Self-Optimization of Low Coverage and High Interference in Real 3G/4G Radio Access Networks

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***Abstract*—This paper presents a new single cell multi-objective optimization algorithm. The objective is to optimize areas of low coverage and high interference, through the adjustment of the antenna tilts and/or antenna orientation. The process is achieved using a specific implementation of a Particle Swarm Optimization (PSO) algorithm. Both the detection of sub-optimal performance areas and its subsequent optimization are supported by drive test data and network topology information. On a 3^{rd} Generation (3G) urban scenario, it was achieved an average optimization gain of 78%.**

Keywords: SON, Self-optimization, Particle Swarm Optimization, Antenna Tilt

I. Introduction

The current mobile networks provide service to an all time record of subscribers. The total number of mobile subscriptions in Q1 2016 was around 7,4 billion [1]. The number of subscriptions is expected to keep growing on average 3% year-on-year, specially supported by the developing markets. In order to respond to this demand, the current and beyond mobile networks, must use its resources as efficiently as possible. The drawback, is that network complexity nowadays, is reaching a point that manual network optimization cannot be executed efficiently. Hence, Self-Organizing Networks (SON) algorithms have been seen as the solution, to automatically manage and optimize a mobile network.

This research work is incremental to [2] and [3] and it targets the self-optimizing algorithms (within SON) of low coverage and high interference scenarios, in 3G and 4^{th} Generation (4G) networks. Based on drive test data that can detect either low coverage or high interference scenarios, a newly objective function implementation, characterizes the problem. Furthermore, it is used by a PSO algorithm [4] to identify a new antenna configuration, that is optimal or at least minimizes the problem, thus optimizing the low coverage and/or interference scenario.

This paper is organized as follows. Section II describes the algorithm implementation, Section III highlights the results obtained and finally in Section IV conclusions are drawn.

II. Cell Multi-objective Optimization

Cell coverage optimization and cell interference mitigation, are generally at two ends of cell optimization procedures. For the first, a new set of antenna physical parameters, that increases the cell coverage area, should fix the low coverage issue. To mitigate interference, parameter values that reduce the cell coverage area should be used. The bottom line, is that these are conflicting objectives. On achieving one objective, it may lead missing the other. In such scenarios, a compromise configuration, that minimizes both the approaches is proposed.

The inverse configuration for coverage and interference optimization, is partly explained by the fact that a cell is not an isolated system and neither it should be. It should exist a certain amount of overlap between neighbor cell's coverage areas, to grant user mobility. Nonetheless, if excessive, it generates interference and diminishes the network performance. On the opposite, it might lead to coverage holes between cells and cause user drop calls. In fact, coverage and interference optimization, result on the configuration of the antenna physical parameters that gets the right amount of cell's overlapped areas.

A. Particle Swarm Optimization

The cell optimization problem is a nonlinear optimization problem. Hence, the need of an optimization algorithm, as the PSO. The PSO maintains a population of particles, where each particle constitutes a potential solution to the problem, composing a swarm. Each particle, has associated with it, the current position x_i, the current velocity v_i and personal best position y_i. Being an iterative algorithm, at each iteration, the velocity vector is updated and then added to the current particle position generating a new ${x_i}'$, a new possible solution. The velocity update formula, is such, that it forces the particles to converge to an optimal solution[4]. This solution is the one, whose parameters values, minimize or maximize the objective function.

B. Optimization Targets

The optimization process aims to enhance coverage holes, overshooting and pilot pollution scenarios [2]. Thus, the PSO objective function minimizes a linear combination of the objective functions for each optimization target, given by Equation 1,

$$C(\Omega) = \alpha_1 C_{CH(\Omega)} + \alpha_2 C_{OS(\Omega)} + \alpha_3 C_{PP(\Omega)}, \qquad (1)$$

where Ω represents the set of antenna adjustable parameter values, C_{CH}, C_{OS}, C_{PP} are the objective function for coverage holes, overshooting and pilot pollution targets, respectively. The α_1, α_2 and α_3 are the respective optimization weights allowing to prioritize any target, for situations where an optimal solution is not feasible.

In turn, an optimization target objective function is calculated using Equation 2,

$$C_{target}(\Omega) = \beta_1 \sum_{c=1}^{k} \left(\frac{c_{bins}}{B} \times c_{severity} \right) + \beta_2 \frac{k}{T}, \quad (2)$$

where k is the number of clusters with the target issue, c_{bins} is the number of bins in the cluster c, B is the total number of the target clusters bins, $c_{severity}$ is the target cluster severity [2] level and T is the total number of clusters that compose the cell's footprint. β_1 and β_2 are configurable to optimize based on the number of the detected data or it's severity for the network.

C. Antenna Physical Parameters

The adjustable antenna physical parameters are the Mechanical Downtilt (MDT), Electrical Downtilt (EDT) and the antenna orientation. They are all optional, and their adjustment will directly lead to an antenna gain variation. It can be estimated either through a theoretical antenna radiation pattern model [6] or using the real antenna pattern.

Based on the original drive test data is predicted the received signal strength, Received Signal Code Power (RSCP) (3G) and Reference Signal Received Power (RSRP) (4G), for the cell being optimized. The signal strength measurements are estimated by simply adding the antenna gain variation, admitted by a new set of antenna parameters, to the original data. The Energy to Interference Ratio (Ec/Io) in 3G and the Reference Signal Received Quality (RSRQ) in 4G, which measures the signal's quality, are calculated based on the new signal strength values.

The updated data might change the number of clusters which are evidence of the optimization targets, as well as it's $c_{severity}$ values. This process affects the optimization objective function values allowing to discern the set of parameter values that optimize a given cell.

III. Results

The algorithm was tested in a urban scenario with real 3G data from a mobile operator. 14 cells where identified with either coverage, overshooting or pilot pollution issues. All 14 cases, were optimized taking equally into account, the 3 optimization targets abovementioned. All cases were optimized, and the results are presented in Table I. In 64% of the cases, it was found an antenna physical parameters configuration that minimized the objective function (Equation 1) to zero, in such a way that the cell performance issues were solved. In 36% of the cases, the found solution, was not optimal but improved the cell performance, according to the objective function value. Taking into account that a gain of 100%, represents an antenna configuration that minimizes the objective function to zero, the average gain, for the cells optimized, was 78%.

TABLE I
Cell Optimization Results.

Optimal Configuration [%]	64
Partial Configuration [%]	36
Average gain [%]	78

In Figure 1 is presented a comparison between results before and after optimization. The blue line represents the objective function value, for each cell before optimization. Regarding the orange line, it indicates the objective function after the cell optimization. It can be ascertained that the objective function values, which defines the low coverage and interference severity, are reduced in the majority of the cases to values close to zero, that represents the optimal scenario.

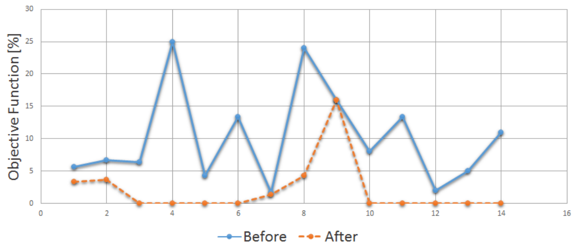

Fig. 1. Comparison of cell optimization results.

IV. Conclusions

This paper introduced a single cell multi-objective antenna physical parameters optimization algorithm. Based on drive-test measurements, the algorithm optimizes low coverage and high interference by proposing the tilt and antenna orientation (optional) values. In a 3G urban scenario, the algorithm optimized the suboptimal performance cells with an average gain of 78%. Also, in 64% of the cases the new antenna configuration amended all coverage and interference issues. Future work is in motion to allow multi-cell optimization.

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