Automatic indoor radio planning

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1 Introduction

In telecommunication, Quality of Service (QoS) is one of the most important metrics to assess a system performance. In wireless systems such as IEEE 802.11 or 3GPP 5G, the QoS depends on the coverage, the throughput and others criteria. A wide range of network design software or planing tools including Automatic Cell Planning (ACP) module for designing, planning and optimizing networks exist. The ACP module allows to optimize the access point (AP) placement so that the coverage or throughput is maximised. The network optimization relies on radio propagation and throughput models. The AP placement optimization based on a user-defined QoS can be defined as a combinatorial optimization problem which is known to be NP-Hard [1]. Many approaches have already been proposed [2], however they require a significant pre-computing with conventional methods. In this work, we propose a fast and hybrid approach to resolve the APs placement problem based on coverage criteria. The resolution method uses a genetic algorithm, and an IA-based radio map prediction model proposed in [3] as the objective function to speed up the optimization process and get rid of the pre-computing step.

2 Problem formulation

The IA-based radio map prediction (RMP) model takes as input a floor plan and the AP location P_n to predict a radio coverage map. The input size of the RMP model is 256x256, thus the AP locations coordinates x_n, y_n are bounded between 0 and 256. The model is able to predict a radio map in less than 0.2 seconds which somehow allows us to test thousands of different AP locations fastly in the optimization process.

2.1 Variables

We aim to place N_{AP} APs spatially, each AP is represented by and integer identifier (ID) associated to coordinates (x, y). Thus, placing one AP is like searching the best ID between N candidates. Indeed, before starting the optimization, we define the APs candidates considering space constraints and a meshing in meter. In our context, for a floor plan, we define an AP candidate every 0.5 meter inside the building. Some candidates may be eliminated according to placement or space constraints (i.e. next to electrical outlets). Let's consider a case where we have 120 candidates and N_{AP} APs to place. When $N_{AP} = 1$, the number of possible solutions is limited to 120. When $N_{AP} = 2$, the number of possible solutions is 120x120 without considering symmetric cases. Indeed, when dealing with RSSI coverage, symmetric cases can be eliminated but not in the case of throughput. Generally, for N_C candidates and N_{AP} APs to place, the number of solution is : $(N_C)^{N_{AP}}$.

2.2 Constraints

In IEEE 802.11 networks, when placing N_{AP} APs, 2 configurations are possible in term of topology: the APs can be connected in cascade or star. No AP shall be out of range of the other APs. In other words, with 2 APs, each AP must be in an optimal range with respect to the other AP to keep a sufficient end-to-end throughput. For instance, APs have to be in a range of [$RSSI_{min}$, $RSSI_{max}$] dBm in term of RSSI with respect to the AP to which it is connected, with $RSSI_{min}$ and $RSSI_{max}$ depending on the characteristics of the considered Wi-Fi equipement.

2.3 Objective function

Our ultimate goal in this case study is to place optimally 2 APs located at P_1, P_2 in a search space Ω =[1,..,N_C] x [1,..,N_C] in order to maximise the coverage $f(P_1, P_2)$ in a given service area Γ for an environment *env*. The optimization problem is defined below:

$$\begin{cases} \max & f(P_1,P_2) = \dfrac{1}{\mathbf{card}(\Gamma)} \displaystyle\sum_{i,j\in\Gamma} \mathbf{1}_S(g(P_1,P_2)[i,j]) & \\ & \textit{with } g(P_1,P_2) = max[g_1(P_1), g_2(P_2)] & \textit{Best server} \\ & \quad g_1(P_1) = RMP(env, P_1) & \textit{radiomap at } P1 \\ & \quad g_2(P_2) = RMP(env, P_2) & \textit{radiomap at } P2 \\ & \quad \mathbf{1}_{Threshold}(Power) := \begin{cases} 1 & \text{if } \ Power >= Threshold, \\ 0 & \text{if } \ Power < Threshold. \end{cases} & \\ \text{s.t.} & RSSImin <= g_1(P_1)[P_2] <= RSSImax & \\ & (P_1,P_2) \in \Omega \textit{ with } P_1 = (x_1,y_1) \textit{ and } P_2 = (x_2,y_2) & \\ & x_1,x_2,y_1,y_2 \text{ in } [0,..,255] & \end{cases} \tag{1}$$

3 Solving approach and experiments

To solve the problem, we implemented an approach based on a population-based meta-heuristic. We focused our experiments on genetic algorithms to evaluate our approach. However, without going deeper, we tested others algorithms like NSGA2 and PSO. The experiments have been conducted with the following settings: a population of 40 individuals (AP candidate), stop after 15 iterations, 30 offsprings, simulated binary crossover with a probability of 0.9, Polynomial Mutation. Finally, in term of execution time, our approach is able to place up to 4 APs in less than 5 minutes with good quality solution.

References

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