Analysis and Optimization of Channel Allocation Strategies in Cellular Network

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Abstract- **In a cellular communication network the service area is divided into hexagonal cells and each cell is under the control of a given base station. The channel assignment problem is that given a set of cells and each with a demand of a given number of channels these have to assign frequencies for each channel so as to minimize the total radio frequency bandwidth of the system. Subject to the given interference restrictions such as co-channel and co-site, adjacent-channel and hand-off constraints. This paper mainly discuss with analysis of channel assignment strategies, study of optimization strategies and design of an efficient allocation strategy based on hyper-heuristic methodology. The simulations are carried out to exploit a mobility model that provides different degrees of offered traffic. Results show that the proposed method can achieve promising results. And it emerges that the hyper-heuristic methodology coupled with the Deviation Method (DM) acceptance criteria yields a practical way to attain near optimal performance when compared with the benchmark instances, leading a pathway to enhance the capacity.**
Keywords component ;(co-channel and co-site, adjacent-channel, Deviation Method (DM))

1. INTRODUCTION

Since the radio spectrum is a scarce resource in wireless networks, the channel assignment problem is becoming more and more crucial as the demand for mobile communication services is growing significantly. The aim of channel assignment is to devise a scheme for assigning channels to cells in the system so as to eliminate channel interference, as well as to minimize the total radio bandwidth requirement of the system " Ref [2]''

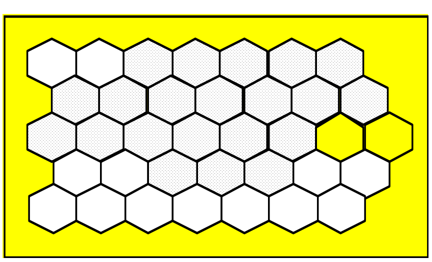


Fig. 1: Typical hexagonal cellular structure

The geographical area covered by a base station (BS) is a cell, which can be represented as a hexagonal network

As shown in Fig 1 "Ref [3]'' A communication network consists of thousand of Cells, each with a BS at the centre with dedicated radio channel and the number of the channels assigned will be based on the traffic requirement for the particular cell. Besides the traffic demand requirement, the assignment of channels is subject to the four types of interference constraints:

Co-channel constraint: The same channel cannot be allocated to certain pairs of radio cells simultaneously.

Adjacent channel constraint: The same adjacent channel cannot be allocated to adjacent cells simultaneously.

Co-site constraint: A minimum channel separation distance must separate any pair of channels assigned in the same cell.

Hand-over separation constraint: As the mobile unit moves from a cell u to an adjacent one v, control must be switched from u to v (hand-over or hand-off), which in turn requires that the broadcasting frequencies used by u and v to serve the mobile, differ by at least some units.

A lot of research has been already done on optimal assignment of channels and it is reported in the literature. In this work the proposed model based on Hyper-heuristic model described in Edmund Burke and Emma Hart "Ref [8]'' and develop an efficient assignment strategy for multi-channel demand.

This piece of research work address the following issues,

Study of channel assignment problem in cellular networks.

Analyze the various factors contributing to CAP such as scarce bandwidth, interference of signals and constraints such as co-channel, co-site, adjacent-channel & hand-off constraints and reviewing the existing solutions for the CAP and state benchmark instances. Developing a mathematical model for the problem. Propose an efficient method using hyper-heuristic methodology. Comparing the results of proposed algorithm with the benchmark instances.

I. MATHEMATICAL MODEL

Frequency bandwidths are allocated to cellular service providers with a range of bandwidth [b_{min},b_{max}]. The bandwidth is partitioned into a set of channels, F (or often called frequencies) and can be represented as positive integers 1, 2, 3, ...,f_{max} where f_{max} is a maximum channel number. A basic channel assignment problem for radio network planning is consists of "Ref [5] and [6]''

N: The number of cells in the network.

D: Demand vector, D = (d_1, d_2, d_N) where d_i : the number of radio channel required in cell i in order to satisfy channel demand.

C: Compatibility matrix, $C=(c_{ij})_{NxN}$ denotes frequency separation required between cell i and cell j.

$Call_{ik}$: Cell i with call k where $1\leq i \leq N$, $1\leq k \leq d_i$.

$f_{ik: A}$ radio channel is assigned to $Call_{ik}$, where f_{ik} Є F.

Frequency separation constraint - | f_{ik} . f_{jm} | ≥ $c_{ij,}$ for all i,j,k,m (i ≠ j ,k ≠ m), c_{ij} is defined in Compatibility Matrix, C. If i=j, it becomes co-site constraint.

Therefore, the channel assignment problem (CAP) is a task to find the minimum bandwidth (span) required by the system i.e.:

Given N, D, C,

Span, f(s)=($f_{ik\ max}$.$f_{ik\ min}$) is minimized.

Where $f_{ik\ max}$ = maximum channel used

$f_{ik\ min}$ = minimum channel used

The goal is to assign frequencies to every call in each cell, satisfying the frequency separation constraints, in such a way that the required system bandwidth becomes minimal.

II. HYPER-HEURISTIC FRAMEWORK

A diagram of a general hyper-heuristic framework is shown in Fig 2. The figure shows that there is a barrier between the low level heuristics and the hyper-heuristic.

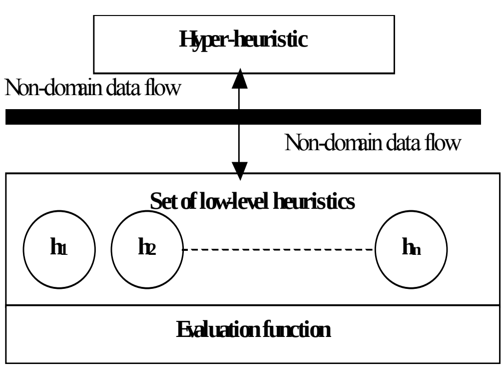


Fig. 2: A Hyper-heuristic Framework

Domain knowledge is not allowed to cross this barrier. Therefore, the hyper-heuristic has no knowledge of the domain under which it is operating.

It only knows it has *n* low level heuristics on which to call and it knows it will be passed the results of a given solution once it has been evaluated by the evaluation function.

Hyper-heuristic framework is used to solve the channel assignment problem. The reasons for using a hyper-heuristics framework for channel assignment problem are:

It is easy for the solution designer to consider the problem by modeling it using simple heuristics.

Simple heuristics are typically faster to implement compared to some other approaches such as graph theory method or genetic algorithm based methods.

It is robust enough to handle a wide range of problem instances by small modifications or additions.

The quality of the solution and (Value of Span f(s)) and computation time of each heuristic to be allowed to cross the barrier. The hyper-heuristic has no knowledge of the problem it is trying to solve, only that it has a set of LLHs, which it can call, and whether it is trying to minimize or maximize the evaluation function. The set of LLHs act as simple local search or other problem specific neighborhood structure and each move by the LLHs will produce a new solution. The hyper-heuristic will make a decision whether to accept or reject the new solution. It will also decide which LLH to call at every step.

Using hyper-heuristic framework the defined algorithm for solution of CAP as follows:

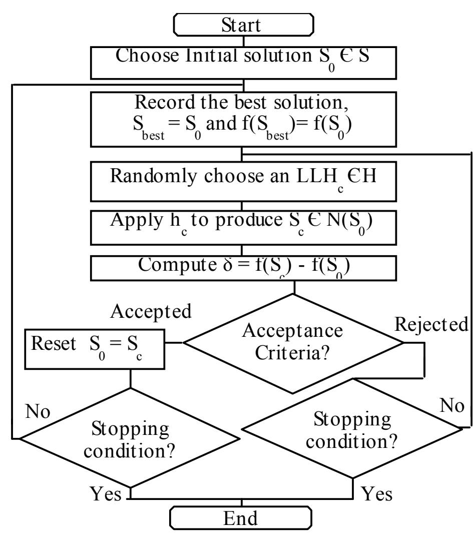


Fig. 3: Flow diagram of CAP solution using Hyper-heuristic framework

III. DESCRIPTION OF LOW LEVEL HEURISTICS

LLH_1: Sort the channel from lowest to highest, delete the call with the most frequently used channel assignment, randomly insert at any point and reassign the channels.

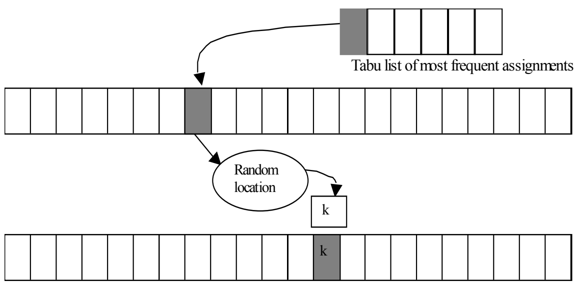


Fig. 4: Description of heuristic LLH_1

***LLH₂*:** Sort the channel from lowest to highest, delete the call with the most recently used channel assignment, randomly insert at any point and reassign the channels.

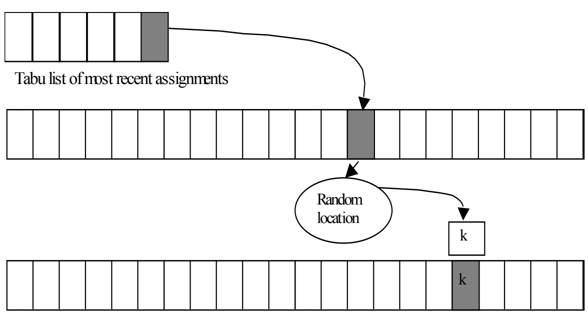


Fig. 5: Description of heuristic LLH_2

***LLH₃*:** Sort the channel from lowest to highest, delete the call with the least frequently used channel assignment, randomly insert at any point and reassign the channels.

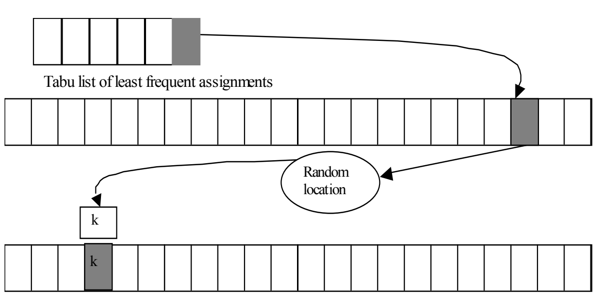


Fig.6: Description of heuristic LLH_3

***LLH₄*:** Sort the channel from lowest to highest, randomly select call to delete, randomly insert at any point and reassign the choose best point to insert and reassign the channels.

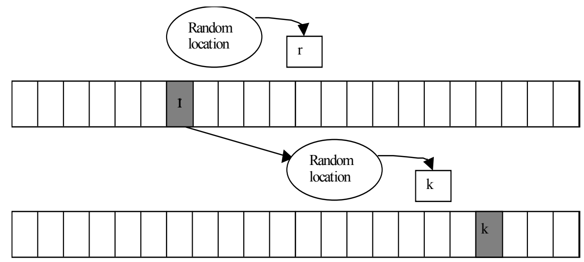


Fig. 7: Description of heuristic LLH_4

***LLH₅*:** Sort the channel from lowest to highest, delete the call with the highest channel assignment, choose the best point to insert and insert at that location. Later reassign the channels.

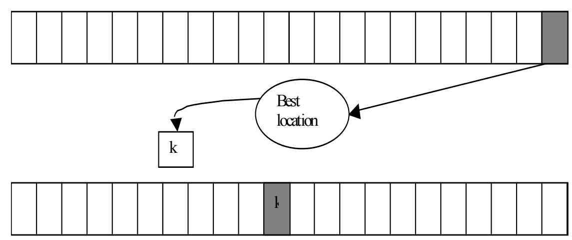


Fig. 8: Description of heuristic LLH_5

***LLH₆*:** Sort the channel from lowest to highest, delete the call with the highest channel assignment, randomly insert at any point and randomly change the call order from insertion point and reassign the channels.

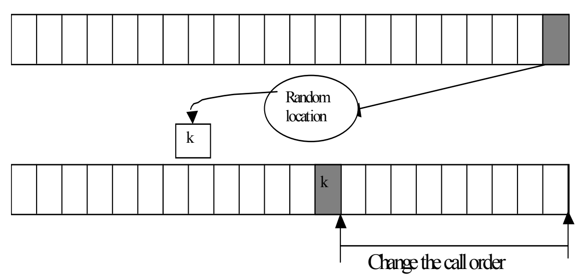


Fig.9: Description of heuristic LLH_6

IV. IMPLEMENTATION

Used object-oriented methodology to implement heuristic design for channel assignment problem. Fig 14 illustrates the functional blocks of the software implementation of hyper-heuristic design.

Control: This class implements Monte Carlo framework of the design.

Problem Definition; Interface to read problem parameters and initialize the data structures. Used two interfaces to read the parameters i) Command line arguments and ii) file based.

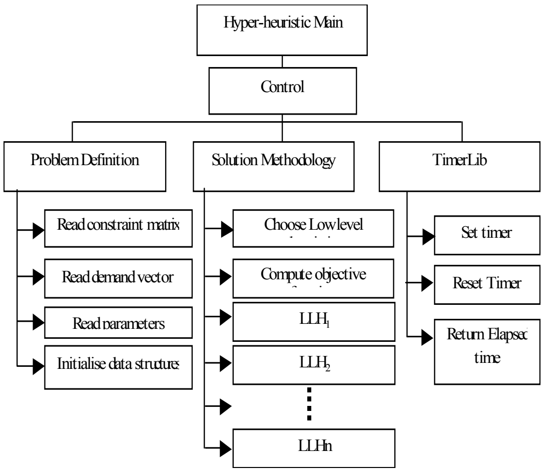


Fig.10: Functional blocks of the hyper-heuristic design

Solution Methodology: Contains interfaces to compute objective function, random move choice function, which is used to decide upon various moves to be called at every step. Also contains the implementation of six low level heuristics.

Util: Provides implementation of basic data structures such as linked list, hash table etc. Also have specialized interfaces to sort the lists, arrange lists in random fashion and reshuffle given lists.

Timer Lib: Provides timer functionality.

V. BENCH MARKS FOR PERFORMANCE

The channel assignment benchmark instances, used in previous works are compared here Chakraborty "Ref [3]'' Sivarajan "Ref [5]'' and Wang & Rush forth "Ref [6]'' to compare the results of our proposed framework. Table 1 illustrates demand vectors for various cluster sizes (21, 25 and 55 cell clusters) and Table 2 illustrates the interference constraint specifications, which includes co-channel, co-site, and adjacent channel constraints.

TABLE 1. TRAFFIC DEMAND VECTORS FOR BENCHMARK INSTANCES

Size	Traffic Demand
21	***D1_21:*** {8 25 8 8 8 15 18 52 77 28 13 15 31 15 36 57 28 8 10 13 8} ***D2_21:*** {5 5 5 8 12 25 30 25 30 40 40 45 20 30 25 15 15 30 20 20 25}
25	***D3_25 :*** {10 11 9 5 9 4 5 7 4 8 8 9 10 7 7 6 4 5 5 7 6 4 5 7 5} ***D4_25: {***5 5 5 8 12 25 30 25 30 40 40 45 20 30 25 15 15 30 20 20 25 8 5 5 5}
55	***D5_55 :*** {5 5 5 8 12 25 30 25 30 40 40 45 20 30 25 15 15 30 20 20 25 8 5 5 5 5 5 5 8 12 25 30 25 30 40 40 45 20 30 20 15 15 30 20 20 25 8 5 5 5 25 8 5 5 5} ***D6_55 :*** {10 11 9 5 9 4 5 7 4 8 8 9 10 7 7 6 4 5 5 7 6 4 5 7 5 10 11 9 5 9 4 5 7 4 8 8 9 10 7 7 6 4 5 5 7 6 4 5 7 5 6 4 5 7 5}

TABLE 2. COMPATIBILITY MATRIX FOR BENCHMARK INSTANCE

No	Cluster Size (N)	Distance cell i & j	C_{ii} entry	C_{ii}	C_{ij} Name
1	21	1 2 >2	2 1 0	6	*C4_21*
2	21	1 2 >2	2 1 0	5	*C6_21*
3	21	1 2 >2	1 1 0	4	*C7_21*
4	21	1 2 >2	2 1 0	4	*C8_21*
5	25	1 2 >2	1 1 0	2	*C1_25*
6	55	1 2 >2	1 1 0	7	*C1_55*

VI. RESULTS

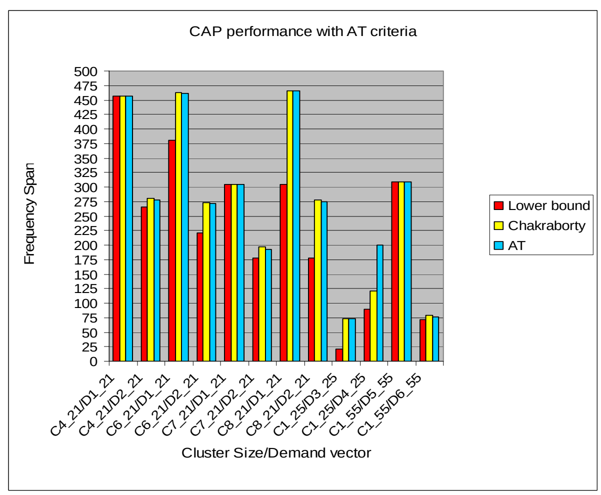
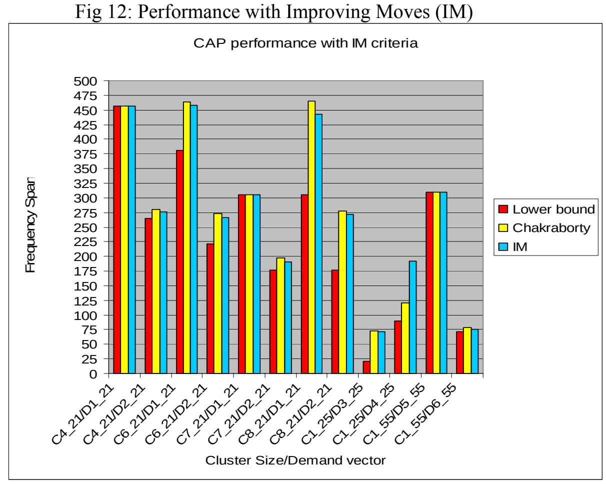


Fig 11: Performance with Always True (AT)

Fig 12: Performance with Improving Moves (IM)



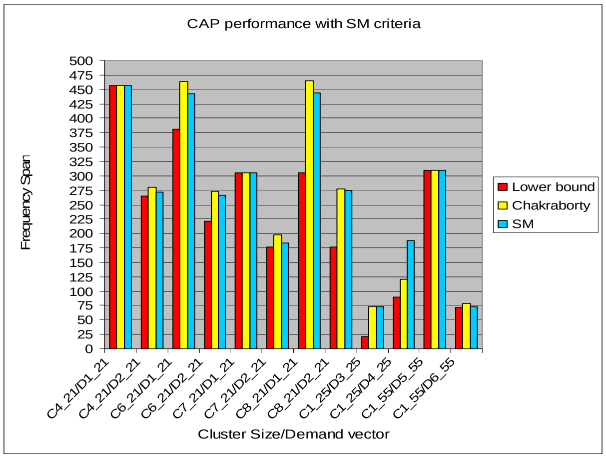


Fig 13: Performance with Step Method (SM)

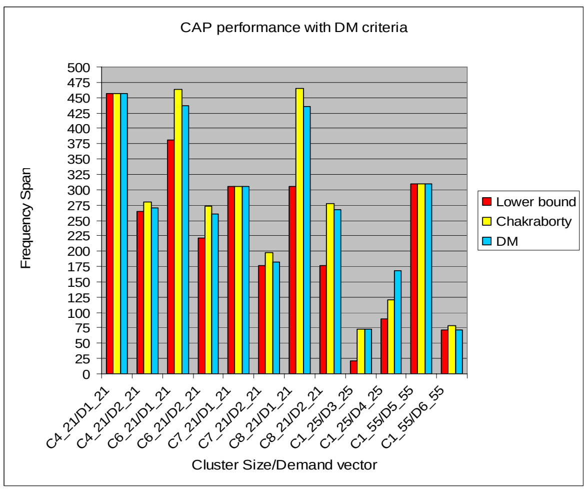


Fig 14: Performance with Deviation Method (DM)

When compared the results, the performance of the Deviation Method (DM) hyper-heuristic is superior compared to the other approaches. This suggests that by controlling the margin of the acceptance solution quality, it will lead to better results. In DM, if the solution quality is worse, compared to the incumbent solution, but if solution lies within the margin limit, it will become a new configuration for the next iteration.
That each channel is ordered -- the first channel has highest priority of being locally used and the last channel has highest priority of being borrowed.

Also each low level heuristics (LLH) develops “favorite” channels from past experience. Adapts faster to traffic changes, but needs more time to search for the highest priority channel.

In this algorithm it is introduced one more control parameter called as ‘Stimulations with no improvement’. As continuously applying a single LLH can lead to state becoming tripped in a local optima. One diversification strategy is to change the neighborhood structure, i.e. by calling different LLHs, similar to idea of Variable Neighborhood Search (VNS). However, VNS keeps applying a single heuristic, until it gets trapped in local optima; hyper-heuristics have a ‘free’ choice at each decision point as to which heuristic to call.

VII. CONCLUSION

It is noticed the significant improvement is achieved by using different strategies to generate initial solutions and study the effect of using good initial solution. In the current setup we use randomly generated solutions using a different neighborhood generating strategy such re-insert the call based on random selection.

Our future work will refine our algorithm in order to further improve the results and analyze the performance of perturbation minimizing frequency assignment problem where in there are short-term demand changes at each cell that increases the number of low-level heuristics from present number of six heuristics sequence and acceptance criteria to enhance the solution.

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