Controlled Repetition Based Communication in VANETs using IEEE 802.11e

Ebrahim Ghazisaeedi[1], Ghazal Farrokhi[2], Saadan Zokaei[3]

K.N.Toosi University of Technology, Electrical and Computer Engineering Department, Tehran, Iran

[1]eghazisaeedi@ieee.org, [2]ghfarrokhi@ee.kntu.ac.ir, [3]szokaei@eetd.kntu.ac.ir

***Abstract*—Since message content is of high importance in Vehicular Ad-hoc Networks (VANETs), we are proposing a network design with the message priority considered as the main factor. In this regard, we have used IEEE 802.11e protocol.**

As in VANETs, topology of network changes fast, wireless links between cars are unreliable. Moreover, in vehicular ad-hoc networks the Bit Error Rate (BER) is high. Thus, in this paper, we proposed to repeat the packets of the messages with the highest priority, to cope with the above mentioned problems. This idea also increases the reliability of messages with the highest priority. Nonetheless, repeating the packets leads to increased number of collisions. Hence, we should control the number of nodes, which broadcast the message, to decrease collisions. To evaluate our method, and find the optimum number of repetitions, we simulated several scenarios both for car-to-car and car-to-infrastructure modes.

***Index Terms*—IEEE 802.11e, MAC Protocol, VANET, Repetitive Transmission, Controlled Repetition Communication, Throughput.**

I. Introduction

Vehicular Networks provide drivers with a new capability to enhance safety on roads in addition to get access to Internet services [1]. Transmitting data over VANETs is possible in two ways. Vehicles are able to transmit data in ad-hoc mode (car-to-car), or in infrastructure mode (car-to-infrastructure) using access points.

Message content has an important role in VANETs. For instance, in safety messages, message reporting an accident is of higher priority than the other messages. Consequently, we should design a vehicular network that priority of the message, based on the message content, is considered as the main factor. In this regard, message with higher priority would be transmitted faster, with lower latency, higher throughput and better reliability in comparison with the lower priority messages. We investigated using IEEE 802.11e, which is based on message priority, as our MAC protocol of VANETs.

IEEE 802.11e EDCA MAC [2, 3] protocol uses Arbitrary Inter-Frame Space (AIFS) and Contention Window (CW) to provide QoS for different categories of traffic, such as Voice, Video, Best Effort and Background. Higher priority messages will wait for shorter AIFS and CW leading to faster transmission and higher probability of channel access [4].

There are a few papers on message priorities. In [5], the authors used Enhanced Distributed Channel Access (EDCA) in IEEE 802.11e to provide a priority scheme. However, the authors did not consider contention among high priority vehicles. This unavoidable contention can lead to significant message errors, causing low communication reliability. In [6], the authors proposed priority CSMA (PCSMA) and polling P-CSMA (PP-CSMA). However, the protocol is not compatible with the IEEE 802.11 and IEEE 802.11e standards. In addition, it is well known that the polling mechanism is not robust to channel errors and dynamic network topologies [4]. In [4], authors proposed using IEEE 802.11e with repetition in VANETs. Nonetheless, repeating packets leads to collision increase in the network, but the authors did not consider this draw back.

Vehicular ad-hoc networks move fast and have erratic topology. As a result, the Bit Error Rate (BER) in this kind of networks is high. In order to increase the reliability of high priority safety messages, we will use repetition communication. Nonetheless, as repeating packets cause collision increase in the network, we control the number of message repetition, based on message priority. In this regards, we piggyback the message after a defined maximum number of message repetition.

In continue, we will describe our proposed method and simulate some scenarios to evaluate our framework.

II. Proposed Method

A. Repetition based communication

Since message content is of high importance, we should use a protocol that priority of the message, based on the message content, is considered as the main factor. In this regard, message with higher priority would be transmitted faster and have better reliability. Thus, we use IEEE 802.11e, which is based on message priority, as our preferred MAC protocol.

Generally, IEEE 802.11e provides different services for different priorities. The protocol uses multiple parameters for each priority to provide different access time to the network. In this regard, each priority has different value of the following parameters: CWmin, CWmax, AIFS and TXOP (Transmission Opportunity).

In order to increase the reliability of safety messages, we will repeat each packet in each message. As mentioned above, BER in vehicular networks is high. Besides, ad-hoc networks, generally, have high collision rate. In addition, in VANETs (car-to-car mode) vehicles move out of each others' radio range continuously, due to their natural mobility. Therefore, we have unreliable wireless links between vehicles. Hence, it is expected that repeating each packet would lead to better reliability for safety messages of highest priority.

All in all, we repeat each packet of each highest priority message to cope with BER of the network and to increase reliability of the massages. Of course, repetition communication after a specific level leads to collision increase in the network. We will study this matter in more details in the next part.

TABLE I.
PRIORITY PARAMETERS

Priority	CWmin	CWmax	AIFS	Number of packet repetition
First (Highest)	CWmin/4	CWmax/2	2	X
Second	CWmin/2	CWmin	3	1
Third	CWmin	CWmax	3	1
Fourth	CWmin	CWmax	7	1

In this method we propose that due to the importance of message content for messages with highest priority, each packet of message is repeated several times. In contrary, messages with lower priority are repeated just once. This means that a vehicle, with a highest priority message, repeats each packet of a message for X times while broadcasting it to its neighbors. Other vehicles which receive the message (with the highest priority) repeat each packet of each message for X times in their radio coverage (Table1). It is predicted that this transmission will continue until the vehicles come to the radio coverage range of each other. Consequently, we expect that this method will increase the reliability and throughput for highest priority messages.

In III.A and III.B we simulate some scenarios to examine the improvement of throughput and received packets, and find the optimum number of repetition (X).

Generally, IEEE 802.11e was designed based on messages priority. Our scenarios are based on cars that move fast in the same direction. We tested our suggested method for both modes of VANETs.

B. Controlling number of message repetition in the network

We tried to increase the reliability of highest priority messages with repeating each packet of each message. Nevertheless, repeating packets leads to an increase in the network's load and as a result, collision in the network will increase. Thus, to control the collision and to decrease it, we control the number of nodes which repeat the message. So, it is expected that number of received of packets and also the received throughput would be increased. It is needed to mention that number of message repetition which is indicated above, is different form number of repetition of each packet of each message.

In this framework we control the message repetition in the network by adding 1 byte header slot to message’s MAC layer. Each vehicle that receive a message, checks the header slot. If the header slot is less than defined value of Max_Rep, then it will increase the header slot value and message will be repeated. In the contrary, if the header slot is equal or more than defined value of Max_Rep, the message will be piggybacked.

In this area, we present some scenarios to find the optimized value of Max_Rep and test our method.

III. EVALUATION

In this section we present four scenarios to examine our method. First, we simulate a scenario to test the repetition communication in VANETs and find the optimum number of repetitions in car-to-car mode. Second, we test the first scenario for car-to-infrastructure mode. Third, we examine our framework in controlling number of message repetition in the network, in car-to car mode. At last, we test the third scenario for car-to-infrastructure mode. We have used NCTUNS Ver. 5.0 [7] to simulate all of the above mentioned scenarios.

A. Repetition based communication in car-to-car mode

As mentioned in II.A, we use repetition based communication to cope with BER of wireless networks and increase the reliability of highest priority messages. Increasing the number of repetition in the network increases the reliability, however after a specific level, increasing the number of repetitions leads to more collisions in the network. Thus, we simulate a scenario to find the optimum number of packet repetition.

In the first scenario we have 10 cars that move in the same direction with maximum velocity of 72km/h. Theses cars have the following parameters:

- All the cars move with maximum velocity of 72km/h and have accelerated motion.
- Car agent software control path, velocity and acceleration of cars based on received signals from neighbor cars and environment.
- Queue is FIFO and maximum length of queue is 50 packets.
- Messages use UDP protocol.
- Bit Error Rate of network is 10^-4
- Length of each packet is 100byte
- Generated data rate is 10Mbps
- RTS Threshold is 3000byte

- Cars use IEEE 802.11e MAC protocol

As you see in Fig. 1, cars are placed randomly in 1-kilometer distance. The first car (in the right) generates a message with highest priority. BER of the network is considered 10^-4 to simulate a real network. The first car transmits its message to its neighbor cars. Each car that receives the message also transmits the message to its neighbors. In this way our highest priority messages will be received by our monitored car which is 1 kilometer away of the first car. We studied the throughput and the number of received packets of the monitored car.

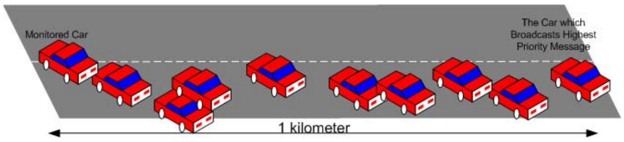

Fig. 1. Topology of first scnario

Generally, nodes in VANETs repeat each packet of each message to their neighbors one time. We have used the above mentioned topology as the basis of our method. So, we have simulated the topology whereas cars repeat packets for one, two, three and four times, and logged the throughput of the monitored car. Moreover, we compared the results to find the optimum number of packet repetition.

As you see in Fig. 2, the throughput will increase to three repetitions. However, after three repetitions, throughput will decrease. This means that by repeating the packet we overcame the BER issue of the network and also increased the reliability of the highest priority message, but after three repetitions of each packet, among all the cars, the collision would be the dominant factor and throughput decreases. All in all, we find that X (optimum number of packet repetition) is equal to three.

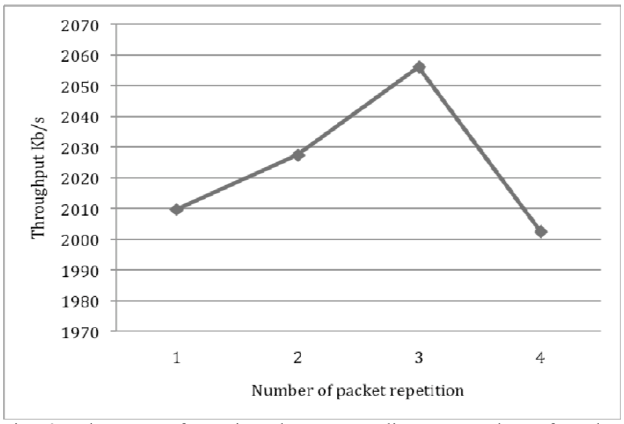

Fig. 2. Throuput of monitored car according to number of packet repetiton for car-to-car mode

B. Repetition based communication in car-to-infrastructure mode

We designed a topology (Fig. 3), in which an access point covers all of the ten cars, in order to see the effects of repetition in car-to-infrastructure mode. This scenario is similar to the first one. However in the latter all the nodes transmit their messages through an access point. All cars use the same parameters as the first scenario. We test this topology for one, two, three and four times of packet repetition.

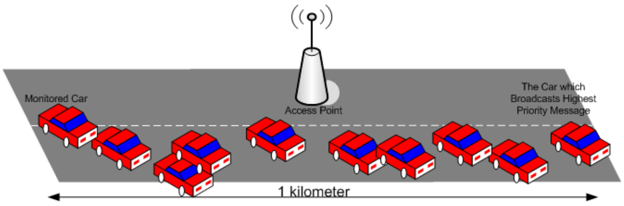

Fig. 3. Topology of second scenario

As you see in Fig. 4, the throughput in monitored car is increased by increasing the packet repetition. However after three times repetition of each packet in each message among all the cars, collision rate increase in the network causes a throughput decrease. As a result, in the car-to-infrastructure mode the optimum number of packet repetition (X) is equal to three, which is the same as in the car-to-car mode.

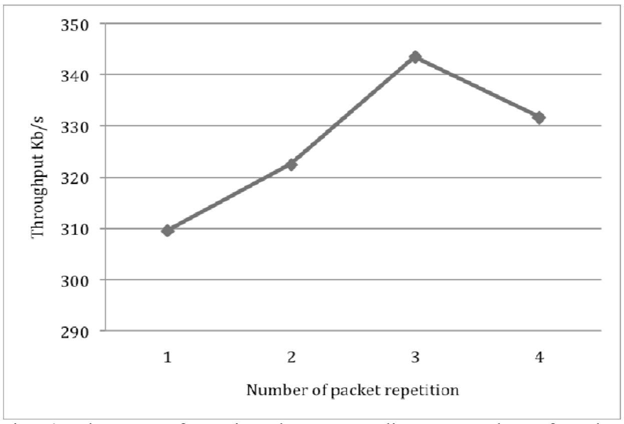

Fig. 4. Throuput of monitored car according to number of packet repetiton for car-to-infrastructure mode

C. Controlling number of message repetition in the network in car-to-car mode

In this section we test method of controlling message repetition, which is explained in II.B. We use the III.A topology for this simulation. Our simulation results showed that maximum number of message repetition in the network is four. We simulate the scenario while four cars except the first car repeat each packet of the message (with the highest priority) for three times. Other cars in the scenario do not broadcast the message. We have also tested this method with three and five cars, instead of four. We achieved higher throughput in the monitored car when there was only four cars except the main cars repeating the message. Thus, the Max_Rep value is four.

After finding the maximum message repetition, we simulated III.A with four cars (except the first car) repeating each packet of the message with the highest priority three times while other cars did not repeat the message. This setting, led to collision decrease in the network. So, it is expected to reach better throughput rate using this method.

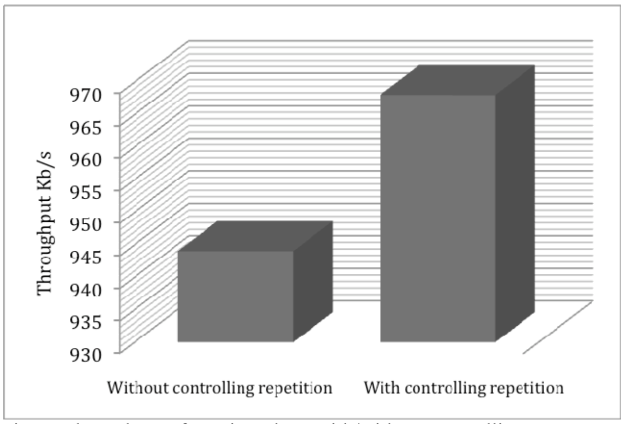

Fig. 5. Throughput of monitored car with/withour controlling message repetiotion, in car-to-car mode.

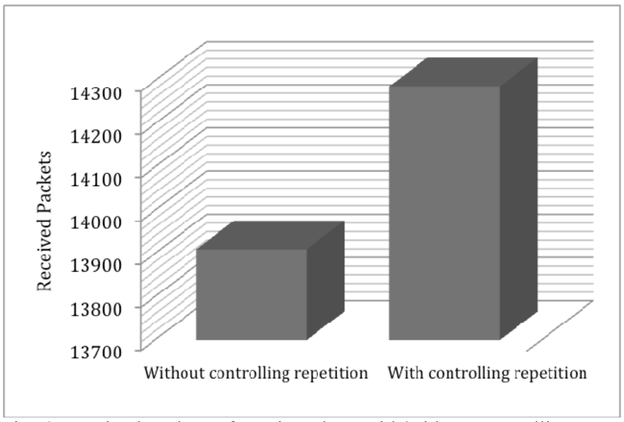

Fig. 6. Received packets of monitored car with/withour controlling message repetition, in car-to-car mode.

As you see in Fig. 5 when we use controlled message repetition method in the network, the throughput of the monitored car is increased in comparison with others not using the method. Moreover, the number of received packets is also increased for the monitored car as you see in Fig. 6.

D. Controlling number of message repetition in the network in car-to-infrastructure mode

In order to simulate the fourth framework, we simulated scenario III.B using our method to test the car-to-infrastructure mode. The current scenario is different from III.B in the way that the main car and four other cars repeat each packet of the message for three times, while the rest do not repeat and act normal.

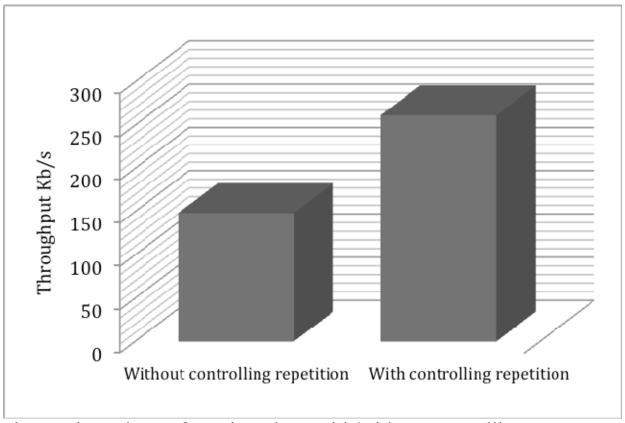

Fig. 7. Throughput of monitored car with/withour controlling message repetiotion, in car-to-infrastructure mode.

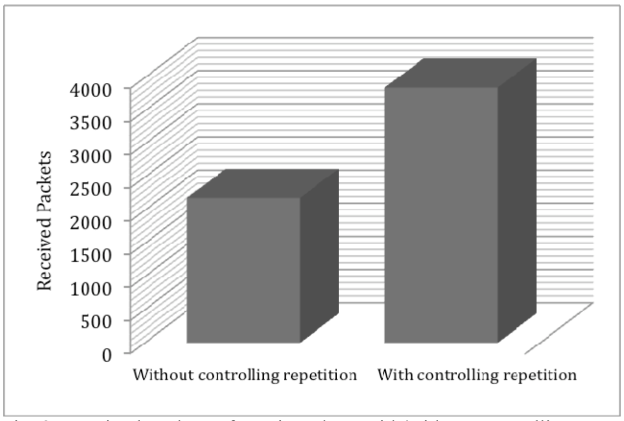

Fig. 8. Received packets of monitored car with/withour controlling message repetition, in car-to-infrastructure mode.

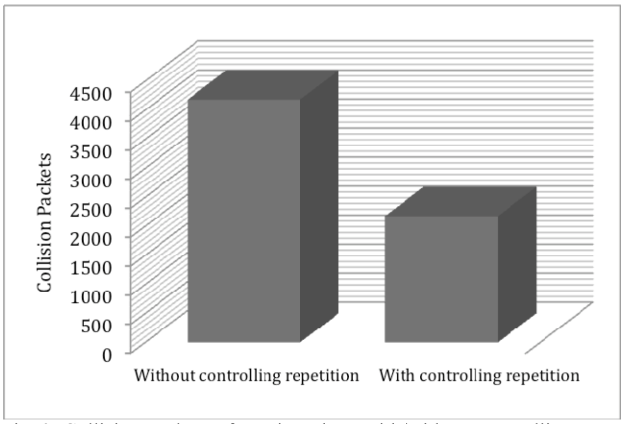

Fig. 9. Collision packets of monitored car with/withour controlling message repetition, in car-to-infrastructure mode.

The results in Fig. 8, 9 and 10 shows that controlling the number of repetition in the network increases the throughput and the number of received packets, as well as collision decrease in the network.

CONCLUSIONS

Since message content in VANETs is of special importance, we used IEEE 802.11e as our preferred MAC protocol and improved it, in order to provide better reliability for highest priority messages. Thus, it is proposed that repetition in each packet of each message, with the highest priority, for three times causes increase in reliability. However, repeating packets leads to collision increase. In this regard, we have controlled the message repetitions after four times.

All in all, the generated message with highest priority will be broadcasted in the network while four cars (except the main car) broadcast and repeat each packet for 3 times. After the fourth car the network acts normal. Nonetheless, for messages with lower priority, cars broadcast each packet just for one time. As a result, it is expected that using this framework we can provide better reliability for important safety messages in VANETs.

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