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A data dissemination scheme based on clustering and probabilistic broadcasting in VANETs

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A B S T R A C T

VANETs (Vehicular Ad hoc Networks) have attracted tremendous attentions due to their high applicability and commercial value. However, the frequent topology changes caused by the fast mobility of nodes create many challenges to the efficient data delivery in vehicular environment. With the aim to guarantee the stable and reliable communication between nodes, in this paper, we propose a novel data dissemination scheme based on Clustering and Probabilistic Broadcasting (CPB). A clustering algorithm is first presented according to the driving directions of vehicles, by which vehicles could exchange their data in a clustered way with sufficient connection duration. In the constructed clustering structure, a probabilistic forwarding is presented to disseminate data among vehicles. Each cluster member forwards the received packet to its cluster head with a calculated probability which is associated with the number of times the same packet is received during one interval. When receiving the sent packet, the elected cluster header continues to disseminate it toward the transmission direction. Simulation results show that our proposed protocol CPB outperforms the existing schemes in terms of information coverage, average message delay and packet delivery ratio.

1. Introduction

As one important component of Internet of Things [1], [2], the Vehicular Ad Hoc Networks (VANETs) now have attracted more and more attentions [3]. In VANETs, vehicles can share and exchange information with each other directly in a Vehicle-to-Vehicle (V2V) way or indirectly in a Vehicle-to-Infrastructure (V2I) manner [4], as shown in Fig. 1. By employing data dissemination relying on V2V and V2I patterns, VANETs can support various applications, e.g., enhancing passenger safety, improving transportation efficiency as well as providing commercial and entertainment services. In order to realize these applications, designing one efficient data dissemination scheme is undoubtedly quite important [5,6].

Actually, be one special Mobile Ad Hoc Network (MANET), VANET has its intrinsic characteristics, which makes it a challenging task to design a stable and reliable data dissemination scheme. First, because of the high mobility of nodes and fast topology changes, link partitions or network fragmentations frequently occur in vehicular environment [7]. This will greatly affect the data transmission and easily leads to severe packet loss. Secondly, as

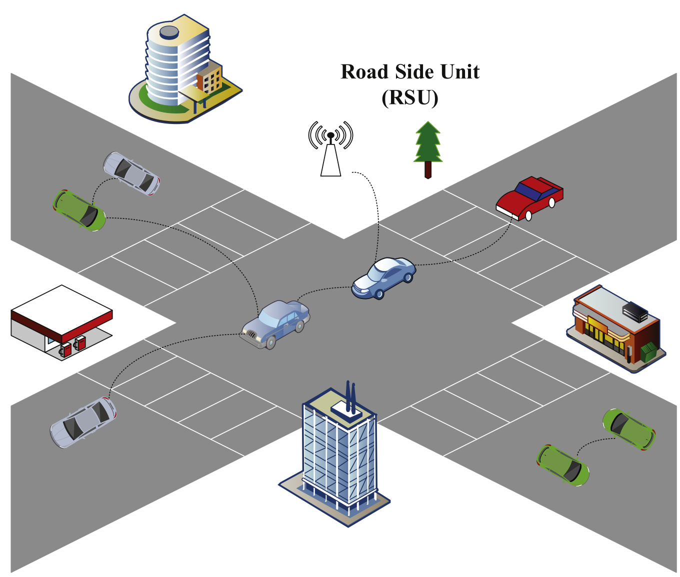

Fig. 1. V2V/V2I network architecture of VANET.

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one decentralized self-organizing network, the VANET lacks a centralized manager to manage the bandwidth allocation and contention resolution operations. Meanwhile, because of the limitation of wireless radio range, data packets between two faraway nodes are required to be forwarded in a multiple-hop manner, thus bringing the scalability issue. Moreover, the broadcast storm may arise when a larger number of nodes in the same vicinity rebroadcast the data packet simultaneously, which can cause severe data redundancy, packet collisions, and significantly waste the limited channel resource [8].

In VANETs, disseminating traffic information is a unique problem. This is because the traffic information is of public interest, and can benefit a group of people rather than a special individual. For example, when one emergency event occurs, the warning message should be disseminated to all vehicles in danger in the zone of interest as soon as possible [9]. A lot of researches have been denoted to design the data dissemination scheme, e.g., delay-based data dissemination and probability-based data dissemination [10], [11]. However, considering the characteristics of VANETs, a flat structure may cause serious hidden nodes and channel contentions problem. Without one central unit as the coordinator, the packet collision probability will be greatly increased, which may lead to the growth of packet loss rate and transmission delay, particularly in the network with high density. In such an environment, infrastructure based network holds a significant advantage over the flat network. This is because that access points allow optimal scheduling of channel access and distribution of network sources in a relatively simple manner. However, this needs to deploy a number of access points throughout the intended coverage area, which will bring the economy and installment cost of access points. To achieve some benefits of an infrastructure based network without the need of physical infrastructures, the clustering scheme is another promising technology, which can create the hierarchy network topology. The clustering approach first makes vehicles form platoons. In this way, vehicles could have sufficient time to connect to each other for fulfilling even complex information exchange with several handshakes. Meanwhile, each vehicle in a cluster could save its power to deliver the packets to its cluster head instead of transmitting these packets to a farther destination by themselves [12]. In addition, using cluster heads, the information redundancy and channel competition could be significantly alleviated by introducing data fusion or packets aggregation. Even a hierarchy network can make many benefits, there are still some challenges in the design of clustering of vehicles, for example, the mobility and distribution of nodes, the extra overheads for clustering forming and maintaining, as well as the channel fading and signal blocking from neighboring vehicles.

According to above descriptions, in this paper, we propose a novel data dissemination scheme named as CPB, on the basis of the directional clustering and probabilistic broadcasting. In our work, we first construct different clusters or platoons among vehicles according to their driving directions and geographic locations. After that, the cluster member calculates the forwarding probability depending on the value of a local-installed counter to guarantee the information coverage as well as packet delivery ratio. With proposed clustering and probability-based forwarding scheme, a series of issues stemming from the characteristics of VANETs, e.g., expanded latency, large packets loss, dynamic topology and frequent disconnection in VANETs, can be well addressed. In summary, the main contributions of our proposed scheme can be generalized as follows:

- We propose one new clustering metric as the guidance of cluster head election by comprehensively taking into account the mobility of vehicles and channel quality. Besides, in order to reduce clustering management overhead, each vehicle makes its own decision on cluster head election in a distributed manner by calculating its own back-off timer associated with the clustering metric.
- We tend to construct the clusters among vehicles with the same driving directions, by which the clusters could be maintained a longer duration and become more stable.
- When the network is initialized by the proposed clustering scheme, one simple and efficient probabilistic forwarding approach is developed to rebroadcast probabilistically, with the aim to reducing redundancy while still ensuring reachability and coverage.
- Experiment simulations are conducted to evaluate the performance of proposed protocol compared with some existing protocols in terms of some given metrics, revealing that our proposed protocol can solve the issues involving low packet delivery ratio and high latency caused by broadcast storm and dynamic network topology.

The remainder of this paper is organized as follows: Section 2 investigates previous related works on data dissemination protocols in VANETs. Section 3 introduces our assumptions and system model. Section 4 gives the framework of our proposed algorithm. Section 5 presents the clustering scheme in detail. Section 6 proposes the probabilistic forwarding scheme. Numerical results and corresponding analysis are given in Section 7, followed by the conclusion in Section 8.

2. Related work

Due to its high potential for improving road safety and traffic efficiency, a lot of data dissemination schemes have been suggested before in vehicular environment. Next, we first review several typical data dissemination protocols in categories, and then present a qualitative comparison among these protocols listed in Table 1.

2.1. Quality of service-based data dissemination

In VANETs, some applications are delay sensitive and have specific requirements in terms of performances, e.g., safety related applications. Thus, there is need to design one efficient quality of service (QoS)-aware data dissemination scheme to guarantee data transmission. Dua et al. propose one novel protocol to maintain QoS for data transmission [13], which can route the packet to the destination from the source node as soon as possible. In the protocol, one newly metric is designed to assign different weights to the corresponding routing paths between nodes, by which the algorithms for route construction and maintenance are developed, respectively. This protocol can solve broadcast storm problem and recover quickly when one link fails. Wahab et al. present one new QoS-based clustering algorithm by taking into account one tradeoff between QoS requirements and high mobility constraints [14]. The objective of the proposed algorithm is to form and maintain stable clusters during data communications while satisfying the QoS conditions.

2.2. Delay-based data dissemination

With the aim to efficiently deal with the broadcast storm problem, delay-based data dissemination solutions have been developed. These solutions depend on timers used by nodes as a distributed way to select one relay node to forward data packets. UGAD [15] adopts delay-sensitive broadcast suppression algorithm in urban VANETs. UGAD makes vehicles at intersections to rebroadcast swiftly by assigning them preferential priorities. In addition, vehicles in their work employ two kinds of forwarding modes in order to satisfy the transmission demand. As a result, this scheme