논문 2009-04-07

Broadcasting Message Reduction Methods in VANET

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Abstract : Most Vehicular Ad hoc Network (VANET) applications rely heavily on broadcast transmission of traffic related information to all reachable nodes within a certain geographical area. Among various broadcast approaches, flooding is the first broadcasting technique. Each node rebroadcasts the received message exactly once, which results in broadcast storm problems. Some mechanisms have been proposed to improve flooding in Mobile Ad hoc Networks (MANET), but they are not effective for VANET and only a few studies have addressed this issue. We propose two distance-based and timer-based broadcast suppression techniques: *15P*(15percent) and *slotted 15P*. In the first (distance based) scheme, node's transmission range is divided into three ranges (80%,15%and5%). Only nodes within 15% range will rebroadcast received packet. Specific packet retransmission range (15%) is introduced to reduce the number of messages reforwarding nodes that will mitigate the broadcaststorm. In the second (timer-based) scheme, waiting time allocation for nodes within 15% range isused to significantly reduce the broadcaststorm. The proposed schemes are distributed and reliedon GPS information and do not requireany other prior knowledge about network topology. To analyze the performance of proposed schemes, statistics such as link load and the number of retransmitted nodes are presented. Our simulation results show that the proposed schemes can significantly reduce link load at high node densities up to 90 percent compared to a simple broadcast flooding technique.

Keywords : VANET, Broadcast storm, Vehicle-to-vehicle communication

I. Introduction

Across the country, towns and cities of all sizes are applying advances in communication and computer technology to improve transportation. The purpose of these transportation technologies, called intelligent transportation systems (ITS), is to improve the safety, efficiency, dependability and cost effectiveness of our transportation system.

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Manuscript received : Feb. 03, 2009., Modify : Mar. 4, 2009., Accepted : Mar. 25. 2009.
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Recent advances in wireless technologies have made communications between vehicles and with roadside infrastructure possible in mobile ad hoc networks (MANETs). This has given birth to a new type of MANET known as the Vehicular Ad-Hoc Network (VANET).

The direct communication between vehicles using an Ad Hoc network, referred to as inter-vehicle communication (IVC) or vehicle ad hoc networks (VANETs), is a relatively new approach. Compared to a cellular system, IVC has three key advantages: lower latency due to direct communication, broader coverage and having no service fee.

Recently, the promises of wireless communications to support vehicular safety applications have led to several research projects around world: the Vehicle Safety Communications Consortium [1] developing the DSRC technology [2] (USA), the Internet ITS Consortium [3] (Japan), the PReVENT project [4] (Europe) or the 'Network on Wheels' project (Germany) [5] are some samples.

To cater to the emerging wireless communication needs with regard to vehicles, in July 2003 ASTM and IEEE adopted the Dedicated Short Range Communication (DSRC) standard (ASTM E 2213-03) [6]. The aim of this standard is to provide wireless communications capabilities for transportation applications within a 1000 m range at typical highway speeds. It provides seven 10 MHz channels at the 5.9 GHz licensed band for ITS applications, with different channels designated for different applications, including one specifically reserved for vehicle-to-vehicle communications.

ITS applications divided into two most relevant areas:

1) Comfort Applications: the main goal of this type of application is to improve passenger comfort and traffic efficiency and/or optimizes the route to a destination. Examples for this category are: traffic information system, weather information, gas station or restaurant location and price information, and interactive communication such as Internet access or music download.

2) Safety Applications: Applications of this category increase the safety of passengers by exchanging safety relevant information via IVC. The information is either presented to the driver or used to activate an actuator of an active safety system. Example applications of this class are: emergency warning system, lane-changing assistant, intersection coordination, traffic sign/signal violation waning, and road-condition warning. Applications of this class usually demand direct vehicle-to-vehicle communication due to the stringent delay requirements.

The main problem of Safety alert application is broadcast storm problem. The primary goal for safety alert application is to deliver the alert message to all following vehicles from the incident site so that drivers may be alerted prior to their natural visual reaction. So time to send alert message from end-to-end must be as fast as possible.

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 neighbour information [17].

In VANET nodes will broadcast packets in order to discover neighbours or propagate useful traffic information. Because of the shared wireless medium, blindly broadcasting of the packets and an excessive number of broadcast packets may lead to frequent contention and collisions in transmission among neighbouring nodes. This problem is sometimes referred to as broadcaststormproblem.

Therefore, we propose two broadcasting algorithms 15P and slotted 15P which provide broadcast suppression. Within transmission range of a node specific rebroadcasting range for nodes is introduced to reduce the number of rebroadcasting nodes that leads to broadcast storm suppression.

The remainder of this paper is organized as follows. Section II presents related work about broadcasting in VANET. In section III we describe 15P and slotted 15P in detail. In section IV we evaluate the proposed algorithms by means of simulations. Finally, Section V concludes the paper.

II. Related Work

In the following we briefly describe related research activities on VANETs and other broadcast techniques proposed for general MANETs.

Simple broadcasting is the simplest method used in Safety alert applications for VANET. In this method after an accident occurred, safety alerts application will simply send alert message to all vehicles proceeding towards accident site. When a vehicle receives a broadcast message for the first time, it retransmits the message. The vehicle then ignores all subsequent broadcast messages it receives from other vehicles, which also rebroadcast the same message. There are two main problems in this simple broadcast method. First, there are a lot of redundant rebroadcast messages because of its flooding nature. Thus, when a message reaches n nodes, the packet will be sent n times. Second, there is a high probability that a message will be received by many hosts in a close proximity. Every host will severely contend with one another for access to the medium and all vehicles in transmission range will rebroadcast alert message.

Unlike other forms of MANETs [7], applications developed for VANETs have a very specific and clear goal of providing intelligent and safe transport systems. Emergency warning for public safety is one of the many applications that is highly time-critical and requires a more intelligent broadcast mechanism than just blind flooding. In [8] the authors studied how broadcast performance scales in VANETs and they proposed a priority-based broadcast scheme that gives higher priority to nodes that need to transmit time-critical messages. The proposed algorithm categorizes nodes in the network into multiple classes with different priorities and schedules packet transmission accordingly. Although this technique is not designed to solve the broadcast storm problem, it can indirectly mitigate the severity of the storm by allowing nodes with higher priority to access the channel as quickly as possible.

In [9] the authors proposed a role-based multicast protocol that suppresses broadcast redundancy by assigning shorter waiting time prior to rebroadcasting to more distant receivers. However, the focus of this study is on achieving maximum reachability in a sparsely connected or fragmented network where the broadcast storm is not the main problem.

In [10] various threshold-based techniques were proposed by Tseng et al., such as the counter-based, distance-based, and location-based schemes. Depending on the scheme considered, a node receiving the broadcast packet compares the predetermined threshold value with its local information, (e.g., the number of duplicate packets received, the relative distance between itself and the sender, or the additional area that can be covered if it rebroadcasts the message). The criteria to adaptively adjust the thresholds according to the number of neighbours were also presented in [11] by Ni et al. The results show that with the aid of a positioning device such as the GPS, the location-based scheme seems to offer the best performance in terms of packet penetration rate and link load. Although our schemes employ a similar concept to the schemes in [10, 11], we use a lightweight distributed algorithm to calculate the forwarding probability and/or waiting time before rebroadcast instead of using threshold values.

Due to specific characteristics of safety messages, broadcasting could be the only possible way for message exchange. So it could be possible to get complete coverage to all relevant vehicles.

Message forwarding can help warning message reach vehicles beyond the radio transmission range. In [12], the authors propose a multi-hop broadcast protocol based on slot reservation MAC. Considering the scenario that not all vehicles will be equipped with wireless transceivers, emergency message forwarding in sparsely connected ad hoc network consisting of highly mobile vehicles is was studied in[13]. Motion properties of vehicles are exploited in [14] to help with message relay. Two protocols to reduce the amount of forwarding messages were proposed in [15].

In [16] authors presented several context-aware packet forwarding protocols for intra-platoon scenarios. Also in [18] some other algorithms have been proposed which can help vehicles to limit the effects of broadcast storm problem.

The method that has been proposed in [19] tries to reduce broadcast storm problem by using probability to decide the vehicle that will rebroadcast alert message. When a vehicle receives a broadcast message for the first time, the vehicle will rebroadcast the alert message with a random probability. This method will help to reduce number of rebroadcasting vehicles and thereby broadcast storm problem. However this could not fully ensure to avoid broadcast storm. It just reduces the chance of its occurrence.

In [20] authors proposed TLO (The last one) broadcast method to reduce end-to-end delay and broadcast storm problem. The TLO algorithm will try to find the last vehicle within transmission range of a sender using neighbor table. In TLO assumed that every vehicle is equipped with GPS. Thus every node of the wireless network, i.e., the moving vehicle, knows the geographical location of vehicles within communication range. That leads to excessive communication among vehicles.

III. Broadcast Suppression Techniques

In this section we propose two broadcast schemes. In the first scheme node have to decide to rebroadcast or not. calculate its own reforwarding waiting time based on GPS information.

A. 15P Broadcasting

In this scheme specific packet retransmission range is introduced to reduce

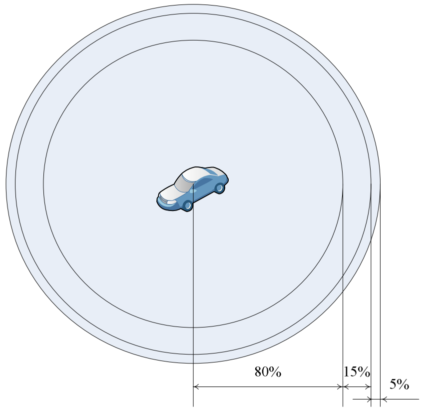

Fig. 1. Transmission range of a node for 15P

the number of nodes that will rebroadcast received message that will cause to broadcast storm reduction. Node's transmission range is divided into three region: 80%, 15% and 5%.

Only nodes within 15% range will rebroadcast received packet. (Fig.1).
Denoting the average transmission range by R and the relative d istance between nodes k(transmitter) and m(receiver) by Dkm, there transmission decision of node m can be defined as

$$0.8R \leq D_{km} \leq 0.95R \qquad (1)$$

For example, in the single-lane with light traffic density case 25 cars/km/lane, node with 500 m transmission range, will have at least 3 cars in the 150 m (two 15% of 500 m) retransmission range. This means that in the worst case each vehicle will have a rebroadcasting node in its communication range.

But as the traffic density increases the number of nodes in the rebroadcasting range will increase. Packet transmission of the nodes at the same time may lead to packet collision. This problem can be avoided using time slot reservation of the 15% range for each node. Thus the node in the time slot will wait specific WAIT_TIME to begin retransmission.

B. Slotted 15P Broadcasting

The main idea of this proposal is similar to TLO [20] to find the last node within communication range of a sender. In this scheme there is no need for neighbor information. Thus it overcomes TLO in the way of complexity.

Same as in the previous scheme, 15P, node's transmission range divided into three. 15P range is divided into time slots with 5-7 m length (the average length of vehicle, in order to have 1 vehicle per slot). Each vehicle will be assigned with specific waiting time according to its location (Eq.2) and a shorter waiting time will be assigned to the nodes located in the farthest region. Two nodes located in the slots next to each other will have Δ more waiting time. After receiving a packet node checks the packet ID and rebroadcasts it at the assigned time slot T.

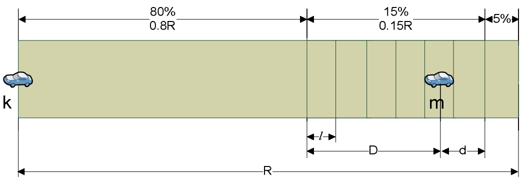

Fig. 2. Range measurements of transmitter and receiver nodes.

In order to compute the waiting time a node has to calculate its slot number n according to location information. It can be done by the following:

$$n = \frac{d}{l}$$

where d is the distance from receiver node to the end of retransmission range, l is the slot length (average vehicle length 5-7m). Putting

$$d = 0.95R - D$$

where R is the transmission range of a node, D is the relative distance between a sender and a receiver, we get

$$n = \frac{0.95R - D}{l}$$

The waiting time WAIT_TIME for a specific node can be expressed as:

$$\text{WAIT\_TIME} = \tau + n \bullet \triangle$$

$$\text{WAIT\_TIME}\,\tau + \frac{0.95R - D}{l} \bullet \triangle \qquad (2)$$

where, τ is a one hop delay, Δ is the waiting time difference between two neighbour slots.

IV. Simulation Results

We consider a one-dimensional line (single-lane network). We developed a network simulator using NS2 [21] to create a broadcast scenario on 5 km a single lane straight road and for each simulation run, a new topology is created and broadcast packets are propagated. Each node has a broadcast range of 500 m. To analyse the performance of proposed schemes, statistics such as link load, the number of retransmitted nodes and packet loss rate are presented.

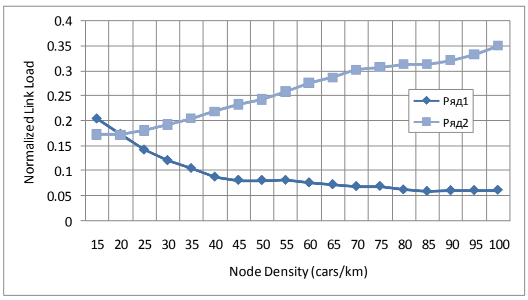

Fig. 3. Link load

Figure 3 shows the link load normalized with respect to measured from the simple flooding case, at different network densitiesforproposedtechniquesmentionedearlier.

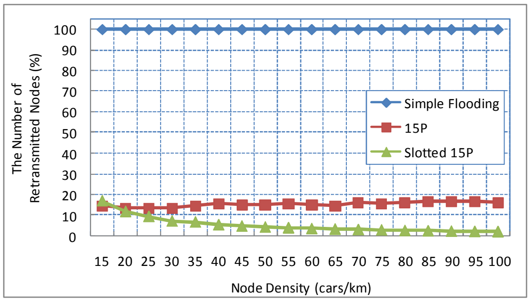

Fig. 4. Comparison of number of retransmitted nodes for (a)15P and (b)slotted 15P

As we can see from the results second proposed scheme shows best link load result. Because, in the 15P scheme as the traffic density increases the number of nodes within retransmission range increases, while in the slotted 15P there is only one node in the communication range that will rebroadcast received packet.

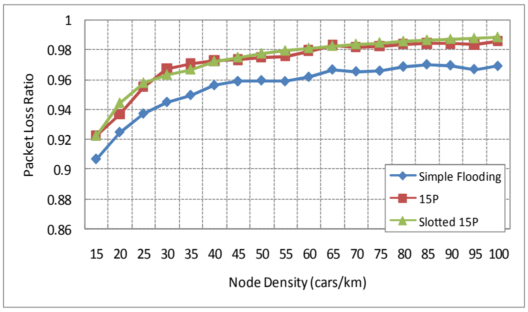

Fig. 5. Packet loss rate

Fig. 5 shows the number of rebroadcasted nodes at three different schemes. We assumed that the number of rebroadcasted nodes measured from the simple flooding is 100 percent. According to this we compared our proposed schemes.

The broadcast packet loss ratio at proposed schemes and simple flooding is shown in figure 5. Note that this packet loss ratio in the scenario considered to the loss of duplicate packets only; therefore the results are very high.

V. Conclusion

We have proposed new broadcast suppression techniques that can significantly reduce packet loss rate in VANET. In these schemes communication range of the node is divided into 3 (80%, 15%, and 5%) ranges. The 15% of the range named rebroadcasting range and the nodes only within this range will rebroadcast the message. The first proposed scheme has a lack in the light traffic densities. Node does not have any node in its 15P retransmission range. In order to improve the performance of this scheme in the light and high traffic densities the rebroadcasting range is divided into slots and nodes within these slots will have different waiting time to rebroadcast received message. This kind of approach will reduce the number of nodes in the same collision domain.

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