International Journal of Electronics and Communication Engineering.
ISSN 0974-2166 Volume 4, Number 3 (2011), pp. 347-358

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# An Efficient Hybrid Channel Allocation Algorithm based on Hot-Spot & Cold-Spot: One Step Ahead from Channel Allocation Algorithms

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**Abstract**

The demand in the mobile communication has remarkably grown in the last two decade. An efficient channel allocation is essential to achieve the good performance in cellular system While the limited number of channels available, requires efficient reuse of channels. To resolve this problem various channel allocation scheme developed by researchers. This paper presents a new hybrid channel allocation algorithm that provides efficient use of the fixed and dynamic channels. Many times a cell becomes a Hot-spot (i.e. unexpected very high traffic that can't be overcome with fixed channels of that cell and the dynamic channel present in the central pool). In this case calls are dropped due to unavailability of the channel while so many channels are free in the neighbor cells which are right now a cold-spot (i.e. very low traffic). Proposed scheme is based on the reuse of these free fixed channels of cold spot in the neighbor hot spot. The performance study of the proposed scheme indicates that the efficiency is improved in terms of call dropping probability.

**Keywords:** Channel allocation schemes, Cellular networks, Hot-Spot, Cold Spot

## Introduction
Cellular communications has experienced explosive growth in the past two decades. Today millions of people around the world use cellular phones. Cellular phones allow a person to make or receive a call from almost anywhere. Likewise, a person is allowed to continue the phone conversation while on the move. Cellular communications is supported by an infrastructure called a cellular network, which integrates cellular phones into the public switched telephone network. 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.

Channel Assignment scheme can be divided into three categories [14]

- *FCA*- Fixed Channel Allocation
- *DCA*- Dynamic Channel Allocation
- *HCA*- Hybrid Channel Allocation

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 Center (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 [5].

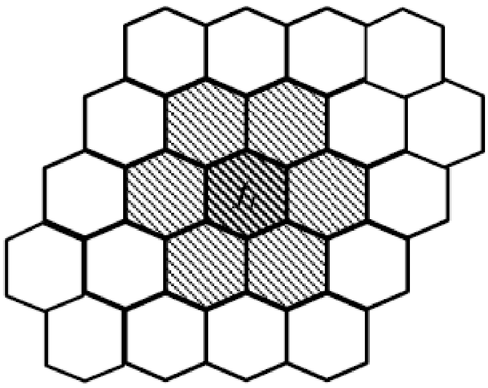

**Figure 1:** Geographical Structure of Cell.

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 [1, 2, 5]. 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 [4, 9]. 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 is 50% or more, FCA performs better than HCA. In the implementation of the proposed algorithm that ratio is also 50% [2].

Various HCA techniques available in the literature are complex and time consuming to implement and they suffer from the large control overhead incurred from system state collection and dissemination. A cell becomes a “hot-spot” when traffic generated in that cell exceeds far beyond its normal traffic load for that particular time duration. An example of a “hot-spot” cell(s) could be the area covered by a Cricket stadium for the duration of a favorite game like India Vs Pakistan World Cup. The reported HCA techniques in the literature do not offer proactive strategies in case a cell in the system becomes a “hot-spot”. Proposed algorithm provides Hot-Spot Resolution, which reduces the call dropping probability in the cell which is hot-Spot.

## Cellular System Architecture

The whole geographical area served in the cellular network is divided into hexagonal-shaped called cells. Each cell is have a base station (BS), it usually present at the center of the cell [14]. The base stations are connected with one another through a fixed wired network, in general. A mobile host can communicate with only with the base station in its cell directly. When a mobile host wants to set up a call, it sends a request to its base station in its cell on the control channel. The call can be set up only if a channel is assigned to support the communication between the mobile host and the base station. No two cells in the system can use the same channel at the same time if they are within minimum channel reuse distance; otherwise, channel interference will arise

### *System Model and Definitions*

The implementation of the proposed scheme uses a cluster of seven cells. It is assumed that each base station can keep the count of number of calls originated (successful or unsuccessful) in its related cell over a given period of time.

This count will help the bases station to determine its present level of “hot-spot” and to send a request notification to MSC for borrow the dynamic channel with the current required number of channels.

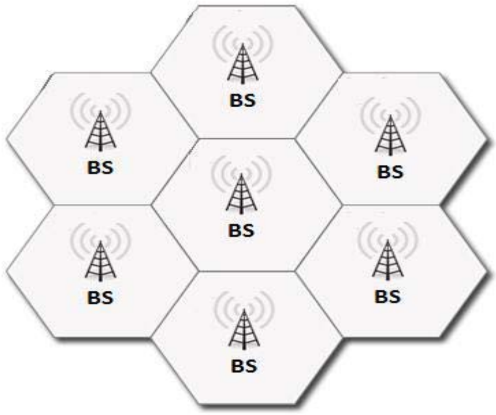


**Figure 2:** Cell Cluster.

The system uses a hybrid channel allocation scheme where the total number of *Tot_ch* channels is divided into two disjoint sets: The set *F* contains the channels for fixed (or static) assignment, while the set *Dp* contains the channels for assignment in dynamic pool at MSC, following expression satisfy every time when channels are distributed

$$Tot\_ch = Dp + 7*F$$

The fixed channels *F* are assigned to each cell in the cluster statically; while dynamic channels are kept in a centralized pool at MSC.

*b*It a cell which has Unexpected very high traffic that can't be overcome with fixed channels of that cell *F* and the dynamic channel present in the central pool *Dp*.

***Cold-spot*** - It is a cell which has very low traffic, selection of a cell as cold spot is made on the basis of free fixed channel factor *Fcf.* A cell *i* will be a cold spot if its *RC (*reserve channel) is positive.

$$RC_i = F - C_i – (F*Fcf)/100;$$

Where $C_i$ – Current calls in cell i.

## Proposed Hybrid Channel Allocation Scheme

The proposed hybrid channel allocation algorithm is described in three phases below:

- Channel acquisition phase
- Hot-Spot Resolution Phase
- Channel release phase.

The steps taken by mobile host, base station and MSC are clearly outlined. flag $f_i$ to 0 at the beginning to indicate that, at the present time, the channel request can be accommodated from the fixed (static) list assigned to the cell.

***Channel Acquisition Phase***

The following Steps are taken from Mobile Host/ Base Station Sides during a channel acquisition phase:

1. When a mobile host wants to initiate a call, it sends the channel request on the control channel to its related base station.
2. If the base station has an available channel from its current fixed channel list (F), it will assign the channel to the mobile host, and channel acquisition phase terminates.
3. If no channel from the fixed list of the cell is available, then base station sends a request to borrow a channel from the central pool located at MSC. It also includes the current requirement of channel.
4. When the base station successfully acquires a channel from the dynamic pool at MSC, then channel acquisition phase terminates

The following steps are taken from MSC Side during a channel acquisition phase:

1. The MSC, on receive a channel request from the base station, If the central pool at MSC have sufficient channel then MSC allocate the required number of channel to cell (even the call generated by the mobile host needed only one channel) and updates the value of Dp (number of channel at dynamic pool) as follows:

$$Dp = Dp - (C_i - n)$$

And the channel acquisition phase terminates.

2. If the MSC not have required channel in the dynamic pool, then the cell i will marked as HOT-SPOT and update flag as follows.

*Flag $f_i = 2$ (i.e. Cell i is an HOT-SPOT)*

And initiate the process of HOT-SPOT Resolution. (Discuss in next section)

***Hot-Spot Resolution Phase***

The following steps are taken from MSC Side during a Hot-Spot Resolution Phase:

3. MSC find the base station which is cold spot.
4. On the basis of RC reserve channels (as discussed earlier)
5. Send a Request to the base station (which is cold spot) for acquire the Fixed channel of the cold spot.
6. Receive the fixed channel of the cold spot and add these channels in the dynamic pool.
7. Again repeat the step number 1 and 2 of the channel acquisition phase at MSC level. If

***Channel Release Phase***

The following Steps are taken from Mobile Host, Base Station during a channel release phase:

1. When a call terminates on a channel at a mobile host, the base station needs to find out which type of channel the call belong If the channel belonged to was

from the fixed (static) pool maintained at the base station, the channel is returned to the pool and channel release phase terminates.

2. However, if the channel being returned belonged to the dynamic pool at MSC, it will returned back to MSC

The following steps are taken from MSC Side during a Channel Release Phase:

1. At MSC, if the returned channels are belong to the Dynamic pool then add these channels to the dynamic pool.
2. At MSC, if the returned channels are belong to the fixed channel of any cell (cold spot) then add these channels will be returned to the cold spot.

## Implementation & Perfprmance Study

Implementation of the proposed scheme is done on the Sun Microsystems Java Technology, Netbeans 6.9.1 Integrated Development Environment. Several metrics can be used to evaluate and compare the performance of the proposed algorithm. In this paper, only the most important metric of *call blocking (denial) probability* is considered.

The call blocking probability is defined as the ratio of the number of new calls initiated by a mobile host which cannot be supported by existing channel arrangement to the total number of new calls initiated (i.e., a call arriving to a cell finds both fixed and dynamic channels busy).

### *Implementation Data structure*

The following implementation parameters are used in proposed algorithm.

Tot_ch – Total available channels

F- Fixed channel allotted in each cell of the cluster of seven cells

Dp – Dynamic channel allotted to the dynamic pool at MSC.

$C_i$ – Current Call Load in cell i.

$Dc_i$ – Dymanic Channel required by the cell i.

Fcf – Free fixed channel factor.

Fc – Number of channel must retain in each cell.

$RC_i$ – Reserve channel that can be reused in other cells

$f_i$ – Flag indicator

if $f_i$ =0 , Cell i is a cold spot.

if $f_i$ =1 , Cell i require some dynamic channels(not a cold spot and not a Hot-Spot).

if $f_i$ =2 , Cell i is a Hot spot.

### *Results & Discussion*

The implementation of the proposed algorithm is tested for various scenarios (Different numbers of calls in the cells of cluster) and observe the call blocking probability in each cell. The call blocking probability was studied under various system parameters.

Figure 3 shows the results for the proposed algorithm for various values *fcf =10, 20, 30* and *Tot_ch=14000*, for CASE 4 (see CASE Table for values of call load). In this figure the call dropping probability before Hot spot resolution was 18.79 (see performance table) while after HOT Spot resolution it is 0 (CDP=0 means completely resolve Hot spot), 2.25 and 6.01 for fcf =10, 20 and 30 respectively. It is obvious that the proposed algorithm improve the efficiency of the system by reducing the call dropping probability.

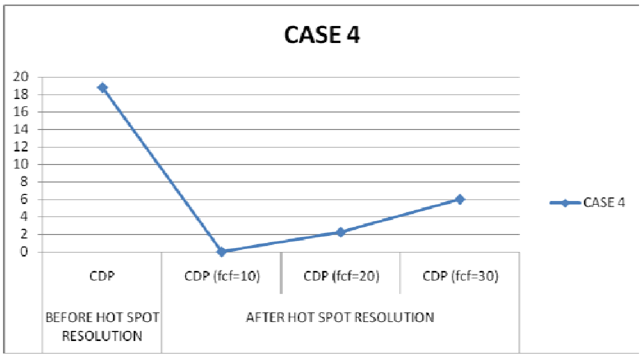


**Figure 3:** Performance Graph for CASE 4.

Figure 4 shows the results for the proposed algorithm for various values *fcf =10, 20, 30* and *Tot_ch=14000*, for CASE 5 (see CASE Table for values of call load). In this figure the call dropping probability before Hot spot resolution was 25.97 (see performance table) while after HOT Spot resolution it is 11.03, 12.98 and 14.93 for fcf =10, 20 and 30 respectively. In this case the Hot Spot is not completely resolve but we can see the call dropping probability is reduced. It is obvious that the proposed algorithm improve the efficiency of the system by reducing the call dropping probability.

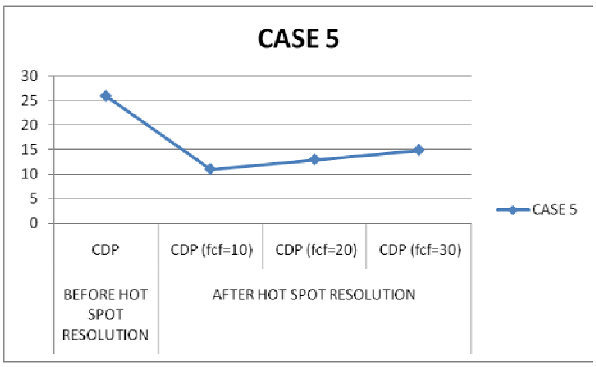


**Figure 4:** Performance Graph for CASE 5.

Figure 5 shows the results for the proposed algorithm for various values *fcf =10, 20, 30* and *Tot_ch=14000*, for CASE 6 (see CASE Table for values of call load ). In this figure the call dropping probability before Hot spot resolution was 27.02 (see performance table) while after HOT Spot resolution it is 8.78, 12.16 and 15.54 for fcf =10, 20 and 30 respectively. In this case the Hot Spot is not completely resolve but we can see the call dropping probability is reduced. It is obvious that the proposed algorithm improve the efficiency of the system by reducing the call dropping probability.

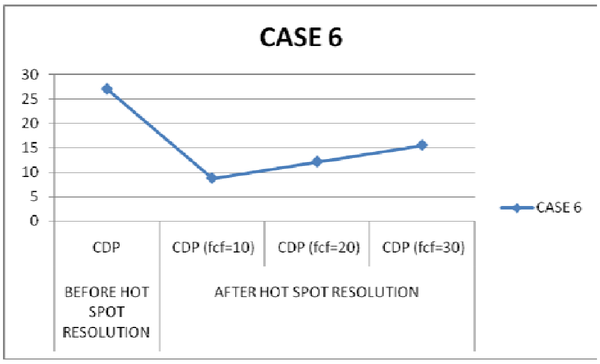


**Figure 5:** Performance Graph for CASE 6.

***Comparison and Discussion***

Figure 4 shows the comparative results for the proposed algorithm for various values *fcf =10, 20, 30* and *Tot_ch=14000*, for all the cases (see CASE Table for values of call load). In this figure the call dropping probability before Hot spot resolution is reduces up to a measurable point on each case that implies the proposed algorithm will work for each and every values of the call load on the cells in a cellular Network. It is obvious that the proposed algorithm improve the efficiency of the system in terms of reducing the call dropping probability.

The proposed strategy is better than FCA, DCA and HCA as it is flexible & static If we decrease the value of fcf , the system performance, in general improves, in both regions of low and high system loads. Such observation can be easily made in Figure 6. The main reason of improvement in result is due to the fact that at higher traffic load, the more channels are available and resolve a “hot spot” cell.

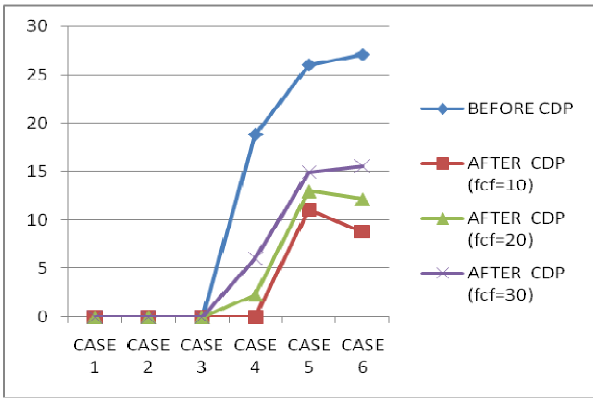


**Figure 6:** Performance Comparison.

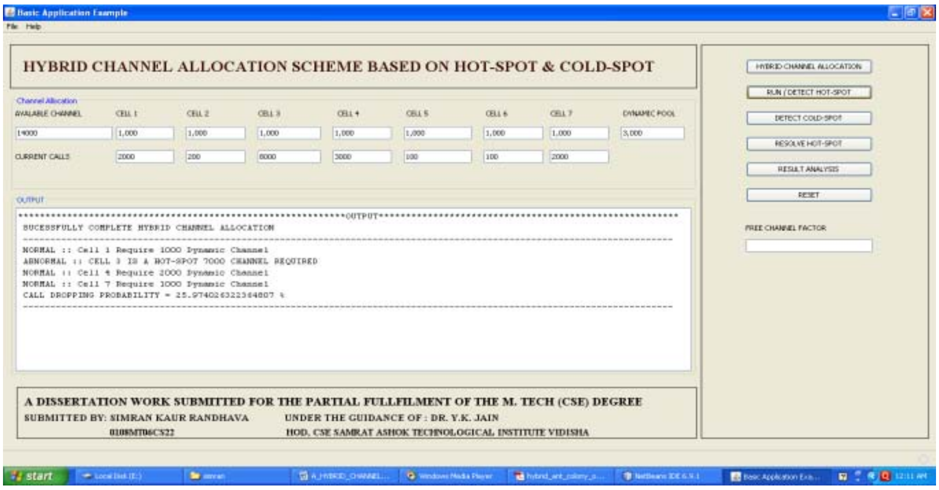


**Figure 7:** Snapshot 1

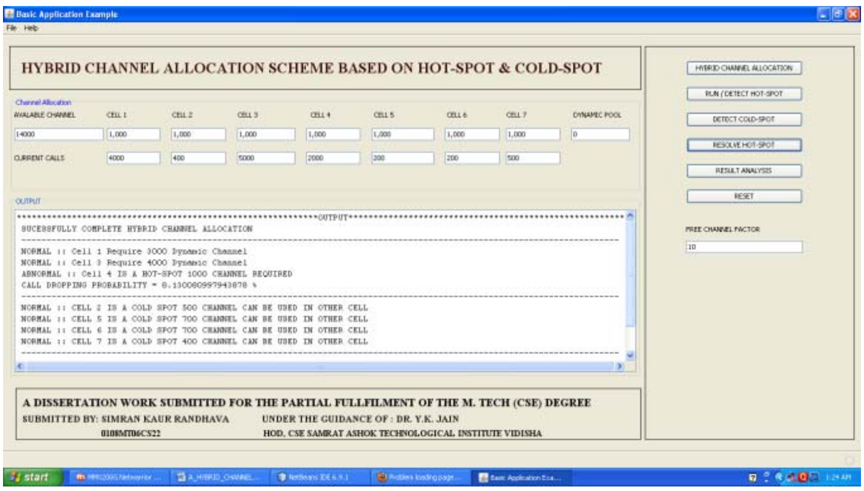


**Figure 8:** Snapshot 2.

**Table 1:** Case Table.

| CASE | SCENARIO | LOAD | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Cell 1 | Cell 2 | Cell 3 | Cell 4 | Cell 5 | Cell 6 | Cell 7 |
| CASE 1 | NORMAL | 100 | 200 | 300 | 400 | 500 | 600 | 700 |
| CASE 2 | NORMAL WITH DYNAMIC CHANNEL | 1500 | 2000 | 500 | 600 | 700 | 800 | 900 |
| CASE 3 | NORMAL WITH DYNAMIC CHANNEL | 3000 | 4000 | 500 | 500 | 3000 | 500 | 500 |
| CASE 4 | HOT SPOT RESOLVE COMPLETELY | 1500 | 500 | 10000 | 500 | 100 | 200 | 500 |
| CASE 5 | HOT SPOT NOT RESOLVE COMPLETELY | 2000 | 200 | 8000 | 3000 | 100 | 100 | 2000 |
| CASE 6 | HOT SPOT NOT RESOLVE COMPLETELY | 500 | 3000 | 500 | 10000 | 500 | 100 | 200 |

**Table 2:** Performance Results

| CASE | BEFORE | AFTER | | |
|---|---|---|---|---|
| | CDP* | CDP (fcf=10) | CDP (fcf=20) | CDP (fcf=30) |
| CASE 1 | 0 | 0 | 0 | 0 |
| CASE 2 | 0 | 0 | 0 | 0 |
| CASE 3 | 0 | 0 | 0 | 0 |
| CASE 4 | 18.79 | 0 | 2.25 | 6.01 |
| CASE 5 | 25.97 | 11.03 | 12.98 | 14.93 |
| CASE 6 | 27.02 | 8.78 | 12.16 | 15.54 |

*CDP – Call Dropping Probability
Fcf – Free channel factor

## Conclusion

This paper presents a novice hybrid channel allocation algorithm that provides efficient use of the fixed and dynamic channels. Many times a cell becomes a Hot-spot (i.e. unexpected very high traffic that can't be overcome with fixed channels of that cell and the dynamic channel present in the central pool). In this case calls are dropped due to unavailability of the channel while so many channels are free in the neighbor cells which are right now a cold-spot (i.e. very low traffic). Proposed scheme is based on the reuse of these free fixed channels of cold spot in the neighbor hot spot. When a call using such a "borrowed" channel terminates, the cell may retain the channel depending upon its current hot-spot level. The performance study of the proposed scheme indicates that the efficiency is improved in terms of reducing call drop rate.

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