Speed Adaptive Beacon Broadcast for Information Dissemination in Vehicular Ad hoc Networks

Sandeep Kad, Vijay Kumar Banga

Abstract: Vehicular Ad hoc Network has been a key component of the Intelligent Transport System. An efficient mechanism for dissemination of information in VANETs is a challenging task. The high mobility of vehicular nodes and varying traffic flows makes selection of best relay vehicle to disseminate information a taxing task. Periodic beaconing for gathering information about the vehicles in the vicinity is though commonly employed in VANETs, but it degrades the performance resulting in channel contention and collisions. This paper presents a Speed Adaptive Beacon Broadcast approach that controls the beaconing rate depending upon the speed at which the vehicle is moving in comparison to the other vehicles in its locality. The selection of the relay vehicle is done keeping in consideration its distance from the source, local density and priority is given to the vehicle which is at the intersection. The approach is evaluated for both highway and urban scenario and simulation outcome reveals that SABB performs well in comparison to some of the existing approaches.

***Index Terms*: Beaconing, Broadcast Storm, Information Dissemination Intelligent Transport System (ITS), Traffic Density, Vehicular Ad hoc Network**

I. INTRODUCTION

Rise in the number of vehicles on the roads is no doubt a symbol of prosperous society, but it has also raised the risk to human life. Even in the presence of strict traffic norms in majority of the nations, the number of road accidents are on the rise. According to a report published by the World Health Organization in the year 2018 [1], there were more than 1.35 million fatalities across the globe due to road accidents and a large number of these accidents were due to human negligence. Prominent automobile manufactures have been involved in developing vehicles with applications which few years back were only in dreams. A driverless car connected with cloud based services [2], efficiently deciding the vehicle's journey in real time, avoiding traffic congestion, minimizing the fuel consumption and air pollution are almost in their final stages. Inter-Vehicular Communication (IVC) can be thought of as a most valuable concepts in ITS with an aim to improve an overall experience of the drivers and travelers. IVC offers a wide range of applications that not only includes safety which helps in avoiding vehicle crashes involving collisions, blind crossings and lane changing [3], but also provide assistance to manage and utilize the road infrastructure and users the comfort on entertainment aspects like information, guidance and internet access services [4]. Safety applications being the primary concern in VANETs, should be addressed efficiently where the driver can be alerted well in advance about the potential danger so that a timely action can be taken and the life risk can be avoided. Studies reveal that a warning message received 0.5s earlier could avoid 60% mishaps [5]. However, due to the limited practical infrastructure, vehicular ad hoc networks operate in challenging communication environment [6]. Researcher from academia and industry have been contributing aggressively, IEEE 802.11p and 1609 standards have been developed to support communication between the vehicles and with infrastructure as well. Vehicle Ad hoc Networks enables the vehicles and the vehicle related infrastructure to exchange data within a range of 1000 m. It is a self-organized networking environment that more or less works on similar lines as MANETs. VANETs can be categorized into Vehicle to Vehicle, Vehicle to Infrastructure, Vehicle to Sensor and Vehicle to Internet networks [7]. On the practical aspects, VANET possesses high mobility, rapid changes in the network topology, frequent disconnections and variation in the network scale like an extremely dense or sparse environment. These characteristics poses a challenging task of disseminating the information in VANETs. In safety related applications, many times the information about the occurrence of event is to be broadcasted to all those vehicles which will be impacted as they will be approaching the affected area if not immediately, but after some time. Broadcasting in the dense environment, if done blindly will result in channel contention and collisions during transmission. Many of the existing approaches need to know about its 1-hop neighbors to gather information about the local topology. Vehicles broadcast beacons periodically resulting in increasing the load on communication channel, collisions and congestion.

In this paper, we propose a Speed based Adaptive Beacon Broadcast (SABB) approach for data dissemination that efficiently delivers data in both the dense and sparse environments.

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This approach is capable of delivering data in the concerned region to the maximum available vehicles with minimum delay in delivery, ensuring mitigation of broadcast storm problem. This approach also aims to address hidden node problems and frequent disconnections which usually occurs in sparse environment.

The contribution in this paper includes- firstly controlling the frequency of beacon messages depending upon the speed at which the vehicle is moving. Secondly, the forwarding relay node is selected keeping in view not only the distance of the potential relay vehicles from the source vehicle, but also the density of vehicles in its local vicinity. The relay vehicle positioned at the intersection/junction is preferably selected so that the information can be disseminated in all the possible directions thus covering a large of number of vehicles with a minimum number of rebroadcasts. Finally, we have simulated the SABB approach and evaluation is done using metrics such as, message delivery ratio, delay, number of transmissions and number of collisions.

The remainder of the paper includes related work in section II with problem identification, followed by assumptions and description of the proposed approach in section III. In section IV, the SABB approach is evaluated in comparison to some state of the art existing approaches on the basis of metrics mentioned above. The final section concludes the paper mentioning future directions for the work proposed.

II. RELATED WORK

With the rise in the number of vehicles, improving the driver's safety and the traffic efficiency has been the prime motive of the researchers in VANETs. The timely dissemination of information under the varying traffic condition is a challenging task. In dense traffic scenarios, broadcast alleviation strategies have been presented to minimize the broadcast storm problem. Flooding based approaches have been commonly used where all the recipient vehicular nodes further disseminates the message. Pure flooding approaches generally leads to a huge number of packet collisions. At the same time, in sparse situations, in the absence of the required number of neighbors the data dissemination becomes difficult. Many solutions have been presented to address information delivery in the varying traffic environment. BROADCOMM [8] approach divides the highway into virtual cells and uses a hierarchical structure comprising two levels. All the vehicular nodes are assumed to be in one cell and these vehicles can communicate to one another and to the neighboring cell nodes in its transmission range. At the next hierarchical level, the vehicle nodes preferably at the geographical center of the cell are referred to as Cell Reflectors (CR) and are similar to cluster heads. This approach is suitable for highway scenarios only and lacks in addressing network partition issues. Reference [9] presented the variants of distance based broadcast suppression techniques – Weighted-p-persistence, Slotted-1-persistence and Slotted-p-persistence where vehicular nodes calculates the rebroadcasting probability using local information. In weighted-p-persistence when a vehicular node receives a packet it verifies if the vehicular node has been the recipient of this packet in the past. If, it is so, it neglects the packet. The rebroadcasting probability of vehicular node is evaluated based upon far the sender is from the recipient. In slotted-1-persistence, the message is rebroadcasted with the probability-1in its time slot, if the same packet is not received in the past whereas, in slotted-p-persistence, the packet is rebroadcasted with predetermined probability p in its time slot if the same packet is not received in the past. Distributed Vehicular Broadcast (DV-CAST) [10] mitigate the broadcast storm and temporal disconnection issues. In this approach the vehicle gathers information about its one hop neighbors by means of periodic beacons. The approach applies broadcast suppression algorithm while disseminating data in well-connected scenarios whereas in the sparse environment, store-carry-forward approach is applied to address network partition. UVCast [11] approach addresses both the broadcast storm issue and network partition using local information available to vehicles in the urban vehicular environment. To disseminate information in multiple directions this approach assigns lower rebroadcast waiting delay to the node positioned at the intersection. It performs in well-connected as well as disconnected environment without the support of any infrastructure.

Adaptive Multidirectional Data dissemination (AMD) [12] approach combines the timeslots keeping in consideration the directional sectors for both highway and urban environment. This approach disseminates the message in multiple directions as per the local road map. Distributed Optimized Timeslot [13] scheme alleviates the broadcast storm problem where suppression is done separately for each broadcast direction. In DRIVE [14] approach information dissemination is done in the area of interest with the aim to avoid the broadcast storm problem and at the same time address network partition issues in sparse scenarios. Reference [15] proposed information dissemination approach with the aim to route the packets quickly to the destination. Different routing paths from the source to destination are assigned weights based upon which packets are forwarded. This approach mitigates broadcast storm and deals efficiently with link failures. Traffic Adaptive data Dissemination (TrAD) [16] takes the road traffic into account while disseminating information. Broadcast suppression mechanism is applied in case of well-connected networks whereas in the case of sparse or disconnected environment store-carry-forwarding approach is used. Rebroadcasting priority for different directional clusters is evaluated keeping in consideration both road traffic and traffic of the network. Speed Adaptive Broadcast [17] is a beacon free approach for delivery of information in multi-hop vehicular environment that estimates vehicle density on the basis of vehicular speed. It has three variants of SAB – Probabilistic-SAB, Slotted-SAB and Grid-SAB. S-SAB detects vehicle density on the basis of speed of vehicles. The timeslots are allocated to the vehicles for rebroadcasting on the basis of which vehicles decides whether to rebroadcast or discard the message. G-SAB avoids same time slots to be assigned to the vehicles moving in different lanes in the same direction, a dissemination delay is added to the vehicles of different lanes thus decreasing data redundancy and collision. Adaptive Data Dissemination Protocol (AddP) [18] controls periodic beaconing and lowers the number of messages in the network. This approach aims to address issues like broadcast storm, hidden node problems, frequent disconnection and ensures the delivery of information with a minimal delay. To control the beaconing frequency, it takes into consideration the local vehicle density. At the time of selecting the forwarding vehicle for information dissemination, sender considers how far the source is from the relay vehicle node and it also considers the local density of the relay vehicle node. This approach is largely dependent upon infrastructure support. Clustering and Probabilistic Broadcasting (CPB) [19] forms cluster for the vehicles moving in a particular direction. The cluster members route the message to the cluster head after calculating the probability upon counting the number of times a message is received during the same interval. An Adaptive Beacon control mechanism [20] ABOR reduces channel contention and load by avoiding fixed periodic beacons. This approach evaluates the beaconing frequency on the basis of position, direction and link availability.

Table–I shows the comparison of some broadcast based techniques.

Table 1. A qualitative comparison of related broadcast based approaches.

Approach	Objective	Forwarding Strategy	Features	Environment	Simulation	Parameters
DV-CAST	Addresses broadcast storm as well as network disconnection issues	Broadcast, position and local topology based, multi-hop, store and carry forward	Utilizes local topology information to handle rebroadcasts, disseminates data in extreme traffic situations	Highway	NS2	Broadcast success rate, Network reachability, Network overhead
UV-CAST	Addresses broadcast storm and network disconnection issues in city environment	Uses distributed gift wrapping algorithm	Multiple vehicles for store carry forward task, Intersection based suppression approach to address broadcast storm	Urban	NS2	Network reachability, Received distance, Transmission overhead and Reception overhead
AMD	To disseminate information in multiple directions, address broadcast storm and disconnected networks	Time slot based suppression mechanism for directional sectors	Multidirectional timeslot based approach to address dense scenarios, uses store carry forward mechanism for disconnected networks	Urban and Highway	OMNET++	Delivery ratio, Delay, Total number of transmissions
DRIVE	Disseminate data in the region of concern, suppress broadcast storm issue and deliver data across network partitions	Position, distance and delay/timer based, store and carry forward	Eliminates broadcast storm , network partition and fragmentation problem	Urban and Highway	OMNET++	Coverage, Delay, Number of total packets transmitted, Number of collisions
TraD	Improving reliability of broadcast transmission, mitigate broadcast storm, controlling channel congestion	Directional cluster, store and carry forward	Dissemination ordering considers distance, density and channel busy ratio	Urban and Highway	OMNET++	Packet deliver ratio, Number of transmission, delay, Data dissemination speed
SAB	Provide scalable data dissemination with no additional communication overhead	Distance/delay timer based	Beacon free approach, estimates traffic density on the basis of speed	Highway	OMNET++	Data delivery ratio, Broadcast overhead per message, Dissemination delay
AddP	Controlling congestion by reducing beacon load in high density scenario and delivering information with minimal delay	Distance and density of vehicles	Controls beaconing using vehicle's local node density, candidate selection mechanism considers distance and density	Urban and Highway	OMNET++	Delivery ratio, redundancy rate, Total number of beacons, Collision ratio, propagation distance
CPB	Addresses the issue of high latency, packet loss, frequent disconnection	Direction based clustering and probabilistic broadcasting	Cluster formed by vehicles moving in same direction for longer connectivity, link quality metric used to represent connectivity	Highway	NS2	Average transmission, delay, Information coverage, Packet delivery ratio
ABOR	Adaptive beaconing mechanism on the basis of link life rime	Based upon vehicle's position speed, direction and participation of vehicle in forwarding set	Opportunistic routing strategy with lower bandwidth requirements	Urban	NS2	Packet delivery ratio, End to end delay, Number of beacons, Routing overhead

It is observed that timely disseminating of data is a challenge in diverse vehicular environment. In urban scenario, vehicle density is high and pure flooding approach results in redundancy of information, medium contention and a high number of collisions. Altogether, it overburdens the limited available resources. The radio signals in the urban environment gets disrupted due to the presence of the high rise buildings. Sometimes due to these obstacles the communication is not feasible as the vehicles on the receiving end are not in the line of sight. As shown in fig. 1 suppose the vehicle 1 intends to broadcast an information to all the vehicle in its transmission range. All the vehicles except vehicle 5 and 6 receives the information. Both these vehicles are within the communication range of the source vehicle if we measure the Euclidian distance of these vehicles from the source in terms of the source vehicle's transmission range, but the presence of high rise buildings obstruct the radio signals and hence the radio signals which otherwise were supposed to be omni-directional just moves in a straight path. The presence of obstacles makes this problem more severe and circumvents the delivery of information to vehicle 5 and 6. The vehicular nodes broadcast small messages in the form of beacons to gather information about the vehicles present in its vicinity. This information exchange is done periodically so that the updated information about the geographical position and other parameters can be made available to the neighboring vehicles. This periodic exchange of information comes at a cost, especially in the dense scenarios where the number of vehicular nodes are high and every message exchanged, utilizes resources that are already limited, resulting in congestion, leading to contention in the medium and collisions. These updates regarding the position of vehicles is very important and if the rate of beaconing is reduced, then the novelty of the position of vehicular nodes in the vicinity is largely impacted. So there is a trade-off between the beaconing rate and the freshness of neighboring vehicle positions. On the other hand in a sparse environment i.e. when traffic movement is low like during night hours or on highways the vehicles may be scattered resulting in frequent disconnections. In such a scenario, delivery of information to all the vehicles in the region of concern is something which is difficult. The proposed approach aims to deliver data both in dense and sparse environment in VANETs.

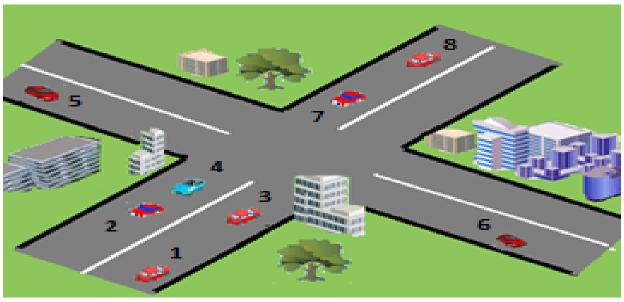


Fig 1. Typical urban environment depicting information dissemination problem

III. ASSUMPTIONS AND PROPOSED APPROACH

In this section we will figure out some of the assumptions which have been considered behind the implementation of the proposed approach and thereafter, we will present the approach. We are assuming a multilane road segment where vehicles are heading in either directions. All the vehicles are DSRC enabled, equipped with Geographical Positioning System (GPS) where vehicles can share their position with neighboring nodes in their vicinity and can evaluate the distance to its 1-hop neighbor. Vehicles are preloaded with the digital maps of streets depicting intersection/junctions. The communication range of each vehicle specifies that this vehicle can communicate with other vehicles that fall within the range except in case, where due to some obstacles the radio signals are affected. Vehicles are fitted with the sensors to detect any hazardous situation. To make communication between vehicles feasible, wireless devices equipped on vehicles needs to be associated, once this is done successfully, thereafter the exchange of information is feasible. Beacon messages are broadcasted periodically by vehicles to share their position with the neighboring vehicles in their vicinity i.e., the vehicles which are 1-hop away. The message contains fields specifying the information like, the unique vehicle *id* (usually on the basis of MAC address), the positional coordinates of the vehicle at the time of disseminating the beacon message, speed of the vehicle, the direction of movement, time to live and list of messages received. Each vehicle stores this information in its Neighbor Information Table (NIT). When the source vehicle initiates information dissemination process, it also specifies the timestamp when the message was initiated, which is used to indicate the freshness of the message. The direction of road segments are labelled as D_1, D_2, D_3 and D_4. The intersection/junction (J) is the point where multiple roads meet. Vehicle moving from D_1 towards the junction is denoted by D_1J. Upon reaching the junction, if this vehicle turns towards D_4, it is denoted by JD_4. The direction for information dissemination depends upon the position of the vehicle at the time of dissemination. Initially the information is to be disseminated in all the directions. For example as shown in fig. 2, vehicle 1 transmits the information in the direction D_1J and JD_1 whereas, if vehicle 9 disseminates, it selects JD_1, JD_2, JD_3 and JD_4 directions for information dissemination. However, if the information is to be rebroadcasted, the selected relay vehicle keeps all other directions in consideration except the direction from which it received the information. For example, if the vehicle 3 and the vehicle 9 receives a message from vehicle 1, vehicle 3 will indicate D_1J as its direction for the message dissemination whereas the vehicle 9 will indicate all the other directions except JD_1 as directions for information dissemination.

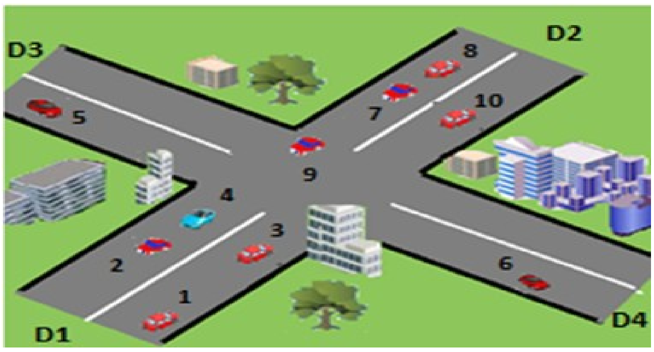


Fig. 2. Scenario depicting the SABB approach

In this paper we are proposing a Speed based Adaptive Beacon Broadcast (SABB) approach where the beacons will be controlled depending upon the flow of traffic in the region. Generally it is observed that, higher the density of traffic on the road segment, lower is the speed of vehicles in that segment and vice versa. Traffic flow's relation between speed and density is given in [21] as

$$Tra\_Flow = S * VD \tag{1}$$

Here, *Tra_Flow* denotes the flow of traffic in the particular region, S indicates the vehicle speed and VD denotes vehicle density. Speed ratio (S_R) can be evaluated on the basis of the current flow of traffic as

$$S_R = \frac{S}{S_{maxi}} \tag{2}$$

Here, S_{maxi} is the maximum speed limit on the road. When S_R approaches zero, it indicates a traffic jam situation or highly dense scenario and when S_R approaches to 1, it indicates a situation where traffic is moving freely and can be referred to as a sparse environment on a highway. A linear relation between speed and density by Greenshields in [21] as

$$S = S_{maxi} - S_{maxi} \times \frac{VD_i}{VD_{maxi}} \tag{3}$$

where VD_i denotes the current vehicular density of vehicle i and VD_{maxi} represents a state of almost traffic jam specifying permissible peak traffic capacity on the road. Eq. 3 can be simplified as

$$S_R = 1 - \frac{VD_i}{VD_{maxi}} \tag{4}$$

If, VD_i is very high, and approaches to almost VD_{maxi} then S_R becomes zero. The large number of frequent beacon messages in the dense scenario adds to the network load leading to congestion and collision resulting in delay in delivery of information. The information to be disseminated may lose its importance, if not delivered in time. In SABB beaconing frequency of a vehicle is adjusted depending upon the speed of the vehicle. Generally in the dense environment the speed of vehicles will be stable and there would not be any rapid changes in the topology i.e., the vehicles will move at a stable pace and will remain connected with its neighbors for a longer duration of time. Thus the frequent exchange of beacons will only be an overhead. As the speed of a vehicle impacts the lifetime of the link with its neighboring vehicular nodes, the vehicles moving at a higher speed will observe frequent disconnections as the relative position change with respect to its neighbors will be more. Thus for vehicles moving at high speed, beaconing interval needs to be small as the updated information about such a vehicle is required more frequently. The beaconing interval for retransmitting a beacon message by a vehicle depending on speed of vehicle can be calculated as shown in Eq. 5.

$$BI_i = \propto + \left(\left(1 - \frac{S_i}{S_{maxi}}\right) * 10\right) + \beta \tag{5}$$

Here, the beacon interval (BI_i) denotes the time between the retransmission of a beacon message by vehicle i, α represents the time which in general is there between two successive beacon transmissions by a vehicle S_i is the speed of vehicle S_{maxi} is the speed limit on the road and β is random value between 0 to 2 *ms* which is basically used to break the synchronization in order to reduce the probability of retransmission by more than one vehicle simultaneously. BI_i can be evaluated as and when there is a change in the speed of the vehicle i. It can be observed (refer to (5)) that vehicles moving at higher speed will have shorter beaconing interval i.e., they can send beacon messages more frequently whereas the vehicles with the slower movement will have larger beaconing interval hence lesser beacon messages will be transmitted in the network which results in controlling congestion and reduction in collisions. This reduced beacon load results in providing the limited available bandwidth to be utilized for delivering information that is more important and needs to be disseminated at the earliest. On the basis of the above description, we have summarized the adaptive beaconing interval in algorithm 1.

Algorithm 1 Calculating beacon interval

Input: *Vehicle's speed, maximum permissible speed on the road*
Output: *Beacon interval*
Initialize: *Every vehicle broadcast beacons to inform the vehicles about its presence in its vicinity. All the vehicles create a neighbor information table to keep track of neighboring vehicles.*
while(1) do
  for (every vehicle (i) in N) do
    evaluate the beacon interval (BI) refer to (5)
    set the timer to BI
      if (BI==0) then
        vehicle i transmits a beacon message
        vehicles in the vicinity updates NIT
      endif
  endfor
end

To disseminate the information to all the vehicles in the region of concern, we need to identify a suitable forwarding node that can act as a relay to deliver information with the minimum possible delay. This needs to be done every time when a vehicle i intends to disseminate a message in the network. In many of the existing approaches, the distance between the sender and the potential relay vehicle is the sole criteria to select the next forwarder i.e., the vehicle at the farthest distance within the communication range of sender is chosen to rebroadcast the message. In SABB approach, selection of relay node takes into consideration its distance from the sender, its local density and vehicles current location. As the vehicles are preloaded with street maps, thus the information about road segments and junctions is available with all the vehicles. The relay node at junction is given higher priority in comparison to the vehicular nodes that are away from junction. The vehicular nodes at the junction can deliver the information in multiple directions due to better line of sight for transmission of signals. Here, a due weightage is also given to the local density of probable forwarder, because higher vehicle density in the vicinity of a vehicle node will result in delivering the message to a larger number of vehicle nodes. All the possible relay nodes calculates their waiting time (*WT*) depending upon whether they are located at the junction or outside the area of junction. Fig. 3 shows the design of rotary intersection according to Indian Road Congress (IRC) [22]. As per standard specifications of IRC, entry radius is of about 20m and the exit radius is 1.5 to 2 times of the entry radius and central islands radius is about 1.3 times of that of the entry curve. Further as per IRC guidelines, the approach width is 3.5 m with a divider of width slightly higher than the approach width. Also, no building can be constructed within 30 m from the edge of the road. After taking all these factors in to consideration it is calculated that about 79 m of radius from the center of intersection point in all directions can be taken as the region where radio signals will not be obstructed because of any concrete structure. This will be same whether rotary is present or the intersection has traffic lights. For the vehicles which are falling outside this region *WT* is calculated otherwise, refer to (6b).

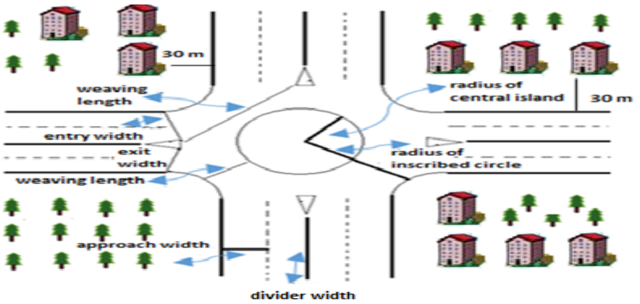


Fig. 3 Rotary intersection/junction with design elements

When a source vehicle node broadcast a message, the message is received by all the vehicles which are in its vicinity. These vehicular nodes calculate their waiting period and initiates a waiting timer refer to (6). During its waiting period if a vehicular node receives the same message again, it can suppress its rebroadcast as redundant broadcast, otherwise, it may lead to a broadcast storm problem. Every time when the message is received by a vehicle, it checks the message id to verify if it has received the message for the first time.

$$WT = \begin{cases} w\left(1-\frac{d_i}{R}\right)+\frac{w}{2}\left(1-\frac{VD_i}{VD_{max}}\right)+Rand[0,0.002] \text{ if vehicle is located at the intersection} & (6a) \\ \left(w+(1-w)\left(1-\frac{d_i}{R}\right)\right)+\frac{1}{2}\left((w)+(1-w)\left(1-\frac{VD_i}{VD_{maxi}}\right)\right)+Rand[0,0.002] \text{ otherwise} & (6b) \end{cases}$$

Here, w refers to the weightage or priority given to the parameters of waiting time, d_i denotes the distance of the vehicle i from the sender vehicle and VD_i denotes current vehicular density in the vicinity of vehicle i. A vehicle verifies the number of neighboring nodes from NIT, if the number of neighbor are not sufficient, the vehicular node initiates neighbor discovery by broadcasting a request beacon to gather neighbor information. This process is generally initiated in the sparse environment where vehicle density is low. The distance between the two vehicle is a measure as Euclidian distance and is measured as

$$d_i = \sqrt{(x_b - x_a)^2 + (y_b - y_a)^2} \quad (7)$$

where x_a and y_b are the coordinates of sender vehicle and x_b and y_b are the coordinates of vehicle i . R is the communication range of sender vehicle. It is desired that farther the distance of vehicle i from source, higher will be priority of the vehicle being selected as forwarding vehicle for rebroadcast i.e., a vehicle that is positioned at border or near to the border of communication radius is given priority. VD_{maxi} indicates maximum density of vehicles and this can be defined depending upon the scenario. A random delay of 0 to 2 *ms* is added to avoid collisions in case more than 1 vehicle are at same distance with similar vehicle density in the neighborhood. Algorithm 2 specifies the steps to calculate the waiting time for rebroadcast. To address hidden node problem, each vehicle monitors the beacon messages to check whether the beacon forwarding vehicle has received the previously disseminated messages. If the message is not in the list, it is disseminated by vehicle.

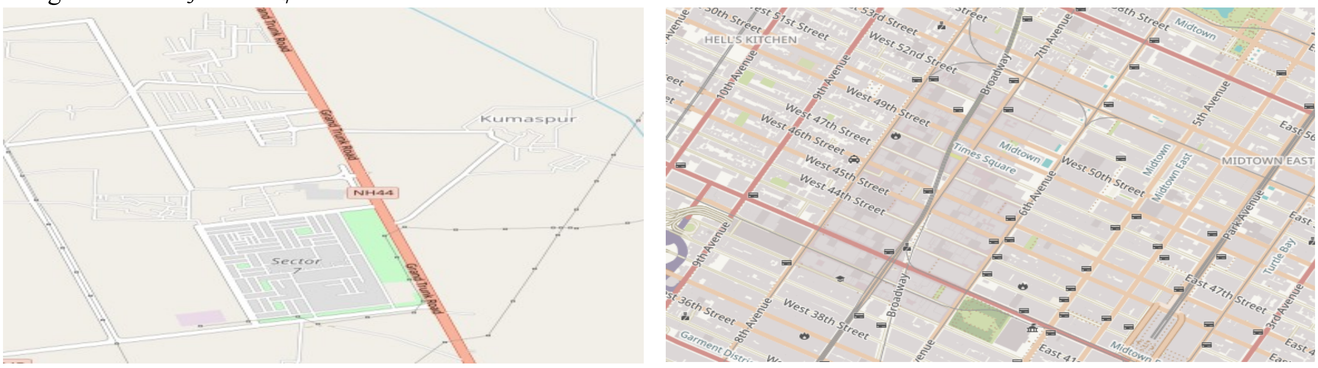
Algorithm 2 Calculating waiting time for rebroadcast

Input: *(x_a, y_a) //Positional coordinates of the sender*
(x_b, y_b) //Positional coordinates of the receiver
VD_i // density of vehicle i in vicinity
Output: *Waiting time (wt) to rebroadcast*
Start:
Compare the positional coordinates of sender and receiver of the message and calculate distance d_i, refer to (7)
Fetch the current local density from neighbor information table

if vehicle is located at intersection
calculate the waiting time refer to (6a)
else
calculate waiting time refer to (6b)
endif

set the timer based upon waiting time
if same message is received again
suppress the rebroadcast
else if(wt = =0)
rebroadcast the message
endif
End

In fig. 2, the message disseminated by vehicle 1 may not be received by 5 and vehicle 6 due to the presence of high rise buildings and other obstacles as the radio signals are obstructed. To rebroadcast the message, if selecting of farthest vehicle from the sender has been the only criteria for choosing the relay vehicle then, vehicle 8 in the scenario would have been the chosen as a relay vehicle for rebroadcast. In such a case, when vehicle 8 rebroadcasts, vehicle 5 and vehicle 6 may not have received the message as the radio signal might have been obstructed. The time taken to deliver the message to vehicle 5 would have been more as in current cycle of rebroadcast, vehicle 5 might not have been covered. However if somehow vehicle 9 at the junction would have been selected as the forwarding relay vehicle, then data dissemination outcome would have been different. It is so because vehicle 9 in present situation would have better line of sight in all the directions, hence vehicle 5 as well as vehicle 6 would have received the message. In our approach the vehicle at the junction point would be preferred as forwarding relay vehicle as it will be able to disseminate the message to both D_3 and D_4 directions in addition to other direction D_2. During the calculation of waiting time before a vehicle can rebroadcast a message, the vehicular node needs to be aware of the number of its 1-hop neighbors in its vicinity. The updated information about its 1-hop neighbors is available in the NIT. If the number of vehicles are less than the minimum number of neighbors ($neigh_{min}$), the vehicular node disseminates a control message requesting for new beacons. Upon receiving the information about the new neighbors, it updates neighbor information table. As the beacon messages includes information about list of messages already received by the vehicle, and if in case a message is not in the received message list, the relay node can rebroadcast the message.



(a) Highway scenario (b) Urban scenario

Figure 4. Simulated Environment

IV. Performance Evaluation

In this section to evaluate the performance of SABB approach, OMNET++[23], a popular mobility simulator for Vehicular Ad hoc Network, SUMO (Simulation of Urban Mobility)[24] is used. Veins framework is used to model Vehicular Ad hoc Network and is compared with state of the art previous works - DV-CAST, AMD and DRIVE in highway scenario and UV-CAST, AMD and DRIVE in urban scenario. To evaluate the performance of the SABB, we have considered two scenarios (i) Delhi-Jalandhar National Highway (NH-44) India, for highway environment shown in fig. 4(a) using open street maps. The stretch of road considered on highway scenario is of 3 km in length and has total of four lanes with two lanes in each direction. (ii) a map from Manhattan, The United States of America, using open street maps as shown in fig. 4(b) is selected for urban scenario within an area of 2 km by 2 km. On both sides of the road, the presence of skyscrapers and other concrete structures acts as obstacles to the radio signals.

We have considered 5 different vehicle flows to evaluate the proposed approach in varying densities i.e. 20, 40, 60, 80, 100 vehicles per lane per km. The traffic flow of 20 vehicles per km represents a sparse scenario whereas, a traffic flow of 80 vehicles per km and more represents dense environment. The mobility traces for both urban and highway environments are created using SUMO which support roads with multiple lanes and vehicles with varying speeds. The speed of vehicle varies depending upon the density of vehicles on the road segment using Kraus model of mobility. In the proposed approach while simulating, we have used Nakagami-m propagation model as it takes into consideration the concrete structures that acts as obstacles, thereby, giving a real impact of fading effect in the wireless channel. The simulations are done for 30 times for each scenario with different random seeds and confidence intervals of 95%. Simulation parameters used for evaluation are shown in Table II.

Table II. Simulation parameters

Frequency Band	5.9 GHz
Transmission Range	200 m(Urban), 250 m (Highway)
Transmission Power	0.98 mW(Urban) 2mW(Highway)
Data Rate	6 Mbps
Beacon Size	32 bytes
Data Message Size	2048 bytes
Propagation Model	Nakagami-m
Highway Length	3 Km
Urban Area	2 Km by 2 Km
Minimum Waiting Period (α)	150 ms
w	0.5
VD_{maxi}	50 vehicles
Simulation Time	900s
No. of Runs	30
Confidence interval	95%

A. Performance Metrics

- Message delivery ratio- It indicates the ratio of the number of message packets received to the number of message packets send. An ideal approach will have 100% packet delivery ratio.
- Number of transmissions- It refers to the total number of packet transmissions by all the vehicles. If the number of transmissions are high, it may lead to broadcast storm
- Delay- This is an important parameter in case the message is time critical,

for example, a safety related information. It indicates the average time taken to disseminate a data packet from source vehicular node to all the vehicles within the region of concern. Lower the delay better is the approach.

- Number of collisions- It indicates the number of message packets which collided during the transmission process. High number of collisions indicates broadcast storm problem.

B. Simulation Results - Highway Scenario

In this subsection, we will discuss the performance of the SABB approach in a highway scenario and compare its outcome with three other approaches – DV-CAST, AMD and DRIVE that supports the highway environment. Fig. 5 reveals the comparison of Message Delivery Ratio (MDR) of the SABB approach with other approaches. It is observed that SABB, AMD and DRIVE are able to attain a MDR of almost 100% above traffic flow of 40 vehicles/km/lane. In the SABB both distance from source as well as the local density of the probable forwarder are taken into consideration, this combination results in better delivery of information. In DV-CAST, the MDR on an average is near to 60%, DV-CAST lacks in mechanism to deal with broadcast redundancy that leads to collisions as a number of vehicles are assigned same time slot. In DRIVE, during low traffic regime in the absence of vehicles in the vicinity, there might be no forwarder in the sweet spot who can receive the information and disseminate it further. Initially when the vehicle density is low, AMD is able to deliver about 80 % of the messages, but as the number of vehicles in the vicinity increases, it possess high MDR of almost 100 %.

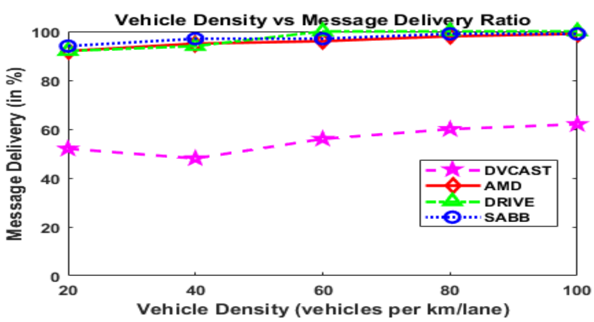


Fig. 5 Message Delivery Ratio

Fig. 6 presents the average delay which specifies the time it takes to transmit data to all the intended vehicular nodes. SABB outperforms DV-CAST and DRIVE in all the varying traffic flows. Due to controlled beaconing, the resources available are utilized in disseminating the data packets resulting in lowering the delay in SABB. In DRIVE, the vehicle may have larger waiting periods for rebroadcast as it depends upon availability of the forwarding vehicle in the sweet spot. If no vehicle is there, then the vehicles outside this spot can rebroadcast the information which in turn results in the higher delay. However with the rise in vehicle density the delay lowers as the possibility of vehicles in sweet spot also rises. DV-CAST has higher delay in comparison to SABB and AMD as more vehicles are involved in rebroadcasting during single timeslot resulting in higher contention and delay. In AMD at lower densities the delay is low, but with rise in traffic density delay becomes bit higher.

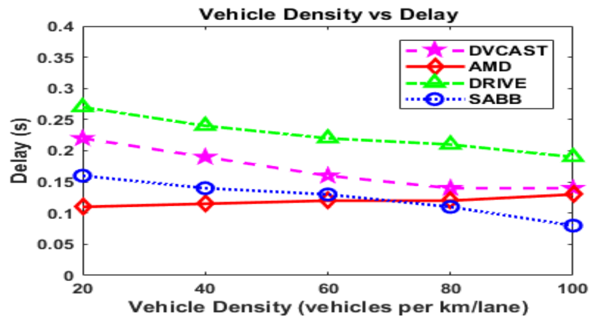


Fig. 6 Delay

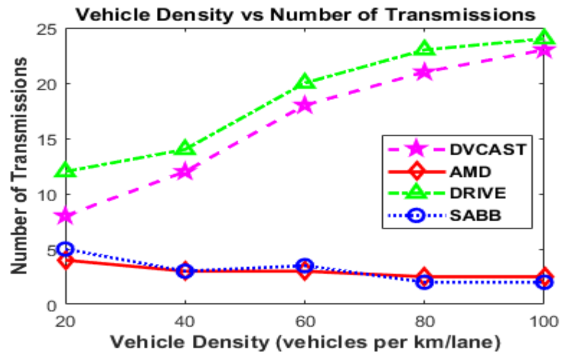


Fig. 7 Number of Transmission

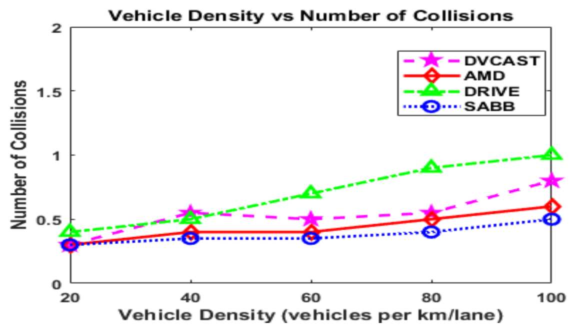


Fig. 8 Number of Collisions

Fig. 7 depicts the total number of transmission carried out by the vehicles to disseminate the information under different traffic situations. SABB and AMD has far lower number of transmissions in comparison to DV-CAST and DRIVE. In SABB, distance of the forwarding vehicular node along with its neighboring density is taken into consideration while deciding the probable forwarder. The number of transmissions gets reduced as the coverage of transmission is improved because of the combination of two aspects i.e., distance and density of vehicles and broadcast storm is reduced. Also the controlled beaconing improves the transmission aspect. However in DV-CAST the number of transmissions are high which is because of large number of periodic transmission of hello messages. The number of transmissions would have been even higher, had the information delivery for DV-CAST been higher. With the rise in number of vehicles, timeslot keeps transmissions in control for AMD. A comparison in the number of collisions amongst different approaches is shown in the fig. 8. Both periodic messages and data messages add to number of collisions which occur in different approaches. As in the SABB, the number of periodic messages are controlled as beaconing interval decides the periodicity of beacon messages depending upon the speed of vehicles. The low number of transmission also contributes in bringing down the number of collisions. It can noted that when the traffic density is low, all the approaches have lesser number of collisions which rises with rise in number of vehicles.

C. Simulation Results - Urban Scenario

In urban scenario we have considered three protocols for comparison i) UV-CAST ii) AMD iii) DRIVE. UV-CAST approach exclusively addresses urban environment. Fig. 9 shows the result of MDR with traffic density varying from 20 to 100 vehicles per sq. km. It can be noticed that the performance of all the approaches is affected when traffic density is low, but once the traffic density rises above 40 vehicles per square km the MDR increases significantly. UV-CAST uses distributed giftwrapping algorithm to choose boundary vehicles for assigning higher priority vehicles at the intersection which may over select store-carry-forward vehicles as admitted by authors, still the performance at higher densities is beyond 90%. At lower density the DRIVE results in low MDR, which may be attributed to it approach where vehicles within the sweet spot are preferred choice for dissemination, and in the absence of same, to some extent MDR is affected. SABB shows considerable improvement once the vehicle's density reaches 40 or above, as the preference is given to the vehicle at the intersection to act as forwarding vehicle for disseminating the information to more vehicles in shorter span.

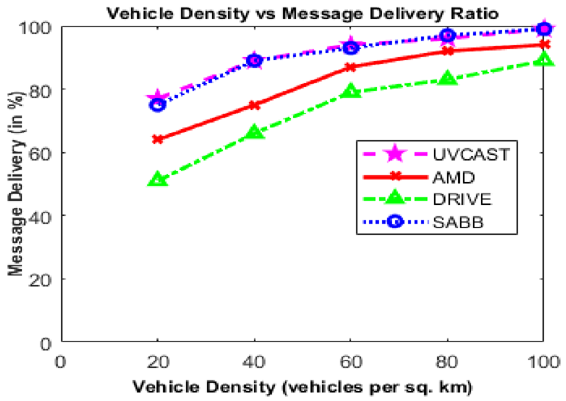


Fig. 9 Message Delivery Ratio

Fig. 10 depicts that at lower densities, the delay is higher in all the approaches but as the flow of traffic increases all the approaches shows considerable improvement. DRIVE performs better with rise in vehicle density as the possibility of availability of vehicle in the sweet spot is high which lower the waiting period for rebroadcasting the information. UV-CAST results in higher delay in comparison to SABB as the giftwrapping algorithm involves higher number of retransmissions that results in additional delay, but otherwise performs better than DRIVE and is comparable with the performance of AMD. In SABB the adaptive beaconing process also contributes in lowering the delay as waiting period is reduced due to lower network load and availability of channel for delivery of data messages.

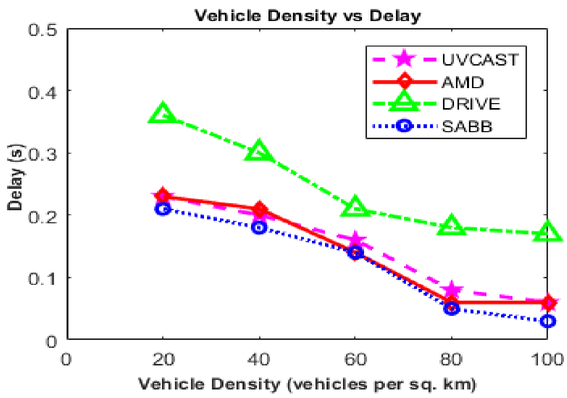


Fig. 10 Delay

Fig. 11 presents the number of data message transmissions done on an average by vehicles. SABB and AMD performs almost equally well as the approaches are able to choose the forwarding vehicle correctly and lowers the number of transmissions leading to better overall performance. UV-CAST results in highest transmission overhead as number of selected store carry forward agent vehicles selected results in high redundant transmissions.

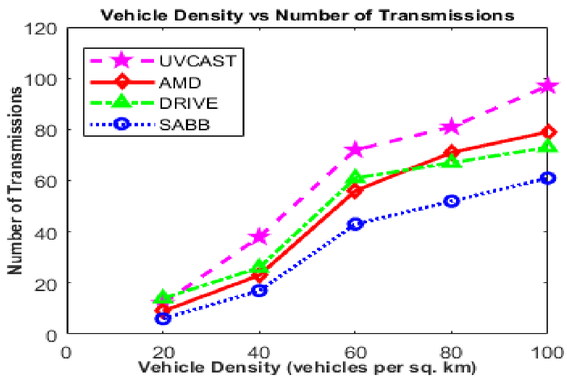


Fig. 11 Number of Transmissions

V. CONCLUSION

This paper presents a Speed Adaptive Beacon Broadcast approach for disseminating information in urban and highway environment that mitigates broadcast storm issues and hidden node problems in VANETs under varying traffic flows. This approach considers both distance as well as density of vehicles in the vicinity while selecting best suitable vehicle for rebroadcasting the information. As the vehicles are preloaded with street maps, so the vehicles at the junction are given priority to be selected as a relay vehicle resulting in delivery of messages in multiple directions simultaneously which otherwise is obstructed due to the presence of skyscrapers in urban environment. The beaconing process is controlled depending upon speed at which the vehicle is moving i.e. vehicle moving at a fast pace is allowed to disseminates beacon more frequently than those which moves at slow speed. Due to adaptive beaconing, the network resources which are already scarce can be better utilized thus resulting in addressing channel bandwidth issues and lowering collisions. SABB is compared with DV-CAST (for highway scenario), UV-CAST(for urban scenario), AMD and DRIVE approaches and it has been observed in the results that the proposed approach performs better in terms of MDR, Delay, number of transmissions and number of collisions. In future, SABB can be analyzed in a more realistic environment while varying both traffic speed and flows. A mathematical model needed to efficiently decide the weightage to be assigned to different components like distance and threshold for traffic density that are involved in evaluating the waiting time.

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