ACO vs EAs for Solving the Automatic Frequency Planning Problem

ABSTRACT

Frequency assignment is a well-known problem in Operations Research for which different mathematical models exist depending on the application specific conditions. However, most of these models are far from considering actual technologies currently deployed in GSM networks (e.g. frequency hopping). These technologies allow the network capacity to be actually increased to some extent by avoiding the interferences provoked by channel reuse due to the limited available radio spectrum, thus improving the Quality of Service (QoS) for subscribers and an income for the operators as well. Therefore, the automatic generation of frequency plans in real GSM networks is of great importance for present GSM operators. This is known as the Automatic Frequency Planning (AFP) problem. In this paper, we focus on solving this problem for a realistic-sized, real-world GSM network by using Evolutionary Algorithms (EAs). To be precise, we have developed a $(1, \lambda)$ EA for which very especialized operators have been proposed and analyzed. Results show that this algorithmic approach is able to compute accurate frequency plans for real-world instances.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods, and Search—*Heuristic methods*; G.1.6 [**Numerical Analysis**]: Optimization—*Global optimization*

General Terms

Algorithms, Experimentation, Performance

Keywords

Ant colony optimization, automatic frequency planning, evolutionary algorithms

1. INTRODUCTION

The *Global System for Mobile* communications (GSM) [12] is an open, digital cellular technology used for transmitting mobile voice and for 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. Indeed, by mid 2006 GSM services are in use by more than 1.8 billion subscribers[1] across 210 countries, representing approximately 77% of the world's cellular market. It is widely accepted that the *Universal Mobile Telecommunication System* (UMTS) [13], the third generation mobile telecommunication system, will coexist with the enhanced releases of the GSM standard (GPRS [9] and EDGE [7]) at least in the first phases. Therefore, GSM is expected to play an important role as a dominating technology for many years.

The success of this multi-service cellular radio system lies in efficiently using the scarcely available radio spectrum. GSM uses *Frequency Division Multiplexing* and *Time Division Multiplexing* schemes to maintain several communication links "in parallel". The available frequency band is slotted into channels (or frequencies) which have to be allocated to the elementary transceivers (TRXs) installed in the base stations of the network. This problem is known as Automatic Frequency Planning (AFP), Frequency Assignment Problem (FAP), or Channel Assignment Problem (CAP). Several different problem types are subsumed under these general terms and many mathematical models have been proposed since the late sixties [1, 6, 11]. This work is focussed on concepts and models which are relevant for current GSM frequency planning [5] and not on simplified models of the abstract problem. In GSM, a network operator has usually a small number of frequencies (few dozens) available to satisfy the demand of several thousands TRXs. A reuse of these frequencies is therefore unavoidable. However, frequency reusing is limited by interferences which could lead the quality of service (QoS) for subscribers to be reduced down to unsatisfactory levels. 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). Additionally, several interference reduction techniques (e.g. frequency hopping, discontinuous transmission, or dynamic power control) [5] have been proposed to enhance the capacity of a given network while using the same frequency spectrum. These techniques are currently in use in present GSM networks and they must be carefully consid-

[1] http://www.wirelessintelligence.com/

ered in AFP problems because they allow both the QoS for subscribers and the income of the operators to be increased.

The AFP problem is a generalization of the graph coloring problem, and thus it is NP-hard [10]. As a consequence, using exact algorithms to solve real-sized instances of AFP problems is not practical, and therefore other approaches are required. Many different methods have been proposed in the literature [1] and, among them, metaheuristic algorithms have proved to be particularly effective. Metaheuristics [3, 8] are stochastic algorithms that sacrifice the guarantee of finding optimal solutions for the sake of (hopefully) getting accurate (also optimal) ones in an reasonable time. This fact is even more important in commercial tools, in which the GSM operator cannot wait for long times to get a frequency plan (e.g. several weeks). Our approach here is to use Evolutionary Algorithms (EAs) [2]. However, it has been reported in the literature that classical EA crossover operators do not work properly for this problem [4, 15]. Our proposal is therefore a fast and accurate $(1, \lambda)$ EA (see [14] for details on this notation) in which there is no need for recombining individuals. A $(1, \lambda)$ EA is an approach that either shows population-based evolutionary capabilities and a low cost per iteration (similar to Simulated Annealing and other trajectory based algorithms). These two are the reasons for choosing this algorithm instead of a regular (μ, λ) EA (like regular GAs) of (1,1) EA (like greedy approaches). The main contribution of this work is not only using a real-world GSM network instance with real data and realistic size (more than 2600 TRXs to be assigned just 18 frequencies) but also that the tentative frequency plans manipulated by the EA are evaluated with a commercial tool which uses accurate models for all the system components (signal propagation, TRX, locations, etc.) and actually deployed GSM interference reduction technologies such as those mentioned above. Both the data as well as the simulator are provided by Optimi Corp.$^{\text{TM}}$. The point here is that standard benchmarks like the Philadelphia instances, CELAR, and COST 259 [6] do not consider such technologies and therefore most of the proposed optimization algorithms are rarely faced with a real GSM frequency planning problem. We have implemented very especialized operators for the $(1, \lambda)$ EA in which deep problem-domain knowledge has been used. Finally, different configurations of the algorithm ($\lambda = 10$ and $\lambda = 20$) showing different balances between intensification/diversification have been tested. The results point out that our approach is able to compute accurate frequency plans that can be directly deployed in the real GSM network used.

The paper is structured as follows. In the next section, we provide the reader with some details about the frequency planning in GSM networks. Section **??** describes the algorithm proposed along with the different operators used. The results of the experiments are analyzed in Section **??**. Finally, conclusions and future lines of research are discussed in the last section.

2. ACKNOWLEDGEMENTS

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