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A congestion avoidance game for information exchange on intersections in heterogeneous vehicular networks

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ABSTRACT

Recently, the concept of HetVNET (Heterogeneous Vehicular NETwork) is greatly motivated by the fact that present wireless networks not only offers their attractive benefits, but also bring their shortcomings together. In this paper, by integrating the GIS (Geographic Information System), GPS (Global Position System), Sensor network, Vehicular Ad Hoc Networks (VANETs) and other localization technologies into our work, we propose a RoS (Requirement of Safety) aware services scheduling in the HetVNET to improve the packets delivery ratio, increase the spectral efficiency and alleviate the packet congestion as well. In addition, through utilizing the SINR-based (Signal to Interference plus Noise Ratio) utility and social optima searching strategy, our proposed algorithm outperforms the IEEE 802.11p in terms of the throughput as well as service miss ratio with the EDF (Earliest Deadline First) queuing mechanism. In addition, to reflect the increased transmission opportunities, the channel busy ratio under different configurations is also compared with a previous work DynB (Dynamic Beaconing).

1. Introduction

In the recent decades, to improve the road safety, traffic efficiency and travel comfort, the Intelligent Transportation System (ITS) has become a very hot topic, which is actually a system consisting of heterogeneous networks such as IoT (Tsai et al., 2014; Qiu et al., 2016a), LTE, VANETs, GPS, GIS, sensor network (Tsai et al., 2016; Tsai, 2016) etc. For this purpose, the concept of HetVNET (Heterogeneous Vehicular NETwork) are thereafter proposed. In general, to make the HetVNET work, the information exchange between different vehicles or vehicles and the infrastructure is very necessary. To reach this goal, two information dissemination ways are usually employed, say the periodic messages (beacons) which exchange states information among vehicles through deployed sensor networks; and the event-driven messages, which are broadcasted when emergencies happen such as rear-end collisions, tunnel fire, rock-falling and so on. Although the success of a critical application may rely on the effective exchange of some event-driven messages in very emergent cases, the periodical broadcasting also plays an important role for safety guarantee in a HetVNET.

Generally speaking, the correctness and up-to-datedness of the safety-related information significantly rely on the reception ratio and frequency of the broadcasts. For instance, in a CCA (Cooperative Collision Avoidance) system, the collision probability between two adjacent vehicles is greatly influenced by the reception ratio of braking promptings sent from surrounding vehicles. As shown in Fig. 1, even though the two following vehicles after the front braking one might have enough time to avoid the possible crash with the help of wireless broadcasting, the packets collisions from other broadcasted or event-driven messages perhaps fail this emergency notification in some cases. Another instance is depicted in Fig. 2 where two vehicles from different directions approaching an unsignalized intersection become blind to each other. For this case, to prevent severer accidents, at least one of the periodical notifications should be received by the two vehicles in danger. (Fig. 3).

Among the other scenarios, the intersection is specifically relying on the efficient packets interchange to improve the awareness and intelligence of vehicles. For example, since long sojourn duration is possible at intersections due to crowded traffics, signal lights or stop signs, vehicles could exchange their collected information at intersections such as passed POIs (Points of interest), current traffic situations, accident locations, road surface conditions and so forth. Additionally, a junction based routing usually require special metrics regarding path construction on intersections, which demands efficient and reliable

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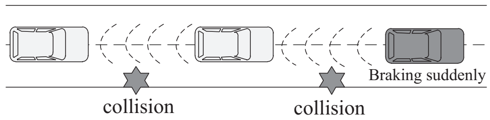

Fig. 1. An example of CCA.\

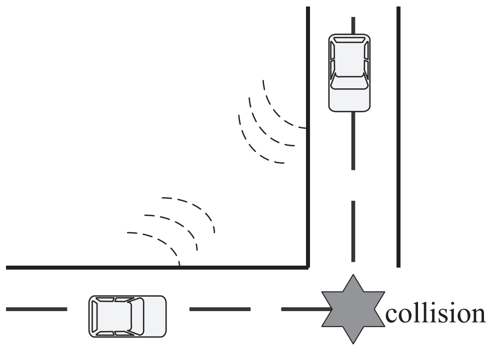

Fig. 2. An example for blind point detection.

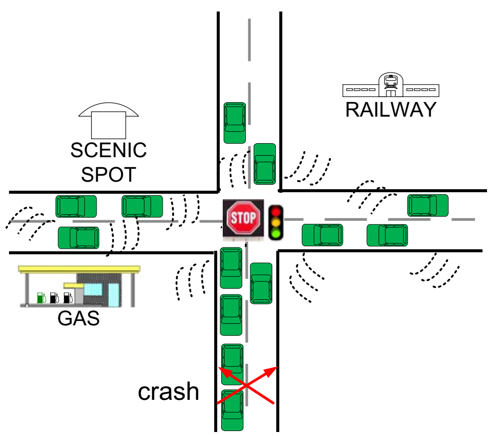

Fig. 3. An example of messages exchanging at an intersection.

information exchange around intersections (Qiu et al., 2016b). Accordingly, in view of the frequent interchange of packets, the communication between vehicles at interactions is very prone to make the channel congested by which the driving safety relying on effective messages interactions might be harmed. Thereupon, an efficient congestion control mechanism for HetVNET is very necessary under such situations.

The rest of our paper is organized as follows. In Section 2, the research motivations and our main contributions are given. After that, we investigated the related works regarding information congestion control in vehicular environment in Section 3. In Section 4, our proposed congestion control scheme is presented with reasonable assumptions. Section 5 shows the performance comparisons and corresponding analysis. Finally, our paper is concluded by Section 6.

2. Motivations and premises

According to the previous works, it can be noticed that the performance of services relying on the periodical beacons significantly reduces especially under much dense environment. For instance, if an accident happens during the rush hours, the simultaneous notifications from vehicles nearby might readily saturate the channel load and result in strong interferences at the receivers. Even for the de facto standard of vehicular networks, i.e., DSRC (Dedicated Short Range Communication), the congestion control problem is still open for further improvement and not well solved.

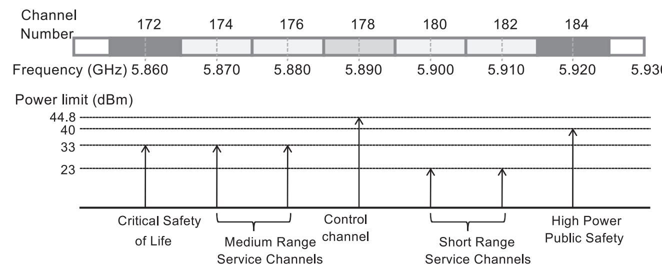

Fig. 4. Multi-channel assignment in DSRC.

As depicted in Fig. 4, the DSRC has assigned seven 10 MHz width channels around 5.9 GHz (Cheng et al., 2007). In addition, a high priority task in DSRC will be correspondingly given a higher transmitting power to guarantee the successful decoding of sent packets. For example, the services related with "public safety" and "critical safety of life" are given high priorities and use relatively high power to make sure that no failure of receiving is occurring on the receiver side, which will then save life and property. However, even the safety related applications are given the highest priorities, the strongest power used in DSRC is still reserved for the control channel, which is always ready to response to the very emergent events and reserve all available bandwidth for those events. Actually, according to the descriptions in (Hartenstein and Laberteaux, 2010) regarding the congestion control on page 258, when an emergent event occurs, all ongoing tasks must be buffered or even stopped if there is a channel occupancy larger than 50%, so as to guarantee sufficient bandwidth for the emergent tasks. In this way, the emergency task will totally occupy the control channel thus leading to an ensured success.

In our work, instead of focusing on the aforementioned event-trigger congestion control scheme which servers for the very emergent cases using the highest transmitting power, i.e., 44.8 dBm, we intend to study the common safety-related applications which depend on the periodical broadcasted beacons. In other words, we only discuss the services including the high power "public safety" and "critical safety of life" as shown in Fig. 4, which use the power below 40 dBm. Therefore, it is worth stressing that even though some modifications to the original IEEE 802.11p standard have been done during the implementation of our scheme, our work still keeps compatible to the original standard instead of replacing it.

Additionally, even CAM (Cooperative Awareness Messaging) which relies on the periodical beacons, are usually used for the best-effort cooperative awareness, whereas the safety services are expected to be supported by the on-demand, event-triggered, high-priority messages (DENMs in the ETSI glossary), we could still find many works investigating safety-related applications depending on CAMs. In (Kloiber et al., 2011), the authors discussed the CAMs-based safety related services especially in a ultra-dense usecase and then denoted that some safety applications will work well with reliable CAMs. In (Ahizoune and Hafid, Ali), a cluster-based contention-free broadcasting scheme is proposed to provide road safety services. As a result, it can be concluded that the study of CAMs-based safety enhancement scheme seems to be very necessary in VANETs depending on the periodic broadcast or multicast.

Additionally, a safety-related event in practice requires instantaneous information exchanging which does not have extra time to permit channels scanning for a BSS (Basic Service Set) and subsequently finish several handshakes to establish a connection. As a result, in order to make the safety-related applications feasible, all employed transceivers need to be operated in the same channel with the same BSSID (Basic Service Set IDentification), with no exception. Note that the IEEE 802.11p standard now provides the "WAVE mode" function. In the WAVE mode, a station can exchange data frames with a BSS using the wildcard BSSID (Jiang, Delgrossi) and does not have to belong to a specific BSS. With the wildcard BSSID, two cars could