On Hybrid Re-Broadcasting Techniques in Vehicular Ad Hoc Networks

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Abstract

Vehicular Ad Hoc NETwork (VANET), a subclass of Mobile Ah Hoc NETwork (MANET) has been a tech-buzz for the last couple of decades. VANET, yet not deployed, promises the ease, comfort, and safety to both drivers and passengers once deployed. The by far most important factor in successful VANET application is the data dissemination scheme. Such data includes scheduled beacons that contain whereabouts information of vehicles. In this paper, we aim at regularly broadcasted beacons and devise an algorithm to disseminate the beacon information up to a maximum distance and alleviate the broadcast storm problem at the same time. According to the proposed scheme, a vehicle before re-broadcasting a beacon, takes into account the current vehicular density in its neighborhood. The re-broadcasters are chosen away from the source of the beacon and among the candidate re-broadcasters, if the density in the neighborhood is high, then the candidate re-broadcaster re-broadcasts the beacon with high probability and with low probability, otherwise. We also performed thorough simulations of our algorithms and the results are sound according to the expectations.

1. Introduction

ITS (Intelligent Transportation System) is no longer a dream because of emerging VANETs (Vehicular Ad Hoc NETworks), a specialized and more ephemeral breed of MANET (Mobile Ad Hoc NETwork) where V2V (Vehicle-to-Vehicle) and V2I (Vehicle-to-Infrastructure) communication paradigms will provide safe, reliable, and infotainment-rich driving experience to the consumers. The importance and potential societal impact of VANET can be confirmed by the rapid proliferation of academia, consortia, and the industry. In literature, examples such as NOW (Network on Wheel) [1], the EPFL Vehicular Network Security [2], and California Path [3] can be found where huge resources have been spawned specifically for ITS research.

VANET messages can be divided mainly into two forms, Scheduled beacons and safety-related messages [4]. The ephemeral nature and unique directional mobility of the vehicles delivering messages to all neighbors, represents a major challenge due to the sporadic nature of wireless communication. Moreover, because of the absence of the infrastructure and the movement patterns of the vehicles, they need to broadcast the information in the neighborhood. In order to construct local and extended views for the drivers, cooperative awareness is essential among the vehicles. Such cooperative awareness is realized through scheduled beacons according to DSRC (Dedicated Short Range Communications) standard [5]. Current DSRC standard recommends the beacon frequency to be between 100ms to 300ms, yet this frequency is controversial among the research community. Nevertheless, efforts have been going on for a dynamic frequency-based beaconing to lessen the channel burden and utilize the full bandwidth [6].

When it comes to local and extended views, then beacons play a prominent role in VANET application because the data from beacons is the main source of cooperative awareness. Local views can be constructed efficiently with single-hop beacon messages but when it comes to extended view, single-hop beacons are of least help. In order to construct extended traffic view, beacons must be re-broadcasted multiple times in order to penetrate the information up to a maximum distance. An easy and naïve way of doing that would be that every receiving node would re-broadcast the beacon again until it would reach a maximum distance. Theoretically this scheme works fine, but it gives rise to rather a more serious nightmare called broadcast storm problem [7,14]. In the literature, there are schemes that address aforementioned issue and propose intelligent re-broadcasting schemes [7].

In this paper we aim at the re-broadcasting mechanism of scheduled beacons in such a way to bridge the gap between efficiency and application requirements. We take into account the current traffic density around the receiver of the beacon and the distance from the sender on which it decides whether to rebroadcast the received beacon or not. Another problem arises from the vehicular density calculation perspective. In case of an ideal privacy-preserved beaconing mechanism, for instance Hussain et al.'s *identityless* scheme [8], it is very challenging to calculate the traffic density where messages are not linkable to each other. However, we relaxed the assumption that the density can be calculated from the number of beacons as long as beacons frequency is known.

The rest of the paper is organized as follows. Section 2 discusses the previous work done regarding broadcast storm problem and re-broadcasting. In section 3, we outline our proposed privacy-aware re-broadcasting scheme followed by

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the performance analysis in section 4. We give our concluding remarks in section 5.

2. Related Work

An ample amount of work has been done regarding broadcasting strategies in VANET [6,7].
Mittage et al. [9] discussed a thorough comparison between single-hop and multi-hop beacons and proposed a piggybacking mechanism to forward the beacons farther than single-hop. Schnaufer et al. [10] emphasized on the question whether single-hop beaconing is enough in VANET or do we need an ideal situation for multi-hop beaconing and proposed SLOPE (Self-Organizing Communication with Protocol Elements).
Considering the delay requirements from VANET applications for traffic safety or cooperative awareness (nevertheless, delay requirements are not stringent in case of cooperative awareness), relaying is usually not favored if the intended vehicles can be reached using a higher transmit power. Yet, it has been shown in [11] that single-hop beaconing occupies a significant part of the channel capacity. Consequently, multi-hop beaconing based on efficient relayers is still required to increase the cooperative awareness farther than one hop.
In [12] the authors analyzed how broadcast performance scales in VANET and they proposed a priority-based broadcast scheme where time-critical messages are given high priority. Nevertheless they did not discuss the beacons rebroadcasting and did not solve the broadcast storm problem.
In [13], the authors proposed distance based mechanism called urban multi-hop broadcast protocol where broadcast redundancy is suppressed by only allowing the farthest vehicle from the transmitter to rebroadcast.
In [18] different threshold-based schemes such as counter-based, geocast-based, and location-based techniques were proposed by Tseng et al.
It is worth noting that all the previous schemes discussed, aim at broadcasting from receivers' point of view. Laouiti et al. instead of thinking from receivers' standpoint, proposed a sender-centric broadcast mechanism, where sender controls the number of relayers among the receivers [15].
Wisipongphan et al. [16] proposed broadcast storm mitigation techniques that include *weighted p-persistence*, *slotted 1-persistence*, and *slotted p-persistence*. Nevertheless, they did not take privacy and the vehicular density factors into account.
As a result of the scrutiny of the previous schemes, in this paper we analyze the effect of vehicular density over the broadcast. We specifically aim at the scheduled beacons in our study. Our proposed scheme takes distance from the transmitter, neighbors density, and probability into account before deciding whether the vehicle under consideration should re-broadcast the received beacon or not.

3. Proposed Hybrid Re-broadcasting Mechanism

In this section, we outline our proposed hybrid multi-hop broadcasting scheme for beacons in VANET.

3.1. Baseline

Beacons are considered to be 'heart-beat' messages in VANET without which the local and extended traffic views would be extremely challenging if not impossible. It is worth noting that the alternatives such as road-side sensors, traffic cameras would do the job, but the infrastructure costs is too high to deploy them in full scale. In this paper, we assume that every vehicle broadcasts beacons according to DSRC standard with a frequency f_b. We assume Hussain et al.'s identityless beaconing mechanism [8]. The abstract privacy-aware identityless beacon format is given below.

$$B_i = B_{data} || Security\ Parameters$$

B_{data} represents the beacon data that includes current timestamp, location, speed, and heading information. Note that beacons are broadcasted anonymously and the security parameters in the beacons make sure that in case of any dispute, the beacons get revoked by the competent authorities.

3.2. Re-broadcasting taxonomy

The re-broadcasting mechanism can be divided into statistical, geometric, and network topology-based which covers probabilistic rebroadcasting and geocast-based re-broadcasting. The taxonomy is shown in Fig. 1 [17].

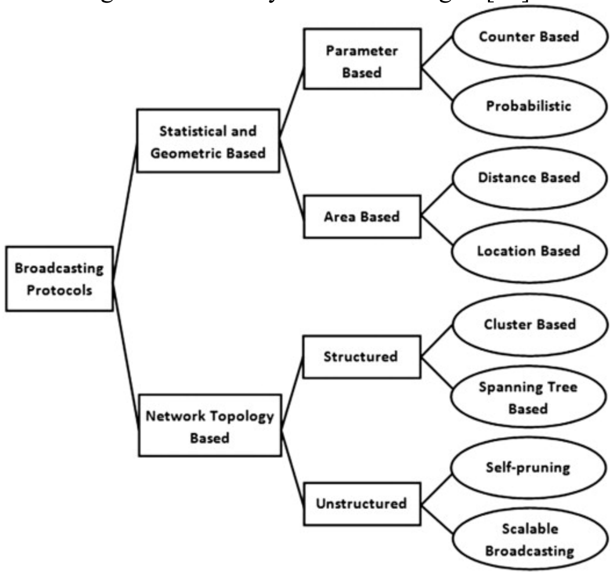

Figure 1. Taxonomy of rebroadcasting mechanisms [17].

Statistical and geometric-based rebroadcasting include probabilistic rebroadcasting, distance-based re-broadcasting, and location-based re-broadcasting. In the literature, distance-based re-broadcasting is termed as geocasting where farthest receiver of the message is selected as relayer so that the information can travel farther enough. In probabilistic approach, every receiver re-broadcasts with pre-defined probability.

3.3. Privacy-aware Traffic Density Calculation

Historically, liability and privacy have always been holding grudges against each other. Preserving user and location privacy are essential in VANET, they might be abused and movement profiles may be generated otherwise. At the same time, due to liability issues, the real identities of users must be revealed in case of any dispute. In the presence of ideal privacy preserving environment, revocation is not less than a major challenge. Meanwhile, when messages are not able to link to each other and to a specific user, traffic density cannot be calculated when only beacon messages are in hand. There are many other ways to calculate traffic density by using roadside sensors and traffic cameras, but we

TABLE 1. Results

Metric/ Scheme	Naïve	Distance based Pure (200m)	Distance with probability		*p*-Persistant Scheme		Density Based (100%,70%, 30%)	
			200m and 30% rest of	150m and 25% rest of	T.R 300m	T.R 250m	Without Delay	With Delay
Reception Rate	184/200	150/200	150/200	150/200	140/200	150/200	165/ 200	175/ 200
**Average Delay (1km)	0.108962 s	0.0724776	0.0744843	0.08654	0.06678	0.077984	0.09613	0.100
Standard Deviation	0.0475367	0.0493439	0.0437502	0.04934	0.03680	0.043065	0.05648	0.607
No.of Relayers*	n-1*	40%~50%	50%~60%	50%~60%	60%~ 70%	60%~70%	65~75%	65~75 %

**Suppose n represents the vehicle number who originated the beacon and the rest of the vehicles are the vehicles ahead of originating vehicles. The serial numbers of the vehicles behind originator are less than n.*
*** Delay is in seconds*

argue that the cost incurred by sensors and cameras is too high. We propose a privacy-preserved vehicle density calculation for our re-broadcasting mechanism.

Let suppose B_i denotes the *i*-th beacon and f_b denotes the beacon frequency, then at time *t*, the vehicular density around the calculator denoted by $D(v)_t$ is given by:

$$D(v)_t = \frac{\sum_{t_k}^{t_{k+1}} B_i}{f_b} + \epsilon$$

ϵ denotes the packets dropped, lost packets, and error margin, since wireless communication may have packet loss. Note that this formula estimates the traffic conditions in the neighborhood, in both forward and backward direction. It is worth noting that for rebroadcasting, we have to consider the vehicles both ahead and behind the candidate for rebroadcasting.

3.4. Re-broadcasting

In this sub-section we outline our re-broadcasting mechanism. In order to rebroadcast a received beacon, the receiver first calculates the current traffic density and classifies the density into three categories dense traffic, average traffic, or sparse traffic. It then calculates its distance from the original sender. If it is farther away from the sender and in a region which we called hot-spot broadcast zone, then it forwards it with a probability p according to our proposed algorithm. Note that for now we consider 1km distance to be covered by a specific beacon.

Algorithm:

1. *Beacon received*
2. *Extract the data and unique beacon identifier*
   a. *Classify the beacons from ahead and behind*
   b. *IF*
      the beacon is older than 2 seconds OR away from 1km, then DROP it
      ELSE
      Calculate the unique hash value and save it
3. *Calculate the traffic density at the moment*
4. *IF*
   $D(v)_t = LOW$ *AND I am at least 200m away from the sender, then re-broadcast according to 1-persistence scheme*
   ELSE IF
   $D(v)_t = AVERAGE$ *AND I am at least 200m away from the sender, then rebroadcast the beacon with a random probability between 50% to 70%*
   ELSE IF
   $D(v)_t = HIGH$ *AND I am at least 200m away Then rebroadcast with 25% probability*

It is worth noting that the number of re-broadcasters is of prime concern in re-broadcasting and we make sure that when the traffic density increases, we do not let broadcast storm problem to happen. And when there are more vehicles in the vicinity, then there are more chances that at least someone will re-broadcast, hence we give small probability to the receivers. Similarly in case of average traffic regime, we give a random probability, between 50% and 70%, to re-broadcast the beacon. In case of sparse traffic regime, we argue that there will not be too many vehicles to create broadcast storm, hence we give 1 probability to the receivers to rebroadcast the beacon. Another important point is that we assume the random equal distribution of the vehicles on the road.

4. Performance Analysis

In this section we outline the results obtained from simulations.

4.1. Simulation setup

We used NS2 version 2.34 to simulate our algorithm. The transmission range of the vehicles was set to 300m and the beacon frequency was set to 250ms. Every vehicle broadcasted 4 beacons per second. Each beacon was given a unique identifier by calculating a hash value from its contents and saved for 1 minute in the vehicles. We performed flooding, pure distance based, and our proposed hybrid re-broadcasting approach.

4.2. Simulation results

Table 1. gives our simulation results. Our performance matrix includes PRR (Packet Reception Rate), Average end-to-end delay, and number of average relayers.

As it can be seen from the table that the naïve broadcast incurs more delay than the distance with probability-based scheme, and p-persistence scheme. Similarly the distance with probability scheme has less number of relayers thereby alleviating the broadcast storm. The PRR is a tradeoff between performance and bandwidth. We alleviate the broadcast storm at the cost of slightly decreased PRR. But it can be argued that this much PRR is sufficiently enough for VANET application.

5. Conclusions

In this paper, we proposed a hybrid mechanism to rebroadcast the received beacons in order to expand the local traffic view to extended traffic view in Vehicular Ad Hoc NETworks (VANETs). Our proposed scheme takes into account, the privacy-aware traffic density, p-persistence based technique, and geocast-based technique to select the relayer for the beacons. The number of re-broadcasters is controlled by dividing the traffic regimes into dense, average, and sparse traffic regimes. In case of dense traffic regime, the number of relayers is lessened and every vehicle rebroadcasts the beacon with certain probability and the traffic density in the neighborhood enables the probability calculation. Our simulation results show that the number of rebroadcasts decreases in case of dense traffic regime thereby alleviating broadcast storm problems.

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