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# Improved Delay Performance in VANET by the Priority Assignment

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**Abstract.** Low delay performance in VANET need to an intensive study. In this article, we proposed a novel priority method to reduce transmission delay of one-hop in VANET. A priority was marked to each message based on static factors, dynamic factors and size of the message. Messages scheduling was implemented based on the priority of messages. The performance of proposed method was analysed in highway scenario on the average delay and waiting delay in queue. Simulation results are consistent with theoretical deriving. Therefore, by using the novel method, low delay and more reliable communication scenarios can be provided in Vehicular Ad-hoc Network.

## 1. Introduction

Vehicular Ad-hoc Network (VANET) has special characteristics such as high rate of topology change, high mobility of nodes, high nodes density, sharing the wireless channels, and frequently broken rout. Those special characteristics in VANET give rise to some challenges in data transmission [1-4]. When number of vehicles is increasing, nodes fiercely contest the channel, networks congestion happen. Wireless channels in VANET are shared channels. When messages of the vehicles are simultaneously sent, this overloads the Medium Access Control (MAC) channels so that these channels are easily congested. Congestion consequently leads to the packet delay and loss. In this situation, the messages that need low latency cannot be timely transmitted due to deficiency in channel access. However, transmitting messages in VANET is a tremendous challenge because multi-channel Radio Frequency with single-radio transceiver shares transmitter. So, it is difficult that controlling delay enhances the communication performance of VANET [5-8].

In VANET, generated messages from vehicles are random and bursty in nature. In order to allow vehicles to connect to the out-of-transmission range road-side unit (RSU), Vehicle-to-vehicle (V2V) communication of multi-hop fashion is generally used [9]. To support a kind of applications including, e.g., car accident alert, road condition warning, video streaming, web browsing, and file sharing, V2V through multi-hop transmission delivers bursty data flows to a remote vehicle [10]. Although multi-hop V2V mode can significantly improve the connectivity probability, end-to-end delay and single hop delay impact the quality of service (QoS) of the vehicular communication and may lead to decrease network throughput inevitable. From users' perspective, end-to-end delay and single hop delay are the most critical factors and are arguably the most important service requirements because they directly show their experiences and satisfaction levels. Thus, an intensive understanding of the single hop queueing performance of different types of data is finished. However, how to analyze the multi-hop end-to-end delay and single hop delay under queueing bound condition still remain as a challenging issue since the bursty data traffic characteristics and highly dynamic channel condition.



The multi-hop delay [11] of the delay sensitive messages is derived by multiplying the single-hop delay and the average hop count. One-hop delay is a period of time under which a packet is transmitted from sender to receiver. The delay is composed of the processing delay ( $D_{proc}$ ), queuing delay ( $D_{queue}$ ), transmission delay ( $D_{trans}$ ), and propagation delay ( $D_{prop}$ ) [12]. The processing delay is the time for extracting header of packets and executing various algorithms. The queuing delay is the waiting time of a packet in a queue before transmitting. The transmission delay is the required time for transmitting all the messages to channel. The propagation delay is the required time for propagation of the packet. Thus:

$$Delay = D_{proc} + D_{queue} + D_{trans} + D_{prop} \quad (1)$$

The rest of the paper is organized as follows. Section II researches delay element. Section III proposes how to prioritize the messages in order to reduce delay time of packets transmission. Section IV analyses delay performance of transmission delay and queueing delay. Section V simulates the proposed strategy in the highway and discusses the obtained results.

## 2. Motivated Element

A delay control method in VANET is performed by prioritizing messages in MAC layer. Delay control means controlling messages transmission opportunity on the wireless channels and providing a fair channel access among the vehicles. Controlling messages transmission opportunity may achieve high communication reliability and bandwidth utilization within the networks. Defining priority of the messages and scheduling messages are designed for MAC layer in different communication channels [13], [14]. Prioritizing and scheduling data can reduce download delay and packet loss, and so on to help serve more requests [15].

Bouassida et al. [16] introduced a method that controlled the access of the wireless channels. By this method, according to utility and validity of messages, and speed of senders and receivers, the messages were marked the priority. Then, the priority was used in the control channel queues and service channel queues. The simulation results showed that the delay time of messages decreased. The introduced method reduced congestion in control channel and delay time of messages. However, in worse-case scenario, the delay time was still more than 50 milliseconds. Suthaputchakun et al. [17] proposed a priority-based method using Enhanced Distributed Channel Access (EDCA) mechanism to increase QoS in highway environments. Each communication message between vehicles was prioritized based on its urgency and its delay constraint. By giving more chance of transmission to messages with higher priority (emergency messages), this approach increased the reliability in vehicular environments. This approach partly improved the delay performance of messages and ratio of successful retransmission.

Generally, congestion control mechanisms in networks include: open-loop mechanism that avoids the congestion without the feedback information from congested messages, and closed-loop mechanism that controls the congestion utilizing feedback information from congested messages [18]. There are three categories congestion control method in VANET. They are transmissions power controlling, transmissions rate controlling, and assigning the priorities to the messages [19].

Prioritizing method reduces the delay by marking the priority of the messages and then using it to reschedule message sequence. In the method, the high priority messages are decided so that they have more chance to acquire the communication channels. Using the method, the channel access is easy so that the channel collisions are decreased. By this method, different types of generated messages in VANET require a strict prioritization. Therefore, the priority method can consequently control channel access opportunity and prevent network congestion.

Generally, the prioritizing and scheduling the messages, which prevents the congestion occurrence in the networks, is thought as an open-loop control method in control theory [20]. Some parameters, such as fairness, reliability, responsiveness, time constraint, data size, service ratio, and data quality, are analysed to increase efficiency of message transmission in VANET [21].

In this paper, a delay control method is presented. The proposed method prioritizing messages includes priority assignment and message scheduling. The former assigns priority to each message based on the static factors, the dynamic factors and the messages size. The latter reschedules the

prioritized messages in the channel queues. The performance of the proposed method is evaluated using average delay performance parameter.

### 3. Priority Assignment Unit

In the priority assignment, the generated messages in the vehicle from applications or from the other vehicles will be marked as index. What time the message will be transmitted is determined for the messages' priorities index. According to static and dynamic factors as well as size of message, we define that the priority of each message hereon is:

$$Priority_{Message} = \frac{Static_{Factor} \times Dynamic_{Factor}}{Message_{size}} \quad (2)$$

$Priority_{Message}$  is directly proportional to  $Static_{Factor}$  and  $Dynamic_{Factor}$ .  $Priority_{Message}$  is opposite proportional to  $Message_{Size}$  because the high priority messages have smaller size compared to the other messages. The  $Static_{Factor}$  is decided on the content of messages and type of applications. Number 1, 2, 3, 4, or 5 is given to  $Static_{Factor}$  if the message is thought as  $Priority_{Service-Low}$ ,  $Priority_{Service-High}$ ,  $Priority_{Safety-Low}$ ,  $Priority_{Beacon}$ , or  $Priority_{Emergency}$  parameter, respectively [16]. These variables are stated in details in [22, 23].

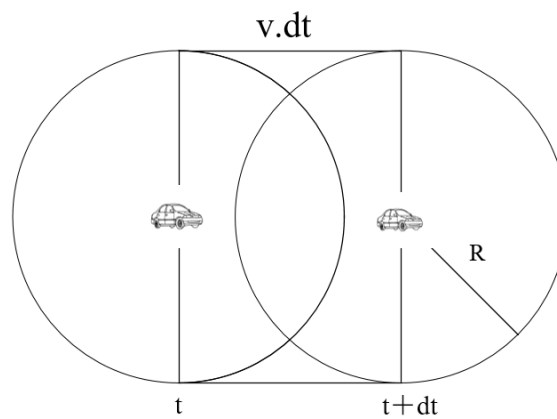
According to the content of messages and type of applications, static factor is decided. In contrast, according to circumstance conditions of vehicle moving, the dynamic factor is decided. Velocity of vehicles, usefulness of messages, validity of messages, weather condition and geographic position are used to calculate the dynamic factor. In the following, these parameters are described in details.

#### 3.1. Velocity Metric (Vel)

According to the total coverage area of a vehicle traveling with velocity  $v$  during time  $dt$ , the relative speed of message sender is defined as follow (Figure 1) [24]:

$$Vel = \frac{\pi \times R^2 + 2 \times R \times v \times dt}{\pi \times R^2} \quad (3)$$

where  $R$  is communication range, and  $v$  is average speed of vehicle in time  $dt$ . The bigger  $Vel$  of the message should be the higher priority. In fact, the probability of disconnection for the vehicle is high when a vehicle moves with higher speed because it covers a bigger area in unit of time.



**Figure 1.** Velocity metric (Vel).

#### 3.2. Usefulness Metric (Use)

This parameter deals with the probability of message retransmissions between the neighbor vehicles. The usefulness is determined by ratio of total communication area and overlapped area (Figure 2) [24]:

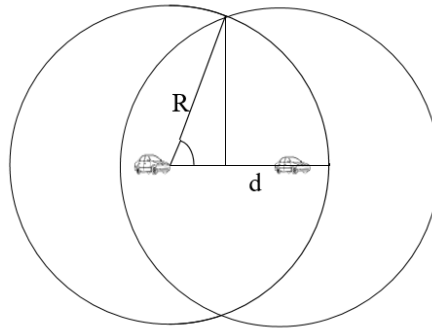
$$Use = \frac{Communication_{Area}}{Overlapped_{Area}} \quad (4)$$

where the  $Overlapped_{Area}$  is calculated using Equation (4):

$$Overlapped_{Area} = 4 \times \left( \arccos\left(\frac{d}{2 \times R}\right) \times \frac{R^2}{2} - \frac{d}{4} \times \sqrt{R^2 - \left(\frac{d}{2}\right)^2} \right) \quad (5)$$

where  $d$  is distance between sender and receiver vehicles. Therefore, the usefulness metric is:

$$Use = \frac{\pi \times R^2}{Overlapped_{Area}} \quad (6)$$



**Figure 2.** Usefulness metric (Use).

### 3.3. Validity Metric (Val)

Validity value shows the messages age. It means the remaining time to the message deadline in real-time applications. When the remaining time to the message deadline is short, the message is given the high priority. The validity can be given by Equation (7) [24]:

$$Val = \frac{Remaining\ Time\ to\ the\ Deadline}{Transferring\ Time} \quad (7)$$

Transferring Time in above equation is an estimated time to transfer message between sender and receiver vehicles in order to normalize.

### 3.4. Weather Conditions Metric (WC)

Messages generated in severer weather condition should first be transferred.

### 3.5. Geographic Position Metric (GP)

The priority of messages produced in rapid position is higher than that in ordinary position.

By combining Equations (3) to (7), the dynamic factor is calculated by Equation (8):

$$Dynamic_{Factor} = \frac{Vel \times Use}{(Val + 1) \times WC \times GP} \quad (8)$$

Based on Equations (2) and (8), consequently message priority and dynamic factor are directly proportional to  $Vel$  metric and  $Use$  metric. However, dynamic factor is opposite proportional to  $(Val + 1)$  sum,  $WC$  metric and  $GP$  metric. In equation (8),  $Val$  metric is added to 1 to avoid ambiguous result when it is equal to zero.

The referenced information to calculate dynamic factor comes from GPS and the routing table. The calculated priorities by using Equation (2) are placed in the header of packets. In fact, EDCA is firstly

finished in the background to prioritize the messages. EDCA is primary priorities in VANET [25], [26].

#### 4. Delay Performance Analysis

Processing delay (nanosecond) is smaller than other delay factors (millisecond). So, the processing delay can be omitted in our computations. The propagation delay equals dividing distance between sender and receiver by the light speed. The propagation delay also can be omitted in our computations since the distance is much smaller than the light speed.

##### 4.1. Transmission Delay Analysis

Theoretically, transmission delay is decided by the average number of backoff slot and successful transmission time after using priority assignment. Transmission delay is calculated by Equation (9):

$$D_{trans} = T_B + T_F + T_s \quad (9)$$

where  $T_B$  is back-off period,  $T_F$  is freezing back-off period, and  $T_s$  is successful transmission period.

If EDCA mechanism is applied to contest,  $(T_B + T_F)$  can be computed on reference [27]. The reference analysed delay performance of IEEE 802.11p in saturation condition. To transmit a frame successfully, the average number of backoff slot that a station needs is

$$E(X_i) = \frac{W-1}{2} + d_i \quad (10)$$

where  $d_i$  indicates the remaining frozen time before the backoff counter is reacted for states  $(k, l)$  with  $k \geq 1$ . The variable  $X_i$  ( $i = 0, 1, 2, 3$ ) represents the total number of backoff slots, which a frame encounters without considering the case when the counter freezes.

If we just consider the successful transmissions, the total number of slots which a frame encounters when the counter freezes is represented the random variable  $B_i$  ( $i = 0, 1, 2, 3$ ). The average frozen slot can get from

$$E(B_i) = \frac{E(X_i)}{1 - p_i} p_i \quad (11)$$

where the probability  $p_i$  means that a station in backoff stage for the priority  $i$  class senses the channel busy.

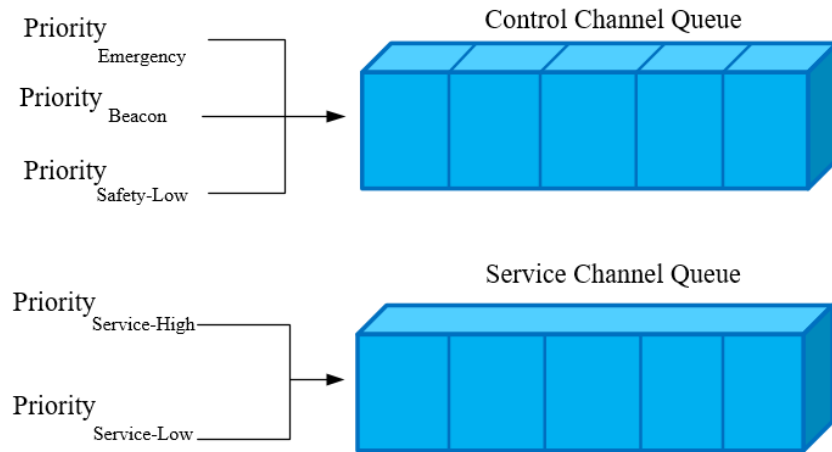
Let  $p_b$  denote the probability that the channel is busy.  $p_s$  denotes the probability that a successful transmission occur in a slot time. The frame transmission delay of the priority  $i$  class is average time of  $\delta$ ,  $(p_s/p_b) T_s$  and  $T_s$  for an idle slot at state  $(k, l)$  ( $k > 0$ ), a busy slot at states  $(k, l)$  ( $k > 0$ ) and a successful transmission at states  $(k, 0)$ , respectively.  $D_{trans}$  can be gotten from

$$D_{trans} = E(X_i)\delta + E(B_i)\frac{p_s}{p_b}T_s + T_s \quad (12)$$

The second term in the formula (12) affects  $D_{trans}$ . When priority assignment unity is used, the term can be decreased until zero.

##### B. Queuing Delay Analysis

Providing a low delay data transferring is crucial in VANET. However, it is a challenging task because VANET has those characteristics, such as: high mobility, high rate of topology change, distributed control, high speed of vehicles, and so on. In order to enhance low delay in VANET, we need to improve IEEE 1609.4 multi-channel MAC. The improve method focuses on the process of message scheduling. According to the message priority, queues sequences in the control and service channel are rescheduled before transferring to the channels. Here, the message scheduling divides into two steps of static scheduling and dynamic scheduling.



**Figure 3.** Static scheduling process

Here, control and service channel queues serve control services and other service in VANET, respectively. According to static factor defined in priority assignment, the messages are sent to either control channel queue or service channel queue in the static scheduling step. The messages with  $\text{Priority}_{\text{Emergency}}$ ,  $\text{Priority}_{\text{Beacon}}$ , and  $\text{Priority}_{\text{Safety-Low}}$  priorities are sent to control channel queue, and the other messages are transferred to service channel queue. When the control channel queue is full, the messages in control channel are moved to service channel queue. The static scheduling process in the message scheduling as shows in the Figure 3.

Two steps implement the dynamic scheduling: first step is using the message priorities in priority assignment, and the second step is rescheduling the messages in each queue. The message priorities of dynamic scheduling are from Equation (2). The packets in each queue will be rescheduled when a new packet is entered into the queue. In fact, the packets in the queue may be a descending order on their priorities. Then, some packets in last in queues are may be dequeued from the channels line. This method for dynamic scheduling is referred as “DySch”.

By Equation (13), the queuing delay is calculated as follows:

$$D_{\text{queue}} = \frac{1}{\mu - \lambda} - \frac{1}{\lambda} \cdot \frac{Q_L \rho^{Q_L}}{1 - \rho^{Q_L}} \quad (13)$$

where,  $\rho$  is utilization which is equal to  $\frac{\lambda}{\mu}$ , where  $\lambda$  and  $\mu$  are packet arrival rate and packet service rate, respectively.  $Q_L$  shows maximum queue length. If reschedule is used on priority assignment unity,  $D_{\text{queue}}$  will be reduced substantially.

Since the priority was added on a message, the messages don't queue and immediately will be sent to the head of line. Therefore, it does not take time for queuing to the head of line.

## 5. Simulation Result Discussions

We take Network Simulator (NS) version 2.35 [28] evaluating the delay performance of the DySch method in VANET. Table 1 and Table 2 show the parameters used in the simulations of scenario. IEEE 802.11p, which is ordinarily used in the VANET, was also used as channel access protocol in MAC layer in the simulation. TwoRayGround was taken as the propagation model of radio frequency in simulation scenario. The generated data traffic is assumed as the Poisson distribution. Routing protocol in simulations is assumed Destination-Sequenced Distance-Vector (DSDV).

**Table 1.** parameters in simulation scenario

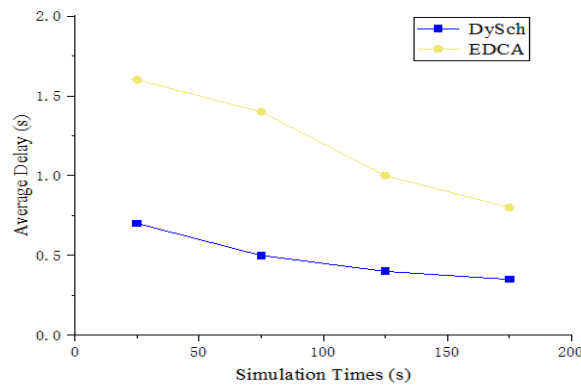
Parameters	Value
Transmission rate	6 Mbps
Bandwidth	6 MHz
Message size	500 Bytes
MAC type	IEEE 802.11p
Propagation model	TwoRayGround
Routing protocol	DSDV
Simulation time	200 s
Simulation runs	20
Back-off time slot length	13 $\mu$ s

**Table 2.** EDCA parameters in the CCH of VANET

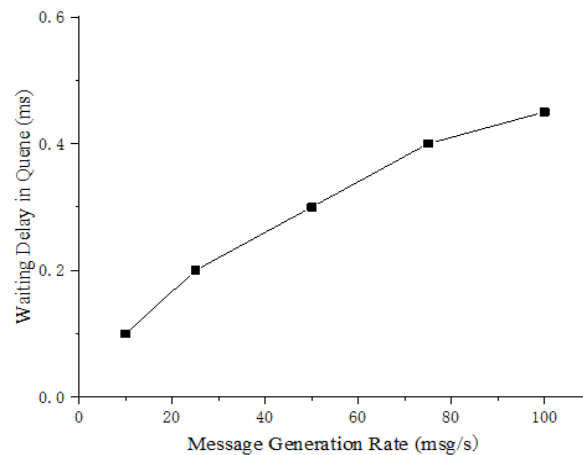
Access category	CWmin	AIFSN
AC <sub>0</sub>	15	9
AC <sub>1</sub>	7	6
AC <sub>2</sub>	3	3
AC <sub>3</sub>	3	2

For evaluation of the proposed method, Fig. 4 shows that the average delay changes with simulation time. EDCA in IEEE 802.11p is the traditional channel contest method. So, average delay metric of DySch approach compares with that of EDCA approach. Nodes number of simulation is 50. The figuration shows that the average delay for EDCA mode and DySch mode both generally declines while simulation time increases. When using DySch method, the average delay time changes from 0.7 ms to 0.6 ms. When using EDCA method, the average delay time is 1.7 ms to 1.2 ms. Therefore, the average delay of using DySch is lower 0.6 ms above than that of using EDCA during 25-175 s simulation time. It means that by using the DySch method, delay performance is improved without feedback information. As above, DySch method should be assumed open-loop mode.





**Figure 4.** The average delay changes with simulation time



**Figure 5.** Variation of waiting delay in queue with message generation rate

In Fig. 5, Variation of waiting delay in queue with safety message generation rate is researched if messages access channel through DySch. The horizontal coordinate represents Message Generation Rate. Vertical coordinate represents waiting delay in queue. The waiting delay in queue, is much low, less than or equal to 0.5 ms. The least waiting delay time is 0.1 ms when the message generation ration is 10 msg/s, and it ascends with parabolic curve to 0.5 ms when the message generation ration is 100 msg/s. This result provides a low queue delay in VANET by DySch. This is because the prioritized message can be fleetly sent to queue head by rescheduling. So, a negligible delay for special messages can be gotten in this approach.

## 6. Conclusion

Delay performance in VANET is intensively focused on. Some new measures are endlessly taken so that the transmitted messages between vehicle and vehicle have the least delay time. In this paper, a novel measure, DySch, which can reduce the transmission delay, was proposed. DySch is distributed strategy. This measure requires that each vehicle independently prioritizes all the generated/received messages on their specification, and then each vehicle reschedules these messages. DySch method put into effect through two steps: the first is priority assignment, and the second is message scheduling. While assigning priority, static factors are calculated based on the content of messages, and dynamic factors are done based on the situation of vehicles, too. After calculating the static factors and dynamic factors, each message can achieve a priority in relation to size of the message. Scheduling message includes static scheduling and dynamic scheduling. According to static factors, static scheduling

transfers the messages to control channel queues. According to dynamic factors, likewise, dynamic scheduling reorders the packets in the queue before the messages are transferred to the channel. That is also that the priority of messages helps Dynamic scheduling implement.

The performance of DySch strategy was analysed in highway scenario on the average delay and waiting delay in queue. Simulation results are consistent with theoretical deriving. Application of DySch method improved the delay performance of VANET because average delay of one-hop is reduced. The average delay may highly be decreased on formula (12). Also, the queue delay can be nought since a packet can immediately arrive at head of line. So, the result showed that the applications of the strategy led to the lower waiting delay in queue. Therefore, more safe and reliable environments can be provided in VANET using DySch strategy.

In the future, some issues will be further researched. QoS model for VANET must be set up. QoS route and QoS MAC for VANET need further modified by tradition and new machine learning theories based on the model.

## 7. Acknowledgement

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