Adaptive Routing Control Mechanism with a Stable Communication Topology Based on Vehicle Geocasting

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Abstract

Vehicular Ad-Hoc Networks (VANETs) are an emerging Telematics environment. VANETs have been applied in many fields, such as congestion avoidance, vehicle tracking, and crash notification. This work propose a novel stable communication control mechanism for VANETs, called dynamic geocast, and the information sharing group is defined by the information in the shared region. The dynamic geocast region also offers seamless and stable inter-vehicle communication based on highway conditions and vehicle status, including vehicle speed, transmission distance, and maximum and minimum speed limits on a highway. The key idea of the adaptive defer time routing algorithm is modified to overcome the problem of frequent network fragmentation, to predict when vehicles are within transmission range, and to identify new relay vehicles before network fragmentation occurs. The proposed transmission management system achieves stable inter-vehicle communication for a dynamic information sharing group in various situations in a highway environment.

The Architecture of Adaptive Route Control Mechanism

For construct a dynamic geocasting information group, the adaptive route control mechanism comprises five roles, including source vehicle, relay vehicle, mobile vehicle, opposite vehicle, tail vehicle, and outside range vehicles based on the geocasting range. The dynamic geocast-information sharing group Sequence Diagram is shown as in Fig. 1.

These roles provide many functions, such as integral group initialization, and as an adaptive route decision process for dense and sparse networks. This work also assumes that network topology frequent changes and network disconnection is in the highway situation, especially in sparse networks. Therefore, this work utilizes opposite road vehicles to temporality help forward messages to a group sharing information and to overcome this network disconnection problem. The source vehicle defines a dynamic geocasting region for the information-sharing group in this work and begins broadcasting a route discovery packet to the tail vehicle. Fig. 2 shows the dynamic geocast region situation for an information-sharing group.

The dynamic geocasting region of group is defined by the use of location information. Therefore, the source vehicle can periodically update location information for group members in a geocasting region. The range of sharing group information is limited by the dynamic geocasting region, which is limited by the geocast packet.

Fig. 3 shows the Adaptive Route Control Mechanism (ARCM) system architecture for inter-vehicle communication among a source vehicle, relay vehicle, tail vehicle, and opposite vehicle. The dynamic geocasting region module functions follow the location of source vehicle to limit the number of packets for the dynamic information-sharing group. The relay vehicle decision module monitor travel information for group vehicles and applies adaptive defer time to select relay vehicle with the longest lifetime. Furthermore, this work also considers the sparse network scenario, and utilizes the opposite road vehicle to help forward a message to overcome network disconnection. The system objective is to provide stable transmission quality for inter-vehicle communication; thus, a novel inter-vehicle seamless control scheme was designed to predict when relay vehicles exceed the transmission range and to establish new routes prior to network fragmentation.

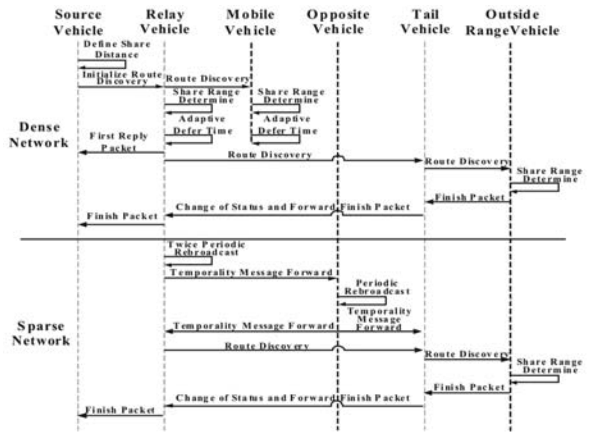

Fig. 1. Dynamic Geocast-Information sharing group Sequence Diagram.

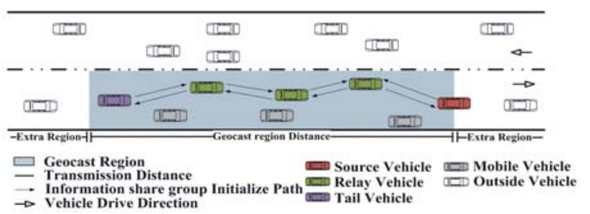

Fig. 2. Dynamic Geocast Region Situation for an information-sharing group.

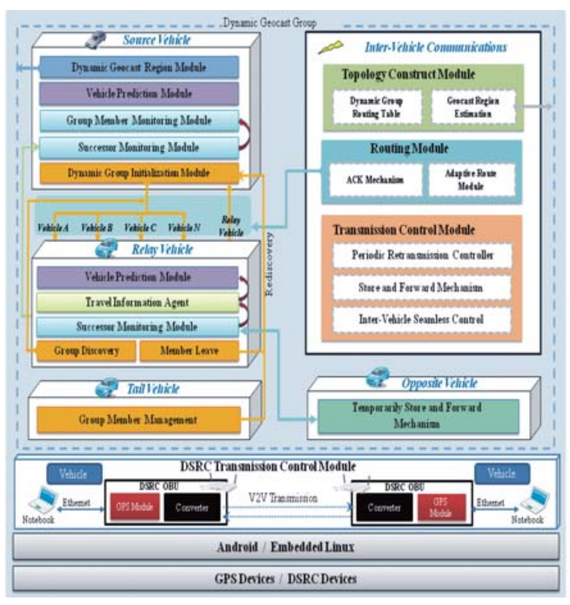

Fig. 3. Architecture of Adaptive Route Control Mechanism.

Adaptive Defer Time Algorithm

The shadow area in Fig. 4 is the geocasting region and forwarding region. If the source vehicle (*s*) broadcasts a message to initial the dynamic group, vehicle (*a*) is selected as the relay vehicle, and the defer time for a message received from vehicle (*s*) is the longest lifetime between the two vehicles. Therefore, the fastest response vehicle is selected as relay. Notably, vehicles do not rebroadcast immediately after receiving a message. This period before rebroadcasting is called defer time. In this work, adaptive defer time is based on various situations to prolong the lifetime of relay vehicle, and to overcome frequent changes in network topology. When vehicles are outside the transmission range, the network fragmentation occurs. Therefore, when vehicle (*c*) wants to forward a message to vehicle (*e*), and vehicle (*e*) is outside the transmission range of vehicle (*c*), the network disconnection occurs. This work utilizes the opposite vehicle as the forwarding vehicle to temporality help forward a message in the geocasting region.

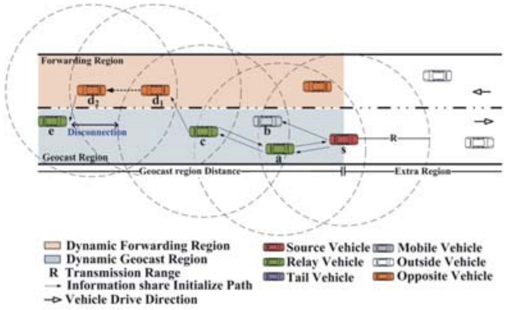

Fig. 4. Dynamic Geocast region for information sharing group.

This work provides stable inter-vehicle communication in VANETs using a novel adaptive defer time algorithm. Upon receiving route discovery packets, vehicles do not need to rebroadcast these packets immediately. Rebroadcast time is determined by the transmission range between two vehicle, which lifetime is the longest, i.e., adaptive defer time (T_{ai}). The rebroadcast time for a subsequent broadcast is based on transmission range (*R*) and its velocity (V_i), as in Eq. (1). For the opposite road vehicle, broadcast time needs the opposite vehicle top speeds (Vs_{max}) to solve the maximum difference speed problem. Rebroadcast time (T_{ri}) ensures that group vehicles do not travel beyond the transmission range of the broadcasting vehicle.

$$T_{ri} = \begin{cases} \frac{2R}{V_i}, \text{if same road} \\ \frac{2R}{V_i + Vs_{max}}, \text{if opposite road} \end{cases} \quad \text{where } i = 1,2,\ldots, n \tag{1}$$

The proposed algorithm mainly uses adaptive defer time to optimize the efficiency of Inter-vehicle communication. To minimize fragmentation, this work mainly selects the shortest adaptive defer time of relay vehicles in various situations to reduce the incidence of network fragmentation. This means is that the longest favourable lifetime of vehicles is in the transmission range between vehicles using Eq. (2).

Notably, V_i and V_j are the travelling velocities of source vehicle (*i*) and vehicle (*j*), respectively. The adaptive defer time is set according to V_i and V_j when calculating differential velocity and to determine the longest lifetime. When source vehicle (*s*) broadcasts a message, relay vehicle (*a*), which has the smallest defer time (T_{ai}), by Eq.(3), forwards the message.

This work also considered the effects of traffic jams on VANETs. Adaptive defer time resulting from broadcast overhead is high during traffic congestion. Since, the values of V_i and V_j are less than V_{min}, this work defines it as a traffic jam situation, which V_{min} is the minimum speed limit on a highway, i.e., if the speed of vehicles is less than the minimum speed limit on the highway, a traffic jam has occurred. Adaptive defer time is based the distance ($D_{i,j}$) between vehicle (*i*) and vehicle (*j*) for route discovery using Eq. (2) to overcome this traffic jam problem. After selecting the relay vehicle with the shortest defer time (T_{ai}) in various scenarios, a new relay vehicle is not selected until prediction time has almost expired. Prediction time can be the prediction value difference in lifetime for two vehicles. Hence, this work utilized this algorithm to provide stable message dissemination for inter-vehicle communication.

$$T_{ai} = \begin{cases} \frac{D_{i,j} \times (V_i - V_j)}{R \times V_i} \times T_{ri}, \text{if } V_i > V_j \\ \frac{(R - D_{i,j}) \times (V_j - V_i)}{R \times V_j} \times T_{ri}, \text{if } V_j > V_i \\ \frac{R - D_{i,j}}{R} \times T_{ri}, \text{if } V_i \text{ and } V_j < V_{min} \\ 0, \text{otherwise} \end{cases} \tag{2}$$

$$T_D = \min\{T_{ai,j} \mid j = 1,2,\ldots,n\}, \text{ where } i \neq j \tag{3}$$

Conclusions and Future Work

This work proposes a novel dynamic geocasting region for the defined integral information-sharing group on a highway. A novel approach is improved and stable transmission quality achieved using a novel adaptive routing strategy. First, the adaptive defer time algorithm of vehicle in dynamic group is used as the preferred relay vehicle to provide steady transmission according to the network state using the proposed defer time algorithm, thereby improving transmission reliability. Travel information of each dynamic group vehicle is monitored to predict when vehicles will be outside the transmission range and to identify new relay vehicles before network fragmentation occurs. Adaptive defer time setting can reduce unnecessary broadcasting in various situations, including dense and sparse networks.

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