GENETIC OPTIMIZATION OF RADIOBASE-STATION SIZING AND LOCATION USING A GIS-BASED FRAMEWORK: EXPERIMENTAL VALIDATION

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***Abstract** - The continuous increase in the complexity of mobile networks, as well as in the requirement of quality-of-service, render the development of an automatic tool for optimum siting and sizing of radiobase stations an urgent task. A framework allowing the integration of geographical information, radiopropagation models, and efficient optimization methods, is proposed as candidate solution; more specifically, a Geographical Information System (GIS) framework, inside which a wide variety of radiopropagation models dynamically interact with a novel binary-coded genetic optimizer using multiple cost functions.*

Results on real cases, such as GSM subnetworks in Umbria region, demonstrate the affordability and reliability of the system, reducing power levels and improving network coverage and quality-of-service.

I. INTRODUCTION

The world of mobile communications is moving faster and faster. The continuous growth of network system complexity, and the need of reduced design times, render the development of effective and efficient optimization strategies to assist the designer in radiobase station (RBS) sizing (emitted power levels for antennas), tilting and siting, one of the most crucial points. Such tools represent the appropriate approach for the application of an electromagnetic-field level control policy, in conjunction with the improvement of quality-of-service standards in mobile networks.

A planning system to optimize the power sizing and the siting of RBSs in a mobile network, can be essentially based on

- accurate electromagnetic (EM) radioprapagation models
- rigorous representation of the geographical characteristics of the studied domain
- flexible optimization methods

Its development must cope with several relevant problems and limitations, one of them being the joint use of the three above enumerated components. Up to now, the three components have rarely been integrated inside a single framework, due to severe theoretical and practical problems (basically computational and implementative), despite a relevant knowledge on any of the three areas is available in the literature.

In this paper we describe a possible architectural solution to the problem, and an effective and efficient optimization strategy, based on new genetic binary approaches. The solution is validated with an experimental test in an urban area. In Section II the system architecture is discussed, as well as the Geographical Information System (GIS) framework used for the integrated representation of the geographical properties. A quick description is also given for the models adopted in the system. Section III focuses on the genetic approach proposed to solve the optimization problem. Section IV shows results, demonstrating the excellent performance of the proposed tool on real cases of mobile GSM subnetworks. Finally, some conclusions are drawn.

II. SYSTEM ARCHITECTURE

The system is composed of three main blocks, reflecting the three issues enumerated in the previous section:

- GIS/DBMS is the global framework, composed of a GIS environment and a dynamically linked database collecting all the parameters of EM sources
- EMP (Electromagnetic Prediction) is the module enclosing the available radiopropagation models
- OP (Optimum Planning), where the optimization routines are embedded.

The three blocks are strictly interconnected and cooperate thanks to efficient software solutions. For the sake of brevity, we omit here details and address the interested reader to [1,2], where a complete system representation is given.

The adopted GIS-tool is Arcview, and Access is the DBMS, whilst all the remaining code is proprietary. By using the GIS/DBMS tools, geographical data are represented, as well as all the existing EM sources (typically heterogeneous: all the artificial sources at all frequencies are taken into account, so that potential interferences among different sources can be considered).

The use of one or more radiopropagation models in EMP allows the accurate estimation of the EM field levels in a selected geographical area, once the region has been gridded by using a suitable mesh (typically chosen by the user). The simplest radiopropagation model refers to the free-space approximation (FSL model) by applying Friis's formula.

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Unluckily, most of the times this highly efficient modelling approach is not accurate enough. Alternative more accurate approaches are available (empirical, semi-deterministic and deterministic) [3-8]. Innovative percolative models are experienced as well [9].

The local field estimation is considered as the input for the optimization module in OP, which, according to a certain cost function (shortly described in the dedicated section), modifies power levels, tilting and sites of the considered RBS so that a new estimation with EMP is more satisfactory. The iterative use of OP and EMP is stopped when suitable convergence criteria are fulfilled.

III. GENETIC OPTIMIZATION

The evolutionary approach [10-13] to the optimum network planning is attractive; moreover the high simplicity and flexibility of the Genetic Algorithms (GA) render their use very amenable to cheaply and optimally locate, rightsize and tilt RBSs. The main issues of our GA are resumed in the following subsection, whilst the interested reader can find the basic principles of GA in [14].

III.1 Chromosomes

The fundamental unit in a GA is the chromosome; in the following we refer to the problem of optimal location and power level sizing but similar choices have been made for the tilting problem. Each chromosome is a binary string codifying for all the RBSs the power transmitted by every cell sector and the position of all the radiation sites.

An example is reported in [1-2], where genes corresponding to sequences of 3 bits for each power correction factor and 2 bits for each RBS location, can be identified thanks to their position in the string.

III.2 Quality of the solution: cost functions MMaF, MDF, MRF, MMiF.

In order to conjugate EM emission control policy and optimal network covering, several cost functions have been implemented [1-2]. EM field levels can be estimated on a certain number of receiver points on the selected gridded area using one or more of the several models described before; among them a reduced set of points is selected. This point set is used to compute the solution cost, according to one of the following optimization criteria

- sum minimization of E over points selected so that E field has maximum intensity (MMaF)
- sum minimization of E over points selected so that E field has minimum intensity (MMiF)
- minimization of the difference between maximum and minimum E field points (MDF)
- sum minimization over randomly chosen points (MRF)

Multi-provider radiation sites are often in the same prediction area; in order to take into account all the EM components (managing with interference problem) the resulting EM field levels must satisfy the following constraints:

$$\left|\overrightarrow{E_k^g}\right| = \left|\sum_{i=1}^{n_{SRB}} \sum_{j=1}^{n_{CELL}(i)} \overrightarrow{E_k^g}(i,j)\right| \geq E_{\min}, \forall k = 1 \ldots n_{rx} \tag{1}$$

$$\left|\overrightarrow{E_k^T}\right| = \left|\sum_{g=1}^{n_g} \overrightarrow{E_k^g}\right| \leq E_{\max}, \forall k = 1 \ldots n_{rx} \tag{2}$$

where $|E^g{}_k|$ and $|E^T{}_k|$ are the r.m.s. electric field values in the *k-th* sample generated by the *g-th* provider and by all the n_g providers respectively; n_{SRB} is the base station number of the *g-th* provider, assuming that the *i-th* RBS must assure the coverage with $n_{CELL}(i)$ cells in some percent of the n_{rx} receiving points. The former bound (1) is related to a minimum E_{min} field to be ensured for coverage purposes, whilst the latter bound (2) is due to the possible existence of radioprotection limits.

IV. RESULTS

Measurements in a medium sized Italian town (Foligno, Umbria) were performed by the authors to validate the simulation results. The broadband (300 *kHz* ÷ 3.0 *GHz*) instrument used was the NARDA Microwave 8718B with the electric field probe 8760D; the assured field range is 0.5 *V/m* ÷ 19.4 *V/m* (+/- 3dB is the instrumental uncertainty).

IV. 1 Numerical evaluation and broadband measurements

Radiation sources are composed of three-cells sites of GSM, TACS and DCS systems (UMTS installation is also in progress); the antennas (mainly located on building roof-tops) have a maximum radiated power of 55.26 W (corresponding to eight TDMA active channels).

Calculations were performed by considering the contributions due to all of the five RBS in the town, located in a squared area of 5 *km* x 5 *km* (see Fig. 1).

In Fig. 2 simulation results obtained with the several implemented model (FSL, empirical and semi-empirical) are compared with measurements; for these values the measurement uncertainty (maximum +/- 3 dB) is taken into account.

A discrepancy between the values obtained with the different models can be easily observed. FSL results are the most conservative: no physical interaction with the surrounding environment is taken into account. On the other side the r.m.s. electric field simulated with the empirical model (COST231

Okumura-Hata) is strongly attenuated because of the intrinsic nature of the approach [3-6]. In the semi-empirical approach (COST 231 Walfisch-Ikegami) simulations are obtained considering three floors (12 *m* high) buildings homogenously distributed in a small area around the RBS with medium distance of 15 *m*. Streets are oriented orthogonally with respect to the wave propagation.

The considered urban area is not densely populated, with wide green or empty areas, and in the large majority of the measurement points receiver and transmitter were in a line-of-sight configuration. This explains the substantial accordance between FSL and experimental data.

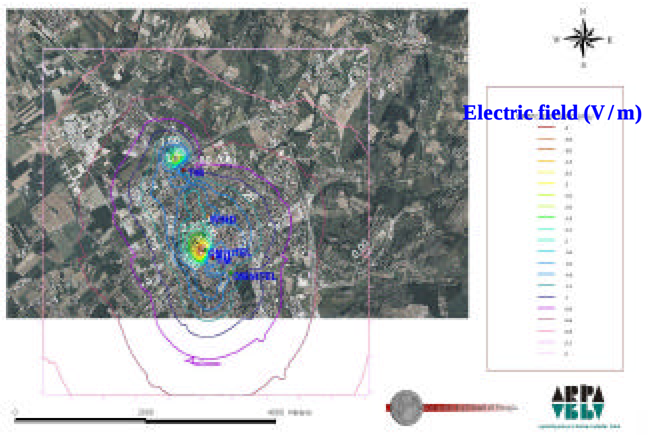

Figure 1. Orthogonalized air photography of the evaluation area with an EM map. Results are attained by using the FSL model (V/m).

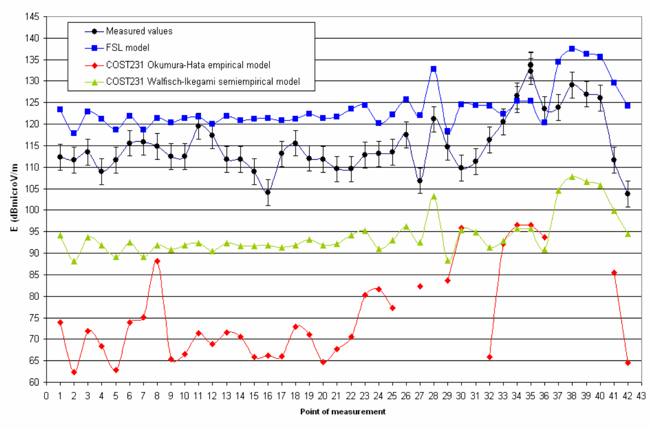

Figure 2. Measurements (black circles) of rms electric field (dBμV/m) and numerically simulated values are reported (blue squares for free-space loss (FSL) simulations, red diamonds for the empirical COST 231 Okumura-Hata model and green triangles for the semi-empirical COST 231 Walfisch-Ikegami model). It should be observed that, in some cases, the empirical model cannot be used, because of the validity range of the approach [3-8].

IV. 2 Optimum planning with GA

A 4-RBS (GSM and DCS) power level optimization is now shown considering a real subnetwork in the area reported in Fig. 1. The 4 considered sites belong to the same provider. The problem is defined over a *4.5 km x 4.5 km* geographical region and the area is meshed with a *150 m* edge. Fig. 3 sketches the optimum power sizing for GSM and DCS cells in the region, each colour in the picture being related to the different optimization performances. Assuming that each point is covered whether the received power level is over a certain threshold, the quality-of-service and the coverage is improved, and field levels generically reduced. The choice among different cost functions, flexible and delegated to the user, allows the selection of a variety of optimization policies.

A maximum power reduction of 50% is attained for all cells with fitness functions Minimum-Max Field (MMaF), Minimum-Min Field (MMiF), Minimum Difference Field (MDF), Minimum Random Field (MRF), and a global reduction of 25,02 W for GSM cells and 5,7 W for the DCS system can be achieved, with apparent advantages for network operators both for their quality-of-services, and for their operating costs.

Similar results, shown in Fig. 4, have been achieved when jointly considering sizing and location.

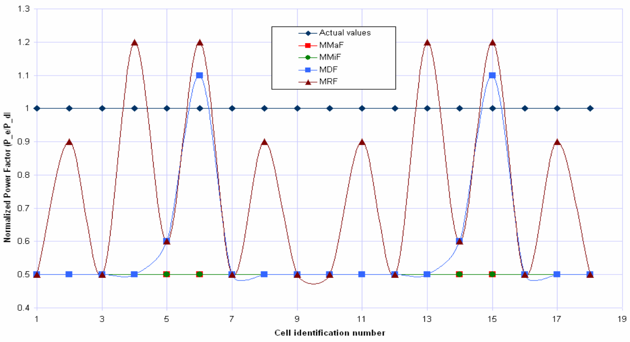

Figure 3 Optimum power rightsizing. Normalized power factor (i.e. the ratio between the optimized power P_e and the unoptimized power P_d) with the four different optimization strategies are reported. Black colored circles stands for unoptimized values whilst red squares represent the optimization strategy MMaF, green circles MMiF, blue squares MDF and brown triangles MRF respectively.

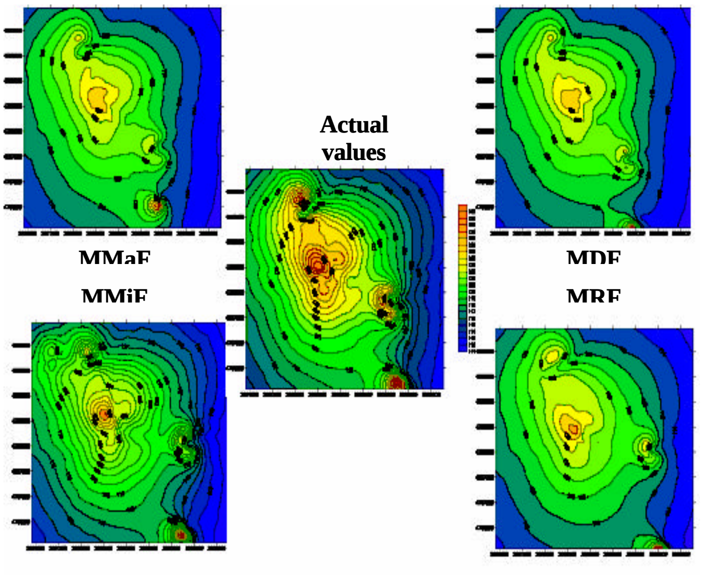

Figure 4 Optimum RBSs rightsizing and location. EM field levels for the different optimization policies.

V. CONCLUSIONS

In this paper a system for the optimum location, tilting and power sizing of radiobase-station antennas in mobile networks has been proposed, and validated with experimental tests. A key-feature is the integration of a wide variety of radiopropagation models inside a GIS framework, dynamically interacting with an innovative binary-coded genetic optimizer using multiple cost functions. Results on real cases demonstrate the accuracy and efficiency of the environment, as well as the apparent amenability to the use in network planning.

VI. REFERENCES

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