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DDGP: Distributed Data Gathering Protocol for vehicular networks

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ABSTRACT

Vehicular Ad-Hoc Network (VANet) is an emerging research area, it offers a wide range of applications including safety, road traffic efficiency, and infotainment applications. Recently researchers are studying the possibility of making use of deployed VANet applications for data collection. In this case, vehicles are considered as mobile collectors that gather both real time and delay tolerant data and deliver them to interested entities. In this paper, we propose a novel Distributed Data Gathering Protocol (DDGP) for the collection of delay tolerant as well as real time data in both urban and highway environments. The main contribution of DDGP is a new medium access technique that enables vehicles to access the channel in a distributed way based on their location information. In addition, DDGP implements a new aggregation scheme, which deletes redundant, expired, and undesired data. We provide an analytical proof of correctness of DDGP, in addition to the performance evaluation through an extensive set of simulation experiments. Our results indicate that DDGP enhances the efficiency and the reliability of the data collection process by outperforming existing schemes in terms of several criteria such as delay and message overhead, aggregation ratio, and data retransmission rate.

1. Introduction

In vehicular networks, many applications have been developed and envisioned to enhance the road safety, the traffic conditions, and passenger's comfort [1,2]. A successful deployment of such applications in Vehicular Ad hoc Networks (VANet) depends on proper information collection and dissemination. This information includes road density, velocity of vehicles, traffic congestion, upcoming event, free parking lots, localization services, shops' sales announcement, etc. To do so, vehicles are equipped with sensing equipment powered through unlimited energy and have a high capacity of data storage and processing.

Many data collection protocols have been developed for VANet. Most of them have been inspired from Wireless Sensor Networks (WSN) and consider the vehicles as mobile collectors [3–7]. However, when compared to WSN, VANet are characterized by a highly dynamic topology, and a different mobility pattern, which makes it infeasible to adopt collection protocols designed for WSN. That is the design of an efficient data collection scheme must be adapted to the specificities of VANet and which takes into consideration the mobility of nodes and their large number. Moreover, the performance of any designed data collection protocol in VANet is related to the medium access technique that is used. An efficient medium access technique must avoid incurring a high number of collisions during packets exchange, and must allow retransmission of erroneous packets.

Existing access techniques in the literature fall under two main classes of access: contention-based techniques and contention-free techniques [8]. The first class is characterized by a random access to the channel. It includes the 802.11p [9], which is the main communication standard for VANet. Nevertheless, several studies [10,11] have indicated that 802.11p, being a CSMA/CA based, suffers from an undesired decrease in throughput and an increase in the delay especially when the number of vehicles increases. To confirm these results, we evaluate the performance of 802.11p standard through simulation study. We consider a road segment in which there are 50 vehicles having data to be transmitted to a cluster head vehicle. Fig. 1a shows that the vehicles' throughput will decrease dramatically due to the increasing number of collision (cf. Fig. 1b). As mentioned earlier, the obtained results can be justified by the random channel access of vehicles.

On the other hand, the contention-free techniques like Time Division Multiple Access (TDMA) and Space Division Multiple Access (SDMA) [12] allow vehicles to access the channel in a scheduled

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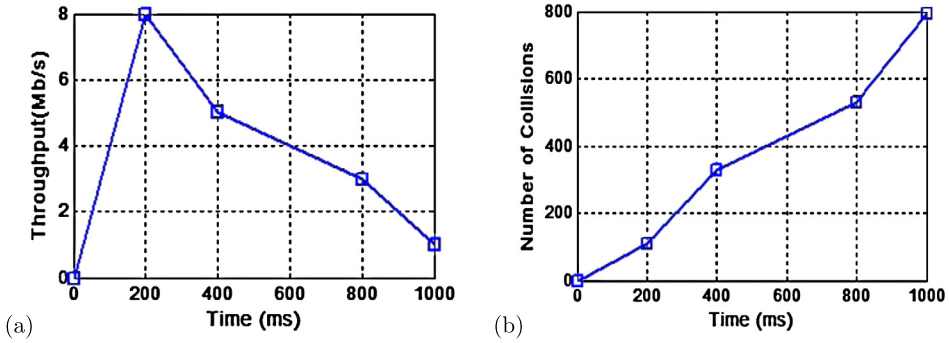

Fig. 1. The performance of 802.11p standard. (a) Throughput. (b) Collision problems.

Table 1
List of acronyms.

Acronyms	Descriptions
CA	Collection Area
CDGP	Clustered Data Gathering Protocol
CGP	Clustered Gathering Protocol
CH	Cluster Head
CS	Collection Segment
CTS	Clear To Send
DDGP	Distributed Data Gathering Protocol
DTD	Delay Tolerant Data
GI	Guard Interval
NRV	New Road Vehicle
RSB	Road Side Backbone
RSC	Road Side Collector
RSCI	Road Side Collectors Initiator
RTD	Real Time Data
RTS	Request To Send
RV	Road Vehicle
RVC	Road Vehicle Collector
RVI	Road Vehicle Initiator
RVS	Road Vehicle Sink
SDMA	Space Division Multiple Access
SS	Silence Segment
TCDGP	Token-based Clustered Data Gathering Protocol
TDMA	Time Division Multiple Access
TS	Time Slot
VL-CSMA	Vehicular Location-based Carrier Sense Multiple Access

way. These techniques guarantee a finite access time to the channel, and enhance the reliability of data transfer. But, this class of access usually needs a centralized controller node to manage the timeslots assignment, and requires a hard segmentation of the road into small cells before affecting a time-slot to each cell.

In previous studies [3,4], we proposed two centralized data collection protocols called CDGP and TCDGP for collecting data in delay tolerant networks (DTN). In this paper, we propose a new Distributed Data Gathering Protocol (DDGP) adapted for both delay tolerant and real time data collection for VANet. The novelty of DDGP protocol lies in the following characteristics: (a) it allows vehicles to access the channel, in a scheduled and distributed manner, based on their geographical positions and by using a novel scheme that we call Vehicular Location-based Carrier Sense Multiple Access (VL-CSMA), (b) it supports delay tolerant as well as real time data collection, (c) it uses a new aggregation scheme based on which undesired and irrelevant data is deleted, which eventually improves the collection efficiency, and finally (d) it is adapted to both urban and highway environments.

The remainder of this paper is organized as follows. In section 2, we present a background on data collection process in VANet and we elaborate on a new taxonomy of data collection protocols in VANet. Subsequently, we detail our new proposed DDGP protocol in section 3. Proof of correctness and the complexities studies are shown in section 4. Then, simulation results are discussed in section 5. Finally, we conclude the paper in section 6. Table 1 shows the list of acronyms used in this paper.

2. Background and related works

In vehicular networks, data collection protocols are used to gather both real time and delay tolerant information in order to support many safety and non-safety related applications like road incidents, vehicles' average speed and positions, road density, congestion information, commercial ads, sale announcement, and upcoming or past events.

Just as for wireless mobile networks, the data collection process in VANet consists of three main phases:

1. *Collection process initiation*: Based on the application requirements, a vehicle or an Road Side Unit (RSU) initiates the data collection process by specifying all input parameters of the process such as the data freshness and type.
2. *Data collection and aggregation*: During this phase, all informed vehicles must collect designated data. In order to enhance the overall performances of the collection operation, a vehicle can aggregate its collected data with those gathered from other vehicles before delivering them to the initiator node.
3. *Data delivery*: Once the collection phase is achieved, the specified collected data must be delivered to the initiator by the collector vehicles.

In the literature, data collection protocols can be classified based on the medium access technique used which may be characterized by scheduled or random medium access way. So, in what follows, we present data collection protocols according to these two main medium access way (scheduled or random).

2.0.1. Scheduled medium access based protocols

In scheduled medium access based protocols [13,3,4], collector vehicles access the medium in an orderly manner. This access is organized either by a centralized node (cluster-head vehicle or an RSU), which allows reducing the number of collision problems during Vehicle to Vehicle (V2V) communications, or by arranging the nodes in a distributed way without the need for a central node.

A scheduled centralized cluster-based protocol named TrafficGather is proposed in [13]. TrafficGather uses static SDMA[1] scheme [12], and consists of three main phases: (1) network configuration phase, during which a vehicle (cluster vehicle, CV_0) initiates the data collection process and it forms a first cluster space (CS), then many CSs are formed, in a dynamic manner by the vehicles. (2) The data collection phase, wherein all vehicles send

[1] A medium access technique that segments the road into small cells, before allocating a time slot to each cell.