Application of Taboo Search and Genetic Algorithms in Planning and Optimization of UMTS Radio Network

Bahareh Jalili, Mehrdad Dianati

Centre for Communication Systems Research (CCSR)
Department of Electronics and Electrical Eng., University of Surrey
Guildford, GU2 7XH, Surrey, UK

Abstract— In contrast to 2G networks, planning and optimization of 3G networks is more than just frequency allocation and coverage planning, due to the nature of WCDMA coding, and it is proved to be an NP-Hard problem. This paper demonstrates the use of two meta-heuristic methods; Taboo Search and Genetic Algorithm in planning and optimization of UMTS radio networks, and compares the efficiency and the results of these two methods.

Keywords- Planning, Optimization, UMTS, 3G Network, Taboo search, Genetic Algorithm

I. INTRODUCTION

In cellular networks, significant cost is associated with Base Station (BS) deployment and operation. By choosing optimum site locations and optimum number of sites, the costs of network setup and operation and maintenance can be reduced significantly. Compared to 2G systems, there are more parameters involved in link budget analysis and coverage planning of 3G networks. For instance, parameters such as Common Pilot Channel (CPICH) power, level of interference, traffic type and distribution, soft capacity, and cell breathing should be considered in network planning and optimisation. Typically, this results in computationally complex optimisation problems that cannot be solved by classical techniques. Thus heuristic search techniques are often applied to provide sub-optimal solutions to these problems [2,3].

Fig. 1 UMTS Planning and Optimization problem

Fig. 1 shows the UMTS planning and optimization process, which consists of two main phases of planning and optimization. There is a preparation phase before the planning, in which coverage and capacity objectives need to be defined, the network planning strategy to be selected and initial design parameters to be agreed on. Planning phase itself comprises of *dimensioning* and *detailed planning*. While Dimensioning

provides rough estimation of network layout and required resources, detailed planning deals with computation of the detailed parameters for every single site. After a network is successfully planned and deployed, there will be ongoing optimization during operation and maintenance phase.

Planning phase can be regarded as an optimization problem, as the best possible set of sites and parameters should be chosen among a predefined set of candidate site locations and network parameters. As there are many parameters involved in planning and optimization of UMTS networks, classical optimization methods can not be used. In literature this kind of problems, which can not be solved using traditional numerical, polynomial, are defined as NP-hard. Due to combined effect of the parameters involved computational time grows in a non-polynomial way with the increase of the problem sizes, therefore, meta-heuristics rather than other exact optimization methods are more suitable for this problem [4]. The sub-optimal search techniques like Taboo Search or Genetic Algorithm can be applied to this kind of problems. Extensive literature review can be found in [1-8]

In this paper, Taboo search technique, which is loosely classified as intelligent [13] is used to tackle the optimization problem in UMTS Radio Access Networks, trying to achieve sub-optimal solutions, where computational time, cost, used power and number of sites are reduced, while the number of served users is increased. In addition, a Genetic Algorithm solution is also implemented and its efficiency is compared with the Taboo search.

II. GENETIC ALGORITHM

Genetic Algorithm is a general-purpose search algorithm based on the principles of evolution observed in nature. It is a guided, random, heuristic search method which mimics the evolution and reproduction concepts as seen in nature and has its roots and even terminology in Charles Darwin's Evolution theory introduced in 1858.

The steps involved in Basic Genetic Algorithm can be broken into the following steps [14]

1. Define the objective function according to the parameters to be optimized and the problem in hand.
2. Present the possible solutions (phenotype) as binary strings (genotype or chromosome). All the

optimization parameters should be placed somewhere inside chromosome structure.

3. Generate a random population of N chromosomes. The population size N needs to be chosen properly as very large numbers lower the performance of the algorithm and small population size causes some areas of the search space to be left unexplored.

Fig. 2 Optimization model using GA and NPSW

4. Evaluate the fitness function of each chromosome in the current generation.
5. To generate the N offsprings for the next generation repeat the following steps:
 - a. Evaluate the fitness of each chromosome in the population, using the objective function.
 - b. Select a pair of individuals from the current population for mating using a random selection method (like, Roulette Wheel, Tournament, Rank selection, ...).
 - c. Based on crossover probability (P_c) and mutation probability (P_m) apply cross over and mutation operators

NPSW (Network Planning Strategies for Wideband CDMA), is a static simulator that estimates capacity and coverage probabilities given a snapshot for user distribution, by performing iterative uplink and downlink analysis until converging with predefined quality of service criteria [15]

In our implementation NPSW is used for calculating the link budget, and Genetic Algorithm is used to define different input parameters to it. The flowchart in Fig. 2 shows this interrelation.

III. TABOO SEARCH

First introduced by Fred Glover [Glover, 1986]; taboo search is a meta-heuristic algorithm, which is used in solving combinatorial optimization problems. Taboo search uses memory structure, in order to improve the performance of a local search, once a potential solution has been determined; it is marked as taboo so that the algorithm does not visit that possibility repeatedly [9].

The basic principle of the taboo search is to define a set of possible solutions, and starting from the current solution, to find a better one in its neighbourhood. A neighbourhood is a set of solutions that are found by applying an appropriate transformation of the current solution. In order for the algorithm to move away from a local minimum, the search allows moves resulting in a degradation of the objective function value, thus avoiding the trap of local optimality. To prevent the search from cycling, solutions obtained recently and moves that reverse the effect of recent moves are considered “taboo” [1].

Fig. 3 Optimization model using TS and NPSW

Taboo search has the capacity to provide solutions very close to optimality and is among the most effective, if not the best, to tackle the difficult problems at hand. These successes have made TS extremely popular among those interested in finding good solutions to the large combinatorial problems encountered in many practical settings [15].

Fig. 3 depicts the Taboo Search flowchart and its interrelation with NPSW.

IV. SYSTEM MODEL

The most important design aspect in using optimization methods are encoding the parameters and defining the objective function.

In this paper binary encoding was used, where each site's CPICH power was represented using 2 bits mapping {0, 24, 30, 33} (dBm) values. The objective function was defined as:

$$F = W1F1 + W2F2 + W3F3$$

Where $F1 = U_s / U_t$; $F2 = (P_t - P_u) / P_t$; $F3 = (S_t - S_o) / S_t$ and $W1+W2+W3 = 1$.

Here U_t is the Total number of users, U_s is the Number of served users, P_t represents Total available CPICH power from all sites, P_u is Total used CPICH power by all sites, S_t shows Total number of sites and S_o represents Total number of on sites

A. Test Scenario

The system model in this paper incorporates seven 3-sector sites, with one site located at the centre and the other six sites on a hexagonal grid, in an area of 13 Km by 13 Km. The path loss model used is Okumura-Hata (flat earth without area correction based on a map) [16] model. Fig. 4 shows the setup and initial site and user distributions.

Fig. 4 Network scenario and user distribution

V. SIMULATION RESULTS

A. Genetic Algorithm

In applying the Genetic Algorithm to this problem, many consecutive simulations were run in order to find the optimum values for the governing parameters like P_m , P_c , population size and number of iterations. Fig. 5 shows the objective value of the fittest individual and each generation's average fitness for 50 iterations.

The results of this optimization can be summarised in the table below:

TABLE 1: GA RESULTS SUMMARY

	Max Possible	First Iteration	Final Iteration
No. of users	1000	764	797
Total CPICH	639	579	507
On Sectors	21	19	17
Fitness Value	N/A	0.5738	0.6267

B. GA in practice: Effect on the network

The main objective of this optimization is to make sure that the network is utilised as efficiently as possible, by increasing the number of served users and decreasing used CPICH and number of "on" sites. During the optimization process, the fittest individuals from each iteration is stored, so that the initial bit string, intermediate ones, and the final one are accessible and the results can be visualised by giving the configuration to the simulator.

Fig. 5 Objective function values for GA

This can be used as verification that the optimization is actually improving the network conditions in practice.

As it can be seen in table 1, the number of served users has increased from 764 users in the initial setup to 797 users in the final setup.

Fig. 6 compares the interference in these two different stages. Red and brown shades indicate high levels of interference and we can see that in the initial set up sectors 1, 3, and 9 have high levels of other to own cell interference (around 90 % to 100 %), and sectors 2, 10 and 14 have interference levels around 70%, where as, after the optimization there only two sector (3 and 14) with 70% interference and the for the rest of the network this value is below 50%.

C. Taboo Search

In applying Taboo Search to the specified optimization scenario, again, many consecutive runs of the algorithm have been done, in order to fine tune the parameters affecting the results and the final results of the search are depicted in Fig. 7 The curve with higher values shows the objective function value of the solution in each iteration and the curve with lower values shows the average population fitness in each iteration.

The corresponding values of the optimized parameters are shown in table 2, where we see that while the number of served users is highly improved, the used CPICH and the number of "on" sites have been decreased.

D. TS in practice: Effect on the network

In the course of optimization problem, the best solution from each iteration is saved, so that the configurations of all

the iterations are available and regeneration of the setup is possible.

Table 2. shows the number of served users at the beginning and the end of optimization process; the number of served user is improved from 735 users to 811 users.

Fig. 6 GA- Interference in first and last iteration

Fig. 7 Objective function values for TS

Fig. 8 shows the other to own cell interference. As it can be seen in the initial setup the interference levels are really high, with two sectors with 100% interference, two sectors with 90%, two sectors around 80% and one sector around 70% interference. However after the optimization, the interference levels are meaningfully decreased, with only two sites with an interference level of around 70% and all other sites below 50%.

TABLE 2: TS RESULTS SUMMARY

	Max Possible	First Iteration	Final Iteration
No. of users	1000	735	811
Total CPICH	639	576	525
On Sectors	21	19	17
Fitness Value	N/A	0.5541	0.6326

Fig. 8 Interference in first and last iteration

VI. COMPARISONS

The effectiveness of the optimization procedures can never be determined unless there is baseline for comparison. Due to the NP-hard nature of our problem, in choosing this comparison method, another heuristic method; Genetic

Algorithm, was used rather than a method based on numerical calculations.

The best approach in comparing the results is using the common parameter in both search methods; the objective function. Through comparing how fast and well the objective function improves, we can characterise the two methods.

Fig. 9 shows the objective function of different search methods. The two solid lines with dots represent the objective function of the fittest individual / solution, and the dashed lines depict the average population / neighbourhood objective function in GA / TS.

Fig. 9 Objective function, a comparison between TA and GA

The results show that while at the beginning of the search the two methods improve at the same pace, there is point where Taboo Search shows better improvement over Genetic Algorithm, keeping its objective function higher through out the search, except at iterations around 35, where decrease of the TS objective function can be described as the effect of diversification and for the search moving to new neighbourhoods in order to discover the search space more thoroughly. As we see the search then picks up again and finally the search ends with higher value of the TS objective function.

Based on this results it can be concluded that in General TS has a much better performance over the GA in all areas and it improves faster.

In terms of computational times, for 50 Iterations, Genetic Algorithm took 19566 second and Taboo search took 20456 seconds, which does not show a lot of difference. The longer time associated with Taboo Search can be considered as the time due to the extra step in Taboo Search in writing to the Taboo List and then again comparing each neighbour against the Taboo List, which adds some time to the computational time.

If the time is not a big issue the optimization can be run for fixed number of iterations, however for scenarios with more complexity and more number of nodes, NPSW computation time will be considerably larger as it will need to calculate more iterations before the network stabilises, and hence calculating the objective function for each individual / neighbour will take longer. In this case, a

trade off can be made between time and number of iterations and the stopping criteria can be set as when the objective function is above a specific threshold or when a defined percentage of improvement is met, in this case the search can be stopped in less iterations and save a lot of computational time.

VII. CONCLUSIONS

The provided results show that in general both methods were successful in optimizing the network, as all the parameters included in objective function showed improvement at the end of the optimization, the practical simulations of the first and final iteration obviously showed higher number of served users, lower total CPICH and lower number of "On" sites. Even the total interference in the network was highly reduced.

However Taboo Search stood higher than the Genetic Algorithm and proved to be a better solution compared with the Genetic Algorithm. Not only Taboo Search arrived at better objective function values, but also it arrived to configurations which could service more number of users with less power and less "on" sites. The results were verified in network simulations and improvements could obviously be seen.

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