Wireless Access Point Configuration Problem
A benchmark problem for open-ended topology and parameter search

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Introduction

Wireless Access Point Configuration problem is proposed as a benchmark problem for testing Natural Computing algorithms in simultaneous open-ended structure and parameter evolution (search).

1 Wireless Access Point Configuration problem

A small city is planning to provide wireless Internet service to its citizens, who are located around the city map below (labeled as circled C). A bunch of wireless access points then need to be placed at several places to cover all the clients as each access point has limited service radius. To reduce the cost, a design solution with minimal number of access points and minimum length of the wires connecting those access points is regarded as optimal. So the question is, how to decide the number of necessary access points and which place should we put. To make it harder, we can ask to maximize the average signal strength at all clients, or add some constraints on the location of the access points. As this problem (not the simplified version) requires simultaneous topology and parameter search, many issues exist.

1.1 Where is the structure to be evolved?

Every wireless access point must be either directly linked to the source radio station or linked to another access point which has been linked to the radio station (directly or indirectly) by wires whose cost is proportionate to its length. All the connected graph is the structure to be evolved.

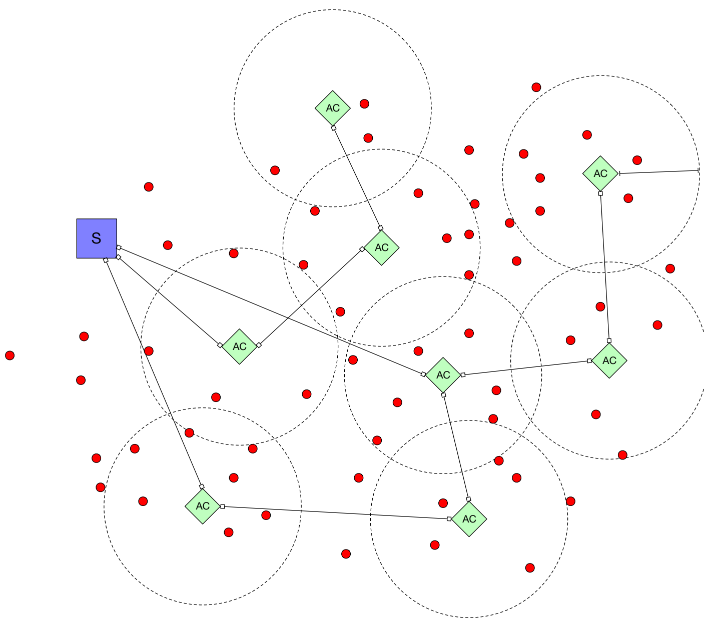

Figure 1: Example of APs configuration.

1.2 What are the parameters to be evolved?

The locations of access points are the parameters to be optimized. Their range can be constrained in a range, e.g. $(x, y)|x, y \in [0, 1000]$. The coordinates of sources, access points and clients are double. The number of client sites should be at least 100.

2 Problem statement

Given a set of n_c clients located at (x_i^c, y_i^c) with $i \in \{1, \ldots, n_c\}$ in an wide area of size $W \times H$ and the position of the source internet connection outlet S located at (x^s, y^s), find the best configuration of the access points such that:

- each client is within the signal transmission radius R_{sig} of at least one access point (fully covered);

- each access point has some cost. So, the total cost is

$$C_{AP} = n_{ap} \cdot C_{ap}$$

where C_{ap} is the cost of each access point, n_{ap} is the number of access point;

- the cost of the wires used to connect the access points is

$$C_W = C_w \cdot \sum_{i,j=0}^{n_{ap}} L_{ij}$$

where C_w is the cost of a unit length wire and L_{ij} is the length of the connection among the access point i anf j if exists.

Minimize the cost of the wires C used to connect the access points using the least number of access points:

$$C = C_{AP} + C_W = n_{ap} \cdot C_{ap} + C_w \cdot \sum_{i,j=0}^{n_{ap}} L_{ij}$$

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Hint: If we make things easy, we only need to evolve the location points and use Minimum Spanning Tree algorithm to find the topology or connections and To test the algorithm synthesis engine, we ask the algorithm to run the Minimum Spanning Tree topology.

Optional. Maximize the average signal intensity of all client sites.

$$S_{intensity} = \frac{1}{n_c} \cdot \sum_{\substack{i,j=1 \\ d_{c_j,r_i} \leq R_{sig}}}^{n_{ap},n_c} \frac{P}{4\pi \cdot d_{c_j,r_i}^2}$$

where P is the power of the access point antenna.

3 Open questions

- Are the problems separable?
- Is the problem NP?
- How is the problem related to TSP?