2005 WSEAS Int. Conf. on DYNAMICAL SYSTEMS and CONTROL, Venice, Italy, November 2-4, 2005 (pp136-141)

Performances Analysis of Different Channel Allocation Schemes for Personal Mobile Communication Networks

[1]GABRIEL SIRBU, [2]ION BOGDAN
[1]Electrical and Electronics Engineering Dept., [2]Telecommunications Dept.
[1]"Dunarea de Jos" Galati University, [2]"Gheorghe Asachi" Iasi Technical University,
[1]Domneasca-47, Galati-800008, [2]Dimitrie Mangeron-63, Iasi-700050
ROMANIA

Abstract: - The actual mobile communication systems need more resources like radio channels and computational load in order to provide proper services in a working area. Models like propagation model of the channel, traffic distribution model and service area model are needed for behavior study of these systems. In this paper we introduce the mentioned models and we make an analysis concerning the new calls blocking probabilities in the communication system for either uniform and nonuniform traffic conditions. Simulation results validate the analysis.

Key-Words: - Channel allocation schemes analysis, Traffic modeling, Propagation modeling, Service area modelling

1 Introduction

Channel allocation schemes are strategies to solve the conflicts between multiple radio carriers in personal mobile communication systems (PCS). Splitting the service area into cells and giving each cell the permission to use a set of specific radio channels solve this problem. The way this is done define the channel allocation scheme and their corresponding performances. In [3], [5], [8], [9] and [10] the four main allocation schemes are described: Fixed Channel Allocation (FCA), Dynamic Channel Allocation (DCA), Hybrid Channel Allocation (HCA), which is a mixture between the two enounced, and Flexible Channel Allocation (Fl.CA).

In the FCA scheme, a number of fixed sets of channels are permanently allocated to a specific number of channels and the cells must be spaced apart to the reuse distance, in a planned manner in order to minimize the cochannel interference.

In DCA scheme, there is a total number of channels which is allocated each cell in the service area on a Carrier to Noise + Interference ratio measurement basis. Whilst the FCA scheme have a good behavior in the heavy traffic conditions, the DCA scheme have a good behavior in the nonuniform traffic conditions [2], [4], [6], [7].

HCA scheme make a good compromise between the first two schemes, by combining the fixed allocated sets with the dynamic one. Although this scheme yield best behavior in different traffic conditions, the major problem is the ratio between the number of fixed allocated channels and dynamically allocated channels. Depending on the total traffic from the service area, this ratio must be dynamically modified, because the dynamically allocated set need a higher computational load, while the fixed sets need a lower computational load. For this reason, the treatment of new calls is made slower, if the dynamically allocated channels set is predominant. In some cases, QoS can influence the evolution of the elected ratio, if the PCS have to carry different types of digital information (video, voice, data) [5]. Fl.CA is dealing with the optimum ratio between the two sets of channels, by following a minimum cost function.

In this paper we have performed a comparative analysis of the mentioned four channel allocation schemes. In Section 2 we introduce the starting points of our work, considering the service area model. In Section 3 we present the traffic parameters models. Section 4 is dealing with the cost function, used to implement the Fl.CA algorithm.. In Section 5 the diagrams of the simulations are presented. Simulation results are illustrated and discussed in Section 6.

2 Cell Layout Model

The entire service area of a radio environment is divided into small areas called cells. A group of cells, namely a cluster, can cover all the service area by copying itself a number of times. Each cell has a base station located in its center. When a mobile user initiates a call, the system has to establish a radio link between the user terminal and the base station of the corresponding cell. The radio link associated channel can interfere with the same channel activated in another cell if cells are not sufficiently spaced apart. The minimum separation distance between the cells that keeps the interference level under a given threshold is the reuse distance. Considering an user u_0 at a distance d_0 from its own base station interfered by m other users u_i separated by distances d_i from the same base station, then the Carrier-to-Interference+Noise ratio (CINR) is [3], [10]:

$$R_{cni} = \frac{A \cdot P_0 \cdot d_0^{-\alpha} \cdot 10^{\frac{\xi_0}{10}}}{N + \sum_{i=1}^{m} A \cdot P_i \cdot d_i^{-\alpha} \cdot 10^{\frac{\xi_i}{10}}} \qquad (1)$$

where P_0 and P_i are the transmitting powers of users u_0 and u_i respectively, α is the path loss exponent, ξ_0 and ξ_i are the standard deviation of the log-normal (shadowing) fading associated to the users u_0 and u_i, respectively, N is the thermal noise power, and A is a network specific propagation coefficient. The greater distances d_i are, the higher R_{cni} is, and the higher transmission quality is, consequently. Fig.1 illustrate this situation.

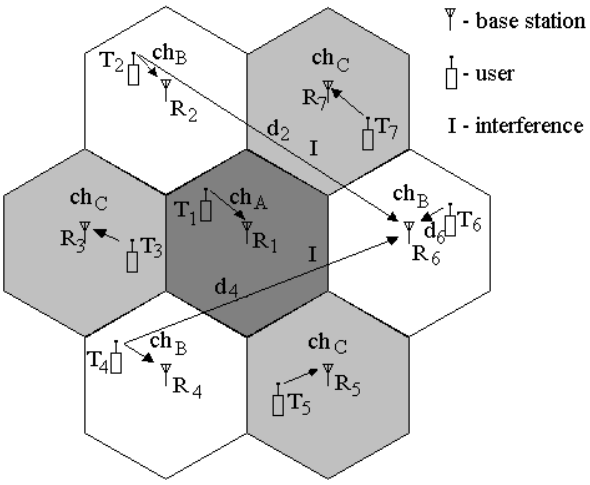

Fig.1. The influences of the neighbors cells

2.1 Cell Mesh Modeling

User distribution is considered to be uniform over one cell area as over the entire cell layout. The cell surface is divided in small areas and result in a lot of small meshes. When a user initiates a call, it occupies one of the randomly generated mesh-positions into the cell. Thus, both the distance between users and base stations and the interference can be precisely evaluated [10].

2.2 Cell Layout and Cell-Wrapping Modelling

In our analysis we considered a number of 19 cells in a cluster. As one can see in Fig.1, it should be taken into account not only one sample cell, but also neighboring cells because the interference from neighboring cells has a significant effect on the performance of the sample cell [7]. In order to calculate the interference of a cell with the neighbors, there have been used 21 hexagonal cells having a normalized radius of 1 and deployed as in Fig.2.

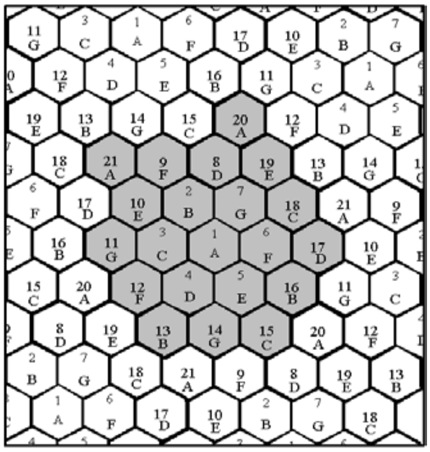

Fig.2 Cell clustering

In order to gather statistics from the entire system cell a wrapping technique is used, thus allowing the same number of neighbors for all of the cells.

If n is the total number of cells in the cluster; and m is the total number of considered cell, then:

W[m , n]

is the wrapping matrix, containing all neighbors of the cluster's cell.

3 Traffic Parameters Model

3.1 Call Generation Model

In our analysis we considered 21 cells, each cell having a number of 25, 30, 35, 40 and 45 users, consequently.

In each cell, when a user initiate a call, a random integer is generated, whose value uniformly fluctuates from 1 to maximum number of meshes in the cell. The call generation have a Poisson distribution with its mean arrival rate of "calls/hour", for each user [11] and is described by the next MATLAB routine:

```
if rand(call/hour) <= current_simulated_time
        #initiate the call;
end.
```

3.2 Call Termination Model

Considering all users in a cell, every initiated call corresponding to a user is terminated after a holding time. The holding time of each call has an exponential distribution with a specified "hold_time" mean value [11].

4 Minimum Cost Function Modeling

In order to obtain the minimum cost function criterion, we first analyzed the FCA, DCA and HCA schemes.

The flowcharts of the FCA, DCA and HCA analysis are in Figures 4, 5 and 6, respective. From these simulations we picked the maximum values of the blocking probabilities, considering the analyzed interval time of 5000 seconds and the minimum number of reserved channels, namely 0.

If we denote the cost function = c, the computational time = t and the blocking probability = p_{block}, then the cost function have the expression:

$$c = \sqrt{t^2 + p_{block}^{\ 2}} \qquad (2)$$

In this expression we need the normalized value of t, so we elected the reserved number of channel, n_{rez} to represent the value of t. In Fig.3 we represented the evolution of computational load and the number of reserved channels that encouraged us to make this assignation.

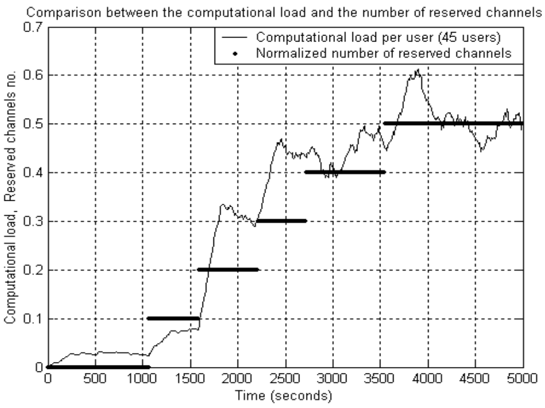

Fig.3 Comparison between the computational load and the number of channels

Having the normalized number of the reserved channels, nn_{rez}, the expression of c become:

$$c = \sqrt{nn_{rez}^{\ 2} + p_{block}^{\ 2}} \qquad (3)$$

The analysis was made considering the HCA scheme, for 45 users and a number of reserved channels in interval [0..35], with the incremental step of 7, starting from 0.

Having the expression in (3), the cost c is minimum for

$$nn_{rez} = p_{block} \qquad (4)$$

and we can find the number of reserved channels satisfying (4). Starting from these results we can derive another expression for the cost function as:

$$c = \max(nn_{rez}, p_{block}) \qquad (5)$$

If we search the minimum value of c, then the minimum cost function, denoted c_{min} is found as

$$c_{\min} = \min(c) = \min\left[\max\left(nn_{rez}, p_{block}\right)\right] \qquad (6)$$

and is satisfied for $nn_{rez} = p_{block}$.

In our simulation we elected (6) to be the minimum cost criterion. In Fig.12 we illustrated the cost function evolution in a system with 35 total number of channels, 45 users per cell, and a number of reserved channels in interval [0..35], with the incremental step of 7, starting from 0.

5 Simulation Algorithms

In this section we present the channel allocation algorithms tested by simulations. Four algorithms are tested, each of them belonging to one of the before mentioned classes: FCA, DCA, HCA and Fl.CA.

The simulations are made for 25, 30, 35, 40 and 45 users per cell, respectively. Each user has an average hold time equal to 120 seconds. For uniform traffic conditions we considered the average call arrival rate equal to 12 times/hour in all cells. For nonuniform traffic distribution we considered the average call arrival rate equal to 24 times/hour in five randomly chosen cells and 12 times/hour for the rest of them. The diagrams that illustrate the mechanism of simulated algorithms are presented in Figures 4, 5, 6 and 7.

Fig.4 describes the FCA algorithm. The program start with the initialization of different variable. After that, every cell get a set of fixed channels. A time loop starts and is indexed with 10 seconds in every cycle. The time loop ends when the simulated time has reached 5000 seconds. In each time cycle the existing calls are tested for the termination criterion. After that, new calls are randomly

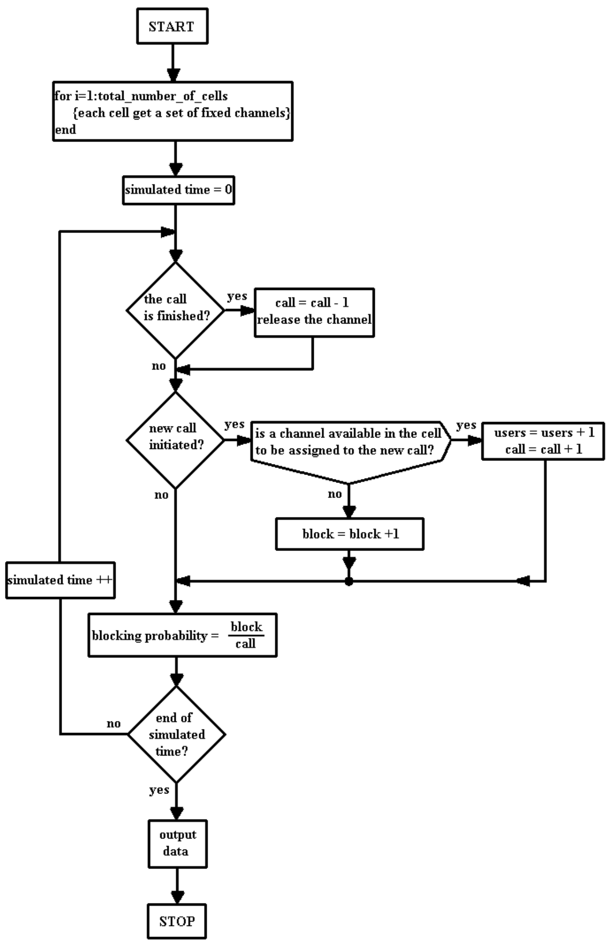

Fig.4 The FCA algorithm

generated and the available channels from the corresponding cell are allocated. A variable *block* is indexed if the channel allocation fails. The blocking probability is obtained as the ratio *block*/*call*, where *call* is the total number of calls trials. At the end, data obtained in simulation is written in the specified file and the program stops.

Fig.5 describes the DCA algorithm, which is approximately the same as the first, the difference consisting in the manner the available channel is searched among the total number of channels in the system.

Fig.6 illustrate the HCA algorithm, which combine the first two strategies. In this case there is a supplementary module in which the reallocation of calls on channels from fixed set of corresponding cell is made.

In Fig.7 is represented the Fl.CA algorithm, for which the modeling is made. Basically, this is a HCA strategy in which the ratio between fixed and reserved channels is variable, so it follow the same steps as in HCA diagram. The supplemental blocks have different functions in the diagram as follows:

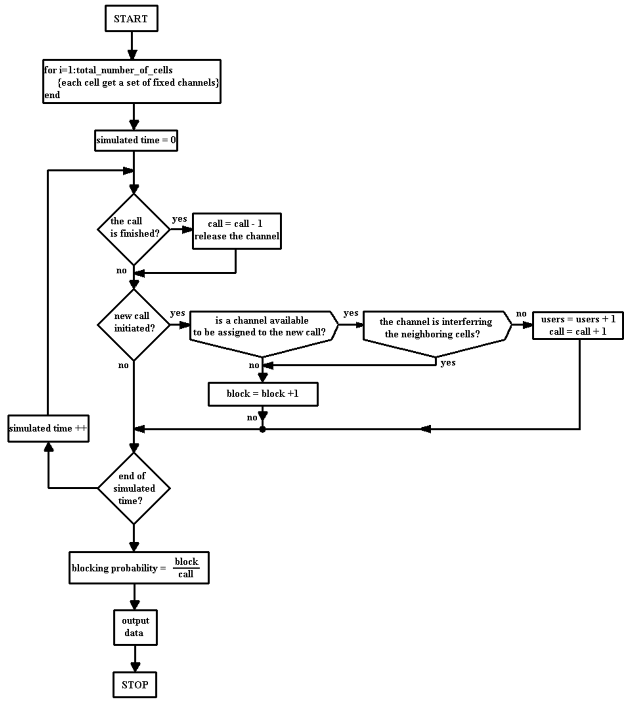

Fig.5 The DCA algorithm

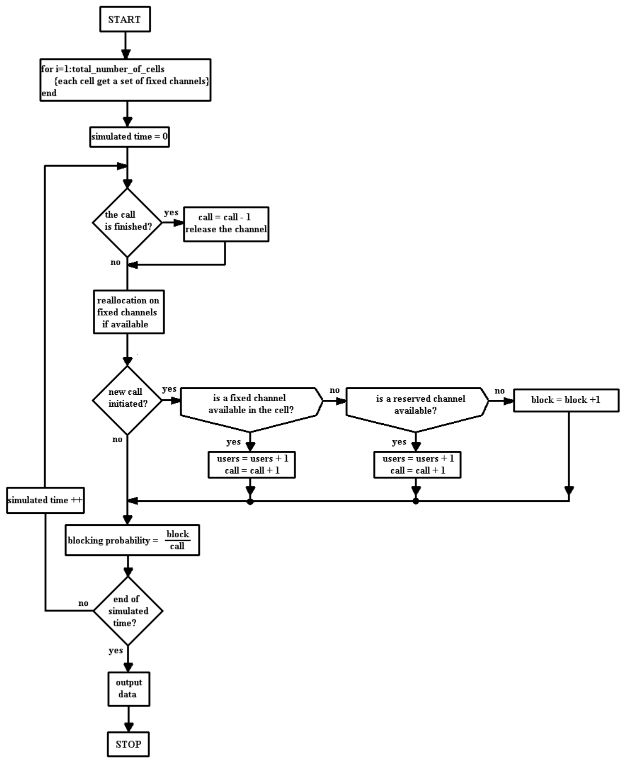

Fig.6 The HCA algorithm

- after the test concerning the finished calls, the fixed and reserved channels are ordered so that the first available to new calls is situated at the boundary between the fixed and reserved channels.
- after the channel allocation to new calls, the cost

function criterion is evaluated and the ratio between the fixed and reserved channels is modified in order to keep the cost function to minimum value.

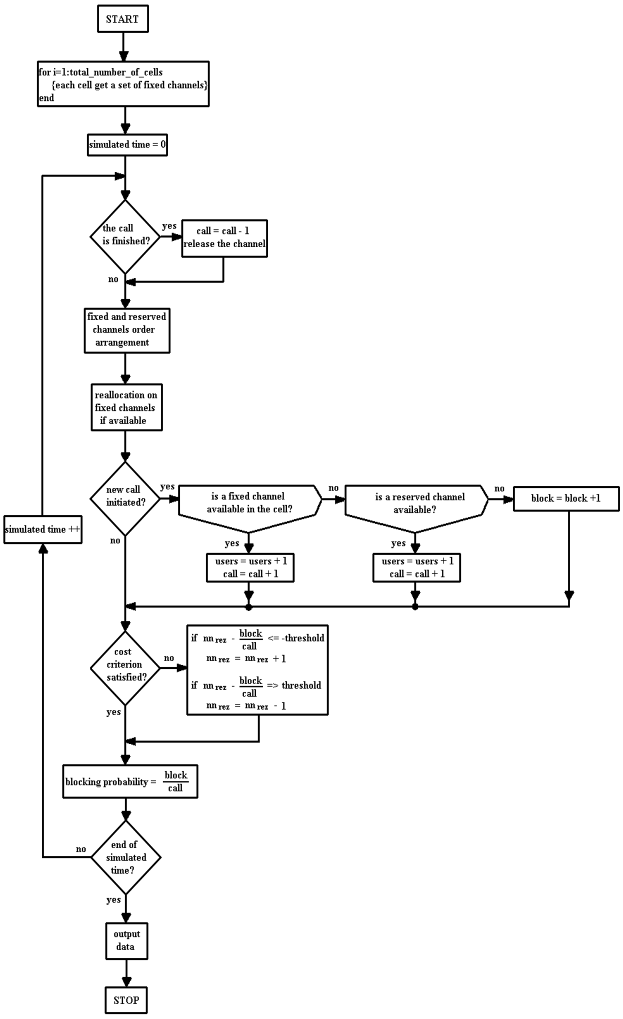

Fig.7 The Fl.CA algorithm

6 Simulation Results

We present here the simulation results of each algorithm. These results have been obtained in two cases: constant traffic conditions and variable traffic conditions and they consist in variation in time of blocking probability with the user number per cell. The same conditions were used for all the algorithms. We present the results in Figures 8-12.

As one can see from these figures:

- Blocking probability is decreasing in value in the order FCA > HCA > Fl.CA > DCA., as in Figures 8 and 9.
- The cost function minimizes the use of the reserved channels in Fl.CA algorithm, as in Fig.10 for uniform traffic conditions, and Fig.11 for nonuniform traffic conditions.

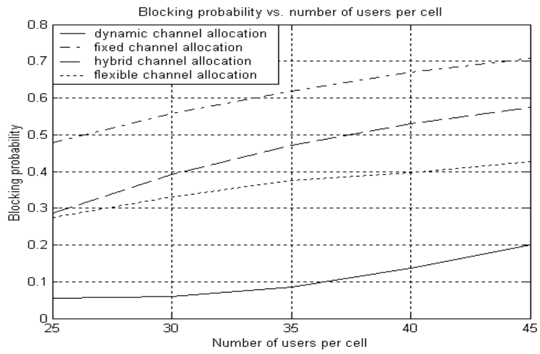

Fig.8 Blocking probabilities with uniform traffic conditions vs. number of users per cell

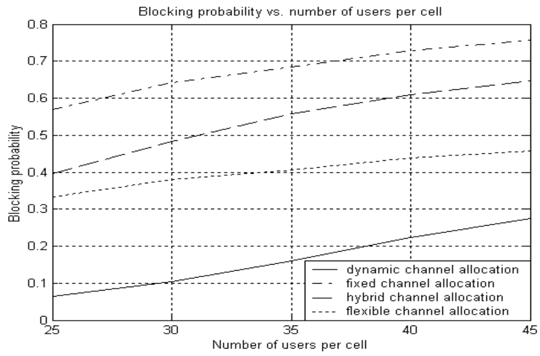

Fig.9 Blocking probabilities with nonuniform traffic conditions vs. number of users per cell

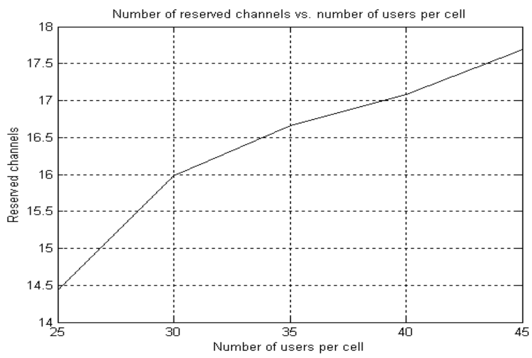

Fig.10 Evolution of reserved channels number in uniform traffic conditions on Fl.CA scheme

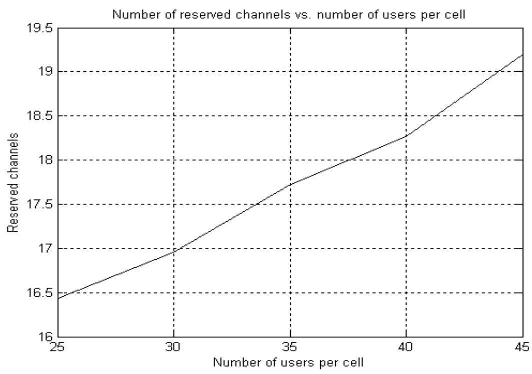

Fig.11 Evolution of reserved channels number in nonuniform traffic conditions on Fl.CA scheme

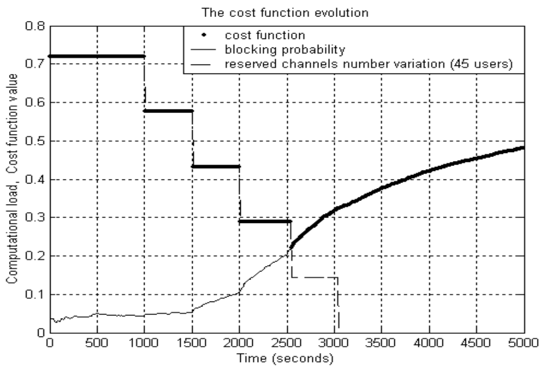

Fig.12 The cost function in Fl.CA strategy, with 45 user per cell and uniform traffic condition

- In the Fl.CA strategy the number of reserved channels have the smallest increasing with the traffic value (number of users per cell), because of the minimum cost criterion implemented, as in Figures 8 and 9.
- Based on the Fl.CA analysis, one can determine the optimum ratio between the fixed and reserved channels in order to implement a HCA scheme.
- Although the DCA scheme yield the smallest blocking probability values, the dynamically allocated channels number have the largest value and the computational load have also the larger value. Fl.CA scheme make a good compromise between the two values.

7 Conclusions

In our work we discussed the models used on channel allocation schemes in personal mobile communication systems. In order to establish the ratio between the fixed and reserved channels in Fl.CA scheme, we proposed a minimum cost function, which use the normalized value of the maximum blocking probability corresponding to minimum number of reserved channels involved in the system, namely zero. In our analysis we obtained these maximum probabilities values from the DCA algorithm.

In our future work we have to estimate these maximum probabilities by taking into account the evolution history of the system, in order to create a software package meant to evaluate by simulation the blocking probability in a cellular network induced by a channel allocation scheme and, thus, to select its parameter in accordance with the system architecture and the traffic distribution on its coverage area.

Acknowledgements

The authors would like to thank the Romanian National University Research Council for supporting part of the work, under the research grant 1350.

References:

[1]A.D.Poularikas "*Probability and Stochastic Processes*", CRC Press LLC,1999

[2]William C. Y. Lee, "Spectrum Efficiency in Cellular", *IEEE Transactions on Vehicular Technology*", Vol.38, No.2, 1989, pp. 69-75.

[3] Katzela I., Naghshineh M., "Channel Assignment Schemes for Cellular Mobile Telecommunication Systems: A comprehensive Survey", *IEEE Personal Communications*, 1996, pp. 10-31

[4] Brendan C. Jones, David J. Skellern, "Derivation of Cochannel and Adjacent Channel Reuse Ratio Distributions in DCA Cellular Systems", *IEEE Transactions on Vehicular Technology*", Vol.49, No.1, 2000, pp. 50-62.

[5] Pang Leang Hiew, Moshe Zukerman, "Efficiency Comparison of Channel Allocation Schemes for Digital Mobile Communication Networks", *IEEE Transactions on Vehicular Technology*", Vol.49, No.3, 2000, pp. 724-733.

[6] Peter J. Smith, Mansoor Shafi, Andrew Tokeley, "On The Effectiveness of Channel Segregation as a Channel Allocation Method in a Variety of Cellular Structures", *IEEE Transactions on Vehicular Technology*, vol.49, No.6, 2000, pp. 2234-2243.

[7] Hurley, S., "Planning Effective Cellular Mobile Radio Networks", *IEEE Transactions on Vehicular Technology*, Vol.51, No.2, 2002, pp. 243-252.

[8] Rudolf Mathar, Jurgen Mattfeldt, "Channel Assignment in Cellular Radio Networks", *IEEE Transactions on Vehicular Technology*, Vol.42, No.4, 1993, pp. 647-656.

[9] M. Frullone, G. Riva, P. Grazioso, M. Missiroli, "*Comparisons of Multiple Access Schemes for Personal Communications Systems in A Mixed Cellular Environment*", Research Report, Fondazione Ugo Bordoni, Italy 1994

[10] Lee, W.C.Y., "*Mobile Communications Design Fundamentals*", Wiley, 1993.

[11] Harada H., Prasad R., "*Simulations and Software Radio for Mobile Communications*", Artech House, 2002.