*Málaga, 2010*

# Informe Ejecutivo

TÍTULO: VANET-2.1-2010: Encaminamiento óptimo mediante OLSR y metaheurísticas (definición del problema)

RESUMEN: En este informe se define el problema de optimización del encaminamiento de paquetes mediante el protocolo OLSR en redes vehiculares. El objetivo es ofrecer la configuración óptima del protocolo *OLSR (Optimized Link State Routing)*, para que el mismo presente el mejor rendimiento posible. Este problema se ha resuelto empleando una combinación de técnicas de optimización (metaheurísticas) y el simulador de redes vehiculares SUMO/Ns-2.

OBJETIVOS:

1. Establecer los parámetros de configuración del protocolo OLSR.
2. Definir el problema de coniguración óptima de OLSR.
3. Presentar la estrategia seguida para resolver este problema.

CONCLUSIONES:

1. Los resultados obtenidos resolviendo el problema que aquí se presenta, muestran que el encaminamiento de paquetes mediante OLSR tiene un amplio margen de mejora. El rendimiento de la versión optimizada de OLSR en VANETs abre la posibilidad de emplearlo para el despliegue de redes vehiculares.

RELACIÓN CON ENTREGABLES:

CO: VANET-1.3-2009 (simultáneo o aconsejable de leer)

*Málaga, 2010*

# Executive Summary

TITLE: VANET-2.1-2010 Optimal routing by means of OLSR and metaheuristics (problem definition)

ABSTRACT: This report presents the definition of the optimal routing problem by means of OLSR and metaheuristics in VANETs. The goal of this problem is to offer the optimal configuration of *OLSR (Optimized Link State Routing)* in order to obtain the best performance of this protocol. The optimization problem has been solved using a combination of the optimization techniques and the SUMO/Ns-2 simulation tool.

GOALS:

1. Establishing the parameters to configure the OLSR routing protocol.
2. Defining the problem of configuring OLSR protocol.
3. Showing how to solve the optimal configuration of OLSR.

CONCLUSIONS:

1. The obtained results of solving this problem shows that OLSR has a wide range of improvement by finding its optimal configuration. The performance of optimized OLSR in VANETs opens the way of using it to deploy vehicular networks.

RELATION WITH DELIVERABLES:

CO: VANET-1.3-2009 (advisable reading)

# Optimal routing by means of OLSR and metaheuristics (problem definition)

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## 1 Introduction

Tntelligent Transportation Systems (ITS) emerge as transportation systems that apply information and communication technologies to enhance safety, mitigate traffic congestion, and reduce the impact on the environment. One of the most promising technologies is the vehicular *ad hoc* network (VANET) [17]. VANETs are self-configuring networks where the nodes are vehicles (equipped with on-board computers), elements of roadside infrastructure, sensors, and pedestrian personal devices, e.g., smart-phones. Over the last years, IEEE working groups are completing the final drafts of the family of standards for Wireless Access in Vehicular Environments (WAVE), IEEE 802.11p and IEEE 1609, specifically designed for VANETs. This technology presents the opportunity to develop powerful car-safety systems capable of gathering, processing, and distributing information. For example, a driver assistance system could collect accurate and up-to-date data about the surrounding environment, detect potentially dangerous situations, and notify the driver [7, 6].

In VANETs, the limitations in coverage and channel capacity of WiFi technologies, the high mobility of the nodes, and the presence of obstacles provoke frequent packet losses, topology changes, and network fragmentation. However, an optimal routing strategy, that makes better use of resources, might offer the possibility of deploying more efficient VANETs. However, routing packets in VANETs is a challenging task, since there is no central manager entity in charge of finding the routing paths among the nodes. Thus, a great deal of effort is dedicated to design efficient routing protocols [25, 28, 29].

Finding well-suited parameter configurations of existing mobile *ad hoc* network protocols is a way of improving their performance, even making the difference between a network that does work or does not, e.g., the networks with high routing load suffer from congestion and cannot ensure timely and reliable delivery of real time safety messages [31].

In this document, we aim at defining an off-line optimization problem in order to efficiently and automatically tune OLSR [9], a widely used mobile *ad hoc* network routing protocol. Although specific routing protocols are emerging for VANET networks, a number of authors are currently using OLSR to deploy vehicular networks [8, 13, 14, 21, 26, 27]. However, the continuous exchange of routing control packets causes the appearance of network congestion, then limiting the global performance of the VANET. Thus, the quality-of-service (QoS) of OLSR significantly depends on the selection of its parameters, what determine the protocol operation. As shown in the results presented in [13, 19], OLSR has a wide range of improvement by changing the configuration parameters. Solving an optimization problem consists in finding the *least-cost* protocol configuration in terms of QoS. However, the number of possible combinations of the values that they can take makes this task very hard.

Due to the high complexity that this kind of problems usually shows, the use of automatic intelligent tools is a mandatory requirement when facing them. In this sense, metaheuristic algorithms [5] emerge as efficient stochastic techniques able to solve optimization problems. Indeed, these algorithms are currently employed in a multitude of engineering problems [3, 11, 24, 30], showing a successful performance. Unfortunately, the use of metaheuristics in the optimization of *ad hoc* networks (and concretely in VANETs) is still limited, and just a few related approaches can be found in the literature.

In Alba et al. [2], a specialized Cellular Multi-Objective Genetic Algorithm (cMOGA) was used for finding an optimal broadcasting strategy in urban mobile *ah hoc* networks (MANETs). In Dorronsoro et al. (2008) [10], six versions of a GA (panmictic and descentralized) were evaluated and used in the design of *ad hoc* injection networks. Particle Swarm Optimization (PSO) algorithm has been used to manage the network resources by Huang et al. [18] proposing a new routing protocol based on this algorithm to make scheduling decisions for reducing the packet loss rate in a theoretical VANET scenario. More recently, García-Nieto et al. [12] optimized the VDTP file transfer protocol in realistic VANET scenarios (urban and highway) by using different metaheuristic techniques.

A simulation process is employed to evaluate the tentative OLSR parameters generated by the optimization algorithms, and providing the fitness values to guide the search process. In this work, the popular network simulator *ns*-2 is used for this task. In turn, a VANET instance has been defined by using real data (roads specification and mobility models) concerning a urban area of the city of Málaga, in Spain.

The remaining of this paper is organized as follows: Section 2, we present a formal approach of this optimization problem. Next, in Section 3, we draw some conclusions about the optimization of OLSR routing problem.

# 2 Problem Overviev

In VANETs, the packets have to travel through the network from one node to the others, what is a complex task in networks having high mobility and no central authority. The routing protocol operates in the core of VANETs, finding updated paths among the mobile nodes in order to allow the effective exchange of information packets. For this reason this article deals with the optimization of a routing protocol, specifically the Optimized Link State Routing (OLRS) protocol [9].

This protocol has been chosen mainly because it presents a series of features that make it well-suited for VANETs: it exhibits very competitive delays in the transmission of data packets in dense (that is an important feature for VANET applications), it adapts well to the continuous topology changes, and OLSR has simple operation that allows it to be easily integrated into different kinds of operating systems and devices. More details about the use of OLSR in VANETs are provided in the following section.

The main drawback of OLSR is the necessity of maintaining the routing table for all the possible routes. Such a drawback is negligible for small scenarios with few nodes, but for large dense networks (with high activity), the overhead of control messages could use additional bandwidth and provoke the network congestion. This constraints the scalability of the studied protocol.

However, this precise performance of OLSR depends significantly on the selection of its parameters [13, 19, 16]. Thus, computing an optimal configuration for the parameters of this protocol is crucial before deploying any VANET, since it could decisively improve the QoS, with a high implication on enlarging the network data rates and reducing the network load. All these features make OLSR a good candidate to be optimally tuned and justifies our election, although nothing prevents our methodology to be applied on new VANET protocols.

## 2.1 Optimized Link State Routing Protocol

Optimized Link State Routing protocol (OLSR) [9] is a *proactive link-state* routing protocol designed for mobile *ad hoc* networks (MANETs and VANETs) with low bandwidth and high mobility. As a proactive protocol, the nodes periodically exchange topology information to establish the routes through the network nodes from any source to any destination. OLSR relies on employing an efficient periodic flooding of control information messages using special nodes that act as *multipoint relays* (MPRs). The use of MPRs significantly reduces the size of control messages and the number of required transmissions [23]. This way, the energy spent by the routing protocol operation is decreased too. According to the topology network information, OLSR computes the routing tables by means of Dijkstra's algorithm.

The core functionality of OLSR consists in two processes:

- *Neighbourhood discovery*: Each node acquires information of its one-hop and two-hop neighbourhood by periodically exchanging *HELLO* and *MID* (multiple interface declaration) protocol information messages. Using this information, each node selects its own set of MPRs among its one-hop neighbours in such a way that its MPRs covers all its two-hop neighbours.

- *Topology dissemination:* Each node maintains topological information about the whole network obtained by *TC* (topology control) messages that are broadcasted by MPRs nodes.

The OLSR mechanisms are regulated by a set of parameters predefined in the IETF OLSR RFC 3626 [9] (see Table 1). These parameters are: the timeouts before resending HELLO, MID, and TC messages (*HELLO_INTERVAL*, *REFRESH_INTERVAL*, and *TC_INTERVAL*, respectively); the "validity time" of the information received via these three message types, which are: *NEIGHB_HOLD_TIME* (HELLO), *MID_HOLD_TIME* (MID), and *TOP_HOLD_TIME* (TC); the *WILLINGNESS* of a node to act as MPR (to carry and forward traffic to other nodes); and *DUP_HOLD_TIME*, that represents the time during which the MPRs record information about the forwarded packets.

Table 1: Main OLSR Parameters and RFC 3626 specified values.

| Parameter | Standard Configuration | Range |
|---|---|---|
| HELLO_INTERVAL | 2.0 s | $\mathbb{R} \in [1.0, 30.0]$ |
| REFRESH_INTERVAL | 2.0 s | $\mathbb{R} \in [1.0, 30.0]$ |
| TC_INTERVAL | 5.0 s | $\mathbb{R} \in [1.0, 30.0]$ |
| WILLINGNESS | 3 | $\mathbb{Z} \in [0, 7]$ |
| NEIGHB_HOLD_TIME | 3× HELLO_INTERVAL | $\mathbb{R} \in [3.0, 100.0]$ |
| TOP_HOLD_TIME | 3× TC_INTERVAL | $\mathbb{R} \in [3.0, 100.0]$ |
| MID_HOLD_TIME | 3× TC_INTERVAL | $\mathbb{R} \in [3.0, 100.0]$ |
| DUP_HOLD_TIME | 30.0 s | $\mathbb{R} \in [3.0, 100.0]$ |

## 2.2 OLSR Parameter Tuning

The standard configuration of OLSR offers a moderate QoS when is used in VANETs [26, 27]. Hence, taking into account the impact of the parameters configuration in the whole network performance, we define here the problem of the optimal OLSR parameter tuning in order to discover the best protocol configuration previously to the deployment of the VANET. The standard OLSR parameters are defined without clear values for their ranges. Table 1 shows the standard OLSR parameter values as specified in the OLSR RFC 3626 [9]. The range of values each parameter can take has been defined here by following OLSR restrictions with the aim of avoiding pointless configurations.

According to that, we can use the OLSR parameters to define a *solution vector* of real variables, each one representing a given OLSR parameter. This way, the solution vector can be fine-tuned automatically by an optimization technique, with the aim of obtaining efficient OLSR parameters configurations for VANETs hopefully outperforming the standard one defined in the In order to evaluate the *quality* or *fitness* of the different OLSR configurations (tentative solutions), we have defined a *communication cost* function in terms of three of the most commonly used QoS metrics in this area [22]:

- *Packet Delivery Ratio (PDR)*. Fraction of the data packets originated by an application that a routing protocol delivers. A data packet is counted as delivered when it is received complete and correct by the destination node.
- *Normalized Routing Load (NRL)*. Ratio of administrative routing packet transmissions to data packets delivered. When counting transmissions, each hop is counted separately.
- *Average End-to-End Delay of a data packet (E2ED)*. Average difference between the time the first data packet is originated by an application and the time this packet is received at its destination.

## 2.3 Optimization Framework

The optimization strategy used to obtain automatically efficient OLSR parameter configurations is carried out by coupling two different stages: an optimization procedure and a simulation stage. The optimization block is carried out by a metaheuristic method that should be conceived to find optimal (or quasi-optimal) solutions in continuos search spaces, which is the case in this work. Since we need to consider many different scenarios, we use a simulation procedure for assigning a quantitative quality value (*fitness*), in terms of communication cost, to the OLSR performance of computed configurations (tentative solutions). This procedure is carried out by means of the *ns-2* [1] network simulator widely used to simulate VANETs accurately [4]. For this work, *ns-2* has been modified in order to interact automatically with the optimization procedure with the aim of accepting new routing parameters, opening the way for similar future research.

As Fig. 1 illustrates, when the used metaheuristic requires the evaluation of a solution, it invokes the simulation procedure of the tentative OLSR configuration over the defined VANET scenario. Then, *ns-2* is started and evaluates the VANET under the circumstances defined by the OLSR routing parameters generated by the optimization algorithm. After the simulation, *ns-2* returns global trace information about the *Packet Delivery Ratio* (PDR), the *Normalized Routing Load* (NRL), and the *Average End-to-End Delay* (E2ED) of the whole mobile vehicular network scenario where there were 10 independent data transfers among the vehicles. This information is used in turn to compute the *communication cost (comm_cost)* function as follows:

$$comm\_cost = w_2 \cdot NRL + w_3 \cdot E2ED - w_1 \cdot PDR \quad (1)$$

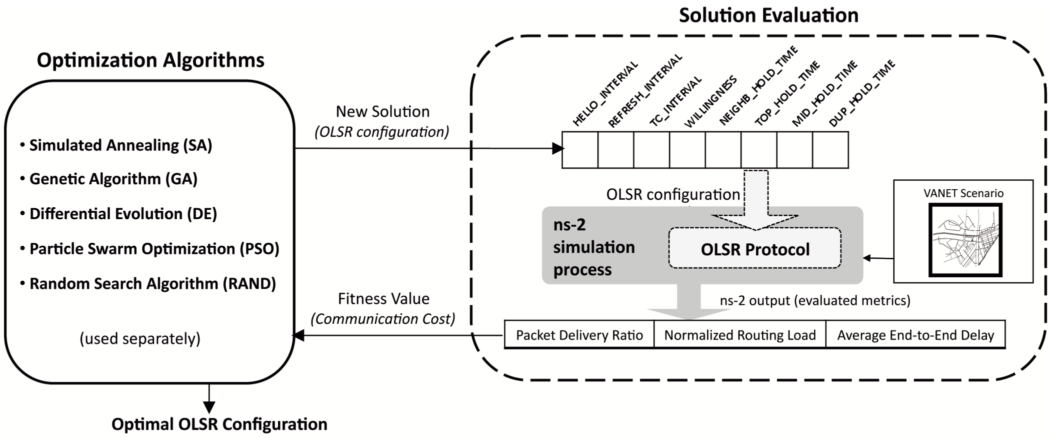


Figure 1: Optimization framework for the automatic OLSR configuration in VANETs. The algorithms invoke the *ns-2* simulator for each solution evaluation.

The communication cost function represents the fitness function of the optimization problem addressed in this paper. In order to improve the QoS, the objective here consists in maximizing PDR, and minimizing both, NRL and E2ED. As expressed in Equation 1, we used an *aggregative minimizing function*, and for this reason PDR was formulated with a negative sign. In this equation, factors $w_1$, $w_2$, and $w_3$ (0.5, 0.2, and 0.3, respectively) were used for weighing the influence of each metric on the resultant fitness value. This way, PDR takes priority over NRL and E2ED since we first look for the routing effectiveness and second (but also important) for the communication efficiency.

### 2.3.1 Urban VANET Scenario

The simulation task should offer a network environment as close as possible to the real world one. Following this idea, we make an effort to define realistic scenarios where VANETs may be deployed.

Since *ns-2* is a network simulator of general purpose, it does not offer a way for directly defining realistic VANETs simulations where the nodes of the network follow the behavior of vehicles in a road with other vehicles, traffic lights, traffic signs, etc. In order to solve this problem, we will use SUMO [20] road traffic simulator to generate a realistic mobility model [15]. This tool returns traces with the mobility definitions of nodes that can be used by *ns-2*. The main advantage of employing SUMO is that it can be used to generate realistic VANET environments by automatically selecting real areas from freely available digital maps, taking into account road directions, traffic signals, traffic rules, etc.

The VANET instance defined in this work contains 30 vehicles moving through the roads selected of an area of 1,200 × 1,200 $m^2$ from the city downtown of Málaga (Spain) during three minutes. The area inside the dotted line box of Fig. 2 shows the roads taken into account to define the VANET urban scenario for our experiments. Through the simulation time, a set of cars exchange data and, as in a urban road, their speed fluctuate between 10 $km/h$ (2.78 $m/s$) and 50 $km/h$ (13.88 $m/s$).

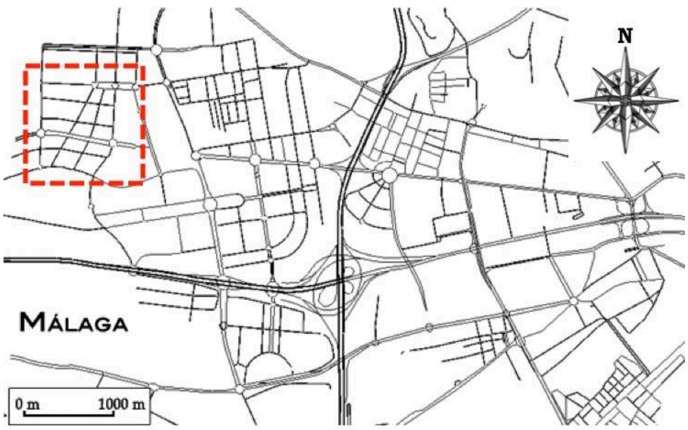


Figure 2: Málaga real urban VANET scenario. Selected area in the city downtown.

For this VANET scenario, we define a specific data flow trustworthy representing different possible communications that may exist. The data flow model performs 10 sessions of a constant bit rate data generator (CBR) which operates over UDP (User Datagram Protocol) agents defined in the nodes (vehicles). This way, the interconnected vehicles exchange the data generated by the CBR agents. The CBR data packet size is 512 bytes and the packet rate is 4 packets per second. The remaining of simulation parameters are summarized in Table 2.

Table 2: Main parameters defined for the *ns-2* simulation.

| Parameter | Value |
|---|---|
| Simulation time | 180 s |
| Simulation area | 1,200 × 1,200 $m^2$ |
| Number of vehicles | 30 |
| Vehicle speed | 10-50 $km/h$ |
| Propagation model | Two Ray Ground |
| Radio frequency | 2.47 GHz |
| Channel bandwidth | 5 Mbps |
| PHY/MAC protocols | IEEE 802.11b |
| Routing protocol | OLSR |
| Transport protocol | UDP |
| CBR data flow | 10 sessions |

# 3 Conclusions

This document defines the optimization problem of the OLSR routing protocol to be used in vehicular *ad hoc* networks by using an automatic optimization tool. This way we want to maximize the performance of this protocol. The number of possible configurations is very large, thus the problem of finding such a combination manually is very difficult. For this task, we have defined an optimization strategy based on coupling optimization algorithms and the *ns-2* network simulator. In the next deliverable, we will present how the problem is solved applying different metaheuristic techniques to solve it. Our general optimization framework constituted by the **Optimization Algorithm + Ns-2 Simulator** can be used to solve multitude of other optimization problems that can be found in the computer network domain.

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