UNIVERSIDAD
DE MÁLAGA

Executive Overview

TITLE: D2.3.1-Problem 1. TSBS Optimal Location Problem (definition)

SUMMARY: In this deliverable we present an optimization problem for CARLINK, called *TSBS Optimal Location Problem*. The goal of this problem is to maximize the total coverage offered by a set of TSBSs *(Traffic Service Base Stations)* while minimizing the number of them. In this first deliverable (D2.3.1) we give an introduction to the formal definition of the optimization problem. In the next deliverable (D2.3.2) we will present different techniques to solve it as well as the obtained results.

GOALS:

1. Define the TSBS Optimal Location Problem.

CONCLUSIONS:

1. The TSBS Optimal Location Problem could assist the real development of the CARLINK platform by minimizing the costs to do it.

D2.3.1-Problem 1. TSBS Optimal Location Problem (definition)

CARLINK::UMA

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1 Introduction

The CARLINK project aims at providing a wireless platform for linking cars which consists of three different parts: the TSCU (*Traffic Service Central Unit*), the TSBSs (*Traffic Service Base Stations*) and the MEUs (*Mobile End Users*). The MEUs provide real time data about traffic and weather that is sent to the TSCU via TSBSs. The data received in the TSCU is processed and sent back to the MEUs through the TSBSs. Therefore, the selection of an appropriate distribution of places along the roads to put the TSBSs is crucial to ensure the correct behaviour of the CARLINK platform.

In this deliverable we present an optimization problem for CARLINK, called *TSBS Optimal Location Problem (TSBS-OLP)*. The goal of this problem is to maximize the total coverage offered by a set of TSBSs while minimizing the number of them (i.e., the cost). In this first deliverable (D2.3.1) we give an introduction to the formal definition of the optimization problem. In the next deliverable (D2.3.2) we will present different techniques to solve it as well as the obtained results.

In Section 2 we give a formal approach to the definition of the TSBS-OLP problem. Afterwards, the Section 3 finalizes this deliverable by giving some conclusions.

2 The Problem Definition

The TSBS Optimal Location Problem is based on a previously defined optimization problem: *The Radio Network Design Problem (RND)*. We firstly introduce the formal definition of the RND problem and secondly we denote what are the modifications to transform this problem into the new one of interest for CARLINK.

2.1 The Radio Network Design Problem

The radio coverage problem aims at covering an area with a set of transmitters. The part of an area that is covered by a transmitter is called a cell. In the following, we will assume that the cells and the area considered are discretized, that is, they can be described as a finite collection of geographical locations (taken from a geo-referenced grid, for example). The computation of cells may be based on sophisticated wave propagation models, on real measurements, or on draft estimations. In any case, we assume that cells can be computed and returned by an *ad hoc* function.

Let us consider the set L of all potentially covered locations and the set M of all potential transmitter locations. Let G be the graph, $(M \subset L, E)$, where E is a set of edges such that each transmitter location is linked to the locations it covers and let the vector $\vec{x}$ be a solution to the problem where $x_i \in \{0, 1\}$, and $i \in [1, |M|]$. The value x_i is 1 or 0 depending on whether a transmitter is being used or not in the corresponding site. As the geographical area needs to be discretized, the potentially covered locations are taken from a grid, as shown in Figure 1.

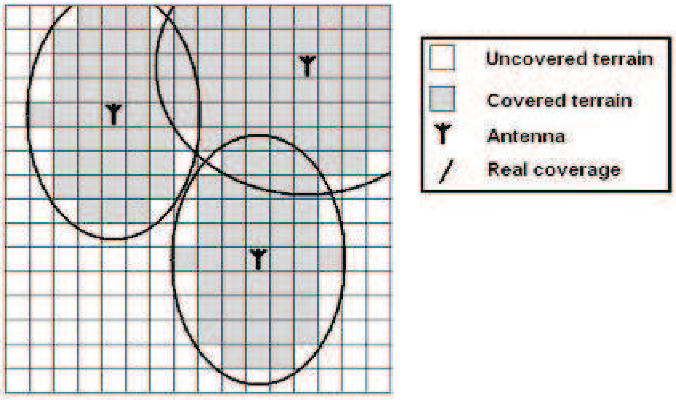


Figure 1: Three candidate transmitter locations and their associated covered cells on a grid.

There are different versions of the RND problem, which differ in the type of antennae that might be placed in every location. There are simple versions with antennae that require no parameters to determine its coverage, and more complex versions in which antennae require some parameters (i.e. direction) to determine the area covered by it.

Searching for the minimum subset of transmitters that covers a maximum surface of an area comes to searching for a subset $M' \subset M$ such that $|M'|$ is minimum and such that $|Neighbors(M', E)|$ is maximum, where

$$Neighbors(M', E) = \{u \in L | \exists v \in M', (u, v) \in E\}, \quad (1)$$

$$M' = \{t \in M | x_t = 1\}. \quad (2)$$

The next step in the definition of an optimization problem is to design a function that evaluates the quality of a given solution. It is called *objective function*. The goal of an optimization algorithm is to maximize or minimize the objective function: i.e., to search the solution that makes maximum or minimum the value of the objective function, respectively. In the case of the RND problem, we consider to maximize the objective function proposed in [2]:

$$f(\vec{x}) = \frac{Coverage(\vec{x})^\alpha}{|M'(\vec{x})|} \quad (3)$$

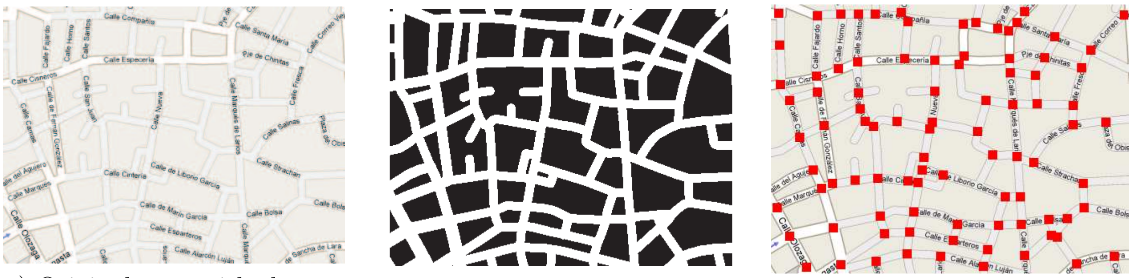
where

$$Coverage(\vec{x}) = 100 \times \frac{|Neighbors(M', E)|}{|Neighbors(M, E)|} \quad (4)$$

The parameter $\alpha > 0$ can be tuned to favor the cover rate item with respect to the number of transmitters. If we set $\alpha = 1$ then the algorithm will not distinguish between a solution with a single antenna producing a coverage C and another with $N >> 1$ antennae producing a coverage $N \times C$. This defeats the purpose of RND since the algorithm would not be searching for solutions that produce high coverages in an efficient way, but only for efficient solutions regardless of the coverage obtained. Therefore we have to set $\alpha > 1$ in order to guide the search towards solutions with high cover rates. Like Calégari et al. did [2], we use $\alpha = 2$.

2.2 The TSBS Optimal Location Problem

One of the problems which can appear during the real development of the CARLINK execution platform is to select the best combination of places to put the TSBSs in order to maximize the coverage of the wireless traffic platform while minimizing the costs to do it. We name this problem *The TSBS Optimal Location Problem (TSBS-OLP)*. Solving this problem is like solving the RND problem but having in mind some differences. The Set L contains the geographical points of the roads, i.e., the locations to be covered (see Figure 2b). The Set M contains the geographical points of the candidate positions to place the TSBSs (see Figure 2c). We consider the intersection of roads as candidate positions since the TSBSs could be placed on top of the traffic signals or the traffic lights. We also consider that the propagation models of the TSBSs are circular and, furthermore, that they are not affected by the presence of obstacles: e.g. buildings.



a) Original map with the area to optimize.

b) Modified map showing the locations to cover.

c) Modified map showing the locations of the TSBSs.

Figure 2: Three different views of the same area to optimize the location of TSBSs. a) Original map. b) Black and white map where the white points are the set of locations to be covered (Set L), i.e., the roads. c) Modified map showing the red squares as the set of transmitter locations (Set M), i.e., the places where the TSBSs can be put (traffic signals or traffic lights in the intersection of roads)

3 Conclusions

This deliverable presents *The TSBS Optimal Location Problem (TSBS-OLP)* which consists in selecting the best combination of candidate positions for placing a set of TSBSs in order to maximize the coverage of the CARLINK wireless traffic platform in the roads of a specific area. As in *The Radio Network Design Problem (RND)* the complexity of finding an appropriate solution becomes hard with the dimension of the covered area. Therefore it is necessary the automation of the problem solving process.

This problem is based on a well known optimization problem called *RND*. We have firstly introduced a formal definition of the RND problem and secondly we have pointed out the main differences with the TSBS-OLP.

In the next deliverable D2.3.2 we will apply different metaheuristics techniques [1] to solve the TSBS-OLP problem. These results could assist the real development of the CARLINK platform by minimizing the costs to do it. An example of successful application of metaheuristics techniques to solve the RND problem can be found in [3].

References

[1] Christian Blum and Andrea Roli. Metaheuristics in combinatorial optimization: Overview and conceptual comparison. *ACM Comput. Surv.*, 35(3):268–308, 2003.

[2] P. Calégari, F. Guidec, P. Kuonen, and D. Kobler. Parallel island-based genetic algorithm for radio network design. *Journal of Parallel and Distributed Computing*, 47(1):86–90, 1997.

[3] M.A. Vega-Rodríguez, J.A. Gómez, E. Alba, D. Vega, S. Priem-Mendes, and G. Molina. Evaluation of Different Metaheuristics Solving the RND Problem. In *Applications of Evolutionary Computing (EvoWorkshops)*, pages 101–110, Valencia, 2007.