Burst Transmission and Frame Aggregation for VANET Communications

Wei Kuang Lai [1] *, Mei-Tso Lin [2], Ting-Huan Kuo[3]

[1] *Department of Computer Science and Engineering, National Sun Yat-sen University*
70 Lienhai Rd.,Kaohsiung City, 80424 , Taiwan
wklai@cse.nsysu.edu.tw

[2] *Department of Computer Science and Engineering, National Sun Yat-sen University*
70 Lienhai Rd.,Kaohsiung City, 80424 , Taiwan
meizur402@gmail.com

[3] *Department of Computer Science and Engineering, National Sun Yat-sen University*
70 Lienhai Rd.,Kaohsiung City, 80424 , Taiwan
daphnekuo0408@gmail.com

Abstract

In vehicular ad hoc networks (VANETs), due to highly mobile and frequently changing topology, available resources and transmission opportunities are restricted. To address this, we propose a burst transmission and frame aggregation (FAB) scheme to enhance transmission opportunity (TXOP) efficiency of IEEE 802.11p. Aggregation and TXOP techniques are useful for improving transmission performance. FAB aggregates frames in the relay node and utilizes the TXOP to transmit these frames to the next hop with a burst transmission. Simulation results show that the proposed FAB scheme can significantly improve the performance of inter-vehicle communications.

Keywords: vehicular ad hoc networks; transmission opportunity; bursting routing; collision; aggregation

1. Introduction

Vehicular ad hoc networks (VANETs) are an important and emerging area of research in the vehicular communication field. VANETs are a subtype of mobile ad hoc networks; however, network topology and channel efficiency in VANETS differ significantly from those in traditional wireless networks due to the high mobility of vehicular environments. Vehicles with wireless communication capabilities (see Refs. 1-4) can communicate with roadside infrastructures or other vehicles, thereby enabling users to access Internet services for required information. Generally, VANET communication refers to hybrid vehicle-to-roadside unit (V2R) communication and inter-vehicle communication described in Refs. 5 and 6. People can enjoy safety, convenience, efficiency, and entertainment with VANET applications. Given the high mobility of vehicles, network topologies and communication links in VANETs change rapidly. Such dynamic characteristics result in restricted network resources; therefore, effective data dissemination is crucial. Managing effective network transmissions to enhance performance in vehicular environments is a primary challenge.

In a vehicular environment, it is probable that many transmissions occur between many senders and receivers. Thus, it is necessary to carefully construct routes for each pair of transmissions. A large number of messages will cause network congestion and degrade transmission efficiency. To avoid affecting network performance, a major task is to determine how and where the received information should be transmitted. In routing processes, some nodes may be selected as relay nodes more frequently; thus, such nodes have a large number of packets to send and must contend for transmission opportunities many times, yet transmission opportunities are limited in VANETs due to the vehicle speed and the collision status.

To improve the efficiency of transmission opportunities for inter-vehicle communications, we propose a burst transmission and frame aggregation (FAB) scheme. The contributions of the paper is as follows:

- Network efficiency is considered. The proposed FAB scheme considers network efficiency in choosing relay nodes. This paper calculates weight values to evaluate different relay nodes. The available frame size, the TXOP limit, the link expiration time, and the maximum transmission rate are taken into account for selecting relay nodes.
- The FAB employs an aggregation technique and utilizes the TXOP in the network. The proposed method attempts to aggregate frames in a single relay node and then transmits these frames to the next hop in the burst mode. The FAB scheme can decrease transmission overheads by having a lower collision rate.
- When data is large, FAB chooses multiple relay nodes in each hop based on the weight values to improve performance. In addition, the FAB scheme can also be used to support data of different classes by allowing data of higher class to be forward in more classes of relay nodes with more TXOPs.

The remainder of this paper is organized as follows. Section 2 describes related research. In Section 3, we propose and analyze the FAB routing method in detail. Simulation results and interpretations are presented in Section 4, and we provide conclusions in Section 5.

2. Related Work

Many studies have attempted to refine VANET routing protocols; however, the focus of these studies has been on establishing good routes (or selecting suitable relay nodes). To the best of our knowledge, not many studies have focused on improving transmission opportunity (TXOP) efficiency for VANETs and selecting relay nodes together.

A well-known routing protocol, i.e., Greedy Perimeter Stateless Routing (GPSR), has been proposed from Ref. 7. GPSR uses the router positions and packet destinations to make packet-forwarding decisions. GPSR makes greedy forwarding decisions using the information about a router’s immediate neighbors in the network topology. GPSR attempts to forward a packet to the farthest neighbor node to minimize the hop count.

Information dissemination in VANETs is typically performed via multi-hop broadcasting or multicasting mechanisms (see Refs. 8 and 9 for more details).

The dissemination technology can be used to extend the reach of emergency or safety warning message, to exchange neighboring information, and to relay data through the Internet. In VANETs, transmission delays bring a significant challenge for real-time applications, especially for emergency message. In order to transmit data more efficiently and steadily in limited resource conditions, most forwarding mechanisms (see Refs. 10 – 16) choose the vehicle farthest from the previous forwarder opportunistically as a new forwarder for fast dissemination. To ease the problem of contention further, 3P3B from Ref. 15 adopts partitioning scheme to reduce competitions between forwarder candidates. Only vehicles in the farthest sector from the sender compete for forwarding; thus, 3P3B achieves faster dissemination speed and shortens the contention duration.

VANET data aggregation methods have been proposed from Refs. 17-20. A Catch-Up scheme (see Ref. 17) can dynamically control the forwarding delays of nearby reports so that they have greater chance to be aggregated at the same node. Another scheme from Ref. 18 focuses on the delay-constrained data aggregation problem in VANETs for maximizing the amount of collected information. The chain heuristic, which finds a set of paths for each destination within the delay limit, is proposed to meet delay bound for multicast networks (see Refs. 19 and 20). A LAODAF scheme from Ref. 21 indicates that how and where the collected data are transmitted is important. A BEB approach from Ref. 22 has been proposed to maintain efficient and real-time video broadcasting. In this method, the transmitted queue makes every effort to broadcast as many shaped video frames as possible within a short time.

TXOP is a channel control method for improving channel utilization in IEEE 802.11e. This scheme increases throughputs and reduces contentions by allowing consecutive frame exchanges. Many studies from Refs. 23-26 incorporate the TXOP scheme to improve network performance. In Ref. 23, the authors evaluate the impact of TXOP limits on achieving efficient burst transmissions. Many methods have also adopted the TXOP scheme for throughput improvement (see Refs. 24 and 25). The paper in Ref. 26 shows that the throughput performance of a high-velocity vehicle degrades significantly. To address this unfairness problem, they adjust the TXOP limits to each vehicle according to their mean velocities. Combining the burst-mode communications and cluster communications are studied in Ref. 27. The purpose is to reduce contention overheads by allowing only the cluster header to contend for the TXOP.

To design an efficient and reliable routing scheme and improve transmission performance of VANETs with highly mobile features, we thus adopt the aggregation technique and consider the TXOP. We propose the FAB scheme to effectively utilize the TXOP. The proposed scheme can enhance transmission performance while minimizing transmission overheads.

3. FAB Routing Method

Preventing transmission delay and keeping connectivity in VANETs are the important issues from Ref. 28. In Table 1, Enhanced distributed channel access (EDCA) supports four access categories. BacKground (BK), Best Effort (BE), Video (VI), and Voice (VO) show. Each access category has different Arbitration inter-frame spacing (AIFS) values and/or TXOP limits. The standard IEEE 802.11 We can specify the TXOP limit for each access category. The TXOP limit is the maximum time duration a node can use to transmit data after it obtains a TXOP. If the TXOP is determined to be zero, such as that for background traffic (BK) or best effort (BE), the node can only transmit one frame after it obtains a TXOP. Obviously, the TXOP efficiency is not good when the TXOP limit is set to zero.

Table 1. The TXOP limit in EDCA

Access Category	AIFS	TXOP Limit
BK	7	0
BE	3	0
VI	2	6.016 ms
VO	2	3.264 ms

In VANETs, vehicles contend for transmission opportunities in a distributed manner. The transmission opportunities in VANET are scarcer than those in typical wireless networks due to the high mobility. In addition, many transmissions occur between many senders and receivers typically. A large number of messages will cause network congestion and degrade transmission efficiency. To avoid affecting network performance, how and where the received information should be transmitted is critical. When a vehicle enters the coverage of another vehicle or a roadside unit, it must contend for transmission opportunities with other vehicles until the link between them breaks. Obviously, two factors affect the transmission performance of a vehicle:

i. the velocity of the vehicle.
ii. the collision rate.

The higher the velocity of the vehicle, the lower the throughput. Even if the vehicle velocity is not high, it may still get poor throughput due to a high collision rate. Therefore, V2R communication is affected significantly, and V2V communication is even more affected by the velocity and collision rate. Thus, in this study, we proposed the FAB scheme to make good use of TXOPs to enhance the transmission capacity of VANETs with highly dynamic characteristics.

When a vehicle attempts to contend for a TXOP, it should follow the backoff algorithm to count down until its back-off timer becomes zero. In addition, the vehicle may need to send an RTS message to occupy the channel prior to a data transmission. Thus, the overheads of each transmission can become very large. Effectively utilizing the TXOPs becomes important for improving performance. The FAB scheme aggregates data frames in the network to increase the amount of available frames for each TXOP. Furthermore, the effects of frame aggregation subsequently can greatly reduce the number of contenders, which reduces transmission delay significantly.

3.1. Selecting relay nodes and transmitting frames

In the FAB scheme, as shown in Fig. 1, a vehicle considers the number of frames to relay and the vehicle's position (i.e., the geometric distance from the destination). From Fig. 1, if we forward frames to the vehicle with the maximum distance, we forward frames to the vehicle nearest to the destination node and thus we can have a minimum number of hop count between the source node and the destination node. However, the further distance between two nodes can also lead to the lower channel efficiency and smaller link expiration time, which is the connection time for a link.

In Fig 1. Vehicle of source 1 and Vehicle of source 2, several parameters can be considered in choosing relay nodes. First parameter is the link expiration time between the source node and the destination node. Second parameter is the TXOP allocated to a node for a transmission. Third parameter is the number of available frames of the chosen vehicle. We can see that three parameters must be considered together. If we choose the vehicle with the larger link expiration time, the allowed time transmission time is still limited by the TXOP. Similarly we cannot consider TXOP only in choosing a relaying node since it is also affected by the link expiration time and the available frames which determines the retransmission capability of the chosen vehicle. Besides, if there are no available frames (bandwidth) in the chosen vehicle for relaying frames, there is no use to forward frames to the vehicle. In Fig. 1 the receiving vehicle may receive frames from two vehicles and if one source has utilized most of the available frames, the other source has better choosing the other vehicle as the relaying node.

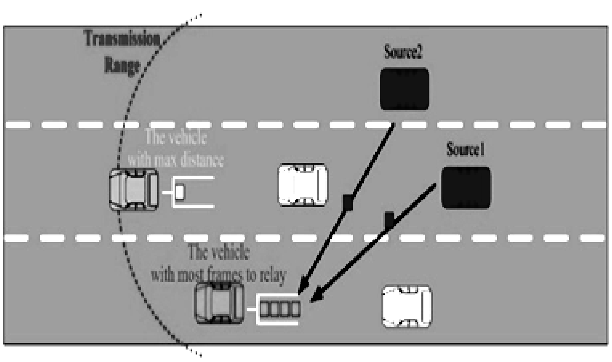

Fig. 1. FAB computes the W values to decide the next hop

In the FAB scheme, vehicles periodically send a message with information about its current position and how many frames it possesses. When a vehicle wants to select another vehicle as the next relay node, the vehicle examines the messages heard from its neighbors for two values: (1) the position and moving direction of the neighbor, and (2) the number of available frames that the neighbor can relay (n_f). Let n_f^i be the available frames of neighbor i. The FAB scheme selects the vehicle with the maximum weight value W in Eq.(1) as the first forwarding node and aggregates frames for data forwarding. The W value takes into account the available frame size, the smaller number of the transmission opportunity and the link expiration time, and the maximum bit rate of the adopted protocol. We will analyze and explain more later about the W value.

$$W_i = \frac{\sum_{j=1}^{n_f^i} f_j}{\min(L_i, T_l) \times B} \quad (1).$$

Here, f_j is the size of frame j, B is the maximum bit rate in accordance with the adopted protocol, T_l is the determined TXOP limit, and L_i is the link expiration time to vehicle i . L_i can be calculated as in Eq. (2) from Ref. 29. We can set a threshold value δ for L_i and those links whose link expiration time is shorter than δ will not be selected for frame transmissions by a vehicle.

where (x_i, y_i) and (x, y) are the positon of vehicle i and the source vehicle, respectively. The speeds of vehicle i and the source vehicle are v_1 and v_2, and the moving directions are θ_1 and θ_2, respectively.

$$L_i = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2}$$
$$a = v_1 \cos\theta_1 - v_2 \cos\theta_2, b = x_i - x, \quad (2),$$
$$c = v_1 \sin\theta_1 - v_2 \sin\theta_2, d = y_i - y$$

Note that if data R^0 is too large, data will be segmented into many frames. In that case, the source node selects more relay nodes for relaying frames. As shown in Fig. 2, The frames relayed by the node with the largest W value is Eq. (3)

$$F^1 = \left(\min\left(\min\left(\sum_{j=1}^{n_f^m} f_j, \min(L_m, T_l) \times B\right)\right), R^0\right) \quad (3),$$

where n_f^m is the number of available frames the vehicle with the maximum W possesses, L_m is the link expiration time of the vehicle with the maximum W, and T_l is the determined TXOP limit.

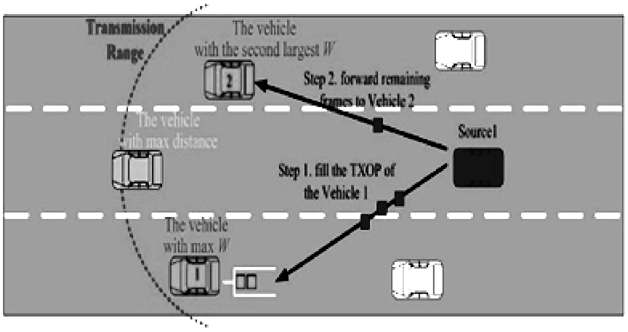

Fig. 2. Frame dispatching when the capacity of the vehicle with the maximum W is not enough

where n_f^m is the number of available frames the vehicle with the maximum W possesses, L_m is the link expiration time of the vehicle with the maximum W, and T_l is the determined TXOP limit. The remaining frames not forwarded by the node with the largest W value would be

$$R^1 = \max\left(R^0 - \min\left(\sum_{j=1}^{n_f^m} f_j, \min(L_m, T_l) \times B)\right), 0\right) \quad (4).$$

Equation (4) can be equal to 0 which means all frames are forwarded and there are no remaining frames.

If the total frame size R^0 of the source vehicle is too large for the vehicle with the maximum W value to relay and the vehicle with the second largest W value is available, the source vehicle will also select the vehicle with the second largest W value to relay the remaining frames. The frame by the vehicle with the second largest W value where n_f^s is the number of available frames the vehicle with the second largest W possesses and L_s is the link expiration time of the vehicle with the second large W value show in Eq. (5).

$$F^2 = \left(\min\left(\min\left(\sum_{j=1}^{n_f^s} f_j, \min(L_s, T_l) \times B)\right)\right), R^1\right) \quad (5),$$

And the remaining frames not forwarded by the node with the second largest W value can be calculated as in (6).

$$R^2 = \max\left(R^1 - \min\left(\sum_{j=1}^{n_f^s} f_j, \min(L_s, T_l) \times B)\right), 0\right) \quad (6).$$

In general, if the remaining size $R^{(r-1)}$ of the source vehicle is too large for the vehicle with the $(r-1)^{th}$ largest W value to relay and the vehicle with the r^{th} largest W value is available, the frames relayed by the vehicle with the r^{th} largest W value is where n_f^r is the number of available frames the vehicle with the r largest W possesses and L_r is the link expiration time of the vehicle with the r largest W value in (7).

$$F^r = \left(\min\left(\min\left(\sum_{j=1}^{n_f^r} f_j, \min(L_r, T_l) \times B)\right)\right), R^{(r-1)}\right) (7),$$

And the remaining frames not forwarded by the node with the r^{th} largest W value can be calculated as in (8).

$$R^r = \max\left(R^{(r-1)} - \min\left(\sum_{j=1}^{n_f^r} f_j, \min(L_r, T_l) \times B)\right), 0\right) (8).$$

The FAB scheme can support the transmission of various traffic types. For supporting differentiated services (Diffserv) in the proposed FAB scheme, vehicles can select different relay vehicles as the next hops according to the type of traffic. Suppose that there are N traffic types coexisting in the network and the priority of traffic type i is higher than that of traffic type i+1 for all $i < N$. When a vehicle wants to forward frames belonging to traffic type i, it must select the relay vehicle from the i-th largest W value as the next hop. As shown in Fig. 3, for example, if a vehicle wants to transmit frames belonging to traffic type 2, it will select Vehicle B, which possesses the second largest W value, as the first relay vehicle. After filling the TXOP of Vehicle B, it can select the vehicle with the third largest W value to forward the remaining frames, and so on. Thus, the FAB scheme can dispatch the frames according to traffic types. Note that the source vehicle begin frame transmissions with Vehicle B whereas in the original sachem the source vehicle can begin frame transmissions with Vehicle A. It is possible that the network throughput can be affected due to the constraints we apply to different classes for supporting Quality of Service (QoS) of different traffic types. To ease the problem, if vehicle is very low in loads, vehicle A can broadcast an addition information to inform the source node that vehicle A can be selected and the constraint of traffic classes can be neglected.

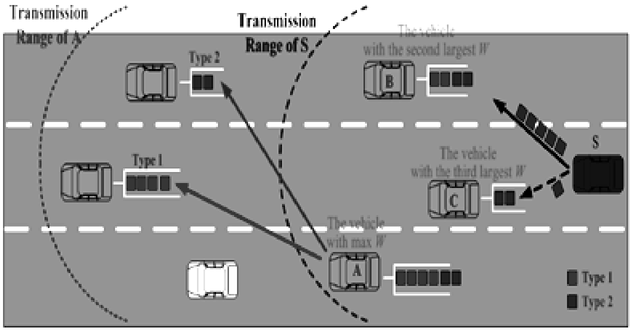

Fig. 3. DiffServ scenario in the FAB scheme.

In addition to the above W value, there are three parameters which allow frames with higher priority to have greater opportunity to be forwarded. In other words, we can also give different parameter values to different traffic classes.

1. The vehicle with a higher traffic class will have a smaller minimum contention window and fewer back-off stages.
2. A vehicle will have a shorter AIFS when it attempts to transmit frames with a higher priority (following the IEEE 802.11 standard).
3. A vehicle will have a longer TXOP when it attempts to transmit frames with a higher priority (following the IEEE 802.11 standard).

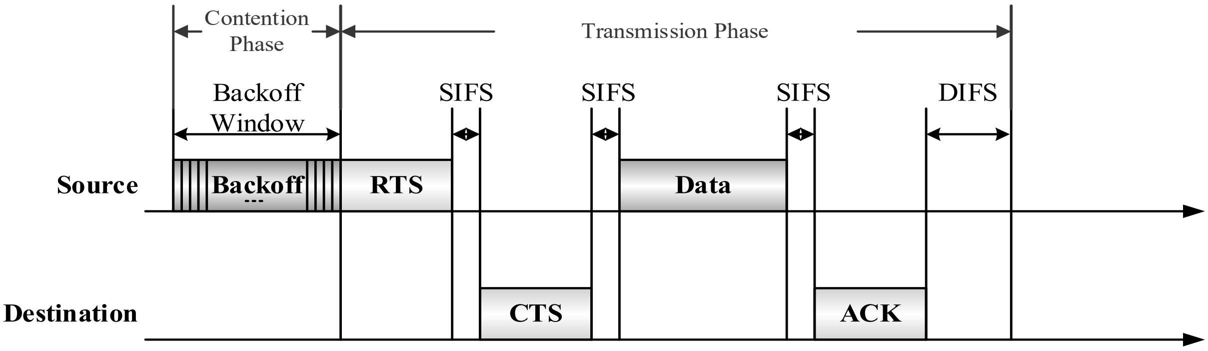

Fig. 4. The overhead in the contention phase and the transmission phase from Ref. 31.

Following these rules, frames of the same traffic type will be aggregated within a relay vehicle and transmitted. according to their traffic type. That is, the FAB scheme can enable differentiated services and extend its applicability for supporting Quality of Service (QoS).

3.2. Analyses and discussions

Fig. 4 shows the overhead in the contention phase and the transmission phase for IEEE 802.11. SIFS value is smaller than DIFS value to give RTS, CTS, data, and ACK a higher transmission priority. First, in (9) we compute the overhead time in the transmission phase, O_T, as follows:

$$O_T = RTS+SIFS+CTS+SIFS+SIFS+ACK+DIFS \qquad (9).$$

To increase the network efficiency E, can be defined where $T(P_C)$ is the transmission delay in a contention-based wireless network with the collision probability P_C and TXOP is the transmission opportunity as in (10). We can either increase the value of TXOP or decrease the value of $T(P_C)$.

$$E = \frac{TXOP}{T(P_C)+O_T+TXOP} \times 100\% \qquad (10),$$

In FAB, we adopt bust-mode transmissions, which has the effect of increasing the value of TXOP. According to the relay node selection criterion, the FAB scheme selects neither the farther vehicle nor the vehicle with the largest link expiration time as the relay node. The FAB scheme lets the frames be aggregated within a vehicle so that the vehicle can transmit these frames in a burst when it obtains a TXOP.

In addition, the burst-mode transmission also has the effect of decreasing $T(P_C)$. This is because the average value of $T(P_C)$ can be estimated as in (6) from Ref.

30.where W is the minimum contention window, and m is the maximum backoff stage.
In computing (11), the contention window size is assume to be a half of the maximum contention window for each backoff stage.

$$T(P_c) = \left[\frac{W}{2} + \cdots + \frac{W2^m}{2} \cdot P_c{}^m + \frac{W2^m}{2} \cdot P_c{}^{m+1} + \cdots\right] \times T_s$$

$$= \left(\frac{W}{2} \times \frac{(2P_c)^{m+1} - 1}{2P_c - 1} + \frac{2^{(m-1)} W P_c{}^{(m+1)}}{1 - P_c}\right) \times T_s \quad (11).$$

T_s is calculated as in (12) from Ref. 30:

$$T_s = 1 \times P_I + T_c^{r/c} \times P_c + T_s^{r/c} \times P_s \quad (12),$$

where P_I is the probability that the channel is idle and P_S is the probability that a station transmits its packet within the slot without a collision. $T_c^{r/c}$ denotes the time of a successful transmission and $T_s^{r/c}$ denotes the time of a collision.

$$T_c^{r/c} = RTS + DIFS \quad (13).$$

$$T_s^{r/c} = RTS + 3(SIFS) + CTS + TXOP + ACK + DIFS \quad (14).$$

Adopting the burst-mode transmission will decrease the total number of transmissions by vehicles, and therefore has a lower collision probability for each transmission. As in (6), a lower collision probability leads to a lower $T(P_C)$. Note that the O_T in (9) is a required overhead for each transmission. We can only reduce the total number of retransmissions by having a lower collision probability P_C. Moreover, the FAB scheme reduces routing overheads because vehicles have lower collision rates and trigger less routing recoveries.
In this paper, we adopt the W value in (1) to select forwarding nodes. We divide the total number of available frames, $\sum_{j=1}^{n_f^i} f_j$, by $\min(L_i, T_l) \times B$ instead of just utilizing $\sum_{j=1}^{n_f^i} f_j$ since we need to also consider the total throughput which is subject to the TXOP limit and link expiration time. Here our selection of W also values the load of forwarding nodes while relaying the frame for the source node. Another possible design it to let $W = \min(\min(L_i, T_l) \times B, \sum_{j=1}^{n_f^i} f_j)$, which only considers the total amount of frames helped by the neighboring node. Since each node can aggregate frames from multiple neighbors, our goal is to forward frames to their destinations. In this paper instead we choose forwarding nodes based on (1).

Table 2. Simulation parameters

Parameters	Values
Network Topology	40 km bidirectional highway
Number of Lanes	4 (2 lanes for each direction)
Vehicle Speed	70 km/h - 100 km/h
Communication Range	250 m
Number of Vehicles	[400, 800] vehicles
Wireless MAC	802.11p
Application	CBR
CBR Rate	10 Mbps
CBR Packet Size	512 bytes
Radio Propagation Model	Nakagami propagation model
Simulation Time	400 seconds

We choose the neighboring node with a higher W value which means it will occupy a smaller portion of the available frames of the neighboring node compared to choosing other nodes with lower W values. By this way, we expect frames to be relayed successfully via the neighboring node. However, our FAB scheme can have the drawback of segmenting data into more parts since we do not select neighboring nodes which can forward the most number of frames.

3.3. Extension to Road Side Unit

Eq. 1 can also be applied to Road Side Unit (RSU). That is, we can treat the RSU as a forwarding node. We can use (2) to obtain link expiration time with v_l =0. However, if we use (1) directly, we make no difference of RSU and vehicles. Since the RSU in general provides us with a more stable connection with a higher throughput, we prefer choosing RSU as the forwarding node. Therefore, we modify the computation of weight for the RSU as (15).

$$W_i = \begin{cases} \frac{\sum_{j=1}^{n_f^i} f_j}{\min(L_i, T_l) \times B} + \theta, if \frac{\sum_{j=1}^{n_f^i} f_j}{\min(L_i, T_l) \times B} > \delta \\ \frac{\sum_{j=1}^{n_f^i} f_j}{\min(L_i, T_l) \times B}, otherwise \end{cases} \quad (15).$$

We let θ be a large enough value to choose the RSU as the forwarding node when $\frac{\sum_{j=1}^{n_f^i} f_j}{\min(L_i, T_l) \times B} > \delta$, where δ is a threshold value to ensure that the RSU will not be overloaded if we choose it as the forwarding node. If $\frac{\sum_{j=1}^{n_f^i} f_j}{\min(L_i, T_l) \times B} \leqq \delta$, we do not particularly favor the RSU and treat it the same as the other vehicles because the RSU may become overloaded if we continue choosing it as the forwarding node.

4. Experimental Results

We adopt NS-2 (version 2.35) as our simulation tool to evaluate the performance of the proposed FAB scheme. The simulation scenario is a four-lane, bidirectional, 40km highway. Vehicles move at random speeds ranging from 70 to 100 km/h. The transmission range of each vehicle and RSU is set to 250 m. The probabilistic Nakagami propagation model is used as the propagation model. In our experiments, there are 20 pairs of transmissions between the sources and destinations, and the number of vehicles varies from 400 to 800. Standard IEEE 802.11p protocol is simulated. Traffic type is CBR traffic with 10 Mbps of transmission rate and 512 bytes of packet size. Here we focus on a high density scenario to show transmission performance.

We simulated 10 independent runs for each configuration and averaged the outcomes to obtain performance graphs. Table 2 lists the experimental parameters. We compare the proposed FAB scheme with GPSR from Ref. 7, a well-known position based routing protocol, and 3P3B from Ref. 15, to illustrate differences in terms of end-to-end delay, collision rate, throughput, and overhead.

First of all, we focus on the performance of end-to-end delay. As shown in Fig. 5, FAB outperforms GPSR and 3P3B significantly no matter how many vehicles are in the topology, since FAB aggregates frames in some vehicles and selects relay nodes according to weights. In other words, in the FAB scheme, it is possible that more frames can be transferred when a vehicle transfer data frames via a stable link with a higher TXOP. The choice of relaying nodes based on the W value also has the effect of balancing network loads.

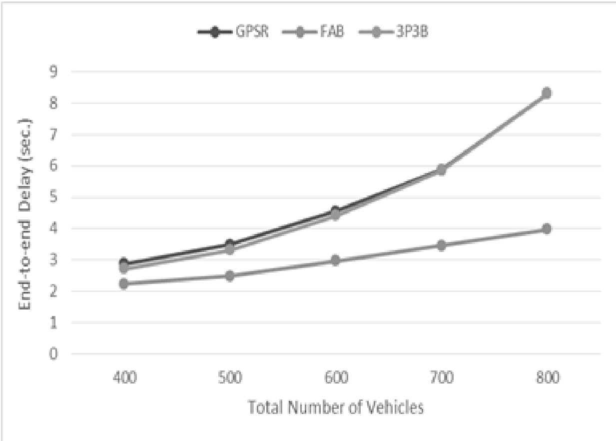

Fig. 5. The end-to-end delays of FAB, GPSR, and 3P3B with various vehicle numbers.

Accordingly, fewer vehicles attempt to contend for TXOPs and lower collision probability can be maintained with the FAB scheme (Fig. 6). We can see that the delay gap between FAB and the other mechanisms increases when more vehicles are in the topology. In 3P3B, only vehicles in the farthest sector from the sender compete for the data forwarding; thus, 3P3B achieves faster dissemination than GPSR; in GPSR, it may select a node immediately moving out of the transmission range of the sender, and thus increase the transmission error rate. As a result, the end-to-end delay of GPSR is slightly higher than that of 3P3B. Overall, FAB has the lowest collision probability. The collision probability of FAB, GPSR, and 3P3B is shown in Fig. 6, which illustrates a similar trend.

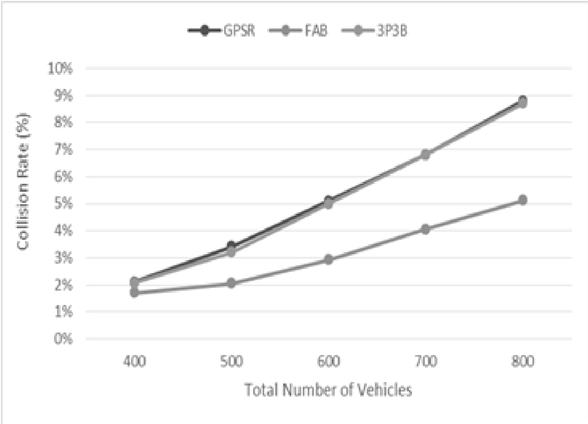

Fig. 6. The collision rates of FAB, GPSR, and 3P3B with various vehicle numbers.

In addition, we also obtain better performance for throughputs in our FAB. Fig. 7 displays the throughput performance for three mechanisms. Our FAB scheme performs better than other two schemes by a large margin as shown in (Fig. 7), especially while the number of vehicles increases. As the number of vehicles increases, the performance of our FAB scheme does not degrade as much as the other two schemes, This suggest that our FAB scheme can support a larger number of vehicles under the same bandwidth constraints.

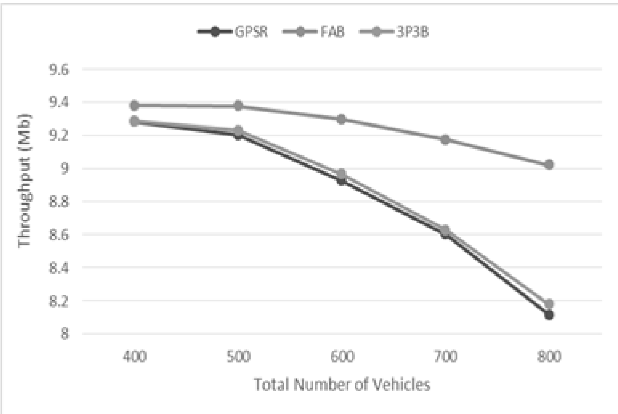

Fig. 7. The throughputs of FAB, GPSR, and 3P3B with various vehicle numbers.

We examine network overheads to further demonstrate the improvement in the FAB scheme. The network overheads in our simulations are the sum of the routing overheads (for routing discovery) and transmission overheads (RTS/CTS). As shown in Fig. 8, the network overheads of the FAB scheme are significantly less than that of the GPSR and 3P3B protocol.

The overheads of the FAB scheme come from transmitting positon information and reporting how many available frames a vehicle possesses. GPSR and 3P3B have higher overheads although they transmit only position information because they have higher collision rates. On the other hand, a small field is sufficient to transfer the information about how many frames a vehicle possesses. Compared to GPSR and 3P3B, fewer vehicles trigger routing discovery messages in FAB. Therefore, the FAB scheme outperforms the GPSR and the 3P3B in terms of network overheads.

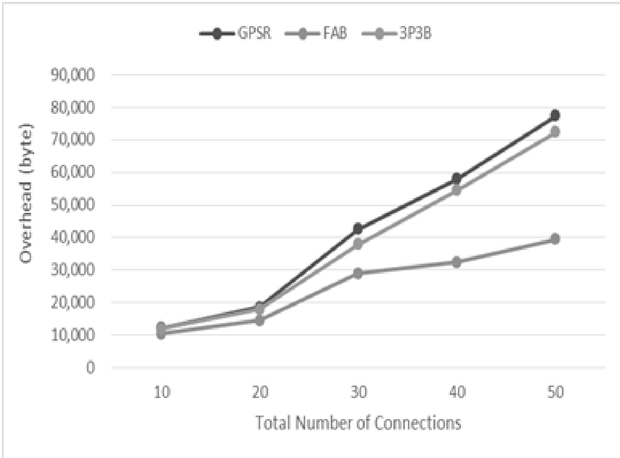

Fig. 8. The overheads for FAB, GPSR, and 3P3B with various connections.

Fig. 9 shows the relationship between the network overhead and the TXOP limit. Generally, a greater TXOP limit results in a lower network overhead. However, the overhead improvement in the FAB scheme is not as significant when TXOP limit is large (6.528 ms in Fig. 9). This is probably due to the fact that the length of each transmission is limited by both the TXOP value and the link expiration time, $(\min(L_i, T_l) \times B)$.

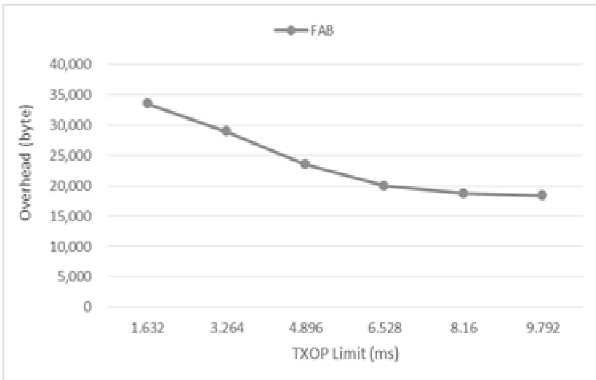

Fig. 9. Relationship between TXOP limit and overhead

5. Conclusions

In vehicular networks, transmitting frames efficiently within transmission opportunities is very important for system performance. TXOPs is very important for improving performance. Generally, there are many transmissions between many senders and receivers in a congested environment, which leads to network congestion and reduces transmission efficiency. In this paper, we propose a novel FAB scheme to enhance transmission performance. FAB also select multiple relay nodes to improve the efficiency of data forwarding if data is large and cannot be forwarded by the node with the largest weight value. FAB can also support traffics with multiple classes. The proposed strategy is evaluated using various metrics such as end-to-end delays, collision rates, and transmission overheads. The FAB scheme aggregates frames in one relay node and allows the relay node to transmit these frames to the next hop in the burst mode. The FAB scheme can increase the transmission volume within one TXOP and decrease the transmission overheads due to n contentions. Our simulation results indicate that the proposed FAB method perform well compared to GPSR and 3P3B in terms of collision rates, throughputs, and network overheads.

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