A Selective Flooding Method for Propagating Emergency Messages in Vehicle Safety Communications

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Abstract

An intelligent vehicle safety system can be constructed by exchanging emergency-related information between any unrelated vehicles, such as urgency stop, traffic accident, and obstacles. In the most of vehicle safety communication applications, an emergency message is propagated in the form of broadcasting. However, it causes a lot of problems in terms of efficiency due to the multi-hop propagation and radio collision problems. This paper presents a selective message forwarding method by assigning a defer time based on the number of the common neighbors. With benefit of this method, only selected vehicles perform a re-broadcasting the received emergency event among the vehicles included in the same wireless coverage. Moreover, the proposed scheme improves the efficiency of message transmission with the selective assignment of priority for forwarding message. To analyze its performance, it has been evaluated by network simulator.

Keywords: Selective Flooding, Vehicle Safety Communications, Emergency Message, Least Common Neighbor, Broadcasting

1. Introduction

Running vehicles are threatening passenger's life by road status, trouble of vehicle, traffic accident and so on. However, various hazardous factors may result in casualties when drivers do not notice hazardous factors or cannot react in time to these hazardous factors. In normal road situation, the driver can easily experience a rear-end collision when an event suddenly occurs. The majority of vehicular manufacturers put emphasis in passive safety system, such as airbag system, crumpling vehicular fame, anti-lock breaking system, crash pre-sensing system, electronic vehicle stability programs and so on, development when traffic accidents occurs. These devices have a limitation to decrease the traffic accident occurrence rate, because the devices are purposed to minimize direct damages in the accident.

In emergency situations, drivers typically rely on the trail brake light of the car immediately ahead to decide his or her braking action. Under typical road situations, this is not always the best collision avoidance method, for various reasons. This is particularly true in many situations where vehicles need to have an extended range of awareness beyond that which drivers can immediately see or vehicle safety system can detect. In many cases, driver's reaction time typically ranges between 0.7 and 1.5 seconds [1]. According to OFCOM's investing reports, if drivers have a 1 second composure time, before reacting to hazardous factor, the 90% of rear-end collision accidents can be reduced [2]. Chain collisions can be potentially decrease, or their severity can be highly reduced, by lowering the delay between the occurrence time of an emergency event and the time at which the vehicles behind are informed of the event [3].

Broadcast service is important for all kinds of networks. Whether a new message needs to be sent to all participants across the network or a destination's location is unknown, broadcasting is a necessary condition [4]. If vehicles run on the same road, these vehicles do not have a pre-relationship with each other. Therefore, the broadcasting service is useful in the inter-vehicle communication. Inter-vehicle communication makes use of a successive broadcasting method which is a flooding to extend

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transmission coverage, as the simple broadcasting considers only 1-hop transmission. However, a simple flooding method drops network efficiency dramatically and results in frequent message collisions, when the density of vehicles is high [4]. Therefore, a number of inter-vehicle communication methods attempt to overcome those problems by using the selective re-broadcasting methods [5, 6].

This paper deals with a kind of the selective re-broadcasting. It makes use of the number of common neighbor for selecting an effective representative node, which relays emergency messages. The message's sender informs its neighbor list included in the sending message. The common neighbors are shared nodes between the sender and the receiver. The more two vehicles close, the more the number of common neighbor increase. If the number of common neighbor is low, two vehicles are away from each other. More appropriate relay node locates enough away in the radio coverage. Proposed method makes use of forward delay time that is proportion to the number of neighbors. The node that has the least common neighbor is selected as relay node in the hop; because the node has the shortest defer time. Because the proposed protocol is based on the LCN (Least Common Neighbor), it called LCN protocol. As a result, few vehicles relay the emergency event among vehicles included in the same wireless coverage; therefore, broadcasting overhead for vehicle safety is reduced.

The remainder of this paper is organized as follows. Section 2 presents background and work relating to selective re-broadcasting; section 3 contains proposed method and protocol steps; section 4 presents the simulation model, the results and the analysis of the proposed approach; the last section concludes this paper.

2. Background and Related works

2.1 Background

There is much research in the area of the V2V (Vehicle-to-Vehicle) communication [7]. The majority of traditional protocols make use of location information to exchange vehicle's current locations periodically with neighbor nodes. These operations require numerous wireless resources and are unrealistic due to the vehicles' high mobility. Sometimes, the location information disables. The GPS that is a representative location system disable in the tunnel, underpass and multi-layered road. Therefore, the majority of vehicle safety-related protocols make use of the directional forwarding protocol, for propagating vehicle emergency information. Those protocols use the inefficient random position method, because exchanging position information is not usually required.

The majority of vehicles that want to be included the safety warning networks have radio transceiver/receivers. The wireless network devices gather neighbor information easily by hearing packets or exchanging hello messages. The proposed protocol not only doesn't acquire location information, but also doesn't exchange any information periodically.

2.2 Related works

Reference [5] introduces two GPS-based message broadcasting methods for adaptive inter-vehicle communication. TRADE (TRAck DEtection) protocol is a method of candidate assignment-based. The protocol requires explicit exchanges of GPS position information between neighbors periodically, and maintains three neighbors group such as front group, rear group, others group. To avoid position information exchanging, DDT (Distance Defer Transmission) protocol uses that each message is stamped sending node's position. In this protocol, nodes which have longer deferred time than re-broadcasting node, give up re-broadcasting. If other nodes did not re-broadcast when its timer is expired, it re-broadcasts the message. GPS based two protocols make use of the location information.

The NB forwarding method [8] serves as a baseline packet-routing mechanism for the target cooperative collision avoidance application. As soon as detecting an emergency event, the detecting vehicle sends CW (Collision Warning) message periodically at regular intervals [9]. Upon receiving a message, a vehicle decides whether to actuate related devices and start generating its own CW messages or ignore the message. Vehicles ignore the message if it comes from back with respect to its direction of movement.

The LPG protocol [9] discusses about vehicle group method for vehicle safety communications. The method makes neighbor vehicle a group and presents communication methods that divide intra-group communication and inter-group communication. In intra-group communication, nodes transmit messages rapidly because they use lower layer communication protocol. In inter-group communication, nodes transmit message with restriction during time because they use upper layer protocol. Necessity that the protocol manages before and behind order of inner group vehicles was occurred. So, vehicles that participate to this vehicle safety communication exchange their location information with neighbor periodically.

3. Least Common Neighbor Flooding

3.1 Common neighbor

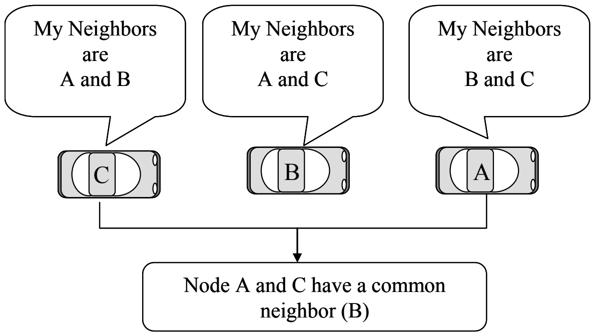

Figure 1. Common neighbor

The common neighbors are nodes shared between two nodes. If two nodes have one or more common neighbor in addition to each other, relay node election procedure is needed. Figure 2 shows a concept of common neighbor. Vehicle A, B and C run on same road and move to same direction. Vehicle A has a neighbor list included vehicle B and C. Vehicle C keeps a list with vehicle A and B. Two vehicles look on vehicle B as a common neighbor. Vehicle A and B regard vehicle C as a common neighbor too. If vehicle A issues a vehicle emergency message, one of its neighbors may play a role of relay node.

3.2 Least common neighbor

Nodes that participate to wireless network are using same wireless interface. Therefore, sizes of node's radio range are similar. Receivers can estimate its relative location from sender using the number of common neighbor, when a sender broadcast an emergency message. Distance between two nodes is nearer, the number of common neighbors increases. On the contrary, distance between two nodes is more estranged, the number of common neighbors decreases. Figure 2 shows the number of neighbor by relative distances between two nodes. In case 1, the sender and receiver are highly near. The number of common neighbors is seven. Two radio ranges are nearly overlapped each other. In case 2, node B is situated near half of node A's radio range. The number of common neighbors decreases by five. Although three new nodes added by node B, They are not A's neighbor nodes. In case 3, node B locates near node A's radio boundary. Only three nodes are the common neighbor between node A and B. The node that has the fewest number of common neighbors is furthest from the sender.

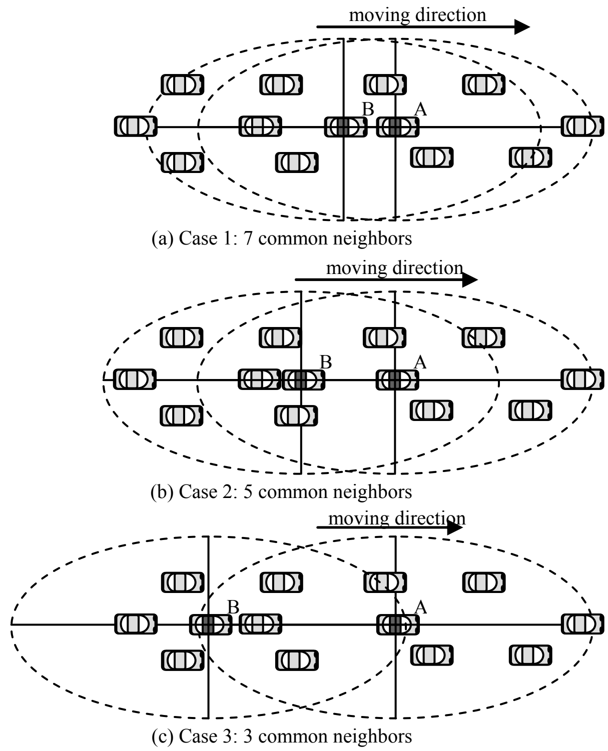

Figure 2. The number of common neighbor change by position of two nodes

This paper defines the node that has minimum common neighbors, that is LCN (the Least Common Neighbor node). There are many LCN nodes in a radio range. Several LCN nodes can locate near radio boundary. Therefore, a LCN is a group of nodes that they have same the number of common neighbor. The number of common neighbor is independent each other. The LCN group is a virtual group. Therefore, there is no need to manage group membership function and no need to maintain the LCN-related information. When new vehicle emergency message is issued from a certain node and is propagated in vehicle safety communication, the LCN group constructs virtually. The LCN members are most suitable as relay node. Therefore, the LCN concept is used to select re-broadcasting node.

3.3 Relay node selection

Proposed scheme introduces a method of relay node selection based deferring time of emergency message relaying. The scheme makes use of the number of common neighbor for selecting an effective representative node, which relays emergency messages. One of LCN members is selected as a relay node.

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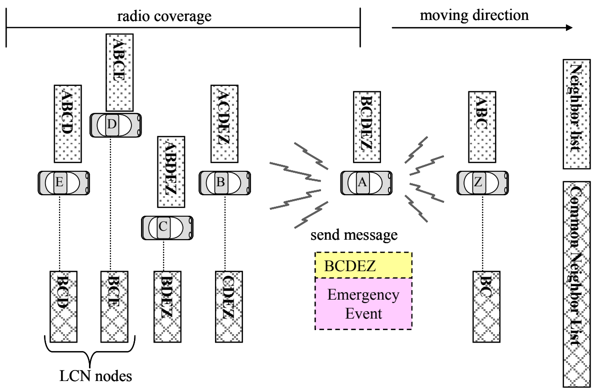

Figure 3. Relay nod selection by common neighbor

Using the concept of LCN, each node calculates its basic deferring time. The deferring times of nodes are directly related with the number of common neighbors. If a node has three common neighbors with message's sender, the node defers relaying a message for three time units. Basic deferring time calculates to multiply the number of common neighbor by milliseconds per neighbor. Figure 3 describes the method of relay node selection.

Assume that vehicle A recognizes a hazard and issues an emergency message including its neighbor list. Vehicle B, C, D, E and Z receive the message simultaneously. All receiving nodes compare its neighbor list with sender's neighbor list including in the message. Vehicle B and C have four common neighbor and vehicle D and E have only three neighbor. Vehicle Z has only two common neighbors, but the number is not fact, because forehead vehicles are omitted in the figure. Vehicle D and E have the smallest number of common neighbor with vehicle A. One of two vehicles may be a relay vehicle.

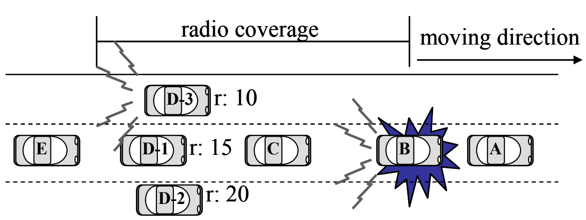

Figure 4. Random value for mitigating competition

In many cases, candidate nodes are many because of structure of road. Vehicles that have same the number of common neighbor may try to relay the received message. There is necessity to solve this competition problem. Proposed method uses random function to mitigate competition of vehicles that they have same number of common neighbor. Figure 4 describes situation that solve competition problem using random value. Vehicle B senses danger situation and issues a vehicle emergency message. Vehicle D-1, D-2 and D-3 receive the message and generate a random number respectively. 15, 20 and 10 are generated at each node. Vehicle D-3 has the smallest number among vehicles. D-3 has highest order.

Relay node selection performs two steps. In the first step, each node calculates its basic deferring time with the number of common neighbors. In the second step, each node gets additional deferring time with random function. Maximum value of random deferring time is smaller than basic deferring unit time. The total deferring time is sum of basic deferring time and random deferring time.

4. Simulation & Performance Analysis

4.1 Simulation environment

Table 1. Simulation Parameters

Simulation parameters	
Parameter	***Value***
Node density	50~500
Vehilce speed	80~120km/h
Simulation area	2500m X 2500m
Number of events	10
MAC protocol	IEEE 802.11
Radio range	250m
Emergency message's TTL	5
Vehicle acceleration	3 times each
Simulation time	30 seconds

The simulation has been implemented in NS-2 (version 2.29) [10]. The proposed protocol was designed for vehicle safety communication. All vehicles depart at different position, and change speed as time goes periodically. The speed steps that each vehicle uses are from 80Km/hr (22.22m/s) to 120Km/hr (33.33m/s). So the topology of vehicles changes continuously. Vehicles do not change moving direction during simulation. The number of lanes is four. So, higher speed vehicles may progress passing lower speed vehicles. In simulation, a certain vehicle belonging to forefront group creates and broadcasts emergency event occasionally until 5 hops distance. The parameters used for the simulation are listed in Table 1. The LCN protocol has been analyzed for its performance with Naive directional flooding protocol [8]. The Naive protocol is named a pure flooding protocol because the protocol does not use selective flooding method.

4.2 Performance evaluation

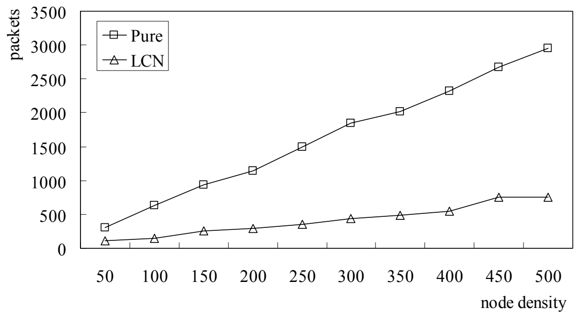

Figure 5. The number of forward packets

Figure 5 depicts the number of forward packets according to the number of vehicles respectively. The number of forward packet increase commensurately with number of vehicle in pure flooding and LCN flooding. But, the number of forward packets of LCN is less than pure flooding. Proposed LCN protocol reduces forwarding packets with decreasing the number of nodes to attempt forward. The LCN achieves emergency packet propagating with 25%~35% of packets that pure flooding uses.

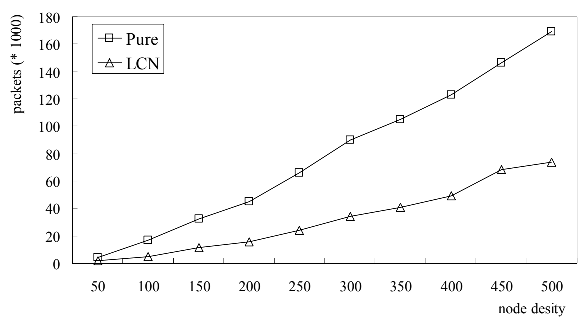

Figure 6. The number of received packets

Figure 6 show the number of received packets. Normally, if the number of vehicles increases, the number of received packets increases exponentially. The number of received packets is deeply related with vehicle density. In case pure flooding, 10 event messages are received about 170,000 times in whole network. Each vehicle receives 340 messages about 10 events averagely when 500 vehicles participate in the network. In case of LCN, the number of packet to receive is less than half degree of pure flooding level. Each vehicle receives around 148 messages when 500 vehicles participate in the network.

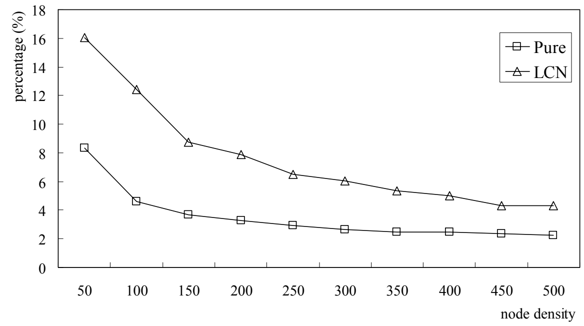

Figure 7. The percentage of effective packets

Figure 8 show the percentage of effective packets. The effective packet means that the packet is not duplicated. Once receiving a new message, every vehicle discards the messages which are duplicated. Of course, the first duplication is very important for implicit acknowledgment. So, the percentage of effective packet may not pass over maximum 50% for reliability. As the number of vehicles increases, the number of effective packets increases proportionally, but the number of received packets increases exponentially. The percentage of effective packets decreases by increasing the number of vehicles. As seen in Figure 8, both protocol is apt to drop the percentage as the number of vehicles increases. Proposed protocol shows packet efficiency about double.

4.3 Discussion

Wireless network technologies (i.e. 5.9 GHz DSRC [8]) for vehicle safety communication have the similar characteristics to 802.11 Wireless LAN transmissions by CSMA. Therefore, transmission delay can be emerged as the number of packet increases. Also, bandwidth efficiency can be dramatically dropped because of repeating send-receive beyond necessity. Proposed protocol uses fewer than half of pure flooding.

Proposed method supports a relay node selection method nearby radio range without position information. But proposed protocol makes use of the hello message scheme to keep neighbor list.

5. Conclusion

The proposed scheme is a kind of selective re-forwarding for vehicle safety communication. The proposed protocol raised the wireless broadcasting efficiency using the number of common neighbor between sender and receiver for relay vehicle selection instead of using random method. Using the proposed

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method, it can conserve costly wireless bandwidth as well as lower packet collision possibility by decreasing the number of sent messages.

In the results of simulation, the proposed method is better than pure flooding protocol for vehicle safety communication in the number of forward packets and the transmission efficiency.

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