HYBRID CHANNEL ALLOCATION IN WIRELESS CELLULAR NETWORKS

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Abstract—The enormous growth of mobile telephone traffic, along with the limited number of channels available, requires efficient reuse of channels. Channel allocation schemes can be divided into three categories: Fixed Channel Allocation (FCA), Dynamic Channel Allocation (DCA) and Hybrid Channel Allocation (HCA). In HCA, channels are divided into two disjoint sets: one set of channels is assigned to each cell on FCA basis, while the others are kept in a central pool for dynamic assignment. This paper presents a hybrid channel allocation notification to the central pool on each channel request that cannot be satisfied locally at the base station. This notification will request more than one channel to be assigned to the requesting cell. When FCA would not support call then borrowed channels will be in use. The simulation study of the protocol indicates that the blocking probability of HCA will be low for less traffic and high for high traffic.

***Keywords**: Channel allocation, wireless networks, exponential distribution.*

I. INTRODUCTION

The recent growth of mobile telephone traffic, along with the limited number of radio frequency channels available in cellular networks, requires efficient reuse of channels. An efficient channel allocation strategy is needed and it should exploit the principle of frequency reuse to increase the availability of channels to support the maximum possible number of calls at any given time. A given frequency channel cannot be used at the same time by two cells in the system if they are within a distance called minimum channel reuse distance, because it will cause radio interference (also known as co-channel interference).Several channel allocation schemes have proposed [1] and they can be divided into three categories: Fixed Channel Allocation (FCA), Dynamic Channel Allocation (DCA), and Hybrid Channel Allocation (HCA). In FCA schemes, a fixed number of channels are assigned to each cell according to predetermined traffic demand and co-channel interference constraints. FCA schemes are very simple; however, they are inflexible, as they do not adapt to changing traffic conditions and user distribution In order to overcome these deficiencies of FCA schemes, DCA schemes have been introduced. In DCA schemes, channels are placed in a pool (usually centralized at Mobile Switching Centre (MSC) or distributed among various base stations) and are assigned to new calls as needed. Any cell can use a channel as long as the interference constraints are satisfied. After the call is over, the channel is returned back to the central pool. At the cost of higher complexity and control message overhead, DCA provides flexibility and traffic adaptability. However, DCA schemes are less efficient than FCA under high load conditions. To improve performance, some DCA schemes use channel reassignment, where on-going calls may be switched, when possible, to reduce the distance between co-channel cells. Another type of DCA strategy involves channel borrowing mechanism from neighboring cells. In such a scheme, channels are assigned to each cell as is normally done in the case of FCA. However, when a call request finds all such channel busy, a channel may be borrowed from a neighboring cell if the borrowing will not violate the co-channel interference constraints [1].

HCA techniques are designed by combining FCA and DCA schemes in an effort to take advantages of both schemes. In HCA, channels are divided into two disjoint sets: one set of channels is assigned to each cell on FCA basis (fixed set), while the others are kept in a central pool for dynamic assignment (dynamic set). The fixed set contains a number of channels that are assigned to cells as in the FCA schemes and such channels are preferred for use in their respective cells.

When a mobile host needs a channel for its call, and all the channels in the fixed set are busy, then a request from the dynamic set is made. The ratio of the number of fixed and dynamic channels plays an important role. It has been found that if the ratio of FCA and DCA forms HCA. The HCA techniques proposed in the literature are complex to implement and they suffer from the large control overhead incurred from system state collection and dissemination.

This paper presents a new HCA scheme that takes into account the level of traffic intensity and blocking probability in a cell.

II. BASIC CHANNEL ALLOCATION SCHEMES

A HCA method, which is composed of two parts. The first part is the allocation of nominal channels for each cell. This is carried out in the planning stage of wireless communication network. The second part is the allocation of channels to ongoing call requests while the wireless network is in use. This is carried out dynamically, when a call originates in a cell without free nominal channels.

Assuming a cellular structured mobile communication system layout, a point of interest is to decide on what Channel Assignment Scheme (CAS) to use. One such scheme is the Fixed Channel Assignment (FCA), where channels can only be used in designated cells [4], [6], [8], [11],[13],[14],[15] .In this case there is a definite relationship between cells and channels that can be used there at any time.

One obvious disadvantage of using this scheme can best be explained using an example. Imagine two neighboring cells with their assigned channels. If at any time, one of the cells happens to have all its channels occupied, and another request for service is made in this same cell, this new request will be denied even though there may be free channels in the neighboring cell at this very instant. The overall result is one of poor channel utilization.

Another channel assignment scheme is the Dynamic Channel Assignment scheme (DCA). In the DCA approach, there is no definite relationship between the cells of the system and the channels that are used in them. Channels are temporarily assigned for use in cells for the duration of the call. After the call is over, the channels are returned and kept in a central pool [2], [4], [6], [7], [14]. To avoid co-channel interference that would result if two neighboring cells used the same channel simultaneously, any channel that is in use in one cell can only be reassigned simultaneously to another cell in the system if the relative distance between the two cells is d, where d is defined as

$$d = D/R \qquad (1)$$

Where R is the radius of the cell and D is the physical distance between the two cell centres (the resulting average spacing between cells using the same channel depends on the criterion of borrowing, but it is usually larger than d). This physical separation that must exist between any two cells using the same channel gives rise to the concept of an Interference cell group. The interference cell group, for a given cell, is comprised of all those cells with which it can interfere if they transmit on the same channel simultaneously.

When a cell wishes to borrow a channel for temporary use, there is usually more than one channel in the central pool and therefore one has to decide which one, out of all the eligible channels, to borrow for use. Many different schemes for a cell borrowing a free channel have been investigated and published [2], [6], [7], [9], [11]. The FCA and DCA are two 'definite' policies, definite in that over the entire service area, and for all time, channels are either assigned with FCA or DCA disciplines. There are two other channel assignment schemes which are a combination of FCA and DCA. The third CAS will be called Constrained Dynamic Channel Assignment (CDCA) scheme [2]. The fourth and last CAS of interest in this paper is the Hybrid Channel Assignment (HCA) scheme [4, 15]. Explanations of these channel assignment algorithms will be given later.

FCA and DCA schemes have been studied quite extensively [6-8], [10], [11], and the results from system simulations have shown that, for low blocking probabilities, the Dynamic system performs much better than the Fixed system. But for very high blocking probabilities, which are synonymous with very large offered traffic, the FCA scheme performs better.

The initiation of requests for service from cell to cell is a random process and, therefore, when DCA is being used, the different channels are assigned to serve calls at random too. Because of this randomness, it is found that cells that have borrowed the same channel for use are, on the average, spaced apart at a greater distance than the minimum required distance d. Consequently DCA schemes are not always successful in reusing the channels the maximum possible number of times. But for FCA systems, the channel assignment to cells is done observing the minimum spacing d and, therefore, it has a higher channel reuse. This is why, in order to improve the performance of DCA systems at large traffic offerings, it has been suggested to use Channel Reassignment techniques [4]**.** The basic goal of Channel Reassignment is to switch calls already in progress, whenever possible, from channels that these calls are using, to other channels, with the objective of keeping the distance between cells using the same channel simultaneously to a minimum. It has been found that, in the case of DCA, the system is not overly sensitive to time and spatial changes in offered traffic, giving rise to almost stable grades of service in each cell [5]. But for the FCA scheme, the service deviation, a measure of the grade of service fluctuations from one cell to another, is very much worsened by these said traffic changes. Another point in favor of DCA over FCA, as deduced from simulation results, is the seeming dependence of the grade of service within an Interference cell group on the average loading within that group and not on it spatial distribution [2], [5].A channel assignment scheme that is superior to FCA and DCA, and which will be called constrained DCA in this paper, was proposed by [9] and by [2] by comparing it to two other channel assignment schemes, using some simulation results. Concluding from results that the CDCA scheme behaved like a full access system, with the number of channels equal to the total channels available for use in the heaviest loaded interference cell group.

In this scheme, each cell has two sets of channels for its use, shown in Fig. 1 as Al, B1, C1 and (A, B), (A, C), (B, C). The former type of sets contains the nominal channels. These channels have been assigned to the cells observing the minimum interference spacing and in all cases are to be preferred for use in their respective cells (nominal cells). If all nominal channels for a particular cell are busy when a new call originates or arrives in a particular cell, then borrowing may take place from the borrow able set, shown in brackets in that cell, provided no interference will result as a consequence of this borrowing. It is of interest, to note that the set in brackets may contain many channels, and therefore the decision on which channel of the set will be borrowed is important. A general conclusion reached by most authors on this subject was that adopting a simple test for borrowing (for example, borrowing the first available channel that satisfies the d constraint) yields performance results quite comparable to systems which do a lot of exhaustive searching for channels that are the ultimate best for borrowing, thus giving rise to a lot of processing per call. Because of this reason, in the research which led to the results presented in this paper, the criterion for borrowing was simply to use the first available channel in the search.

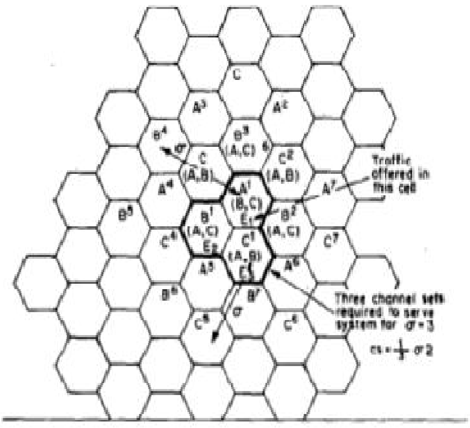

Figure 1. Hexagon cellular layout. Key: A^i, B^i, C^i sets of channels that are assigned to cells for use there as first choice. (A, B), (A, C),(B, C) sets of channels that can be borrowed for use in the cells where indicated, provided such borrowing meets interference constraints imposed on the system [15].

In the Hybrid Channel Assignment Scheme, employ a mixture of two schemes (thus the name Hybrid). These are the FCA and DCA schemes. Assume a total of *T* duplex channels for service and that they are divided into two sets A and B, not necessarily equal. Then channel set A contains channels that are used, in the system using the FCA scheme. Channel set B contains those channels that can be used in any cell in the system, using the DCA scheme [4], [15].Up to now, the question of exactly in what ratio to divide T channels into the two sets A and B has remained unanswered.

III. DESCRIPTION OF SIMULATED SYSTEM

Basic assumptions

1. For the investigation of the optimum division between fixed and dynamic channels, a system with a very large cellular layout should be used, but the statistics should be collected from the central cells only. The reason for considering a large cellular layout was to overcome the edge effects. Using a small system for this kind of study is bad because the cells around the edges do not have enough neighboring cells to cause calls to be blocked, whereas the centrally located cells have a lot of neighboring cells and therefore every time the central cells wish to borrow, chances are the neighboring cells will be using the desired channels. This gives rise to the central cells having higher blocking probabilities than those at three edges.

2. The calls in each cell are assumed to have a Poisson distribution with known arrival rate, λ calls/hour.

3. The service time per call, in any cell, is assumed to be exponentially distributed, with a mean of 180 seconds. Thus the loading will be:

—— [Erlangs]

(2)

4. The first available channel in the search that satisfies the spacing constraint is borrowed for use.

5. It is assumed that the mobiles are identifiable entities and could operate on any channel, as dictated by the base stations.

6. The base stations could transmit on any borrowed frequency at all times, as assigned to them by the system controller.

Now consider a system having uniform spatial offered traffic and using a HCA scheme. The steps involved in the simulation are as follows:

a) Assumed that the long term average offered traffic in Erlangs was known. Then using the tables for the Erlang B traffic formula [12] now determine the number of channels required in each cell to give the desired grade of service assuming that a FCA scheme was in use. The desired number of channels for cells 1, 2, 3 ... was represented by (NC) Fig. 2.

b) Then consider a mobile communications system with uniformly offered traffic that requires (NC) channels per cell, on the average. the ratio of Fixed to Dynamic channels that carry the most traffic at the desired grade of service. Let this, ratio be represented F: D, where D is the average number of static channels per cell, is the average number of dynamic channels per cell and F+ D = (TC).

c) Now using the results obtained in Step b above, channels are assigned to the cells of the mobile communications system.

Consider, for example, a cell that has offered traffic of E, Erlangs. Then normally (TC) channels would be needed to give a desired grade of service. But from the simulation results only F channels are assigned to cell 1 and 1, channels are given to the entire system for use as Dynamic channels.

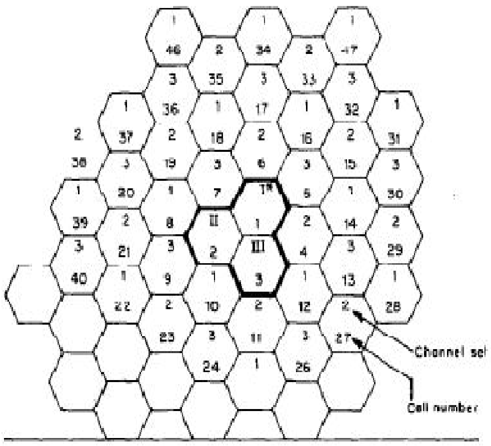

Figure 2. Cellular layout for system that was simulated.[15]

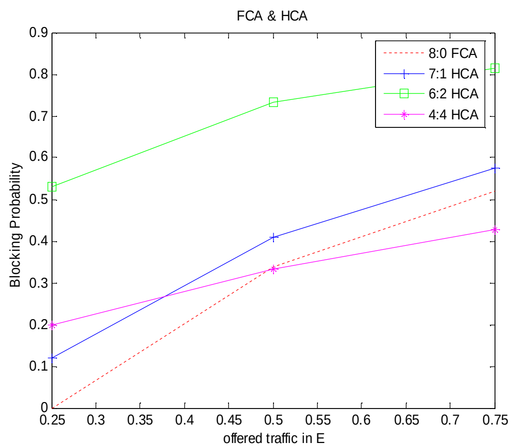

Figure 3.Simulation results showing the comparison between FCA and HCA

TABLE I. DIFFERENT SYSTEM COMBINATION INVESTIGATED

Average channels loading per cell in uniformly loaded system	Channel partition for Hybrid simulation Fixed	Dynamic	Traffic in Erlangs
8	8	0	5,6,7,8
	7	1	
	6	2	
	4	4	

IV. CONCLUSION

The obtained results indicate that the Fixed to dynamic Channel Assignment scheme ratio per cell is equal performs better than other ratios. The simulation study of the protocol indicates that the blocking probability low for less traffic in FCA case, while for high traffic fixed and dynamic channels should equal so that blocking probability remain less. Beyond this, for different combination of ratios HCA has low blocking for less traffic and high for high traffic.

To further improve the performance, there is no division of fixed and dynamic channels groups. Dynamic channel pool includes all the channels in the system.

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