Paper

An effective method of channels assignment for third generation cellular system

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Abstract — An original hybrid method of channels assignment for DS-CDMA system is discussed in the paper. This method combines standard PN codes assignment policy and dynamic channel assignment procedure that minimise the cost of channel assignment. OPNET simulation model DS-CDMA system was used for assessment of the hybrid method. The results of simulation presented in the paper confirmed that the proposed method importantly improves the quality of services in the third generation cellular system.

Keywords — W-CDMA, dynamic channel assignment, 3G.

1. Introduction

The work on the development of world-wide standard of third generation (3G) mobile radio system on the basis of UMTS/FPLMTS/IMT-2000 has been carried out by standardization institutes of Europe (ETSI), Japan (ARIB) and United States (ITA) under the umbrella of the International Telecommunication Union. Wideband code division multiple access (CDMA) has been chosen as the mainstream air interface solution for such networks. It is assumed that IMT-2000 will provide a wide range of services, especially multimedia and high-bit-rate packet data which require a high network capacity and appropriate quality of services.

The capacity of 3G-CDMA systems depends on the level of interference caused by each user. On the other hand the interferences depend on many factors such as user's activity, required data rate, geographical deployment of the users, power control accuracy, type of code sequences and its assignment scheme, etc. [1–3]. Most of these factors are out of control as they depend mainly on the user's behaviour. However power control procedures or channels assignment policy can be modified in a way which allows improving the system's capacity and QoS.

In our investigations we have focussed on the code sequences management method for DS-CDMA system. The hybrid channels assignment method (HCA) presented here combines two schemes, e.g. fixed and dynamic channel assignment.

The channels assignment policy for standard DS-CDMA system as well as system conditions concerning code management methods are shortly described in Section 2 of this paper. In Section 3 a general idea of HCA algorithm is presented and discussed. A general idea of HCA algorithm is presented and discussed. Simulation method was used for verification and validation of the proposed method. A description of OPNET simulation model as well as simulation results we have obtained are presented in Section 4.

2. Channel assignment for DS-CDMA systems

In widely known systems (like IS-95, IS-665, UMTS) the same sets of code sequences is used by each base station but with different phase shifts [4, 7]. The auto-correlation and cross-correlation features of such codes are specific for the defined codes family and in consequence they limit the system capacity [2, 3, 5]. The spreading codes management procedure is often based on simple choosing of one (or more) from predefined big family of codes (code shifts).

The user's requirements for services that should be provided by the mobile communications system cause the necessity of handling many services in the same time. Since such services are provided with different data rates, additional codes are used, for example orthogonal variable spreading factor (OVSF) channelisation codes in UMTS. They are designed for fitting different data rate services into the wideband radio channel with a constant bandwidth. The spreading of baseband signals is realised using so called scrambling codes (gold sequences in UMTS). OVSF codes are mutually orthogonal, so the basic co-channel interferences depend on scrambling auto and cross-correlation functions. By using different scrambling codes families with different correlation characteristics as well as by their efficient management it is possible to decrease the total level of interference and in consequence increase the system's capacity.

3. Hybrid channels assignment for 3G wireless systems

The channel assignment to a particular call could be realised by calculating minimal correlation factors at the time of assignment, with regard to each channel in the interference area or by sharing the channels into separate groups. In our case, cellular network is divided into three-cell groups like in sectorised systems. Let us assume the same radius in each sector. The proposed HCA channel assignment scheme is shown in Figs. 1 and 2. In this case all N_k channels are divided into two groups F – "fixed" channels (can be used over the whole system) and T – "dynamic" channels (optimised channels over the sectors).

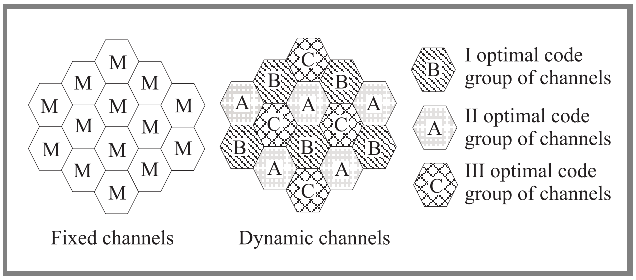

Fig. 1. Channels assignment scheme: M – number of fixed channels; A, B, C – numbers of dynamic channels.

All channels can be centrally managed. The first $F = \{1,2,\dots,M\}$ channels are available in each cell. The last $T = \{M+1, M+2,\dots,N_k\}$ channels are split into three sectors. In this group of channels we have $K-M$ channels optimised in each sector and $\big((N_k - M)/3\big)$ channels, which are used for priority calls and for handled over calls.

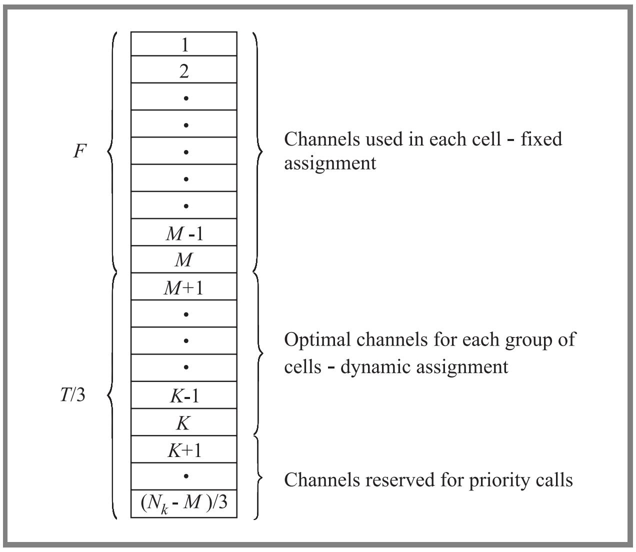

Fig. 2. Channels arrangement.

The total number of channels N_T in the system can be calculated as follows:

$$N_T = L \cdot M + [L/3] \cdot |F| + \big(L - 3 \cdot [L/3]\big) \cdot |F|/3\,, \tag{1}$$

where: L is the number of cells in the system, $|F|$ – number of channels in the set F and $[L/3]$ – an integer part of $L/3$.

A channel assignment for a particular call from group F is quite simple. While a new call arrives the first free channel is used. Of course the criterion of minimal reuse distance should be fulfilled.

If all M fixed channels are already in usage then the dynamic channel is selected for a new call. For channel assignment from set T, an algorithm proposed in [6] is recommended. In this case, channels are allocated on the basis of minimisation of so-called cost function $C_x(i)$ defined for each available channel among all interference environment of cell x, e.g:

$$C_x(i^*) = \min_{i \in L(x)} \big\{C_x(i)\big\}\,, \tag{2}$$

where: i^* – channel assigned to the new call in cell $x, L(x)$ – set of channels available for cell x (so excluding channels assigned to x and all cells from its interference environment), $C_x(i)$ – total cost of each channel from $L(x)$.

The cost $C_x(i)$ is calculated as a sum of weighted function $\mathrm{q}_x(i)$ and the costs $C_x(k,i)$ of channel i assignment related to each k channel from interference neighbourhood $I(x)$, where $C_x(k,i)$ is an integer value from 0 to 3.

After releasing the dynamic channels are reallocated again in order to choose the optimal interference level using similar rule. In [6] this algorithm is proposed as a unique method for the whole cellular network. In our case, the allocation of dynamic channel is used only if there are not enough fixed channels.

4. Simulation experiments

Correctness of the above channels assignment algorithm as well as its efficiency for DS-CDMA cellular system was assessed during simulation experiments. Taking into account DS-CDMA system complexity, the OPNET simulation package was used for investigations. The basic elements of implemented network are shown in Fig. 3.

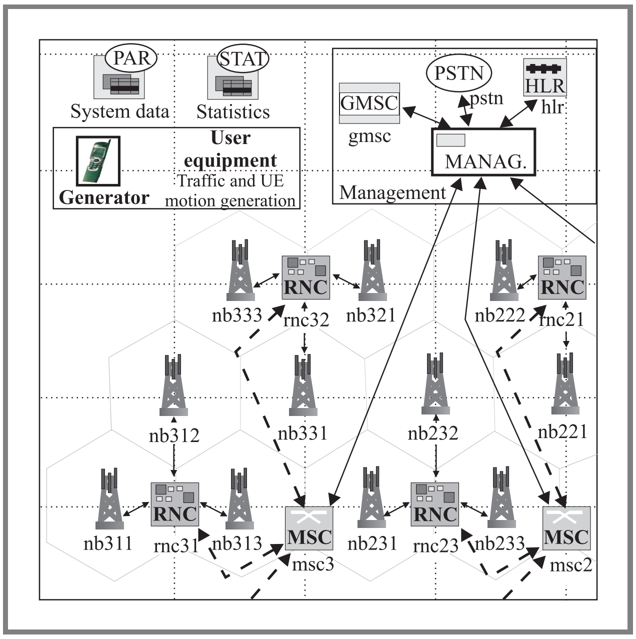

Fig. 3. An example of DS-CDMA cellular network.

The network consists of 34 base stations (nb), 10 radio network controllers (rnc), 3 mobile switching centres (msc) and other elements such as VLRs, HLR, PSTN, GMSC as well as traffic and user's movement generator.

Both calls and handover blocking probabilities were selected as the basic measures of the QoS for DS-CDMA system. These measures were also used for assessment of HCA algorithm efficiency.

The following system's parameters were assumed for simulation:

- UL/DL carrier frequency: 1922.6/2112.6 MHz;
- chip rate: 3.84 Mchps;
- propagation model: COST 231 Walfish-Ikegami;
- user's effective data rate: 12.2, 64, 144, 384;
- user's activity coefficient: 100% (0.75 Erl per user);
- mobile station (UE – user equipment) max. power: 21 dBm;
- UE antenna gain: 0 dB;
- base station (NB) max. power: 43 dBm;
- NB antenna gain: 10 dB;
- UE and NB sensitivity: −110 dBm;
- handover type: soft (2 base stations in the active set).

In CDMA systems interferences can be caused both by users and base stations, as it is shown in Fig. 4.

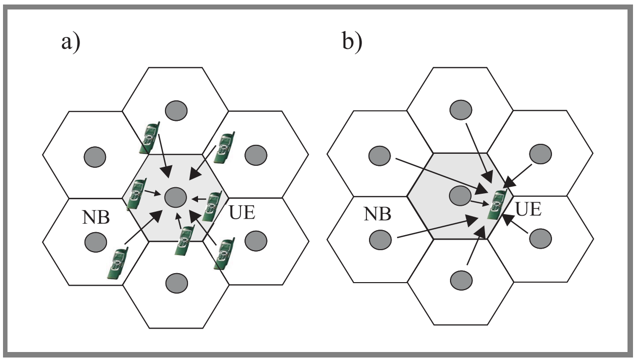

Fig. 4. Interferences caused by users UE (a) and by base stations NB (b).

The required level of E_b/N_0 in NB location (Uplink – UL) is:

$$\left(\frac{E_b}{N_0}\right)_{req} = \frac{P_{od}\cdot(SF)}{I_{\text{intra\_NB}} + I_{\text{inter NB}} + N_0}, \tag{3}$$

where: SF – spreading factor, P_{od} – received signal power, $I_{\text{intra\_NB}}$, $I_{\text{inter\_NB}}$ – intra and intercell interferences, N_0 – noise power density.

Let us assume that power control is performed ideally. It means that signal power at NB receiver input incoming from all UEs is exactly the same:

$$L^n_{b1}\cdot P^n_{nad1} = \ldots = L^n_{bm_n}\cdot P^n_{nadm_n}, \tag{4}$$

where: L^n_{b1} – signal attenuation in cell n from UE_1, P^n_{nad1} – transmitted signal power by UE_1 in cell n, m_k – number of UEs.

So, the signal power received by NB_n from UE_k is as follows:

$$P_{od} = L^n_{bk}\cdot P^n_{nadk}. \tag{5}$$

The level of intracell interferences that influence UE_k is defined as:

$$\begin{aligned} I_{\text{intra\_NB}} &= L^n_{b1}\cdot P^n_{nad1} + \ldots + L^n_{bk-1}\cdot P^n_{nadk-1} + \\ &+ L^n_{bk+1}\cdot P^n_{nadk+1} + \ldots + L^n_{bm_n}\cdot P^n_{nadm_n} \end{aligned} \tag{6}$$

and level of intercell interferences as:

$$\begin{aligned} I_{\text{inter\_NB}} &= \sum_{i=1}^{m_1} L^1_{b1}\cdot P^1_{nadi} + \ldots + \sum_{i=1}^{m_{n-1}} L^{n-1}_{bi}\cdot P^{n-1}_{nadi} + \\ &+ \sum_{i=1}^{m_{n+1}} L^{n+1}_{bi}\cdot P^{n+1}_{nadi} + \ldots + \sum_{i=1}^{m_L} L^L_{bi}\cdot P^L_{nadi}, \end{aligned} \tag{7}$$

where: L – number of base stations in the system, $m_1, m_2, \ldots, m_n, \ldots, m_L$ – number of active users.

A similar situation is in downlink (DL) calculations. The required level of E_b/N_0 in UE can be written as:

$$\left(\frac{E_b}{N_0}\right)_{req} = \frac{P_{od}\cdot(SF)}{I_{\text{intra\_UE}} + I_{\text{inter UE}} + N_0}, \tag{8}$$

where: $I_{\text{intra\_UE}}$, $I_{\text{inter\_UE}}$ – intra and intercell interference that can be calculated from:

$$\begin{aligned} I_{\text{intra\_UE}} &= L^n_{bk}\big(P^n_{nad1} + \ldots + P^n_{nadk} + \\ &+ P^n_{nadk+1} + \ldots + P^n_{nadm_n}\big) \end{aligned} \tag{9}$$

and

$$\begin{aligned} I_{\text{inter\_UE}} &= L^1_{bk}\sum_{i=1}^{m_1} P^1_{nadi} + \ldots + L^{n-1}_{bk}\sum_{i=1}^{m_{n-1}} P^{n-1}_{nadi} + \\ &+ L^{n+1}_{bk}\sum_{i=1}^{m_{n+1}} P^{n+1}_{nadi} + \ldots + L^L_{bk}\sum_{i=1}^{m_L} P^L_{nadi}. \end{aligned} \tag{10}$$

Above functional equations describe DS-CDMA system behaviour. During simulation, required E_b/N_0 can be calculated and on this basis the decision concerning the calls or the handovers blocking is made. Such a situation takes place when E_b/N_0 exceeds the level shown in Table 1. In this case dynamic channel assignment procedure is running.

Table 1
Required level of E_b/N_0

Effective data rate [kbit/s]	12.2	64	144	384
Uplink	5.1	1.7	0.9	0.9
Downlink	7.9			

Figures 5 – 10 show the simulation results. Standard channels assignment scheme based on [7] and the HCA method (denoted in the figures as the modified) are compared.

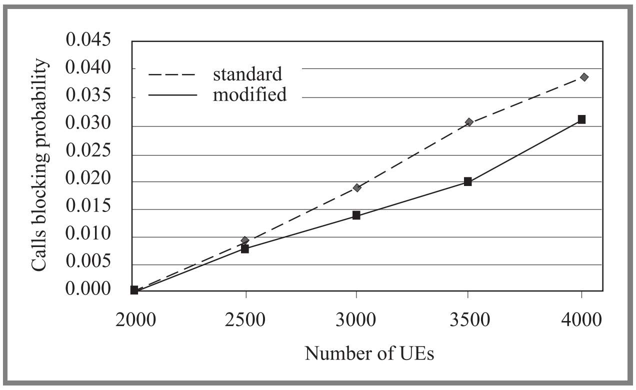

Fig. 5. Call blocking probability versus number of UEs.

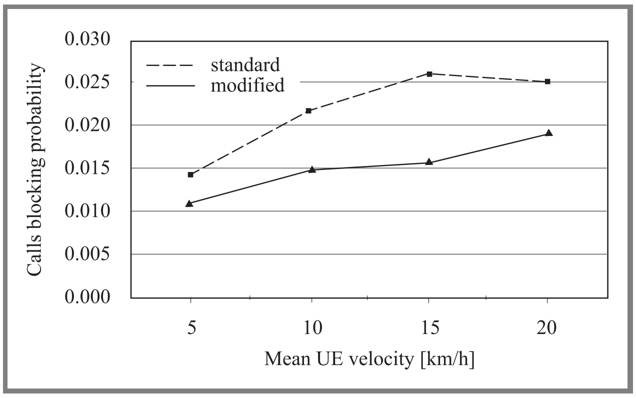

Fig. 6. Call blocking probability versus mean velocity of UEs.

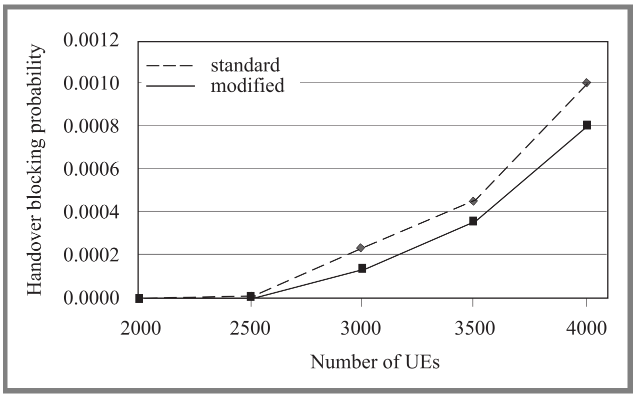

Fig. 7. Handover blocking probability versus number of UEs.

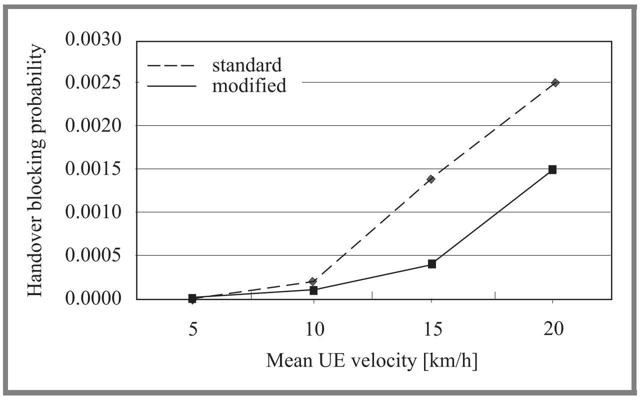

Fig. 8. Handover blocking probability versus mean velocity of UE.

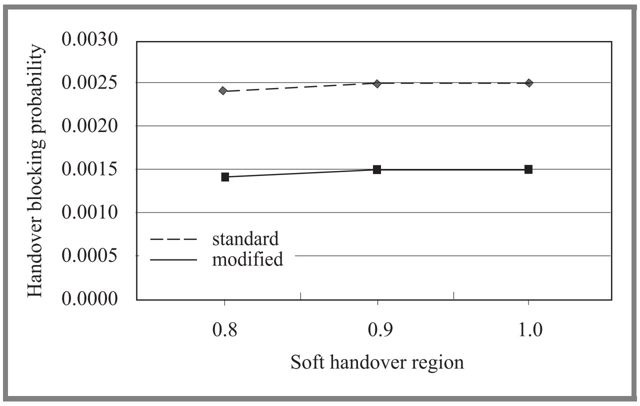

Fig. 9. Handover blocking probability versus soft handover region.

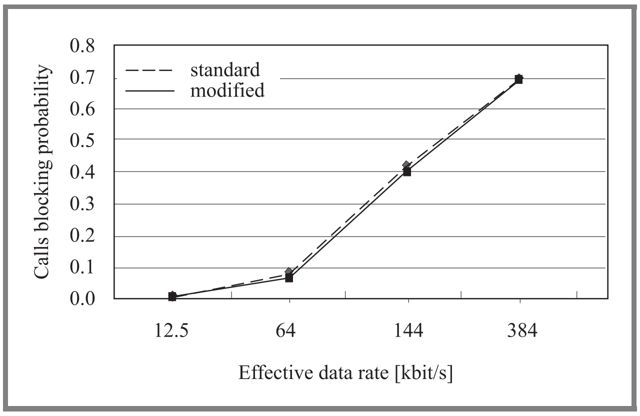

Fig. 10. Call blocking probability versus UE effective data rate.

The influence of the number of UEs on QoS measures is shown in Figs. 5 and 7. The traffic intensity in the system in this case varies from 1500 Erl to 3000 Erl.
Call and handover blocking probabilities versus mean velocity of UEs are shown in Figs. 6 and 8.
Handover blocking probability versus so-called soft handover region is shown in Fig. 9. The soft handover region

is defined here as the ratio of cell radius and radius of the circle, where UE starts soft handover process.

Calls blocking probability versus UE effective data rate is presented in Fig. 10.

5. Conclusion

On the basis of the simulation results shown in previous section, we can notice that HCA scheme significantly decreases calls and handover blocking probability in comparison with the standard method. The QoS improvement is particularly visible in case of high system load, where HCA can effectively manage the channels. The same situation is when UEs increase their velocity. In the microcellular systems, number of users crossing the cell boundary is very high. So the traffic caused by this effect is high (even higher then basic traffic). By using HCA we can see significant increase the QoS for higher user's velocity.
From Fig. 10 we can notice that the blocking probability is very high for effective data rates above 12.2 kbit/s. It is caused by high traffic (the same for all data rates) generated by the users. Summarising we can conclude that the proposed channel allocation method seems to be suitable for third generation cellular system.

References

[1] W. C. Lee, "Overview of cellular CDMA", *IEEE Trans. Veh. Technol.*, vol. 40, no. 2, 1991.

[2] H. Jeon, S. Shin, T. Hwang, and C. Kang, "Revers link capacity analysis of a CDMA cellular system with mixed cell sizes", *IEEE Trans. Veh. Technol.*, vol. 49, no. 6, 2000.

[3] P. Gajewski, J. Krygier, J. Łopatka, and J. Buczyński, "Performance of a DS-CDMA system with dynamic channel allocation and soft handover", in *Proc. ISSSTA'98*, RPA, 1998.

[4] D. E. Everitt, "Traffic engineering of the radio interface for cellular mobile networks", *Proc. IEEE*, vol. 82, no. 9, 1994.

[5] M. B. Pursley and H. F. A. Roefs, "Numerical evaluation of correlation parameters for optional phases of binary shift-register sequences", *IEEE Trans. Commun.*, vol. COM-27, no. 10, 1979.

[6] E. Del Re, R. Fantacci, and G. Gimbene, "Handover and dynamic channel allocation techniques in mobile cellular networks", *IEEE Trans. Veh. Technol.*, vol. VT-44, no. 2, 1995.

[7] 3GPP UMTS Techn. Specif. TS 25.213: "Spreading and modulation", Dec. 2001.

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