International Journal of Applied Science and Engineering
2017. 14, 3: 101-119

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

Chiu-Ching Tuan[a], Yi-Chao Wu[b*], and Chi-Fu Hung[a]

[a]*Department of Electronic Engineering, National Taipei University of Technology, Taipei, Taiwan*
[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 EMDM 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

*Corresponding author; e-mail: alanwu@mail.chihlee.edu.tw
doi: 10.6703/IJASE.2017.14(3).101

Received 13 October 2015
Revised 7 August 2016
Accepted 15 September 2016

broadcasting mechanisms focused on reduce 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 passes 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.

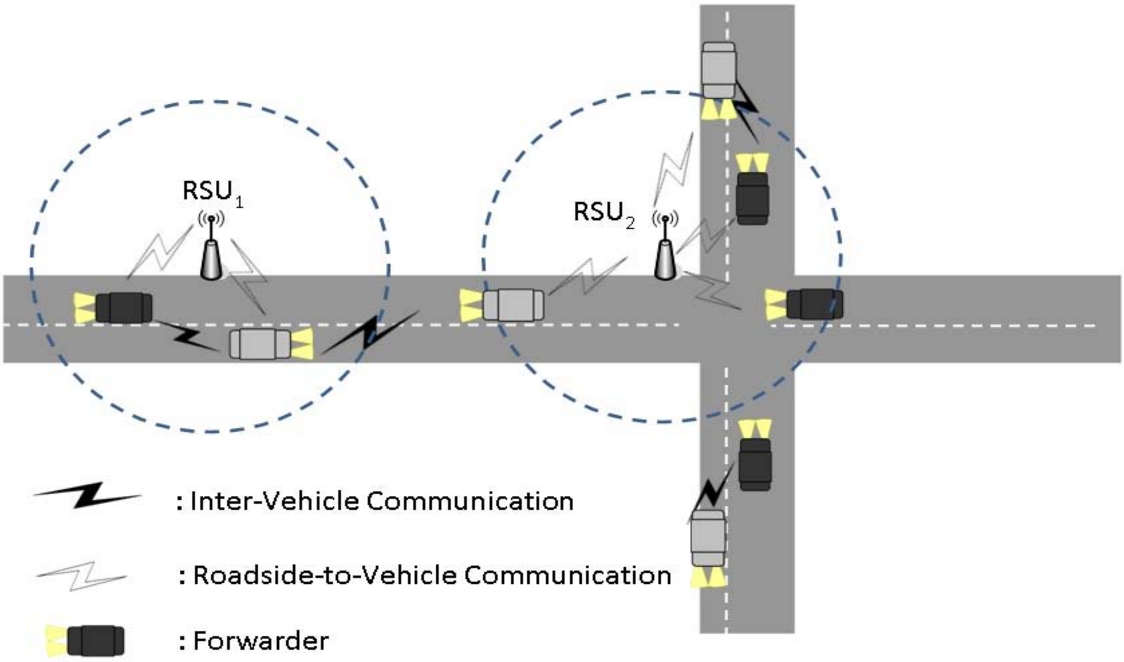


Figure 1. Communication in VANET [6-8]

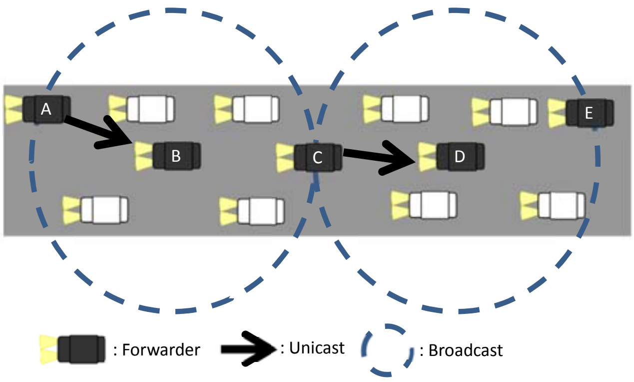


Figure 2. Unicast-Broadcast [16]

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 *sw* 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 cast, 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 $(rand+1)\times s$. The *s* was defined as the number of the last cell and *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.

$$cl \le \frac{\sqrt{R^2 - sw^2}}{3} \quad (1)$$

$$WT = (rand+1)\times s \quad (2)$$

$$WT = rand \times s \quad (3)$$

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 $(rand\times s+1)-(rand\times s)=1$ 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.

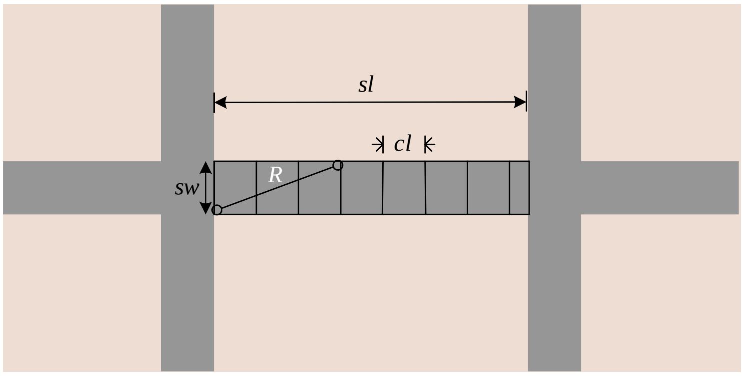


Figure 3. Cell in CBS [17]

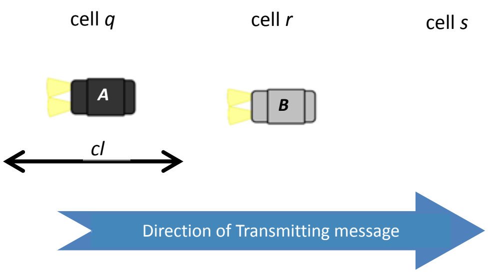


Figure 4. WT of CBS in Case 1

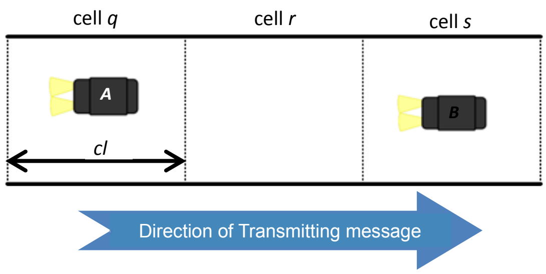


Figure 5. WT of CBS in Case 2

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. 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.

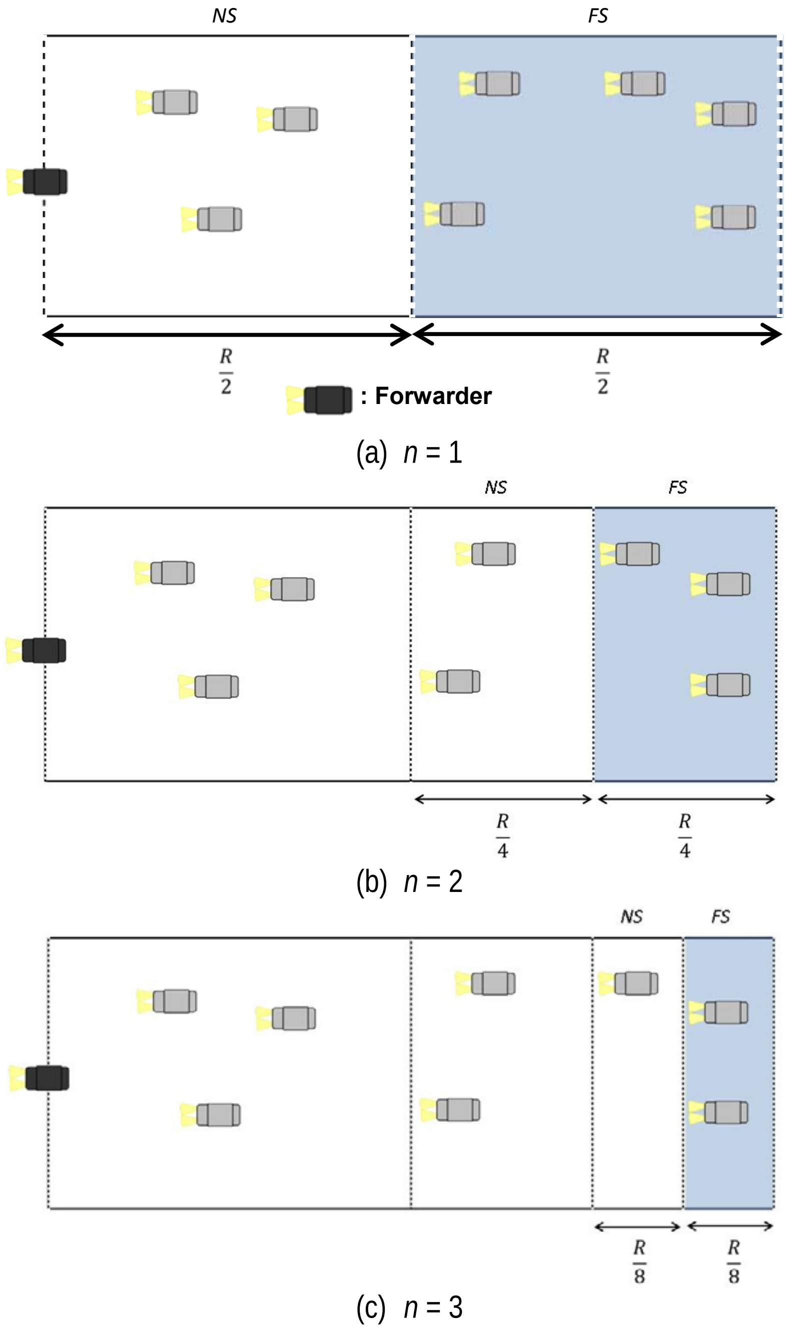


Figure 6. Example in BPAB while a car existed in *NS* receives a black-burst (High density of cars)

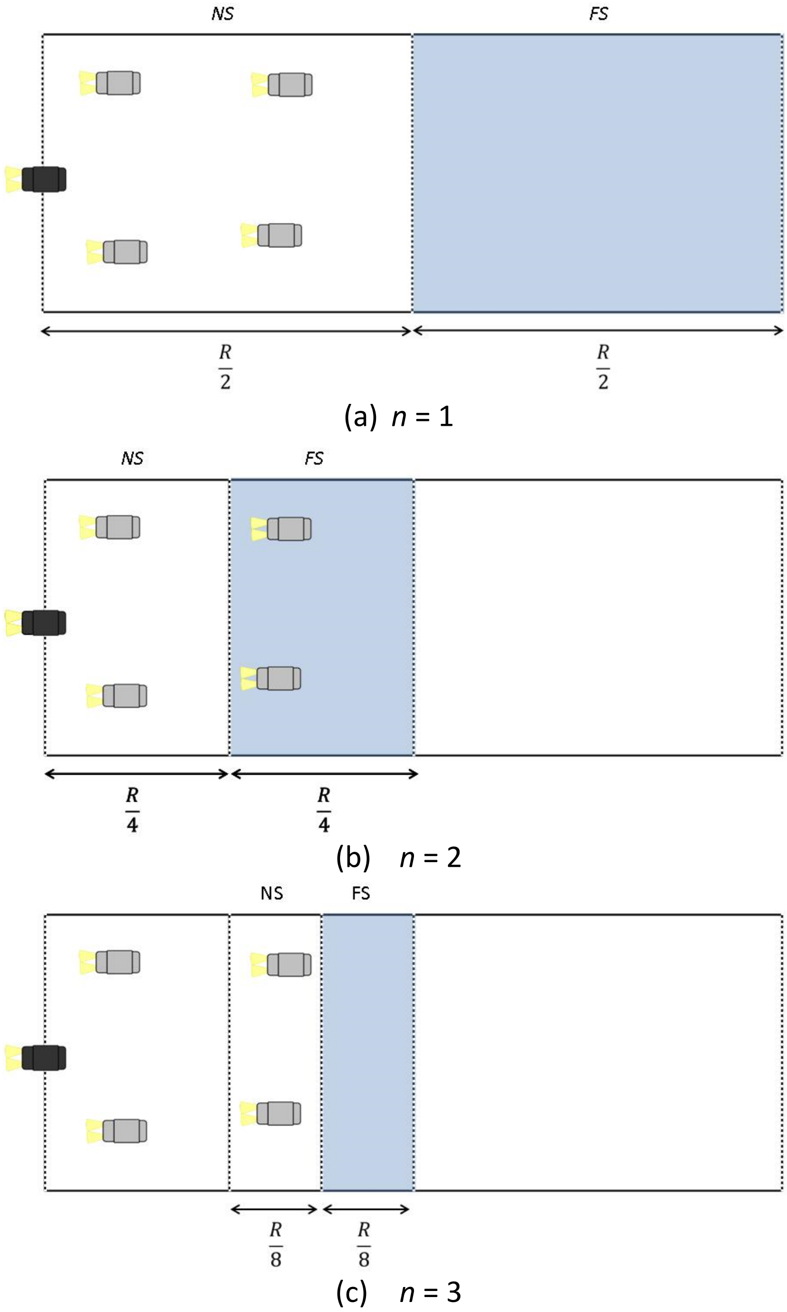


Figure 7. Example in BPAB while a car existed in *NS* receives nothing (Low density of cars)

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.

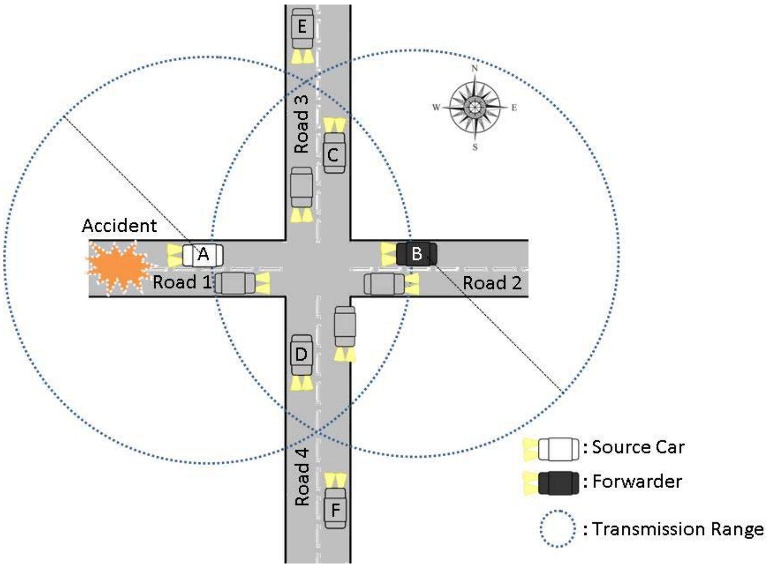


Figure 8. Example in CBS and BPAB while a car passes a crossroads

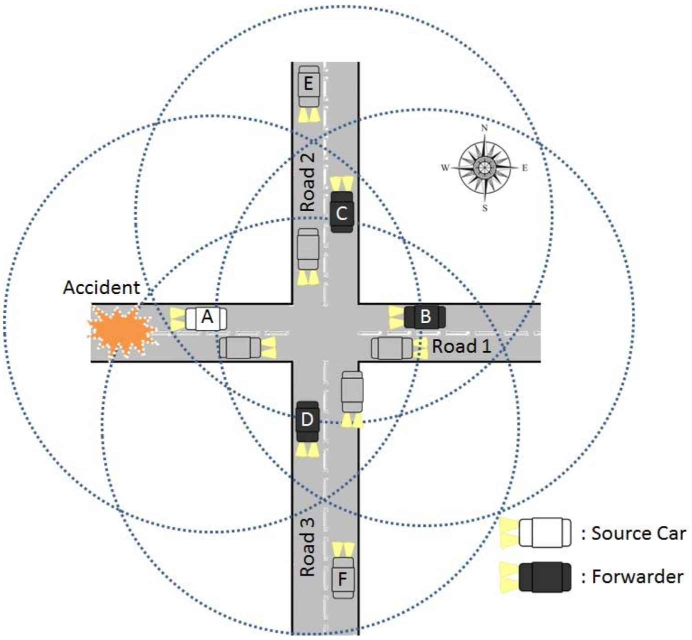


Figure 9. Multiple forwarders in EMBM

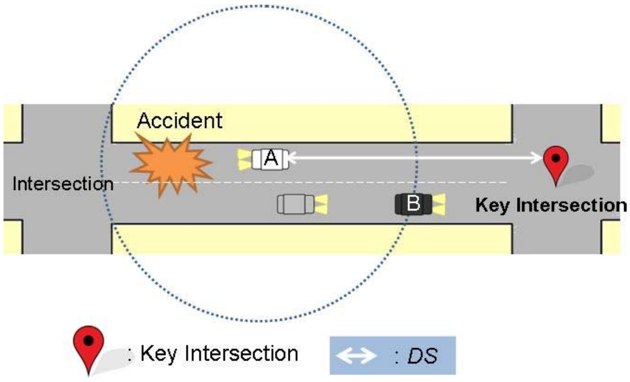


Figure 10. Definition of key intersection without the crossroads

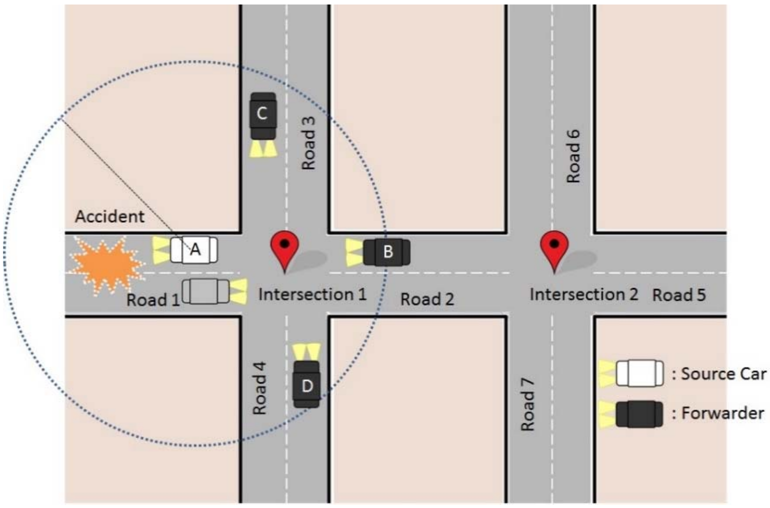


Figure 11. Definition of key intersection with the crossroads

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.

$$S_i = \begin{cases} \left\lceil \frac{(DS - DC_i) \times n}{R} \right\rceil, & \text{if the moving direction was cocurrent} \\ \left\lceil \frac{(DS + DC_i) \times n}{R} \right\rceil, & \text{if the moving direction was opposite} \end{cases} \quad (4)$$

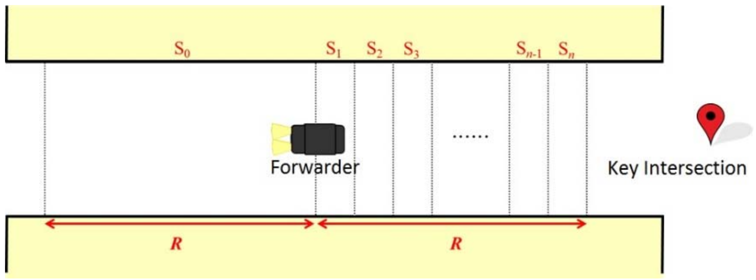


Figure 12. Segment in EMBM

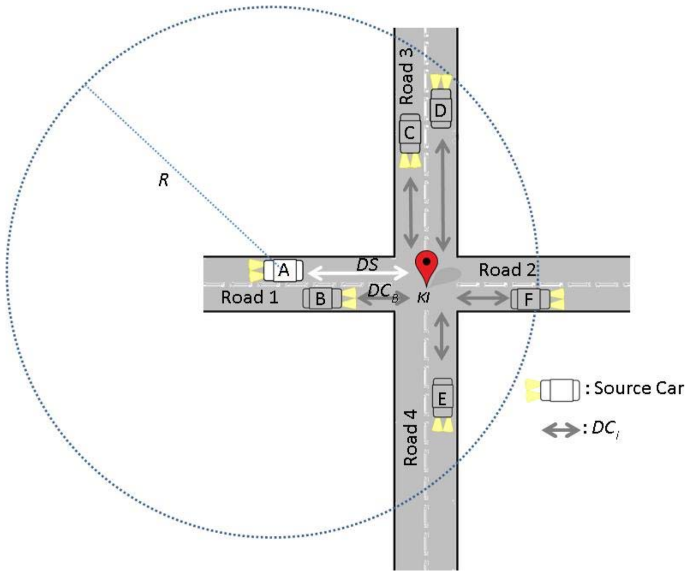


Figure 13. Distance of candidate

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.

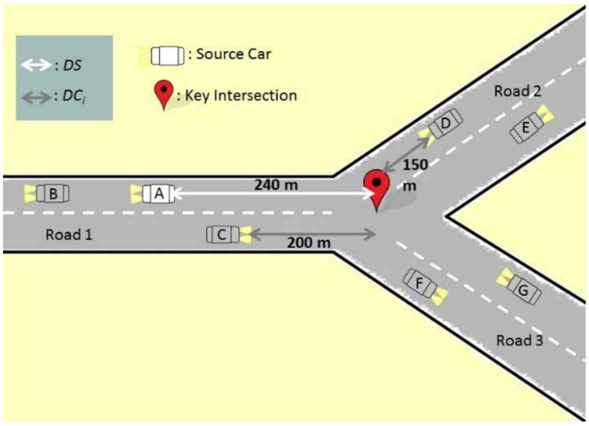
3.3 Waiting Time

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

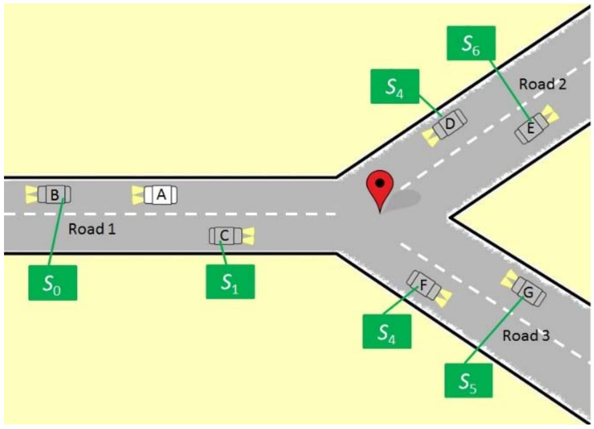
S_{i+1}received nothing after WT_{i+1}. Once car i received nothing after m slot time, WT_i was calculated as (6).

$$WT_i = n - i + 1 + RT_i \tag{5}$$

$$WT_i = WT_i - m \tag{6}$$

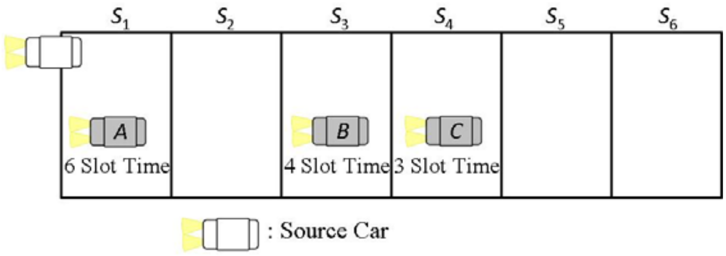


(a) Before broadcasting region segment

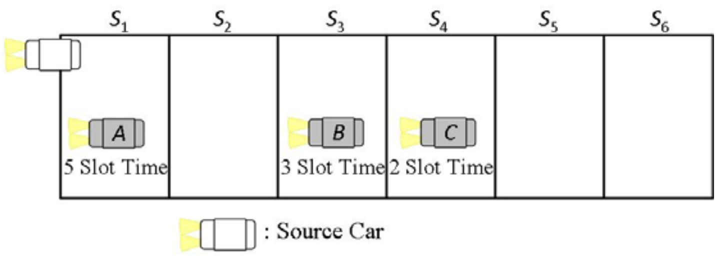


(b) After broadcasting region segment

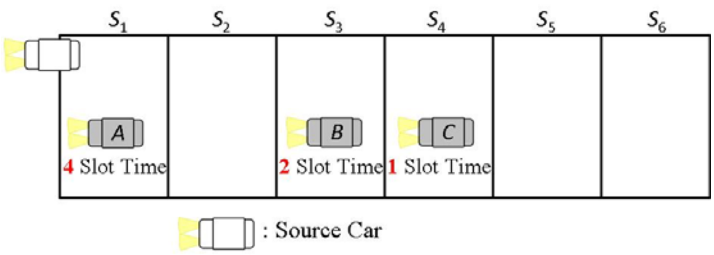
Figure 14. Segment Calculation in EMBM



(a) Initial *WT*



(b) *WT* without reducing after one slot time



(c) *WT* with reducing after one slot time

Figure 15. Example of waiting time in EMBM

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_4 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_4 decreased from 3 slot time to 2 slot time. The flow chart of EMBM was shown in Figure 16.

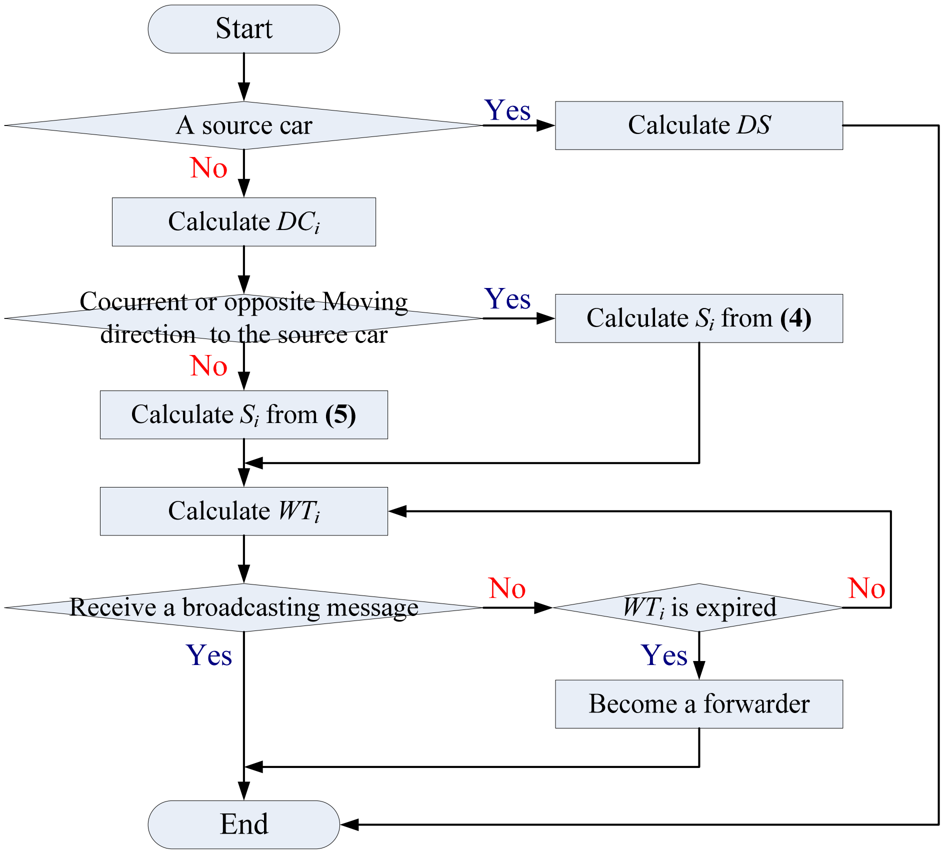


Figure 16. Flow Chart of EMBM

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

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

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.

$$BS = \sum_{i=1}^{k} \frac{D_i}{T_i} \tag{7}$$

$$CEM = \sum_{i=1}^{k} \frac{N_i^r}{N_i} \tag{8}$$

$$BT = \frac{\sum_{i=1}^{k} T_i}{k} \tag{9}$$

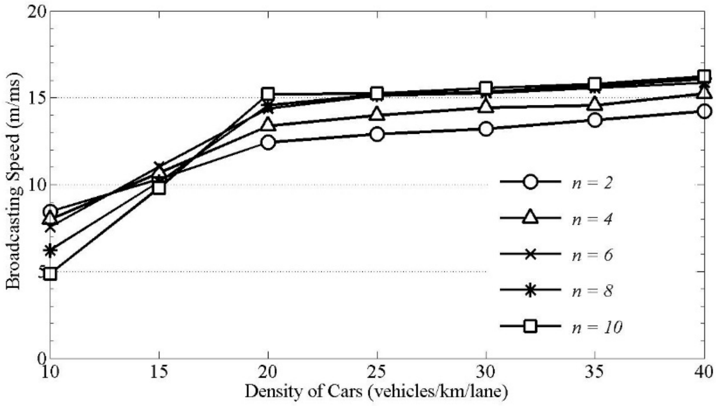
4.2 Broadcasting Speed

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*.

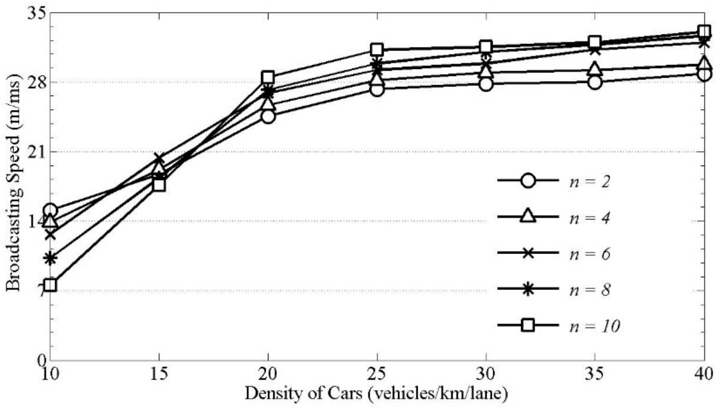
In Table 2(a)-(c), *BS* decreased while *n* increased in low *Den*. However, *BS* increased while *n* increased in high *Den*. We could find that *BS* decreased rapidly while *n* was larger than 6 in low *Den*. While *n* was larger than 6 in high *Den*, *BS* increased smoothly. Thus the threshold value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

4.3. Coverage of Emergence Messages

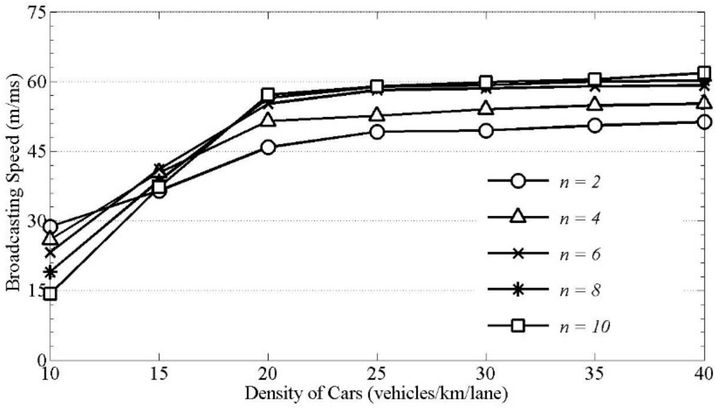
CEM was the main performance metric in our simulation. Once *CEM* was low, it means that more cars could not receive the emergency messages. Here, *n* was set to 6, *MS* was set to 40-50, and *R* was set to 600. *CEM* was evaluated under EMBM, CBS, and BPAB in non-crossroads and crossroads, as shown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



(a) *R* = 300 m



(b) *R* = 600 m



(c) *R* = 900 m

Figure 17. BS in EMBM for different R\

Table 2. EMBM in BS for different n

(a) $R = 300$

	Value of *n*				
	2	4	6	8	10
DS = 10 (Low)	8.45	7.99	7.56	6.21	4.86
DS = 40 (High)	14.22	15.24	15.86	16.09	16.24

(b) $R = 600$

	Value of *n*				
	2	4	6	8	10
DS = 10 (Low)	15.07	13.89	12.67	10.25	7.58
DS = 40 (High)	28.84	29.73	31.97	32.65	33.06

(c) $R = 900$

	Value of *n*				
	2	4	6	8	10
DS = 10 (Low)	28.73	25.89	23.19	18.92	14.25
DS = 40 (High)	51.28	55.22	59.14	60.21	61.85

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 than20. 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.

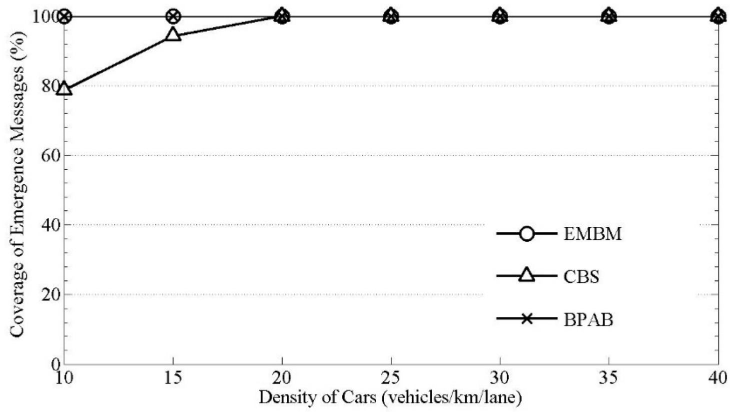
In Figure 18(b), *CEM* in EMBM was higher 64.3% and 48.9% than *those* in CBS and BPAB, respectively, in low *Den*, such as 10. In high *Den*, such as 40, EMBM was higher 46.6% and 44.9% than *those* in CBS and BPAB, respectively. Hence, EMBM may be more suitable than CBS and BPAB for *CEM* in low *Den*.

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.

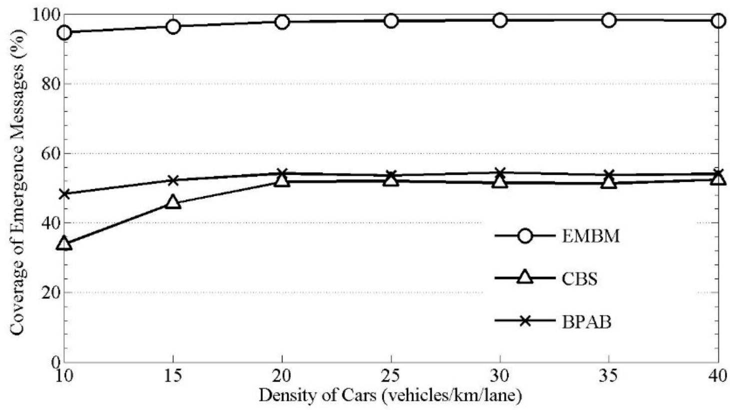
4.4. Broadcasting Time

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.



(a) Non-Crossroads



(b) Crossroads

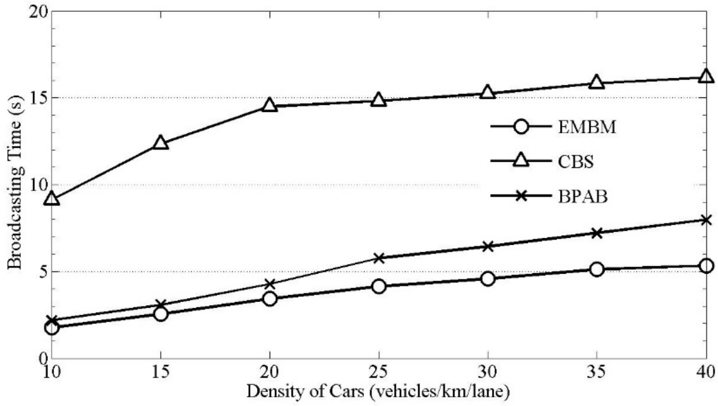
Figure 18. CEM under EMBM, CBS, and BPAB

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*.

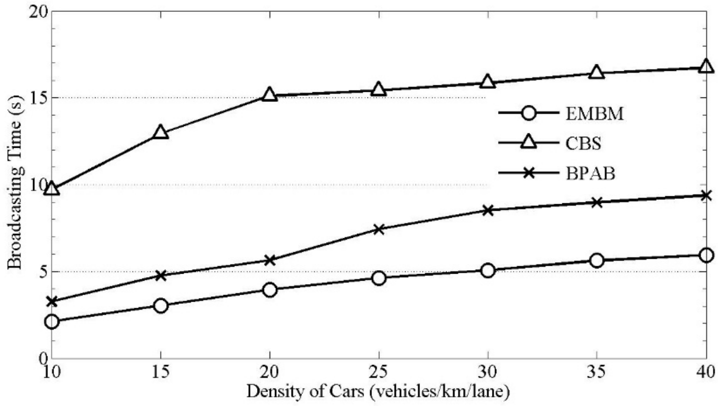
5. Conclusions

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.

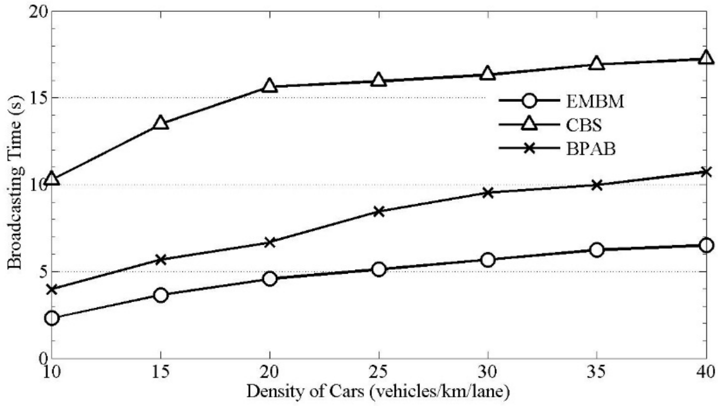
VANET was often used in intelligent transportation system, ITS, since the cars could communicate to each other without RSU. In ITS, cooperative collision avoidance (CCA) was the important application for prevent the traffic accidents. To address issue, many broadcasting algorithms in VAMET were proposed. 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.



(a) *MS* = 20-30 km/hr



(b) *MS* = 40-50 km/hr



(c) *MS* = 60-70 km/hr

Figure 19. *BT* under EMBM, CBS, and BPAB

In the existing messages broadcasting algorithms, only one forwarder was secelted 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

[1] Samara, G., Al-Salihy, W. A. H., and Sures, R. 2010. Security Issues and Challenges of Vehicular Ad Hoc Networks (VANET). In *Proceedings of IEEE International Conference on New Trends in Information Science and Service Science*, Gyeongju, Korea, May 11-13, 2010: 393-398.

[2] Kosch, T., Adler, C. J., Eichler, S., Schroth, C., and Strassberger, M. 2006. The Scalability Problem of Vehicular Ad Hoc Networks and How to Solve It. *IEEE Wireless Communications*, 13, 5: 22-28. doi**:** 10.1109/WC-M.2006.250354

[3] Tayal, S. and Tripathy, M. R. 2012. VANET-Challenges in Selection of Vehicular Mobility model. In *Proceedings of IEEE International Conference on the Advanced Computing and Communication Technologies*, Rohtak, Haryana, India, January 7-8, 2012: 231-235. doi: 10.1109/ACCT.2012.119

[4] Chaurasia, B. K., Tomar, R. S., Verma, S., and Tomar, G. S. 2012. Suitability of MANET Routing Protocols for Vehicular Ad hoc Networks. In *Proceedings of IEEE International Conference on Communication Systems and Network Technologies*. Rajkot, Gujrat, India, May 11-13, 2012: 334-338. doi: 10.1109/CSNT.2012.78

[5] Ding, B., Chen, Z., Wang, Y., and Yu, H. 2011. An Improved AODV Routing Protocol for VANETs. In *Proceedings of IEEE International Conference on Wireless Communications and Signal Processing*. Nanjing, China, November 9-11, 2011: 1-5. doi: 10.1109/WCSP.2011. 6096736.

[6] Jiang, D. and Delgrossi, L. 2008. IEEE 802.11p: Towards an International Standard for Wireless Access in Vehicular Environments. In *Proceedings of IEEE International Conference on Vehicular Technology*. Calgary, Canada, September 21-24, 2008: 2036-2040. doi: 10.1109/VETECS.2008.458.

[7] Sujitha, T. and Devi, S. P. 2014. Intelligent Transportation System for Vehicular Ad-Hoc Networks. *International Journal of Emerging Technology and Advanced Engineering*. 4, 3: 56-60.
[8] Prakash, A. and Tripathi, R. 2008. Vehicular Ad Hoc Networks toward Intelligent Transport Systems. In *Proceedings of TENCON* 2008-2008 IEEE region 10 Conference, Hyderabad, Indai, November 19-21, 2008: 1-6. doi: 10.1109/TENCON.2008.4766817
[9] Offor, P. I. 2013. Vehicle Ad Hoc Network (VANET): Safety Benefits and Security Challenges. *Social Science Research Network* (*SRRN*). Available from: https://ssrn.com/abstract=2206077. doi: 10.2139/ssrn.2206077.
[10] Kenney, J. B. 2011. Dedicated Short-Range Communications (DSRC) Standards in the United States. *IEEE Proceedings*. 99, 7: 1162-1182. doi: 10.1109/JPROC.2011.2132790
[11] Topkis, D. M. 1989. All-to-All Broadcast by Flooding in Communications Networks. *IEEE Transactions on Computers*. 38, 9: 1330-1333. doi: 10.1109/12.29474
[12] Ni, S.-Y., Tseng, T.-C., Chen, Y.-S., and Sheu, J.-P. 2002. The Broadcast Storm Problem in a Mobile Ad Hoc Network. *Wireless Networks*. 8, 2-3: 153-167.
[13] Ware, C., Wysocki, T., and Chicharo, J. 2001. Hidden Terminal Jamming Problems in IEEE 802.11 Mobile Ad Hoc Networks. In *Proceedings of IEEE International Conference on Communication*, Helsinki, Finland, June 11-14, 2001: 261-265. doi: 10.1109/ICC.2001.936314
[14] Perkins, C. E. 2008. "*Ad Hoc Networking*". Addison-Wesley. Boston. U.S.A.
[15] Sivakumar, D., Suseela, B., and Varadharajan, R. 2012. A Survey of Routing Algorithms for MANET. In *Proceedings of IEEE International Conference on Advances in Engineering, Science and Management*, Tamil Nadu, India, March 30-31: 625-640.
[16] Doukha, Z. and Moussaoui, S. 2011. Dissemination of an Emergency Message in a Vehicular Ad Hoc Network. In *Proceedings of IEEE International Conference on Communications, Computing and Control Applications*, Hammamet, Tunisia, March 3-5:1-6. doi: 10.1109/CCCA.2011.6031228
[17] Ho, A. H., Ho, Y. H., Hua, K. A., and Villafane, R. 2009. A Near-Optimal Broadcast Technique for Vehicular Networks. In *Proceedings of IEEE International Symposium on Wireless Telecommunications*, Prague, Czech Republic, April 22-24: 1-8. doi: 10.1109/WTS.2009.5068998.
[18] Sahoo, J., Wu, E. H.-K., Sahu, P. K. and Gerla, M. 2011. Binary-Partition-Assisted MAC-Layer Broadcast for Emergency Message Dissemination in VANETs. *IEEE Transactions on Intelligent Transportation Systems*. 12, 3: 757-770. doi: 10.1109/TITS.2011.2159003.
[19] Tseng, Y.-T., Jan, R.-H., Chen, C., Wang, C.-F., and Li, H.-H. 2010. A Vehicle-Density-Based Forwarding Scheme for Emergency Message Broadcasts in VANETs. In *Proceedings of IEEE International Conference on Mobile Ad-Hoc and Sensor Systems*. San Francisco, CA, USA, November 8-12: 703-708. doi: 10.1109/MASS.2010.5663803.
[20] Zhuo, X., Hua, S., Miao, L., M., and Dai, Y. 2011. Direction Matters: A Decentralized Direction-Based TDMA Scheduling Strategy for VANET. In *Proceedings of IEEE International Conference on Communication Technology*, Jinan, China, September 25-28: 566-571. doi: 10.1109/ICCT.2011.6157940.
[21] Barradi, M., Hafid, A. S., and Aljahdali, S. 2012. Highway Multihop Broadcast Protocols for Vehicular Networks. In *Proceedings of IEEE International Conference on Communications*. Ottawa, Canada, June 10-15: 5296-5300. doi: 10.1109/ICC.2012.6364493.