Data Dissemination for Heterogeneous Transmission Ranges in VANets

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***Abstract*—Distance is a key measure when implementing timer-based dissemination protocols in Vehicular Ad-hoc Networks (VANets). In which the transmission is deferred proportional to distance, aiming to order vehicles transmission, such that the farthest vehicle gets the highest opportunity to relay the message. This will ensure long hops along the road to speed up the dissemination and cover more nodes. However, in case of heterogeneous transmission ranges, the farthest distance will not ensure a proper choice of relay nodes to disseminate the message. Vehicles, whose transmission area enclosed by the sender or have small non-covered transmission area, might be chosen as relay vehicle. This may inhabit other nodes from relaying the message and end the dissemination process early and before it reach the required region. In this paper, we propose the Area Defer Transmission (ADT) dissemination algorithm. ADT enables each vehicle to independently decide to transmit or suppress transmission considering heterogeneous transmission ranges and the amount of area that would be covered by potential new transmission.**

The performance of the proposed ADT algorithm has been evaluated using an actual road map with complex road scenarios and real movement traces. It has also been thoroughly investigated and compared with other distance-based algorithms. The results demonstrate that ADT achieves high delivery ratio, high propagation speed and less relay ratio with fewer hops that reach long distances.

I. INTRODUCTION

Efficient data dissemination is considered one of the significant problems with VANets, as the majority of VANets applications require propagating messages in a very short time to all other vehicles within a range of a few kilometres from the source. However, high mobility, non-uniform vehicle densities and limited wireless channel bandwidth, cause reachability and delay issues difficult to manage. This is due to a low packet reception rate, which could be caused by either intermittent connectivity in sparse environments, or high redundancy and severe packet contention during high density.

In the literature, a common method to overcome redundancy and contentions is to control the number of vehicles that can relay the broadcast message. Relay vehicles should be selected in a way that ensures high reception rate and acceptable end-to-end delay. Dissemination approaches can generally be classified into two categories: knowledge based approach, and instantaneous approach [3], [4], [7], [8], [10]–[17]. In the knowledge-based approach, the selection of relay nodes is based on information about the network topology that is collected prior to receiving any messages to be disseminated.

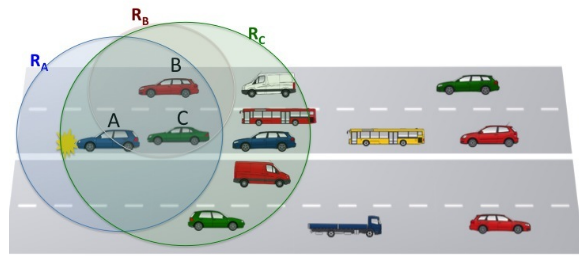

Fig. 1: Eaxmple of hetrogenous transmission ranges

The decision to forward the message can be made at the sender or at the receiver. With the instantaneous approach, the decision is based on information in the message and local information at the node, such as position coordinates and speed. The decision to forward the message is always made at the receiver, and is typically based on distance as the main parameter. The decision to relay the message is either made probabilistically, or/and based on deferred time. In timer-based, the transmission is deferred proportional to the distance between the sender and receiver. In the literature that adopting the instantaneous approach always assumes an equal maximum transmission range for all vehicles in the network.

The vehicles transmission ranges are typically heterogeneous, which could be due to transmission power value, the interference level, and multipath or fading. This is the case, despite the many scholars who are proposing dynamic adjustment of transmission power for vehicles, to prevent congestion in high density networks such as [2], [6], [18], [19]. Thus, the decision to relay the message based only on the distance in heterogeneous transmission ranges will not be practical. For example, Figure 1 shows that after transmission by vehicle A, vehicle B will have the shortest defer time according to the distance value, and will retransmit before C. If C cancels the transmission after receiving a redundant copy of the message from B, many vehicles in the transmission range of C will not be aware of the message. In this case, area is a better measure than distance to select the next node to relay the message. The concept of using area has been initiated in [9] for Mobile Ad Hoc Network (MANET). In this study [9], the algorithm calculate the area covered by previous transmission and the amount of area that would be covered by potential new transmission. If the result is greater than a given threshold, the node retransmits. Unfortunately, this work assumes the same transmission range for all nodes. Therefore, calculating the non-covered area by previous transmission when transmission ranges are homogeneous is different that when transmission ranges are heterogeneous. Furthermore, nodes transmissions are not ordered in way that gives the high opportunity to nodes that would cover large non-covered area. This will lead to the same case described earlier, in the example shown in Figure 1

In light of the above, our contribution is to introduce timer-based dissemination protocol for heterogeneous transmission power (i.e. maximum transmission range). Rather than distance, the proposed approach will consider the overlapping transmission area of the sender and the receiver. It will be implemented using actual road map with complex road scenarios and real movement traces generated by Simulation of Urban MObility (SUMO) [1], and compared with Distance Based Forwarding (DBF) [12] and directional distance defer time (DdDT) [5] approaches, both of which are different versions of a distance-based approach.

The rest of the paper is organized as follows: Section II is an overview of related work in the field, and Section III describes proposed Area Defer Transmission (ADT) scheme with illustrative examples. Performance evaluation of the proposed approach compared to distance-based approaches is provided in Section IV, using actual road traffic scenarios. Finally, Section V presents the conclusion.

II. Literature Review

A simple approach of dissemination is to use traditional flooding, where each node in the network re-transmits the message when it is received the first time, without any information about other nodes in the network. The main advantage of this approach is that it provides very fast data dissemination, if there is no contention or collisions [9]. Furthermore, each broadcast message will take all possible routes to reach other nodes. However, this approach is not suitable for VANets environments, which can be dense or sparse at different times and spaces. In high density vehicles, the approach will have severe contention due to unnecessary redundant retransmissions (i.e. the well-known broadcast storm problem), and it will not be propagated beyond the transmission range in sparse networks. In both cases, the messages will be prevented from reaching all other nodes.

A feasible solution to the broadcast storm problem is to reduce the number of redundant transmissions. This is achieved by controlling the number of nodes that relay the broadcast message. Proper selection of relay nodes governs high message reception rates, acceptable overall end-to-end communication delays, and efficient bandwidth usage. Due to space limitation, we limit literature review to schemes specifically designed for inter-vehicles communication and do not depend on neighbours-table stored at each node, to which we refer as instantaneous dissemination schemes. In instantaneous dissemination algorithms, receiving vehicles make the decision to forward the message based on the information extracted from the message and local information at the receiving vehicle.

Distance Defer Transmission (DDT) [15] is a timer-based approach. The receiving vehicle defers retransmitting the message for a time that is inversely proportional to the distance from the transmitting vehicle; thus, the farthest receiver retransmits first. When the defer time expires and the node has not received the message from other neighbour vehicles, it retransmits the message using the same protocol. It has been shown that DDT outperforms network topology based protocols in sparse networks, due to the back-off time used.

The wait time in the algorithm proposed in [8] is based on sensed signal level. Each node classifies itself into one of the three groups: the Preferred group (PG), the IN group or the OUT group. The PG is the nodes with signal power greater than the OUT group and less than the IN group. The IN group is the nodes with a signal stronger than the PG. After a node is classified, it waits for a hold-off period before deciding whether to rebroadcast a packet or not. The hold-off time, and the strategy for making a rebroadcasting decision, depends on the group the node belongs to, with the priority of rebroadcasting given to the PG group, followed by the OUT group.

The scheme in [3], [11], assume linear road represented by an x-axis in the direction of vehicles movement and the message is propagated in the opposite direction with respect to vehicle movement. When a node receives a message for the first time, it defers transmission for a time proportional to the time necessary to transmit a full message. During the waiting if a node receives another copy propagated in the same direction of vehicle movement (e.g. d(tx,rx)$<$0), the receiver can safely avoid forward the message. Otherwise, the receiver computes the minimum estimated distance from the received copies and enter new waiting time. If no new copies of the message are received during the waiting time the node decides to retransmit the message probabilistically, based on the distance from the closest relay node.

Distance-to-Mean (DTM) [14] uses a wait time, which is proportional to the distance between transmitter and receiver, to observe the neighbours that retransmit a particular message. Using the positional information, it calculates spatial mean of those neighbours and finds the distance from the receiving node to calculated spatial mean. When the distance is large, the node will cover larger amount of additional area by rebroadcasting than when the distance is small. DTM method sets a threshold value such that any node that measure the distance to be greater than the threshold will retransmit the message.

Distance Based Forwarding (DBF) [12] is an enhanced version of DDT [15]. It is integrate hop count with a timer-based approach to avoid possible contention that could be happened due to simultaneous transmission. The node suppresses the transmission if the same packet is received twice from different nodes with greater hop count. The algorithm proposed in [5] for multi hop dissemination is also a timer-based approach that computes the timer as a function of distance. However, it uses a directional distance (adjacent side) instead of Euclidean distance (hypotenuse side) between the node and sender.

All the aforementioned algorithms are intended to reduce the number of redundant transmissions without considering the heterogeneous of vehicles transmission ranges. The difference in transmission ranges could affect the selection of the proper relay node to retransmit the message, as shown in the example Figure 1. In addition, the dissemination protocols reported in the literature are mostly performed on a simple straight road section. More realistic scenarios involving complex interconnected road structures are required.

III. Area Defer Transmission (ADT) Scheme

The Area Defer Transmission (ADT) dissemination does not rely on network topology information. Instead, each node decides independently based on information inside the message, such as position and local information at the receiving vehicle. In ADT, each node calculates a wait time to order the retransmission among nodes. ADT wait time is based on the overlap between the receiving vehicle and the sender transmission area. The rationale behind letting the time depend on the overlap area is that when a node hears the message for the first time, and its overlap area with the transmitting node is small compared to the total transmission area of the receiving node, the additional coverage that can be achieved by retransmitting the message will be significant. Thus, the decision to forward the message should be taken with high priority and, accordingly, with the transmission deferral proportional to the overlap area between the sender and receiver.

A. Overlapping Between Two Heterogeneous Transmission Ranges

The overlapped area between vehicle v_i and vehicle v_j maximum transmission areas, A_{ij}, could be one of four cases, as shown in Equation 1.

$$A_{ij} = \begin{cases} 0 & \text{if } d_{ij} > R_i + R_j \\ \pi * R_j^2 & \text{if } R_i - d_{ij} \geq R_j \text{ and } R_j < R_i \\ \pi * R_i^2 & \text{if } R_j - d_{ij} \geq R_i \text{ and } R_i < R_j \\ \frac{\theta_j R_j^2 - R_j^2 sin(\theta_j) + \theta_i R_i^2 - R_i^2 sin(\theta_i)}{2} & \text{Otherwise} \end{cases} \tag{1}$$

such that $\theta_j = 2cos^{-1}\left(\frac{R_i^2 + d_{ij}^2 - R_j^2}{2R_i d_{ij}}\right)$, and
$\theta_i = 2cos^{-1}\left(\frac{R_j^2 + d_{ij}^2 - R_i^2}{2R_j d_{ij}}\right)$

An example of each case is presented in Figure 2, where v_i is the sender and v_j is the receiver. Figure 2a depicts the case when the two vehicles become out of transmission range after receiving the message, due to mobility. In this case, because there is no overlapping area between the two vehicles (i.e. $A_{ij} = 0$), the receiver vj should be given highest priority to relay the message. Figure 2b shows the case when the transmission range of the receiver, v_j, is less than the transmission range of the sender, v_i, and the receiver maximum transmission range is enclosed by the sender transmission area. In this

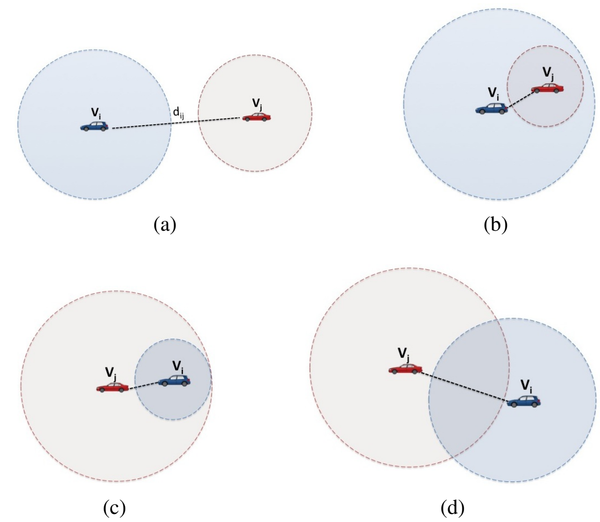

Fig. 2: Overlapping scenarios

case, the overlapping area is equal to the receiver maximum transmission area. Accordingly, the entire transmission area of receiver is already covered by the sender, and repeating the transmission is of no benefit.

Figures 2c and 2d illustrate the case when the sender covers part of the receiver transmission area. Figure 2c depicts the third case of Equation 1, when the overlapping area is equal to sender transmission area. On the other hand, Figure 2d illustrates when part of the sender and receiver transmission ranges overlap, as shown in the fourth case of Equation 1. Referring to the example shown in Figure 3, this formula is derived as follows:

The aim is to compute the overlapped transmission area of two vehicles V_A and V_B with different maximum transmission ranges of R_A and R_B respectively. If we consider the transmission area to be circular, then the radius of V_A and V_B transmission areas is R_A and R_B respectively. Let V_A be the center of the first transmission area with coordinate (x_A, y_B) and V_B be the center of the other transmission area with coordinate (x_B, y_B). Then, the distance between V_A and V_B after displacement is calculated as follows:

$$d_{AB} = \sqrt{\left(x_B + tS_j sin\gamma_j - x_A - tS_i sin\gamma_i\right)^2 - \left(y_B + tS_j cos\gamma_j - y_A - tS_i cos\gamma_i\right)^2}$$

where t is the difference between the send time and the receive time of the message, and γ_A, S_A, γ_B, and S_B are the orientation and speed of vehicle A and vehicle B respectively. Note that the overlapping area is formed by two segments, and bisected by the chord CD that belongs to sectors A and B. The area of circle sectors A and B are given by:

$$C_A = \frac{\theta_A}{2} * R_A^2 \ , \ C_B = \frac{\theta_B}{2} * R_B^2$$

In order to find the area of the two sector segments (i.e. the overlapping area), we first need to find the area of the triangles CAD and CBD. Then, the area of each segment can

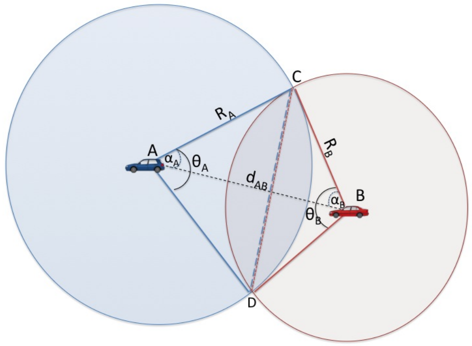

Fig. 3: Calculate overlapped transmission area of two vehicles

be determined by the difference in area between the sector and the associated triangle. To obtain the area of the triangles, we must calculate the angles θ_A and θ_B using a cosine formula, as follows:

$$R_A^2 = R_B^2 + d_{AB}^2 - 2 * R_A * d_{AB} * cos(\alpha_B)$$

$$cos(\alpha_B) = \frac{R_A^2 + d_{AB}^2 - R_B^2}{2 * R_A * d_{AB}}$$

$$\alpha_B = cos^{-1}\left(\frac{R_A^2 + d_{AB}^2 - R_B^2}{2 * R_A * d_{AB}}\right)$$

$$\theta_B = 2 * \alpha_B$$

$$\theta_B = 2 * cos^{-1}\left(\frac{R_A^2 + d_{AB}^2 - R_B^2}{2 * R_A * d_{AB}}\right)$$

Similarly,

$$\theta_A = 2 * cos^{-1}\left(\frac{R_B^2 + d_{AB}^2 - R_A^2}{2 * R_B * d_{AB}}\right)$$

Then, the overlapped area is given by subtracting the area of each sector from the respective triangles as follows:

$$A_{AB} = \frac{\theta_B R_B^2 - R_B^2 sin(\theta_B)}{2} + \frac{\theta_A R_A^2 - R_A^2 sin(\theta_A)}{2} \quad (2)$$

B. Transmission time Calculations

When vehicle v_i broadcasts a message to the surrounding area, vehicles in its radio transmission range receive the message. The transmission area of the sender vehicle covers a circular area with a radius equal to its maximum transmission range, R_i. The vehicle that receives the message, say v_j, checks if the message has been received before, as illustrated in Algorithm 1 Lines 9-12. If not v_j computes the area not covered by previous transmission as shown in Equation 3.

$$\hat{A}_j = (1 - \frac{A_{ij}}{\pi * R_j^2}) \quad (3)$$

where A_{ij} is computed using Equation 1. If $\hat{A}_j$ is greater than a particular threshold, it starts a timer before transmission, as shown in Equation 4. This timer is proportional to the overlap of the maximum transmission ranges of the sender and the receiver vehicle.

$$\tau = T_{max}(\frac{A_{ij}}{\pi * R_j^2}) + \delta \quad (4)$$

where T_{max} is the highest possible delay in which the message still beneficial, and δ is a random variable. The random variable component is used to avoid collisions caused by simultaneous transmissions from two or more vehicles within the transmission range of the sender. The importance of the random number concept has been introduced, with different values, by a number of scholars including [3], [5]. In our case, the transmission is delayed by a uniform random amount within DIFS as proposed by [5].

As a result, the receiver with the least overlapping area with the sender has the shortest waiting time ,because the additional coverage that can be achieved by re-transmitting the message will be significant. Accordingly, it has the highest opportunity to retransmit the message. If the timer expires before receiving another copy of the same message, the vehicle proceeds with the transmission. Otherwise, it suppresses the scheduled transmission for the same message to reduce redundancy, as shown in Algorithm1 Lines 19-26.

IV. Performance Evaluation

Our approach is compared with Distance Based Forwarding (DBF) [12], and another distance version algorithm presented in [5]. DBF, which is an enhanced version of the timer-based approach DDT [15], integrates hop count with a timer-based approach, to avoid contention due to simultaneous transmission. The hop count is used to suppress transmission if the same packet is received twice from different nodes. The nodes cancel the scheduled transmission of the message if they receives a new message with one hop greater than the previously received message.

The algorithm in [5] is also a timer-based approach that computes the timer as a function of distance. However, it uses a directional distance, d_d, between the node and sender, rather than Euclidean distance, d_e. Therefore, it will now be referred to as DdDT in this paper. The directional distance d_d is computed as follows:

$d_d = d_e cos\theta$, where

$d_e = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}$, and $\quad \theta = arctan\left(\frac{y_j - y_i}{x_j - x_i}\right)$

Both approaches start a timer, τ, before transmission, where τ is calculated as follows:

$$\tau = T_{max}\left(1 - \frac{d_{ij}}{R_{max}}\right)$$

In BDF, $d_{ij} = d_e$, while $d_{ij} = d_d$ in the DdDT approach. The vehicle whose timer is due in the DdDT approach, retransmits the message after a brief random time in DIFS. The purpose of the short time is to avoid possible collisions caused by concurrent transmissions from two or more vehicles with the same defer time.

A. Simulation Set up and Performance Metrics

Results in this section were obtained using the NS2 network simulator. The simulation is based on data from a real map of downtown Ottawa streets (see Figure 4), which was

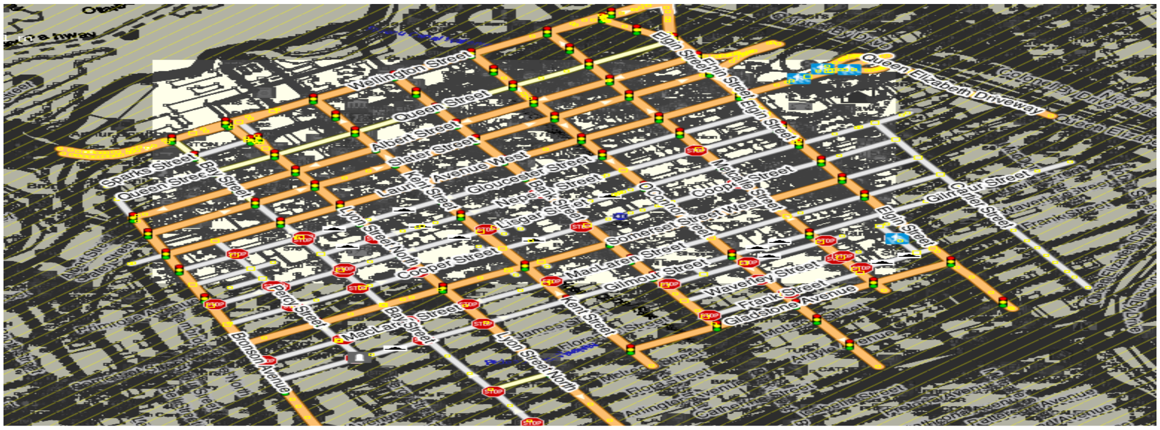

Fig. 4: Map used in the simulation

Algorithm 1 ADT scheme at vehicle j

Notation:
$\mathbb{P}$: Set of distinct received messages.
$\mathbb{W}$: Set of messages scheduled for transmission.
msg_k: Message k received from vehicle i.
A_{ij}: Overlap transmission area between the transmitter i and receiver j.
$\hat{A}_j$: Non covered transmission area of vehicle j by vehicle$i$.
τ_k: Defer time for message k before transmission.
M: ADT threshold value.
if $msg_k \notin \mathbb{P}$ and message life time not expired **then**
  $\mathbb{P} = msg_k \cup \mathbb{P}$
  compute A_{ij} using Equation 1
  $\hat{A}_j = 1 - \frac{A_{ij}}{\pi * R_j^2}$
  if $\hat{A}_j >= M$ **then**
    $\tau_k = T_{max}(\frac{A_{ij}}{\pi * R_j^2}) + \delta$
    $\mathbb{W} = \mathbb{W} \cup msg_k$;
  else
    drop msg_k;
  end if
else
  /* Redundant message */
  if $msg_k \in \mathbb{W}$ **then**
    /* Suppress scheduled message for transmission */
    $\mathbb{W} = \mathbb{W} - msg_k$;
    drop msg_k;
  end if
end if
/*broadcast scheduled messages when deferred time expired */
for each $msg_L \in \mathbb{W}$ **do**
  if τ_L== current time **then**
    broadcast(msg_L);
    $\mathbb{W} = \mathbb{W} - msg_L$;
  end if
end for

TABLE I: Simulation parameters

Parameter name	Value
Network simulator	NS2.35
Propagation Model	TwoRayGround
Mac and physical layer	IEEE 802.11p
Noise floor	-99dBm
Carrier sense threshold	-85dBm
Antenna	OmniAntenna
Simulation time	500s
Traffic generator	SUMO
Transmission range (R)	Randomly selected from 100-600m
Number of vehicles (N)	50-500 vehicles
Message life time	700ms
T_{max}	500ms
ADT threshold M	0, 0.1, 0.2, 0.3, 0.4

generated from Openstreetmap. The map includes highways and secondary roads, intersections, highway junctions, traffic lights, etc. to represent realistic scenarios. The real movement traces are generated using Simulation of Urban MObility (SUMO) [1]. SUMO is microscopic road traffic simulation package that combines vehicle movement with lane changing and intersection control, and constrains vehicle movements to selected streets.

Transmission power for each vehicle is selected randomly, to achieve a maximum transmission range of 100 to 600m. A new event driven message is generated every four seconds from arbitrarily selected source vehicle. The list of simulation parameters used in this work is given in Table 1. The performance metrics used to evaluate the ADT, DBF and DdDT approaches with a confidence level of 95% are listed after Table I.

- *Maximum hops traversed*: the average number of maximum hops the messages traversed.
- *Average propagated distance*: the average distance the messages traversed in the network.
- *Maximum propagation delay*: the average difference between when the messages are originated and when they reach the maximum propagation distance.

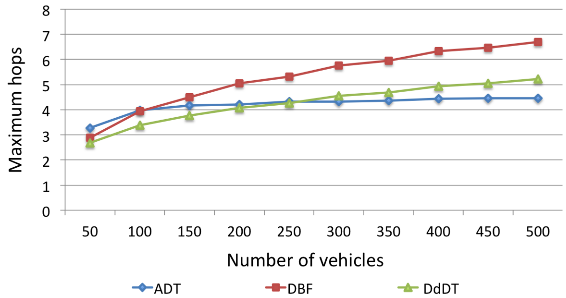

Fig. 5: Hops count vs number of vehicles

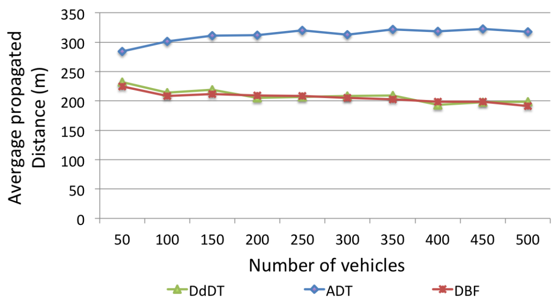

Fig. 6: Maximum propagated distance

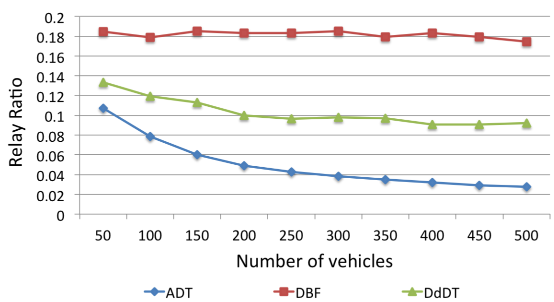

Fig. 7: Ratio of relay nodes

- *Relay ratio*: this measures the ratio of vehicles in the network that retransmit the source message.
- *Relay coverage ratio*: this metrics evaluates the quality of the selected relay vehicles, by quantifying number of vehicles receiving the message from a single relay vehicle transmission.
- *Delivery ratio*: measures the proportion of vehicles in the network that successfully receive the message.
- *Relay latency*: the average difference between the time a message is received and the time it is retransmitted per one relay node (i.e. defer time).
- *Propagation speed*: the average rate at which the message can propagate per second.
- *Redundancy rate*: measures number of duplicate messages in the network per one source message.

B. Results

The first part of the experiments is used to evaluate the ADT core algorithm compared to BDF and DdDT algorithms. This is done by studying their performance under the effect of different values of vehicles density of the network. Data traffic used is only event driven data. Also, we evaluate the performance of the algorithms with realistic data traffic. This is achieved by generating event driven traffic in conjunction with periodic beacons traffic that generated by each node to neighbouring vehicles in the same transmission range. The second part of the experiments assess ADT algorithm under different threshold values. Data traffic generated for those experiments are periodic beaconing by each node and event driven data traffic.

1) Comparison of different dissemination protocols: In this section, we report the results of comparing the performance of the ADT approach, to the DBF and DdDT approaches. The threshold value for ADT is equal to zero. Therefore, regardless of the percentage of the covered area, the nodes always retransmit when the timer expires and no redundant copies received during the waiting time. Event driven messages are generated every four seconds and assigned to a source node randomly chosen from the entire pool of the network nodes.

In Figure 5, we demonstrate the effect of increasing the number of vehicles into the number of hops the messages traversed. The figure shows an increase in the number of hops traversed with the increase of vehicle density for the DdDT and DBF approaches, while it is more stable for the ADT approach, particularly with respect to high density. With an increased number of vehicles in the network, messages in the ADT approach traversed less hops than the DBF and DdDT approaches, and also propagated to a greater distance than the others, as shown in Figure 6. This is because DBF and DdDT are based on the distance to defer retransmission. Thus, vehicles with small non overlapping areas with the sender transmission area transmit first, while other vehicles with large transmission areas not overlapped with the sender suppress their transmission. This yields to more vehicles relaying the message, as shown in Figure 7.

In Figure 7, the ratio of vehicles relay the message in DBF is almost 18% of the vehicles in the network for all densities, and for DdDT it is 9% to 13% of the vehicles. ADT outperforms both approaches with a much lower relay ratio of 2% to 10%, even though its propagation distance is higher than the others, as presented previously in Figure 6. This implies that ADT is scalable to density changes.

Figure 8 illustrates the number of vehicles receiving the message from one relay node. It is measure the quality of the selected node to relay the message in terms of the number of vehicles receiving the transmitted message. ADT relay selection outperforms other approaches, where ADT relay vehicles transmission reach more vehicles than the other approaches, and the number increases almost linearly when the number of vehicles increases. This is also depicted in Figure 9, where the proportion of vehicles in the network that successfully receive the message in ADT is much higher than with DdDT and DBF; 95% with ADT, compared to 71% with DBF and 58% with DdDT.

Figure 10 shows the average relay latency of messages before transmission. Although the average message defer time in ADT is larger than with the other approaches, the speed

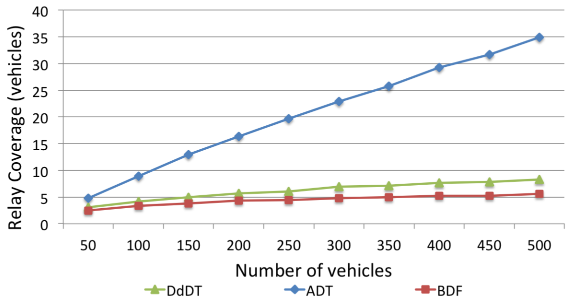

Fig. 8: Number of vehicles receiving the message per one relay

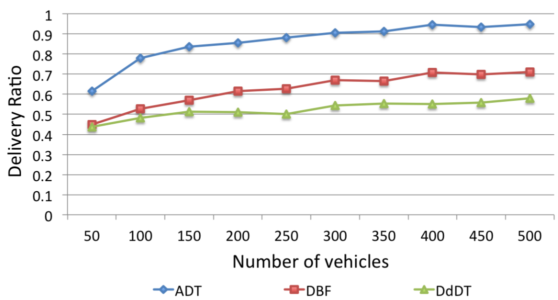

Fig. 9: Delivery ratio

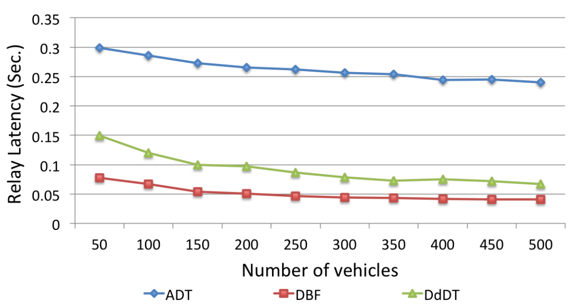

Fig. 10: Average latency per one relay

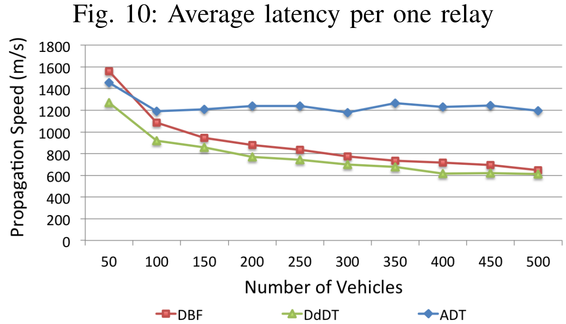

Fig. 11: Average propagation speed

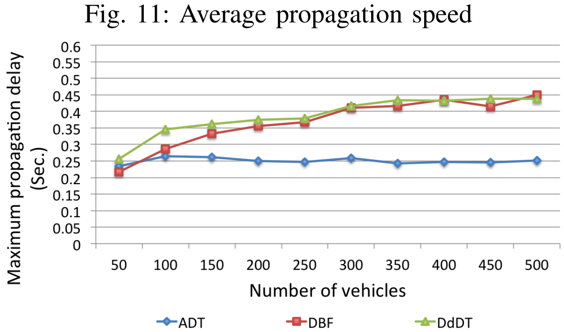

Fig. 12: Propagation delay for achieved maximum distance

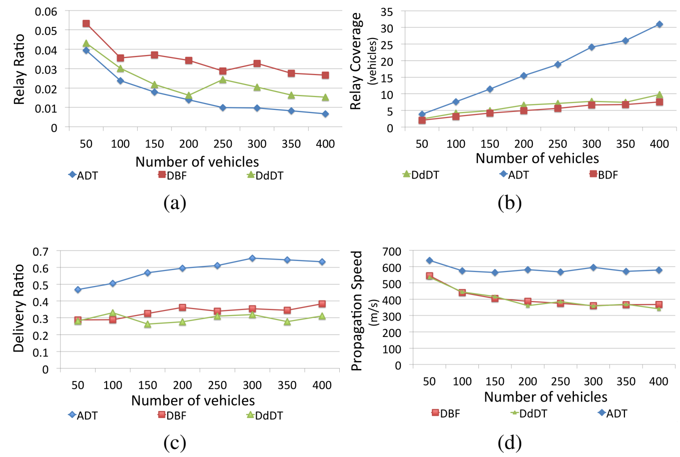

Fig. 13: Accommodate periodic and event driven data traffic

of disseminating the message is much higher, as shown in Figure 11. This is because ADT traversing greater distances than other approaches, which are traversing more hops than ADT. This is also shown in Figure 12, where the propagation delay for the maximum distance reached in ADT is less than the other approaches.

In Figure 13, we evaluate the performance of the three approaches when the network data traffic include event driven traffic to be disseminated as well as beacons data traffic generated periodically by each node to neighbouring vehicles in the same transmission range. Event driven messages are generated every four seconds by a random source node in the network nodes, while periodic beacons are generated every three seconds by all the nodes in the network. The purpose is to observe the behaviour of the algorithm under realistic data traffic scenario. The same behaviour, as conducted earlier, is shown in Figure 13a, Figure 13b, Figure 13c, and Figure 13d, where ADT outperform other approaches, in which it has less vehicles relay the message with high coverage per relay node, as well as high delivery ratio and high propagation speed.

2) ADT with Different Thresholds: The second part of the experiments, study ADT under different threshold values. In this part of experiments the network is loaded with data traffic that include periodic beacons, which are generated every three seconds by all the nodes in the network to one-hop neighbours. Beside, event driven messages that generated every four seconds by arbitrary node in the network.

The idea of using a threshold value was looking to reduce redundancy by reducing number of nodes retransmitting the message, and accordingly increase delivery ratio. Figure 14a and Figure 14b show that the ratio of nodes that relay the messages is reduced with the increase of the threshold values and accordingly the redundancy of messages are reduced.

In Figure 14c the average speed of message propagation is increased with the increase of threshold. This is due the fact the message is not propagating to far distance with the increase of the threshold values, as shown in Figure14d. Despite the

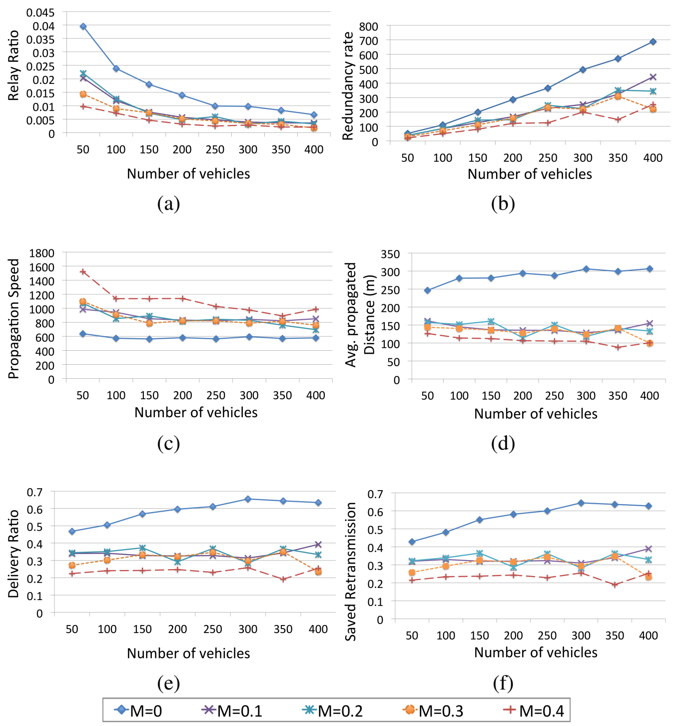

Fig. 14: ADT with different threshold values

reduction of relay ratio and redundancy rate the delivery ratio is reduced, as presented in Figure 14e. This reveals that the redundancy in ADT is accompanied with covering new areas, which is confirmed in Figure 14f. Figure 14f clarifies the ratio of vehicles receiving the message and do not retransmit the message to the total receiving vehicles. It is clear in the figure that saved re-transmission ratio when there is no threshold is much higher than when threshold is used. Therefore, depending on the timer to defer and order transmission that based on overlapping area is enough to reduce the useless redundancy in ADT.

V. Conclusion

In this paper, we presented the Area Defer Transmission (ADT) dissemination algorithm for heterogeneous transmission range in vehicle networks. The algorithm does not rely on network topology information; instead, every node makes independent decisions by drawing on information in the message and local data at the receiving vehicle. ADT order nodes transmission according to the amount of area that would be covered by potential new transmission.

The simulation results prove that more vehicles receive a message transmitted by a single relay vehicle with ADT than with other distance versions. This confirms the hypothesis that relay nodes selected by ADT are more effective than others, owing to their higher delivery ratios and propagation speeds, and fewer hops that reach long distances.

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