

A scrambling code planning example is given in Table 1[1].

As for scrambling code group allocation, actual cell coverage size should further be sufficiently considered. PSC reuse distance should be determined considering of actual conditions of the zone, and scrambling code allocation of boundary zones should be planned uniformly. Furthermore, some PSC of scrambling code groups should be reserved according to the network development for the use of the capacity extension of future network.

The mobile stations should search cells and establish synchronization with neighboring cells as quickly as possible to permit fast handover. Therefore, in actual scrambling code planning it is required that scrambling code of current cell and its adjacent cells should belong to as fewer scrambling code groups as possible. Since demodulation of one more scrambling code group may cost an additional 20 ms time[2], rational scrambling code planning according to network structure and wireless environments is of crucial importance. For instance, in dense city zone, high density of base stations forms relatively more complex adjacent cell lists and handover relationships, and fewer scrambling code groups should be used in order to reduce search time and raise quality of network. Therefore, not all of the scrambling code groups will be used up in actual planning. The actual number used will be determined according to future network planning. Furthermore, if a second carrier is used in the network, all scrambling codes could be repeatedly.

3 Conclusions

Since with WCDMA systems, new service demands are introduced and differences exist compared to 2G GSM systems in such aspects as system wireless interface and wireless network planning. Therefore, designing of WCDMA systems is also different from that of GSM systems. This article made in-depth discussion concerning scrambling code planning issue of WCDMA systems. It concluded that the main principle for scrambling code planning is to raise reuse distance to the most under the condition of code resources and combining actual characteristics of the zone. In scrambling code planning, the planning method based on scrambling code group could accelerate the cell searching procedure for mobile stations, and will help make planning more flexible and easier. All these conclusions are preferable guidance to the WCDMA wireless network planning engineers.

References

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Received: 2005-08-18

Biography

Mei Hui received his Master's degree from Nanjing University of Posts and Telecommunications. He is now working for Network Manager Center of Jiangxi Branch of China Mobile, dedicated to research on network optimization and planning of the province, and 3G network planning.