AN AUTOMATIC FREQUENCY PLANNING OF GSM NETWORKS USING EVOLUTIONARY ALGORITHMS

Prof. T.venkateswarlu.
Dept of electronics and communication
S.V. University College Engg.
Tirupathi,india

K.Naresh [M.Tech]
Dept of electronics and communication
S.V. University College Engg
Tirupathi,india

Abstract - The last few years have seen a tremendous demand for wireless services. Service providers have to accommodate this rapid growth on their existing networks as well as make plans for new networks. Therefore, there is a need for a cell planning and frequency planning tools incorporating optimization techniques to assist RF engineers for initial as well as the future growth planning. This paper proposes an innovative approach for automatic frequency planning in both the new and an existing network. The new approach replaces the current tedious and inaccurate manual process, simplifies planning, and also reduces operational costs. In addition, this process makes use of powerful EA(evolutionary algorithms) algorithms, which can provide a near optimum solution.

Key words: AFP, evolutionary algorithms, GSM, Site selection, propagation models, link budget.

1. INTRODUCTION TO GSM

The *Global System for Mobile* communication (GSM) is an open, digital cellular technology used for transmitting mobile voice and data services. GSM is also referred to as 2G, because it represents the second generation of this technology, and it is certainly the most successful mobile communication system.

An outline of the GSM network architecture is shown in Fig. 1. As it can be seen, GSM networks are built out of many different components. The most relevant ones to frequency planning are the Base Transceiver Station (BTS) and the transceivers (TRXs). Essentially, a BTS is a set of TRXs. In GSM, one TRX is shared by up to eight users in TDMA (*Time Division Multiple Access*) mode. The main role of a TRX is to provide conversion between the digital traffic data on the network side and radio communication between the mobile terminal and the GSM network. The site at which a BTS is installed is usually organized in sectors: one to three sectors are typical. Each sector defines a cell. Conventionally, RF engineers have to spend a considerable amount of time to plan and configure a network. Also, this exercise has to be done constantly to keep up with the increase in traffic demand and envisaged system growth. This process, performed manually, is usually based on prior experience and intuition and has to go through several iterations before achieving satisfactory performance. At the same time, this approach does not necessarily guarantee an optimum solution, since, even if a large number of potential cell sites exist in a region, only a small number of them can be considered due to the complexity and the time involved.

In GSM, a network operator has usually a small number of frequencies available to satisfy the demand of several thousand TRXs. A reuse of these frequencies is therefore unavoidable. Consequently, the automatic generation of frequency plans in real GSM networks is a very important task for present GSM operators not only in the initial deployment of the system, but also in subsequent expansions/modifications of the network, solving unpredicted interference reports, and/or handling anticipate scenarios (e.g. an expected increase in the traffic demand in some areas).

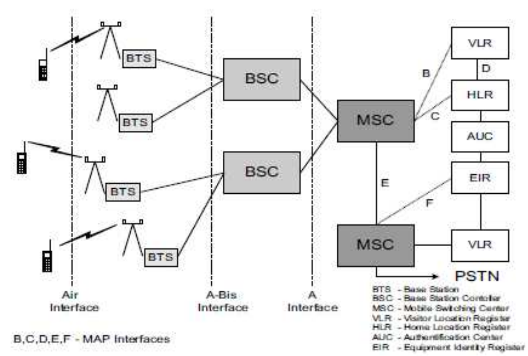

Fig .1. Outline of GSM network architecture

In GSM, significant interference may occur if the same or adjacent channels are used in neighboring cells. Correspondingly, they are named co-channel and adjacent channel interference. Many different constraints are defined to avoid strong interference in the GSM network. These constraints are based on how close the channels assigned to a pair of TRXs may be. These are called separation constraints, and they seek to ensure the proper transmission and reception at each TRX and/or that the call handover between cells is supported. Several sources of constraint separation exist: co-site separation, when two or more TRXs are installed in the same site, or co-cell separation, when two TRXs serve the same cell (i.e., they are installed in the same sector). This is intentionally an informal description of the AFP problem in GSM networks. It is out the scope of this work to propose a precise model of the problem, since we use proprietary software which is aware of all these concepts, as well as the consideration of all the existing interference reduction techniques developed for efficiently using the scarce frequency spectrum available in GSM.

Initially, when the demand for wireless services was low, the manual planning approach could be employed with reasonable amount of confidence. However, the explosive growth in traffic has led to a need for an increase in the density of cell sites which leads to increase in clusters. This in turn has resulted in greater network complexity, making it extremely difficult to manually plan cell sites and adding frequency's to them for optimum performance. In an extremely competitive industry as we see today, this cuts into the competitiveness of service providers and equipment manufacturers. Therefore, the manual planning methods are being replaced by automatic cell and frequency planning techniques. The automatic frequency planning tools take advantage of powerful optimization algorithms that enable to arrive at a near-optimum solution through the evaluation of a large number of potential cell sites and adapting frequency's to them in a relatively short time. Therefore, now, the optimum subset that maximizes capacity and coverage and at the same time minimizes cost can be chosen automatically.

Optimization of initial frequency planning was considered in [2] for a GSM network where it was shown to automatically find the optimal frequency's from given data such as traffic map information, radio propagation models, radio equipment and preferred potential sites. In this paper, we propose a methodology for automatic frequency planning. The new process results in a significant reduction of operational costs, and at the same time, also enables the allocation of network resources more effectively.

The paper is organized as follows. In section 2, we describe the system model and provide a brief outline of the automatic frequency planning process for a new network [5]. Section 3 covers AFP problem and the algorithm used in the frequency planning process of a network. An experimental validation and advantages of AFP are reported in section 4 and finally section 5 concludes the paper.

2 . DESCRIPTION OF THE MODEL

In the initial planning of a network, the cell site locations are optimized to provide adequate coverage for a given traffic distribution. The first step is the discretization of the user traffic information into a bin-level traffic map with an appropriate resolution. This map is then converted to demand nodes as shown in Figure 2 with a traffic weight information and clutter information associated with it. The weight information is related to the number of subscribers (Erlangs) and the clutter information that of the land usage (urban, suburban, rural etc.) in the area of interest. The next step is the creation of a set of potential cell sites. This list may include the set of preferred locations (if any) along with several other potential locations. where automatic cell planning will give best results in finding locations for sites.

The third step is the computation of radio coverage for each potential cell site location. Radio coverage computations are made using transmit power requirements given by link budgets, site-specific propagation models, and the possible types, heights and orientations of the antennas considered. The automatic process can quickly evaluate a large number of possible options. The final step is then assigning best possible frequencies to each cell site. This is achieved by the use of powerful optimization algorithms like EA(evolutionary algorithms) where the set with the largest "weighted traffic coverage to cost ratio" is selected in each iteration, to arrive at the final solution. The "cost" here refers to the actual cost of deploying a new cell site. The covered demand nodes with desired C/I ratio are deducted from the traffic map at each iteration, and the process continues till the required percentage of nodes is covered with low interference.

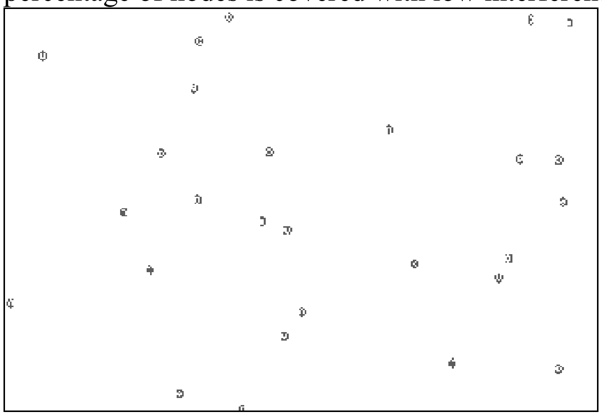

Figure 2 . Demand Nodes

3. THE AUTOMATIC FREQUENCY PLANNING PROBLEM

The frequency planning is the last step in the layout of a GSM network. Prior to tackling this problem, the network designer has to address some other issues: where to install the BTSs or how to set configuration parameters of the antennas (tilt, azimuth, etc.). Once the sites for the BTSs are per sector has to be fixed. This number depends on the traffic demand which the corresponding sector has to support. The result of this process is a quantity of TRXs per cell. A channel has to be allocated to every TRX and this is the main goal of the AFP [8]. Neither DCA nor HCA are supported in GSM, so we only consider FCA. We now explain the most important parameters to be taken into account in GSM frequency planning.

The new problem involves taking into account the existing frequency's for cell site locations and finding optimum frequency's for the cell sites so as to meet the growing traffic needs efficiently and effectively. The demand nodes and potential cell sites are created as discussed in section 2.

The first step in the growth frequency planning process is defining cost function:

3.1 COST FUNCTION

As it was stated before, we have used a proprietary application provided by Atoll.™, that allows us to estimate the performance of the tentative frequency plans generated by the evolutionary optimizer. Factors like transmitter radiation range, carrier to interference ratio(C/I), RxQual, and BER are evaluated. This commercial tool combines all aspects of network configuration (BCCHs, TCHs, etc.) including interference reduction techniques (frequency hopping, discontinuous transmission, etc.) in a unique cost function, *C*, which measures the impact of proposed frequency plans on capacity, coverage, QoS objectives, and network expenditures. This function can be roughly defined as:

$$C=\sum (\text{cost } I M (v).E(v))+\text{cost Neighbor}(v)) \qquad ---(1)$$

That is, for each sector v which is a potential victim of interference, the associated cost is composed of two terms, a signaling cost computed with the interference matrix (*CostIM* (v)) that is scaled by the traffic allocated to v, E (v), and a cost coming from the current frequency assignment in the neighbors of v. Of course, the lower the total cost the better the frequency plan, i.e., this is a minimization problem.

3.2 ALGORITHES USED IN:

This optimization technique firstly generates μ initial solutions. Next, the algorithm perturbs and evaluates these μ individuals at each iteration, from which β new ones are obtained. Then, the best μ solutions taken from the newly generated and μ individuals are moved to the next iteration. An outline of the algorithm is shown in Fig. 3

```
P = new Population(μ);
 PAux = new Population(β);
 init(P);
 evaluate(P);
 for iteration = 0 to NUMBER OF ITERATIONS do
   for i = 1 to  β do
      individual = select(P);
      perturbation = perturb(individual);
      evaluate(perturbation);
      PAux = add To(PAux,perturbation);
   end for
 P = bestIndividuals (Paux,β)
 end for
```

Fig .3. Pseudo code for EA

As stated before, the configurations used in this work employ a value of μ = 1. The seeding procedure for generating the initial solution and the perturbation operator are the core components defining the exploration capabilities of the (1,μ) EA. The definition of these two procedures is detailed below in Sections 3.2.1 and 3.2.2.

3.2.1 SOLUTION INTIALIZATION

Individuals are initialized site by site using a constructive method. For each site in the GSM network, a hopefully optimal frequency assignment is heuristically computed independently and without taking into account possible interferences from any other site. A simple greedy heuristic [5] is the method used (see Fig. 4 for its pseudo code). Given a site *s*, all its TRXs installed are randomly ranked (line3).Then, random frequencies are assigned to the TRXs so that neither co-channel nor adjacent-channel interferences are provoked (lines 5 and 6).

```
1: trxs = frequencies =null
2: trxs = TRXsFromSite(s);
3: random shuffle(trxs);
4: for t in trxs do
5: f =chooseInterferenceFreeFrequency
(t,frequencies);
6: assign(t,f);
7: frequencies = insert(frequencies,t);
8: end
```

Fig.4. Pseudo code for greedy heuristic

3.2.2 PERTURBATION OPERATOR

In (μ,β) EAs, the perturbation operator largely determines the search capabilities of the algorithm. The mechanism proposed is based on modifying the channels allocated to a number of transceivers. It first has to select the set of TRXs to be modified and, next, it chooses the new channels which will be allocated. The two proposed methods are as follows:

1. TRX Selection: At each operation, one single site is perturbed. The way of selecting the site is to choose first a TRX *t* and then the site considered is the one at which *t* is installed. Two strategies for choosing *t* have been used:

(a) Binary Tournament: It uses the same information from the simulator as the last greedy operation in the initialization method. Given two randomly chosen TRXs, this strategy returns the "hardest to deal with", i.e., the one which is preferred to be updated first. With this configuration, the perturbation mainly promotes intensification.

(b) Random: The transceiver is randomly chosen using a uniform distribution from the whole set of TRXs. This strategy enhances the diversification capabilities of the algorithm. Since β off springs have to be generated at each step of the algorithm, we have studied several configurations in which $\beta 1$ perturbations use the first strategy while $\beta 2$ use the second one, so that β1+β2 = β. This will allow us to test different diversification/intensification tradeoffs in the EA.

2. Frequency Selection: Let *s* be the site chosen in the previous step. Firstly, *s* is assigned a hopefully interference-free frequency planning with the same strategy used in the initialization method (Fig. 4).

```
trxs = TRXsFromSite(s);
applySimpleGreedyHeuristic(s);
trxs = rank(trxs);
for t in trxs do
f =chooseMinimumInterference
   Frequency(t,neighbors(s));
assign(t,f);
end for
```

Fig. 5. Pseudo code of frequency selection Strategy

We have therefore avoided the strongest intra-site interferences. The next step aims at refining this frequency plan by reducing the interferences with the neighboring sites. The strategy proceeds iterating through all the TRXs installed in *s*. Again, these TRXs are ranked in decreasing order with the accurate information coming from the simulator. Finally, for each TRX *t*, if a frequency *f*, different from the currently assigned one, allows both to keep the intra-site interference-free assignment and to reduce the

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interference from the neighbors, then *t* is assigned *f* otherwise, it does nothing. All the available frequencies for *t* are examined. A pseudo code of the method is included in Fig. 5. Note that this procedure guarantees that no interference will occur among the TRXs installed in a site. Result after applying AFP for given network as shown below fig. 6.

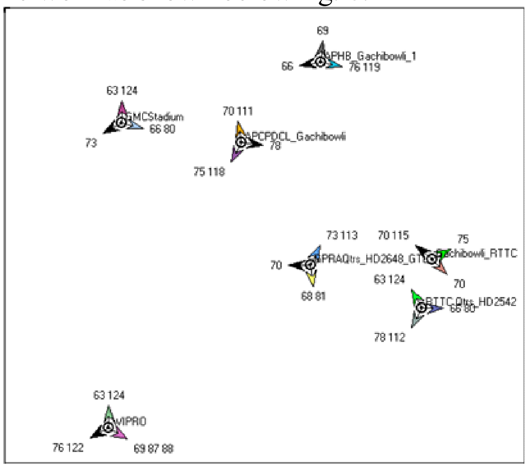

Fig. 6. Resultant frequency assignments after applying AFP

The methodology and algorithms have been tested with real traffic in several existing networks requiring future growth projection. The accuracy of the procedure, however, is dependent on the choice of the appropriate propagation model and the path loss predictions based on them. In networks where the propagation models are well tuned to the terrain, the results obtained using the automatic approach outperformed the manual process significantly, and gave very good coverage to cost ratio in the areas with increased user traffic. Also, the considerable reduction in the time involved in arriving at the solution is a tremendous improvement over the conventional long, tedious and inaccurate manual process.

However, in networks where accurate models are not available, the server associated with each demand node do's not necessarily turn out to be the best one, thereby making the sorting process ineffective. Also, as a result of the above, the wrong sites are recommended for cell-splitting. Additionally, lack of accurate propagation models results in either an overestimation or an underestimation of the coverage area. An overestimation of the coverage area results in more traffic being removed causing a coverage limited situation during deployment. On the contrary, an underestimated coverage results in less traffic being removed (i.e. more traffic being left behind), necessitating more new sites than possibly needed, resulting in coverage overlaps. Thus, in these cases, the cell site configuration and locations do not turn out to be optimal for the network under consideration. In such situations, **we** see that the automatic process does not offer any benefit. Thus we see that the optimality of the solution generated by the automatic process is strongly dependent on the accuracy of the radio coverage area computation of the existing as well as the potential cell sites.

4. RESULT

ADVANTAGES WITH AFP:

1. Less time for frequency planning even for large network with heavy amount of cell sites.

2. Capacity, QoS, quality of network improved while carrier to interference(C/I) increased by large amount when compared with manual planning.

3. In Fig. 6 highlighted zones are with low C/I i.e below 12dB.these are the regions where call drops occur in network. These regions are efficiently removed by using automatic frequency planning in network (as shown in fig. 7.)

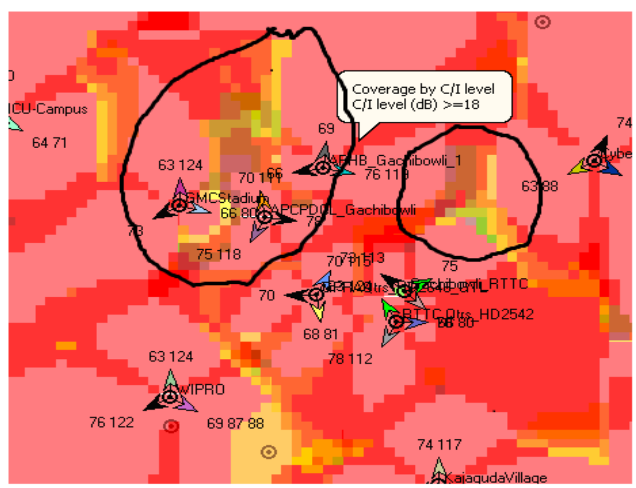

Fig. 6.Interference zones occurred in manual planning

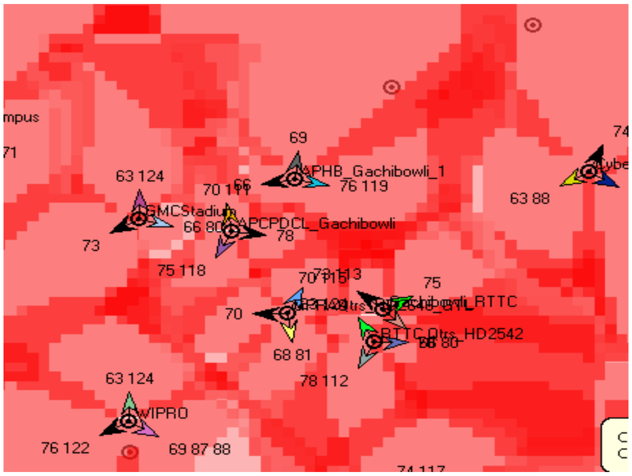

Fig.7. Removed interference zones in automatic frequency planning

5. CONCLUSIONS

An innovative process is proposed, which automatically assigns optimum frequencies for new network and also for new sites in an existing network. It has been shown that significant improvement over the current design methodology is achieved, with reduction in operational costs. Hence, the application of this process leads to an efficient and effective way for RF planning. Also, in coordination with Automatic Cell Planning algorithms, the new proposed process can function as a network advisory system that optimizes network resources efficiently.

However, we also see that the efficiency of the method is dependent on the availability of site specific models that can accurately estimate the median path loss. While the increasing traffic demand clearly justifies the use of automatic approaches for planning process, careful study of the propagation mechanism has to be attempted in order to derive the desired benefit.

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ABOUT THE AUTHOR:

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