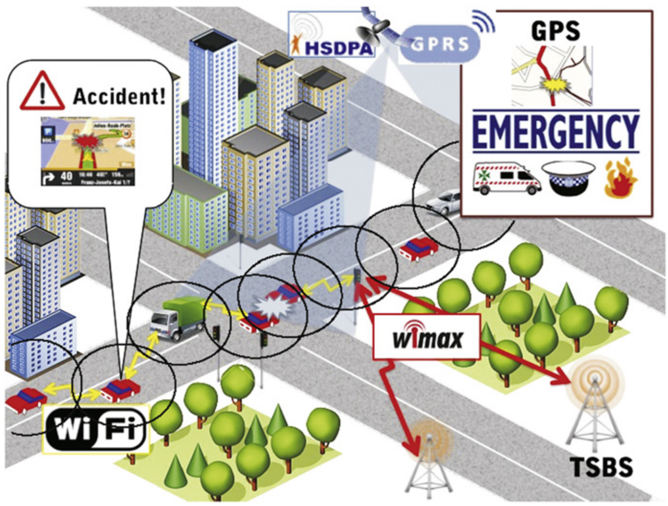

Fig. 1. Typical urban VANET scenario. Circles represent the WiFi coverage of vehicles.

metaheuristics (population and trajectory based algorithms), with suitable operators for real parameter optimization, and with heterogeneous schemes of population and evolution. This way, we offer a set of initial results allowing future comparisons with other modern techniques.

For our tests, two typical car-to-car environment instances have been defined: Urban and Highway VANETs, both in special connection to the work done in the *CARLINK CELTIC European Project* for linking cars. We rely both on a flexible simulation structure using *ns*- 2 (The Network Simulator Project—Ns-2; Alba et al., 2008c) (a well-known realistic VANET simulator), and real tests for optimizing the transmission time, the number of lost packets, and the amount of data transferred. One additional contribution of this work is to provide the specialist with a useful platform, embedded within *ns*-2, to configure network protocols (available in http://neo.lcc.uma.es/staff/jamal/portal/) and hence obtaining a fair QoS control in VANETs.

The remaining of this paper is organized as follows. In the next section we briefly describe the most relevant related works found in the current literature. In Section 3 we introduce the Optimal File Transfer Configuration problem. Section 4 provides preliminary descriptions of the compared algorithms. In Section 5, the optimization strategy and fitness function are described. Experimental results and comparisons are presented in Section 6, including performance, scalability, and technical analyses of the resulted VANET configurations. Conclusions and future work are drawn in Section 7.

2. Related work

Few related works can be found in the specialized literature concerning the use of metaheuristics for the optimization of mobile ad hoc networks (MANETs). Vanhatupa et al. (2006) proposed a flexible Genetic Algorithm for optimizing channel assignment in mesh wireless networks. In that work, the network capacity was increased by 20% while keeping the coverage above 80%. In Alba et al. (2007c), a specialized Cellular Multi-Objective Genetic Algorithm (cMOGA) was used for finding an optimal broadcasting strategy in Urban MANETs, obtaining in this case three objectives fronts with coverage, bandwidth, and duration as performance metrics. The use of multi-objective techniques in this kind of works provides the specialists with a range of non-dominated solutions which can help them in the decision making process. Nevertheless, the use of (mono-objective) aggregated functions allows us the possibility of weighting the objectives and assign more (or less) importance to them for better guiding the search. This way, in Dorronsoro et al. (2008), six versions of GAs (panmictic and descentralized) were evaluated and successfully used in the design of ad hoc injection networks. From a different point of view, and due to its specific design, ant colony optimization (ACO) has been successfully adapted for implementing new routing protocols for MANETs (Di Caro et al., 2005), as well as for resource management (Chiang et al., 2007). Nevertheless, in these two last cases, the routing load provoked by the internal operations of ACOs makes these approaches unfeasible for large networks. More recently, Huang et al. (2009) proposed a new routing protocol based on a PSO to make scheduling decisions for reducing the packet loss rate in a theoretical VANET scenario.

In our work, besides of using the optimization technique itself as a protocol algorithm, our main contribution consists of improving the performance of an existing protocol by optimally tuning its parameters. This way, we will hopefully obtain optimal configurations in the network design phase without incorporating extra management load to the actual network operation.

3. Problem overview

The optimal File Transfer Configuration consists in optimizing the main parameters required by an application communication protocol. This protocol, called VDTP (vehicular data transfer protocol) (Alba et al., 2006), operates on the transport layer protocols of VANETs, allowing the *end-to-end* file transfer. This implies that considerations about the *multi-hop* interconnection mode and routing issues can be avoided, since they are carried out by the previous down layer protocols (e.g., UDP, DSR, IP, etc.). Therefore, the different vehicles that constitute the nodes in a given VANET can exchange complete files of information to each other by using VDTP. In this section, we briefly describe the VDTP, detailing the main parameters to be optimized.

3.1. Vehicular data transfer protocol

VDTP is a connectionless protocol which operates on DSR (Johnson et al., 2001), a routing protocol for multi-hop wireless ad hoc networks. In VDTP, the communication process is carried out by both a file *petitioner*, which tries to download a file, and a file *owner*, which stores the file. This transfer protocol operates by using the following packets: *FIRQ* (*file information request*), *FIRP* (*file information reply*), *DRQ* (*data request*), and *DRP* (*data reply*). As shown in Fig. 2(a), once the file petitioner knows the name and the location of a given file, it starts the communication by using the FIRQ packet in order to obtain the file size. Then, the petitioner waits for this information which is sent by the owner by means of a FIRP packet. After receiving the information about the file size, the petitioner computes the number of segments in which the file will be split, dividing the file size by the *chunk_size*. The petitioner starts the transfer by sending a DRQ(1) packet asking for the first segment of the file; then it waits for the first data chunk sent by the owner which uses the DRP(1) packet. This operation is repeated by both, petitioner and owner, until transferring the last chunk DRP(n), and hence making up the complete file.

In VANETs, it is usual to work in a hostile medium which can provoke a high number of lost packets during the communication process. In this sense, VDTP provides the specialist with several mechanisms based on timers and counters, in order to solve such