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A scalable data dissemination protocol based on vehicles trajectories analysis

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ABSTRACT

Since the last decade, the emergence of affordable wireless devices in vehicle ad-hoc networks has been a key step towards improving road safety as well as transport efficiency. Informing vehicles about interesting safety and non-safety events is of key interest. Thus, the design of an efficient data dissemination protocol has been of paramount importance. A careful scrutiny of the pioneering vehicle-to-vehicle data dissemination approaches highlights that geocasting is the most feasible approach for VANET applications, more especially in safety applications, since safety events are of interest mainly to vehicles located within a specific area, commonly called ZOR or Zone Of Relevance, close to the event. Indeed, the most challenging issue in geocast protocols is the definition of the ZOR for a given event dissemination. In this paper, we introduce a new geocast approach, called *Data Dissemination Protocol based on Map Splitting* (DPMS). The main thrust of DPMS consists of building the zones of relevance through the mining of correlations between vehicles' trajectories and crossed regions. To do so, we rely on the Formal Concept Analysis (FCA), which is a method of extracting interesting clusters from relational data. The performed experiments show that DPMS outperforms its competitors in terms of effectiveness and efficiency.

1. Introduction

Owing to the embedded devices into modern cars, the issues related to transportation (e.g., traffic congestion, road safety and driver comfort) are grasping more and more interest. In fact, thanks to these embedded devices, vehicles are able to detect several types of basic events (e.g., accidents, empty parking places, bottling, obstacles, weather conditions, road cut, to mention a few). Interestingly enough, vehicles are also able to exchange such information through a Vehicular Ad-hoc Network (VANET). Indeed, this network enables advanced Intelligent Transportation System (ITS) services including various safety and non-safety applications. In this respect, a core and challenging issue in vehicular networks is the design of an efficient data dissemination protocol able to inform vehicles about important events. The thriving challenge would be to maximize the reachability ratio, i.e., by only informing the interested vehicles, and by avoiding as far as possible the broadcast storm problem.[1] A careful scrutiny of the pioneering vehicle-to-vehicle data dissemination approaches highlights two main categories to do that: broadcast or geocast based techniques. It is worthy to mention that the main moan to be addressed in the broadcast techniques relies on the message dissemination to all the vehicles in the networks without exception, which is costly and useless in various scenario since vehicles are not always concerned by all events. This drawback has contributed to the emergence of another alternative: geocast-based techniques allowing information delivery to vehicles inside a specific region. Indeed, geocasting is the most feasible data dissemination approach for VANET applications, more especially in safety applications, since safety events are of interest to vehicles within a specific area standing close to the event location. Interestingly enough, a geocast-based approach needs to cope with the following requirements:

1. Determine the geocast area, also called *Zone Of Relevance* (ZOR) of an event;
2. Deliver the message to all vehicles within the ZOR; and
3. Keep the geocasted message alive in the network for a desired delay, such that the disseminated information could reach all the arriving vehicles.

Although the literature witnesses a wealthy number of geocast-based techniques for data dissemination, only few of them consider all of the three aforementioned requirements. Indeed, the

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[1] The broadcast storm is known to lead to network saturation as well as conflict and collision issues

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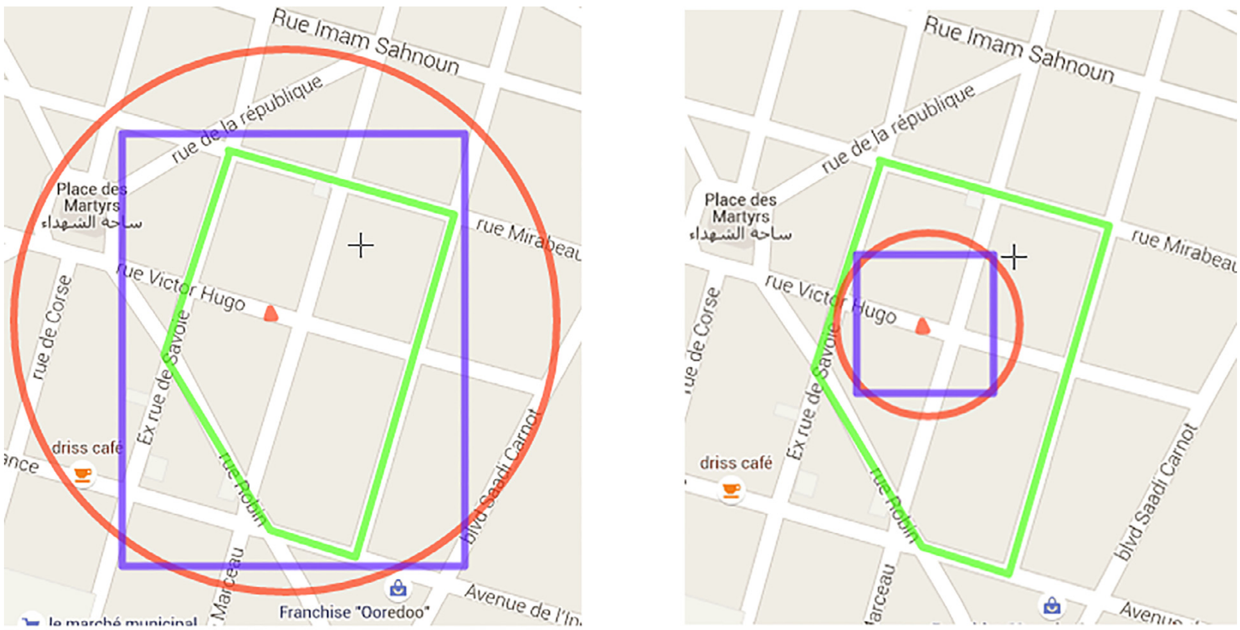

(a) The target region is too wide **(b)** The target region is too narrow

Fig. 1. Zone of relevance vs target region specifications.

most challenging issue for geocast protocols is the definition of the ZOR for an event dissemination. Unfortunately, the existing geocast-based protocols define the ZOR in a simplified manner as: a rectangle [1–3], or a circle or polygon [4] which is strongly restrictive. For example, in Fig. 1, the green region is considered as the ZOR of an accident warning; however, the target regions are specified as a circle or a rectangle, which are smaller or larger than the ZOR. Therefore, in the first case (Fig. 1a), a lot of unnecessary messages are exchanged and send to unconcerned vehicles. Whereas, in the second case (Fig. 1b), many concerned vehicles won't receive the message.

In order to cope with the aforementioned requirements, we propose here a new geocast approach for urban area, called Data Dissemination Protocol based on Map Splitting *(DPMS)*. DPMS aims to reach a high reachability ratio as well as a high geocast precision by sending messages only to vehicles in the ZOR with a minimum overhead cost. The main originality of DPMS is the computation of the ZORs through the unveiling of strong connections between the set vehicle trajectories and a set of regions. Thus, the determination of the ZORs can be seen as an instantiation of the cover set problem [5], i.e., finding the minimal coverage of the boolean matrix, in terms of formal concepts, keeping track of the relationship between vehicle trajectories and map regions.

The remainder of this paper is organized as follows. In Section 2, we describe the pioneering existing approaches in order to show their limitations/drawbacks. In Section 3, we thoroughly describe the main idea of our dissemination protocol, before presenting in Section 4 the simulation settings and the evaluation of the proposed DPMS protocol. Also, a comparison between DPMS and other main geocast protocols is presented here. The last section concludes this study and pins down several future directions.

2. Related work

VANET security applications aim at improving drivers and passengers safety on roads by notifying any dangerous situation. Generally, these applications are based on data dissemination, which are most of the time periodic. This is to enable the state of the road and surrounding vehicles. The VANET data dissemination protocols can be categorized as infrastructure-based and infrastructure-less [4]. The infrastructure-based protocols [6–8] use RoadSide Units (RSU) in junctions and along the roads to store and disseminate VANET messages. These protocols generally achieve good results. However, they rely on costly infrastructures. In this respect, infrastructure-less protocols have been recently attracting more interest by the scientific community due to their capability to disseminate information without relying on a costly infrastructure. They can be categorized into either broadcast or geocast data dissemination protocols [9]. In the following, we discuss the most recent ideas including intelligent broadcasting and geocasting techniques.

2.1. Broadcast-based data dissemination

Broadcasting techniques are frequently used in VANETs for data sharing, traffic information, weather, entertainment and commercial announcements, with the aim to disseminate information to all vehicles, without exception, using blind or moderated flooding mechanisms [9–11]. Within a blind flooding, a vehicle broadcasts each received or detected information to all neighboring vehicles. This approach can increase reachability by informing all interested vehicles. However, it undoubtedly leads to network congestion, conflict and collision issues, often named the broadcast storm problem [10]. In the literature, several research studies have attempted to improve this by adopting various suppression techniques, which are probabilistic (e.g., weighted p-persistence) [10], timer-based (i.e., Slotted 1-persistence) [10], or hybrid (*i.e.*, Slotted p-persistence) [10]. These techniques have tempted to reduce the broadcast redundancy and the packet loss ratio by decreasing the number of vehicles spreading the same message while ensuring a high reachability. In p-weighted persistence [10], a forwarding probability is assigned to each neighboring vehicle according to its distance to the message broadcaster. A higher forwarding probability is assigned to the vehicles that are located farther away from