Ad Hoc Networks 37 (2016) 228–239

Contents lists available at ScienceDirect

Ad Hoc Networks

journal homepage: www.elsevier.com/locate/adhoc

A novel approach for scalable multi-hop data dissemination in vehicular ad hoc networks

Moumena Chaqfeh*, Abderrahmane Lakas

College of Information Technology, UAE University, Al Ain, United Arab Emirates

ARTICLE INFO

Article history:
Received 16 March 2015
Revised 8 July 2015
Accepted 27 August 2015
Available online 29 September 2015

Keywords:
Vehicular Ad hoc Networks (VANETs)
Data dissemination
Traffic density
Data redundancy
Broadcast overhead
Speed adaptive broadcast

ABSTRACT

Vehicular Ad hoc Networks (VANETs) have the potential to improve road safety and travel convenience, by providing self-organizing decentralized environments to disseminate traffic data, without requiring fixed infrastructure. The public interest of traffic data makes it appropriate for VANET data dissemination methods to rely on broadcasting. However, scalability issues arise when broadcasting under high density scenarios, where the high percentage of data redundancy and packet collisions may easily lead to the broadcast storm problem. Existing solutions either do not scale well under high density scenarios, or require extra overhead to estimate traffic density, so as to manage data dissemination accordingly. In this paper, we provide a novel approach for data dissemination in multi-hop VAENT that relies on traffic regime estimation to provide scalable broadcast, without extra communication overhead. Simulation results show the efficiency of our broadcasting approach in achieving low broadcasting overhead while maintaining the high data delivery ratio.

1. Introduction

Vehicular Ad hoc Networks (VANETs) aim at improving road safety and travel convenience, by providing a self-organizing network environment, without requiring a fixed infrastructure or centralized administration. In VANETs, vehicles are enabled to communicate cooperatively for exchanging information about road conditions and travel situations. With the increasing number of vehicles being equipped with communication capabilities, VANETs are expected to be available in the near future. When such vehicular networks are already in place, many of the proposed Intelligent Transportation Systems (ITS) can be supported [1,2].

The public interest of traffic data makes it more appropriate for VANET data dissemination methods to rely on broadcasting. However, broadcasting in dense networks suffers from a high percentage of redundant data that wastes the limited radio channel bandwidth. Moreover, packet collisions may lead to broadcast storm problem since a large number of vehicles in the same vicinity may rebroadcast the same data nearly simultaneously. The broadcast storm problem is still challenging in the context of VANET, since rapid changes in the network topology are difficult to predict and manage [3], while data redundancy should be limited.

A common employed solution to deal with such scalability issues is reducing the percentage of redundant data. This is typically done by selecting only some of the vehicles to relay data as opposed to letting every single vehicle rebroadcasting it. A major challenge in existing broadcast solutions is to reduce data redundancy while maintaining the high delivery ratio [4]. Existing solutions either do not scale well under high-density scenarios, or require gathering neighborhood data via beacons to estimate traffic density, such that vehicles can manage their broadcasts accordingly. Beaconing with a fixed period may have several drawbacks on the networking performance such as: wasted bandwidth, delaying of data packet and increased network congestion [5]. Beaconing alone can generate a high load on the network, and

* Corresponding author. Tel.: +971 507534848
E-mail addresses: moumena@uaeu.ac.ae (M. Chaqfeh), alakas@uaeu.ac.ae (A. Lakas).

http://dx.doi.org/10.1016/j.adhoc.2015.08.021
1570-8705/

therefore cannot be simply regarded as "background traffic" [6]. It is shown that when all vehicles send 200 bytes beacons every 100 ms (each vehicle sends 10 packets of 200 bytes data every second), channel would be 80% loaded at the range of 300 m [7], and sending 5 packets with the same mentioned settings would cause a channel load of 40%. Despite that beaconing will be part of VANET safety management, it is crucial for data dissemination methods to maintain the size of exploited beacons, in order to preserve the limited available bandwidth.

In this paper, we aim at providing scalable data dissemination in multi-hop VANETs, without the extra communication overhead of beacons. We propose and evaluate three variations of Speed Adaptive Broadcast (SAB): the Probabilistic SAB (P-SAB), the Slotted SAB (S-SAB), and the Grid SAB (G-SAB). Our broadcasting approach dynamically detects traffic regime via speed data without gathering density information, by utilizing the negative correlation between the speed and the density proven in traffic flow theory [8]. The reason of considering the speed instead of the density to estimate traffic regime is that the former does not require neighbor knowledge, while the latter does. The dynamic estimation of traffic regime in SAB allows for decentralized broadcast management, where each vehicle sets its rebroadcasting probability or delay according to traffic condition. The contribution of this work is three folds:

- First, we propose a novel approach for broadcast mitigation in VANETs that overcomes the limitations of existing approaches.
- Second, to our best knowledge, we are the first to succeed in adapting VANET broadcasting to traffic regime without extra communication overhead.
- Third, we prove the efficiency of Speed Adaptive Broadcast under high density scenarios.

The remainder of this paper is organized as follows: in the second section, we provide a background on the topic and we review related work. In the third section, we describe the three variations of Speed Adaptive Broadcast (SAB), and we evaluate their performance via simulation results in the fourth section. The last section provides concluding comments and suggestions for further work.

2. Background and related work

Broadcasting forms the basis of all communication types in ad hoc networks [9]. In VANETs, the public interest of traffic data makes it appropriate to utilize broadcasting in data dissemination. Flooding is the simplest broadcasting style, where the originating vehicle broadcasts a message to all its one-hop neighbors. In multi-hop dissemination, all receiving neighbors would rebroadcast the same message to their one-hop neighbors, and so on. Simple broadcast may easily lead to the broadcast storm problem in high density networks, when many vehicles in the same vicinity broadcast nearly simultaneously and too many collisions occur. Therefore, plain flooding does not scale with dense networks, due to the excessive dissemination of the same data, which wastes the limited available channel bandwidth.

Fig. 1 illustrates the broadcast storm problem in plain flooding. In the figure, node A initiates a broadcast and data

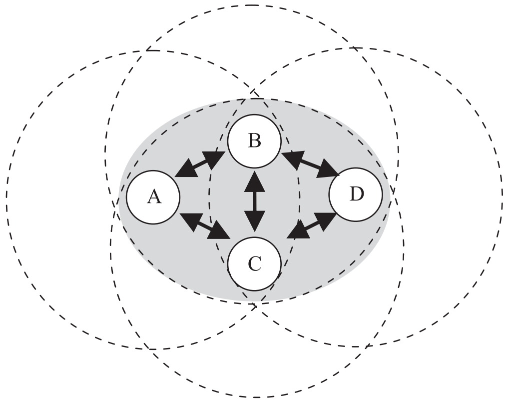

Fig. 1. The broadcast storm problem.

is received by nodes B and C. B and C rebroadcast the data if they had not broadcasted it before. Therefore, after receiving the data, D will rebroadcast if there is no collision. Flooding is extremely costly and may easily lead to the following [9]:

- Redundant rebroadcasts; that occurs when a node decides to rebroadcast data to its neighbors; however, they have already received the same data. In Fig. 1, since node A is within the transmission range of B and C, it will receive two redundant copies of the data from B and C, which is the same case with nodes B and C, as they receive the message from node D and also from each other.
- Packet collisions; which result in packet loss or corrupted messages. In the case illustrated in Fig 1, if nodes B and C broadcast at approximately the same time, there is a possibility of a packet collision at node D.

While efficient solutions for the broadcast storm problem are known in the context of Mobile Ad hoc Networks (MANETs), VANETs are still posing multiple challenges for existing broadcast mitigation strategies and solutions, basically because of the mobility feature that characterizes these environments. For a basic overview on mobile networks, we refer to [10]. In the rest of this section, we first describe existing solutions for the broadcast storm problem in the context of VANETs. Then, we provide a comparison among them to identify the benefits of our proposed approach.

2.1. Existing broadcast mitigation solutions

The basic approach that is commonly used for broadcast mitigation is to decrease the number of redundant data packets so that the delivery overhead is reduced, by selecting only a subset of vehicles to rebroadcast [11]. Protocols designed for data dissemination in VANETs present lightweight solutions in terms of data redundancy overhead. Among these protocols, two basic schemes can be distinguished: The Probabilistic scheme and the Delay-based scheme.

In the probabilistic scheme, a different rebroadcast probability is assigned to each receiving vehicle. Since only part of the vehicles will participate in data forwarding, redundancy overhead as well as the number of collisions is reduced. The main challenge of the probabilistic approaches is to determine an optimal probability assignment function