Dynamic Zonal Broadcasting for Effective Data Dissemination in VANET

Masters Project Final Report

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Abstract

Broadcasting relevant messages in the most efficient manner is important in a vehicular network scenario. To achieve efficient message transmission, selecting the right kind of protocol that would reduce both the number of rebroadcasts and the transmission time is necessary. To reduce the number of broadcasts, each recipient node determines the message relevance and decides on participating in the message transmission. The decision-making ability of the node determines the overall efficiency of the dissemination technique based on the employed protocol.

The protocol developed in this project is an improvement over IVG [1]. In the IVG protocol, each vehicle associates a timer with each received message and rebroadcasts it once the timer is elapsed. The defer time is set based on the offset in distance from which the message was received. Thus if a vehicle receiving the message is the farthest from the source, its timer elapses first.

The proposed protocol improves the efficiency by reducing defer time slot interval. The protocol divides the road segment into zones such that at any given time the number of vehicles in a zone cannot be more than the number of lanes in that road segment. This allows for the defer time to be based on the difference in the number of zones from which the message was received instead of the distance offset.

1. Introduction

A Vehicular Ad-hoc Network (VANET) is a Mobile Ad-hoc Network (MANET) that concerns vehicle-to-vehicle and vehicle-to-infrastructure communication. Unique characteristics such as higher node speeds and restricted road topology differentiate VANET from other MANETs. Communication between vehicles and roadside infrastructure in VANET is over short to medium range wireless technologies. More recently DSRC[7] (Dedicated Short Range Communications), an RF technology-based standard, has been designed exclusively for automotive communications.

Like most MANETs, data is propagated in VANETs through the exchange of messages between the nodes. Unlike MANETs, the restricted road topology imposes a directional nature to the message flow. Also due to higher node speeds and unstable connectivity among the nodes, it becomes necessary that data be transmitted in the most efficient of ways and with minimal delay. Hence, propagating data to the intended node or region of interest is a unique problem in VANETs and requires incorporating effective techniques to disseminate data.

2. Solving Data Dissemination

Data broadcasted from a vehicle is usually received by all the nodes within the transmission range. The problem of data dissemination is hence concerned with propagating data not within but beyond the transmission range of the sender.

An intuitively simple way to disseminate data beyond the transmission range is through flooding. In flooding each node receiving the message would simply rebroadcast the message without any regard to its current position or any other factors. Thus data is propagated beyond the transmission range when a node at the edge of the transmission range rebroadcasts the message.

Flooding is trivial, but at higher node densities, it is an inefficient technique causing collisions and unnecessary broadcasts resulting in the broadcast storm problem [2]. To overcome the shortcomings of flooding, intelligent and controlled broadcasting among the vehicles is necessary.

For effective broadcasting, each vehicle upon receiving a message would make a decision to rebroadcast the message depending on whether or not it is the farthest node in the transmission range. Thus the decision-making ability of each vehicle on participating in the message propagation is dependent on its awareness of vehicles around it and determines the overall effectiveness of the technique used in disseminating data.

Many approaches have been proposed for data dissemination, *such as IVG[1], MDDV[9], and p-IVG[3].* In general, the approach is to deduce a mechanism to determine the next transmitting node to propagate the message. Creating positional awareness among the nodes to determine the farthest node is costlier in terms of the messages needed and also volatile considering the highly mobile nature of the nodes. Thus most proposed techniques resort to alternative timer and probability-based models to determine the farthest node.

The idea in timer/probability is to associate a wait time with each vehicle when it receives a message and broadcast the message if it does not hear another vehicle broadcasting the message within the wait time. The wait time is determined on various factors defined based on the protocol preferred.

In Zonal Broadcasting protocol, we propose a hybrid of the approaches presented in IVG and p-IVG to produce a timer-based mechanism. The mechanism proposes to reduce time delay between broadcasts and also eliminate redundant retransmissions by incorporating factors that are unique and specific to VANET.

2.1 Exploiting the unique characteristics

VANET is uniquely characterized and governed by factors that both pose and provide solutions to distinct problems. The need to explore these factors is of essence to accommodate the solutions required for the problems encountered.

- *Road Topology - VANET is laid on* network that is well defined. The path each node might take can be predicted and exploited to determine the position that it would take.
- *Geo Positional Information* - *Geo-positional information* is simply the most valuable piece of information available in VANET. Together with the

road topology it effectively determines the precise position of the vehicle in the network.

♦ *Vehicle Speed - The speed of* the vehicle is a binding factor that allows predicting the density of vehicles and further to vary the delay between broadcasts based on the vehicle density.

♦ *Vehicle Lane - When the node* density is higher, the lanes of the vehicle offers the information needed to efficiently disseminate data. When more than one vehicle is pres*ent in a sin*gle zone, defer time is determined based on the current lane in which the vehicle is present.

2.2 A closer look at IVG (Inter Vehicle Geocast)[1]

In IVG each vehicle associates a timer to received messages and rebroadcasts the message when the timer expires if it has not already heard any other vehicle broadcasting the received message. In this context, defer time may be defined as the time at which the timer elapses and each vehicle, depending on the technique used, is nominated to transmit the message.

The defer time in IVG is set based on the difference in distances between the transmitting node and the node that received the message. Thus the timer associated with the farthest vehicle receiving the message times out first and rebroadcasts the message.

2.2.1 Calculating Defer Time in IVG

$$T_x = \left(T_{\max}\right)\left(\frac{(R^{\varepsilon} - D_{sx}{}^{\varepsilon})}{R^{\varepsilon}}\right)$$ *where, ...(Equation 1)*

T_x - *Defer time*
T_{max} - *Max defer time*
R - *Transmission range*
D_{SX} - *Distance between transmitter and receiver*
ε - *Distribution constant (2 for uniform distribution)*

The defer time in IVG is dependent on the difference in distance between the transmitting and receiving vehicle. Tmax is the maximum tolerable defer time between broadcasts. When $D_{sx} = R$, the message is received by the farthest vehicle in the transmission range and $T_x = 0$. When $D_{sx}=0$, the vehicle receiving the message is at the same offset as the vehicle transmitting the message and hence will have $T_x=T_{max}$. Thus, the defer time T_x, will range between 0 and T_{max} in the case of IVG.

Although IVG solves the problem to a certain extent, it fails to provide a solution when node density is higher. At higher densities, vehicles are too close to each other. Two or more vehicles can be at the same exact distance from the transmitting vehicle and their timers will expire at the same time. In such a scenario IVG fails to avoid collisions and duplicate rebroadcasts.

3. Dynamic Zonal Broadcasting

Dynamic Zonal Broadcasting aims to overcome the shortcomings of IVG and provides an efficient solution to the Data Dissemination problem through a two fold approach by incorporating the unique characteristics of VANET in its solution.

The two fold approach:

- *Reducing defer time intervals by dividing the road segment into* *dynamic zones.*

- *Incorporating lane IDs in generating defer times to avoid duplicate timeouts.*

3.1 Reducing Defer Time Intervals

The road segments are divided into zones; a zone is defined as a region or a segment of road with no more than one vehicle present in each lane. The premise is based on the fact that at higher speeds inter-vehicle distance increases and hence the length of the road segment covered by a single vehicle increases.

Figure 1 illustrates the flow of traffic at different speeds. The blue cars in figure 1(a) have lesser inter-vehicular distance when compared to yellow and green cars in figure 1(b) and figure 1(c) respectively. Hence, zone length needs to correspond to the inter-vehicular distances and depends on the speed of the vehicle.

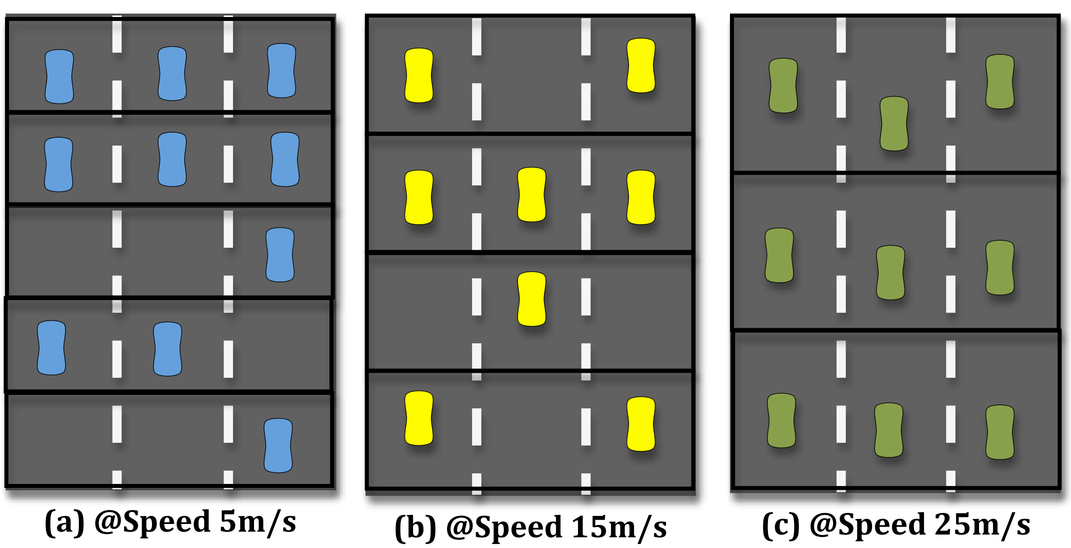


Figure 1: Dynamic Zone Lengths with Varied Vehicle Speeds

The length of the zone is determined based on the current speed of the vehicle receiving the message. Zone length is increased in increments of 1m for every 5m/s increase in vehicle speed. Further, each zone has an associated defer time which acts as a base defer time for vehicles present in that zone.

In IVG, the defer time is uniquely associated with each unit of distance; dividing road segments into zones and associating base defer time for each zone allows us to have the same time interval over an entire length of the zone. This improves efficiency by reducing the number of defer time intervals.

3.2 Incorporating Lane ID in Generating Defer Time

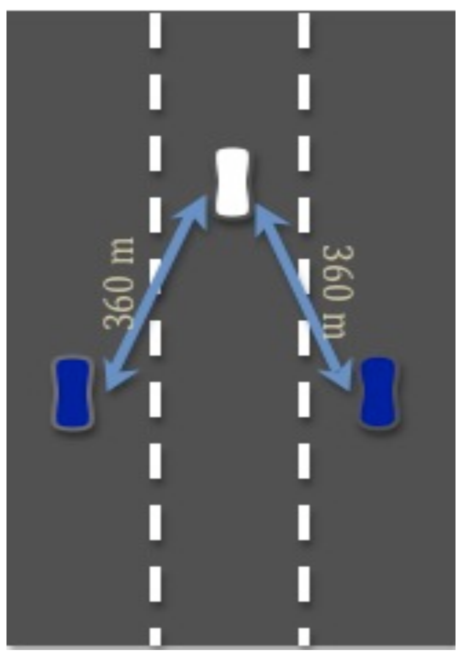


Figure 2: Calculating Defer Time for Vehicles at Equal Distances

Figure 2 represents the scenario in which 2 blue cars, which are at equal distance from the white car, receive a message broadcasting by the white car. In this scenario the defer time calculated using IVG are identical and hence create room for collisions.

In Zonal Broadcasting, the defer time is not calculated based on the distance between the vehicles rather is based on the difference in the number of zones between the vehicles. Hence Zonal broadcasting requires that all vehicles in the same zone have unique defer times.

Borrowed from p-IVG[3], the idea of incorporating lane ID in generating the defer time, solves the problem of uniquely associating defer times to multiple vehicles in a zone.

From the previous discussion, we have an associated base defer time for each of the zones. Each zone as defined has no more than one vehicle in each lane. Hence, we can generate unique defer times for multiple vehicles in a zone based on the lane in which the vehicle is present.

However, the lane ID component should be incorporated such that the defer time generated should reside between the base defer time associated with the current zone of the vehicle and that of the zone next to it.

3.3 Calculating Defer Time in Zonal Broadcasting

In Zonal Broadcasting, we define the distance between the receiving and transmitting vehicles in terms of zones. Defer time here is dependent on difference in the zone numbers between the transmitting and receiving vehicles.

$$T_x = \left(T_{\max}\right)\left(\frac{(Z^{\varepsilon}_{\max} - Z^{\varepsilon}_{sx}) + \left(\frac{l_{curr}}{\left(l_{total} + 1\right)}\right)}{R^{\varepsilon}}\right) \quad \text{.....................(Equation 2)}$$

where,

T_x - *Defer time*
T_{max} - *Max defer time*
R - *Transmission range*
Z_{max} - *Maximum number of zones at current Speed*
Z_{recr} - *Difference between the transmitting zone and receiving zone*
l_{curr} - *Current Lane number*
l_{total} - *Total number of lanes*
ε - *Distribution constant (2 for uniform distribution)*

The defer time within a zone is further dependent on the lane of the receiving vehicle *($l_{curr}/l_{total}+1$).* When $Z_{sx}=Z_{max}$ and $l_{curr}=0$, the message is received by the vehicle in the farthest zone and in lane 0, $T_x=0$. When $Z_{sx}=0$ and $l_{curr}=l_{total}$, the vehicle receiving the message is in the same zone as the one transmitting it and in the far left lane, $T_x = \frac{\left(T_{\max}\right)\left(Z^{\varepsilon}_{\max} + \frac{l_{total}}{l_{total}+1}\right)}{R^{\varepsilon}}$.

Thus, the defer time will range between 0 and $\frac{\left(T_{\max}\right)\left(Z^{\varepsilon}_{\max} + \frac{l_{total}}{l_{total}+1}\right)}{R^{\varepsilon}}$ in the case of Zonal Broadcasting.

4. Methodology

To evaluate Zonal Broadcasting, a simulation model was setup to represent a 3 lane highway using ASH[4] (Application Aware SWANS with Highway Mobility), which is an extension of SWANS[5] (Scalable Wireless

Adhoc Network Simulation) built on top of Jist[6](Java in simulation time). To verify the improvements of Zonal Broadcasting over IVG, both protocols were implemented and compared in the simulation model.

The summary of the simulation setup is described in Table 1.

Transmission Range: 400m	Inter-vehicular distance: 50 m
Highway length: 100000m	Zone Length Range: 3-7m
No of lanes: 3	Max Speed: 27m/s

Table 1: Simulation Model Setup

Vehicles were introduced in all 3 lanes with an inter-vehicular distance of 50m. Message flow was unidirectional and opposite in direction to the flow of traffic. The transmission range was limited to 400m, an acceptable value for most wireless technologies including DSRC.

Each vehicle maintains a message store in which it holds all received messages. Upon receiving a message, the message store is checked to see if the message has already been received. If the message does not exist in the store, a defer time is calculated and associated at which the message is scheduled to rebroadcast. If the same message is heard from another vehicle closer to the destination region before the timer elapses then the received message is marked as received and terminated from rebroadcasting.

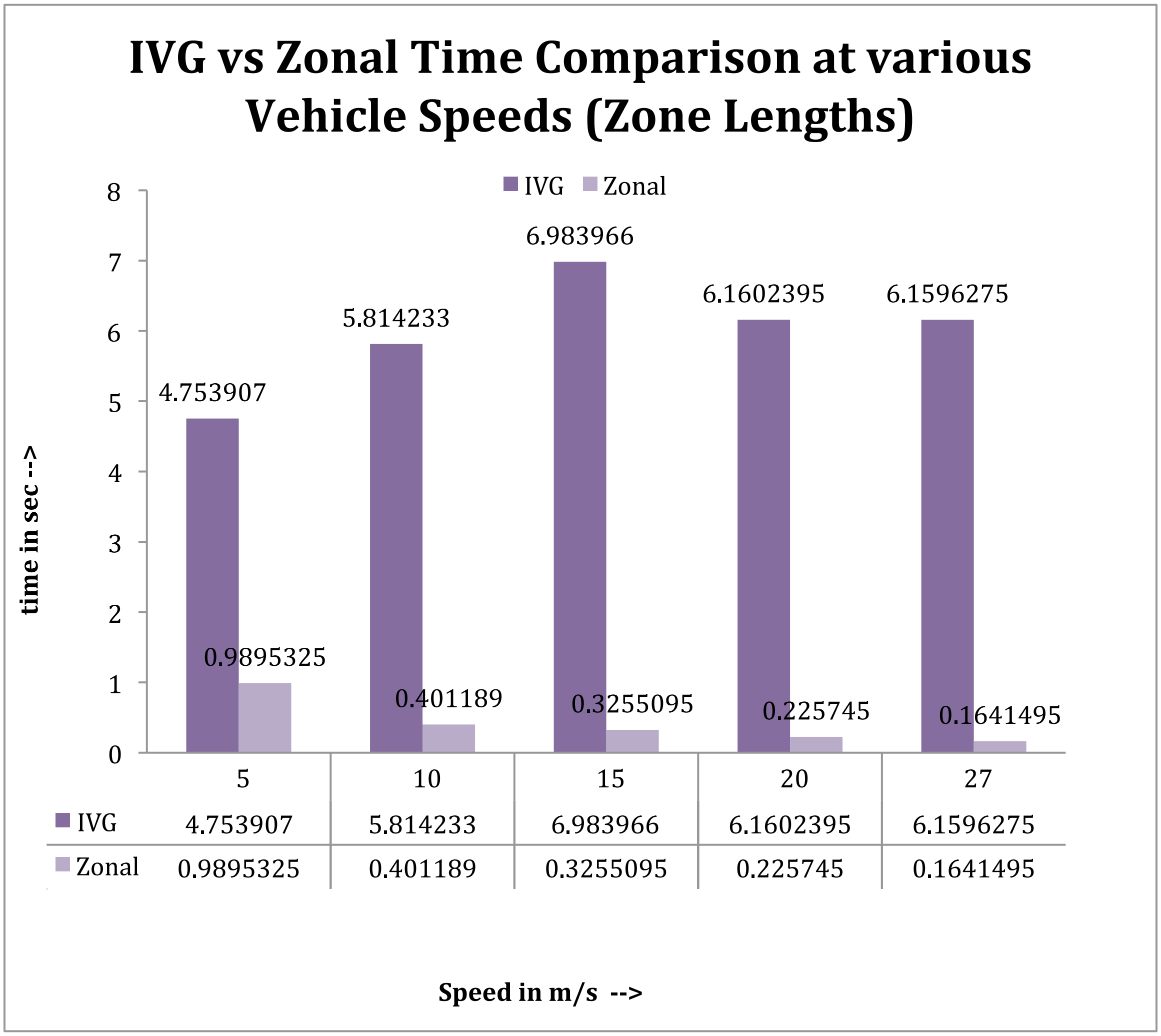
In Zonal Broadcasting each vehicle dynamically determines the zone length based on its current speed. The initial zone length was set at 3m and increased in increments of 1m for every 5m/s increase in speed. The max zone length was defined to be 7m.

Each experiment can be described as consisting of several runs. Each run is initiated when the farthest vehicle, with the max offset in the highway model transmits a message at a predefined simulation time and is completed when the last vehicle, with the least offset in the highway model and in the direction of message flow, receives the message. The difference in the simulation time between initiation and completion of each run corresponds to the message transmission time. The difference in the offset distance between the vehicle initiating the message transmission and that of the last vehicle receiving the message corresponds to the distance travelled by the message.

For a given run, all vehicles use the same protocol for calculating the defer time. If the same vehicle speed is maintained between runs, at a given simulation time, all vehicles will be at the same offset position on the highway as they were in the previous run. Thus modeling similar traffic conditions allows comparing the performance between IVG and Zonal Broadcasting at various vehicle speeds.

5. Results

Figure 3 illustrates the comparison of message transmission time between IVG and Zonal Broadcasting. Each consecutive pair of dark and light shaded columns represent the message transmission time for IVG and Zonal Broadcasting, respectively, at that given speed.



	5	10	15	20	27
IVG	4.753907	5.814233	6.983966	6.1602395	6.1596275
Zonal	0.9895325	0.401189	0.3255095	0.225745	0.1641495

Figure 3: Time Comparison at Various Vehicle Speeds

We can observe a drastic improvement in Zonal Broadcast transmission time with an increase in speed, attributed to the reduced time delay due to increased zonal lengths. We need to note that each pair of consecutive columns represent different traffic conditions and the comparison represented in Figure 3 is between IVG and Zonal Broadcasting readings corresponding to a given speed.

Figure 4 plots the time delay between each rebroadcast in IVG and Zonal Broadcasting. We see from the figure that Zonal Broadcasting has a decreased overall time delay.

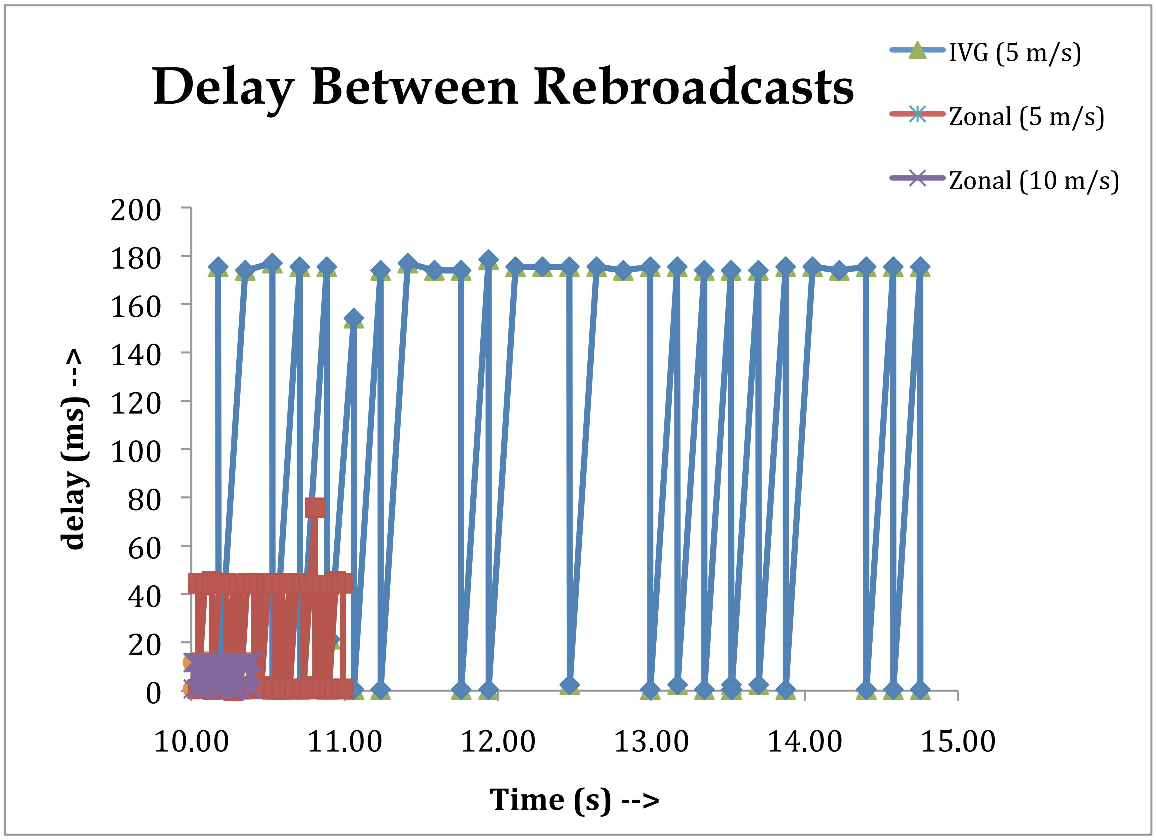


Figure 4: Comparison of Delay between rebroadcasts

Most rebroadcasts for IVG had a time delay that hovers between 0 and 170ms. In the case of Zonal Broadcasting however, it was seen that as Zone Length increased with speed, lower time delays were observed between rebroadcasts. At 5m/s speed, the delay time for Zonal Broadcasting is between 0 and 50ms, whereas at 10m/s speed, the delay between two consecutive broadcast is between 0 and 20ms.

Figure 5 represents the gain achieved in distance by using Zonal Broadcasting over IVG. Here we plot the difference in final distances between source and destination at various initial distances.

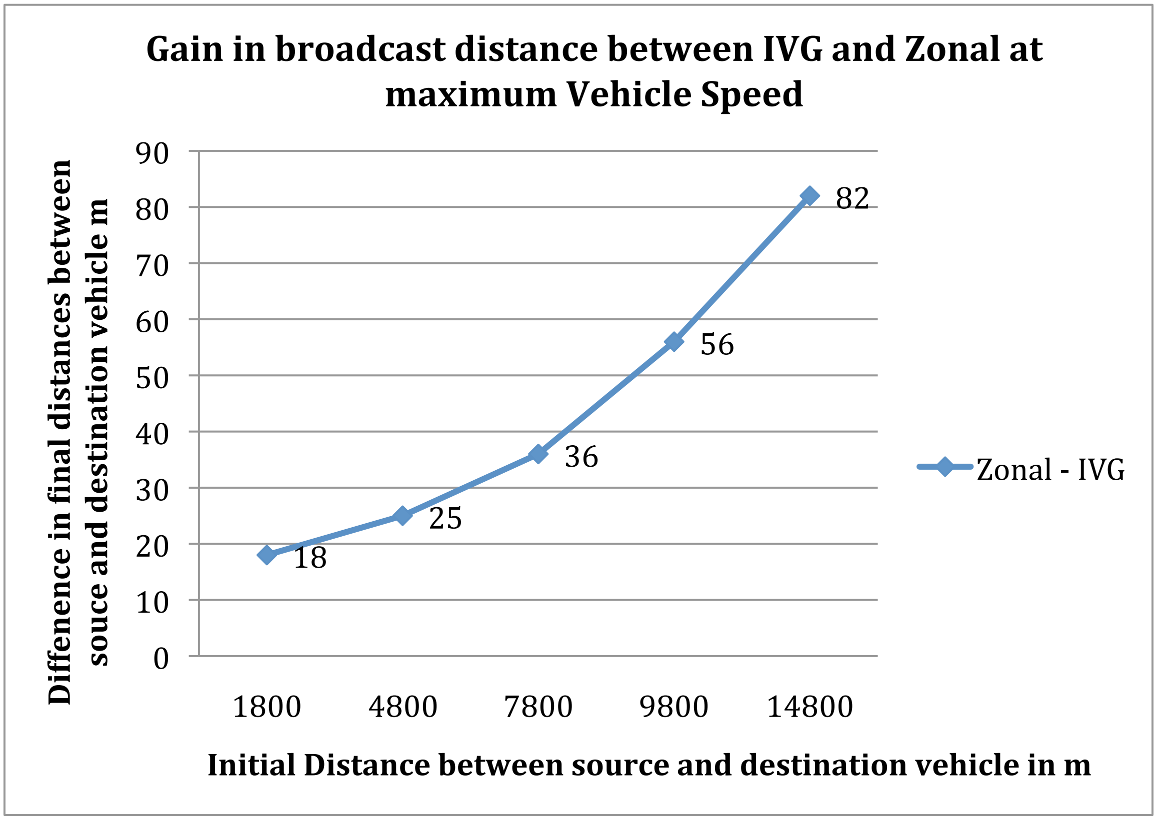


Figure 5: Difference in Distances at Which Message was Received in IVG and Zonal Broadcasting.

At the max speed, when the initial distance is 1800m, by using Zonal Broadcasting, the message reaches the destination vehicle when it is still 18m away from the region that it would have received the message when using IVG. Similarly we see that as the distance between the source and destination regions are increased, the gain in distance also increases.

6. Conclusions

Data Dissemination in VANETs is a unique problem stimulated by factors such as vehicle speed, geographical location and road topology. This project intended to study the influence of these factors on Data Dissemination in

VANETs and to explore ways to incorporate them in improving the dissemination technique employed.

We deduce the correlations between vehicle speed and inter-vehicular distance in a highway model and propose an effective mechanism to reduce time delays between message rebroadcasts. To reduce duplicate rebroadcasts we integrate the proposed technique with the one identified in p-IVG and propose an efficient Data Dissemination protocol, Dynamic Zonal Broadcasting.

Further, the proposed protocol is compared with IVG to verify the improvement. The results prove a significant reduction in delay times when compared to IVG.

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