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An information congestion control scheme in the Internet of Vehicles: A bargaining game approach☆

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ABSTRACT

In VANETs (Vehicular Ad Hoc Networks), the information exchange plays an important role for context awareness. However, at intersections, a channel congestion is likely occurring if no control scheme is applied for the exchange especially when the vehicle density is high. To solve this problem, a congestion control scheme is proposed based on the non-cooperative bargaining game. First, vehicles approaching intersections are divided into clusters. By introducing a simple channel-load estimation scheme, our bargaining game is presented by which the cluster leaders could negotiate an optimal combination of the transmitting power and packet generation rate for their members. When the Nash Equilibrium of our game is reached, the utility of each player will be maximized without making the channel congested. Numerical results show that our scheme could alleviate the possible packets collisions thus reducing the average experienced delay and increasing the packets delivery ratio on the receiver side.

1. Introduction

In the last few years, VANETs have been rapidly evolving and new scenarios have been coming out [1]. As an example, the integration of the concept of the Internet of Things (IoTs) with the VANETs has brought to a novel paradigm, namely the Internet of Vehicles (IoVs): by allowing the vehicles to be durably connected to the Internet, they can form the IoVs that is an interconnected set of vehicles which provide information for common services such as traffic management and road safety. To achieve these goals, vehicles generally rely on two information dissemination ways: I) Periodic messages (beacons): exchanging states information among nodes periodically, e.g. position, speed, yaw angle and so forth; II) Event-driven messages: broadcasting in case of emergency happening, e.g. collisions, road surface collapse, tunnel fire etc. If a large number of vehicles send beacons at a higher rate or the event-driven messages are broadcasted too often, the communication channel will readily be congested. In this case, some new generated event-driven messages may not be able to access the channel at all, thus providing no safety guarantee.

Note that, till now, the only proposed congestion control mechanism in the popular IEEE 802.11p draft is to prevent any message, except from the highest priority, to be transmitted if the measured channel occupancy is larger than 50% [2].

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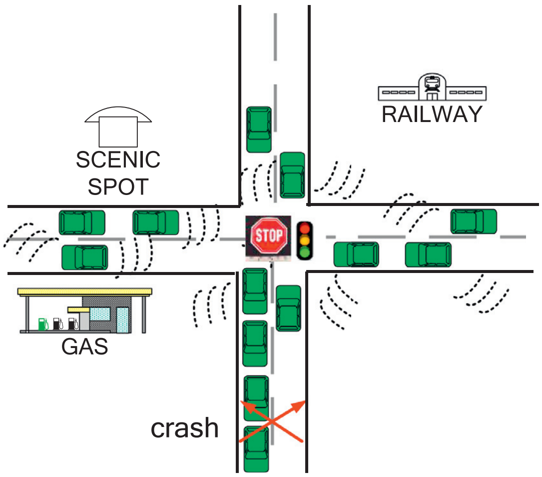

Fig. 1. An example of the information exchange at an intersection.

However, this scheme sacrifices awareness among vehicles and cannot be applied to the periodical beacon congestion case where no event driven application exists. Moreover, the reserved bandwidth for emergencies could not be fully utilized in most event driven cases because only a few bits are needed to be transmitted to others as notifications.

Compared to other deployment cases, the intersections, where a high vehicle density and variety of application use-cases may occur, are greatly depending on the frequent message exchanges. For example, since long sojourn duration is possible at intersections due to crowded traffics, traffic lights or stop signs, vehicles could exchange their collected information such as passed POIs (Points of interests), current traffic situations, accident locations, road surface conditions and so forth, as illustrated in Fig. 1. Besides, the intersections or junctions based routing protocols [3,4] in VANETs need to get important decision metrics regarding path selection around intersections, which impose strict requirement on the data exchange from or to nodes nearby the intersections in terms of the packets delivery ratio and average transmission delay. Some routing strategies [5] even turn to the right-turn vehicles to store-carry-forward the delay sensitive information so as to reduce the experienced delay. Accordingly, considering the frequent exchanges of application specific information at intersections, vehicle-to-vehicle communications around interactions has a higher possibility to result in the channel congestion, which in turn may pose serious threats to the driving safety relying on the effective messages interactions. Thereupon, an efficient congestion control mechanism is much necessary in such scenario. However, to our best knowledge, such issue has not been investigated thoroughly in our envisioned case.

To solve above issues, in our work, an open loop congestion control approach at road intersection has been proposed, which aims to prevent the possible channel congestion in advance with our presented cluster-based channel load monitoring model and game theory based load control strategy. In each reference interval, the selected cluster leaders represent their cluster members to negotiate an agreement in terms of the transmission power and packets generation rate for information exchange between clusters using our proposed bargaining game. Since vehicles move with a relative lower speed when approaching intersections, the game theory based scheme is feasible in view of sufficient convergence time.

In summary, the contributions of our work can be generalized as follows:

1. By monitoring the channel load, a clustering based bargaining game is proposed among cluster leaders to reduce the channel congestion at intersections through the adjustment of the transmitting power and packets generation rate.
2. To make our game feasible in the dynamic changing environment, the price factor and a parameter ε are introduced to speed up the convergence of the game.

The rest of the paper is organized as follows. Some related works have been reviewed in Section 2. Section 3 introduces our model assumptions and proposed congestion control framework. In Section 4, the details of our congestion control scheme are given with presented load monitoring/estimating strategy and envisioned non-cooperative bargain game. Numerical results and corresponding performance evaluations are presented in Section 5. Our works are concluded in Section 6.

2. Related works

In VANETs, a congestion control strategy may not be performed well in a centralized way, which proves to be successful in the wired and stationary networks. Thereupon, in most of the VANETs applications, the distributed and self-organized mechanism should be introduced to make the algorithms execute locally on each node. For decentralized congestion control schemes, there have been several works which can be mainly classified into three categories, i.e. utility, power control and rate adjustment based. Next, let us discuses some related works regarding these categories as follows.

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