Driving Hazards Message Propagation Using Road Side Infrastructure in VANETs

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Abstract. VANET is a special form of Mobile Ad hoc Network (MANET) where the moving nodes are vehicles. Vehicles on the highway can encounter hazardous driving condition like slippery road, road blocks, hairpin curves and other unexpected obstacles. Speedy delivery of such information to other vehicles can help to prevent road accidents and improve passenger safety. The traffic on the highways may not be dense and hence vehicle-to-vehicle communication will not satisfy the requirements. In this paper, we propose the use of Road Side InfrastrUcture (RSU) for propagating the safety message to nearby vehicles travelling in the direction of the road hazard. Vehicles coming across such dangerous road condition will communicate the information to the nearest RSUs. RSUs will selectively forward these messages to other relevant RSUs which in turn will propagate the message to vehicles approaching the unsafe road areas. RSUs use aggregation strategy in order to reduce redundancy, and network overhead. As vehicles would normally travel at high speed on the highways, propagation over a longer distance is required to avoid accidents, ensure passenger safety and prevent vehicular damage.

Keywords: Safety Message Dissemination, Road Hazard, Road Side Infrastructure, Selective Transmission, Aggregation.

1 Introduction

Vehicular Ad hoc Network (VANET) is a key component of Intelligent Transport System (ITS). Each vehicle is equipped with wireless communication devices capable of communicating with each other along with GPS receivers to map the location. VANET is a self organizing network and provides an infrastructure to enhance passenger safety and travelling comfort [1]. VANET provides two types of communication: Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) called Road Side infrastructUres (RSUs). The RSUs are stationary devices which are deployed on roadside capable of exchanging important information such as road condition, accidents and other emergency and safety related messages with the On Board Unit (OBU) equipped on vehicle. The Federal Communications Commission (FCC), USA, allotted

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75MHz frequency spectrum between 5.580 and 5.925 GHz band for Dedicated Short Range Communications (DSRC) in VANETs. The DSRC spectrum is developed to support safety and periodic data transfer through Control and Service Channels respectively. The channel 178 of DSRC is primarily used for exchanging safety messages whereas other periodic hello messages are broadcast through service channels [2]. These messages are used to propagate hazardous event which is ahead of the vehicle and hence warn driver to react based on the received information.

There are a number of major differences between VANET and MANET [3]. VANETs have nodes as vehicles such as cars, dumpers, and trucks etc., which have high mobility as compared to nodes in MANET. However, the movement of the vehicles is restricted to fixed roads and highways unlike in MANETs. In VANET, vehicles have adequate power resources for V2I and V2V communication.

VANET applications are broadly classified as safety and comfort (non- safety) applications [4]. Safety applications propagates safety related information such as abnormal road conditions warning, smooth curve warning, accident warning and traffic jam along the travelling path of the vehicles in the network. The comfort applications can be further classified as convenience and commercial applications and are delay-tolerant. Some of the examples of convenience applications are finding gas filling stations, free parking lots, and nearest hotels. Commercial applications are available for road navigation that allows road maps to be downloaded into GPS systems. Remote vehicle diagnosis is another example of this type of applications. Advertisements and internet access would also be classified under commercial applications.

Road safety applications require fast and reliable propagation of safety messages in network. So it is necessary to use suitable messaging in order to propagate hazardous events as early as possible to the vehicles which are approaching the hazardous location. We propose a message dissemination technique that consumes minimum network bandwidth by selectively transmitting the road safety messages only to vehicles approaching the treacherous road locations.

In this paper we assume that pre-installed infrastructure, RSU, are available to disseminate safety message on the highway. In our proposed approach, RSU will not broadcast the safety message to all vehicles but will selectively propagate only to relevant vehicles likely to traverse the hazardous zones. The rest of the paper is organized as follows: In section 2, we discuss the work related to safety message dissemination techniques. In section 3, we discuss our proposed RSU- based safety message propagation and section 4 concludes the paper.

2 Related Work

One of the common techniques used for safety message dissemination is broadcasting or pure flooding. Simple broadcasting techniques cause broadcast storm problem due to duplication of message transmission [5]. There is high bandwidth usage and duplicate reception of the same messages from different vehicles leading to message congestion and degradation in network performance.

We discuss the related work that uses vehicle to vehicle safety message dissemination on highways. Erwin Van de Velde et al have been proposed a new routing algorithm called REACT, to choose a best forwarder for sending packet along a trajectory on highways using vehicle to vehicle communication [6]. Vehicles exchange beacon messages to know the neighbors position. A node will rebroadcast the packet if it can cover large distance than the transmitter. Yao-Tsung et al have been proposed a Position-based Adaptive Broadcast (PAB) algorithm for delivery of emergency messages. This protocol uses vehicle to vehicle communication [7]. The relay nodes are identified based on the position, direction and velocity of receiving vehicle; mostly, farther nodes are identified as relay nodes in order to propagate messages quickly. The messages are ignored by the vehicles which are travelling in opposite direction. The authors also calculated time delay based on the velocity of vehicles to differ the retransmission. The authors also noticed that the PAB algorithm gives enough time to the drivers to react against emergency event. However, they also pointed out that there are many simultaneous transmissions due to chain events leading to data congestion. Vehicular Reactive Routing (VRR) protocol has been designed by Martin Koubek et al for data dissemination on highways in WAVE based VANETs [8]. VRR is designed for the logical link control layer of WAVE stack. The sender node identifies the relay nodes from each direction with respect to the distance between its neighbors and inserts the information about suitable relay node into the packet. VRR protocol maintains neighboring information in its routing table in order to find out suitable forwarding node. The authors pointed out that this protocol will not provide advantage for simple broadcasting but it can give significant benefit on the systems which uses route discovery process. As future extension, the authors mentioned that the delivery ratio for distant nodes to be considered by resending the broadcast data.

All of the above work is based on vehicle to vehicle communication. In sparse networks identifying the next hop would be difficult due to the large distance of vehicles on highways. VANETs tend to be disconnected, consisting of a collection of disjoint clusters of cars. To overcome the limitations imposed by lack of connection, Mahmoud Abuelela et al have been proposed Smart Opportunistic Data dissemination Approach (SODA) to disseminate packets in sparse networks on highways [9]. Though cars find neighbors to transmit packets to a longer distance, it may not deliver through these neighbors. Instead, cars that move very fast will carry packets until destination in order to use bandwidth effectively.

Data aggregation is one of the powerful techniques to collect similar or dissimilar messages from the neighboring vehicles in order to minimize network overhead and to reduce information redundancy. Khaled Ibrahim et al have been presented a new aggregation technique for aggregating vehicles data without losing accuracy [10]. Vehicles form clusters by exchanging location and speed information periodically to create local view of the vehicle and transmits aggregated record to the neighbors to make a local view up to 1.6km. To extend the local view, the aggregated message of the cluster is transmitted to other clusters. The authors pointed out that there must be a mechanism introduced to minimize number of message broadcast and to build an algorithm for increasing security.

Bruno Defude et al have been developed a system called Vehicular Event Sharing with a mobile P2P Architecture (VESPA) to share information among vehicles in order to extract knowledge from neighboring vehicles [11]. The authors have focused on knowledge extraction and how to aggregate data about dangerous hazards such as accidents, emergency braking and other emergency events or to know the available parking lots. Aggregated messages are stored in a matrix and sent to the neighbors.

Martin Koubek et al have presented Event Suppression for Safety Message Dissemination (ESSMD) scheme to reduce simultaneous reception of same event message from the number of neighboring vehicles [12]. The authors have used an aggregation strategy in which the transmitter has to wait for 10ms or 100ms in order to aggregate the messages received during that time and the aggregated message will be transmitted as one packet. ESSMD+ Rep (repetitions) method was introduced to improve the reliability of ESSMD. The authors pointed out that the packet transmission delay of this scheme is increased due to aggregation.

Kai Liu et al have been proposed a RSU-Assisted Multi-channel Coordination (RAMC) MAC protocol to broadcast safety and non-safety information to all the neighboring vehicles [13]. RSUs will monitor the both service and control channels of DSRC in order to collect emergency warning messages from vehicles. RSUs will aggregate the received information and transmit to the vehicles which are in its transmission range in both service and control channel so that vehicles will not miss the information. The focus of the work is on high delivery ratio and low delay for safety messages. The performance analysis showed that the delay of emergency warning messages such as accidents is much less when compared to status safety messages.

Pratibha Tomar et al have been proposed an approach for emergency data dissemination in sparse and dense networks of VANETs [14]. Highways are divided into clusters with respect to RSUs. The emergency messages are propagated using car to car communication in dense networks whereas in sparse networks, RSU is propagating emergency messages. The authors have pointed out RSUs will help to achieve low latency communication of the safety messages. The authors have based their work for two lane highway traffic which needs to be extended to other type of road networks.

3 Proposed Method

In our proposed system, we look at safety message dissemination of hazardous road condition on highways; where such conditions are normally encountered. In urban areas, the civic authorizes would ensure that the city roads are kept clean and safe for smooth transport of vehicles. Hence we focus our research to highways and look at a fast and efficient method of safety message dissemination of status of dangerous road conditions and obstacles. The traffic on the highways may not be dense and hence only vehicle-to-vehicle communication will not satisfy the requirements. So we propose the deployment of RSUs which can be used to propagate all types of safety, emergency, convenience and commercial message to the vehicles travelling on the highways. We also assume that RSUs can communicate directly with each other even in the absence of vehicular traffic to propagate the messages over a longer distance. As vehicles would normally travel at high speed on the highway, propagation over a longer distance is required to avoid accidents, ensure passenger safety and prevent vehicular damage.

In our proposed solution, vehicles traversing a hazardous area will transmit the information to the nearest RSU. We assume that vehicles are equipped with GPS to know the location of the hazardous area. RSUs will periodically send “hello” message to indicate its location. Hence vehicles will know the location of the nearest RSU. This information has to be efficiently disseminated to vehicles approaching the hazardous areas as early as possible to untoward incidents. The same message may be transmitted by many vehicles that have traversed the hazardous area. Fig. 1 shows a sample scenario.

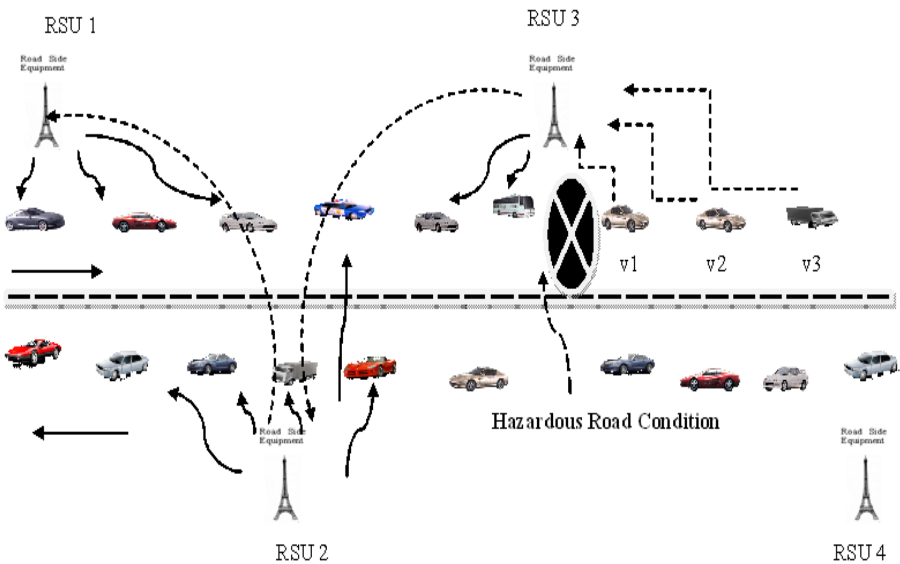

Fig. 1. Hazardous event on travelling path. The dotted line shows safety message delivery to RSUs and solid line shows broadcasting safety message.

Vehicles v1, v2, v3 who have encountered the hazard in the road would send a message to RSU3. RSU3 would receive the messages from the vehicles and send a single message to RSU2 which in turn will forward to RSU1. Since the hazard is before RSU4, message will not be forwarded to RSU4 by RSU3. RSU1, RSU2 and RSU3 will broadcast to vehicles to within the range covered by them. Vehicles in the overlapping zone of the RSUs will receive messages from both RSUs.

We present another scenario depicted in Fig. 2.

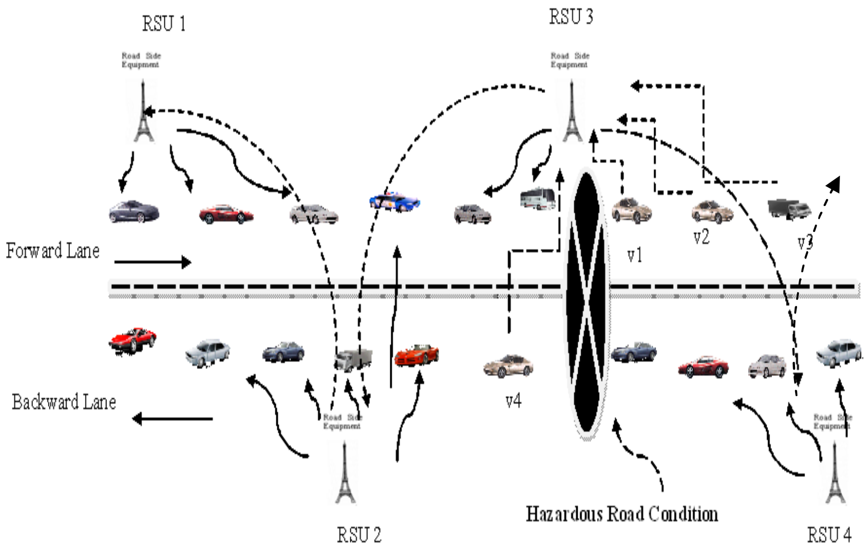

Fig. 2. Hazardous event at both lanes. The dotted line shows safety message delivery to RSUs and solid line shows broadcasting safety message.

Here the hazardous road condition is found on both lanes of the highway. For example, a landslide could have left obstacles on the road. Vehicles travelling on both sides of the road will send the safety message to RSU3. In this case, RSU3 will send the message to both RSU2 and RSU4 for forwarding to other RSU in both directions.

In both the above scenarios, RSU3 will examine and aggregate the messages to avoid duplication of the same message. The message is sent only to the relevant RSUs for re-transmission to the vehicles travelling in the direction of the dangerous area. As such messages will indicate the location of the dangerous area; vehicles can decide to change their travelling route to avoid the hazardous areas. Vehicles can choose to disregard the message if it is not relevant to them. For instance, if a vehicle is planning to turn off the highway before the dangerous area, the message would not be relevant.

RSUs will also aggregate and transmit all hazardous road condition messages to the highway authorities to enable them to rectify such conditions. RSUs will continue to send the message of a particular hazardous location, till it stops getting messages about the concerned location. This would happen if may be the obstacle has been removed or a slippery road condition has been attended by the highway authorities. The highway authorities can also directly communicate with the RSU regarding the rectification of the road condition.

3.1 RSUs "hello" Message

Each of the RSU will broadcast periodic "hello" messages within its transmission range. These messages would include the ID and location of the RSU as given in Fig. 3.

RSU_ID	*Date, Time*	*Location*

Fig. 3. RSU periodic message

These messages are captured by the vehicles that are within the transmission range of a particular RSU and enable the vehicle to know the location of the nearest RSUs. Location is expressed as GPS coordinates of latitude and longitude.

3.2 Vehicle to RSU Message

A vehicle detecting any dangerous road condition such as slippery road, road block or any other unsafe zones along its travelling path will generate a safety message with the contents as shown in Fig. 4. This message is sent to the nearest RSU whose location is obtained from the RSUs "hello" message.

V_ID (source)	*Vehicle Location*	*Vehicle direction of movement*	*RSU_ID (destination)*	*Safety message*

Date, Time of message	*Hazardous_ Location*	*Type of Hazard*

Fig. 4. Vehicle to RSU message

Vehicle location and the hazardous location will be indicated as GPS coordinates. Each message should include the date and time of sending the message. We assume there is an on board clock in every vehicle that would provide the date and time. The hazard type would have to be identified by the vehicle driver; such as slippery road, ice on road, uneven road, obstacle on road etc.

3.3 RSU to RSU Message

RSU will forward the safety message received from RSUs in their near vicinity. RSUs can combine and forward the safety messages received from other RSUs with the safety messages received from vehicles in their zone.

3.4 RSU to Highway Authority

RSUs can deliver the same safety message to the Highway Authorities (HA) to enable them to attend and correct the road problems and hazardous conditions. HA can look at messages received from many RSUs and draw up an appropriate action plan.

4 Conclusion and Future Work

In this paper, we have discussed the use of Road Side infrastrUcture for selectively propagating safety messages about hazardous road condition to enhance passenger safety on highways. We have proposed forwarding of messages to relevant areas in order to warn vehicles approaching the danger zone. As future work, we intend to implement and test the proposed safety message model using SUMO and NS2.

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