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Diseño Inteligente de Redes Inalámbricas de Comunicación
Conserjería de Innovación, Ciencia y Empresa
P07-TIC-03044
http://diricom.lcc.uma.es

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Informe Ejecutivo

TÍTULO: TSBS Optimal Location Problem (definition)

RESUMEN: Este informe presenta un problema de optimización que aparece en el diseño de redes vehiculares inalámbricas llamado *TSBS Optimal Location Problem*. El objetivo de este problema consiste en seleccionar un número mínimo de estaciones base (TSBSs *Traffic Service Base Stations*) de forma que se maximice la cobertura ofrecida en carretera. En este primer informe (SEM-1.0-2008) presentamos de manera formal el problema de optimización, mientras que en el siguiente relacionado (SEM-2.0-2008) definiremos diferentes técnicas para resolverlo, además de comentar los resultados obtenidos sobre diferentes escenarios.

OBJETIVOS:

1. Definir el problema de colocación de estaciones base (TSBS Optimal Location Problem)

CONCLUSIONES:

1. El problema de colocación de estaciones bases puede asistir al desarrollo de una infraestructura para redes vehiculares minimizando los costes requeridos.

RELACIÓN CON ENTREGABLES:

CO: SEM-2.0-2008 (simultáneo o aconsejable de leer)

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Executive Summary

TITLE: TSBS Optimal Location Problem (definition)

ABSTRACT: In this deliverable we present an optimization problem that emerges in the design of vehicular networks with wireless infrastructure, called *TSBS Optimal Location Problem*. The goal of this problem is to maximize the total coverage installed by a set of TSBSs *(Traffic Service Base Stations)* while minimizing the number of them. In this first deliverable (SEM-1.0-2008) we give an introduction to the formal definition of the optimization problem. In the next deliverable (SEM-2.0-2008) 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 a infrastructure of vehicular networks by minimizing its deployment cost.

RELATED DOCUMENTS:

CO: SEM-2.0-2008 (advisable reading)

TSBS Optimal Location Problem (definition)

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1 Introduction

In order to provide a wireless platform for linking cars, a possible solution consists of developing a system with 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 platform.

In this deliverable we present an optimization problem 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 (SEM-1.0-2008) we give an introduction to the formal definition of the optimization problem. In the next deliverable (SEM-2.0-2008) 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, 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 adopted to transform this problem into the TSBS-OLP.

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.

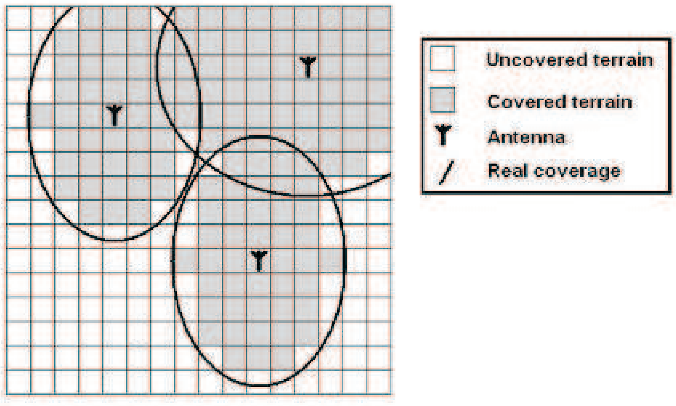


Figure 1: Three candidate transmitter locations and their associated covered cells on a grid.

There are different versions of the RND problem, which differ each other 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 (e.g. direction) to determine its area covered.

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

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

$$M' = \{t \in M | x_t = 1\}. \tag{2}$$

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 [1]:

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

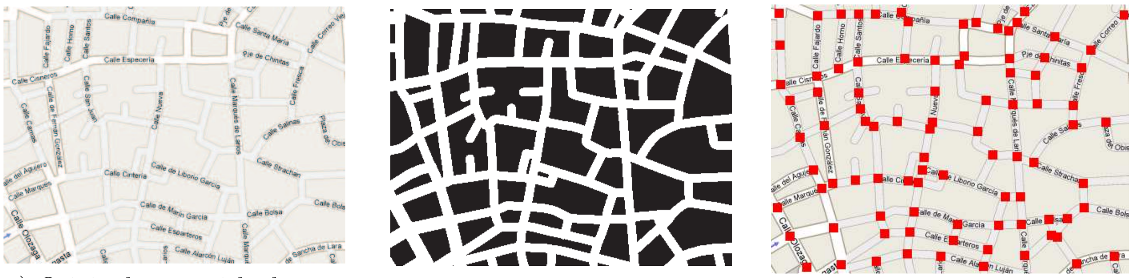
where

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

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 in [1], we use $\alpha = 2$.

2.2 The TSBS Optimal Location Problem

One of the problems which can appear during the real development of the wireless 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 its cost. 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 squares as the set of the potential 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 *TSBS Optimal Location Problem (TSBS-OLP)* which lies in selecting the best combination of candidate positions for placing a set of TSBSs in order to maximize the coverage of a wireless traffic platform in the roads of a specific area. As in *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.

References

[1] 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.