A Reliable Broadcast Method for Vehicular Ad hoc Networks Considering Fragmentation and Intersection Problems

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Abstract

Vehicular Ad hoc Networks (VANETs) are new network environment for intelligent transportation systems. Many of applications in VANETs are based on dissemination of information, so broadcasting is one of the fundamental services in these networks. Broadcasting in VANET is a challenging task since these networks often lack continuous end-to-end connectivity and also have different road topologies. In this paper we present a broadcast method that improves the reception rates of broadcast messages by overcoming problem of connectivity gaps and omitting unreliability that occurs at intersections. We have simulated our method in NS2, simulation results show our method delivers message to most of vehicles by assuring propagating message in all roads and passing connectivity gaps.

1. Introduction

Recently, mobile computing has become a hot topic in research. Although computer and communication devices are becoming smaller and more powerful, mobility still challenges applications of mobile computing especially in the area of ad hoc networking. A mobile ad hoc network consists of mobile hosts that communicate via wireless links. Due to mobility, the topology of the network changes continuously and wireless links break down and reestablish frequently. Moreover, an ad hoc network operates in the absence of fixed infrastructure forcing the hosts to organize the exchange of information decentrally. A prominent type of mobile ad hoc networks is direct wireless communication between vehicles in road traffic. In this network, the vehicles are equipped with a computer controlled radio modem allowing them to contact other equipped vehicles in their vicinity. This type of network is named Vehicular Ad hoc Network (VANET).We believe that the best applications of inter-vehicle communication are to provide improved comfort and additional safety in driving. Most of safety applications require dissemination of information among participating vehicles, so broadcasting is one of fundamental services in these networks, which because of high importance of exchanged messages especially in safety applications require high reliability in delivering messages to all vehicles [1].

According to [2] more than 30% of all accidents happen at intersections so broadcasting at intersection requires high reliability.

In these networks because of high node mobility, network may be partitioned and lack continues end-to-end connectivity ,broadcasting must consider this problem either.

In this paper we have proposed a broadcast method that considers above problems. The proposed method by using highly dynamic nature of VANET, omits effects of network partitioning on broadcasting. This method by classifying vehicles based on the road they move, has increased reliability of broadcasting at intersections.

The remainder of this paper is organized as follows. Section 2 presents related work on broadcasting in VANET, section 3 describes intersection problem and proposed method; section 4 presents the simulation model, the results and the analysis of the proposed approach; the last section concludes this paper.

2. Related Works

Early research on inter vehicle communication began in the 1990s, inspired by research in the area of intelligent transportation systems (ITS) initiated by the Department of Transportation (DOT) in the U.S. With the decreasing cost of components for communication and positioning [e.g., global positioning systems (GPS)] in the recent past, IVC became more attractive

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[3]. Various research projects were initiated [4][5][6], some explicitly focused on IVC, others considering IVC as one of many possibilities for data distribution.

Among IVC systems, Vehicular Ad hoc Network (VANET) that relay on direct communication of vehicles with no need to any infrastructure has attracted a lot of interest .Data dissemination is one of the frequently used services in VANET ,several research groups have explored the idea of data dissemination for it. Flooding is suggested as the most common approach for broadcasting without need to explicit neighbor information [7].Simulation shows that flooding results in severe performance degradation, especially with high node density, as a result of the broadcast storm problem [8]. Following the high interest and potential of inter-vehicle communications, several strategies for information dissemination have been suggested that improve simple flooding. In [9] and [12], proposed methods are based on selection of the furthest receiver node as the next forwarder of message .In [10], the proposed method assigns the duty of forwarding the broadcast packet to only one vehicle by dividing the road portion inside the transmission range into segments and choosing the vehicle in the furthest empty segment as a forwarder. In [11], a selective message forwarding method is presented that assigns each node a defer time based on the number of common neighbors with the relay. By this assignment the node that has least common neighbor is chosen as a forwarder. In [13], a greedy forwarding approach is used in order to reduce the number of redundant transmissions.

But when the network is partitioned above approaches fail to deliver message to all vehicles. Some methods have been suggested for overcoming this problem. In [1], the proposed solution, considers that the vehicle having to rebroadcast message must be ensured of existence of neighbors reachable by the broadcasted message. This insurance is done by maintaining a list of neighbors by each vehicle. But having and maintenance of list of neighbors needs exchanging a lot of information messages that generate a significant overload in network. Also as alarm messages are unexpected, determining the set of neighbors delays for rebroadcast when emergency. In [14], the broadcast protocol suggests broadcasting the message periodically by relays .This method causes redundant retransmissions of messages .Also in this method for reducing overhead of retransmission an interval for period of rebroadcast is suggested that this interval makes delay in delivering message to vehicles. In [15], the proposed method considers bidirectional ways and uses vehicles on the other direction to bridge between partitions of network, but suggested protocol isn't useful in one directional ways.

Also above methods don’t consider unreliability that occurs at intersections. At intersections overlap of communication range of vehicles in different roads may stop broadcasting in some ways.

By considering existing methods and their problems, in this paper we propose a new reliable broadcast method that overcomes above troubles.

3. Proposed Method

We assume instrumented vehicles are equipped a GPS device enabling the vehicle to know their location, and sensors reporting crashes, engine statistics, etc.

When a vehicle broadcasts a message, all vehicles in its communication range receive it through their sensors. To broadcast message out of communication range, some intermediate vehicles called relays are selected as forwarder of message .The selection of forwarder must insure delivering messages to most possible vehicles which haven't not received the message yet. The furthest nodes are the best choices to be selected as forwarders.

To select furthest vehicles, every node when receives the message, by knowing its own position and position of the sender that is included in broadcast message determines a waiting time. This waiting time is determined based on the distance d to the sender, such that the waiting time is shorter for more distant receivers, equation 1.

$$WT(d) = -\frac{MaxWT}{Range} * d + MaxW \qquad (1)$$

Where d: distance to the sender, Max WT: maximum waiting time, Range: transmission range

By this method small waiting time of furthest nodes expires first and they are selected as the forwarder of message. The furthest nodes broadcast message at first. After the broadcasting of furthest vehicles, vehicles which are between the main senders and relay upon receiving of duplicates cancel their retransmission. This canceling is due to their retransmission range is covered by transmission range of last forwarders and their retransmission will be redundant. With this mechanism for reducing redundant transmission only furthest nodes are selected as forwarders and rebroadcast the message .Other nodes when receive duplicates cancel their transmission. This selection of furthest forwarder is repeated to inform other vehicles, “Figure. 1”.

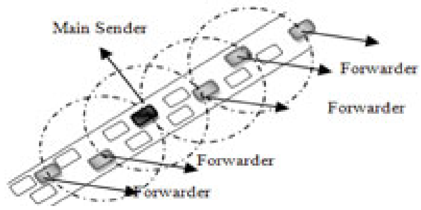

Figure 1.Furthest nodes in each step are forwarders

This mechanism is the base of most broadcasting methods but as we describe here it suffer unreliability at intersections. When there is an intersection in the path of the packet broadcast, communication range of a vehicle in one road may cover some vehicles in other roads. This covering causes broadcasting of vehicles in one road affects on broadcasting process in other roads. So there is the probability of broadcasting stop in some roads. Notice to "Figure. 2".

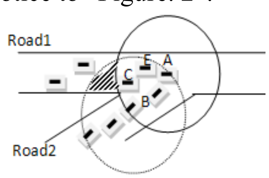

Figure 2.Propagation stop in Road 1

In this figure we consider broadcasting of message to vehicles behind of A. After broadcasting message by vehicle A, vehicles B and C and E receive the message, and compute a defer time based on their distance to A. Vehicle B is the furthest receiver, so its defer time expires first and retransmit the message ,after its retransmission, vehicle C and E receive duplicates and to reduce redundancy cancel their retransmission .In this condition in road 1 there isn't no node that haven't been received duplicate and can be selected as relay(a vehicle in hatched region). This condition causes stop of message propagation in Road1 and message doesn't deliver to vehicles in this way. This case occurs in many intersection scenarios.

To solve this problem we have proposed classifying of vehicles based on to the way they move in. By this classification we limit propagation effect of vehicles to vehicles in same roads. We classify them into six class, two main back and forward groups and each of them into three classes. In this classification we use location information of sender and receiver and also vector of their direction.

1) Back Vehicles: Back vehicles as it is shown in "Figure. 3", are vehicles that cos of angle between a vector from their position to the relay and vector of relay moving direction is greater than0.

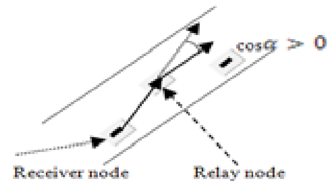

Figure 3. Receiver is a back vehicle

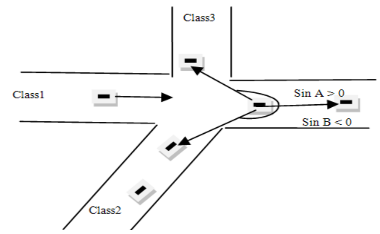

Figure 4.Classifying back vehicles into three classes

For distinguish between back vehicles moving on different roads constitute an intersection, we propose classifying back vehicles into three classes .These classes are shown in "Figure.4".

Class1 are back vehicles that angle between a vector from their position to the forwarder and vector of forwarder moving direction is equal to 0.Class 2 are vehicles that Sin of angle between a vector from relay to their position and vector of relay moving direction is lower than 0.Class3 are vehicles that sin of angle between a vector from relay to their position and vector of relay moving direction is greater than 0.

2) Ahead Vehicles: Ahead vehicles as it is shown in "Figure .5 " are vehicles that that cos of angle between a vector from their position to the relay and vector of relay moving direction is lower than 0.

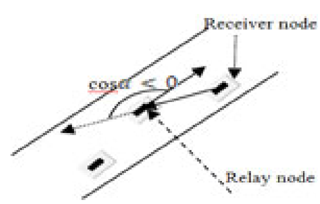

Figure 5.Receiver is a Ahead vehicle

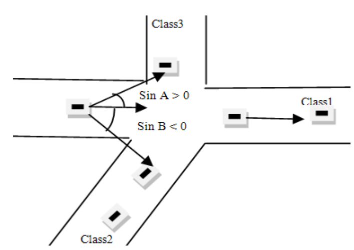

Figure 6. Classifying Ahead vehicles into three classes

We have classified ahead vehicles into three classes either. It is shown in “Figure .6”. Class1 are vehicles that Sin of angle between a vector from relay to their position and vector of relay moving direction is equal to 180. Class 2 are that sin of this angle is lower than 0. Class 3 are vehicles that sin of this is greater than 0.

By this classifying we distinct between vehicles on different roads constituting an intersection so we can limit broadcast effects to vehicles in same classes. According to these classification, after starting broadcast by a vehicle all receivers specify what class are belonging to, based on their position and position of last relay that is included in broadcasted message. Every vehicle by specifying its class only if receives duplicate message from a vehicle in same class cancels its retransmission so broadcasting is limited to vehicles in same class. By applying this mechanism, in “Figure.2”, vehicle C doesn’t cancel its rebroadcast, because it hasn’t received duplicate message from a vehicle in same class and so propagation could be continued in road 1.

As we mentioned before one of characteristics of vehicular ad hoc network is the probability of network partitioning. In partitioned networks broadcast transmissions can be impaired by connectivity holes, so that here is no appropriate vehicle in the direction of dissemination that relay task could be assigned to it. These events, in turn, abruptly interrupt the forwarding process before the packet life time has expired or all vehicles that messages must be delivered to them have received it.”Figure. 7”.

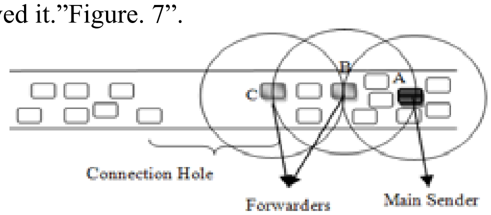

Figure 7 .A connection hole in direction of propagation

The first step to overcome fragmentation problem is detecting a connection hole. Our method detects a connection hole as follows: Each forwarding vehicle stores the message and sets a waiting timer τ. If this timer expires without receiving a duplicate message, it means broadcast hasn’t been performed by next-hop forwarder and we can conclude there is a fragment in the direction of dissemination.

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After detection a connection hole by the last forwarder, our method suggests frequently sending hello message in order to understand entrance of a new vehicle to its communication range. The last forwarder includes in this hello message its id and its position ,every receiver of this message puts its location and id in the received hello message and returns it back to the forwarder. if the forwarder receives this hello messages while having information about entrance of a vehicle in direction of dissemination, the forwarder will broadcast the message and by assigning forward task to the new entered vehicle propagation could be continued .But if the forwarder doesn’t detect entrance of a new vehicle in the direction of dissemination the procedure of sending small message is repeated until detecting an appropriate forwarder. If the message life time is reached but no new vehicle is detected this process will be stopped.

Our proposed method allows node store message until new neighbor move into their vicinity and then propagation is continued .The main advantage of our proposed protocol is its low overhead that is due to an on demand using of hello messages only when encountering fragmentations.

4. Simulation

In this section, we discuss the simulation results obtained by our protocol and evaluate its performance. First though, we describe the simulation setup, including the scenario utilized, and the communication strategies’ configuration.

4.1. Simulation Setup

The simulation has been implemented in NS2(Version 2.30) . In Our scenario roads are straight 5km long bidirectional with 2 lanes per direction. We determine the distribution of vehicles and their velocity from Freeway traffic model .In this model vehicles depart at different position, and change speed as time goes periodically so the higher speed vehicles may progress passing lower speed vehicles. The speed steps that each vehicle uses are from 80Km/hr (22.22m/s) to 120Km/hr (33.33m/s). We assume that transmission range of all vehicles is 200 Meter. We have tested our method in different node densities(25~250 node)

4.2. Performance Evaluation

The simulation starts by initiating the message dissemination from a vehicle at the end of the simulated road stretch. In our simulation we have assumed that message lifetime isn't a limiting factor and the simulation proceeds until all vehicles that are in front of crashed vehicle have passed it. In this simulation our major metric is the ratio of informed vehicles to the number of all in front vehicles.

At first we have evaluated behavior of our proposed method in different network conditions. "Figure .8" shows the scenario that we have tested our method on it.

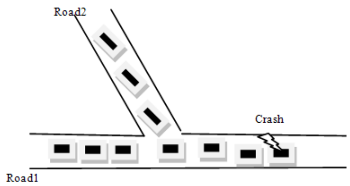

Figure 8.Evaluated Scenario

In digram1, simulation results show the time, that our method delivers message to different percentage of equipped vehicles.

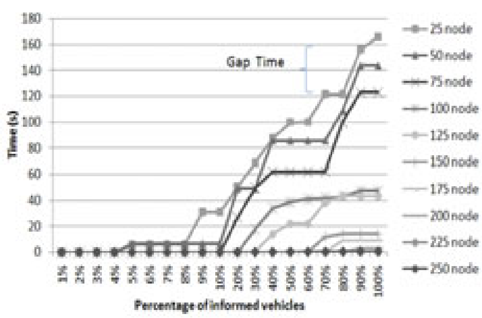

Diagram 1.Time of delivering message

As we expect in sparse network (25~75 node) number of fragmentation and gap time is high, so it takes much time to deliver message to different percentage of vehicles. In medium network (100~175 node) by increasing number of equipped vehicles , number of gaps and also Gap time is decreased that result in lower times in delivering message to vehicles. In a dense network (200~250 node) it takes few time to deliver message to all vehicles. As we expect according to this diagram, time to deliver message to all vehicles is decreased by increasing number of equipped vehicles.

Overcoming fragmentations takes time to deliver message to all vehicles .Diagram2 shows this time in different node densities. As we expect in this diagram with increasing number of equipped vehicles, the delivery time has decreased. With above simulations we showed our protocol assures delivering message to all vehicles by passing gaps.

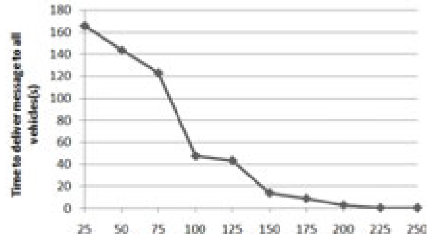

Diagram 2 .Time of delivering message

One of the major chrematistics of our protocol is its low overhead. In diagram 3 we have compared overhead of our method with role based method [11] that considers fragmentation problem.

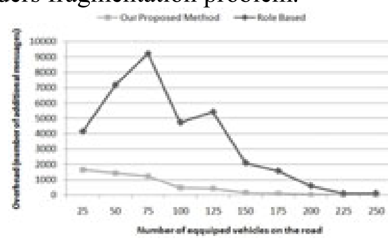

Diagram 3.Comparison of Overhead

In Role Based method detecting is done by using neighboring information, so as to every vehicles checks list of its neighbor frequently and if there isn't new neighbor in its list ,it detects fragmentation and after detecting gaps by periodic checking of neighbors list entrance of a new vehicle is understood. So Role Based method for all broadcasting decisions needs to frequently sending of neighboring information by each vehicle. But our method only in fragmentation for understanding entrance of new vehicle needs sending messages frequently so it's overhead is too much lower. We have compared overhead of this two method in deferent node densities in diagram 3. We have assumed that period of sending messages are same in both methods. As we expect our proposed method has very low overhead in comparison of Role Based Method. In this diagram by increasing number of equipped vehicles on the road number of fragmentation and their length is decreased ,so overcoming fragmentation need lower number of additional transmitted messages ,that results in a descending curve.

Also we have compared performance of our method with Role Based in number of vehicles that message delivered to them. Diagram 4 shows the number of informed vehicles in both methods .We have varied number of vehicles on the road between 25~250 nodes.

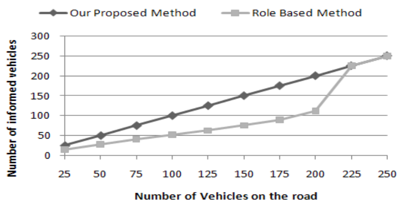

Diagram 4.Comparision of number of received vehicles

As it is seen, our method has delivered message to vehicles on both roads but in Role Based method when the network isn't dense message haven't been delivered to vehicles on one road and so number of equipped vehicles is rather half of our method. In high node density two methods have equal performance that is because of high probability of being vehicles in both roads that can be selected as relays.

5. Conclusion and outlook

In this paper we presented an approach to broadcast a message among highly mobile vehicles in road traffic. This method considers unreliability that can occur at intersection, it also considers fragmentation. simulation results show our method delivers message to as much as possible vehicles by passing gaps, it also assures delivering message to all vehicles constituting intersection.

But broadcasting in VANET is a challenging task because of different road topologies and also varying types of nodes in it .For future work considering charsteristics like bends, curve roads, different communication ranges of vehicles will help in improving delivery ratio of dissemination process.

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