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An adaptative Backoff mechanism for VANETs

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***Abstract*— Backoff time is an important mechanism to ensure the stability of the network. This paper presents a simple solution for VANET networks which tries to minimize the probability of collision, and to optimize the back-off distribution. At first, we propose a new scheme for dynamic adaptation of contention window (CW) size in order to achieve better throughput performance and lower average end-to-end delay. The CW is adapted according to the instantaneous information about the channel conditions by using the artificial neural network.**

Collision rate, the number of network nodes, queue length and distance between sender and receiver are used as inputs of neural network. Our second idea is summarized on trying to retard a communication if it has a strong chance to produce a collision based on distance. Our contribution can be easily implemented as extension of EDCA. The simulation results show that the proposed method is able to increase throughput, reduce packet collision rate and delay time.

Keywords*— *Contention Window; EDCA protocol; IEEE 802.11p; VANETs

I. INTRODUCTION

The Medium Access Control (MAC) is one of the main challenges in vehicular networks. The MAC layer of the 802.11p standard uses CSMA/CA mechanism and Binary Exponential Backoff (BEB) for Contention Window (CW) adjustment as a method of congestion control. In this standard, a random back off period is generated for each user contending for the channel. The goal of the backoff mechanism is to reduce the probability that the collisions due to the same frames continue to occur. We have observed from the different studies [1], [2] in this area, that the contention window value has a very important role in the evolution of the performance of the MAC protocol. The CW configuration used by the current version of the standard is statically set, independently of the network conditions (number of contending stations, collision rate…). The main reason is that the protocol has been designed for wireless local area networks, where there is an access point and a limited number of clients. Furthermore, the use of RTS / CTS limits collisions [3]. In addition, vehicular networks are not yet deployed.

After the introduction of the IEEE 802.11e standard, much research interested in minimizing the contention window to reduce the delay caused by the transmission of video and voice applications. Based on an estimation of the network conditions, these researches reduce future collisions by increasing and decreasing window sizes according to network state. It is important to note that, vehicular networks have an important advantage over MANETs, they have no power or storage limitations. So, they can be easily equipped with hardware device and software frameworks. In this paper, we introduce a theoretic approach to estimate the congestion level based on neural network. The output value of the model is used to determine the network conditions indicator and to dynamically find the appropriate contention window range, according to the environmental conditions. The proposed scheme tries to reduce collisions, achieve better throughput performance, and lower average end-to-end delay by optimizing the back-off distribution to improve the probability of successful transmission. In addition, we propose an algorithm which tries to decrease the saturation of the network based on the distance between the receiver and the sender. When the network is highly congested, this algorithm attempts to reduce congestions and collisions to ensure the functioning of the network.

The rest of the paper is structured as follows. In Section 2, we present some approaches to adjust the size of the contention window that can be used in the context of vehicular networks. In Section 3, we describe in detail the proposal Contention Window adaptation based on Neural Networks. In section 4, we mention some simulation results for the proposed solution. Section 5 lists the conclusion and future work.

II. RELATED WORK

Many solutions based on 802.11p, and which are the subject of recent computing publications and communications are proposed to adapt the contention window for back-off algorithm [4],[5],[6],[7],[8]. We can see four approaches which are respectively based on the number of active stations, on the error rate or reception rate, on packet queue length and on the channel occupancy rate (the ratio of channel busy time). The density-based adaption window mechanisms show that the optimum contention window depends on the number of contending node. [4], [5], [6], [7] use density to adapt contention windows. The idea of these approaches is to increase the contention window when the number of nodes is large and decrease the value otherwise. Therefore, there are other parameters that can reflect the network status or congestion level such as the error rate. When there are too many collision messages, the contention window should be increased, and when the channel is idle for a significant period, it must be decremented. Balon, and al [9] propose to add a sequence number in the MAC header. This allows measuring the percentage of message loss and average reception rate. In [10], the authors use the number of detected collisions to adjust CW. A threshold is used for this adaptation. Another adaptation work [2] is to adjust the contention window based on the number of consecutive transmissions successfully received, and the number of successive collisions. A simple parabolic function is used to increase and decrease the CW value. Jiang, and al [11] have proposed an approach for the optimization of CSMA (oCSMA). This protocol Provides a contention window adaptation based on the queue length. This is a very interesting work because a large queue length reflects high traffic load. Wang, and al [12] develop an algorithm based on the channel occupancy time to set the appropriate CW. This parameter is measured by the CCA function periodically.

Another interesting approach [8] and [13] introduces several channel state levels. The main idea of this work is to divide the backoff range into small backoff sub-ranges. Each subrange relates to a contention level. Liang, et al [14] use the number of back-off counter pause calculated during the channel access contention to adjust the contention window.

Due to uncertainties in the behavior of vehicular networks, research community is motivated to define precise analytical models that attempt to reflect accurately the real behavior of the network. Thus, we found that we can classify the adaptation window methods according to the model used.

Several works in this context are threshold based methods or probabilistic methods. Others are based on Markov chains to describe the behavior of EDCA protocol. Alternatively, the theory of fuzzy sets seeks to represent the uncertainty in the vague information or imprecise. This technique is used for adjusting the size of the contention window. In our work, we propose to use neural network to adapt the contention window. To our knowledge, no existing research addresses this question.

In the next section, we present our solution which has mainly the same objectives as these works. The main difference is on how to estimate the channel conditions and the factors taken into account for the contention window updating. Our contribution consists on the use of neural network analytical model and learning method to select the convenient CW value in order to improve the performance of backoff algorithm.

III. PROPOSAL SOLUTION

A. *Description of the solution*

An extension to the IEEE 802.11p MAC protocol is proposed in this paper, called NN-ACW (Neural Network Approach Method for Adjusting the Contention Window Size in VANETs). The main contribution consists in a formal method that estimates the congestion level of the network, and then adapts the contention window interval to reduce the large number of collisions and try to decrease unnecessary additional delay.

We focus on a new Backoff algorithm based on probability of one-hop packet reception. We have observed as seen in the previous section, that this probability depends on several factors. The first factor is the number of contending station; this parameter has an important role in the selection of adequate contention window value. The second factor is the collision rate. Several researches use this parameter for the adaptation. The third factor is the packet queue length which is local information. It may reflect the congestion state in the network at the node. The last used factor is the distance between sender and receiver node. We use this parameter because if the distance is large, the collision probability increases that is the signal power weakens and the probability of being intermediate nodes between sender and receiver increase. The purpose of using several parameters is to increase the reliability about channel condition. Each parameter has a priority which depends on its impact on the network performance and seniority or certainty of the information.

Our first solution consists in automatic augmentation and decrease of the back-off value by limiting the CW interval. There is no need to wait for the degradation of the services network to do something about. In the second place, we added a mechanism for network management when the network is congested in order to reduce collisions and congestions because the evolution of the vehicular network is not predictable. The objective of our second proposition is to try to enhance the scalability of IEEE 802.11-based vehicular networks. It is a question of guaranteeing a good cost-benefit relationship between collisions and throughput. Our proposal mechanism has an advantage to be suitable when the traffic load increases because of a corresponding increase in collisions, and it is well appropriated in V2V communications as well as V2I communications. Using the density, the rate of collision, queue length and the distance to adjust the contention window, the network can already adapt and thus maintains its stability.

1) *Neural networks:*

This section discusses the application of artificial neural network technique which is trained to perform contention windows adaptation for vehicular networks. In our application we use the multilayer perceptron (MLP) neural model that is proposed by Frank Rosemblatt in 1958. The first layer is the input layer which consists of four parameters coming from the Mac 802.11p protocol (density, queue length, collision rate, and distance), these are selected as the influence factors for the choice of the optimal contention window size.

The second layer is the hidden layer which contains 4 units. This configuration provided a good compromise between accuracy and network performance. The third layer is the output layer. The modification rate of contention window is the unique output for this layer. The learning method used in this work is backpropagation, the activation and error function are a log-sigmoid function and standard sum-of-squared error function, respectively. Fig. 1presents the architecture of the neural network.

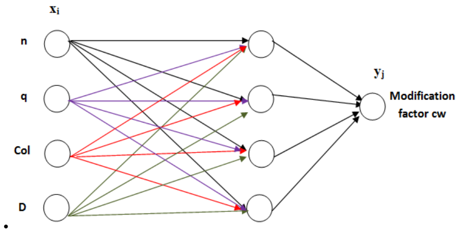


Fig. 1. Neural network architecture.

Neural network requires that the range of both input and output values should be between 0 and 1 due to restriction of sigmoid function, thus the data is unified. The unified input parameters are given by:

$$n = \frac{\text{number of station}}{\text{n\_ max}},$$

$$col = \frac{\text{collision rate}}{\text{max collision rate}},$$

$$q = \frac{\text{queue length}}{\text{max queue length}},$$

$$d = \frac{\text{distance}}{\text{transmission range}},$$

Where, n_max and max collision rate are fixed by simulation in very dense scenario.

2) *Contention Window adaptation*

Our proposal adaptation is based on some rules, which are deduced from the related works [2],[4],[5]... They represent the global observations in order to estimate the system status.

This work is based on the following observation: Under low density, a small backoff is returned. On the Other Hand, if the network is dense, the backoff value is great. In addition, if both collision rate and queue length are large, CW value must increase, otherwise it must decrease. Also, if the distance between a sender and a receiver is large, the probability of collision is high, thus the backoff value is great. If one parameter is large and another is small, the CW is somewhere in the middle based on the priority of the parameter. In this work, we combine these rules by using artificial neural network. The distributed updated contention window algorithm is based on the value of neural network output which reflects the probability of collision. When more nodes are contending for the channel, the neural network output is great. Thus, it would be desirable to have larger CWs in order to avoid too frequent collisions. On the other hand, if the output is small, smaller CWs would help to reduce the channel idle time. Our solution adjusts CW interval by changing the lower and the upper bound.

The contention window becomes [CWl,CWh] instead of [0,CW]. Proper choice of the thresholds value (threshold1, threshold2, threshold3) in CW adaptation is very important and affects the performance of the system. The detailed contention window updating mechanism can be found in Algorithm 1.

Algorithm 1

```
Ti = yi * CW          where yi is the ANN output

if ( yi < threshold1)  then  backoff range = [ 0, (1- yi)*CW]

else     if ( yi > threshold2) then
                                  backoff range = [Ti, CW*2+ Ti]

         else      if (yi > threshold3)  then

                                  backoff range = [0, CW + Ti]

                   else   backoff range = [0, CW]
                   end if
         end if
end if
```

3) *Scalability and saturation conditions*

The nature of vehicular networks with frequent changes creates a highly dynamic topology and can cause network performance degradation if the protocols are not designed to handle such situations. For this raison, and to ensure the scalability, an additional mechanism for manage network when the congestion level is great is required. Our second contribution is to manage the network when it is saturated. We use the neural network output as indicator, and if the node finds that this parameter exceeds a certain threshold, the node retards some communications based on the distance, which can be estimated from the transmission power, in order to reduce the traffic, and the contention in the network. The contention window value is doubled if the distance between the node and the destination is large. We prioritize the Communication from short to medium distance between the source and the destination because the probability of reception decreases as the distance increases, which can lead collisions. In this proposition, there is no need to exchange control messages between nodes. However, based on the distance, the message integrity may, not arrive. That makes our proposition more suitable for non-critical messages rather than critical messages. In addition, all nodes have not an equal opportunity to transmit their data, but the most important is to improve network performances by reducing collisions and delays and increasing the throughput, since the standard 802.11p based on random selection of backoff does not guarantee equitable sharing of the medium.

IV. SIMULATION AND RESULTS

The simulation is performed using NS-2. The neural network was written in the C++ programming language as an additional program to NS-2. The performance of our contention window adaptation algorithm and our distance based adaptation approach are compared with that of IEEE 802.11p in terms of average throughput, UDP collision rate, and end to end delay. Vehicles move in two directions on a road of 1 km composed of 3 lanes in each direction. The network behavior was tested in several densities. CW adjustment algorithm is performed under different conditions from the low density to the saturation conditions. RTS/CTS is used to prevent collisions due to hidden nodes. Each vehicle generates a single type of CBR traffic with packet sizes of 512 bytes every 0.15 second. The list of simulation parameters are given in table 1.

TABLE 1. SIMULATION PARAMETERS

Density of vehicles	10, 20, 40, 70, 90, 130, 150 vehicle / lane / km
Maximum vehicle speed	30 m/s
packet size	512 Bytes
generation rate	4 packets per second
Segment	1000m

Fig. 2 illustrates the comparison of end to end delay as a function of the density. The figure shows that as the number of stations increases, the delay increases in both IEEE 802.11p Basic Access and our contention window adaptation. This is because the increase of their contention window sizes, we also note that the network suffers from frequent retransmission due to collisions under high density. The average end-to-end delay is lower for the proposed scheme than for the default scheme in all cases. As can be observed from fig 2, there is not too much delay variation when the density is low because the difference between the contention window sizes is not so important.

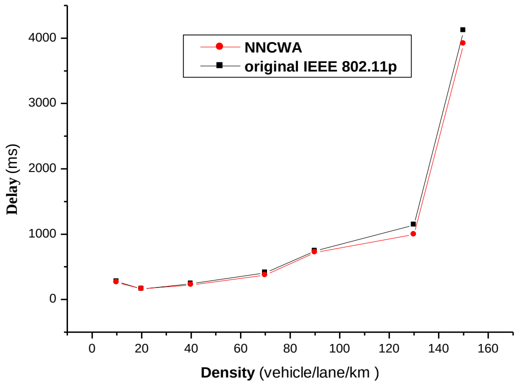
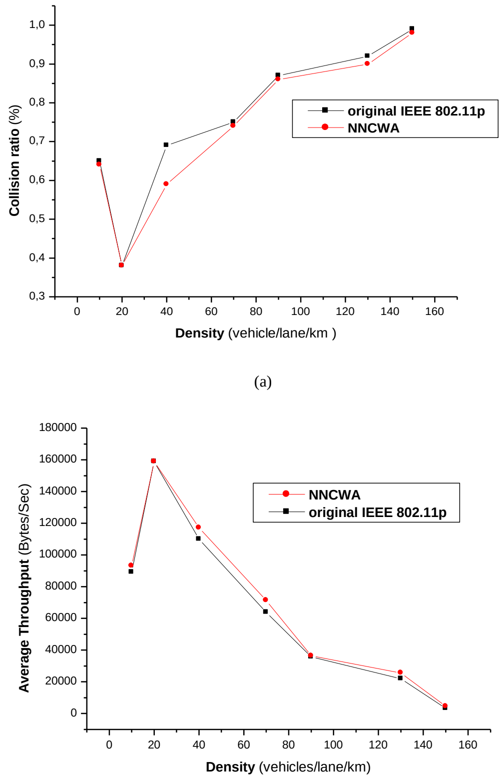


Fig. 2. Average delay.

Fig. 3 (a) and (b) provides the collision rate and throughput respectively for different network scenarios: The higher the number of stations, the lower the throughput. On the contrary, collision rate increase as increasing the number of contending nodes.

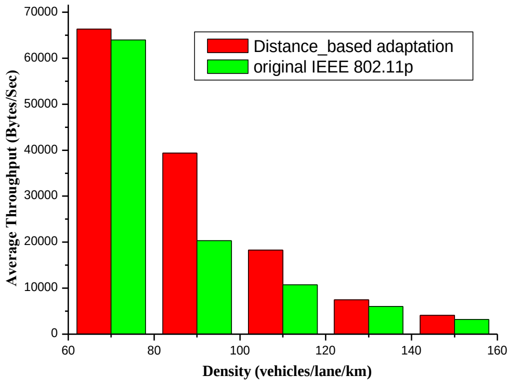


(a)

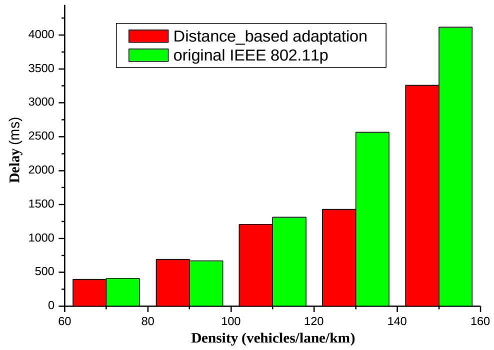
(b)

Fig. 3. Collision ration and Average Throughput.

However, we can observe that our proposition performs better than IEEE 802.11p Basic Access. We notice that there is a fast decrease of throughput and a fast increase of collision rate when the density is more than 20v/lane/km. This is because there are many nodes transmitting packets at the same time, the chance of collision increases thus the node will increase its contention window size while it detects packet transmission of the other nodes. Furthermore, the Figure 3 verifies the fact that choosing the correct backoff window size can increase network throughput and decrease collision rate. The saturation throughput highly depends on the number of contending stations and on the values of the contention Window limits.



(a)



(b)

Fig. 4. Average Throughput and End to End Delay of Distance based CW adaptation approch.

Fig. 4 (a) and (b) compare the average throughput and delay versus density, of the IEEE 802.11p and our distance based adaptation algorithm. We can see that, our second proposed algorithm is able to reduce the End to End delay and to improve the throughput in the most cases. In certain scenario, such as 70v/km/lane, we can see a small difference between the proposed scheme and the basic standard in the delay and throughput. This is justified by the fact that a message may not arrive in integrity which can increase the End to End delay and decrease the throughput.

V. CONCLUSION

In this paper we have proposed a new contention window adaptation mechanism according to the channel congestion level. To estimate the network conditions, we use a neural network model. The output of this model is used to adjust CW size. It is possible, by observing the network status, to estimate the average backoff window size that maximizes the throughput and minimizes both the collision rate and delay. We have also proposed a CW adjustment mechanism which tries to decrease the saturation of the network based on the distance between the receiver and the sender. The proposed work is evaluated by the simulation. We presented the impact of the contention window adaptation on the packet loss, throughput, and delay for different scenarios. The results show that our proposition provides better throughput and lower delay, and decrease collision rate compared to the original IEEE 802.11p standard. The CW adaptation scheme can be easily implemented as extension of EDCA protocol for IEEE 802.11p.

As a future work, we plan to study and test other learning sets, and we will investigate to provide better contention window updating algorithm.

REFERENCES

[1] M. J. Booysen, S. Zeadally et G. -J. v. Rooyen, «Survey of media access control protocols for vehicular ad hoc networks,» IET Communications, vol. 5, p. 1619–1631, 2011.

[2] R. STANICA, «Congestion Control in Vehicular Ad-Hoc Networks,» chez thèse de doctorat, TOULOUSE, Institut National Polytechnique de Toulouse (INP Toulouse), 2011.

[3] A. M. Igartua, C. V. Frías, L. J. de la Cruz Llopis et S. E. Gargallo, «Dynamic framework with adaptive contention window and multipath routing for video-streaming services over mobile ad hoc networks,» Springer Science+Business Media, p. 379–390, 2010.

[4] F. Calì, M. Conti et E. Gregori, «Dynamic Tuning of the IEEE 802.11 Protocol to Achieve a Theoretical Throughput Limit,» IEEE/ACM Transactions on Networking, vol. 8, n° 16, pp. 785-799, December 2000.

[5] H. C. Jang et W. C. Feng, « Network Status Detection-Based Dynamic Adaptation of Contention Window in IEEE 802.11p,» Proceedings of the IEEE 71st Vehicular Technology Conference (VTC Spring 2010), pp. 1-5, May 2010.

[6] J. Alapati, B. Pandya, S. N. Merchan et U. Desai, «Back-off and Retransmission Strategies for Throughput Enhancement of Broadcast Transmissions in 802.11p Proceedings of the 21st IEEE Intellig,» Proceedings of the 21st IEEE Intelligent Vehicles Symposium (IV 2010), pp. 700-705, June 2010.

[7] A. Barbosa, A. L. Bessa, A. Sérgio, F. M. Rober et J. C. Jùnior, «An Adaptive Mechanism for Access Control in VANETs,» ICN 2011 : The Tenth International Conference on Networks, 2011.

[8] A. Balador et A. Movaghar, «The Novel Contention Window Control Scheme for IEEE 802.11 Mac Protocol,» Second International Conference on Networks Security, Wireless Communications and Trusted Computing, pp. 134 - 137, 24-25 April 2010.

[9] N. Balon et J. Guo, «Increasing Broadcast Reliability in Vehicular Ad Hoc Networks,» Proceedings of the 3rd ACM International Workshop on Vehicular Ad Hoc Networks (VANET 2006), pp. 104-105, September 2006.

[10] D. B. Rawat, D. C. Popescu, G. Yan et S. Olariu, «Enhancing VANET Performance by Joint Adaptation of Transmission Power and Contention Window Size,» IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED SYSTEMS, 2011.

[11] L. Jiang et J. Walrand, «A Distributed CSMA Algorithm for Throughput and Utility Maximization in Wireless Networks IEEE/ACM Transactions on Networking,» IEEE/ACM TRANSACTIONS ON NETWORKING, vol. 18, n° 13, pp. 960-972, June 2010.

[12] Y. Wang, A. Ahmed, B. Krishnamachari et K. Psounis, «IEEE 802.11p Performance Evaluation and Protocol Enhancement,» Proceedings of the 4th IEEE International Conference on Vehicular Electronics and and Safety (ICVES 2008), pp. 317-322, 22-24 September 2008.

[13] A. Balador, A. Movaghar, S. Jabbehdari et D. Kanellopoulos, «A Novel Contention Window Control Scheme for IEEE 802.11 WLANs,» IETE Tech Rev , vol. 29, pp. 202-212, 2012.

[14] H. M. Liang, S. Zeadally, N. k. Chilamkurti et S. Ce-Kuen, «A novel pause count backoff algorithm for channel access in IEEE 802.11 based wireless LANs,» International Symposium on Computer Science and its Applications (CSA'08), vol. 20, pp. 163-8, 2008.