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Dynamic Load Balancing Using Selective Borrowing in Wireless Network

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Abstract

The demand for mobile communication has been growing day by day. Resource flexibility is one of the most important issues in the coming generation of mobile communication. Radio frequency channels are a scarce resource and have to be reused as much as possible. Different techniques are required to increase the efficiency & flexibility of the network to deal with new services and to adopt the new traffic profiles and characteristics Many channel assignment schemes such as fixed channel assignment (FCA), dynamic channel assignment (DCA) and hybrid channel assignment (HCA) have been proposed to assign frequencies to cells with a goal to maximize the frequency reuse. In this paper, we make a review of the characteristics of various channel assignment specially dynamic (LBSB)schemes.

Keywords: Efficiency, Channel allocation, Mobile communication, FCA, DCA, Resource flexibility, CBWL, LBSB.

Introduction

Now days you can see a remarkable growth of the mobile communication users in recent times. The fact that a very limited radio frequency spectrum allocated to this service means that the frequency channels have to be reused as much as possible in order to get the many thousands of simultaneous calls that may arise in a typical mobile communication environment.

A cellular mobile network is the collection of geometric areas, called *cells* (typically hexagonal-shaped), each connected to a *base station* (BS) located at its centre. A number of cells (or BS's) are connected to a *mobile switching centre* (MSC) which is used as a gateway of the cellular network to the existing wired networks like Public Switched Telephone Network (PSTN), Integrated Services Digital Network (ISDN) etc.

In cellular mobile communications field, frequency channels are limited and due to this limitation of resources, we reuse the frequency channels efficiently, many channel allocation schemes such as fixed channel assignment (FCA), dynamic channel assignment (DCA) and hybrid channel assignment (HCA) have been proposed to allocate frequencies to cells with a goal to maximize the frequency reuse. Channel assignment must satisfy some constraints to avoid interference between neighboring channels. The following constraints have considered in channel assignment problem:

(a) The co-channel constraint: The same radio frequency cannot be reused in the cells within a certain distance from each other.
(b) Adjacent channel constraint: Any pair of channels in adjacent cells must have a specified distance.
(c) The co-site constraint: Any pair of channels in the same cell must have a specified distance.

In Fixed Channel Assignment Strategy. Each cell is allocated a predetermined set of voice channels for its exclusive use. Users in a particular cell , a call attempt can only be served if unused channel in that particular cell is available For efficient operation, FCA systems typically allocate channels in a manner that maximizes frequency reuse. Thus, in a FCA system, the distance between cells using the same channel is the minimum reuse distance for that system.. FCA schemes are simple, however, they do not adapt to changing traffic conditions and user distribution. Dynamic Channel Allocation (DCA) attempts to alleviate the problem mentioned for FCA systems when offered traffic is non-uniform. In DCA systems, no set relationship exists between channels and cells. Instead, channels are part of a pool of resources. Whenever a channel is needed by a cell, the channel is allocated under the constraint that frequency reuse requirements can not be violated. However, DCA strategies are less efficient than FCA under high load conditions.

To overcome this drawback, HCA techniques were

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introduced combining FCA and DCA schemes.

More recently, a channel borrowing scheme called channel borrowing without locking (CBWL) is proposed where channels of each base station are divided into seven distinct group to eliminate channel locking for co-channel cells .

Fixed channel allocation

In a fixed channel allocation scheme, a set of channels is permanently allocate specific channels to specific cells. In a simple uniform channel distribution scheme, the overall average blocking probability of the mobile system is the same as the call blocking probability in a cell. In a non-uniform channel allocation, the number of channels allocated to each cell depends on the expected traffic profile on the cell. Heavily loaded cells are allocated more channels than lighted loaded cells. Given the traffic load in each cell and the compact pattern allocation of channels, non-uniform pattern allocation algorithms attempts to find a compact pattern that minimize the average blocking probability in the entire mobile system. Simulation results shows that the blocking probability in a non-uniform compact pattern allocation is always lower than the uniform channel allocation .

Channel Borrowing Scheme

In a channel borrowing scheme, a cell that has used all its nominal channels can borrow free channels from its neighboring cells to accommodate new request for call and these channels should not interfere with existing call. When a channel is borrowed, several other cells are not allowed to use that channel. This is known as channel locking. Channel borrowing schemes can be classified into simple and hybrid.

In a simple borrowing scheme, channels in a cell are borrowed from a neighboring cell for temporary use. In hybrid channel borrowing strategies, the set of channels assigned to each cell is grouped into two subsets. One set is used only for the nominally assigned cell while the other set is allowed to be lent to neighboring cells. The objective of the borrowing schemes is to reduce the number of locked channels caused by channel borrowing. The following are the several variation of the simple borrowing strategies that have been proposed .

Borrow from the Richest (SBR)
Basic Algorithm (BA)
Basic Algorithm with Re assignment (BAR) Borrow First Available (BFA)

The performance comparison for SBR,BA and BFA schemes were evaluated by simulation in with two-dimensional hexagonal layout with 360 service channels. The offered load was adjusted for an average blocking probability of 0.02. A summary of the comparison results are shown below .

Scheme	Complexity	Flexibility
Borrow from richest	Moderate	Moderate
Baisc algo.	High	Moderate
BA with reassignment	High	Moderate
Borrow First Available	Low	Low

Dynamic Channel Allocation

Fixed channel assignment schemes are not able to provide high channel efficiency due to the non- uniform nature of traffic in a cellular system. In a dynamic channel assignment (DCA) scheme, all channels are kept in a central pool of channels and are assigned dynamically as new calls arrive in a system. After a call is completed, the channel is returned to the central pool . In DCA, a channel can be used in any cell provided that signal interference constrains are satisfied. The main idea of DCA schemes is to use different cost functions to evaluate the cost of using a channel and select the one with minimum cost . The cost function might depend on the blocking probability of the cell, how frequently the channel is used, the reuse distance and channel occupancy distribution . Based on the type of control they employ, DCA schemes can be classified into the following categories :

Centralized DCA
Distributed DCA
CIR measurement DCA
One dimension system
Centralized DCA Scheme:

In a centralized DCA schemes, a channel from the central pool is assigned to a cell based on a cost function. To evaluate the cost function, the following techniques are used :

First Available channel (FA)
Mean Square (MSQ)
Nearest Neighbor (NN)
Nearest Neighbor plus One (NN+1)

Computer simulation of FA, MSQ, NN and NN+1 strategies show that NN is superior with low blocking probability followed by MSQ and FA under light traffic condition.

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Category	Low	Medium	High
Blocking Probability	NN	MSQ	NN+
Forced Termination	NN+1	MSQ	FA
Channel Changing	NN+1	MSQ	FA
Carried Traffic	NN	MSQ	FA

Distributed DCA Schemes

Due the simplicity and ease of design of algorithms, the distributed dynamic channel allocation approaches resulted in good performance results in micro-cellular system.These algorithms use local information about the availability of channel in the cell (cell-based) or signal strength measurements. The cell-based distributed DCA scheme provides close to optimal channel allocation, but at the expense of exchange of status information between base stations large number of times . In the signal strength measurement based scheme, a base station uses only local information, without a need to interact with other base stations in the system. Nevertheless, distributed allocation schemes must address the problem of efficient co-channel interference avoidance and reducing messaging overhead issues.

Hybrid Channel Allocation

Hybrid channel assignment (HCA) schemes are achieved by combining FCA and DCA techniques. In HCA scheme, the total available channels are divided into two sets as fixed and dynamic sets. The fixed set contains channels that are assigned to cells as in FCA schemes while any of the DCA schemes could be used for the dynamic set of channels. Many HCA schemes include channel re- ordering and call-queuing instead of call-blocking. The ratio of fixed to dynamic channel is an important parameter that defines the performance of the system. This ratio is a function of traffic load and would vary over time.

Performance evaluation of different HCA schemes measured the probability of blocking as the load increases for different ratios of fixed to dynamic cells. For a given system with fixed to dynamic ratio of 3:1, the HCA gives a better grade of service that FCA for load increases up to 50 percent . Simulation studies showed that system with most dynamic channels gives the lowest probability of queuing for load increased up to 15 percent of the base load where as loads over 40 percent, systems with no dynamic load gives the best performance. From load of 32 to 40 percent, systems with low dynamic channel gives best performance.

Load Balancing scheme

An extension to the dynamic load balancing with selective borrowing scheme (LBSB) in discussed in. In this scheme, a cell tries to borrow channels from adjacent cells before its nominal channel set is used up. Channels are borrowed and reassigned internally via intra-cellular handoffs.

In this scheme, In the LBSB, a cell is classified as 'hot', if its degrees of coldness defined as the ratio of the number of available channel to the total number of channel; channels allocated to that cell is less than or equal to some threshold value 'h'. Otherwise, the cell is 'cold'. Aided by a channel-allocation strategy within each cell, it has been presented that the centralized. LBSB achieves most perfect load balancing and leads to a significant improvement over FCA,simple borrowing, directories and CBWL schemes in case of an overloaded cellular system.

Let C = Number of allocated channels to the cell.

Degree of coldness,

$$d_c = \frac{\text{Channels available}}{C} \quad (1)$$

A cell is hot if $d_c < h$ where 'h' is the threshold parameter. Typical values of h are 0.2, 0.25 etc. indicating that about 75% to 80% of the nominal channels are in use. For a network with N cells, the average network channel availability is given by,

$$d_{cavg} = 1/N \sum d_c(i) \quad (2)$$

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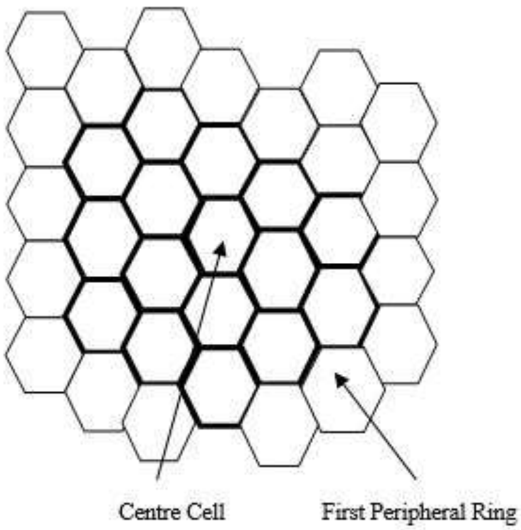

Fig 1. Cell Network Structure.

A hotspot region can then be defined to consist of tessellated hot cells as in Fig 1. A ring is a group of cells that contain at least one hot cell. An arbitrary center cell is chosen and ring i (i = 0,1,2 ,3…) is i number of rings away from the center cell. Ring 0 is unique since it contains the center cell antherefore the center cell by definition must be a hot. All other rings contain 6i cells as can be seen from hexagonal geometry. Cells can be either corner or non-corner cells. The First Peripheral Ring is defined as the first ring encountered which contains all cold cells.

For the generic case of a hot cell surrounded by hot cells, the individual cell demand is labelled X and is given by,

$$X = C (d_{cavg} - h) \quad (3)$$

This is the channel demand for a hot cell, and demands of other cell states would be modifications of X. The demand of X for the hot cell is satisfied via channel borrowing. For a cell in ring i, the number of channels which cells in ring i+1 can lend is denoted by l_{i+1}, where

$$li+1 = \frac{3i(i+1) + 1 X}{6(i+1)} \quad (4)$$

The demand of each cell in the entire network is computed beforehand and a channel demand graph is constructed. Having accomplished that, the channel migration process begins with ring i handing off some calls to the borrowed channels from ring i+1. The handoffs free ring i's nominal channel set allowing channels to be lent to cells in ring i-1. This is then repeated for each ring in the network until the center cell is reached. The end result would be a balanced network with all cells having almost equal traffic loads and hence a reduced blocking probability. LBSB has two disadvantages. First, too much dependency on the central server maintenance of continuous status information of the cells in an environment. The traffic load changes dynamically leading to enormous amount of updating traffic, consumption of bandwidth and message delays. Second, the strategy of the channel borrowing for load balancing usually uses fixed threshold values to distinguish the status of each cell. Threshold values, however, are fixed and cannot indicate the degree of the load. Since load status may exhibit a sharp distinction state level, the channel borrowing or lending action will be made frequently around the threshold, possibly resulting in ping-pong series fluctuation. This results in wasting a significant amount of efforts in transferring channels back and forth.

Enhancements to this scheme

We have made some enhancement to load balancing scheme in as follows:

- Channel demand, X

Assuming the initial network had an average degree of coldness, which was above the threshold parameter. If a particular cell i started off as being heavily loaded or having a huge difference between its channel availability and the average network channel availability, then the computed demand X would be insufficient to alleviate the traffic load.

For example;

For a network consisting of 36 cells, let us assume that cells 1 to 36 had 18 channels available on average and the total channels allocated to each cell was 100. Now, if the threshold parameter h is 0.16, let us compute the demand X.

$d_{cavg} = 18 / 100 = 0.18$

From (3)

$X = 100 \times (0.18- 0.16)$

= 2 channels.

Now if, the center cell, cell 0 had only 2 channel savailable (other cells may have more than 20 channels available resulting in an average of 18 channels available) to begin with, the load balancing algorithm will try to lend X=2 channels. This gives cell 0 a total of 4 channels after balancing. However, it results in cell 0 having a degree of coldness of 0.04, which is still much less than h! The algorithm has failed to bring the cell to the cold safe state after load balancing.

- Demand in a complete hotspot coordinate System

The use of the coordinate system for a complete hotspot was found to generate an

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unequal traffic demand among cells in a particular array. The problem affects the row of non-corner cells in a particular array, which have values of increasing j.
For example:
Consider a network with 4 rings. A cell array in ring 4 would have cells with coordinates $C_{4,0}$ to $C_{4,3}$. The amount of channels borrowed using the equation in [11] Lemma 1 for non-corner cells results in the following

Channels borrowed
$C_{4,1}$ = 7/8 l_{i+1}
$C_{4,2}$ = 5/8 l_{i+1}
$C_{4,3}$ = 3/8 l_{i+1}

This represents an unequal borrowing trend, resulting in a network that has unbalanced rates of borrowing within the cell arrays of all the rings. The situation is magnified as the number of rings in the network are increased. However, the effect will only be noticed in particular cells that have their channels heavily borrowed from adjacent cells and channel availability close to the threshold parameter.
The performance of our scheme was investigated with different traffic loads with varying parameters. We were interested in looking at the blocking probabilities resulting from different call arrival rates. The trend of blocking probabilities with various threshold parameters h is also examined. The duration of the simulation was varied to test the performance of the scheme in steady state.
In a simulation, a network of two rings was configured and a threshold parameter of h= 0.18 was chosen. The computed average degree of coldness for the network was approximately 0.19. The duration of the simulation was set to t=60 iterations. The graph demonstrates that channel assignment with load balancing is capable of handling the incoming traffic and performs brilliantly with very low blocking probability. The increased traffic loads only result in a marginal increase in blocking probability.

Conclusion

In this paper, we have reviewed the main characteristics of various channel assignment schemes in mobile communication system. A more comprehensive review is discussed in . A lot of research has been done in the area of centralized, decentralized, adaptive and power control based channel allocation schemes. In distributed channel allocation where channels are borrowed from a suitable cold cell.The suitability of a cold cell as a lender is determined by an optimization function consisting three cell parameters, namely, coldness , nearness and hot cell blockade. In the second part ,A channel assignment scheme is proposed where the assignment is done on the basis of different priority classesin which the user demands are subdivided.

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