Emergency Messages Broadcasting with Multi-Forwarder in Vehicular Ad Hoc Networks

Chiu-Ching Tuan\textsuperscript{a}, Yi-Chao Wu\textsuperscript{b,\*}, and Chi-Fu Hung\textsuperscript{a}

\textsuperscript{a}Department of Electronic Engineering, National Taipei University of Technology, Taipei, Taiwan
\textsuperscript{b}Department of Information Management, Chihlee University of Technology, New Taipei City, Taiwan

Abstract: One important application in Vehicular ad hoc networks, VANET, is applied for the cooperative collision avoidance (CCA) in the intelligent transportation system, ITS. In CCA, a driver could broadcast emergency messages to advice the vehicle behind accident through VANET. Thus how to design an efficient broadcasting method for forwarding the emergency messages is important in ITS. However, most of researches focused on avoiding broadcast storm by selecting only one forwarder for broadcasting. In this way, it caused that emergency messages could not be spread in other direction roads. Thus the cars in these directions of the crossroad cannot receive the emergency messages to prevent the traffic accident. To address this issue, we proposed an emergency messages broadcasting by multi-forwarder (EMBM) to select the appropriate forwarders for each brand at the intersection. Thus the emergency message could be forwarded through each brand when the messages were broadcasted across the intersection. The simulation results showed that the reachability in EMBM was 44.9 \% and higher than that in binary partition assisted broadcast (BPAB), and 46.6 \% higher than that in cell broadcast for streets, CBS. The average delay time of EMBM was 32.3 \% lower than that in BPAB, and 69.1 \% lower than that in CBS.

Keywords: Vehicular ad hoc networks; cooperative collision avoidance; intelligent transportation system; emergency message; broadcast storm; broadcast, multi-forwarder.

1. Introduction

Vehicular ad hoc networks, VANET, was a new kind of mobile ad hoc networks (MANET). However, the current protocols and algorithms in MANET cannot be used directly for VANET due to the faster speed and more frequent dynamic topology than those in MANET. Hence, to propose the protocols and algorithms for VANET was important recently [1-6]. In VANET, how to promote the traffic safety in the intelligent transportation system, ITS, was the important issue recently [7-8]. In general, the first car broadcasts the emergency messages to the behind ones by VANET when the first car detects an accident. Thus the behind cars could have sufficient time to avoid the locale of the accident [1].

In the existing broadcasting algorithms of VANET [2], it aimed to broadcast the message to the destination node with the minimum time, such as flooding broadcasting. However, the flooding broadcasting will cause the broadcast storm and hidden terminal problems [3-4]. Thus many
broadcasting mechanisms focused on reducing the redundant messages. Most of them were to limit
the area of broadcasting to reducing the redundant forwarding packet [5, 9]. In these solutions,
however, only a car could be elected a forwarder to broadcast the messages in one direction in the
crossroads. The cars in the other directions of the crossroads cannot receive the emergency
message and thus cannot avoid the traffic accident. Thus, how to elect a forwarder in each direction
of the crossroads was important. It was also the requirement for the cooperative collision avoidance
(CCA) in ITS [10].

To address the above issue, we proposed an emergency messages broadcasting by multi-
forwarder, EMBM, in this paper. In EMBM, it selected a car to be the forwarder in a direct road
to reduce the broadcast storm and hidden terminal problems. While the car passed the crossroads,
EMBM will assign the multiple forwarders in each direction of the crossroads to ensure that the
cars in each of directions must receive the emergency messages to prevent the traffic accident. In
the existing broadcasting algorithms [11-13], it was a problem that the waiting time of selecting a
new forwarder increased if the density of cars was low. To address this issue, EMBM also involved
a proposed waiting policy to reduce the waiting time of selecting a new forwarder in the low
density of cars.

The remainder of the paper was in the following sections. Section 2 stated the related work.
Section 3 presented our proposed EMBM in detail. Section 4 showed the simulation results. Finally,
we concluded this paper in Section 5.

2. Related Work

MANET was consisted of a larger number of mobile hosts which could communication to each
other within the communication range without any base station. Thus MANET had attracted a lot
of attention recently. The packets could be forwarded to the destination by several intermediate
hosts [14-15]. By the fast development of technique in vehicle and wireless communication, how
to make MANET be applied among vehicles became important. The new ad hoc networks for
vehicle called VANET was thus proposed recently. In VANET, each car is equipped with an on-
broad unit, OBU, to communicate with another car or the roadside unit (RSU) in the road [6-8], as
shown in Figure 1. The gray car was the normal car but the block car was the forwarder. The data
exchanging among cars may be done by OBU and RSU.

In CCA of ITS, the main goal is to prevent the accidents by forwarding the emergency messages.
Dedicated short range communication, DSRC [10], was the original communication in ITS. In
DSRC, a car received the data from RSU. The data was transmitted by several RSUs. Hence, how
to exchange data between two different RSUs in handover mechanism was important for
forwarding messages in different cars. It may be a heavy loading in ITS. Moreover, it may not be
worked in the low density of RSUs in some roads. Therefore, VANET became the new
communication for ITS, because the data in VANET could be transmitted with the multiple hops
by OBU-OBU and OBC-RSU, jointly [6-8]. In some roads, the density of RSUs was low. To solve
this problem, the emergency messages could be broadcasted by OBU-OBU without OBU-RSU in
our proposal. Obviously, to propose an efficient broadcasting algorithm was important for
forwarding the emergency messages in VANET.

In unicast-broadcast protocol was a proactive broadcasting protocol. [16], a node $i$ broadcasted
a message to the neighboring nodes within its transmission range. One of these nodes which has
the maximal distance from itself to node $i$ becomes a new forwarder. For example, the source node
$A$ unicasts a message to node $B$. The forwarder $B$ unicasts the message to node $C$ and node $C$
becomes a new forwarder, as shown in Figure 2.
In unicast-broadcast protocol, the nodes transmit the data to neighboring nodes without waiting the contention time once these nodes receive the messages. However, the unicast-broadcast protocol needs to broadcast a HELLO message to its neighboring nodes to update the information of its neighbors periodically. Since the speed in VANET was faster than that in MANET, the overhead of broadcasting the controlled messages increased rapidly. The performance of network will decrease.

To address this issue, some reactive broadcasting protocols were proposed [17-21]. In the urban area, the cell broadcast for streets (CBS) [17] and binary partition assisted broadcast (BPAB) [18] were the typical solutions for reactive broadcast protocols in urban area. In CBS, the street was divided into several cells. The length of each cell was the same and calculated based on (1). $R$ and
were defined as the transmission radius of node and the width of street. The length of the last cell was less than or equal to $cl$, as shown in Figure 3.

The waiting time of node $B$ could be divided into 2 cases to be discussed. In the first case, the waiting time, $WT$, was set in (2), if the cell of node $B$ was the neighboring cell of node $A$. To avoid the collision for broadcasting between neighboring cells, $WT$ was added to $s$ as $(\text{rand} + 1) \times s$. The $s$ was defined as the number of the last cell and $\text{rand}$ was a random value for zero to one. For example, $s$ was set to 2, as show in Figure 4. In the second case, $WT$ was set in (3), if the cell of node $B$ was not the neighboring cell of node $A$, as shown in Figure 5.

\[
\begin{align*}
cl & \leq \frac{\sqrt{R^2 - sw^2}}{3} \\
WT & = (\text{rand} + 1) \times s \\
WT & = \text{rand} \times s
\end{align*}
\]

In CBS, a rebroadcast from an intersection also has the advantage of propagating the packet to the intersecting street in addition to the street the packet is currently on and thus reaches more nodes than a rebroadcast from a segment cell. However, the rebroadcast was still only sent to a direction in the intersection without to all directions in the intersection. A rebroadcast from an intersection aimed to reducing the rebroadcasting time, such as $(\text{rand} \times s + 1) - (\text{rand} \times s) = 1$ time unit. CBS addressed nothing for broadcasting with the multiple forwarders in the crossroads. Moreover, it was an overhead for each vehicle node to update its cell periodically in CBS.

![Figure 3. Cell in CBS [17]](image)

![Figure 4. WT of CBS in Case 1](image)
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Figure 5. WT of CBS in Case 2

CBS addressed nothing while a vehicle passed a crossroads. Moreover, CBS did not consider the issue for the density of vehicles. While the density of vehicles was low, WT of the vehicle node close to the source node was much longer. The performance of broadcasting thus decreased rapidly.

BPAB used a jamming signal called black-burst to dichotomize the broadcasting region by \( n \) times. The region near the source node was defined as \( NS \). The region far from source node was defined as \( FS \). If a car existed in \( NS \) receives a black-burst from \( FS \), \( FS \) was divided into a new \( FS \) and \( NS \). If a car existed in \( NS \) receives nothing, \( NS \) was divided into a new \( FS \) and \( NS \). This procedure was process until the number of processing equals to \( n \).

For example, \( n \) was set to 3. A car existed in \( NS \) receives a black-burst from \( FS \). The broadcasting region \((R)\) was calculated as \( R/2 \). \( FS \) and \( NS \) were shown in Figure 6(a). Since the cars in \( NS \) receive the black-burst from \( FS \), the new \( FS \) and \( NS \) were shown in Figure 6(b). In the same way, the new \( FS \) and \( NS \) were shown in Figure 6(c) since the number of dichotomizing the region equaled to 3. While a car existed in \( NS \) receives nothing from \( FS \) and \( n \) was set to 3. The example in BPAB was shown in Figure 7.

No matter the car in \( NS \) receives a black-burst or nothing, a broadcasting region, such as \( NS \) or \( FS \), needed to be dichotomized by \( n \) times. In Figures 6 and 7, it showed that BPAB was more suitable in low density of cars than in the high density of cars. Moreover, most of cars need to broadcast the black-burst in much times. The network bandwidth may thus decrease rapidly.

Unfortunately, CBS and BPAB still focused on solving the broadcast storm and hidden terminal problems. They addressed nothing for the multiple forwarders to transmit the emergent messages while a car passes a crossroads. Figure 8 showed that only car \( B \) was elected a forwarder to broadcast the emergency messages to the behind cars in road 2. In roads 3 and 4, cars \( E \) and \( F \) cannot receive the emergency messages, since no forwarder exist in these roads. To address this issue, we proposed an emergency messages broadcasting by multi-forwarder, EMBM. CBS and BPAB were the main comparisons in our research.

3. Emergency Messages Broadcasting with Multi-Forwarder

Vehicular ad hoc networks, VANET, is important in intelligent transportation system, ITS, since the data could be transmitted by several OBUs without RSU [6-8]. In ITS, to prevent the traffic accident was an important issue. In general, the broadcasting algorithms were often used to forward emergency messages by several elected forwarders [17-21]. However, most of them focused on avoiding the broadcasting storm and hidden terminal problems.

In fact, cars may often pass the crossroads in urban city. However, none of them addressed to select the multiple forwarders in each direction of the crossroads. In Figure 8, we could find that the cars in some directions, such as roads 3 and 4, cannot receive the emergency messages. It indicated that each direction of the crossroads required a forwarder to broadcast the emergency messages.
messages. Therefore, an emergency messages broadcasting by multi-forwarder, EMBM, was proposed in this paper.

In EMBM, a car was elected to be a forwarder in each direction of road while the source car passed a crossroads to broadcast the emergent message, as shown in Figure 9. Since only a car in one direction will be elected a forwarder in EMBM, EMBM also could solve the broadcasting storm and hidden terminal problems as same as CBS and BPAB. EMBM assumed that each car was equipped with the position system and the navigation map, such as GPS and Google map.

**Figure 6.** Example in BPAB while a car existed in NS receives a black-burst (High density of cars)
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3.1 Key Intersection Selection

In EMBM, the first intersection behind the source car was defined as Key Intersection (KI), as shown in Figure 10. The distance between the source car $A$ and $KI$ was defined as the distance of source ($DS$). While car $A$ detected an accident, it broadcasts an emergency message to the behind car $B$. While the source car $A$ passes the crossroads, the intersection 1 was set to $KI$ of car $A$, as shown in Figure 11. Cars $B$, $C$, and $D$ were the forwarders in each direction of crossroads. $KI$ of car $B$ was changed to intersection 2. Thus other cars in roads 2, 3, and 4 could receive the emergency messages. In the same way, the forwarders will be elected in roads 5, 6, and 7.
Figure 8. Example in CBS and BPAB while a car passes a crossroads

Figure 9. Multiple forwarders in EMBM
3.2 Forwarder Election

The broadcasting region in EMBM was divided into $n$ segments. The width of each segment was calculated as $R/n$, where $R$ denoted the transmission radius, as shown in Figure 12. Each car $i$ calculated the distance of candidate $i$, $DC_i$, as shown in Figure 13. Based on $DS$ and $DC_i$, car $i$ could calculate the segment which it located in. To maximize the coverage of broadcasting, the car in the farthest segment will elected as the forwarder. In EBMB, while the moving direction of two cars was the cocurrent or opposite, the located segment $i$ ($S_i$) of the car could be calculated as (4). While the car was in front of the source car, its located segment was calculated as $S_0$.

$$
S_i = \begin{cases} 
\frac{(DS - DC_i) \times n}{R}, & \text{if the moving direction was cocurrent} \\
\frac{(DS + DC_i) \times n}{R}, & \text{if the moving direction was opposite} 
\end{cases}
$$

(4)
For example, \( n \) was set to 6 and \( R \) was set to 600 meter, as shown in Figure 14(a). Since car \( C \) moved in opposite direction of car \( A \), \( S_C \) was calculated as \( S_1 \) from (4). \( S_D \) was calculated as \( S_4 \) from (4), because the moving direction of car \( D \) was not the concurrent or opposite. Each located segment of each car could be calculated, as shown in Figure 14(b). In this case, cars \( E \) and \( G \) were the new forwarders in roads 2 and 3.

### 3.3 Waiting Time

Assume the broadcasting region divided into \( n \) segments. The waiting time of car \( i \) \( (WT_i) \) in \( S_i \) was calculated as (5), where \( RT_i \) was a random value for each car \( i \). Based on (5), each car could determine its \( WT \) without coordinating other cars. Since the car could broadcast the message in the beginning of the slot, we set \( 1 < RT_i < 2 \) to avoid the collision for broadcasting message. If \( WT_i \) was expired, car in \( S_i \) became a forwarder and broadcasted a \( HELLO \) message. Once car \( i \) received a \( HELLO \) message from the new forwarder, it stopped calculating \( WT_i \). For example, in Figure 15(a), \( n \) was set to 6 and \( WT_A \) in \( S_1 \) was calculated as 6 slot time. It showed that car \( C \) in the farthest segment became a forwarder after 3 slot time. Since \( RT_j \) was a random value, only one car could become the forwarder if their \( WT \) was expired, simultaneously. To reduce the waiting time in the low density of cars, the count of \( WT_i \) was reduced by one after one slot time if the cars in
$S_{i+1}$ received nothing after $WT_{i+1}$. Once car $i$ received nothing after $m$ slot time, $WT_i$ was calculated as (6).

\[ WT_i = n - i + 1 + RT_i \]  \hspace{1cm} (5)

\[ WT_i = WT_i - m \]  \hspace{1cm} (6)

![Figure 14. Segment Calculation in EMBM](image1)

(a) Before broadcasting region segment \hspace{3cm} (b) After broadcasting region segment

![Figure 15. Example of waiting time in EMBM](image2)

(a) Initial WT \hspace{3cm} (b) WT without reducing after one slot time \hspace{3cm} (c) WT with reducing after one slot time
For example, $n$ was set to 6 and the initial $WT_i$ was calculated, as shown in Figure 15. After one slot time, $WT_i$ was calculated, as shown in Figure 15(b). If car $C$ does not receive any message from $S_5$ and $S_6$, the count of $WT_i$ could be reduced by one as 1 slot time, as shown in Figure 15(c). The total waiting time thus could be reduced by one. Hence car $C$ could become a forwarder next slot time. $WT_i$ decreased from 3 slot time to 2 slot time. The flow chart of EMBM was shown in Figure 16.

![Flow Chart of EMBM](image)

**Figure 16. Flow Chart of EMBM**

### 3.4 Summary

It showed that the multiple forwarders existed in each direction of the crossroads while a source car passed the crossroads in EMBM. Only one forwarder existed in a direction. Hence, the emergency messages could be broadcasted in the crossroads. In addition, the waiting time could be reduced in EMBM while the density of cars was lower. It showed that EMBM could be applied for CCA in ITS.

### 4. Simulation results

Simulation results in EMBM were compared with CBS and BPAB by Java language in Eclipse 3.7.2. The simulation environment was listed in Table 1. Three tunable parameters were in the simulation, such as the moving speed of car ($MS$), the density of cars ($Den$), and the transmission radius ($R$). $MS$ was set to 20-30, 40-50, and 60-70 (km/hr). $Den$ was ranged from 10 to 40 (vehicles/km/lane). $R$ was set to 300, 600, and 900 (m).
### Table 1. Simulation parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation area</td>
<td>$10 \times 10$ km$^2$</td>
</tr>
<tr>
<td>Moving speed of car ($MS$)</td>
<td>20-30, 40-50, 60-70 km/hr</td>
</tr>
<tr>
<td>Density of cars ($Den$)</td>
<td>10-40 vehicles/km/lane</td>
</tr>
<tr>
<td>Transmission Radius ($R$)</td>
<td>300, 600, 900 m</td>
</tr>
<tr>
<td>Moving model</td>
<td>Manhattan mobility model</td>
</tr>
<tr>
<td>MAC</td>
<td>802.11p</td>
</tr>
<tr>
<td>Packet size</td>
<td>512 bytes</td>
</tr>
<tr>
<td>Data Transmission Rate</td>
<td>3 Mbps</td>
</tr>
<tr>
<td>One slot time</td>
<td>16 ms</td>
</tr>
<tr>
<td>Simulation times</td>
<td>500</td>
</tr>
</tbody>
</table>

### 4.1. Performance Metrics

Broadcasting speed ($BS$), coverage of emergence messages ($CEM$), and broadcasting time ($BT$) were the performance metrics in our simulation. Let $k$ denote the number of forwarding, $BS$ was defined as (7), where $D_i$ denoted the distance and $T_i$ denoted the time in the $i$th forwarding. In (7), the distance was defined as the real transmission distance not the hop counts. Hence, equation (7) denoted the real transmission data rate. It was better while $BS$ increased. $CEM$ was defined as (8), where $N_i^r$ denoted the numbers of cars received the emergency messages in the $i$th broadcasting. $N_i$ denoted the number of total cars in the $i$th broadcasting. $BT$ was defined as (9). While $CEM$ increased or $BT$ decreased, the performance evaluation was good.

\[
BS = \sum_{i=1}^{k} \frac{D_i}{T_i}
\]  

\[
CEM = \sum_{i=1}^{k} \frac{N_i^r}{N_i}
\]

\[
BT = \sum_{i=1}^{k} \frac{T_i}{k}
\]

### 4.2 Broadcasting Speed

To obtain the optimal $n$ for EMBM in our simulation, $BS$ was evaluated in different $R$. $Den$ was set from 10 to 40 in the increment by 5 in different $R$. The $n$ was set from 2 to 10 in the increment by 2. $MS$ was set to 40-50. Figure 17(a)-(c) showed $BS$ while $R$ were set to 300, 600, and 900, respectively. Figure 17 showed that $BS$ increased smoothly while $Den$ was larger than 20. While $Den$ was less than 20, $BS$ increased rapidly. Moreover, $BS$ increased while $R$ increased. It showed that EMBM could be used in lower $Den$ and higher $R$.

In Table 2(a)-(c), $BS$ decreased while $n$ increased in low $Den$. However, $BS$ increased while $n$ increased in high $Den$. We could find that $BS$ decreased rapidly while $n$ was larger than 6 in low $Den$. While $n$ was larger than 6 in high $Den$, $BS$ increased smoothly. Thus the threshold value of $n$ was 6 in low and high $Den$. Hence, $n$ was set to 6 for $CEM$ and $BT$. 

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4.3. Coverage of Emergence Messages

*CEM* was the main performance metric in our simulation. Once *CEM* was low, it means that more cars could not receive the emergency messages. Here, *n* was set to 6, *MS* was set to 40-50, and *R* was set to 600. *CEM* was evaluated under EMBM, CBS, and BPAB in non-crossroads and crossroads, as shown in Figure 18.

![Graph showing CEM coverage for different R values](image)

**Figure 17. BS in EMBM for different R**
Table 2. EMBM in BS for different n

<table>
<thead>
<tr>
<th></th>
<th>Value of n</th>
<th></th>
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<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>DS = 10 (Low)</td>
<td>8.45</td>
<td>7.99</td>
<td>7.56</td>
<td>6.21</td>
<td>4.86</td>
</tr>
<tr>
<td>DS = 40 (High)</td>
<td>14.22</td>
<td>15.24</td>
<td>15.86</td>
<td>16.09</td>
<td>16.24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Value of n</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>DS = 10 (Low)</td>
<td>15.07</td>
<td>13.89</td>
<td>12.67</td>
<td>10.25</td>
<td>7.58</td>
</tr>
<tr>
<td>DS = 40 (High)</td>
<td>28.84</td>
<td>29.73</td>
<td>31.97</td>
<td>32.65</td>
<td>33.06</td>
</tr>
</tbody>
</table>

In Figure 18(a), CEM in EMBM and BPAB were all 100% but CEM in CBS was below 100%. It showed that CEM in EMBM and BPAB were higher than that in CBS while Den was less than 20. While Den was larger than 20, EMBM, CBS, and BPAB were almost the same. Thus EMBM and BPAB could be worked in non-crossroads. However, CBS only could be applied in high Den of the non-crossroads.

In Figure 18(b), CEM in EMBM was higher 64.3% and 48.9% than those in CBS and BPAB, respectively, in low Den, such as 10. In high Den, such as 40, EMBM was higher 46.6% and 44.9% than those in CBS and BPAB, respectively. Hence, EMBM may be more suitable than CBS and BPAB for CEM in low Den.

It showed that CEM in CBS and BPAB decreased rapidly in the crossroads since CEM in CBS and BPAB were all below 60%. However, CEM in EMBM was converged to 100% in the crossroads. Figure 18 proved that CBS and BPAB addressed nothing for broadcasting emergency messages in the crossroads. CBS BPAB could not work for broadcasting emergency messages in the crossroads.

4.4. Broadcasting Time

In the broadcasting algorithms, BT was another important performance metric especially for broadcasting emergency messages. If BT was high, the cars still may not avoid the traffic accident even through the cars received the emergency messages. In this simulation, n and R were set to 6 and 600, respectively. BT was evaluated under EMBM, CBS, and BPAB for different MS, as shown in Figure 19.

While MS was set to 20-30, BT in EMBM was lower 80% and 19% than those in CBS and BPAB in low Den, such as 10. In high Den, such as 40, BT in EMBM was lower 66% and 33% than those in CBS and BPAB. While MS was set to 40-50, BT in EMBM was lower 78% and 35% than those in CBS and BPAB in low Den, such as 10. In high Den, such as 40, BT in EMBM was lower 64% and 36% than those in CBS and BPAB. While MS was set to 60-70, BT in EMBM was lower 77% and 42% than those in CBS and BPAB in low Den, such as 10. In high Den, such as 40, BT in EMBM was lower 62% and 40% than those in CBS and BPAB.
It showed that EMBM needed less time to broadcast emergency messages than CBS and BPAB for different MS. BT in EMBM, CBS, and BPAB all increased while MS increased. However, BT in EMBM could be converged to a fixed value while Den was larger than 20 in different MS. It presented that EMBM was more suitable than CBS and BPAB in high Den for BT.

5. Conclusions

Vehicular ad hoc networks, VANET, was a special kind of mobile ad hoc networks, MANET. Since the moving speed of host was faster and the topology was limited by the road, the existing protocols and algorithms in MANET cannot be applied for VANET. Hence, many protocols and algorithms were proposed for VANET.

VANET was often used in intelligent transportation system, ITS, since the cars could communicate to each other without RSU. In ITS, cooperative collision avoidance (CCA) was the important application for prevent the traffic accidents. To address issue, many broadcasting algorithms in VAMET were proposed. However, most of them focused on addressing the broadcast storm and hidden terminal problems. None of them addressed for the multiple forwarder in the crossroads. In fact, the crossroads often existed in the urban city.
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Figure 19. $BT$ under EMBM, CBS, and BPAB
In the existing messages broadcasting algorithms, only one forwarder was selected to broadcast the message. Once an emergency message met a road intersection, it only could select one direction of the road intersection to forward the emergency message. The cars in other directions of road intersection cannot receive emergency message. In fact, the emergency messages could not be lost in the crossroads. To address this issue, we proposed an emergency messages broadcasting by multi-forwarder, EMBM, in this paper. In EMBM, the multiple forwarders existed in the crossroads. Only one forwarder existed in a direction of the crossroads. To reduce the broadcasting time, EMBM involved a novel broadcasting area segment and a new waiting time methods.

The simulation results demonstrated that the coverage of emergence messages (CEM) in EMBM was higher than those in CBS and BPAB. In the crossroads, CEM in EMBM was over 90%. However, CEM in CBS and BPAB was below 60% in the crossroads. It proved that EMBM was more suitable than CBS and BPAB for CEM. For the broadcasting time (BT), EMBM needed less BT than CBS and BPAB. It proved that EMBM could have higher CEM with lower BT for broadcasting emergency messages even through in different moving speed of car, density of cars, and broadcasting radius.

In EMBM, the optimal value of $n$ was based on the different environments. Thus how to propose an efficient method to determine the optimal $n$ in different environments was the future work. In addition, the quality of service (QoS) of the emergency messages may be integrated into EMBM in the future.

References


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