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An opportunistic routing based on symmetrical traffic distribution in vehicular networks☆

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ABSTRACT

Efficient data delivery accompanied with low end-to-end delay is important in vehicular ad-hoc networks and optimal route selection is vital to improve these performance metrics. Different routing algorithms are proposed in VANETs. This paper reviews and analyzes these algorithms briefly and based on the analysis, a new opportunistic-based routing algorithm (OSTD) is proposed for urban scenarios. The proposed algorithm severely considers the type of vehicular distribution in the calculation of utility function. This utility function is used to evaluate the routes in the network. The reason of such a severe consideration is expressed and evaluated in the paper. Vehicle's driving path predictability is also used in the algorithm to forward the packet to a more suitable next hop, as vehicular mobility is the reflection of human social activity. Simulation results show that OSTD achieves a higher delivery ratio and lower end-to-end delay and packet loss compared to the other well-known protocols.

1. Introduction

Nowadays vehicles become able to use wireless communication technology. Hence, vehicular ad hoc network (VANET) arises. VANET is a special type of mobile ad-hoc network (MANET) in which vehicles act as nodes. Unlike MANET, vehicles move on predefined roads; their velocity depends on the speed signs and they also have to follow traffic signs and traffic signals [1]. There are numerous applications for VANETs and they can be used for different purposes, such as improving safety (accident avoidance, incident notification), driving enhancement (congestion monitoring, parking space allocation) and commercial services (business, entertainment) [2].

The main challenge of these kinds of applications is how to maintain persistent connection among vehicle nodes to transmit data from source to destination via wireless multi-hop transmission or carry-and-forward techniques. One of the key research topics is to design effective data delivery schemes. Therefore, some research works have been conducted on this topic recently. Among the existing schemes, some works focus on selecting a candidate intersection to forward data according to the density of vehicles on the road in city environment, such as VADD [3]. However, not only the density but also the distribution of vehicles on the road can affect the node's connectivity.

On the other hand, some research works have shown that human trajectories show a high degree of temporal and spatial regularity [4, 5].Most of trips made by the drivers are repetitive and formed by traveling between a limited number of sources and destinations. Therefore, vehicular driving paths are predictable [6] and using this predictability in data forwarding can improve connectivity in VANETs.

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In this study, driving path predictability, vehicular density and their way of distribution over the road are used to propose an Opportunistic routing, based on Symmetrical Traffic Distribution (OSTD) for data delivery improvement.

The rest of the paper is organized as follows: In Section 2, different routing protocols in vehicular ad hoc networks are briefly introduced. OSTD is presented in Section 3, and is evaluated by a simulation study in Section 4. Finally, Section 5 concludes the paper.

2. Related works

VANETs have some characteristics such as, high mobility, frequent topology changes, frequent network fragmentation, uneven distribution of vehicles, and no power and computation constraints, which differ from MANETs. Therefore, MANET's routing protocols, such as AODV [7] and DSR [8] are not suitable for VANETs and routing is one of the challenges in vehicular networks. Since a Global Positioning System (GPS) device will be a standard component in the future vehicles, position-based routing protocols attract some attentions in VANETs. Position based schemes use the geographical positioning information to select the next forwarding hop. Packet is sent to the next hop neighbor that is closer to the destination, without any map knowledge. This technique is called greedy forwarding toward the destination. They do not keep global network information and their performance mainly depends on the network connectivity. Thus position based routing schemes cannot work well when the vehicular traffic is sparse and of none uniform distribution. GPSR [9] and ASTAR [10] are examples of position based routing. To solve this problem, opportunistic routing has been proposed that can cope with the sparse and partitioned networks. No end-to-end path is assumed between source and destination in opportunistic routing schemes. Moreover, nodes do not require the global knowledge of network topology to forward the message. Routes are built dynamically and each node selects its next hop based on local information or carries the message until a suitable next hop is found. This comes at a price of additional delay in message delivery, due to the lower speed of vehicle's movement compared to the wireless communication's speed. Effective buffering of message also takes role in the delay increase of the network. VADD and MDDV [11] are examples of opportunistic routing.

Some works combine position based routing and opportunistic routing together. This class of protocols uses geographical maps in addition to location information to route the packets. TADS [12] and ACAR [13] are two examples of this category.

Traffic Aware Data delivery Scheme (TADS) is a protocol that chooses intersections dynamically to forward packets through a route toward the destination. Intersections are determined based on the link quality and the remaining Euclidean distance to the destination. Vehicular traffic condition is used to estimate the link quality in this scheme. The next hop through the next selected intersection is the node with minimum distance to the destination.

Adaptive connectivity aware routing (ACAR) protocol selects an optimal route with the best transmission quality. This transmission quality is based on statistical and real-time vehicular density that is gathered through an on-the-fly density collection process. At first, the route is computed based on statistical density information obtained from the pre-loaded map. Route's information is put in the packets' header and the packets will be transmitted along the selected route. While the packets are forwarded toward the destination, vehicular densities of the road segments will be collected as well. This process is called on-the-fly density collection. When on-the-fly density collection is completed, the destination will be aware of the density information of the road segments. ACAR protocol is suitable for both day time and night time city scenarios. However, when the vehicular density increases, ACAR may choose the highest density road to forward all the packets, which causes Medium Access Control (MAC) layer collisions. Therefore, delivery ratio cannot have much improvement and sometimes may decrease.

Some opportunistic routing protocols use human behavior based trajectories for route selection. Most of vehicular networks exhibit some sort of regularity and periodicity in their mobility patterns. And this can help the routing protocols to select a more suitable path. For example, public transportation networks follow periodic schedules. Even most individuals have fairly repetitive movement patterns, for instance driving to and from the work places at approximately same times of the day. Ahmed and Kanhere [14] proposed a scheme that incorporates the periodic behavior of mobility patterns to choose the best forwarder.

Most of the vehicles are equipped by GPS and navigation systems at the present time. Therefore, vehicle's location is available. Vehicles are installed with a pre-loaded digital map, which not only describes the road topology, but also is accompanied by traffic statistics such as vehicular density and average speed.

Most of the trips made by the drivers are repetitive because they travel between a limited number of sources and destinations. Thus, vehicles can be classified into three groups, based on their driving path predictability [15]. Vehicles with fixed driving trajectory, such as buses and tramways, vehicles with almost regular trajectories, such as private cars that travel between limited numbers of places such as home, workplace, supermarket, and park. Driving paths of these vehicles are almost predictable and some methods have been proposed recently to predict the private car's driving path [16–18]. Lastly, there are vehicles with variable driving paths that do not have certain destinations, such as taxies. However, if their destination is determined in the initial stage of the trip, their trajectories will be predictable. In a research, a driving path prediction method is proposed for taxies with the assumption of destination information gathering [19]. In this study, the predictable vehicular trajectory is used to help finding a suitable route. As was mentioned, this predictability is the consequence of human individual or social behaviors.

Therefore, driving path prediction of the vehicles is feasible and each vehicle can know its driving path beforehand. If vehicles broadcast their driving path in the hello messages, each of them can earn the trajectory of the vehicles that it meets on the road and this helps to choose a more suitable next hop. On the other hand, vehicular distribution can also be considered to select a