Detecting Hazardous Vehicles and Disseminating their Behavior in Urban Areas

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***Abstract*—Speeding cars and motorcycles constantly varying their speed, changing lanes or committing other apparent traffic violations as well as police cars and ambulances responding to incidents, are examples of vehicles that demonstrate hazardous traffic patterns. We propose a detection and a broadcasting protocol that run on top of vehicular ad-hoc networks and effectively alert drivers about such hazardous vehicles in urban environments.**

***Keywords*-Collision Warning System, Moving Vehicles, VANETs, ad-hoc networking.**

I. Description of the Problem

Contemporary vehicles are equipped with noteworthy computational and communication devices and multiple-type sensory equipment. A number of application services that exploit vehicles' resources and provide a better driving experience, have been proposed over the last decade. Examples of such services include the cooperative discovery of available parking spaces [7] and cooperative collision avoidance [9], [5], [8], [2], [3]. Since drivers' and passengers' safety is of critical importance, cooperative collision warning systems (CCWSs) have received a lot of attention lately.

In this paper, we focus on the detection of abnormal traffic situations and the propagation of the related emergency information. More precisely, our approach is designed to handle hazardous situations originated by driving behavior that deviates from the patterns specified by local and federal traffic regulations. Vehicles abruptly accelerating or slowing down, tailgating or constantly changing lanes are a threat for the safety of law-abiding travelers. In regard to these cases, the detection and broadcasting protocols incorporated in existing CCWSs appear to be insufficient in the following aspects:

- Existing detection protocols assume that the vehicles demonstrating hazardous driving behavior have communication capabilities and periodically transmit information such as their vehicle ID [6] and position [5], [2], [9]. In practice, however, a vehicle violating traffic regulations may not be protocol-compliant and refuse to reveal its ID and geo-temporal information. In order to overcome this limitation we propose a detection protocol where vehicles use their motion-sensor devices [4] to sense hazardous vehicles' movement and cooperatively detect hazardous traffic situations.
- The majority of existing CCWS broadcasting protocols propagate emergency messages about a hazardous event, to the vehicles that follow [9], [8], [3]. However, hazardous vehicles frequently exceed the posted speed limits. In this case, it is critical to timely alert those traveling ahead.
- A hazardous vehicle may generate tens or even hundreds of events by constantly changing lanes or abruptly accelerating and decelerating. Current CCWS protocols impose a significant communication overhead, since they disseminate a single emergency report for each detected event. Moreover, in urban environments the density of vehicles is high and the percentage of those equipped with communication resources is constantly increasing. Thus, the efficient utilization of the DSRC control channel [1] is important.

The detection and broadcasting protocols we propose in this paper attempt to handle these three issues. Their operation is outlined in Fig. 1. Vehicles v_1, v_2 and v_3 detect, through their motion sensors, a moving object h that passes by in a close distance, with a high relative velocity. The three vehicles share their motion sensor information and decide that a hazardous traffic situation is taking place. They also decide that v_3 must initiate the formation of a chain of broadcasting nodes that will be responsible for the propagation of the emergency information. Here, the "broadcasting chain" will be formed by vehicles v_3, v_4, v_5 and v_6 and the messages they broadcast will cover the entire area where dangerous incidents may occur. A broadcasting node periodically transmits a report so that *a)* endangered vehicles are informed about the latest status of the hazardous situation and *b)* vehicles entering the avenue segment where the hazardous situation is taking place are promptly alerted. Furthermore, each node is close to the limit of the transmission range of the previous node in the chain. In this way, our approach attempts to cover the area of interest with the minimum number of transmitters possible, yielding an important gain for the total communication cost of alerting endangered vehicles.

Next, we outline the key aspects of our detection and broadcasting protocols in Sections II and III, respectively.

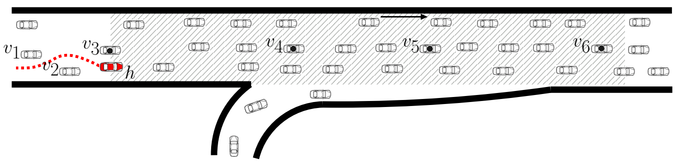

Fig. 1. Outline of our protocols' operation

II. Detection Protocol

Our detection protocol enables vehicles to cooperatively detect a hazardous traffic situation. The basic assumption of the detection protocol is that the vehicles capable of detecting hazardous situations must be equipped with communication resources and sensors [4] that can provide estimations for: *a)* the distance to a moving object and *b)* the relative velocity between the vehicle and the object.

Our protocol uses the "Hazard Indicator" (*HI*) metric for detecting a hazardous situation. A vehicle v_1 traveling at velocity v, that senses an object within a distance d moving with relative velocity rv, will compute *HI* = $\frac{v*rv}{d^c}$. Coefficient c is 1.0 when the object is detected by the side sensors of v_1 and 0.5 when detected by the sensors installed in the front and rear end of v_1. The intuition behind *HI* is that the lower the distance d in between and the higher the relative velocity rv, the more severe is the hazard implied. The hazard is even more severe in case a low distance and a high relative velocity are observed when traveling at high speeds. Furthermore, coefficient c amplifies the effect of distance d [1] when the moving object is detected by the front or rear end sensors of v_1 (e.g. tailgating on high speed avenues).

Vehicle v_1 will transmit an emergency report when the *HI* it perceives exceeds a predefined "Hazard Indicator Transmission Threshold" (*HITT*). Surrounding vehicles that also perceive an *HI* > *HITT*, will in turn transmit a report containing their perceived *HI*. Vehicles receiving emergency reports compute the sum of the received *HI*s, i.e. $\sum_i HI_i$. Once a vehicle observes an $\sum_i HI_i$ greater than the "Initiate Broadcasting Chain Threshold" (*IBCT*), it initiates a broadcasting chain. Our broadcasting protocol provides a mechanism for conflict resolution, in case two or more vehicles attempt to initiate a broadcasting chain. Note that the values of *HITT* and *IBCT* depend on the weather conditions. For instance, lower thresholds are used during rainy weather compared to those applied during normal weather conditions.

An emergency report contains estimations for the position and speed of a hazardous vehicle h, so that the endangered vehicles can compute an approximation of when h will enter their vicinity. After the formation of the broadcasting chain, a vehicle may detect a hazardous one with a position and speed much different from the estimations broadcasted by the chain. In that case, the vehicle will communicate with the nearest chain's node, to report an update for the hazardous situation. Since more than one vehicle may be triggering a hazardous situation, our detection protocol uses heuristics to distinguish between updates referring to different vehicles.

[1]we assume a distance unit such that $d > 1$

III. Broadcasting Protocol

Our broadcasting protocol is based on the notion of the "broadcasting chain" (Fig. 1). The basic mechanisms of the protocol are the following:

- *Determination of the chain's first node:* Once a hazardous situation is detected, vehicles must coordinate in order to decide which one will become the first node in the broadcasting chain.
- *Formation of the chain:* Based on the type of the hazardous situation, the chain must extend towards the same or the opposite direction from the vehicles' direction of movement. The fundamental principle applied in the formation and maintenance of the broadcasting chain is that each node is responsible for deciding the next one in the chain.
- *Maintenance of the chain:* The broadcasting chain extends over the area where dangerous incidents may happen. The area's extent is decided based on the estimated position and speed of the hazardous vehicles that sustain a hazardous traffic situation. Since each of the broadcasting nodes travels in a different speed, our protocol needs to constantly re–assign the responsibility for acting as a broadcasting node to the appropriate vehicles as long as a hazardous situation is taking place.

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