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# RTAD: A real-time adaptive dissemination system for VANETs

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ABSTRACT

Efficient message dissemination is of utmost importance to propel the development of useful services and applications in Vehicular ad hoc Networks (VANETs). In this paper, we propose a novel adaptive system that allows each vehicle to automatically adopt the most suitable dissemination scheme in order to fit the warning message delivery policy to each specific situation. Our mechanism uses as input parameters the vehicular density and the topological characteristics of the environment where the vehicles are located, in order to decide which dissemination scheme to use. We compare our proposal with respect to two static dissemination schemes (eMDR and NJL), and three adaptive dissemination systems (UV-CAST, FDPD, and DV-CAST). Simulation results demonstrate that our approach significantly improves upon these solutions, being able to support more efficient warning message dissemination in all situations ranging from low densities with complex maps, to high densities in simple scenarios. In particular, RTAD improves existing approaches in terms of percentage of vehicles informed, while significantly reducing the number of messages sent, thus mitigating broadcast storms.



## 1. Introduction

Modern Intelligent Transportation Systems (ITS) are being propelled by the development and adoption of wireless telecommunications and computing technologies, which allow our roads and highways to be both safer and more efficient transportation platforms. Vehicular ad hoc Networks (VANETs) are wireless communication networks which support cooperative driving among vehicles on the road. In such networks, vehicles act as communication nodes and relays, establishing dynamic vehicular networks together with other nearby vehicles [2].

The specific characteristics of VANETs favor the development of attractive and challenging services and applications, including road safety [7,4], traffic flow management [25,36], road status monitoring [14], environmental protection [21], and mobile infotainment [24]. In this work we focus on traffic safety and efficient warning message dissemination, where the main goal is to reduce the latency and to increase the accuracy of the information received by nearby vehicles when a dangerous situation occurs [41].

In a VANET, any vehicle detecting an abnormal situation (i.e., accident, slippery road, etc.) rapidly starts notifying the anomaly to nearby vehicles to spread the alert information in a short period of time [13]. Thus, broadcasting warning messages can be useful to alert nearby vehicles. However, this dissemination is strongly affected by: (i) the signal attenuation due to the distance between the sender and receiver (especially in low vehicular density areas), (ii) the effect of obstacles in signal transmission (very usual in urban areas, e.g., due to buildings), and (iii) a reduced message delivery effectiveness due to serious redundancy, contention, and massive packet collisions provoked by simultaneous forwarding, usually known as broadcast storm (prone to occur in highly congested areas) [37]. Therefore, knowing the density of vehicles and the characteristics of the area where the vehicles are moving (e.g., in terms of topological complexity) can offer better opportunities for message delivery.

We consider that new adaptive proposals for warning message dissemination in urban environments are needed, offering efficient broadcasting techniques around the affected area, taking into account the current vehicular density, as well as the topology of the scenario where vehicles are located. This can be beneficial in order to increase the efficiency of the warning message dissemination process, and also to reduce broadcast storm related problems. The objective is to increase the probability of correctly alert surrounding vehicles, thereby preventing new dangerous situations.

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In this paper we propose RTAD, a real-time adaptive dissemination system that allows each vehicle to automatically adopt the most suitable dissemination scheme to adapt the warning message delivery policy to each specific situation. Our mechanism uses as input parameters the estimated vehicular density (according to a neighbor-based density estimation scheme) and the topological characteristics of the environment where the vehicles are located, using them to decide which dissemination scheme to use, maximizing the message delivery effectiveness, and avoiding or mitigating broadcast storms. In addition, we also propose the Nearest Junction Located (NJL), our novel warning message dissemination scheme specially designed for being used in highly congested urban areas.

This work is an extended version of a preliminary contribution presented in Sanguesa et al. [27]. In particular, we have implemented and assessed the feasibility of RTAD. Additionally, since the RTAD system needs to estimate the vehicle density to select the most appropriate broadcast scheme, our approach uses the number of neighbors, instead of the number of beacons received, to estimate the vehicle density. In order to assess RTAD's performance, we tested it under four different scenarios: two of them previously used to calibrate the algorithm (Amsterdam and Los Angeles), and two new scenarios (Sydney and Santiago de Chile) characterized by larger map areas, as well as having one (Sydney) or two (Santiago de Chile) different downtown areas. Finally, we have included a comparison between our proposal and two static broadcast schemes (eMDR and NJL), as well as three adaptive systems (UV-CAST, FPDP and DV-CAST).

The paper is organized as follows: in Section 2 we present the simulation environment used to validate our proposal and some previous concepts. In Section 3 we make a preliminary analysis of different broadcast schemes, and we present the Most Suitable Broadcast Selection Algorithm proposed. Section 4 introduces RTAD, our real-time adaptive warning dissemination system. Section 5 presents and discusses the obtained results. In Section 6 we review previous works closely related to our proposal, highlighting the main similarities and differences. Finally, Section 7 concludes this paper.

## 2. Simulation environment and previous concepts

Simulation results presented in this paper were obtained using the ns-2 simulator [3], modified to consider the IEEE 802.11p standard.[1] In terms of the physical layer, the data rate used for packet broadcasting is 6 Mbit/s, as this is the maximum rate for broadcasting in 802.11p [8]. The MAC layer was also extended to include four different channel access priorities. Therefore, application messages are categorized into four different Access Categories (ACs), where AC0 has the lowest and AC3 the highest priority. The purpose of the 802.11p standard is to provide the minimum set of specifications required to ensure interoperability between wireless devices when attempting to communicate in potentially fast-changing communication environments. For our simulations, we chose the IEEE 802.11p because it is expected to be widely adopted by the industry.

The simulator was also modified to make use of our *Real Attenuation and Visibility* (RAV) scheme [18], which proved to increase the level of realism in VANET simulations using real urban roadmaps in the presence of obstacles. The RAV propagation model is presented in detail in Section 2.1. As for vehicular mobility, it has been obtained with CityMob for Roadmaps (C4R) [5], a mobility generator based on the SUMO traffic simulator [10], able to import maps directly from OpenStreetMap [22], and make them available for being used by the ns-2 simulator. C4R has microscopic traffic capabilities such as: collision-free vehicle movement and overtaking, multi-lane streets with lane changing, junction-based right-of-way rules, and traffic lights.

To generate the movements for the simulated vehicles, we used the Krauss mobility model [12,11] available in SUMO with some modifications to allow multi-lane behavior. This model is based on collision avoidance among vehicles by adjusting the speed of a vehicle to the speed of its predecessor using the following formula:

$$v(t+1) = v_1(t) + \frac{g(t) - v_1(t)\tau}{\tau + 1} - \eta(t), \quad (1)$$

where $v$ represents the speed of the vehicle in m/s, $t$ represents the current simulation time in seconds, $v_1$ is the speed of the leading vehicle in m/s, $g$ is the gap to the leading vehicle in meters, $\tau$ is the driver's reaction time (set to 1 s in our simulations), and $\eta$ is a random variable uniformly distributed over the interval [0, 1] m/s.

Our mobility simulations also account for areas with different vehicle densities. In a real town, traffic is not uniformly distributed; there are downtowns or points of interest that may attract vehicles. Hence, we include the ideas presented in the *Downtown Model* [16] to add points of attraction in realistic roadmaps.

With regard to data traffic, vehicles operate in two modes: (a) warning mode and (b) normal mode. Warning mode vehicles inform other vehicles about their status by sending warning messages periodically with the highest priority at the MAC layer; each vehicle is only allowed to propagate them once for each sequence number. Normal mode vehicles enable the diffusion of these warning messages and, periodically, they also send *beacons* with information such as their positions and speed. These periodic messages have lower priority than warning messages, and they are only useful in the vicinity of the vehicles, hence not being broadcasted by other vehicles.

The roadmaps used in the simulations were selected in order to have different profile scenarios (i.e., with different topology characteristics). Table 1 and Fig. 1 show the topology and the main features of the cities simulated, respectively. Note that we included a column labeled as *SJ Ratio*, which represents the result of dividing the number of streets between the number of junctions. As shown, the first four cities (Rome, Valencia, Sydney, and Amsterdam) present an SJ ratio greater than 1, which indicates that they have a complex topology, while the rest of the cities (Los Angeles, San Francisco, and Madrid) present a lower SJ value, which indicates that they have a simple topology. In Section 2.2 we detail how we account for the number of streets.

We are interested in the following performance metrics: (i) percentage of informed vehicles and (ii) number of messages received per vehicle. The percentage of informed vehicles is the percentage of vehicles that do receive the warning messages sent by warning mode vehicles. The number of messages received per vehicle

**Table 1**
Map features.

| Map | Streets | Junctions | SJ ratio |
|---|---|---|---|
| Rome | 1655 | 1193 | 1.387 |
| Valencia | 2829 | 2233 | 1.267 |
| Sydney | 872 | 814 | 1.071 |
| Amsterdam | 1494 | 1449 | 1.031 |
| Los Angeles | 287 | 306 | 0.938 |
| San Francisco | 725 | 818 | 0.886 |
| Madrid | 628 | 715 | 0.878 |

[1] All these improvements and modifications are available at http://www.grc.upv.es/software/.