RADIO RESOURCES MANAGEMENT IN MOBILE CELLULAR NETWORKS

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Abstract. This paper presents a comparison of channel allocation schemes for mobile cellular networks. Three schemes have been evaluated: Fixed Channel Allocation (FCA), Dynamic Channel Allocation (DCA) and Channel Allocation with Space and Time Variations (CA-STV). The third scheme uses information about mobile users profiles for getting adaptability to traffic fluctuations. Results were obtained using a simulation environment for mobile cellular networks called *CELSA*, which implements a user mobility model based on personal, space and time characteristics. The results provide insight into the efficiency of taking into account the mobile users personal profiles, the current cell characteristics and the time of the day in the channel allocation algorithm.
Key Words: wireless communications, radio resource management, and performance analysis.

1 INTRODUCTION

The rapid growth in demand for mobile communications has led to intense research efforts in developing simulation tools and environments for evaluating the use of the scarce spectrum allocated for cellular communications [4, 12].

New applications and services are expected to emerge with the 3rd and 4th generations o mobile communications and suitable Quality of Service (QoS) levels for each application have to be provided by the network infrastructure.

A range of channel allocation schemes has been proposed [8] to increase the cellula systems efficiency in radio resource management. An important research issue is how to evaluate these schemes. The results are highly influenced by the mobility model used in the evaluation. The task of modelling the human behaviour is very complicated and many simplifications have to be adopted, but it is also extremely necessary for achieving practical results.

In this paper we have used a three-dimensional mobility model [2], which is implemented the *CELSA* simulation environment. In this model, users are classified in different groups; and the cells are grouped depending on their "attraction" to the users. The time is also classified in zones in which users present similar mobility characteristics. Using this model it is possible to obtain more realistic mobility and traffic generation processes.

The paper is structured as follows: in section 2 we present a three-dimensional mobilit model. In the section 3 we discuss the channel allocation algorithms and the simulation environment is described in section 4. In section 5 we present the simulations results and finally, we draw some conclusions in section 6.

2 THE MOBILITY MODEL

The problem of creating a model, which predicts mobile users movements, is a complex task because it tries to predict human behaviour to which there are many related parameters. In order to construct an efficient model it is necessary to consider different factors like geographical characteristics of the regions, users economical characteristics and the time of the day. With this information, it is possible to classify users, regions and periods of time in different groups defining a multidimensional mobility model.

Many models found in the literature use simplifications that make easier mobility analysis and solutions to equations. In [9], for example, the author considers that the number of users in a cell remains constant at all time. In [5], the rate of handoff attempts arriving in one cell is equal to the rate of users leaving this cell and trying to allocate a channel in another cell. In (Fantacci 2000), handoff attempts in each cell are considered as generated according to independent Poisson processes. The users speed is considered constant in [3] and, in [13] and [9] the direction of users movements is uniformly distributed between [0, 2π[.

Although all these simplifications are useful to calculate the Quality of Service (QoS) parameters of the cellular system, they can damage the mobility model credibility. In this paper, we use a model [2, 14], which classifies the mobility in different profiles; trying to cover as many users behaviour patterns as possible.

The environment is divided in three dimensions:

- *Personal Dimension*: describes different users classes depending on their mobility behaviour.
- *Time Dimension*: describes periods of time with different mobility characteristics.
- *Space Dimension*: describes the “attraction” characteristics of each region (cell).

The mobility profile is specified by a combination of personal, time and space dimension information, as shown in Fig. 1. A certain type of user (personal dimension), during a specific period of the day (time dimension) and in one determinate region has a specific profile.

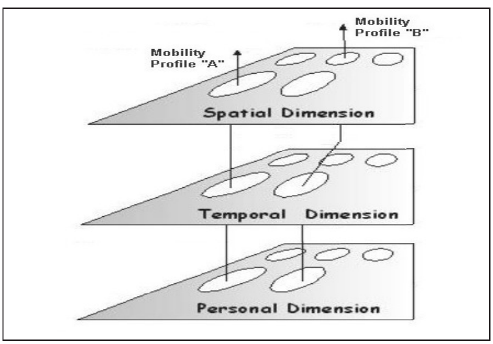


Fig. 1: Three dimensional mobility model

2.1 PERSONAL DIMENSION

In this dimension, the model defines groups of users that have similar behaviours during the day, i. e., people who moves to similar areas in the city. The model defines three types of users, namely:

- Working User (WR): a person who wakes up in the morning, goes to work where he/she spends many hours and comes back home at night. This is repeated on a daily basis.
- Residential User (RE): a user who doesn't work and spends many hours at home or moving to banks, supermarkets to shop during the day.
- High Mobility User (HM): a person who spends all day moving from one place to another, like taxi drivers, for example. These users have a random behaviour because they can choose any cell as a destination and start the trip at random times.

2.2 Time Dimension

The mobility pattern is highly influenced by the time. During the first hours in the for example, there is a big flux of users leaving their homes and going to work places. At the end of the afternoon the movements are more intense from work places to home areas. The model defines six time zones in which users have specific mobility characteristics. Table 1 shows theses time zones.

Table 1: Time Zones Description

Time Zones	Time Period	Description
1	06:00 to 08:00	Morning Rush Hours
2	08:00 to 12:00	Morning Working Hours
3	12:00 to 14:00	Day Free Hours
4	14:00 to 18:00	Afternoon Working Hours
5	18:00 to 20:00	Night Rush Hours
6	20:00 to 24:00	Night Free Hours

2.3 Space Dimension

Each cell in the system is classified depending on the region where its located. Each type o cell defined in this dimension has a certain "attraction power" over users during some period of time. This attraction is related to geographical and economics characteristics. One cell in a residential area can attract more users during the time zones 1 and 5, for example. On the other hand, a cell located in a downtown centre can attract more users in time zones 2 and 4 Depending on the "attraction power" cells can be classified as: Home (H), Working (W), Bank (B), Shopping (S) and Entertainment (E) cells.

2.4 Mobility Profile Definition

Combining information from these three dimensions, the model defines different profiles o mobility. Each profile is represented by an algorithm which determines the destination cell, the time a user stays in each cell before reaching the destination, which is a random variable exponentially distributed with mean μ, and the destination residence time which is uniformly distributed between $[t_1, t_2]$ minutes.

The algorithm chooses the destination cell depending on the personal profile of each u High mobility users have a random behaviour and the destination can be any cell of the system in any instant of time with the same probability. Workers and Residential users are more predictable and each one has a schedule with probabilities for each type of attraction point (cell) and for each time zone, as we can see in Table 2 and Table 3.

Table 2 (a): Residential users attraction points probabilities

Zone	H %	W %	B %	S %	E %
1	100	0	0	0	0
2	20	10	20	40	10
3	40	10	40	10	0
4	30	10	10	20	30
5	50	0	0	30	20
6	60	0	0	10	30

Table 2(b): Working users attraction points probabilities

Zone	H %	W %	B %	S %	E %
1	100	0	0	0	0
2	10	80	10	0	0
3	40	10	30	20	0
4	10	70	10	10	0
5	40	20	10	20	10
6	60	0	0	20	20

After a destination has been chosen, the next step is to define the mobile route that it will take on his trip. A route is a sequence of cells defined by the simulator. There are some routes that can be chosen and the simulator selects the first on that connects the current user cell and the destination cell.

3 CHANNEL ALLOCATION SCHEMES

In mobile cellular networks radio channels are the resources available for connected active mobile users. The more users the network has, the more important is the efficiency in the reuse of the limited frequency spectrum available. The channel allocation algorithms are responsible for getting the efficient reuse of channels and contribute for determining the QoS level of the system.

However, this reutilization is restricted by the co channel interference, which limits the u of one channel by more than one mobile at the same time. Two mobiles can use the same channel only if at least the co channel reuse distance separates them.

Many allocation schemes can be found in the literature [8], but they can be classif extremes: Fixed Channel Allocation (FCA) and Dynamic Channel Allocation (DCA). In the FCA schemes, each cell has its own set of channels. In the DCA there is no relationship between channels and cells, examples are found in [1], [6] [8] and 13. All channels are kept in a central pool and are assigned dynamically to cells as new calls arrive in the system, and the number of channels in each cell is adaptively changed to accommodate traffic fluctuations.

Current standards developments of TDMA/FDMA digital cellular mobile network suppor fixed channel allocation [12]. In FCA, the allocation relies heavily on frequency planning and will not be able to adapt dynamically to the changing condition of the offered traffic as DCA schemes.

In view of this “deficiency” of FCA, some systems have already applied the DCA s as the digital enhanced cordless telecommunication system (DECT) and the Japanese personal handy phone system (PHS). DCA is also currently supported by GSM and will be supported by PCS and D AMPS in the near future as the incorporation of DCA into their evolving standards is in an advanced stage. The evaluation of the benefits of DCA over FCA is therefore important to telecommunications providers who are considering upgrading their existing channel allocation equipment [6].

3.1 CHANNEL ALLOCATION WITH SPACE AND TIME VARIATIONS (*CA STV*)

This scheme, initially proposed in [15], uses information about users mobility profiles, such as the "attraction power" of the cells and the time zones during the day in which users have similar behaviours. With this information we can predict the traffic characteristics and channels can be distributed in a non uniform way so that the number of channels in each cell can also vary depending on the time.

The CA STV scheme assumes that each cell is classified into ones of the five profile defined in the space dimension of the model explained above. The time zones have also to be defined according to the same mobility model. Each cluster has a channel allocation matrix that defines the fraction of channels assigned for each type of cell during each time zone.

The CA STV is a non uniform channel allocation scheme where the number of channels assigned for each cell will change with the time zone. As in DCA schemes, for implementing CA STV, additional transmitters/receivers will have to be added onto all base stations so that they are capable of transmitting and receiving in all available frequency carriers. The CA STV also tries to adapt to the changing condition of the offered traffic, but not dynamically.

In DCA the selection of a candidate channel can increase the algorithm complexity what difficulties the real implementation. In CA STV the changes are defined a priori, using the traffic forecasts and the reconfiguration of the channels allocated for each base station will occur only between time zones.

We the efficiency of the CA STV proposal will be compared to the following channel allocation algorithms:

- FCA – If M is the total number of channels, each cell has its set of $S=M/7$ channels, where 7 is the reuse factor;
- DCA First Available (DCA FA) – In this scheme the first available channel within the reuse distance encountered during a channel search is assigned to the call;

4 THE SIMULATION ENVIRONMENT

The CELSA simulation tool was initially developed for analysis of the signalling in TDMA mobile cellular networks [7, 14], but it has been extended for doing resource management and performance analysis of channel allocations schemes.

The simulation platform implementation was divided into three modules

1. Mobility and Traffic Generation;
2. Signalling of Scenarios and Messages;
3. Network Structure and Configuration;

The first module is responsible for generating the traffic load applied to the system i simulations and for modelling users mobility characteristics. This module contains the implementation of the three dimensional mobility model described in section 2.

The second module supplies information about the exchanged messages when one specifi procedure occurs (e.g. messages between the entities of a network when a handoff procedure must be executed). These messages have different sizes in bytes and each procedure has its own messages that are exchanged in a specific sequence. During the execution of each procedure, the tool simulates the messages exchanged between network components (RBS – Radio Base Station, MSC – Mobile Switch Center, VLR – Virtual Location Register, HLR – Home Location Register and MU – Mobile Unit), considering the load of each message and its time of processing in each network component.

CELSA implements the main procedures of a cellular network, such as Power Up, Cal Origination, Location Update, Handoff and Power Down, for both GSM and IS 41/136 systems, considering signalling messages sequences and their lengths. By computing the message sizes for each procedure it is possible to estimate the signalling load in the network.

The network architecture and configuration module is responsible for platform manage and for the traffic of information between the modules. This module is responsible for accounting the signalling load and for estimates the QoS parameters of the network during the simulations. This module also allows the evaluation of very complex systems, making possible changes and/or upgrades in the number of location areas for each switch, allowing the identification of unbalanced loads, operation and testing of new procedures or services.

The SIMSCRIPT II.5 [11] simulation language was used for implementing the tool, offers high flexibility. The modular implementation makes it possible to examine different mobility models, traffic distributions and topologies, as well as new procedures that can be implemented.

The CELSA simulation tool has a graphical interface. Using this interface the user ca construct a simulation of any topology, by just selecting, connecting and defining the properties of the network components. It's possible to have a map in the background that helps to place the components and simulate a real network over a specific city.

It is possible to configure component properties, such RBS coverage area and number o channels available. In addiction we can define the space dimension classification for each cell (Residential, Working, Bank, Shopping or Entertainment area) and the possible routes in the topology. The information about personal profiles, such as the total number of users, the percentage of users in each profile and the attraction point's probabilities schedules for the Working and Residential users can also be defined in the graphic interface. All this configuration information reflects the mobility model described in the previous section.

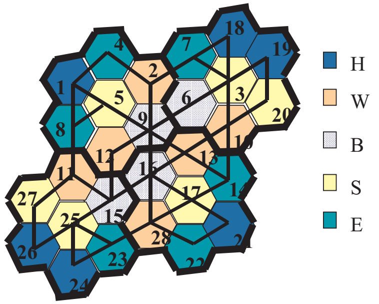
5 Performance Analysis

The performance analysis considers the blocking probability and the handoff failure probability as QoS parameters. They are estimated by the mean percentage of new calls blocked and the mean percentage of handoff requests that fail because there is no channel available in the next cell during the simulation.

We consider a 28 cell network as showed in Fig.2 (a). The cells are organized in f clusters, each of seven cells. The connections between cells that forms the possible routes defined in the mobility model are also indicate in Fig.2 (a). The following assumptions are considered in the performance analysis:

- The call duration is random and exponentially distributed with an expected value of t_{CALL} minutes.
- Blocked calls are cleared.
- The call arrival process is considered a Poisson process with mean λ calls/sec.
- There are 5000 mobile users in the system and 60% are Workers (WR), 15% are Residential (RE) users and 25% are High Mobility (HM) users.
- The cell residence time is exponentially distributed, as described in the mobility model, with mean μ minutes.
- The destination cell residence time is uniformly distributed between $[t_1, t_2]$ minutes.
- There are M channels available in the system.

We have considered two distinct simulation scenarios. The scenario 1 was used to evalu the blocking probability using each allocation algorithm. In scenario 2, the handoff generation process and the handoff failure probability were analysed for each allocation scheme. The parameters used in the two scenarios are showed in Fig. 2(b).



Parameters	Scenario 1	Scenario 2
λ (calls/sec)	0,8	0,6
μ (min.)	3,6	2
t_{CALL} (min.)	2	4
$[t_1, t_2]$ (min.)	[48, 60]	[30, 42]
M	105	105

Fig. 2(a) Topology simulated

Fig. 2(b) Scenarios 1 and 2 parameters.

5.1 Scenario 1

In this scenario we have studied the traffic distribution over all the simulated topology and during all the time zones. With this information, we can estimate which regions are submitted to intense traffic conditions during each time zone, so that we can choose the values of the channel allocation matrix defined in CA STV algorithm in a way that more critical areas receive a large number of channels.

Fig. 3(a) shows the percentage of the total traffic by cell for each of the five cell W, B, S and E) described in the mobility model. The results were obtained computing all new call requests in the system during a simulation from 6:00 (Zone 1) to 24:00 (Zone 6).

During the Zone 1, for example, cells have a high traffic load, because of the values in the attraction points tables (Tables 2(a) and (b)). During the Zone 2, the traffic is more intense in the Working cells, where most of the 60% of users (Workers) are supposed to be. In Zone 3 we can see a more equilibrated situation, what represents the users going home, users going to center areas, such as Bank and Shopping cells, or users who stay in the work place. The others zones results are also in line with the mobility model. In Zone 4, we have again a high traffic load in working cells and in Zones 5 and 6 the arrival rate increased in Home, Shopping and Entertainment cells.

Observing the traffic conditions, we have chosen the values of the channel allocation matri for the CA STV scheme and the matrix used in the following experiments is showed in Fig 3(b). Using the CELSA´s graphic interface, the simulation designer can change these values easily at any time. In Zone 2, we have reserved 40% of the channel in each cluster for working cells. On the other hand, in Zone 6 we have changed the priority to Home areas and we have assigned 40% of the channels to this kind of cell. Although the main goal is to provide a better QoS level in cells under high traffic loads, in the light loaded cells the systems try to allocate at least 10% of all channels in order to have a minimum QoS level.

In this scenario we have also obtained the blocking probability by scell for simulation between 9:30 and 10: 30 am (Fig. 4(a)) and between 21:30 and 22:30 in the night (Fig. 4(b)).

As we can see in Fig 4(a), the CA-STV scheme had a much better performance than FCA or DCA-FA in the Working and Bank cells. These types of cell have a more intense traffic during this time. In the Bank cells the blocking probability using CA-STV was very low compared to the other schemes. Moreover, in the Home, Shopping and Entertainment cells the CA-STV had a high blocking probability than FCA and DCA-FA. But, as specified in the mobility model, these types of cell, at this time of the day, have a lighter traffic load.

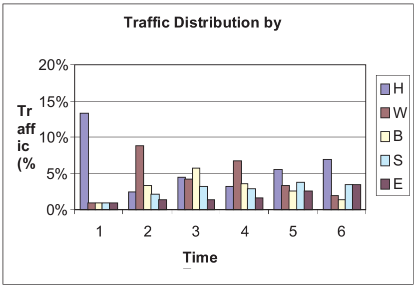


Fig. 3 (a) Traffic Distribution for each type of cell

Time Zone	channels by cluster (%)				
	R	W	B	S	E
1	50	20	10	10	10
2	20	40	10	20	10
3	30	30	20	10	10
4	20	40	10	10	20
5	30	20	10	20	20
6	40	10	10	10	30

Fig. 3 (b) Channel Allocation Matrix

The results in Fig. 4 (b) show again the efficiency of CA-STV in heavy loaded cells, w are represented by Home and Entertainment cells during this time of the day. Even in Bank cells CA-STV performed better than FCA or DCA-FA. Only in Working and Shopping cells other schemes had lower blocking probability, but this regions have a light traffic load during the simulation period. The results have also demonstrated that the DCA-FA scheme don't performs well under heavy traffic condition, as can be noted in Fig. 4(b).

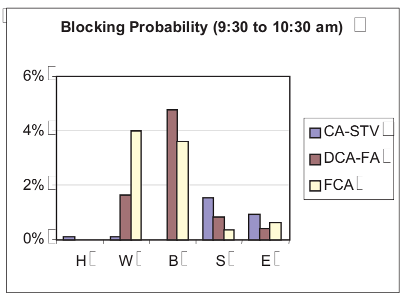


Fig. 4(a) Blocking Probability (Zone 2)

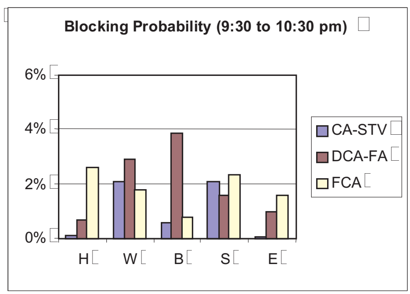


Fig. 4(b) Blocking Probability (Zone 6)

5.2 SCENARIO 2

In this second scenario, the main goal is to compare performance of the channel allocation algorithms under high handoff traffic. In addiction, we show how the blocking probability affects the handoff process. Finally, we evaluate the handoff failure probability for the three schemes.

The parameters used in this scenario (Fig. 2(b)) change the traffic load and it increases probability of handoff procedures by users. The mean call time was increased and at the same time, the mean cell residence time and destination residence time were reduced. All these changes affect the traffic generation process in the same way as if we had reduced the cell size and increased the mobile user speed.

Fig 5(a) shows the percentage of new call requests that execute a handoff procedure each algorithm in scenarios 1 and 2 The results were obtained in a simulation between 18:30 and 1900 (Zone 5). This is a period when most users are moving in home direction. We can observe how the parameters have increased the handoff traffic in scenario 2.

The results also indicate the CA STV scheme supported high handoff traffic than other allocation algorithms. This occurred because the handoff traffic depends on the channel allocation efficiency. So, since CA STV had the lower blocking probabilities it will handle more handoffs. Fig. 6(b) shows results of a simulation between 12:30 and 1300, where we can see again the amount of handoff traffic handled for each channel allocation algorithm.

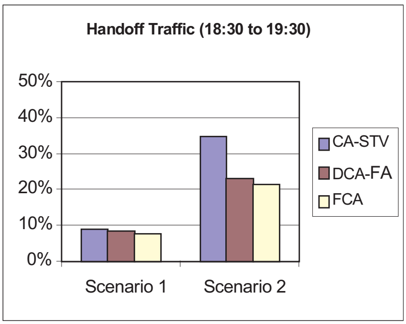


Fig. 5(a) Handoff Traffic (Zone 5)

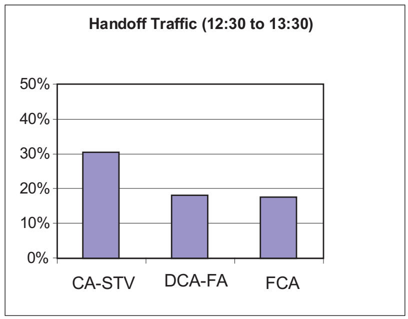


Fig. 5(b) Handoff Traffic (Zone 3)

The handoff failure probability results are presented in Fig. 6(a) and (b). As we can se DCA FA scheme had the worst performance in all types of cell in the two time zones simulated. In zone 5, CA STV had the best performance and in addition, it also had the highest handoff traffic. Using the CA STV scheme, during this period of time, the system had provided the best QoS levels.

In Fig.6(b) we present the results of a simulation in zone 3, and in this period the FC presented the lowest handoff failure probability. The DCA FA scheme had again the worst performance and the CA STV performance was close to FCA only in Working cells. Although the handoff failure probabilities using FCA were lower than CA STV, the handoff traffic in the system using CA STV was more than 10% higher than using FCA. Considering that, the more traffic the system can handle, the more efficient the channel allocation, the CA STV continues performs better than FCA and DCA FA.

The bad results got by DCA FA in scenario 2 showed that as the handoff traffic increase the gain of a dynamic allocation decrease drastically compared with the fixed allocation techniques.

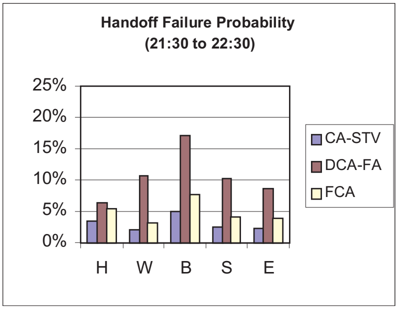


Fig. 6(a) Handoff Failure Prob. (Zone 5)

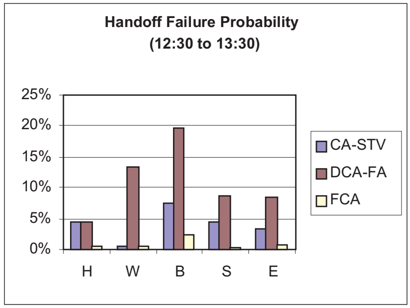


Fig. 6(b) Handoff Failure Prob. (Zone 3)

6 CONCLUSIONS

This paper has presented a performance comparison of radio channel allocation schemes in mobile cellular networks. The results were obtained using a simulation environment called *CELSA* developed for analysis of signalling load and QoS parameters in TDMA based networks.

We have considered a mobility model, which take into account different characteristics of users, regions and periods of time for define mobility profiles. We have implemented this three dimensional mobility model in the simulation environment and used it for evaluating the efficiency of channel allocation schemes. We have implemented the following schemes: FCA, DCA FA and CA STV. The last one, uses information extracted from the traffic load generated by the mobility model implemented and distributes the channels in a non uniform fashion. The numerical results obtained by simulation provide insight into efficiency gain of CA STV in cells under high traffic conditions, where it presented the lowest blocking probability. The analysis of handoff failure probability showed in some conditions the FCA scheme had performed better the CA STV, but CA_STV can support a higher traffic of new calls and consequently higher handoff traffic in all experiments.

In conclusion, we have demonstrated the efficiency of a simulation environment that implements a three dimensional mobility model on the performance analysis of channel allocation schemes, which determines the QoS provided by mobile cellular networks.

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