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Adapted and Some New Strategies for Frequency Assignment Problem in Cellular System

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***Abstract* — The Frequency Assignment Problem is assignment of frequencies or channels to establish link between base station and mobile transmitter in cellular system. To avoid interference, minimum separation between assigned frequencies is required. This problem is NP-hard. Due to limited availability of spectrum and reuse of same frequencies at different geographical locations, an excellent assignment is to be done, which must satisfy electromagnetic constraints with respect to demand in each cell. This paper presents new strategies for frequency assignment in cellular radio networks. The objective is to assign the frequency satisfying electromagnetic constraints for given demand with minimum use of frequency bandwidth. The proposed strategies are implemented on benchmark test problems. In frequency assignment, call ordering is done with help of computational intelligent techniques and assignment part is done with FEA strategy. To speed up the assignment process to find good assignments, we proposed modified strategies. The performance of the proposed strategies compared with Frequency Exhaustive Assignment (FEA). The results obtained are very optimistic and encouraging.**

***Keywords* — Frequency Exhaustive Assignment, Combinatorial Optimization, Frequency Assignment Problem Optimization.**

I. Introduction

Over the past years, due to tremendous increase in number of users and their demand for both voice and data services, more and more discrete channels are required to cope with situation. On other hand, available electromagnetic spectrum is limited, the cost of which may be very high. The main problem of planning and operating a mobile communication system is the selection of compatible frequencies to be reused for different channels. The channel plan should utilize the all available frequencies with minimum interference due to co-channel and adjacent channel operation. Various other nets are already present in that area, so the new assignments must be compatible not only with each other but with the old ones as well. The numbers of channels are required to fulfill the demand with minimum span of frequencies. It can be obtained by good assignment. The objective of the work is to utilize minimum span using this computational technique for excellent assignment of channels [10]. There are some good approaches are described in the literature [1], [3], [4], [5]. Previous strategies available in literature [6], [7], [8], [9] are implemented independently to any call order generated and repeated thousands of time to find optimal assignment. This process may not certainly give optimal results because it is totally depends upon the chance. In this paper all possible new change in existing strategies and some new approaches are also presented. This paper is a step forward in this direction. The remainder of the paper is organized as follows: Section II gives a brief description of strategies while Section III outlines the proposed algorithm steps of proposed. Section IV outlines strategies implementation of new and modified strategies for solving MSFAP benchmark problems. In section V, the computational experiments undertaken and the results and comparison with other conventional strategies are presented. Finally, the conclusions and future directions are outlined in Section VI.

II. Description of Proposed Strategies

The following new and modified strategies are proposed for FAP:

Some proposed strategies applied on call ordering as follows:

A. Modified swap strategy for call order:

Swap strategy is cited in [10], it is further modified.

Steps of fixed start Frequency assignment strategy combined the FEA strategy**:**

Call list (CL1) prepared by meta-heuristics or computational intelligent technique used.
Loop (CL)
Loop (L1) over all call numbers CL1 of call list co
Loop (L2) over all z frequencies (sorted in increasing order)
Assign the current frequency to call number coli and quit Loop (L2), if this assignment does not lead to interferences
End (L2)
End (L1)
Find minimum numbers of the frequencies (F1) are required to satisfy given constraints for current call list
Swap the call order out comes as new call list (CL_i)
Loop (L1) over all call numbers CL_i of call list co
Loop (L2) over all z frequencies (sorted in increasing order)
Assign the current frequency to call number coli and quit Loop (L2), if this assignment does not lead to interferences
End (L2)
End (L1)
Find minimum numbers of the frequencies (F_i) are required to satisfy given constraints for current call list
If F_i is greater than F1, then retain call list CL1, otherwise CL_i
End (CL)

B. Random Selection strategy for call order:

Swap is further modified as follows:

Swap is continuously changed in place of call as stated in (A). In random start instead of continue, two random selected calls from call list are to be replaced with each other. Then prepare F_i and retain Cl*i* for final assignment.

C. Flip strategy for call order:

Flip the call list. Then prepares F_i and retain Cl_i for final assignment.

Some proposed strategies applied on Final assignment as follows:

New Flip Strategy:

The final assignment is to be flipped. Rearrangement strategies are already proposed in literature. The starting row for flip is very important. The following two flips are proposed.

(a) Clock-Wise Flip:

The starting row for flip is selected, and then flips the assignments in step clockwise. Then prepare F_i and retain Cl_i for final assignment.

(b) Anti Clock-Wise Flip:

The starting row for flip is selected, and then flips the assignments in step clockwise. Then prepare F_i and retain Cl_i for final assignment.

III. Algorithm Steps of Proposed Strategies

Based on the strategies proposed in previous section, the generalized steps of algorithm for the channel-assignment problem as follows:

/**find* prey order **co** *with* $S_{min.}$ */

for*; */* loop terminated completing all iteration or optimum assignment obtained*/

/*prepare result as **co** and starting FEA technique to find ***F***A and $S_{min.}$*/

FA: =Actual frequency assignment to call list (xo)

f_{min}= $C_{\max}$ * ($D_{\max}$-1) +1;

f_{max}: =assign frequency to call list (xo)

for

x_i: = select first element of call order co(i)

cn: =cell number= co (i)

F_1:=first frequency assigned to x1

FA_{1cn}=1

/* next step to assign frequency to next call x_j in call order

f_k: =another frequency assigned to x_j

f_k=$\boldsymbol{F}A_{1cn}$ +C_{ij};

end

/*check possibility of assignment and find compatible available frequency*/

/*repeat same step until call order and all assignment completed*/

/* changes co using selected strategy*/

swap (co)/Randomly change co/

Flip (clockwise or anticlockwise)

/* repeat all steps of FEA strategy for complete assignment*/

if S_{min} =optimum value

FA and $S_{min.}$

IV. The Implementation of Strategies for Solving MS-FAP Benchmark Problems

Problem description of MS-FAP:

Given:

N: the number of cells

d_i, 1≤ i ≤ N: the number of requested calls (demands) in cell i

C_{ij}, 1 ≤ i, j≤ N : the frequency separation required between a call in cell i and j

Find: f_{ik}, 1≤ i ≤ N, 1≤ k ≤ d_i : the frequency assigned to the call in cell j such that subject to the separation constraints, $\left|f_{ik} - f_{jl}\right| \geq C_{ij}$, for all i, j, k, l except for i = j and k = l, Minimize Max f_{ik} for all i, k

As shown above in four steps, the FEA strategy [6], [7] assign calls, in the order they appear, to the minimum available frequencies, while satisfying the constraints. Starting from the top of the call order list, assign the least possible frequency to each call, consistent among previous assignments without violating the separation constraints.

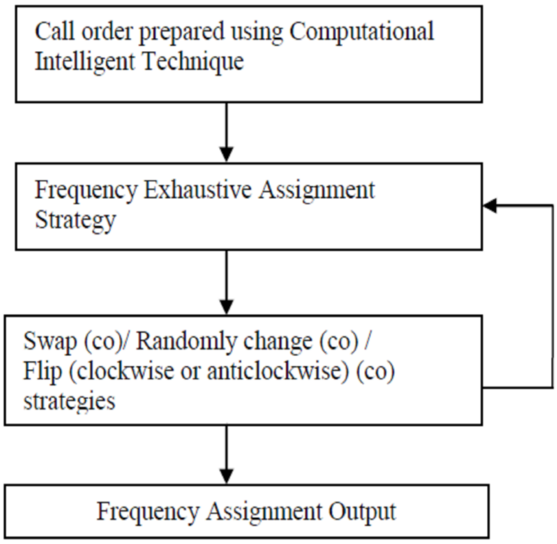

Fig.1. Flow Chart for complete assignment

As shown above in Figure 1, the FEA strategy assign calls, in the order they appear, to the minimum available frequencies, while satisfying the constraints. Initially, starting at top of the call order list, assign to each call the least possible frequency, consistent with previous assignments without violating the separation constraints. It if further extended by using proposed strategies, preparing new call list, then again applying FEA strategy. If new assignment gives better results, then replace the previous call order with the call order, which provides the better results. This process will continue till optimal/optimum result obtained or terminating condition like number of iteration competed as decided.

To implement above steps, the most difficult benchmark FAP problem, the Philadelphia FAP is most studied and difficult FAP benchmark problems originally presented by Anderson in 1973 [2] and used by most of the researchers to illustrate their results. These most frequently researched benchmark FAP problems are based on the area around Philadelphia. Therefore, the proposed algorithm has also been implemented on these problems and analyzed minutely to verify the performance of the algorithm.

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The Philadelphia FAP problem consists of cells located in a hexagonal grid as shown in Figure 2 as geometrical structure; network graph is presented in Figure 3.The details of difficult instances, demand vector and compatibility separation matrix are tabulated in Table I, II and III respectively.

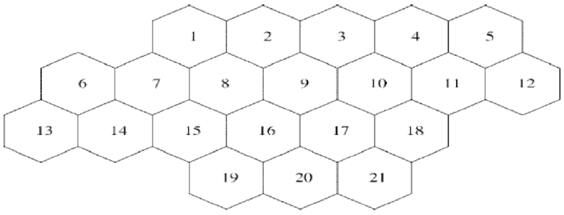

Fig.2. The geometrical structure of 21-cell system

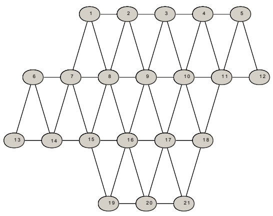

Fig.3. The Network graph of 21-cell system

Table I: Details of the most difficult Instances

Instance	No. of cell	ACC	CCC	CSC	Demand	
PHIL02	21	2	1	5	D_2	481
PHIL06	21	2	1	5	D_2	470

Table II: Demand Vectors *D1* And *D2* for Philadelphia Benchmark Problems

	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}
D_1	8	25	8	8	8	15	18	52	77	28
D_2	5	5	5	8	12	25	30	25	30	40

	d_{11}	d_{12}	d_{13}	d_{14}	d_{15}	d_{16}	d_{17}	d_{18}	d_{19}	d_{20}	d_{21}
D_1	13	15	31	15	36	57	28	8	10	13	8
D_2	40	45	20	30	25	15	15	30	20	20	25

The compatibility seperation matrix for most difficult problems PHIL 2 and problem PHIL6 with demand vector *D1* and *D2* repectively is given in Table VII below.

Table III: Compatibility Separation Matrix[21×21]
c_{ij} : CSC =5,ACC=2,CCC=1

5	2	1	0	0	1	2	2	1	0	0	0	0	1	1	1	0	0	0	0	0
2	5	2	1	0	0	1	2	2	1	0	0	0	0	1	1	1	0	0	0	0
1	2	5	2	1	0	0	1	2	2	1	0	0	0	0	1	1	1	0	0	0
0	1	2	5	2	0	0	0	1	2	2	1	0	0	0	0	1	1	0	0	0
0	0	1	2	5	0	0	0	0	1	2	2	0	0	0	0	0	1	0	0	0
1	0	0	0	0	5	2	1	0	0	0	0	2	2	1	0	0	0	0	0	0
2	1	0	0	0	2	5	2	1	0	0	0	1	2	2	1	0	0	1	0	0
2	2	1	0	0	1	2	5	2	1	0	0	0	1	2	2	1	0	1	1	0
1	2	2	1	0	0	1	2	5	2	1	0	0	0	1	2	2	1	1	1	1
0	1	2	2	1	0	0	1	2	5	2	1	0	0	0	1	2	2	0	1	1
0	0	1	2	2	0	0	0	1	2	5	2	0	0	0	0	1	2	0	0	1
0	0	0	1	2	0	0	0	0	1	2	5	0	0	0	0	0	1	0	0	0
0	0	0	0	0	2	1	0	0	0	0	0	5	2	1	0	0	0	0	0	0
1	0	0	0	0	2	2	1	0	0	0	0	2	5	2	1	0	0	1	0	0
1	1	0	0	0	1	2	2	1	0	0	0	1	2	5	2	1	0	2	1	0
1	1	1	0	0	0	1	2	2	1	0	0	0	1	2	5	2	1	2	2	1
0	1	1	1	0	0	0	1	2	2	1	0	0	0	1	2	5	2	1	2	2
0	0	1	1	1	0	0	0	1	2	2	1	0	0	0	1	2	5	0	1	2
0	0	0	0	0	0	1	1	1	0	0	0	0	1	2	2	1	0	5	2	1
0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	2	2	1	2	5	2
0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	2	2	1	2	5

The evolved algorithm is implemented for assignment of frequencies or channels to establish link between base station and mobile transmitter in cellular systems. The Frequency Exhaustive Assignment (FEA) approach [6] is combined to assign frequencies for call ordering for minimum span frequency assignment problem. The proposed algorithm is used to modify call order and then assign channels deterministically to the calls to minimize the required bandwidth.

V. Computational Results & Discussions

As the results are tabulated in Table IV, it is concluded that for the same call order, FEA strategy gives the optimal solution value 259 for problem PHIL02,this result is improved by using proposed strategies that gives 257,255,254,254 by FEA-SWAP, FEA-RANDOM, FEA-FLIP(CW) and FEA-FLIP(ACW) respectively.

For PHIL06 problem ,the same call order, FEA strategy gives the optimal solution value 432,this result is improved by using proposed strategies that gives 428,427427(optimum value) with 100% convergence, 428, 428 by FEA-SWAP, FEA-RANDOM, FEA-FLIP(CW) and FEA-FLIP(ACW) respectively.

So, the proposed strategies have proved its ability to improve the solution obtained and its further usefulness.

It has been implemented on PC employing Intel Core i5-560M processor with 4GB RAM and using MATLAB version 2012a software.

Table IV: Comparisons of Required Spectrum

Problem	FEA[6],[7]	FEA-SWAP	FEA-RANDOM	FEA-FLIP(CW)	FEA-FLIP(ACW)
PHIL02	259	257	255	254	254
PHIL06	432	428	427(optimum) with 100% convergence	428	428

VI. Conclusion

The proposed strategies, which are based on swap, random and flip phenomenon has been described for the MS-FAP. The most difficult problem chosen to formalize the problem takes the case of multi-interference. The computational results presented are very promising for benchmark considered. With dynamic changes in demand for same compatibility matrix, result can be obtained for dynamic assignment problem also.

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