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Review Article

A probabilistic routing by using multi-hop retransmission forecast with packet collision-aware constraints in vehicular networks

Ahmad Mostafa [a], Anna Maria Vegni [b,*], Dharma P. Agrawal [a]

[a] School of Computing Sciences and Informatics, Center for Distributed and Mobile Computing, University of Cincinnati, Cincinnati, OH 45221-0008, USA
[b] Department of Engineering, COMLAB Telecommunication Lab., University of Roma Tre, Rome, Italy

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A B S T R A C T

In this paper, we introduce a novel reliable and low-collision packet-forwarding scheme for vehicular ad hoc networks, based on a probabilistic rebroadcasting. Our proposed scheme, called Collision-Aware REliable FORwarding (CAREFOR), works in a distributed fashion where each vehicle receiving a packet, rebroadcasts it based on a predefined probability. This probability is manipulated by different physical factors derived from the vehicular environment, including density of the vehicles in the vicinity, distance between transmitting and receiving vehicles, and finally, transmission range of the next-hop. All these factors are combined into one probability that enables each vehicle to evaluate whether there is another vehicle that ought to be receiving this message and could be feasible if the message is rebroadcasted. The success of rebroadcast is determined based on allowing the message to travel the furthest possible distance with the least amount of packet rebroadcast collision.

CAREFOR is different from other existing techniques as it accounts for the effect of the next-hop transmission in the rebroadcast decision. Simulation results show the effectiveness of our approach in terms of limited number of rebroadcasts needed with low collision probability as compared to existing techniques. Two and three-hops message retransmissions are also considered.

Contents

* Corresponding author. Tel.: +39 06 57337357.
E-mail address: annamaria.vegni@uniroma3.it (A.M. Vegni).

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1. Introduction

In the past few years, Vehicular Ad hoc NETworks (VANETs) have emerged as a critical component of Intelligent Transportation System (ITS), which can be considered to be a special kind of Mobile Ad hoc NETworks (MANETs), where mobile nodes are the vehicles. Due to the nature of the vehicles, node mobility in a VANET is constrained by certain paths (*i.e.*, highways and rural/urban roads), and with certain speed limits. Communication in a VANET can be carried in one of the two fashions [1]. The first is Vehicle-to-Vehicle (V2V) communication paradigm, where the vehicles communicate in an ad hoc multi-hop method. The second is Vehicle-to-Infrastructure (V2I), where vehicles communicate to a Road Side Unit (RSU) or an Access Point (AP) on the sides of a road or a highway. The main objective of the VANET design is to provide different categories of applications including Internet access, as well as safety and traffic congestion to vehicles, operators, and passengers.

V2V protocol provides vehicular communications through a Dedicated Short-Range Communication (DSRC) in multi-hop mode that exploits flooding of information for vehicular data applications [2]. With an increasing number of vehicles equipped with *on-board* wireless devices, (*e.g.*, UMTS, IEEE 802.11*p*, GPS, Bluetooth, etc.) and sensors (*e.g.*, radar, lidar, camera, etc.), efficient transport and management applications are helping in optimizing the flows of vehicles by reducing the travel time and avoiding any traffic congestion. On the other hand, non-safety applications are expected to create new commercial opportunities by increasing the market penetration of the technology and enhancing its cost-effectiveness. *Comfort* and *infotainment* applications aim to support road travelers with needed information and entertainment to make the journey enjoyable. Such applications are numerous and range from traditional IP-based applications (*e.g.*, media streaming, voice over IP, web browsing, etc.) to unique requirements for the vehicular environment (*e.g.*, point of interest advertisements, maps download, parking payments, automatic toll services, etc.) [1].

Besides the nature of a VANET, the characteristics of a vehicular network are different from that of a traditional MANET. This is due to difference in the node mobility between the two types of networks. Although in MANET, the nodes are mobile, however, their speeds traditionally do not exceed 5 [m/s], which is different than VANETs where the node mobility reaches up to 40 [m/s]. This variation in speed and mobility causes the topology of VANETs to be highly dynamic, which in turn, causes disruptions in established connections and frequent link failure.

The study of connectivity in VANETs is not only important to evaluate the network performance and to understand packet exchange among vehicles, and between vehicles and RSUs; both modeling and prediction are crucial in enabling network designers to effectively improve the network deployment planning and resource management in order to meet applications' requirements [3].

Frequent topological changes of a VANET makes it not very efficient to rely on existing MANET protocols. Rebroadcasting packets by multiple vehicles causes an increase in redundant data, which leads to wasted bandwidth and misuse of radio channels in the network. One of the main objectives of packet rebroadcasting in a VANET is to minimize this redundancy while still guaranteeing packet delivery to all relevant vehicles.

Due to these unique features of a VANET, several types of routing protocols have been introduced in the literature [4]. These protocols are mainly defined taking certain attributes of the VANET into account, such as (i) connectivity-based, (ii) mobility-based, (iii) infrastructure-based, (iv) location-based, and (v) probability-based routing protocols. Later on, many techniques are used to exploit probability theory in system's dynamics, representing the likelihood of certain events such as the probability of link breakage at a given transmission power. Many such routing protocols utilize a probability model to indicate the state of a wireless communication link between two adjacent nodes, while using many different parameters (*e.g.*, link lifetime in the network) as a major routing parameter.

In this paper, we propose a probability-based multi-hop broadcast protocol, called *Collision-Aware REliable FORwarding* (CAREFOR) with an objective of reducing the number of rebroadcasts in the network. This minimizes the number of packets in the system, which leads to a lower collision probability and eventually improved throughput. CAREFOR achieves this by allowing the vehicles to compute the probability of their successful transmission in case they are selected to rebroadcast the packet if there exists no better candidate for rebroadcast. A better candidate would be a vehicle that has a chance of delivering the packet for a larger number of uncovered vehicles with fewer number of retransmissions and with minimum packet collisions. Hence, the CAREFOR algorithm relies both on collision avoidance and on a reliable forwarding mechanism. By using both, CAREFOR is able to limit the number of retransmissions while maintaining lower collision value.

The rest of the paper is organized as follows. Section 2 discusses some recent research on routing protocols for VANETs. We mainly highlight the work of [5], which is the foundation of our CAREFOR technique. In Section 3, we describe CAREFOR technique with details mainly covering the theoretical analysis of the next-hop vehicle election probability, and the collision probability estimation. Section 4 describes the main phases of CAREFOR algorithm. The simulation results demonstrate the effectiveness of our technique and are presented in Section 5, also supported by considerations on the use of two versus three hops forward prediction. Finally, conclusion and future work are drawn at the end of the paper.

2. Related work

Many categories of routing protocols in VANETs have been described in the literature over the past few years. One of these schemes is the probability-based routing protocol that avoids flooding of the network with duplicates of