Abstract

Vehicular Delay Tolerant Networks (VDTNs) have been proposed to address the communication challenges through the store and forward techniques. These techniques employ the intermediate nodes, which take custody of the data and forward them when possible, but this method could generate congestion and lost packets if the intermediate nodes are not properly selected. However, the selection of the intermediate nodes remains as a central challenge. Therefore, we propose an efficient destination-based algorithm for dynamic custodian management by selecting the intermediate nodes according to the importance of the message, destination, current location and speed of the vehicles. An experimental evaluation was performed with real traces of taxis in the Shanghai city to show the feasibility and assess the performance of the approach. The results revealed an outstanding performance in terms of delivery ratio.

Key words: VANETs, VDTN, Custody, Data dissemination

1. Introduction

Nowadays, the Vehicular Ad Hoc Networks (VANETs) are widely used by the applications of Intelligent Transportation System (ITS) to disseminate information. The dissemination of information requires intermediate nodes (i.e., guards, relay nodes, custodians or carriers) to store and forward the information. Many recent studies have focused on the dissemination of information, using the store and forward technique to provide a reliable communication system. Flooding [1] disseminates the information to all the vehicles causing high rate of unnecessary duplication of data and congestion. In an effort to reduce these problems, the selection of the intermediate nodes has been considered the vehicular
density, the direction of the vehicles, the connectivity and delays of the paths [2-5]. Additionally, many investigators have considered the message context [6-8]. However, these studies do not consider the destination of the vehicles and the group mobility patterns. In order to disseminate the information taking into account the destination of the vehicles and group mobility patterns, we propose an efficient Destination-Based Algorithm for dynamic custodian management (DBDA). The aim of DBDA is to extend the previous studies addressing in a clever way the disconnection problems in sparse networks and the scalability problem in dense networks, to improve the delivery ratio and to reduce the unnecessary duplication of data, congestion and the delivery delay. The performance of DBDA is evaluated by simulations, using a real-world scenario and realistic vehicular traces. The simulation results revealed an outstanding performance in terms of delivery rate and delivery delay above all on the critical messages, it could be confirmed that the destination and group mobility patterns are valuable elements in the selection of custodians during the dissemination of the information to improve the delivery rate and decrease the congestion and delivery delay.

The rest of the paper is structured as follows. In section 2 we present the related work. Section 3 explains the assumptions of the proposal. In section 4, the destination-based dissemination algorithm is described. Section 5 shows the performance and the evaluation of the proposal. Finally, the conclusions of our work are presented in section 6.

2. Related Work

Context Assisted Routing (CAR) [9] addresses the disconnections by converting the road infrastructure into a weight-oriented graph. CAR proposed a mobile network partitioning method in square geographic regions, and nodes in the region are responsible for generating, receiving, storing and disseminating specific traffic context data (static or dynamic data) in the region. Likewise, Connected Dominating Set (CDS) [3] used a graph with junctions of the roads to explore the possibility of information exchange at the intersections of road segments. In order to disseminate the information, CDS implements a query message method, taking into account the direction and speed of the vehicles, the density and the connectivity of the path. CAR and CDS utilize geographic forwarding by focusing mainly on network connectivity. Whereas, Connectivity-aware Minimum-delay Geographic Routing (CMGR) [8] considers the communication delay, adapting the idea of a beaconing period. This method selects the most appropriate route according to the direction of the vehicles, the delay, bandwidth and connectivity of the route, assuming that the density along the path does not change. Another example of a method designed to target delay sensitive applications is PROMPT [5]. This method determines the paths by considering the total path delay and fairness, not just the network connectivity. PROMPT employs traffic statistics to gather information of the network connectivity but the statistics become stale after a time due to potential changes in route selection and traffic demands.

In contrast, Hybrid publish-subscribe [7] takes into account the destination of the vehicles, proposing a pub/sub model to disseminate information mainly to subscribers without affecting non-interested vehicles. Although the destination is considered when calculating the delay, little attention has been paid to the group mobility patterns and classification of the messages.

3. Assumptions

In the network three entities are considered: mobile nodes (MN), cluster head (CH), and base station (BS). Each vehicle has onboard units with Global Position System (GPS) or Navigation System (NS). The destination of each vehicle is known. The historical information of the traffic and density of each street are available. The communication is content-based. The routing is geographic-based. A Publish/Subscribe strategy is utilized, in which the CH can be both, information provider (publisher) and information consumer (subscriber). The requests to the BS and the dissemination of data to the cluster members are responsibility of the CH. Vehicles periodically (at each $\Delta t$) exchange information to choose the CH and the affiliations to each cluster.
4. Dissemination Algorithm

The basic steps of the dissemination algorithm are shown in Figure 1. The step of match the message against the subscription is implemented by the match function providing the relevance value of the message. This relevance is used to rebroadcast the message to the interested vehicles.

After the CH obtains the relevance value, the CH makes some verification to decide if the message will be published (forwarded to its cluster members) or forwarded to its neighbor nodes or dropped, by checking the following thresholds:

- **Relevance Threshold (RT):** This threshold determines which messages are important for the cluster members. If the relevance value of the message is less than the threshold, the message has to be published and forwarded to the cluster members.

- **Storage Threshold (ST):** Before publishing a message, the CH verifies if the available storage is greater than or equal to the storage threshold. When the available storage is less than the storage threshold, the CH deletes the publication with the highest relevance value and adds the new message. Furthermore, if the condition presented in equation (1) is true the deleted publication is forwarding to all the nearby CHs.

\[ t - CT > TTL \]  

Where \( t \) is the current time, \( CT \) is the creation time of the message and \( TTL \) is the time to live of the message.

- **Dissemination Threshold (DT):** The goal of this threshold is to adjust dynamically the algorithm according to the vehicular density to avoid congestion in dense networks and packets lost in sparse networks. The CH determines the number of retransmissions of the messages depending on the vehicular density.

The configuration of the thresholds is dynamic according to the environment. The value of the Relevance threshold depends of the type messages in a period of time, the value of the storage threshold is the 2% of the storage capacity and the value of the dissemination threshold is the media of the density statistics in a specific road.

In an effort to rebroadcast or propagate the messages efficiently, we consider two scenarios, 1) when the information is propagated within the target location or POI and 2) when it is propagated out of the target location (delivery-IN and delivery-OUT [2]). In the first scenario the goal is to send the automatic subscriptions to all the vehicles (i.e. broadcast) within the current location and send the custom subscriptions only to the interested vehicles through the "Relevance" value. Therefore, a variation of the flooding dissemination is implemented, in which the CH sends the messages to all its neighbors and each CH rebroadcast the messages to its clusters members.

The second scenario is more complicated, the CH has to select the best carriers or custodies of the messages to reach the target location (POI) (e.g. multicast, geocast and unicast) maintaining the uninterested message delivery as low as possible. The selection of the best carriers performs the following tasks:

- **Density Measures:** The dissemination algorithm takes the advantage of statistics of the road to calculate the density. This vehicular density is an essential factor to ensure a high delivery ratio because we need to select a path with good connectivity being dense enough to reach the target location but not too dense to generate overhead and low bandwidth. Therefore we used a similar version of the method proposed in CMGR [4] to calculate the connectivity in the network through the average expected value of the
density at certain period of time $T$ ($T_{n,p}$). In order to calculate this value, the variables of changing rate in the neighboring area of vehicle $V$ ($\gamma_v$) and density neighboring area of the vehicle $V$ ($\rho_v$). $\gamma_v$ is calculated by statistics and $\rho_v$ is calculated by the message exchanges as can be seen in equation (2).

$$\rho_v = \frac{N_v}{Lca_v}$$

where $N_v$ is the number of vehicles in the transmission range of $V$, and $Lca_v$ is the length of coverage area.

The density of the neighboring area of the vehicle $V$ during certain period of time $T$ ($T_{n,p}$) is calculated through the equation (3).

$$T_{n,p} = \rho_v + \gamma_v(T)$$

Additionally, the number of retransmission of the messages can be adjusted according to the density and the priority of the messages through a forwarding method which only rebroadcast the updates of information in the junctions (Graph-Based Predictive Location Service) [9] when it exists dense scenarios and low priority messages.

b) Paths Managements: In an effort to avoid the congestions of the flooding dissemination the vehicles can forward the data only through specific paths on the road. The selection of the paths is implemented with the information provided by the road maps (e.g. number of lanes, junctions of the road). Similarly to the method presented in CDS [3] and CAR [9]. However, we take into account the $(x, y)$ location of each junction to select the best path in terms of shortest distance to the POI (Dijkstra algorithm is used to calculate the shortest path) and highest connectivity. In order to improve the performance of the algorithm.

c) Custody Transfer: For the purpose of reducing the packet loss and delivery delay in sparse networks when there is no path with enough connectivty, the algorithm implements a store and forward technique selecting custody to carry the messages. The selection of the custody depends of the relevance value of the message, the current speed of the vehicle and storage capacity of the vehicle, giving priority to the critical messages to reduce the delivery delay. When a custody of an specific message is leaving the POI, it has to transfer the message to other custody. In order to ensure the delivery delay of the messages, an acknowledge mechanism is performed. In this mechanism the current custody has to carry the message until it finds another custody which assumes the responsibility for the message.

5. Performance Evaluation

The evaluation of the proposal is performed through a set of simulations. These simulations were developed in Java JDeveloper due to the diversity and flexibility of the scenario makes the task of configuring and adapting difficult in a generic simulator. In order to perform these simulations, we included the information of 4000 taxis of Shanghai city obtained from the Wireless and Sensor Networks laboratory of Shanghai Jiao Tong University [3]. This data contains a collection of GPS information of real-time locations of taxis in the urban city of Shanghai. The GPS information comprises the Id of taxi, the longitude, latitude and angle of the current location of the taxi, speed of the taxi, and the time that the GPS record was sent. This information provides real traces of the taxis, fitting each of the GPS registers to maps of the roads, with help of the interpolation in cases when the data obtained by GPS did not provide a clear trajectory. Additionally we modified this data by adding the destination of the taxi's trajectories. The general parameters that we used during the simulation are listed in Table I.

Each taxi followed its trajectory. When it reached its destination, the taxi was removed from the network and inserted from its initial location. This

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