I-BROADCAST: BROADCASTING SCHEME FOR VEHICULAR AD-HOC NETWORKS

A Thesis by

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DEDICATION

To my parents, my sister and friends

I-BROADCAST: BROADCASTING SCHEME FOR VEHICULAR AD-HOC NETWORKS

The following faculty members have examined the final copy of this Thesis for form and content and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Science, with a major in Electrical Engineering.

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ABSTRACT

With the rapid development of wireless technology and the wide availability of low cost wireless devices, the domain of mobile computer networks has expanded in the recent past. Mobile ad-hoc networks promise to be the feature of wireless networking technology, which opens up new frontiers of research and continuous development. One such frontier is VANET – Vehicular ad-hoc network. VANET is a type of mobile ad-hoc network that is formed between and among the nearby vehicles. It enables them to communicate among themselves and with the fixed unit or access point called the roadside unit. The nearby vehicles exchange safety messages among themselves and with the roadside units. The safety messages are broadcasted, which ensures that all the mobile nodes receive the safety message being sent out. This creates several issues such as broadcast storms, collisions and contention among the neighboring nodes or vehicles, which is referred as the broadcast problem. The main objective of this thesis is to propose an efficient scheme, that will greatly reduce or possibly eliminate the broadcast problem in VANET`s and to put forth a safety application called as Remote Chase Ender (RCE). This would aid the police officers to end vehicle chases. To address the issue of broadcast problem in VANET`s, we propose a broadcast scheme known as i-broadcast and evaluate its performance.

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LIST OF ABBREVIATIONS

ACK	Acknowledgement
AODV	Ad-hoc on-demand Distance-Vector routing
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CTB	Clear to Broadcast
CTS	Clear to Send
DARPA	Defense Advanced Research Projects Agency
DSDV	Destination-Sequenced Distance-Vector routing protocol
DSR	Dynamic Source Routing
DSRC	Dedicated Short Range Communication
EVDO	Evolution Data Only/Evolution Data Optimized
FTP	File Transfer Protocol
GloMo	Global Mobile Information Systems
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
iMANET	Internet based Mobile Ad-hoc Network
InVANET	Intelligent VANET
IP	Internet Protocol
IXRTT	Interexchange Radio Transmission Technologies
LAN	Local Area Network
LMR	Lightweight Mobile Routing
MAC	Medium Access Control

LIST OF ABBREVIATIONS (Cont.)

MANET	Mobile Ad-hoc Networks
NIC	Network Interface Card
NTDR	Near-Term Digital Radio
OBD	On-board diagnostics
OLSR	Optimized Link State Routing
PDA	Personal Digital Assistant
PARNET	Propionic Acidemia Research Network
PRNet	Packet Radio Network
RTB	Request to Broadcast
RCE	Remote Chase Ender
RSU	Road Side Unit
RTS	Request to Send
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
UDP	User Datagram Protocol
V2V	Vehicle to Vehicle
VANET	Vehicular ad-hoc network
WEP	Wired Equivalent Privacy
WLAN	Wireless Local Area Network

CHAPTER 1

INTRODUCTION

1.1 Overview

In the recent past, wireless networks have rapidly expanded due to the wide availability of less expensive wireless devices such as PDA`s, laptops and mobile phones. There are two main classifications of wireless networks, infrastructure based networks and infrastructure less networks or ad-hoc networks. As the name indicates infrastructure based networks need and depend on the backbone infrastructure to provide connectivity between the nodes. Cellular networks and Wireless LAN`s are examples for infrastructure based networks. In infrastructure less networks, the mobile nodes themselves are a part of the backbone. They are capable of communicating directly with other nodes in the network. VANET`s underlying architecture differs from that of traditional mobile ad-hoc networks. VANET`s cannot be classified as infrastructure based network nor be classified as an infrastructure less network. The reason being, the mobile nodes will be able to exchange messages between themselves as well as the road side units. Road side units (RSU) are nodes that can be either mobile or fixed. Examples of mobile RSU`s include, police vehicles, service vehicles, smart traffic lights, and other infrastructure that have the capability to legitimately send/receive safety or non-safety messages.

VANET`s is formed by a collection of nodes or necessarily vehicles and RSU`s that are equipped with a small onboard wireless equipment that represent an ad-hoc node travelling along a highway or a road. The ad-hoc nature of each node enables them to send and receive messages among their neighboring nodes and is also capable of exchanging messages with the road side units. The topology in the case of VANET`s is rapidly changing and is also somewhat predictable. One main characteristic that determines the lifetime of the connection between two nodes is relative velocity. It is apparent that when the vehicles travel in different directions, they have a very less connection time when compared to nodes that are travelling in the same direction. The rapid change in topology of VANET`s is due to the fact that the vehicles travel at high velocities. The predictable nature is due to the fact that the motion and direction of the travelling vehicles are controlled by the highway. Though the traditional ad-hoc networks have a rapidly changing topology there is very little predictability involved. The implementation of VANET is restrained by the factors such as rapidly changing topology, broadcast storm problem and are more difficult to implement. More research and development are required to fully implement VANET`s.

1.2 Historical Developments

In 1970 ALOHA was introduced by the University of Hawaii. Though ALOHA was implemented to provide campus wide network connectivity, it provided a sparkling start, introducing the concept of transmitting and receiving data through a shared radio media. ALOHA was architected to use two different frequency channels, one for sending the messages and other for receiving the messages. All messages that were received are immediately resent allowing the transmitting systems to know whether the messages were received or not, it also accounted for any collisions. If collisions were detected the transmitting systems would retransmit the same message after a short period of time. Though the data rate of ALOHA was minimum, it proved the possibility of transmitting data through a shared radio media and led to the development of PARNET.

PARNET is a packet switched radio technology, which was developed under the sponsorship of DARPA. PARNET enabled mobile users to communicate directly with other mobile users. Radio technology rapidly developed in the past decades which lead to the deployment of various wireless systems such as cellular phones, cordless phones messaging systems, satellites and many others.

Later in 1983 DARPA developed and effective packet switched technology called SURAN (Survivable Radio Networks). SURAN included advancements over its predecessors including store and forward and bandwidth sharing.

In the mid 90`s two proposals were made that could enable the wireless hosts to communicate with each other without the need of an infrastructure. This marked the birth of a new wireless technology popularly known as ad-hoc networks. Thus the ad-hoc networking era had begun.

Around the mid 90`s the department of defense developed Global Mobile Information Systems, popularly known as (GloMo) and Near-Term Digital Radio (NTDR). GloMo aimed at providing Ethernet type multimedia connectivity for handheld devices. It used CSMA/CA and TDMA as the channel access techniques. The NTDR is clustered ad-hoc network that is used by the US army and is the only real ad-hoc network that is in use today. Later IETF formed a work group to standardize the IP protocol to suit the need for ad-hoc network which lead to the development of several proactive and reactive routing protocols for ad-hoc networks. Further developments eventually lead to the development of MANET`s (Mobile ad-hoc networks), in which the wireless nodes are self configuring and are free to move forming an arbitrary topology.

Later in the early 2000 research were conducted to incorporate the mobile ad-hoc technology to provide communication between vehicles that could enable drivers to drive safely which lead to the development of VANET`s (Vehicular ad-hoc networks). It was proposed that the vehicles should be able to communicate with other vehicles nearby and also able to communicate with the roadside units, which marked the arrival of VANET era.

1.3 Characteristics of Ad-Hoc networks

1.3.1 Mobility

In ad-hoc networks the nodes randomly and rapidly move and reposition themselves causing rapid change in topology, requiring reconfiguration and recalculation of the various parameters. The nodes can have group mobility or might move along preplanned routes. The selection of the routes and performance are greatly impacted by the mobility of the nodes.

1.3.2 Self-organization

The nodes in an ad-hoc network should recalculate the various parameters such as addressing, clustering, position, topology, routing and reconfigure themselves.

1.3.3 Bandwidth

In ad-hoc networks bandwidth is impacted by various factors such as congestion, noise, signal fading and collisions. Due to the various constraints the effective data rate is low compared to that of wired networks.

1.3.4 Scalability

Ad-hoc networks can range from two nodes to a network with several thousand nodes. The nature of Infrastructure less ad-hoc networks imposes one of the greatest challenges in ad-hoc networks i.e. to maintain a balance between mobility and scalability when the networks grow large. They have very little tolerance for mobility and scalability.

1.3.5 Security

Ad-hoc networks are exposed to most of the attacks as that of the wired or infrastructure based networks like spoofing, denial of service, eavesdropping, etc. Such attacks are truncated and defended by security mechanisms.

1.4 Characteristics of VANET`s

Vehicular ad-hoc networks inherit the characteristics of ad-hoc networks and additionally VANET`s are affected by the environmental conditions that are prevailing along the highway.

1.5 Research overview

This research work aims at proposing a broadcast scheme for VANET`s that would greatly reduce unnecessary redundant rebroadcasting and thereby avoiding/reducing the negative effects of broadcast storm problem.

The proposed scheme is based on the fact that continuous rebroadcasting of the messages not only fails to appreciably increase the reachability of the messages but also introduces various issues such as broadcast storms and collisions.

1.5.1 Problem Identification

In VANET`s the safety messages are broadcast in nature. The safety messages are continuously rebroadcasted to increase the reachability of the message. This causes several issues in VANET`s including broadcast storm, high contention and collisions. Previous research that were conducted indicate that continuous rebroadcasting of messages not only fail to appreciably increase the reachability of the messages but also causes broadcast storm problems in VANET`s. If the rebroadcasting of messages are controlled effectively, it would not only eliminate the broadcast storm problem but also increase the efficiency of VANET`s.

1.5.2 Proposed Solution

This research mainly aims to effectively control unnecessary rebroadcasts there by reducing the effects of redundant rebroadcasts, contention and collisions. The reduction or rebroadcasts is accomplished by tagging the messages. In a broader view highways are divided into different sector and each sector is allocated a range of message ID`s. The message that is generated within a particular sector will have a message ID that is allocated to the sector in which the vehicle is currently travelling. The vehicles that receive the message will record the message ID`s and will exchange hello messages containing the message ID. By including the message ID in the hello messages, nodes will be able to identify the message and will be able to selectively rebroadcast the message when required. This approach eliminates the need of unnecessary rebroadcasting. Since unnecessary rebroadcasting is eliminated, redundant rebroadcasting, contention and collision issues can be avoided.

1.6 Traffic bottleneck wave

In the real world scenario most of the traffic congestion conditions that exist are not caused by accidents alone. Traffic congestion can be caused by multifarious reasons. Traffic congestions if caused by vehicular accidents should clear out once the collided vehicles have been removed, but it does not. Traffic bottlenecks can be created by reasons as simple as an overreaction by a single driver. The traffic bottlenecks or congestions behave like a wave that is travelling in the opposite direction of the moving traffic spreading to a vast horizon. The traffic bottleneck wave phenomenon can be explained by with the help of the following figures and corresponding explanations.

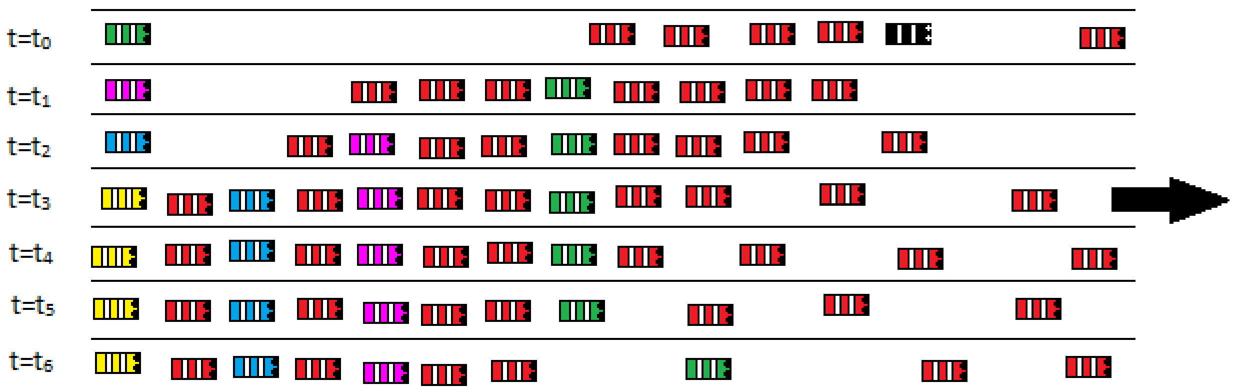

Figure 1.1: Traffic congestion and evaporation

Let us assume that at time $'t = t_0'$ a vehicle was wrecked; the wrecked vehicle is shown as black in color. The vehicles in the same lane that were following the wrecked vehicle are forced to stop and they pile up behind the wrecked vehicle. The number of vehicles that pile up depends on the vehicle density on that particular road. At time $'t = t_1'$, the wrecked vehicle has been removed so as the road block, in the mean time more vehicles pileup behind the road block and the vehicles come to a standstill. At time $'t = t_2'$ the traffic bottleneck slowly starts to dissolve towards the right and more and more vehicles pileup. To the left, notice the green, blue, violet and yellow vehicles. Though the roadblock has been removed, the vehicles cannot move at their own will. This is due to the fact that each vehicle has to wait until the vehicle in front has moved and allow a time lag to maintain a safe following distance. This lag spreads like a shock wave affecting all the vehicles along that lane. At time $'t = t_3'$, the violet, blue and yellow cars have been absorbed into the bottleneck and have come to a grinding stop. This phenomenon spreads like a shock wave travelling in the direction opposite as that of the moving traffic. At times $'t_4'$, $'t_5'$, $'t_6'$ the cars start to move liquidating the traffic bottleneck on the right, whereas more and more cars start to pileup on the left long after the roadblock was removed. Similar type of behavior is exhibited even when a driver overreacts, whenever a vehicle reduces its speed below the average speed of the vehicles in that particular road traffic bottlenecks could be caused. Traffic bottlenecks can persist for any length of time ($'T'$) depending on the traffic density on that particular road. It is directly proportional to the traffic density. If the traffic density is higher, then the traffic bottle necks can exist for a longer time.

Similar is the case when two lanes merge, if the speed of the vehicle is reduced well below the average speed, bottlenecks occur in the lane traffic. In case of lane merging, traffic density in the lane increases abruptly. The vehicles are forced to reduce their speed which falls way below the average speed of that particular lane and eventually causes traffic bottlenecks. Figure 1.2, shows the comparison of lane merging with prior knowledge to that of without the prior knowledge of the event. It can be seen that if the vehicles have prior knowledge about the lane merging they could adjust the speed in order to accommodate the abrupt increase in traffic density. If the vehicles are not informed, then all vehicles reduce their speed abruptly and fall way below the average speed which creates a shock wave. This creates a bottleneck that spreads in the direction opposite to the direction of travel.

In order to avoid such traffic bottlenecks the average speed of the vehicles in that particular road should be adjusted before hitting the traffic bottleneck, which is only possible by prior knowledge of the event. If the vehicles are aware prior to the incident being absorbed in to the traffic bottleneck, the vehicles could adjust their speed and could possibly avoid a traffic bottle neck situation.

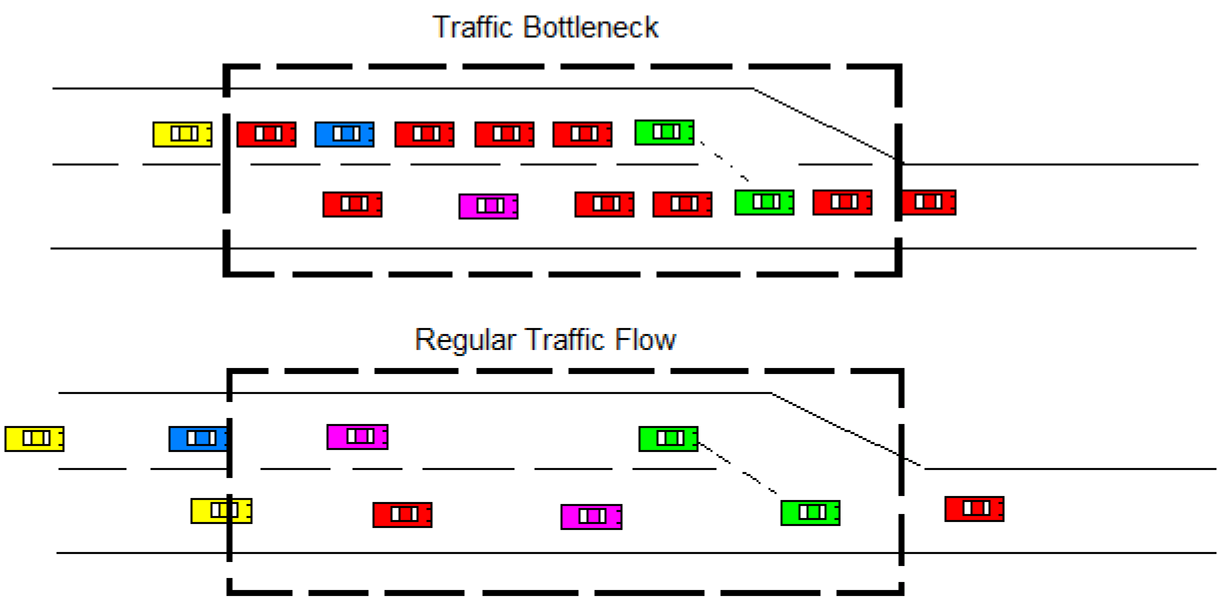

Figure 1.2: Lane Merging

Now if we know that beforehand knowledge of the incident could avoid traffic bottlenecks and future accidents, it would be logical to think ways in order to propagate the message. Propagating traffic information could be done by two ways, one by setting up repeaters along the highway and equipping vehicles with suitable receivers or by propagation through vehicles and distributing it to other peers. If the former approach is adapted, thousands of repeaters and amplifiers need to be installed as well as to equip vehicles with receivers. It would be rather considerable to think that propagation of information to the vehicles would prove more efficient and cost effective.

1.7 Thesis Organization

The thesis is organized as follows. Chapter 2 gives an overview of ad-hoc networks and wireless communication; it also presents the review of different protocols and broadcast schemes for VANET`s that propose a solution that would optimize broadcast propagation in VANET`s. Chapter 3 explores the proposed broadcast suppression scheme along with its characteristics and gives an overview analysis by comparing and contrasting various parameters proposed in the scheme with that of redundant rebroadcasting. Chapter 4 describes Groovenet and discusses the simulation setup along with the results obtained followed by corresponding discussions. Finally, Chapter 5 gives concludes the thesis and also cites future works that can be carried out in order to further enhance the proposed broadcast suppression scheme.

Chapter 2

Literature Review

This chapter provides a brief overview of wireless communication standards along with the working of VANET`s and the approaches that were proposed before, to contain the negative effects of unnecessary rebroadcasting. It also finally discusses the various message types and their corresponding characteristics.

2.1 Wireless Communication

This branch of telecommunication can transfer data without the help of wires. Few evident examples of wireless communication are cellular communication, Personal digital computers, GPS, computer mouse, headsets, satellite television, cordless phones etc. It has a significant role to be played in the multimedia society. The wireless network supports various standards like 802.11, 802.11a, 802.11b, 802.11g, 802.11n etc. These are collectively known as the Wi-Fi technology.

2.1.1 802.11

- Merits: The first WLAN standard which is a roadmap for other technologies to build on.
- Demerits: It was able to support maximum bandwidth of 2 Mbps which did not support many applications.

2.1.2 802.11b

- Merits: Less expensive, signals are not easily obstructed.
- Demerits: Low throughput

2.1.3 802.11a

- Merits: High throughput

- Demerits: Very expensive, short range signals can easily be broken.

2.1.4 802.11g

- Merits: Higher throughput and good signal strength.
- Demerits: Expensive when compared to 801.11b.

2.1.5 802.11n

- Merits: Higher throughput, best signal range and resistant to interference from outside sources.
- Demerits: 802.11b/g signal may interfere with the 802.11n standard.

2.2 Challenges in Wireless Communication

Being a challenging technology it faces competition at every facet like the following:

2.2.1 Data rate enhancement

Multimedia service is growing in a faster phase. In order to meet the requirements, the network should be capable of supporting high throughput. Due to the high rate of video traffic compression the network should be efficient enough to support them.

2.2.2 Reducing the size and cost

Smaller the device the more convenient it is to use. Reducing the cost can also make the use of wireless network widespread.

2.2.3 Minimizing the power usage

The wireless devices are smaller so size of the battery is the question of concern. They have a limited range. It is great challenge to use the power efficiently on the wireless networks.

2.2.4 Providing user security

Due to the liquidity of the network it is more vulnerable to attacks. So providing security on the air is a challenge.

The IEEE 802.11 provides a feature called Wired Equivalent Privacy (WEP) authenticates and encrypts data.

2.3 Alternate wireless technologies

2.3.1 Bluetooth

Bluetooth does not fall within the 802.11 family it supports a short range communication of 10 meters having a bandwidth of 1-3 Mbps.It requires a low production cost as it is still being used in small devices like PDA‟s, cell phones etc. This field requires more research to support normal WLAN networking supporting high bandwidth and throughput.

2.3.2 WiMax

WiMax supports long range communication and does not use any Wi-Fi standards. Challenges are met efficiently by wireless networks. As the scope of this field is wide and is always growing at a faster phase.

2.4 Ad-hoc networks

Is a branch of wireless network using 802.11 standards; it does not depend on any infrastructure to transfer data. Each node is responsible for transferring the packet, rather than a router or an access point doing the job. The node forwarding the packet is selected instantaneously based on the availability of nodes in the network. It is considered to be a peer network between the nodes. So connection to the internet is possible if one of the nodes has access to the public network. It will share the resource with the other nodes; else connection to the internet would be impossible. It is a not a permanent network as it changes based on the availability of nodes.

2.4.1 Organization of Ad-hoc networks

Nodes within the transmission range of stay connected. If a node moves away from the transmission range of a node, it still remains connected via different node although it is far off from the range. This feature ensures that all nodes remain well connected in an ad-hoc network. In a small office environment, a LAN can be setup instantaneously by setting the NIC card to ad-hoc mode then files can be transferred without the help of any cable and access point.

2.4.2 Different types of ad-hoc networks

(i) MANET (Mobile Ad-hoc Networks)

In addition to the ad-hoc nature they are capable of routing traffic. It is a mesh network. It consists of mobile devices connected through wireless links. The efficiency of MANET depends on routing the traffic. The following are the different types of networks in MANET:

- VANET (Vehicular Ad-hoc networks)

  Inter vehicular communication on the road is achieved using VANET with the help of Road Side Units.

- InVANET (Intelligent Vehicular Ad-hoc Networks)

  It has some additional intelligence added to VANET which makes the vehicle act efficiently at the time of emergency.

- iMANET(Internet based Mobile ad-hoc networks)

It acts like a bridge between mobile nodes and fixed internet gateway nodes. It does not use the normal ad-hoc routing algorithm.

2.4.3 Advantages of Ad-hoc networks

(i) Economical

Cost effective it saves a lot of money as there is no infrastructure needed to build this network.

(ii) Less Setup Time

Short time to setup it only requires a radio NIC on the device to create an ad-hoc network. So it is much quicker when compared to the setup of other infrastructure based networks.

2.4.4 Disadvantages of Ad-hoc networks

(i) Support smaller networks

The ad-hoc network proves to be efficient on a smaller network as it does not make use of any access points to forward the packet. But in a larger network, access points are required to have non overlapping channels, reduce medium access contention and to reduce collisions. The beacon interval taken to alert the non-transmitting nodes can degrade the performance of ad-hoc networks as it adds additional packet transmission.

(ii) Inefficient Internet Access

Access to the internet is not as efficient. A wired network with access point is required to meet the requirements of a larger group.

(iii) Network Management

Due to the lack of a central device in the ad-hoc network it is difficult to manage the network. Performing security audits is difficult as there is no access point to monitor the topology. The only way to manage the ad-hoc network is at the user level. It again adds more overhead to packet transmission.

2.5 Broadcast storm

In wireless Ad-hoc network multi-hop relaying is done to increase the area covered by the message and to increase the probability of message delivery. The most feasible method to perform multi-hop relaying is to flood/rebroadcast the message. Redundant rebroadcasting of the message causes three major issues with wireless Ad-hoc networks.

2.5.1 Flooding

Multi-hop relaying in VANET`s is achieved through flooding. In VANET`s, flooding is done in such a way that when a node receives a safety message the node then rebroadcasts the message and the rebroadcasting node will ignore the subsequent messages that are broadcasted by its peers, due to the fact that it has already received the message. Even though the node ignores the redundant rebroadcast, it still has to process the entire message to identify that the message is redundant. Redundant rebroadcasting forces a node to listen to the message and process it in order to only identify that it is a redundant rebroadcast. Redundant rebroadcasting causes inefficient use of bandwidth. Even though flooding increases the probability of a message being delivered it also induces redundant rebroadcasts, strong contention and severe collisions.

2.5.2 Redundant rebroadcasting

Each node that receives a broadcast message rebroadcasts the message again. For an example, if a message is generated by a node with *n* nodes in a transmission range would force each and every node to rebroadcast the message at least once. This would result in *n* additional rebroadcasts. It would be effective to identify and suppress redundant rebroadcasts, in such a way that the nodes will be well informed and will selectively rebroadcast the message only when required.

2.5.3 Contention

Contention occurs when the probability of the nearby nodes receiving the message is higher. Each node that is in close proximity that received the message will try to rebroadcast the message causing severe contention.

2.5.4 Collisions

Since the messages are broadcasted, collisions occur due to absence of collision detection mechanism. In broadcasts RTS/CTS are not included.

The four above mentioned issues are collectively known as broadcast storm problem and occur due to the fact that rebroadcasting is not done effectively. Several researchers had put forth various approaches to control rebroadcasting; the most prominent approaches are discussed in the following sections.

2.6 The Broadcast Storm Problem in Mobile Ad-Hoc Network

In this research work [1] five approaches are suggested to control the number of broadcasts. In the first approach when a node receives a message it retransmits the message with a probability 'P'. In the second approach, a counter is used and the number of times a message is received is counted before a message is transmitted. If the counter exceeds the threshold then the message is transmitted. In the third approach the distance between the sender and receiver „D_{min}' is calculated from the transmitted and received power. If „D_{min}' is lesser than the „D_{thr}' then the message is not rebroadcasted. In the fourth approach the position of the node is calculated and if the coverage area is higher than a predetermined coverage threshold then the message is retransmitted else the message is not rebroadcasted. The fifth approach is dividing the transmission area into clusters.

The approaches presented in this research work strongly suggest that location based scheme performs effectively under all circumstances and the counter based scheme effectively controls the negative effects of flooding [11].

2.7 Vehicle-to-Vehicle safety messaging in DSRC

In this research work [2] authors explore six MAC protocols. The message is rebroadcasted *k* times without (AFR) a guarantee that the message is being received. In Asynchronous Fixed Repetition, the message is rebroadcasted k times among the total $'n'$ slots; the value of $'k'$ is fixed. The second protocol (Asynchronous Persistent Repetition) the message is repeated *k* number of times as in AFR but here the value of $'k'$ varies. The message transmission probability is given by $'k/n'$ where $'k'$ is the configuration parameter and $'n'$ is the total number of transmission slots. Thirdly, Synchronous Fixed Repetition (SFR) is used. SFR is similar to the AFR except the slots are globally synchronized. Fourth, Synchronous Persistent Repetitions SPR is used which is similar to SFR except that p-persistent are considered. Fifth, AFR-CS with carrier sensing is used, in this approach carrier sensing is done and if the medium is free the message is rebroadcasted and the message is dropped if the medium is occupied. Sixth, APR with carrier sensing APR-CS is used, which is similar to AFR-CS except the messages are repeated with p- persistent. Authors finally conclude that 802.11a can be used for DSRC [11].

2.8 Urban Multi-Hop Broadcast Protocol for Inter-Vehicle Communication Systems

In this research work [3] Urban Multi-hop Broadcast protocol (UMB) is proposed. According to UMB protocol the broadcast messages are not relayed by all nodes, instead the farthest node from the sender is selected and the farthest node is selected for relaying the message to other nodes. It also introduces Request To Broadcast (RTB) and Clear To Broadcast signaling. RTB is sent from the transmitter to the farthest node, if it receives a CTB from the receiver the message is broadcast to the receiver. The farthest node is selected by black burst. In the case of intersections, repeaters are used to avoid the effect of shadowing by large buildings. The research also suggests various techniques to avoid loops. This research work tries to reduce collisions and increase the effectiveness of broadcast without overloading the medium.

The UMB protocol fares well when compared to all other flooding mechanisms reducing the load on the network [11].

2.9 A Vehicle-to-Vehicle Communication Protocol for Cooperative Collision Warning

In this research work [4] Vehicular Collision Warning Communication (VCWC) protocol is proposed. There are two approaches considered, passive and active. In the passive approach each and every vehicle constantly sends updates about its state to the neighboring vehicles. The neighboring vehicles receive the updates and process them to know if the vehicle is in a dangerous state. The drawback of passive approach is that the medium is always saturated. In the active approach, a vehicle sends out an Emergency Warning Message (EWM) only when an emergency situation such as sudden deceleration occurs. VCWC protocol uses active approach. The EWM warning system allows multiple vehicles to communicate simultaneously [11].

2.10 Broadcast Reception Rates and Effects of Priority Access in 802.11-Based Vehicular Ad-Hoc Networks

In this research work [5] the authors study the probability of message being received at a certain distance from the transmitter and the deterministic and non-deterministic results are compared in VANTET`s. The authors conclude that Non-deterministic approach has very low reception rates compared to deterministic model. The reception rates decrease with the increase in distance of separation between the sender and the receiver even though the receiver is within the transmission range of the sender. This brings up the fact that multi hop relaying and reception strategies should be used to increase the reception rate of the messages in VANET`s [11].

2.11 Message Categories:

In VANET`s, the messages divided into three categories, Safety of life, safety and Non Safety messages. Safety of life message is given the highest priority followed by safety and Non safety messages are given the lowest priority.

2.11.1 Safety of life

As the name indicates Safety of life messages carry information that directly and immediately impact the safety of the vehicle that is travelling along the highway. Safety of life messages has the highest priority and the latency should be minimal.

Example: Intersection collision warning/ Avoidance.

2.11.2 Safety Message

As the name indicates Safety messages carry information that could impact the safety of the vehicle that is travelling along the highway, but is less crucial when compared to safety of life messages. Since safety messages are more like a warning and are not life threatening, latency up to 1000 ms is allowed.

Example: Work zone warning

2.11.3 Non Safety message

As the name indicates Non Safety messages carry information that would not impact the safety of the vehicle that is travelling along the highway. The latency allowed depends on the type of the message.

Example: Toll collection.

Chapter 3

I-Broadcast scheme

Majority of the proposals in this area intend to suppress the broadcast without the identification of redundant broadcasts. This forces the nodes to transmit, receive and process the message even to know that it is redundant and unnecessary. In the proposed scheme broadcast message identity tags are used to effectively suppress the broadcasts with message identification. This chapter discusses the various characteristics of redundant rebroadcasting and an overview of the proposed scheme.

3.1 Redundant rebroadcasting

As the name indicates, each node that receives a broadcast message from its peers, rebroadcasts the message and ignores subsequent rebroadcasts of the same message.

Let us assume that there are $'n'$ nodes in a highway segment, if a node initiates a broadcast message, all other nodes in the transmission range that received the message will rebroadcast the message at least once and ignore subsequent broadcasts. One broadcast followed by $'n-1'$rebroadcasts that are redundant are genarated.

3.1.1 Need for redundant rebroadcasting

In VANET`s rebroadcasting is done to ensure that the broadcasted message reaches all the nodes and to increase the probability of the message being received by a node that is experiencing collisions or currently offline. Though the redundant rebroadcasting is intended to increase probability of the message being delivered, it is inefficient**.**

From the previous research that has been carried out, it was learnt that redundant rebroadcasting in the region that contains more than four nodes, the expected additional coverage is below 0.05% [1].

3.1.2 Effects of redundant rebroadcasting

In redundant rebroadcasting, every node broadcasts the message that it has received at least once and ignores subsequent broadcasts of the same message.

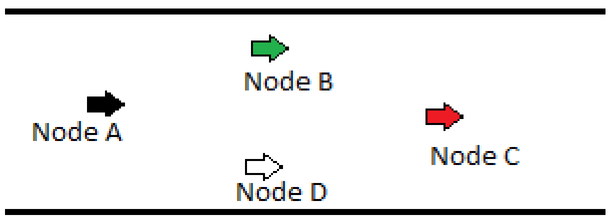

Figure 3.1: Transmission range

In order to explain the effects of redundant rebroadcasting, let us assume that there are four nodes travelling along a highway within the transmission range of each other, as shown in Figure 3.1. Let us consider that, Node C generates a safety of life broadcast message. Since Nodes A, B and D are within the transmission range of Node C, Nodes A, B and D will receive the rebroadcasts, process the rebroadcasts and will redundantly rebroadcast the message at least once and ignore subsequent rebroadcasts. This very nature of redundant rebroadcasting forces the nodes not only to listen, process and rebroadcast the message but also causes inefficient use of bandwidth, strong contention and collisions.

This calls for an efficient scheme that would suppress the redundant rebroadcast as well as serve the purpose of redundant rebroadcasting.

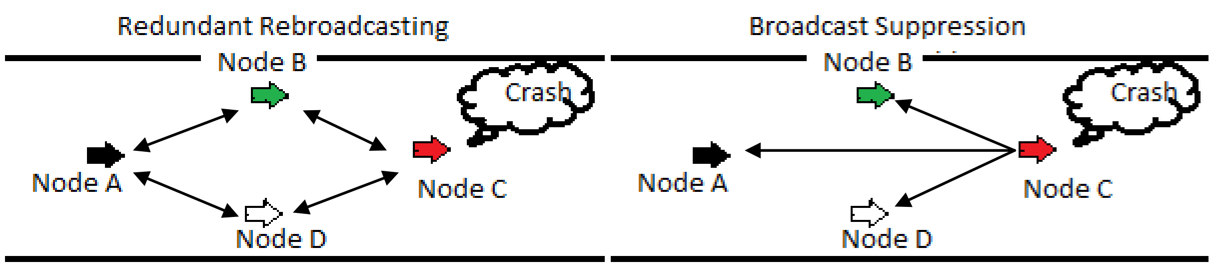

Figure 3.2: Redundant rebroadcasting and Broadcast suppression

Figure 3.2, shows the number of redundant broadcasts generated due to repeated rebroadcasting. When an efficient broadcast suppression is employed, unnecessary redundant rebroadcasts can be reduced while serving the purpose of rebroadcasting.

It is learnt from the previous research that redundant rebroadcasting of message in a region with more than four nodes, the expected additional coverage is below 0.05 % [1]. The above analysis suggests that redundant rebroadcasting should be reduced to avoid the negative impacts of redundant rebroadcasting.

3.1.3 Advantages of rebroadcast suppression

- ✓ Unnecessary rebroadcasts are suppressed.
- ✓ Hidden terminal issue is less likely to occur.
- ✓ Efficient usage of bandwidth.
- ✓ Reduced collisions.
- ✓ Reduced Latency.

3.2 Proposed broadcast tagging scheme

Designing broadcast suppression scheme for VANET mandates that the scheme be efficient in suppressing redundant rebroadcasts, robust and bandwidth efficient. In order to maintain and keep the nodes informed about the local topology if not the global topology, mandates the beaconing of hello messages between the neighboring nodes, as required by most of the safety applications. Though the beaconing of hello messages is a bit inefficient concerning bandwidth usage, the proposed protocol uses the tags attached to the hello/broadcast messages that help in identifying redundant rebroadcasts and to suppress them.

The following assumptions were made while designing *i*-broadcast scheme. First it is assumed that the nodes are equipped with a GPS and a wireless communication device. Second, it is assumed that infrastructure is not present. Third, the vehicles should be capable of beaconing hello messages at a predefined frequency. The hello messages that are exchanged according to the scheme contain an information tag which differentiates it from the regular hello messages.

3.2.1 Design principle

The proposed scheme makes use of hello message tags to obtain local topology information, as opposed to global topology which can be made available to the nodes with the help of roadside units and other sources in the future.

3.2.1.1 Message Tag

Hello messages that are beaconed by all the nodes to gain local connectivity information contain a tag. The tag carries information about the initiator/originator of the message, message type, sector ID and the broadcast message ID. The tagged information is used to identify suppress the redundant rebroadcast. The tag is designed to be four bytes long. Figure 3.3 shows the tag.

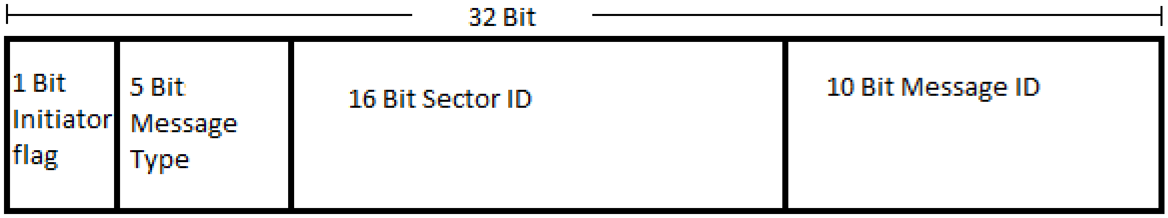

Figure 3.3: Message Tag

Following are the fields that are included in the tag.

- ✓ Initiator bit – 'B_i'
- ✓ Message type – 'M_t'
- ✓ Sector ID – 'S_i'
- ✓ Message ID – 'M_i'

(i) Initiator Bit ('B_i'):

The initiator bit field in the tag is used to differentiate a message from its rebroadcast. This bit is set by the originator of the message and all other nodes that rebroadcast/relay the message will reset the initiator bit.

If the bit is set, the probability of the nodes suppressing the message from rebroadcasting is less likely, when the bit is reset the nodes will have either suppress or rebroadcast the message depending on other indicators.

(ii) Message type ('M_t'):

The next five bits are allocated for the message type field. This equips the node with the ability to decide which message they can discard and the type of messages that needs to be processed. Currently “Open Message”, “Hello Message”, “Relay message”“ and “RCE” are assigned a message type of “00000”, “00001”, “00010”“ and “11111” respectively. All other values are reserved for future use.

(iii) Sector Id ('S_i'):

Two bytes, that immediately follow the message type field is the sector ID field. According to the proposed scheme, the highway is segmented into different sectors based on the mile marker. Each sector is given a unique sector ID. For an example let us consider highway ABC that starts with mile marker 0 and ends with mile marker 200. Then highway ABC eastbound will have a sector ID as one from mile marker 0 to mile marker 10 and will have a sector ID of two from mile marker 11 to mile marker 20 and so on. Similarly, highway ABC westbound will have a sector ID as one from mile marker "191"" to mile marker „200" and will have a sector ID of two from mile marker "181"" to mile marker "190"" and so on. One important factor that should be noted is that, the order in which the sector ID`s are allocated is always reversed for the opposite direction of the highway.

(iv) Message ID ('M_i'):

The message Id field is ten bits in length. This field is set by the initiator of the broadcast message and is not changed when rebroadcasted. Each sector can have up to 2^{10} message ID`s and are reset when the limit is reached.

3.2.2 Working

The effectiveness of broadcast suppression depends on how informed the node is about the local topology of the network. In order to effectively suppress unnecessary broadcasts, the nodes should not only be able to determine if the broadcasted message is redundant or not, but also rebroadcast/suppress the message when required. According to the proposed scheme, all nodes that participate in the vehicular ad hoc network will beacon tagged hello messages at a predetermined frequency. The tags are similar to extension headers that are included in both the hello messages and the broadcast message itself.

The highway is segmented into different sectors based on the mile marker, each of these sectors have a range of message ID`s. According to the highway sector a node is travelling in, the node that originates a broadcast will populate the tag with corresponding information. All other nodes that hear the hello message /broadcast message along with the tag will retain the information that is contained in the tag. Tagged hello messages are exchanged between the nodes at a predetermined frequency, all the nodes will be aware of the last known broadcast`s message ID for the corresponding sector. When another node initiates a broadcast message for the same sector of the highway, the node will populate a new tag with the required information based on the information that was present in the last known tag. All other nodes that hear the broadcast will reset the 'B_i' bit and will relay/ rebroadcast the message. When the message ID reaches the maximum value the nodes reset the message ID to the initial value of the sector.

3.2.3 Broadcast suppression

Broadcast suppression reduces bandwidth utilization and broadcast storm problem. To effectively reduce the redundant broadcasts the node should be able to identify the message that needs to be relayed/rebroadcasted opposed to the messages that appear to be legitimate initial broadcast. The identification should be done before the rebroadcasting is done, this can be done by keeping nodes informed on what message/broadcast is prevalent and relevant for that sector. Message identification is done by the tags. Since the tags are exchanged periodically at a predetermined frequency every node can be made aware of the latest broadcast message.

A tag is considered to be superior if,

1. The initiator bit is set and the message type is not "00000"".
2. The sector id is higher.
3. The message id is higher.

If a node receives a message with a tag that is inferior from one of its peers, it is apparent that the node needs to be updated with the latest message, then the message is rebroadcasted and the rebroadcast is only done by the node that is closest node that sent the message with an inferior tag determined. The nodes entering a new sector from the previous sector will exchange hello messages with tag containing the message ID of the last known broadcast of the previous sector of the highway, the nodes in the new sector will receive the tag and will recognize that the tag is inferior and will broadcast the message. By identifying, suppressing and selectively rebroadcasting the message, unnecessary redundant rebroadcasts can be effectively suppressed. This inturn results in efficient use of bandwidth and effective reduction/elimination of the broadcast storm problem.

The following scenarios are considered to explain the proposed scheme in detail.

Scenario 1: *A node enters a new sector of the highway.*

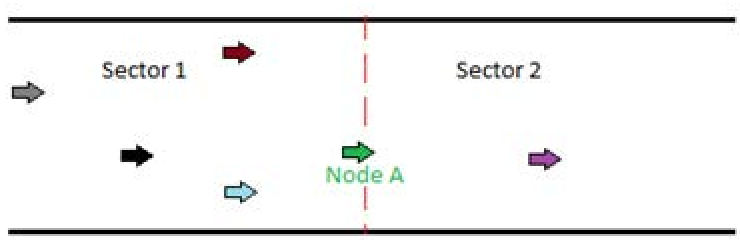

Figure 3.4: Scenario 1

As shown in Figure 3.4, Node A enters sector 2 from sector 1. Let us assume that the last known message ID for sector one is *x + (n-1).* Even after entering sector 2, Node A will still beacon messages with a tag from the previous sector. The nodes in sector 2 that hear the hello messages from Node A will compare the tag from Node A to that of their own, nodes in sector 2 will know that Node A has tag and node A needs to be updated. The nearest node to node A will broadcast the message.

Scenario 2: Crash in a divided highway

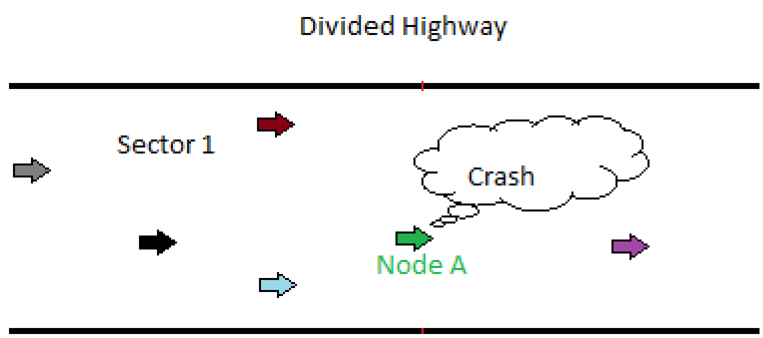

Figure 3.5: Scenario 2

Consider the following scenario in which Node A has crashed in a divided highway, as shown in Figure 3.5. The node that suffered a crash, broadcasts a message with the message ID'x', the nodes that within the transmission range of the node that crashed will hear the broadcast and will update the tag information and will exchange tags with the message ID 'x' and rebroadcast the message until a message with the same or superior message ID is received. The nodes that are approaching the crash site that did not get the message will exchange tags with the nodes that are closer to the crash site and will have an inferior tag. The node that is closest to the node that sent inferior hello will rebroadcast the message and this process repeats and all others will suppress the rebroadcast.

Scenario 3: Crash in an undivided highway.

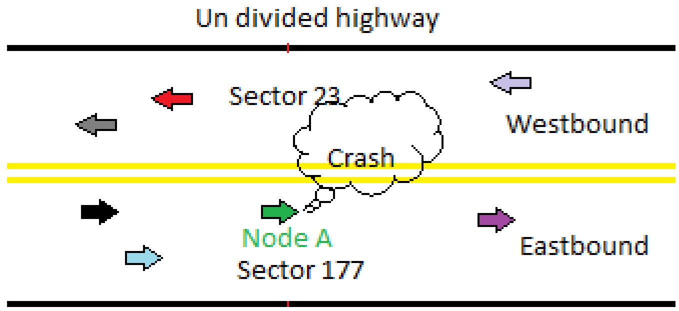

Figure 3.6: Scenario 3

Consider the following scenario in which Node A has crashed in an eastbound undivided highway, as shown in Figure 3.6. The node that suffered a crash, broadcasts a message with the message ID$'x'$, sector ID 177 and the message contained is safety of life message. Since the highway is divided the traffic safety incident can affect both the lanes. It is possible that the nodes in the eastbound direction have come to a stop and have no neighbors. The message broadcast scenario is similar to the divided highway scenario with one critical difference. In an undivided highway scenario the vehicles that are travelling in the opposite direction store the broadcast message with the message type as Relay “00010”” and rebroadcast the safety of life message for a limited number of sectors for which the message is relevant. Default is three sectors.

Scenario 4: A node enters a new highway:

Consider the following scenario in which Node A enters Highway X eastboundy, as shown in Figure 3.7. Since Node A has entered a new highway, the tag information that node A has cached is irrelevant to the current highway. Node A will originate broadcasts with type open “00000”” and will start to increment its message ID and will update its tag when it hears a message form it peers along the highway.

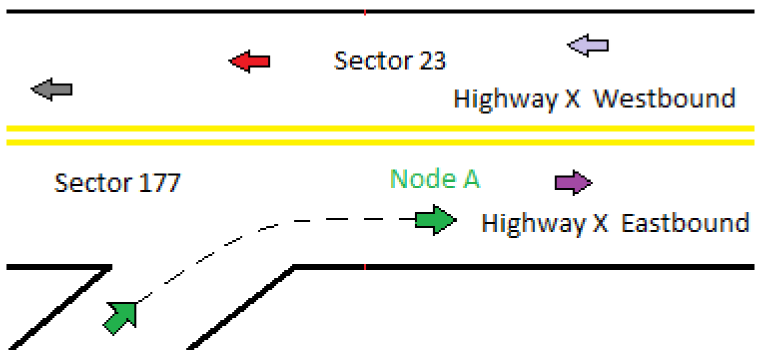

Figure 3.7: Scenario 4

3.2.4 Algorithm

1. Node A is in Listening/ Learning state.
2. Node A receives a message from node B.
3. Determine the highway type UD (Divided (0)/ Undivided (1)), Direction of travel (DT) (1- Same, 0- Opposite) highway sector, message type and if B is the initiator of the message.
4. If message type is “00010” go to step 14.
5. If UD=0 & DT=1 go to step 9.
6. If UD=0 & DT=0 go to step 1
7. If UD=1, if the message is safety of life and DT=0, rebroadcast the message for three sectors with a message type “00010”.
8. Compare the tag of the received message to the cached message tag.
9. If the tag is inferior go to step 12
10. If the tag is superior, process the message and rebroadcast the message if B is the initiator of the message then go to step x until a message with a superior tag or an equivalent tag is received.

11. If the message ID is the same, go to step 1.
12. Determine if Node A is the closest node to Node B.
13. If closest, rebroadcast Else goes to step 1.
14. Rebroadcast message until a message is received with superior or the same tag, go to step 1

3.3 Analysis

To compare the proposed and the current approach employed in VANET`s, a simple scenario is considered. Let 'd' be the transmission range of a node. Assume that there are 'N' nodes randomly positioned within three sectors. Let 'L_s' denote the length of a sector in miles. In the observation time period „t", let us assume that „n" number of broadcast messages are generated by node that suffered a safety incident.

3.3.1Redundant Rebroadcasting

Number of messages

Let the total number of broadcasts in time period „t" by redundant rebroadcasting approach be denoted by 'M_{RR}'. As stated before, in redundant rebroadcasting every node that hears a broadcast at least once. Therefore, the total number of messages will be proportional to the number of safety messages generated and the number of nodes. Then, MRR is given by the following equation.

$M_{RR} = n \times N - j$; -- 1

Where 'j' denotes the number of messages that are lost due to collisions. The value of 'j' was computed using statistical data.

Total energy spent

Let ‘$E\mu$’ be the energy spent by a node in processing one broadcast message. The total energy spent by a node in processing a message is proportional to the sum of energy spent by a node in processing one broadcast message and that of a rebroadcast message. Then, the total energy spent be a node, ‘$E\beta_{RR}$’ is given by

$E\beta_{RR} = E\mu * n + E_K$; -- 2

Where ‘E_K’, is the energy is spent by node in processing rebroadcasts.

Transmission Range

In redundant rebroadcasting, the maximum transmission range of a message is directly proportional to the transmission range of last node that has the message. Transmission range it varies with vehicle density. The maximum transmission range that can be achieved by redundant rebroadcasting scheme T_{RR} is given by,

$d < T_{RR} < d_{last}$; -- 3

Where,

‘d_{last}’ = Transmission range of the last node that relays the message.

3.3.2 i-Broadcast scheme

Let the total number of broadcasts in time period 't' generated by i-broadcast scheme be denoted by ‘M_{BI}’. In the proposed scheme a node broadcasts a message redundantly only when there is an absolute need. Therefore, the total number of messages will be proportional to the number of safety messages generated and expectation of the number of retransmissions by relay node and the expectation of a node to rebroadcast the message.

Then,

$M_{BI} = n + E(X) + E(X_R)$; -- 4

'$E(X_R)$', is the expectation of the number of retransmissions of the relay node and '$E(X)$' is the expectation of number of rebroadcasts of the other nodes within a sector. The values of '$E(X)$' and '$E(X_R)$' can be calculated using the following equation.

$$E[N_\Delta] = \int_0^{2\pi} \int_{\rho 1}^{\rho 2} N_\Delta \frac{1}{\pi \rho_1^2} r dr d\theta ; \text{ -- 5}$$

This is the number of expected nodes that can rebroadcast the message initiated by the source node in a circular region bounded by radii '$\rho 1$' & '$\rho 2$' [13].

Total energy spent

Let '$E\mu$' be the energy spent by a node in processing one broadcast message. Then the total energy spent by a node in the transmission range '$E\beta_{ib}$' is given by

$E\beta_{ib} = E\mu * n + E_K$; -- 6

Transmission Range

The transmission range in the proposed approach is increased and it does not vary with vehicle density. The transmission range „T_{Ri}'of the message lies between 'L_s' and '$3L_s$' when a message is relayed.

$L_s < T_{Ri} < 3L_s$ --- 7

It is a notable fact that the maximum transmission distance of a message does not depend on the transmission range of the node and is bounded.

Chapter 4

Simulation Results and Analysis

This chapter gives an overview of the simulator used and also discusses the results along with corresponding explanation.

4.1 Groovenet Overview

Groovenet v1.0.1 [6] is a simulator developed using C++ and Qt graphics cross platform library in Linux. This hybrid simulating tool supports the following standards: Dedicated Short Range Communication (DSRC), Simulations across multiple channels, Denso Based DSRC network.

Groovenet has the following unique characteristics when compared to the existing ad hoc network simulators:

- For accurate representation of the vehicles, Groovenet has the following models: simple car following, traffic lights, lane changing and simulated GPS model.
- The GUI generates maps automatically, with any number vehicles in United States. All vehicles are displayed based on their current location recorded from the GPS.
- It supports three types of nodes, fixed infrastructure nodes, mobile gateways and vehicles which have the capacity to do multi hoping of data over one or more DSRC channels.
- Groovenet collars up many message types, GPS message which is a broadcast and keeps track of the neighbor‟s position, Vehicle emergency and warning event messages with priorities.

- The simulator can support interfaces with following standards: 5.9GHz DSRC interface, IEEE802.11a/b/g, 1xRTT and EVDO cellular interfaces. TCP/UDP sockets are used to establish communication. Real vehicles communicate with each other using DSRC or 802.11. Cellular interface is used for communication between mobile gateways and infrastructure nodes.
- Groovenet is called a hybrid simulator as it allows communication between real and simulated vehicles. Real vehicle communicate with simulated vehicle only within its transmission range.
- It has the capability to communicate with the vehicles on board computers and read the ODB-II codes. Events like deceleration, braking, air bag deployment can lead to the generation of alert or warning messages.

4.1.1 Groovenet Architecture

Groovenet serves dual purpose as a simulator as well as a test bed for on-road experiments. As shown in Figure 4.1, the map database and the Simulator test file are the necessary inputs for the simulation mode. The onboard diagnosis, GPS positioning and one more interfaces are the required for test bed experiments. The simulator gives the outputs in the following forms

- It gives a visual map which pictures the vehicles location.
- All the events, vehicles data and communication is generated as a log files and given as an output.
- Packets can select any number of interfaces and transmit for real vehicle communication.

The Core has a model manager with which models register and an event queue schedules events for individual vehicle and its model. When started Groovenet reads text files and converts them into binary encoded files with a pictorial graph in it.

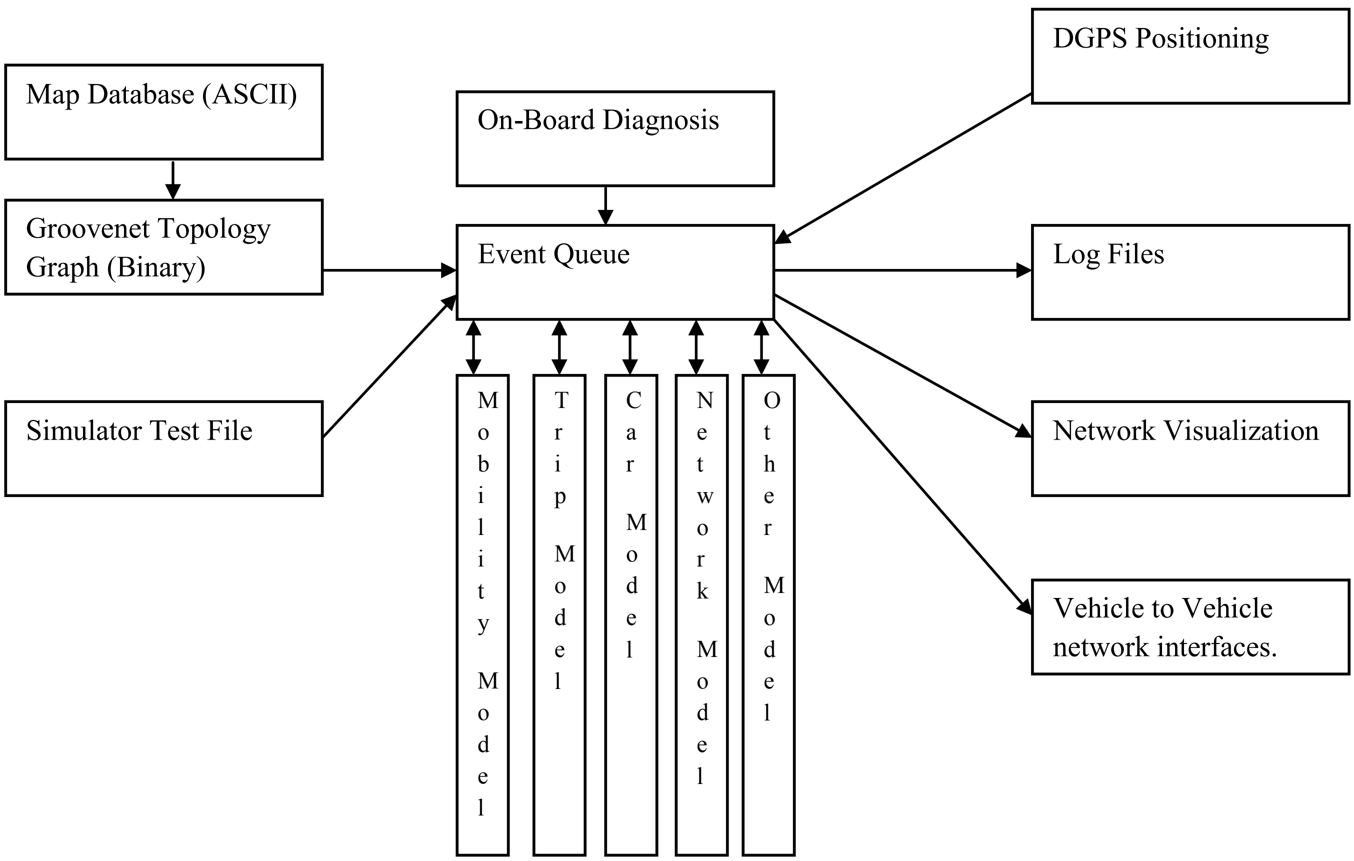

Figure 4.1: Groovenet Architecture

4.1.2 Simulation parameters:

All the simulations were done with the following parameters, unless stated otherwise.

- Propagation mode: Free space
- Spectrum: DSRC
- Number of channels: Seven

- Simulation Area: 1Km *1Km square area, unless stated otherwise.
- Transmission Range: 300 m – 1Km
- Simulation runtime: Varies with simulation
- Packet nature: Broadcast
- Message Type: Safety of life (Car Crash)
- Communication is strictly Vehicle to Vehicle.
- All messages are broadcast in nature and are safety of life messages.
- All vehicles exchange periodic hello messages.
- Road type is undivided, unless stated otherwise.
- Tag information was included in the data portion of the message for simulation puroses.
- External interferences were not taken into consideration
- Number of nodes: Simulations were done with 10,30,50,80,100 nodes in order to measure the characteristics of the proposed scheme under different traffic conditions
- Medium access/collision avoidance: CSMA/CA

4.2 Performance metrics:

The Performance of the proposed Broadcasting scheme for VANET`s was evaluated by measuring the following metrics:

- Packet Loss ratio
- Total delay to disseminate a broadcast message to a node that is 10 Km away
- Number of rebroadcasts generated

4.3 Results and Discussion:

Simulations were run with 10,30,50,80,100 nodes and the performance metrics were measured. Detailed results and corresponding discussion are as follows

4.3.1 Packet loss ratio:

Packet loss ratio is the ratio between the number of packets lost to the sum of number of packets lost and the number of packets received successfully.

Packet loss ratio is an important parameter that measures the reliability of a broadcast scheme. As one would think, the packet loss ratio and the efficiency of a broadcast scheme are inversely proportional. Packet loss ratio benchmarks reliability, in order for the scheme to be reliable, packet loss ratio should me minimum. In order to measure the packet loss ratio, a fixed number of packets were generated in each simulation trial and their corresponding loss was measured. To calibrate the efficiency of the proposed broadcast scheme simulations were run with 10, 30, 50, 80 and 100 nodes. All nodes were randomly positioned and travel at uniform velocity.

Figure 4.2 shows the packet loss ratio plot of the proposed broadcast scheme. Three different trials were run with the same setup and parameters. The average of the three trials is also plotted in Figure 4.3. It can be seen that packet loss ratio increases with increase in node density. As the node density increases, the probability of packet loss is higher. The simulation results show that the proposed scheme performs well and the packet loss ratio is low when compared to other similar approaches. Though the proposed scheme does not have direct parameters to control the packet loss, it does so indirectly by suppressing unnecessary rebroadcasting. According to the proposed scheme, need to rebroadcast a packet arise when a peer needs to be updated or when a relay packet is broadcasted. Since the need to rebroadcast a packet arises only when it is absolutely needed, collisions and contentions are reduced to a great extent which results in reduction in packet loss and better packet loss ratio. In redundant rebroadcasting, every node that receives a broadcast should rebroadcast it at least once and ignore subsequent rebroadcast, this causes collisions and contention. From the plots it can be deciphered that, the packet loss ratio stays well below 6.5 %. Even when there are 100 nodes per Km, packet loss ratio is very less when compared to other similar approaches. The reduction in packet loss can be attributed to the efficiency.

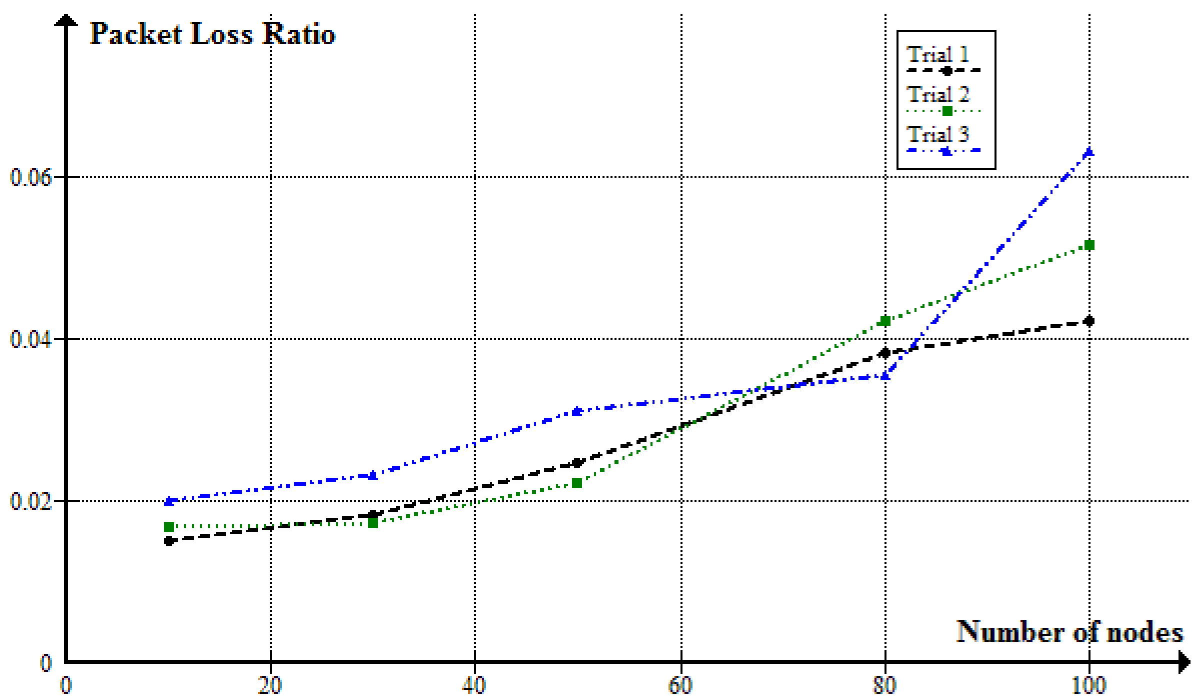

Figure 4.2: Packet loss ratio, Trial 1, 2&3.

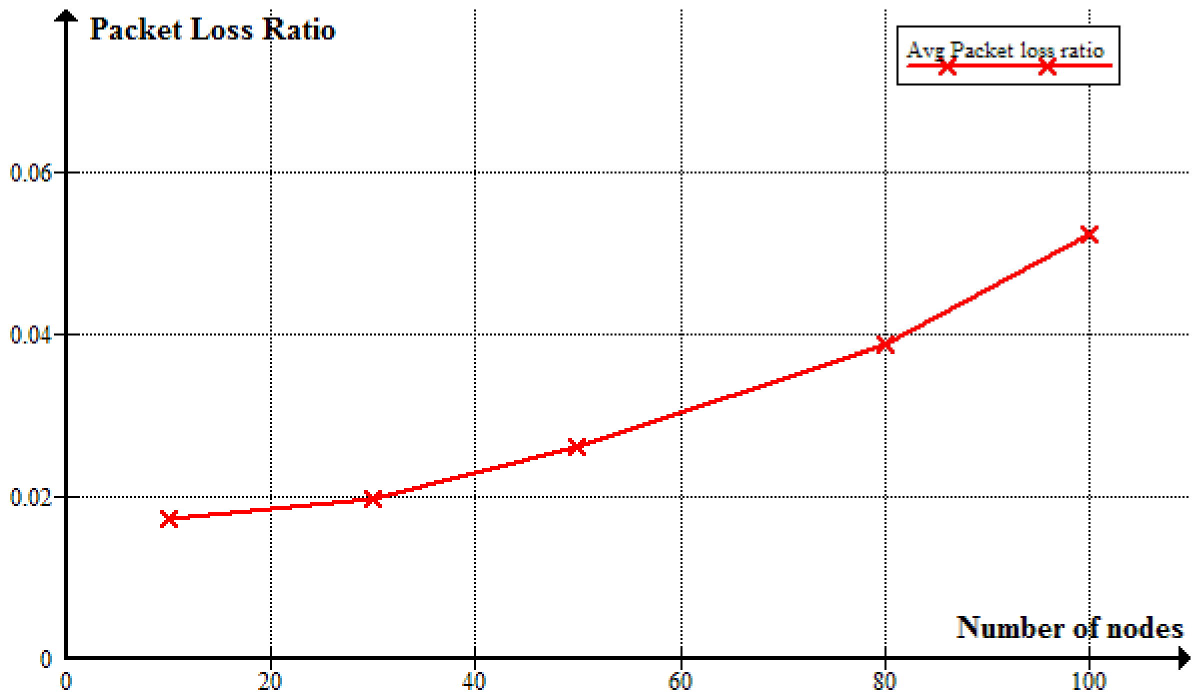

Figure 4.3: Average packet loss ratio

4.3.2 Number of Rebroadcast generated

The main goal of this research work is to reduce the unnecessary rebroadcasts and subsequently reduce issues such as collisions, contention and inefficient usage of bandwidth can be avoided.

Figures 4.4 through 4.8 show the comparison the number of rebroadcast that was generated by redundant broadcasting and that of proposed i-broadcast scheme, to disseminate a safety of life broadcast message. Five different trials were run with the same setup and parameters. Figure 4.9 shows the average number of rebroadcasts generated for both the approaches. From the plots it can be seen that, the proposed i-broadcast scheme reduces the number of rebroadcasts by more than 40% when compared to that of redundant rebroadcasting.

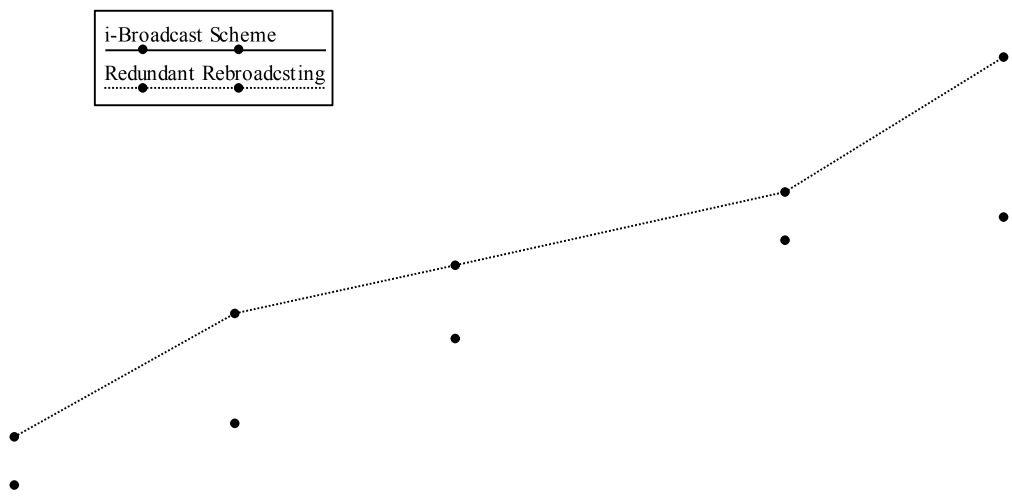

Figure 4.4: Number of rebroadcasts generated, trial 1

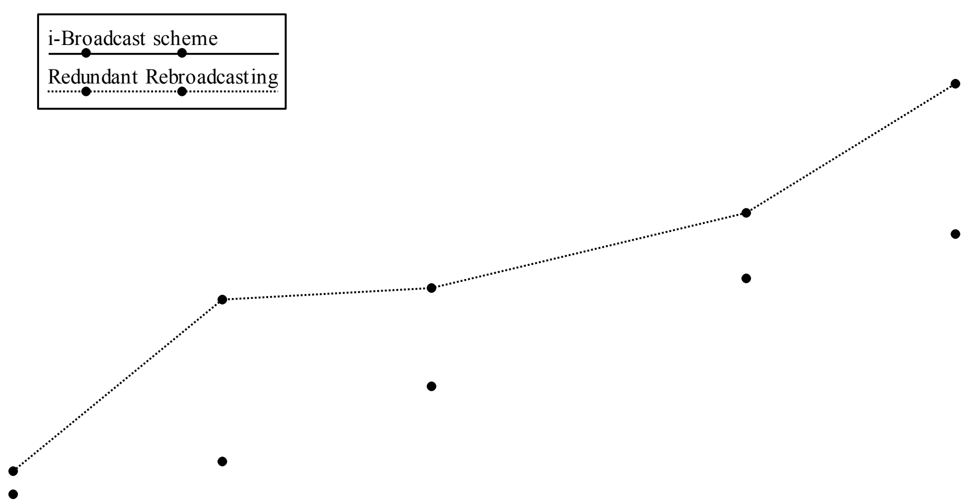

Figure 4.5: Number of rebroadcasts generated, trial 2

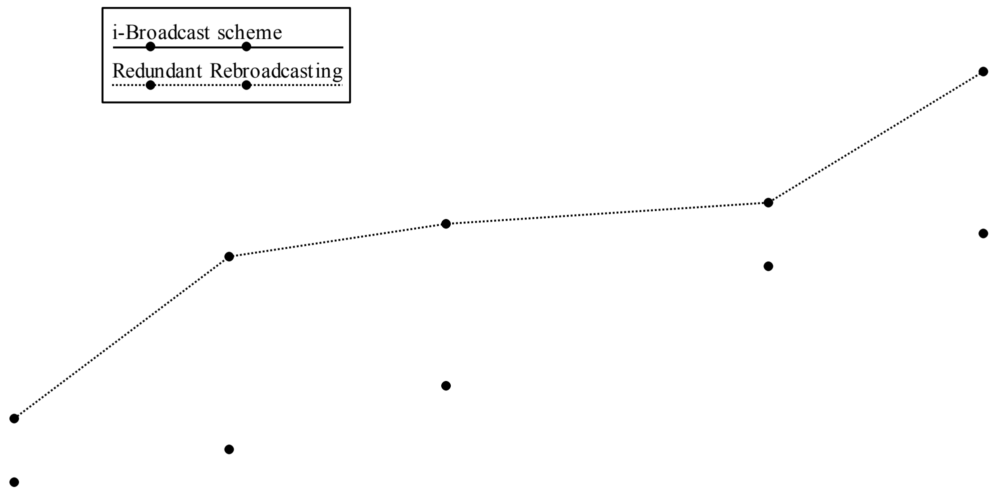

Figure 4.6: Number of rebroadcasts generated, trial 3

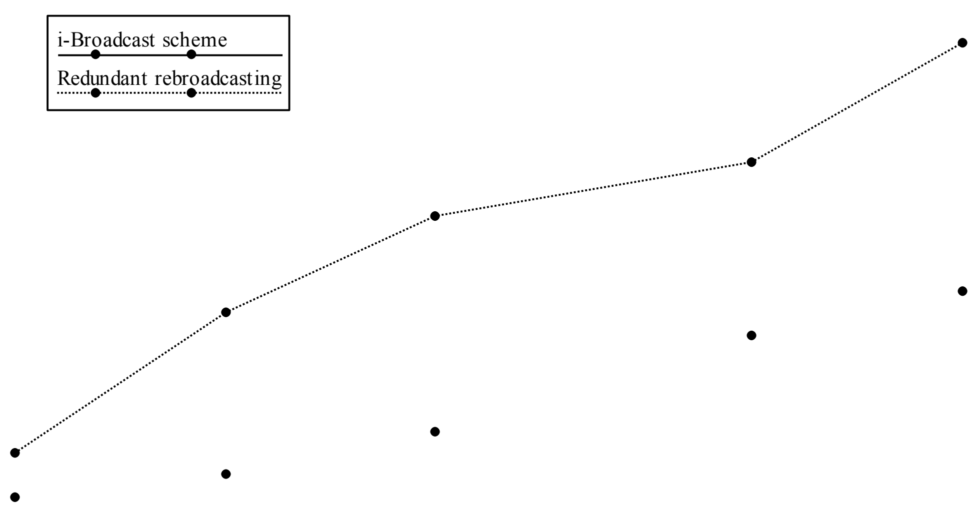

Figure 4.7: Number of rebroadcasts generated, trial 4

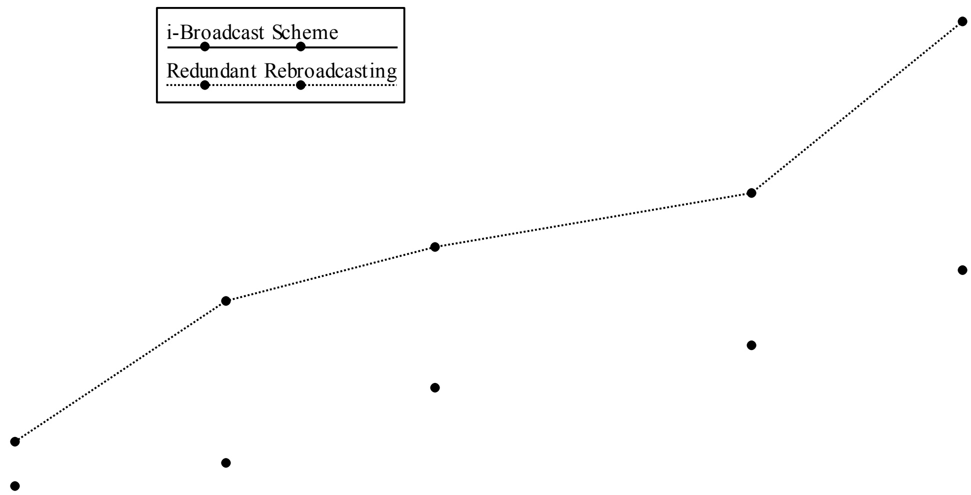

Figure 4.8: Number of rebroadcasts generated, trial 5

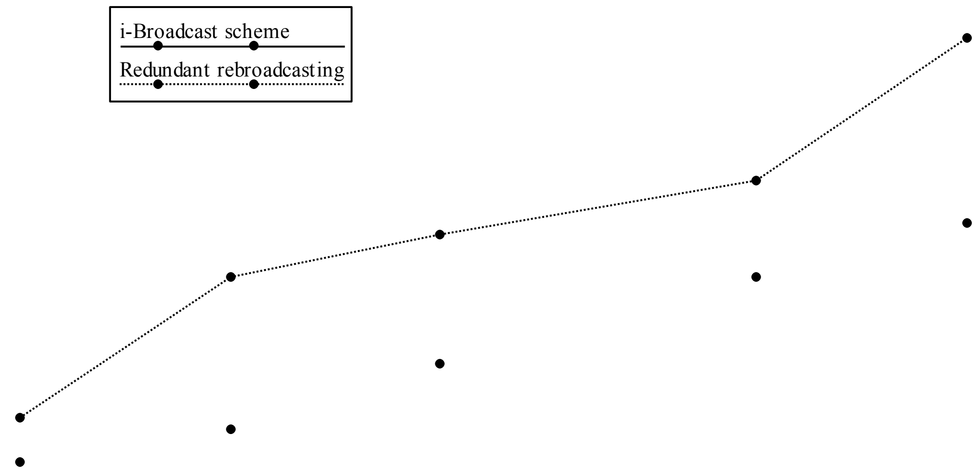

Figure 4.9: Average Number of rebroadcasts generated

Though the number of rebroadcasts tends to increase with increase in number of nodes, slope of the curve is very less and steady when compared to redundant rebroadcasting. This shows that the proposed scheme is not only reliable but efficient. Since the messages generated were safety of life messages, the vehicles travelling in opposite direction relay the message in order to ensure that the message reaches the nodes that are approaching the incident. The number of rebroadcasts that were generated by the i-broadcast scheme does not saturate as one might expect.

4.3.3 Delay

Delay is another important parameter that benchmarks the effectiveness of the scheme. In VANET`s the majority of the messages are safety messages and carry vital information that could impact the life and safety of the driver. Since the reaction time of the driver is very less approximately 0.7 sec, the delay incurred in packet delivery should be very less. As a thumb rule, 150 ms delay is the upper limit of permissible delay. For this simulation an undivided highway was considered. The distance of separation between the node that originated the broadcast and the intended receiver node was 10Km.

Figure 4.10 shows the total delay plot to disseminate a broadcast message to a node that is 10 Km away from the originator of the message. It is logical to think that, when the number of nodes increases there will be more nodes to propagate the message. This assumption is only true if an efficient broadcast suppression scheme is employed, otherwise as the node density increases, so does the probability of collisions and contention. Thus an efficient broadcast scheme should be in place to reduce delay particularly in VANET`s. From the total delay plot, it can be seen that the total delay incurred is well within 110 ms and the delay tends to decrease with the increase in node density. Thus the efficiency of the proposed broadcast suppression scheme is evident.

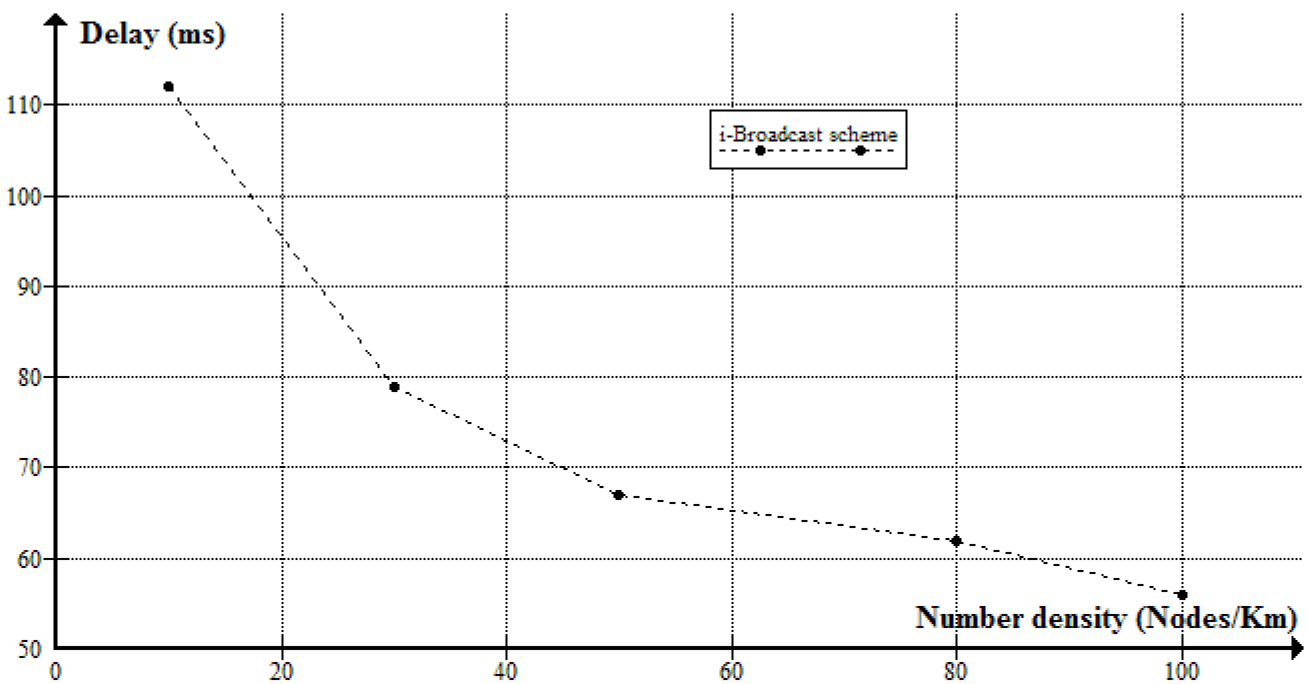

Figure 4.10: Total delay to disseminate a broadcast to a node that is 10 Km away

Chapter 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

This research work proposes a broadcasting scheme for VANET`s to contain redundant rebroadcasts. In VANET`s rebroadcasting is done to ensure that the broadcasted message reaches all the nodes and to increase the probability of the message being received by a node that is experiencing collisions or currently offline. However redundant rebroadcasting is ineffective and might cause excessive rebroadcasting, contention and collisions. Thus this research work tried to contain unnecessary redundant rebroadcasts. The proposed i-broadcast scheme introduces message ID`s and tagging of packets. The tagging mechanism that is introduced by the proposed scheme equips the nodes with the ability to identify, categorize and suppress redundant rebroadcasts thereby reducing unnecessary contention and collisions. The effectiveness of the proposed scheme was evaluated using Groovenet software. The simulation results showed that there is a significant reduction in rebroadcasts. In conclusion the proposed broadcast mechanism has been successfully implemented for VANET`s with the achievement of the research goal put forth by this thesis.

5.2 Future Works

The future works include fine tuning the proposed scheme to suit and support smart traffic lights and other road side infrastructure. More simulations on a divided highway will prove useful in studying and improving the scheme. The possibility of elimination of periodic beckoning of hello messages might also be considered.

Combining other broadcasting schemes and the proposed scheme could result in a more efficient broadcast scheme.

5.2.1 Remote Chase Ender

As the name indicates RCE application would equip the police officers with the ability to shut down the suspect`s vehicle without the his/her consent. This can be accomplished by sending an RCE message from the police vehicle to the suspect"s vehicle that is involved in a chase. RCE message is given a message type of “11111”.The message is unicasted for this application.

REFERENCES

LIST OF REFERENCES

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APPENDIX

APPENDIX

A1. Number of rebroadcasts generated by i-broadcast scheme:

Number of nodes	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
10	4	7	3	4	4	4.4
30	9	8	6	6	6	7
50	16	15	12	10	13	13.2
80	24	25	23	19	17	21.6
100	26	29	26	23	24	25.6

A2.Number of rebroadcasts generated by redundant rebroadcast scheme:

Number of nodes	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
10	8	7	9	8	8	8
30	18	23	24	21	21	21.4
50	22	24	27	30	26	25.8
80	28	31	29	35	31	30.8
100	39	43	41	46	47	43.2

A3.Packet loss ratio of i-broadcast scheme:

Number of nodes	Trial 1	Trial 2	Trial 3	Average
10	0.015	0.0168	0.02	0.017267
30	0.0183	0.0174	0.0232	0.019633
50	0.0248	0.0223	0.0312	0.0261
80	0.0382	0.0423	0.0356	0.0387
100	0.0423	0.0517	0.0632	0.0524