Performance Analysis of Position-based Routing Protocols in VANETs with Respect to Local Maximum Problem

By Abdelmuttlib Ibrahim Abdalla Ahmed

531-FBAS/MSCS/S09

Supervisor
Prof Dr. Muhammad Sher
Chairman of Computer Sciences Department,
Faculty of Basic and Applied Sciences,
International Islamic University,
Islamabad

Co-supervisor
Dr. Sajjad Ahmad Madani
Head of Computer Science Department
COMSATS Institute of Information Technology
Abbottabad, Campus

Department of Computer Science
Faculty of Basic and Applied Sciences
INTERNATIONAL ISLAMIC UNIVERSITY, ISLAMABAD
PAKISTAN
2011

Computer science
Computer software

International Islamic University, Islamabad

Dated: 30.12. 2011

Final Approval

It is certified that we have examined the thesis titled "**Performance Analysis of Position-Based Routing Protocols in VANETs With Respect To Local Maximum Problem**" submitted by Abdelmuttlib", Registration No.531-FBAS/MSCS/S09 and found as per standard. In our judgment, this research sufficient to warrant it's acceptance by international Islamic university, Islamabad for the award of MS Degree in Computer Science.

Committee

External Examiner
Dr.Usman Ashraf
Assistant Professor
Department of Computer Science & Engineering
AIR University, Islamabad

Internal Examiner
Dr.Muhammad Zubair
Assistant Professor
Department of Computer Science
International Islamic University, Islamabad

Supervisor
Prof Dr. Muhammad Sher
Chairman of Computer Sciences Department,
International Islamic University, Islamabad

Co-Supervisor
Dr. Sajjad Ahmad Madani
Head of Computer Science Department
COMSATS Institute of Information Technology
Abbottabad, Campus

ABSTRACT

Vehicular Ad hoc NETworks(VANET), is beneficial in military field and useful for other applications for instance emergency and rescue where cellular networks is unavailable or utilizable. Some commercial applications are supported as well, since there are needs for pervasive computing. The crucial factor for the success of VANET applications is routing. Where, it is necessary to deal with frequent topology changes effectively. Recent Mobile Ad hoc NETworks (MANET) routing protocols unable to fulfill these requirements in city environments. Current research aims to analyze performance of position-based routing protocol for inter-vehicle ad-hoc network with respect to local Maximum Problem, namely, IDTAR, GyTAR, A-STAR and GSR. Where, Intersections-based Distance and Traffic aware Routing protocol (IDTAR) is proposed in the current study. IDTAR is an inter-vehicle ad-hoc routing protocol developed for urban areas. IDTAR composed from two modules: first, deal with dynamic selection of suitable junction through which a packet pass to reach the destination, considering the score of curvemetric distance and density of vehicle , *second*, recovery strategy, in case of local maximum problem occurrence it uses Re-compute-anchor-path . This research, present detailed description of IDTAR then it shows its contributed value compared to other legacy routing protocols of VANET. Simulation carried out in different scenarios in different city maps to gain high accuracy and to show the impact of road topology and number roads on overall performance of position-based routing protocols. The results gave significant performance variation.

DECLARATION

I hereby declare that this work, neither as a whole nor as a part has been copied out from any source. It is further declared that I have conducted this is research and have accomplished this thesis entirely on the basis of our personal effort and under sincere of my Supervisor Dr.Muhammad Sher and my Co-supervisor Dr. Sajjad Ahmad Madani. If any part of this project is proved to be copied out from any source or found to be reproduction of some other project, I shall stand by the consequences. No portion of the work presented in this dissertation has been submitted in support of any application for any other degree or qualification of this or any other university or institute of learning.

ABDELMUTTLIB
531-FBAS/MSCS/S09

A Dissertation submitted to the
Department of Computer Science
International Islamic University Islamabad
As a partial fulfillment of requirements for the award of the
degree of
MS in Computer Science

DEDICATION

I dedicate this work to soul of my beloved mother

ACKNOWLEDGMENT

Thanks to my ALMIGHTY ALLAH, the most merciful the most beneficent, for giving me courage, potency, and persistence to complete this thesis.

I am extremely thankful to my supervisors, Prof Dr.Muhammad Sher and Dr.Sajjad Ahmad Madani, for giving me this opportunity to work with them. Without their support, this research would not have been possible.

I would like to thank my extended family and my friends for everything's.

I am thankful to Departments of Computer Science and faculty members in IIU, ISLAMABAD for guidance, knowledge, and valuable days.

I am indebted to the Departments of Computer Science and faculty members in COMSATS, ABBOTABAD for providing me such a creative environment of research.

I would like to show appreciation to Mr. S.M Bilal, who gave me valued courage and support.

I am thankful to my friends and missions fellow Ageeb and Abdulhadi, who courage me to overcome the hurdles.

I am thankful to Mr.Noor-ul-Amin and Mr.Saadat Iqbal for everything's.

I express my thanks to my friend Nizamuddin and the rest of my colleagues, for the good friendship.

I would also like to thank Group of the research associates in COMSATS, ABBOTABAD they are like my family while I was with them.

TABLE OF CONTENTS

LIST of TABLES

LIST of FIGURES

LIST of ACRONYMS

AIS	Automatic identification system
AODV	Ad hoc on demand distance vector
ASTM	Applications Society for testing and materials
ARIB	Association of radio industries and businesses
ASK	Amplitude shift keying
A-STAR	Anchor based street and traffic aware routing
ASTM	American society for testing and materials
ASTM	American society for testing and materials
CAN	Controller area network
CAR	Connectivity-aware routing
CBF	Contention-based forwarding
CBR	Constant bit rate
CDMA	Code division multiple access
CEN	European committee for standardization
CSMA	Carrier-sense multiple access
CSMM	City section mobility model
DCF	Distributed coordination function
DSR	Dynamic source routing
DSRC	Dedicated short range communication
FCC	Federal communications commission
FDMA	Frequency division multiple access
GeOpps	Geographical opportunistic routing

GPCR	Greedy perimeter coordinator routing
GPSR	Greedy perimeter stateless routing for wireless networks
GRANT	Greedy routing with abstract neighbor table
GSM	Global System for Mobile Communications
GSR	Geographic source routing
GYTAR	Improved greedy traffic aware routing protocol
IDM	Intelligent driver model
IP	Internet protocol
IVC	In-vehicle communication
IVC	Inter-vehicle communication
LIN	Local interconnect network
LOUVRE	Landmark overlays for urban vehicular routing environments
MANET	Mobile ad hoc network
OBU	Onboard unit
OBU	On-board unit
OFDM	Orthogonal frequency division multiplexing
OFDM	Orthogonal frequency division multiplexing
PGB	Preferred group broadcasting
PSK	Phase shift keying
RDSTMC	Traffic message channel of the radio data system
RSU	Roadside unit
RSU	Road side unit
RUM	Rice university model
SDMA	Space division multiple access
SSM	Stop sign model

STBR	Street topology based routing
STRAW	Street random waypoint
TCP	Transmission control protocol
TDMA	Time division multiple access
TDMA	Time division multiple access
TO-GO	Topology-assist geo-opportunistic routing
TORA	Temporally ordered routing algorithm
TSM	Traffic sign model
UDP	User datagram protocol
UMTS	Universal Mobile Telecommunications System
UTRA	UMTS terrestrial radio access
VANET	A vehicular ad-hoc network
VNI	Virtual navigation interface
VRC	Vehicle-to-roadside communication
WAVE	Wireless access in vehicular environments

Chapter 1

Introduction

1 Introduction

A Vehicular Ad-Hoc Network (VANET) is a type of mobile ad-hoc network where vehicles communicate wirelessly to provide safety and comfort. Vehicles are equipped with wireless communication nodes to provide network connectivity. Such type of network operates with no need for legacy infra-structure or legacy client/server. Where each vehicle equipped with communication device considers as Ad-Hoc node and can communicate with other nodes in its wireless network. This network helps drivers to select the best way in the area and to avoid crashes [138].

Routing always play a crucial role in the success of any VANET application. Due to frequent changing topology and high speed of vehicles, a traditional routing protocol does not perform well.

In VANETs, routing protocols use greedy routing to forward data packets [107][117][126][104]. In greedy routing, forwarding node send data packets to the node which is closest to the destination, thus position based routing. It may be possible that forwarding node may not find other node closer to destination than itself as shown in Figure1.1. The scenario is called local optimum or local maximum problem where the forwarding vehicle can not find suitable vehicle in its radio range to forward the packet.

1.1 Scope of the Study

The study concerned with simulation and performance analysis of position-based routing protocols with respect to Local Maximum Problem, specifically

- Geographic Source Routing *(GSR)*[117],

- A anchor-based Street and Traffic aware routing with statically rated map (*STAR-SR*)[126].
- Improved Greedy Traffic Aware Routing protocol (*GyTAR)*[104].
- *Our* proposed protocol (Intersection-based Distance and Traffic Aware Routing protocol (*IDTAR*)) Detailed in chapter 5.

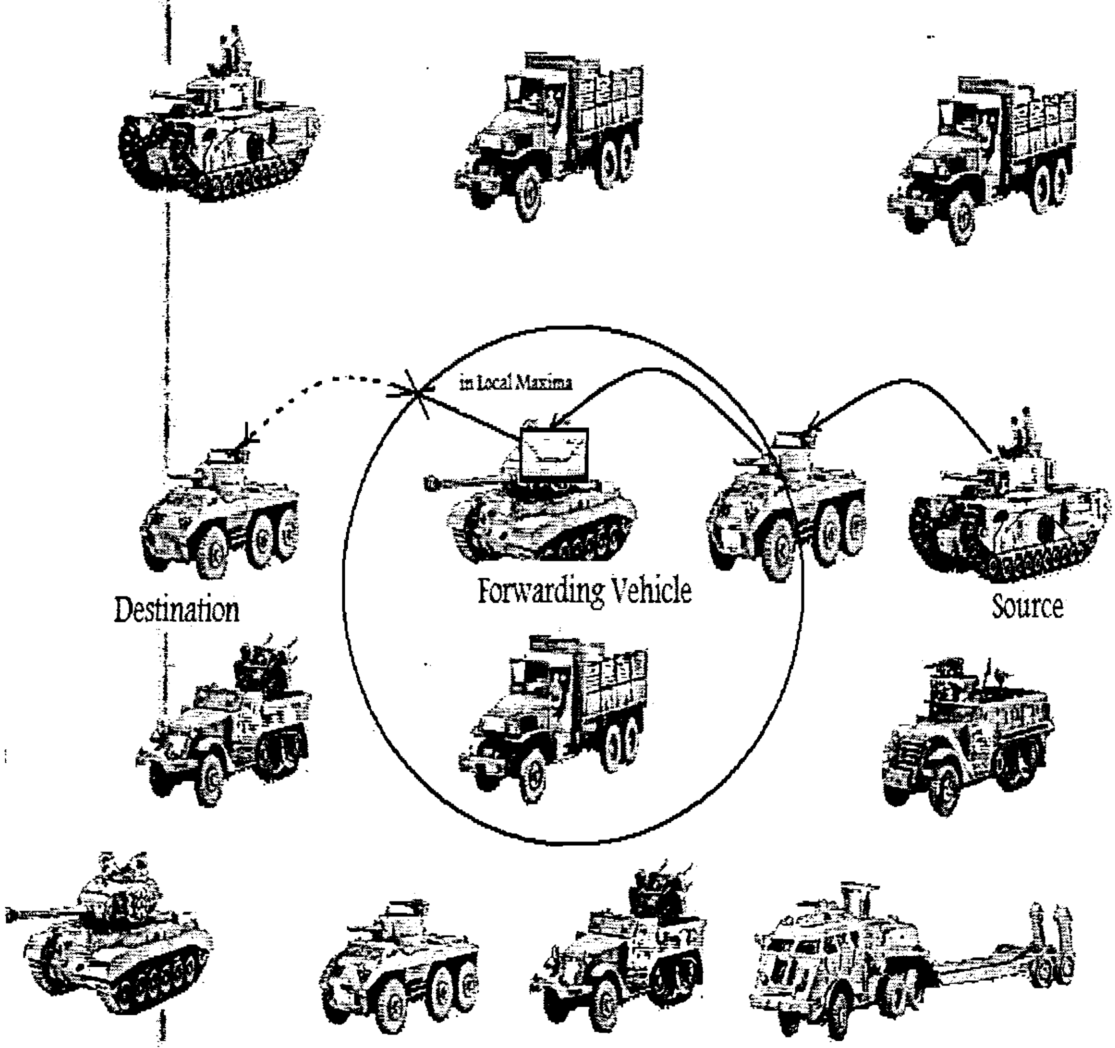

Figure 1.1: Local Maximum Problem in VANETs

1.2 Related Studies

Many studies [109][126], compared the performance of topology-based routing protocols, namely Ad hoc on Demand Distance Vector (AODV)[128] and Dynamic Source Routing (DSR)[106], against position-based routing protocols .The results show that position-based routing protocols perform better than topology-based routing protocols. Recently, enormous numbers of position-based routing protocols have been introduced and are the most distinguished protocols considered in this study. This section gives overview on these protocols then it has been discussed extensively in chapter three.

GSR[117], combines position-based routing with geographical information, Dijkstra algorithm used to calculate shortest path on the graphical model of city, where the junction modeled as vertex and streets as edges The junctions set establishes the path to the destination. GSR[117] follows carry-and-forward strategy to counter local maximum problem. For the experiments small part of the city of Berlin (6.25 km × 3.45 km) was modeled as a graph of streets with 28 vertices and 67 edges. The limitations *GSR* of are that it does not consider the *vehicle density*/connectivity between two junctions; so the route might not be connected through. Therefore, high possibility of Local Maximum Problem occurrence.

An anchor-based Street and Traffic aware routing with statically rated map (*A-STAR-SR)* [126] uses route information to select anchor paths considering weight of line of buses. *A-STAR*[126] introduced new recovery strategy in which new-anchor-path is calculated when the packet get stuck in local maximum problem and this is area declare as "Out-of-Service" temporary and it will not be used in calculation of anchor path. Grid map used (2800x2400 m^2) the number of roads segments and intersections not mentioned clearly. The limitation of that research is that Simulation has been done in just one network of roads.

Improved Greedy Traffic Aware Routing protocol (*GyTAR*) [104] uses both city map and the vehicles density to select the intermediate junctions that data packets pass through to reach the desired destination. GyTAR[104] introduced improved greedy forwarding strategy to route data packets between two consequent junctions where, in improved greedy forwarding strategy the direction and speed of the vehicle are consider, also uses carry and forward strategy in order to recover from the Local Maximum Problem. The terrain area of the experiments was 2500×2000 m^2 , consists of 16 intersections and 26 two way roads, The limitation of research [104] are:

- The comparison conducted in the study has taken GyTAR [104], GSR [117] and it has avoided A-STAR [104] the most recent Overlaid Position-based routing protocol at that time.
- The Simulation has been done just in one network of roads.

The details of all the aforementioned protocols with different properties are summarized in Table 1.

1.3 Research Problem

The problem is that all overlaid Position-based routing (GSR[117], A-STAR[126] and GyTAR[104]) suffer from performance degradation due to handling local maximum problem. However, there has been no detailed analysis, where all these protocols implemented in one city scenario (grid/portion of city) without considering various number of roads networks.

Table 1.1: Characteristics of Position-based Routing Protocols for VANETs

Protocol / Characteristics	GSR	A-STAR-SR	GYTAR	IDTAR
Forwarding method	Greedy forwarding	Greedy forwarding	Improved Greedy forwarding	Greedy forwarding
Recovery Strategy	Carry-and-forward	Recomputed anchor_path	Carry-and-forward	Re-compute anchor_path
Anchor-selection	Dijkastra algorithm with weight of hop count	Dijkastra algorithm with weight of road	Dynamically selects anchor based on traffic density and curvemetric distance	Dynamically selects anchor based on traffic density and curvemetric distance
Digital map required	Yes	Yes	Yes	Yes

1.4 Significance & Objectives of the Study

VANET maintains human safety and time also it can be beneficial in military field, so improvement of routing in VANETs increases the feasibility of its applications.

- This study proposes new effective position-based routing protocol named Intersection-based Distance and Traffic Aware Routing protocol (IDTAR).
- This research is the first empirical detailed study to analysis the most recent four position-based routing protocols in unified environments.

1.5 Research Methodology

The study is basically experimental and evaluative. It adopts the *quantitative* and *qualitative* approaches by gathering data produced via running the simulator for all the protocols of the study. The data, then, analyzed *qualitatively* so we judge which of the protocols perform better. The study population consists of GSR [117], A-STAR-SR[126], GyTAR[104] and IDTAR.

1.6 Thesis in Brief

The first chapter is an introduction containing a brief historical background about VANETs, its Routing protocols and Local Maximum problem. Besides, it has stated the questions, objectives, and significance of the study.

Chapter discusses the Fundamentals of Vehicular Communications and VANETs. It lists the characteristics and applications of VANETs and it discusses communication schemes, radio propagation model and security issues in VANETs.

The third chapter presents literature review where of position-based routing protocols.

The fourth chapter discuss local maximum problem then defines problem of the research.

The fifth chapter presents the proposed protocol and discusses the simulation setting and scenarios

The sixth chapter present result of all city scenario simulation and the discussion of those results.

The seventh chapter state the conclusions of the overall study, where intersection-based distance and traffic aware (IDTAR) gives better performance in scenarios further it shows the impact of road and intersections number on performance of position-based routing protocols.

Chapter 2

Background Knowledge

2 Background Knowledge

Nowadays vehicles have become sophisticated electronic networks. Where, various components exchange their information and cooperate for ensuring vehicle safety and reliability. Furthermore, the vehicle can communicate with the surrounding environment by wireless communication to provide wide range of luxury, advanced safety and business services.

2.1 Classifications of Vehicular Communications

Vehicular communication can be classified based on their specific characteristics and technologies as follows:

- In-vehicle communication
- Vehicle-to-infrastructure communication
- Inter-vehicle communication

2.1.1 In-Vehicle Communication (IVC)

In-vehicle communications (IVC) concerns information exchange between various components within a vehicle. Currently, IVC is being used in contemporary cars. Generally, there are two application fields for in-vehicle communication:

- In-vehicle network of sensors, actuators and controllers.
- High rate multi-media communication for comfort applications.

In-vehicle communication networks distinguished by the stable topology, because it has clearly defined set of possible communication devices and based on guided medium of communication. Exactly, topologies are bus and ring. Particularly controller networks have highly sensitive to delay and integrity, whereas in case of comfort applications the delay or data integrity violation are less sensitive when higher data rates are preferred.

Recently, usage of the integrated electronic components in vehicles increased. Consequently standardized communication systems for in-vehicle communication are become very important. The famous standard in Europe for controller communication in vehicles is the Controller Area Network (CAN) [1], detailed in Table 2.1. Modern vehicles use several CAN buses in order to decouple different functional areas of the vehicle and balance the load on the bus. For low cost in-vehicle networks, the dominant standard is the Local Interconnect Network (LIN) [4] protocol. LIN sub networks are connected to CAN networks by a LIN-to-CAN gateway, so a hierarchical in-vehicle network constructed.

2.1.2 Vehicle-To-Roadside Communication (VRC)

This type of communication known as vehicle-to-infrastructure communication, in this paradigm the communication establishes between the vehicle and a fixed infrastructure Figure (2.1(B)). This communication can be unidirectional or bidirectional. Broadcast systems support unidirectional transfer of information from a broadcast station (roadside) to the vehicle. Specifically, in systems allowing bidirectional communication, the vehicle communicates point-to-point via base-station or access-point. In VRC, the base station achieves coordination of the communication, such as physical layer synchronization and medium access. Furthermore, the base-station can provide access control and neglect unnecessary load.

Table 2.1: Wireless Technologies and Standard for In-vehicle Communications

	ZigBee	UWB (ultra-wide band)	Bluetooth	Wireless USB (Universal Serial Port)	Wireless CAN
Standard/ Technology	Ratified in December 2004	Transmitting information spread over a large bandwidth (>500 MHz)	First launched (1998)	Short-range, high bandwidth Based on the WiMedia Alliance's UWB	CANRF (CAN over RF)/ CAN Bridge
Coverage	10 and 75 meters	< 60 cm for a 500 MHz wide pulse, <23 cm for a 1.3 GHz bandwidth pulse	1 meter, 10 meters, 100 meters	480 Mbit/s at up to 3 meters and 110 Mbit/ s at up to 10 meters	/500 feet (152.4M)
Bit Rate	20-250 kbit/s per Channel	extremely high data rates 1000+ Mbps	3 Mbit/s (Version 2.0 (WiMedia)Alliance (proposed)	480 Mbit/s at distances up to 3 meters and 110 Mbit/s at up to 10 meters	20kbps/ 52.8kbps 164.4kbps
Applications	Entertainment, smart Lighting control, advanced temperature control, safety & security,	Used at very low energy levels for short-range high bandwidth communications by using a larger portion of the radio spectrum	Connect and exchange information between devices such as mobile phones , laptops, personal computers, video game consoles, etc	Game controllers, digital cameras, MP3 players, hard disks and flash drives. Also suitable for transferring parallel video streams.	Communication among sensors and ECUs

Bi-directional VRC technologies can be sub-divided into cellular mobile phone systems and short range/WLAN-like systems .VRC employ the existing cellular infrastructure, such as GMS and UMTS networks, and can provide information wherever the infrastructure is available.

The range of VRC is proportion to the capability of air interface and infrastructure, it is varies from tens of meters for wireless local area technologies to hundreds of kilometers for public radio systems.

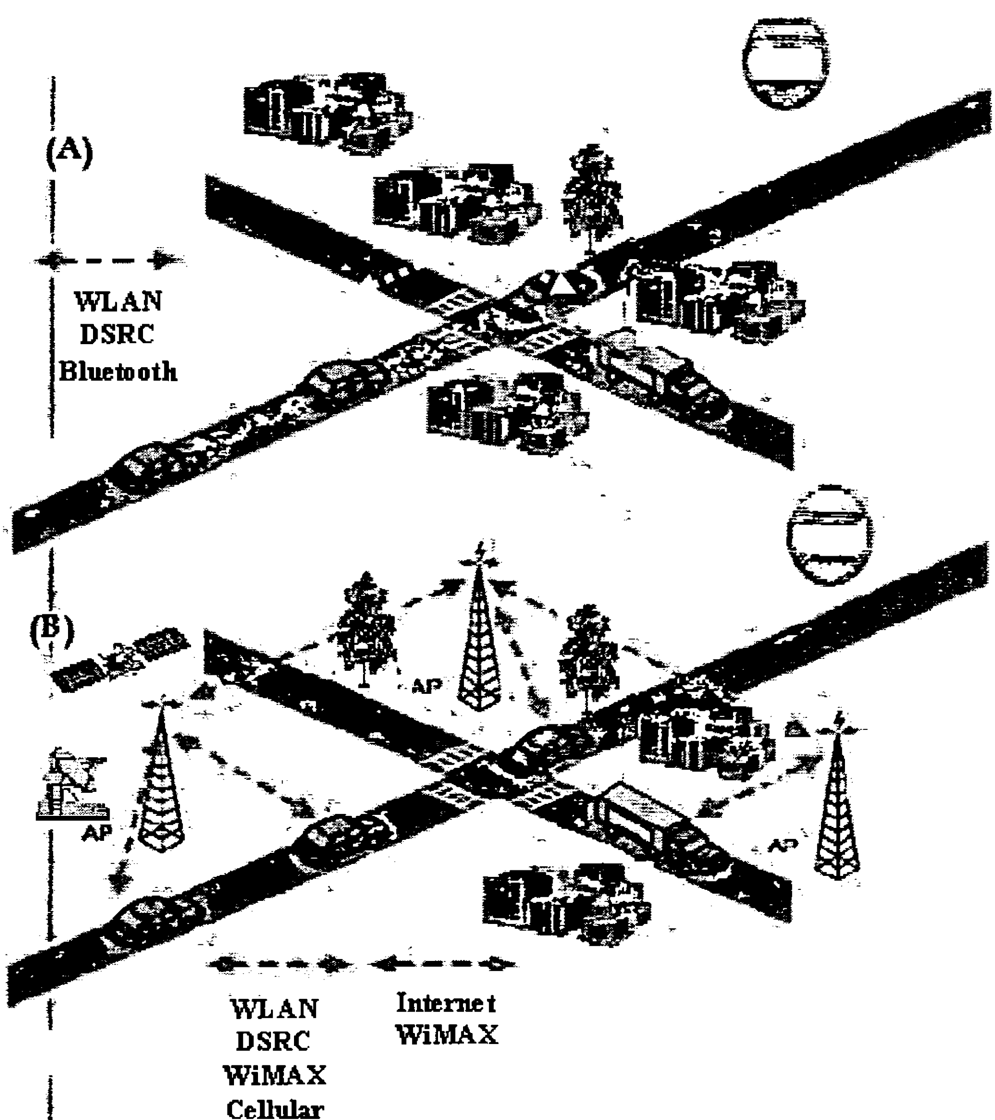

Figure 2.1: Communication Schemes in VANETs

A simplified model of broadcast systems are public radio stations, which utilize the FM radio system to allows information transmission between vehicles through the Traffic Message Channel of the Radio Data System (RDSTMC)[89].

The dominant technologies for bi-directional VRC are cellular mobile phone systems, such as GSM/IS-95 and UMTS/cdma2000 [7] shown in Table (2.2). Cellular networks offer accessibility to a wide range of voice and data services. For data services, packet-oriented standards such as GPRS are often used. The cellular air interface can be installed either directly in the vehicle or it is job carried out by the mobile phone of the driver, which can be integrated with in-vehicle communication through dedicated bridge.

Short and medium range vehicle-to-roadside communication for services such as electronic toll collection, authentication for restricted access roadways and traveler information are provided by the Dedicated Short Range Communication (DSRC) standards, detailed in Section (2.2.1). It is the basis for revised IEEE 802.11WLAN [10],[11] for WAVE, discussed in Section(2.2.2).

A new application area for VRC is the connection of VANETs to existing wire-line networks such as the Internet [13]. An access point at the roadside serves as a gateway and forwards data packets from the VANETs to the wire-line network and vice-versa. Medium range VRC standards, such as WAVE, which further support vehicles direct communication, are beneficial in such case because the same air interface can be used for VRC as well as for IVC.

2.1.3 Inter-Vehicle Communication (IVC)

In this paradigm, vehicle communicates directly with other vehicles, so called Car-to-Car Communication, where information exchange is allowed without requiring any fixed infrastructure. While a resemble form of communication has been deployed on a large scale in marine traffic with the Automatic Identification System (AIS) [14],[15] and in aviation with the Automatic Dependant Surveillance - Broadcast (ADS-B) [15],[16],[17] system, but it is not widely used in the automotive sector.

A crucial need for any kind of IVC is an air interface to facilitate ad hoc communication. In IVC, synchronization and medium access cannot be coordinated by a base station. The network is self-organized and allows peer-to-peer communication between any two vehicles which are within mutual transmission range. Therefore, medium access and synchronization must be maintained in a decentralized manner [18],[19],[20]. IVC can be identified as follows:

- **Single-hop:** In single-hop IVC, the source and destination of messages are in the radio range of each other and communicate directly.
- **Multi-hop:** In this paradigm messages exchange over area larger than the radio range of a single vehicle, therefore, multi-hop (IVC) exploited to establish the connection.

Some comfort applications [21] introduced, in spite conventional IEEE 802.11b WLAN is available. Single standard for IVC and VRC is preferable to avoid installation of another dedicated air interface. Many standards developed for VRC [88], can support IVC. The IEEE 802.11p standard introduces specific channels to IVC and is suitable for IVC-based ad hoc networks [25]. An alternative way is the extension of legacy cellular standards for supporting ad hoc communication. The modification of the UMTS is UTRA, Time Division Multiple Access (TDMA) standard, named UTRA TDD Ad Hoc [26][27] .The methods which Combined ad hoc with cellular operation are feasible [28].

2.2 Wireless Access Standards in VANETs

Currently, several standards exist for wireless access in VANETs. These standards can deal with protocols that applicable to transponder-device and communication protocols, security treatments, addressing, and routing. The dominant standards for wireless access in VANET [88] are detailed as follows:

2.2.1 Dedicated Short Range Communication (DSRC)

DSRC deals with short and medium range communications, aimed to provide IVC and VRC. In such communication paradigm wide range of applications can be supported. The merit of DSRC is that, it provides high data transfer rates and low delay in small range. ASTM declared the ASTM-DSRC as standard in 2003, it has been designed based on the physical layer of IEEE 802.11 and it MAC layer as well [29]. ASTM-DSRC has been published later as ASTM E2213-03. In February 2004, the States Federal Communications Commission United (FCC) issued services report. DSRC is free since the FCC, does not charge for the use but it is licensed [32]. In FCC the allocation of certain channels is required and all introduced radios should follow the standard. Since, safety applications are favored over the rest of VANET applications, to eliminate the possibility of performance decrement and to preserve human life. Table (3) shows comparison between recent DSRC regional standards .Where, many studies [30], [29] discuss in-depth DSRC from different point of views.

Table 2.2: Wireless Technologies for IVC and VRC

	GSM/3G	WiFi (Wi-Fi Alliance Version of 802.11n)	WiMax	DSRC
Standard/ Technology	Third generation cellular Technology in 2001	New Wi-Fi technology with MIMO standard in 2009, 802.11n standard in 2009	Broadband technology in 2007	A short to medium range communications
Coverage	Kilometers	500m	5 km	1000m
Bit Rate	2-3 Mbps	600Mbps using MIMO	75Mbps	6 to 27 Mbps
Applications	Between Vehicle and Mobile phone communication	Roadside to vehicle and vehicle to vehicle communication	Internet access, Email, Voice over IP	Roadside to vehicle and inter-vehicular communication

Table 2.3:standards in Europe, US and Japan

Features	ASTM-USA	CEN-EUROPE	ARIB-JAPAN
Communication	Half-duplex	Half-duplex	Half-duplex (OBU) /Full duplex (RSU)
Frequencies of Radio Band	5.9 GHz 75 MHz bandwidth	5.8 GHz 20 MHz bandwidth	5.8 GHz 80 MHz bandwidth
Channels	7	4	7
Channel Separation	10 MHz	5 MHz	5 MHz
Rate of Transmission	3-27 Mbits/s	Down-link/500 Kbits/s Up-link/ 250 Kbits/s	1 or 4 MBits/s
Coverage	1000 meters (max)	15-20 meters	30 meters
Modulation	OFDM	RSU: 2-ASK OBU: 2-PSK	2- ASK, 4-PSK

2.2.2 IEEE 1609-Standards for WAVE (IEEE 802.11p)

Vehicles can communicate with each other via exploiting 802.11a compatible devices [33]. In VANET classical IEEE 802.11 MAC performs badly due constrains of VANET scenarios. In such environments, sensing for beacons from an Access Point following multiple handshakes processes to establish communication is too much complex and generates undesired overheads. To satisfy VANET needs for dealing with IEEE-MAC, IEEE 802.11p (WAVE) joined DSRC team with IEEE 802.11 team-work [33]. One of the merits of incorporating DSRC into IEEE 802.11 is that

WAVE becomes standard. Figure (2.3) shows IEEE 802.11p WAVE introduces RoadSide Unit (RSU), and OnBoard Unit (OBU) both can work as stationary or mobile devices. Table 2.4. Shows summary of IEEE 1609/802.16e standard.

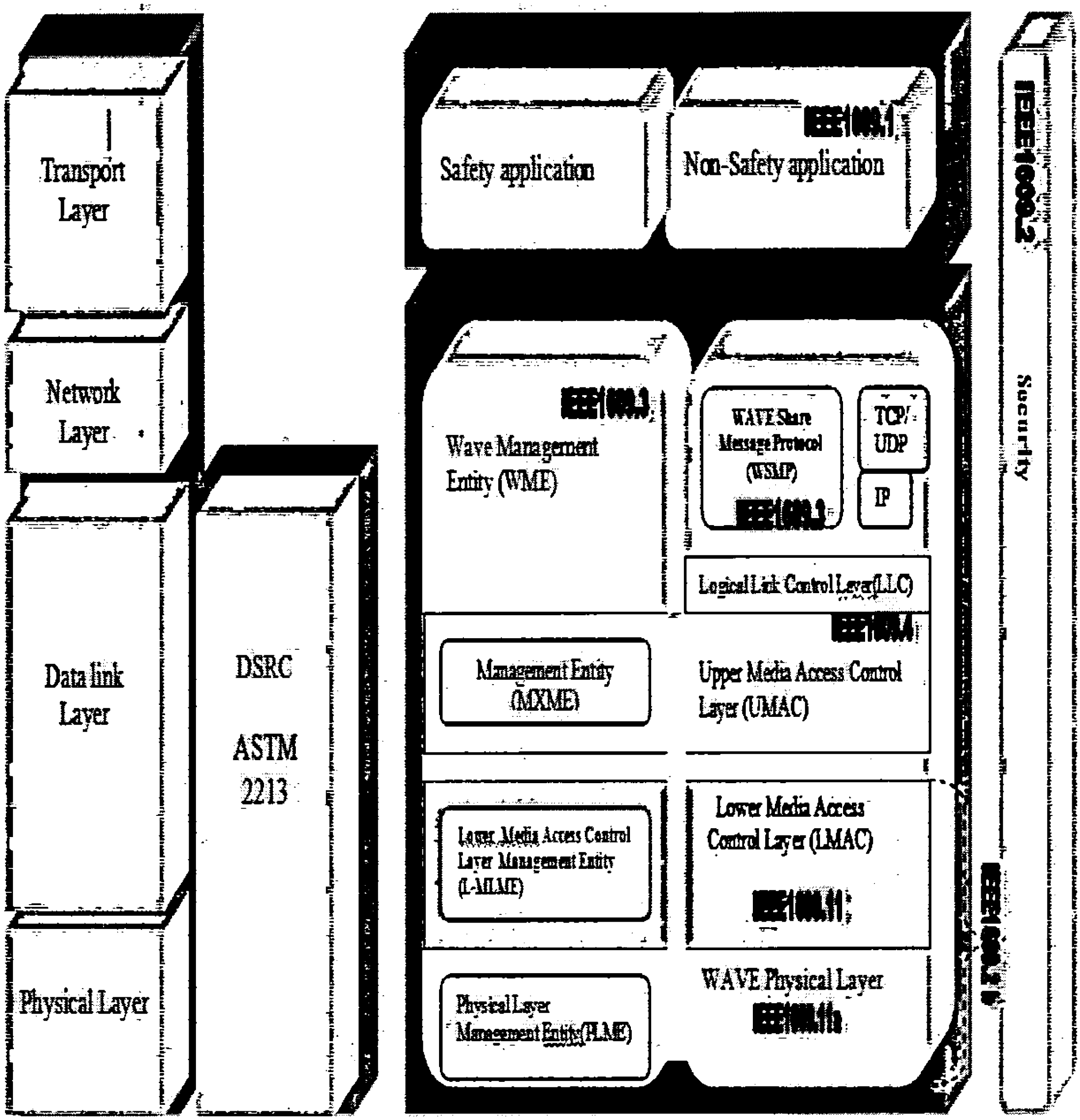

Figure 2.2: WAVE, IEEE 1609, IEEE 802.11p and the OSI Reference Model

Table 2.4 : IEEE 1609/802.16e standards

IEEE Standard	Reference	Description
IEEE 1609	[IEEE 1455, 1999]	Specify architecture, communication model, management structure, security mechanisms and physical access for wireless communications in the VANETs.
IEEE 1609.1-2006	[IEEE 1609, 2006]	Provide WAVE applications interoperability, describes major components of the WAVE architecture, and defines command and message formats.
IEEE 1609.2-2006	[IEEE 1609, 2006]	Describes security services for WAVE management and application messages.
IEEE 1609.3-2007	[IEEE 1609.3, 2007]	Concern with addressing and routing within a WAVE, defines WAVE Short Message Protocol (WSMP) as an alternative to IP for applications.
IEEE 1609.4-2006	[IEEE 1609.4, 2006]	Describes enhancements made to the 802.11 Media Access Control Layer to support WAVE.
IEEE 802.16e	[IEEE 802.16-2004, 2004]	Support interoperable multi-vendor products.

2.3 Vehicular Ad Hoc Networks (VANETs)

VANET is the subtype of MANETs facilitates communication between vehicles. Vehicles communicate by IVC, whereas each vehicle forwards information, which received from other vehicles. Here, the term 'information forwarding' is used instead of 'packet forwarding', since packets can also be processed and modified at intermediate nodes, This approach is also used widely in ad hoc sensor networks [39], respectively VANET consider as special kind of wireless packet switching network.

There are different delimiters led to the development of VANETs, briefly presented as follows. Afterwards, applications and characteristics of VANETs are considered. In addition, the required background information on medium access techniques and models for the wireless channel are given. Typical road topology definition method for VANET are characterized then mobility model are discussed at last security issues are addressed.

2.3.1 The Journey from MANETs to VANETs

In packet switched networks, instead of setting up a dedicated connection, data packets from multiple users are transmitted on a single link. Early research on wireless packet switched networks started in the 1970s with the development of a simple protocol for radio channel access (ALOHA protocol) [34],[35], at the University of Hawaii. A fully connected ground network of stationary terminals was considered. The communication was always following the direction from a terminal to the computer center or vice-versa [36].

The assumption of stationary nodes dropped in mobile packet radio networks, which consider the mobility of users [37]. However, these networks still distinguish between a mobile terminal (source or sink for information flow) and a repeater. In a MANET [38], each node is potential source of information and acts in the same time as a mobile router which forwards data packets received from other nodes.

In VANETs (whereas in classic MANETs packets are forwarded without any modification of the payload) additional information can be stored and *transported physically on-board* the vehicle. Due to the specific movement pattern of vehicles on roads, this form of physical transport is more effective than in an usual MANET and can contribute significantly to achieving a large range in which information can be disseminated.

2.3.2 Applications of VANETs

The applications in VANETs categorized into [141]:

- **Public Safety Applications**

Safeties applications basically aim to avoid accidents. Warning systems proposed to reduce vehicle collisions occurrence.

- **Traffic Management Applications**

Aims to improving traffic flow, the traffic management applications duties involve *traffic scheduling, monitoring*, and *emergency* treatment.

- **Traffic Coordination and Traffic Assistance**

This type of applications need close range IVC with real-time constraints, it can be enabled in *Sparse Roadside-to-Vehicle Communication* (SIVC)/*Ubiquitous Roadside-to-Vehicle Communication* (URVC) system.

- **Traveler Information Support Applications**

This sort of applications provides data, such as updated local maps, the location of services points.

- **Comfort Applications**

Comfort applications mainly concern on making traveling more luxury.

2.3.3 Characteristics and Requirements of VANETs

VANET is classified as subgroup of Mobile Ad Hoc Networks (MANETs), and its main characteristics stated as follow [41]:

- Constrained Road Topology and High Mobility of vehicle
- Frequently Changing Network Topology
- Initially Low Market Penetration Ratio
- Potentially Unbounded Network Size
- Anonymous Addressee
- Real-Time Data Exchange
- Potential Support From Infrastructure
- Better Physical Protection

Scalability is considered as one of the necessary requirements for VANET. The study in [42] shows that an ad hoc network containing N nodes achieved data rate per source-destination pair decreases approximately by $1/\sqrt{N}$. This result holds even if optimal selection of transmission ranges and traffic pattern is assumed. However, the ad hoc network considered in [42] is fixed and does not take mobility of the individual nodes into account. Its model for capacity calculation is applied to a *mobile* ad hoc network in study [43]; the result states that the mobility increases the capacity. For a random mobile ad hoc network without delay constraints, the data rate can be kept constant even as N increases. Moreover, most VANET applications do not require individual source destination communication but instead can use a local broadcast of their current information to other vehicles in range. Vehicles sensing identical information do not need to transmit any data.

2.3.4 Wireless Channel

The wireless channel is unpredictable [44]. On its path from sender to destination a signal is subjected to reflection, scatterings and absorbency due to presence of objects in the propagation environment. Magnitude in multiple paths can be interfered. Generally, vehicles move on roads, this flowing can cross plain lands to trees to high raise building in urban areas. So radio channel modeling for various propagation environments with reasonable accuracy is required.

As mentioned in study [84] Propagation models, commonly, can be classified *in large scale and fading* or *small-scale models*. From an applied point of view it can be either *deterministic* or *probabilistic.*

2.3.5 Common Classification of Radio Propagation Models

Radio propagation models commonly, categorized in *large scale or small-scale* models

- **Large-Scale Model**

large scale model has effects on radio wave propagation mentioned as follows:

  - *Reflection*: occurs when a wave encounters a large surface with specific properties.
  - *Diffraction*: Huy-gens' Principle, defines every point on a wave-front is a seed for a secondary wave front. Therefore, the waves propagate via holes or around edges. Knife-edge diffraction model can model this phenomenon [45].
  - *Scattering:* The wave will scatters whenever it encounters an object smaller than wavelength, scattering of the wave occurs in all directions.

- **Small-Scale Model**

In Small-scale, multiple version of the original signal can reach receiver. That happens because of reflection and diffraction in radio waves, which lead to difference in arrival time and the phase, this phenomenon known as fading.

2.3.6 Applied Classification of Radio Propagation Models

In this class radio propagation model can be either deterministic or probabilistic.

- **Deterministic Models**

These models allow us to calculate the strength of received signal, using environment factors, distance between a transmitter T and a receiver R.

  - **Free Space Model**

  This model is sometimes also referred to as Friis model [46]. It models a single communication path. The received power depends only on the transmitted power, the antenna gain and the distance between the sender and the receiver, as shown in Figure.(2.3.(a)). The idea is that, as a radio wave travels away from an (omni-directional) antenna, the power decreases with the square of the distance.

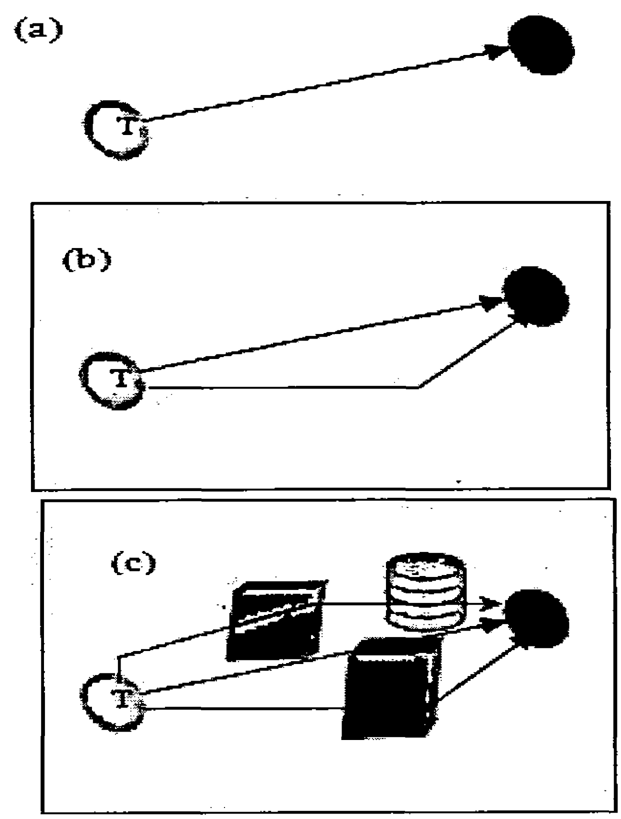

Figure 2.3: a) Free-Space Propagation, b) Two-Ray Ground Propagation, c) Ray-Tracing Propagation

- ### Two-Ray Ground Model

The two-ray ground model also accounts for a reflection via the ground, given the dielectric properties of the earth in addition to the direct line of sight (LOS). As a result, nodes are positioned on a plane as depicted in Figure (2.3(b)). This model gives more accurate predictions at longer range than the Free Space model [45].

- ### Ray Tracing Model

This model used to predict propagation for cellular systems. Modeling the propagation environment plays a critical role in the development, planning and deployment of cellular systems [47]. Since coverage and bandwidth are important issues for these systems, so careful site planning is very important. Ray tracing models can consider the exact position, orientation and electrical properties of individual buildings in the environment in which the system is needed to function. Using the rules for reflection, diffraction and scattering all rays emanating from the source traveling towards a receiver can be modeled, as shown in Fig. (2.4. C).

- **Probabilistic Models**

These models used to realize modeling of radio wave propagation [44]. A probabilistic model considers a deterministic model as one of the inputs consequently gets a mean transmission range. For every transmission the received power is then drawn from a distribution, as illustrated in Figure(2.4). In certain probability two nodes close to each other may not be able to communicate, although it can also happen with a certain probability that two nodes beyond the deterministic transmission range can communicate. These effects distribution governs by the probabilistic model and its parameters.

- ***Log-Normal Shadowing:*** This model adopts normal distribution, it distribute reception power with variance $\propto$ in the logarithmic domain.

- ***Rayleigh:*** Rayleigh [45] used in the absence of LOS, and the existence of multi-path components. Rayleigh combines intensive variations in the signal power.

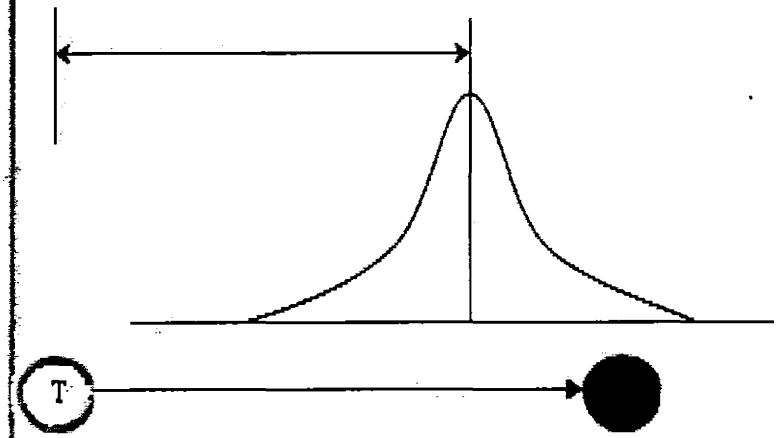

Figure 2.4: Probabilistic Propagation

2.3.7 Medium Access Control

In VANETs, the wireless channel needs to be shared by all vehicles within a local area. Consequently, the access to the wireless medium must be coordinated so that the data transmitted by an individual vehicle is not affected by the transmission of other communication partner. Generally, transmission in wireless communication system can be separated through one of the following techniques:

- Time (Time Division Multiple Access, TDMA),
- Frequency (Frequency Division Multiple Access, FDMA),
- Space (Space Division Multiple Access, SDMA) and
- Code (Code Division Multiple Access, CDMA).

In a vehicular ad hoc network, normally TDMA is employed since the other multiple access methods have to counter the following difficulties in a VANET scenario: In a single carrier system, the receiver can only listen to one frequency at a time. FDMA therefore requires a coordination which vehicle is active (sending or receiving) at which frequency. Due to the rapidly changing topology in a VANET, this coordination is cumbersome task. Even, decentralized combined

FDMA+TDMA "is a methods have been proposed, to exploit multiple frequency channels of the proposed IEEE 802.11p standard". [49].SDMA, which uses directional antennas to isolate the traffic, is not reasonable in case a vehicle wants to broadcast to all other vehicles in the local area. CDMA suffers from the famous near-far effect (power-impairment problem [50]) meaning that a near simultaneous transmission may impede the detection of a code used by a vehicle farther away. The reason is that since communication occurs in a decentralized ad-hoc fashion and is dominated by broadcast, neither a central station nor a specific receiver, for which the power level can be adjusted, exist. For TDMA systems, many of medium access protocols have been introduced. The simplest, the ALOHA protocol [51], does not use any coordination at all. A node transmits whenever it has data to send. An enhanced variant, slotted ALOHA, doubles rate of the data by assuming that the nodes are synchronized in time and start transmissions only at specific instances in time (so called slots). Reservation based ALOHA protocols (R-ALOHA) use an even higher degree of coordination and reserve resources in advance so that collisions can be nearly completely avoided. For vehicular ad hoc networks, several R-ALOHA variants have been proposed [52]. A various approach is taken by the CSMA protocol. In CSMA, every node check the status of wireless channel prior to a transmission. If signal power exceeding the *carrier-sense threshold* is detected, the medium will be assumed as busy and the transmitter defers its transmission. IEEE 802.11 employs CSMA with Collision Avoidance (CA) [53]: whenever the medium detected busy, the node chooses a uniformly distributed random number within a range termed the *contention window*. It specifies the time which a station has to wait after detecting an idle medium before it is begin transmission. Acknowledgement techniques are used to detect transmission failures. When packet transmissions succeed, the contention window is reset to its minimum value.

2.3.8 Mobility Models in Vehicular Networks

The earlier mobility models [70] [71] used to simulate MANET, assume the land obstacles free and nodes able to move freely in the whole simulation area. This is realistic for some applications of pedestrians but unsuitable for VANET, where it is necessary to consider constrained routes and obstacles.

There are two classes of mobility models used in the simulation of networks: *traces* and *synthetic models* [72]. Traces are those mobility patterns that are observed in real life systems and provide accurate information. In traces models it is not easy to model ad hoc. In such environments it is necessary to employ *synthetic models*. Synthetic models try to realistically represent the behaviors of vehicles without need for traces. VANET Mobility models simulate movements of vehicles in routes considering parameters differ from a model to another. Recently, some models introduced traffic control mechanisms such as stop signs/traffic lights at route junctions, and others just assume continuous movement at these points. These models vary in term of consider number of lane, security distance. It is difficult to test and evaluate protocol implementations in real environments, because of logistics difficulties, cost issues and technology shortages. A critical issue in a simulation study of VANETs is the need for a mobility model which reflects the real behavior of vehicles.

Mobility pattern of nodes in a VANET can significantly influence route discovery, maintenance, reconstruction, consistency and caching mechanism and this can affect data dissemination [73]. Fast movement of the vehicles, lead to high change in the topology. Therefore, frequent route reorganization is needed to avoid disconnection and packet losses. Generally, the following factors should be considered in modeling VANETs' mobility:

The dominant mobility models are detailed in table 2.5 .

Table 2.5: Major Vehicular Mobility Models

	Initial Position	**Destina-tion**	**Acceleration**	**Multi-lane**	**Intersection**	**Overtaking**	**Topology**
FREEWAY[74]	random on lane	random on lane	no	yes	no	no	no
Manhattan[74]	random	random	uniform	yes	yes	no	no
RUM[76]	random on graph	random on graph	no	no	no	no	no
STRAW[80]	random on graph	random on graph	uniform	no	traffic lights, signs	no	yes
Canu MobiSim[140]	random on AP	random on AP	uniform	no	no	no	graph, building
CSMM[75]	Pre-specific	random	uniform	yes	traffic lights/ signs	no	graph
SSM/ TSM[78]	Random	random	no	no	random traffic lights, traffic signs	no	graph
VanetMobi-Sim[69]	random on AP	random on AP	uniform	yes	Random traffic lights, traffic signs	Mobile	graph, building

2.3.9 Road Topology Definition

Road topology is a crucial factor to achieve realistic results from simulation of vehicular mobility. Vehicular Mobility Simulators [69] defined road topology as follows:

- *User-defined graph*: specifies topology of the road by listing the vertices of the graph and the edges that used for connection.
- *GDF map*: get ready map contains road topology from a Geographical Data File (GDF) [66].
- *TIGER map*: extracts road topology from a TIGER database [67]. this database is open and contains digital descriptions of all districts of the United States.
- *Clustered Voronoi graph*: the road topology is randomly made by maintaining a Voronoi tessellation on points distributed non-uniformly. VANETs simulators consider different road densities in present in the area which named *clusters* [69].In the mentioned way, the road topology modeled as a graph, the movement of vehicles is constrained over the edges.

2.3.10 Global Mobile System Simulator (Glomosim)

GloMoSim[139] is a simulator for wireless networks, designed as library-based for sequential and parallel processing. This library comprises a set of modules, each of these module deals with specific wireless communication protocol in the stack. Protocol stack is designed as a set of layers, each with its own API. Models of protocols at one layer interact with a lower and higher layer via these APIs. The modular implementation enables consistent comparison of multiple protocols at a given layer. Glomosim is scalable simulator. Where, it has been developed using PARSEC, a C-based parallel language, new protocol can be developed and added to Glomosim library.

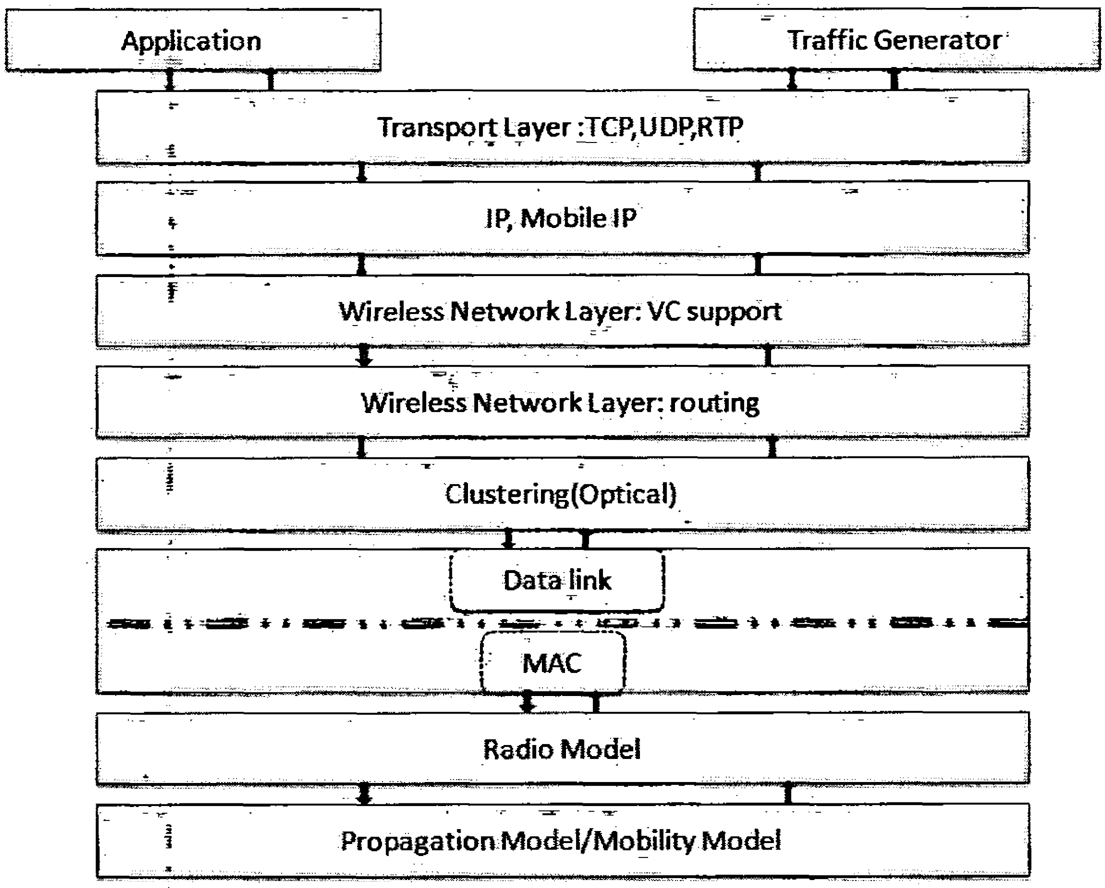

Figure 2.5: Glomosim Architecture

Chapter 3

Literature Survey

3 Literature Survey

This chapter shows the literature survey of position-based routing protocol in VANETs, but at the beginning it discusses the pioneer topology-based protocol (AODV[128], DSR[106]) which adopted in VANETs for some time before invention of overlaid position-based routing protocols as follows:

Perkins et al. in 1999[128] introduced Ad Hoc On Demand Distance Vector (AODV) topology-based protocol which follows reactive strategy .Broadcast(RREQ) query is received, nodes record the address of the node sending the query in their routing table. The task of recording the previous hop named *backward learning*. Reply packet (RREP) will be sent when the packet reach the destination, RREP follows the complete path obtained from backward learning. The nodes record its previous hop, along the path, *forward path* from the source establishes. The flooding of query and it is reply establish a full duplex path. The source will be acknowledged in case of link failure. Then the same process will be followed to establish new route, in VANETs this process infeasible due to frequent network fragmentation and local maximum problems occurrence which has no effective recovery strategy in AODV.

Naumov et.al. in 2006 [122] developed Preferred Group Broadcasting (AODV+PGB), PGB strategy used to decrease broadcast overhead result from AODV's route establishing. Broadcast signal enable the receivers to recognize whether they are member of preferred group or not. PGB limitations are:

- Broadcasting will stop whenever the group gets due to network fragmentation and PGB has no strategy to recovery from this problem.

- Route discovery task may take longer than before.

Johnson et.al. in 1996[106]. Proposed Dynamic Source Routing (DSR), is a reactive topology-based routing protocol. In DSR, the query packet keeps in its header all addresses of the intermediate nodes that it has passed during its journey. The destination node gets the full path from the query packet, and uses follow it in the replay source. So, the source can select a routing path to the destination. The limitation of DSR[106] is that has undesirable routing overhead because it attaches the full route information with the packet.

Jaap et al. in 2005[103] conducted evaluation study between AODV[128], DSR[106] and TORA in urban area environment. The study have used mobility model based on Manhattan model. Vehicle's speed adjusted based on roads circumstances [101]. The results showed that AODV perform well. AODV then DSR and TORA came at the end. The common limitation of these protocols is that, all of which suffer from performance degradation as network densities increase.

Karp et.al.in 2000 [107] introduced Greedy Perimeter Stateless Routing (GPSR), Non-overlaid position-based routing protocol, where the node forwards a packet using *greedy strategy*. Whenever, GPSR packet counter local maximum it will switch to *perimeter mode,* which follows right-hand rule. *Perimeter mode* will perform a *face change* . They call it *face routing* because the packet traverses many faces formed by nodes in the network until it reaches a node closer to the destination than where the packet entered in the perimeter mode and where the face routing started.

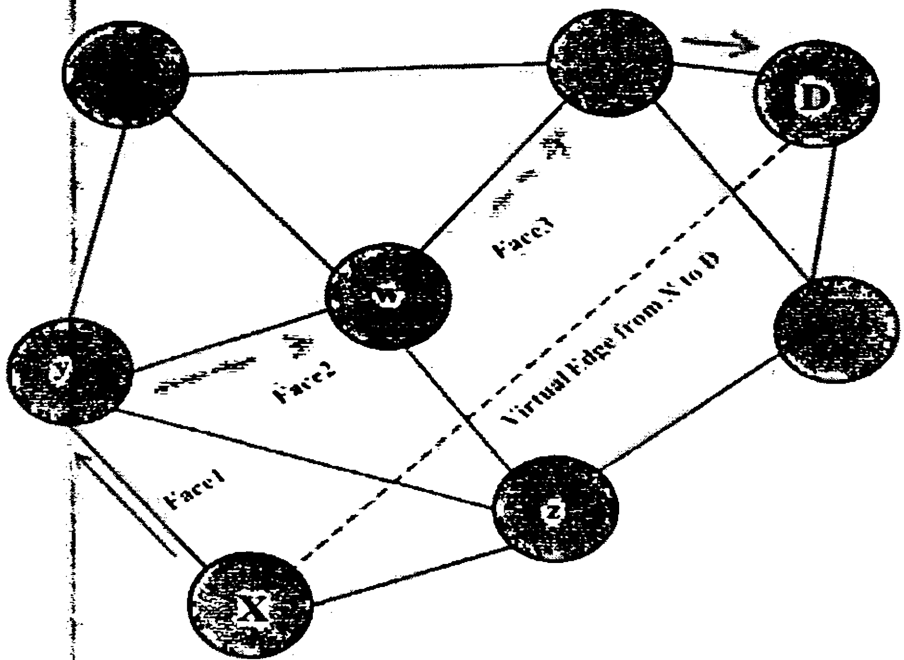

Figure 3.1: : Right hand rule in GPSR's perimeter mode

GPSR uses two algorithms that generate Relative Neighborhood Graph (RNG) [127] and Gabriel Graph (GG) [99], to avoid routing loops. The limitations of GPSR[107] are:

- Network disconnection: the planarization methods assume that the connection only depends on the distances, without considering other factors like high raised building.
- Routing Loops: Routing loops can be occurred while using perimeter method due to high mobility in VANETs.
- Wrong Direction: Whereas, the perimeter mode follows the 'Right Hand Rule,' this may lead to routes longer than the needed.

Fubler etc.al. in 2002 [97] have compared GPSR[107] and DSR[106] in the highway scenario the result shows that packet delivery ratio of DSR reduces when the communication distance becomes larger. This is because DSR establish full route from the source to destination. Observed, maintenance cost proportionate to the length of the route. The study concludes that GPSR[107] is better than DSR[106] in VANETs.

Lochert et al. in 2005[118], Greedy Perimeter Coordinator Routing (GPCR) is overlaid position-based routing protocol. In VANETs Due to high mobility of nodes, planarization becomes hard, inaccurate, and frequent procedure. This study reported that city street map actually forms a planar graph, conventional node planarization suggested to be replaced by represented the planar graph in new form using the roads, nodes will forward the packets along roads in greedy or in perimeter mode incase of local maximum problem, at junctions decision about which next road segment to turn will be made. GPCR enhances a performance of routing, where, the packets passes through closest nodes in the perimeter mode. Moreover, decision of routing avoids packets forwarding in wrong direction.

Lee et.al.in 2007[110] have developed Gpsrj+, it eliminates unwanted overhead stop at a junction by keeping topological maps. Gpsrj+ predicts direction of neighboring junction by sending two-hop beacons. Prediction helps in making best forwarding decision.

Naumov et al. in 2007[123] introduced Connectivity-Aware Routing (CAR). In CAR route discovery strategy resemble to that used by AODV[128]. Where, the nodes that involved in the path do not register all the information, which relevant, to route discovery. Exactly, the next *anchor points* will be registered from route discovery information in the concerned packet. Whenever, multiple packets reach destination for path discovery purpose, destination will chose the optimal route, compromising between connectivity and the cost. CAR uses Advanced Greedy Forwarding (AGF) to send reply packet through the registered anchor points. The source starts transmission after receiving the feedback. CAR uses greedy technique to forward data packets .

Lochert et.al.in 2003 [117] published Geographic Source Routing (GSR).GSR uses position-based routing method supported by city map. For computing a path, GSR uses dijkastra on street map. Street map modeled by overlaid graph, in which, junction nodes modeled as vertices and the streets modeled by edges to connect that vertices. Junctions group establishes the complete path from source to destination. Greedy-mode will be used to forward Packets between the involved junctions. In the experiments, Videlio simulator [108] has been used to vehicles movements' simulation with corporation of special model to change the lanes. Simulation results showed that GSR performs better than AODV[128] and DSR[106].

Limitations of the research are that *GSR does not count vehicle density between two involved junctions during path establishment. Therefore, GSR is subject to frequent occurrence of Local Maximum Problem.*

Seet et.al.in 2004[126] have designed and implemented Anchor-Based Street and Traffic Aware Routing (A-STAR) , A-STAR forward data packets through anchor points as in GSR[117]. A-STAR is traffic aware routing protocol, where; traffic is one of the considerable factors in anchor selection. *Statically rated map used by A-STAR, where, the graph modeled bus routes, which present stable traffic.* A-STAR uses Dijkstra algorithm to calculate routes to destination over the statically rated map (supported by weight of line of buses). A-STAR introduced new recovery algorithm for handling local maximum problem, where the anchor path will be computed from the node in which local maximum problem occurred and its road segment will be broadcasted as "out-of-service" temporarily. M-Grid mobility model has been used in the study. Simulation results judge that A-STAR[126] performs better than GSR[117] and GPSR[107]. The limitation of the study is that *The Simulation has been done in just one network of roads.*

Forderer et.al.in 2005[95], have developed Street Topology Based Routing protocol (STBR).in STBR road connectivity computed at junction vehicles. At an intersection, one of the vehicles will be selected as a master node to do the task of connectivity checking between current and next junctions. Master nodes exchange link information through broadcasting messages. That to provide every master node, with link information of others masters. Neighbor table of every master node consist of two-level junction.

Jerbi et.al.in 2007[104] have introduced Greedy Traffic Aware Routing (GyTAR). GyTAR is a position-based routing protocol for the urban areas. GyTAR composed of two parts; the first part, concern on choosing a appropriate next-junctions. *Second* part deal with forwarding data packet between the two involved junctions, this part uses improved greedy forwarding algorithm. Thus, data packet passes successively towards destination, considering vehicles density in streets selection. GyTAR selects intermediate junctions dynamically and one by one, exploiting the map to identify the position of the neighboring junctions. A score of traffic and the distance curvemetric is given to every junction. The optimum next-junction is the geographically closest to the destination and having the highest vehicular traffic in another word the junction with the highest score. After selection of destination junction, improved greedy algorithm will be employed to forward data packets between the currently involved junctions. Every node maintains a neighbor-table to trace location, speed and direction of the neighboring nodes. Neighbor table, always update through periodic beacons, exchange between all nodes. Therefore, the forwarding node computes the new predicted location of each neighbor with support of speed and direction of neighboring nodes from a neighbors table.

Figure 3.2, showed *Improved greedy strategy*, where vehicle (1), going in the same direction with forwarding vehicle where, vehicle (1) faster than vehicle (2), data packet will be forwarded to vehicle (2) where, at time (2), it became the closest vehicle to next-junction. Observed, without employing improved greedy algorithm, vehicle (4) will be chosen as the next hop. Whereas, it was the closer to the destination at time (1).Despite the improved greedy routing strategy, the local maximum remains, whereàs forwarding vehicle can be closer vehicle to the next junction. GyTAR uses "carry-and-forward" to recover from such local maximum problem. where, data packet will be buffered until the next junction enter radio range of buffering vehicle as shown in Figure 3.3 (a) or up to presence of another vehicle in its transmission range, between the vehicle and the next junction as shown in Figure 3.3 (b). The Simulation has been done in 2500m x 2000m map with density of 100-300 vehicles. Simulation result showed that GyTAR[104] performs better than GSR[117] in terms of packet delivery ratio. The limitations of the study are that:

- *The Simulation has been done just in one Network of Roads.*

The comparison considered GyTAR[104], GSR[117] and it has avoided A-STAR[126] the most recent Overlaid Position-based routing protocol at that time.

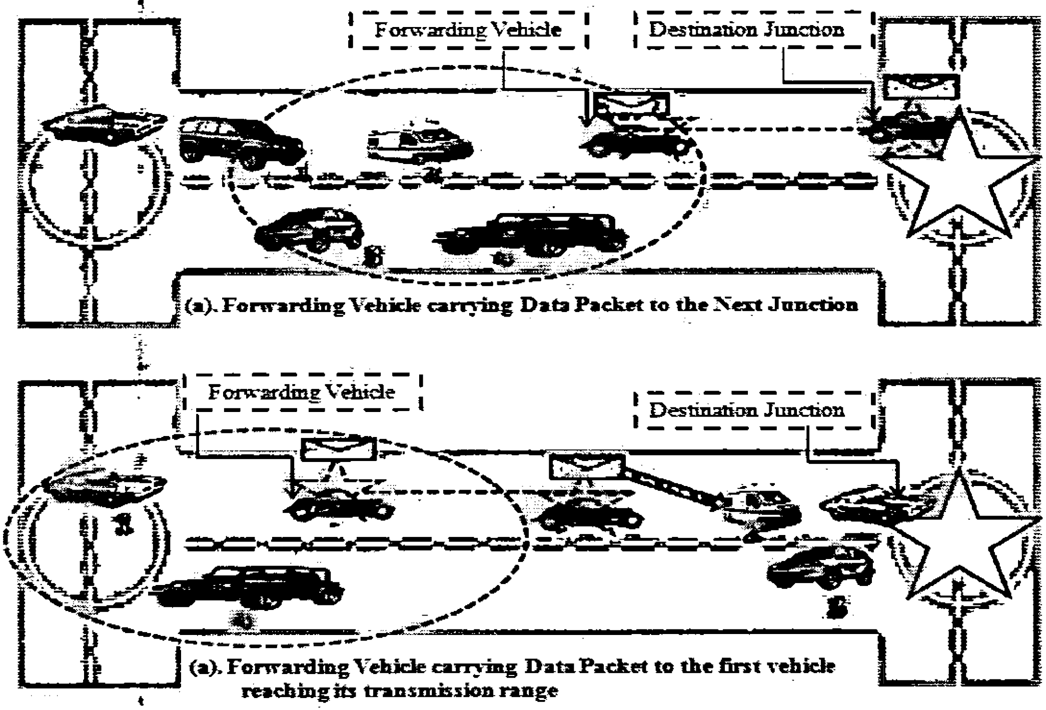

Figure 3.2: packet forwarding between two junctions using improved greedy strategy

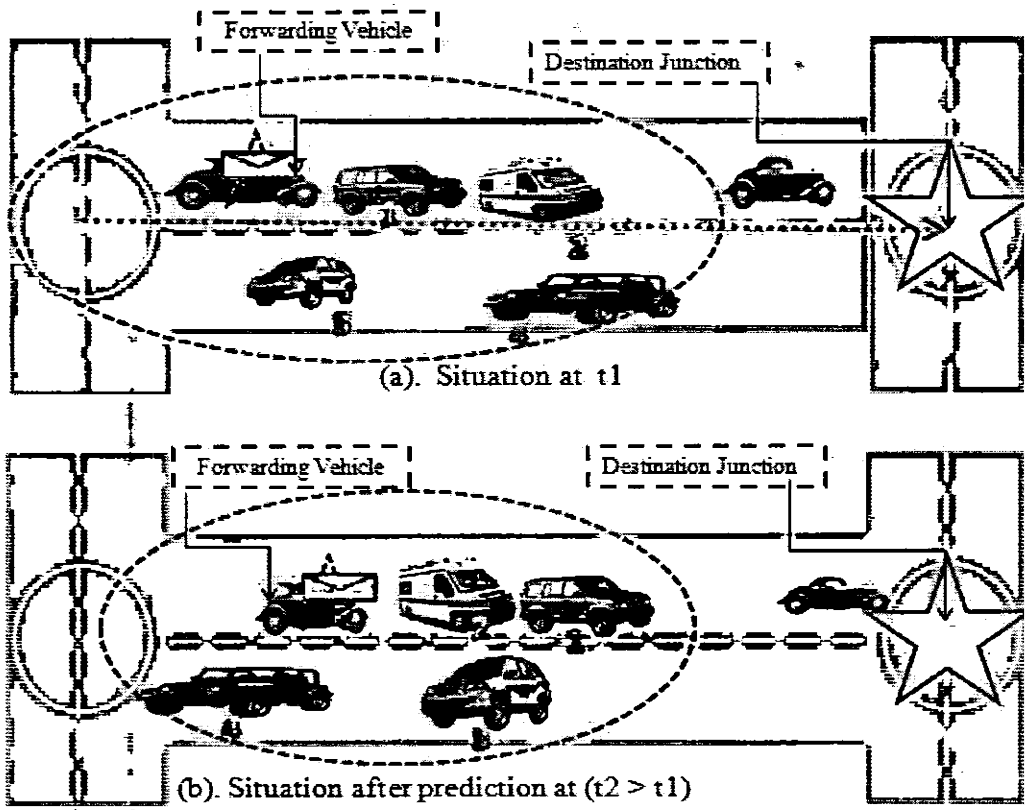

Figure 3.3: Carry -and-Forward recovery strategy

Lee et.al.in 2008[111] published Landmark Overlays for Urban Vehicular Routing Environments (LOUVRE). LOUVRE gives threshold to vehicular density. The connection through the link remains regardless the distribution of vehicles on the link. Consequently, this overlay links will be used as apart of many routes. Therefore, geo-proactive overlay routing reduces the cost of establishing routes. LOUVRE computes vehicles density on the road in a peer-to-peer way to exclude the need of roadside devices. LOUVRE uses Dijkstra to select shortest path with density threshold consideration. The simulations results show that LOUVRE better than GPCR[118] and GPSR[107] in term of packet delivery ratio and the delay also decreased.
The limitations of this protocol are: *first*, lack of scalability. *Secondly*, LOUVRE does not consider local maximum and it has no recovery mode.

FuBler et.al.2004 in [98] Contention-Based Forwarding (CBF).CBF does not uses beacons .where, data packets will be broadcasted to all neighbors then the receiving neighbors decide regard to further forwarding if need. Intermediate forwarding vehicle of broadcasted data packet consider the distance from them to the destination and the distance of last hops to destination vehicle. The simulation result showed than CBF gives packet delivery ratio better than that of GPSR[107]. The limitations of the study are: *first*, the overhead of data packet broadcasting and beacon not analysis in detail, population of the study should be increased to help in fair judgment.

Chapter 4

Problem Definition

4 Problem Definition

In Position-based routing protocols the vehicle make forwarding decision based on the position of vehicle's one-hop neighbors and the position of the receiver. Position of the receiver (destination), the source associate destination position with data in the packet header. The forwarding vehicle gets the position of the neighboring vehicles by sending periodic beacons with random jitter. Where, the neighbors Vehicles are within a vehicle's radio range. Position-based routing assumes each vehicle knows its location, and the sending vehicle knows the receiving vehicle's location by using GPS. Position-based routing protocols follow *Greedy Strategy* [107] to make forwarding decision [17]. Where, In Greedy Strategy the source forward the packet to next vehicle in its radio rang geographically closest to the destination. One of the important advantages of Greedy Forwarding is that it's relying only on the knowledge about the immediate neighbor's, not the whole network member.

4.1 Local Maximum Problem in Position-based Routing Protocols

In VANET, the movement of vehicles is constrained by the street layout. Moreover, vehicle has to deal with problems like radio obstacles, which highly affect the connectivity. Therefore, a packet could not be forwarded if the vehicle does not have a connection with the neighboring vehicle which is geographically closer to the destination than itself, such problem known as ***Local Maximum Problem*** [107].

The robustness of greedy strategy to route using only neighbor vehicles positions lead to one instantly limitation is that the topologies in which the only route to a destination needs a packet traverse instantly in geometric distance from the forwarding vehicle to the packet destination [107],[136].

A example of such a topology is illustrated by *Figure 4.1.* There, vehicle x is closer to the destination D than its neighbors vehicles w and y, also the dashed arc around D has a radius equal to the distance between x and D. Although two paths, $(x \to y \to z \to D)$ and $(D x \to w \to v \to D)$, lead to D, x will not select to forward to w or y using greedy forwarding. Vehicle x is in a local maximum in its closeness to destination D. Some alternative mechanism must be used to recover from this local maximum problem.

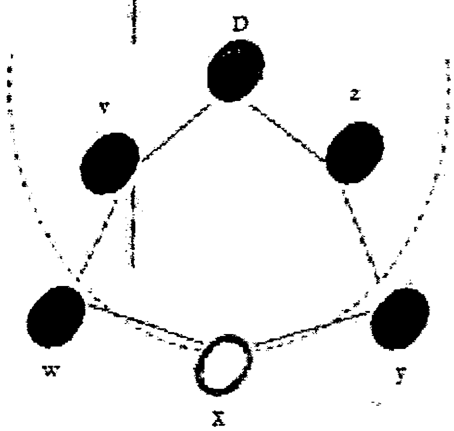

Figure 4..4.1: (a) Greedy forwarding failure respect

x is a local maximum in its geographic proximity to D; w and y are farther from D.

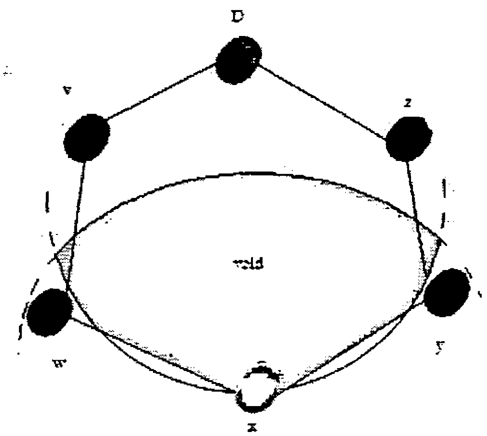

Figure 4.1 :(b) Node x's void with

to destination D

In an urban environment, mobility constrains and frequently encountered obstacles like high raise building which make *local maximum[107]* occurs frequently. As a result, the performance of geographic routing protocols in VANET can be highly affected.

4.2 Problem of Current Research

The problem is that all overlaid Position-based routing protocols for instance the most distinguished (GSR [117], A-STAR [126] and GyTAR [104]) suffer from performance degradation due to handling local maximum problem. We have selected these three protocols because GSR[117] is the first protocol used position-based routing method with support of city map and the first protocol introduced carry-and-forward strategy to recover from local maximum problem, where A-STAR[126] introduced Recompute-ancher-path strategy to recover from local maximum problem and GyTAR[104] enhanced the use of carry-and-forward by improving Greedy Strategy.

However, there has been no detailed analysis, where all these protocols implemented in one city scenario (grid/portion of city) without considering various roads networks.

Chapter 5

Intersection-based Distance and Traffic Aware Routing Protocol (Our Proposed Protocol)

5 Intersection-based Distance and Traffic Aware Routing Protocol

This chapter present the proposal of routing protocol for VANETs, based on three Legacy protocols, namely GyTAR [104], A-STAR [126] and GSR [117].

Our proposed protocol named Intersection-based Distance and Traffic Aware Routing (IDTAR) designed to provide reasonable performance by finding robust routes, consequently decreasing occurrence of local maximum problem and the cost of recovery strategy in the city environments. It like GyTAR [104] composed from to modules: first, selection of the suitable junctions to pass a packet through which to the destination .Second, greedy forwarding strategy between the two involved junctions. Where, the packet will be passed successively closer towards the destination along streets that have high density of vehicles.

5.1 Intersection (Junction) Selection

The idea of this module borrowed from GyTAR [104]. Where, the map of streets topology will be used to route data packets between the vehicles. IDTAR chose intermediate junctions dynamically and one by one, considering vehicular density factor and distance to destination: to choose the next junction, the intermediate /source vehicle, in a junction uses the digital map to get location of the neighbouring junctions. The optimal next junction (the junction have highest score) is the closest junction to the destination in term of distance and having the highest vehicular density.

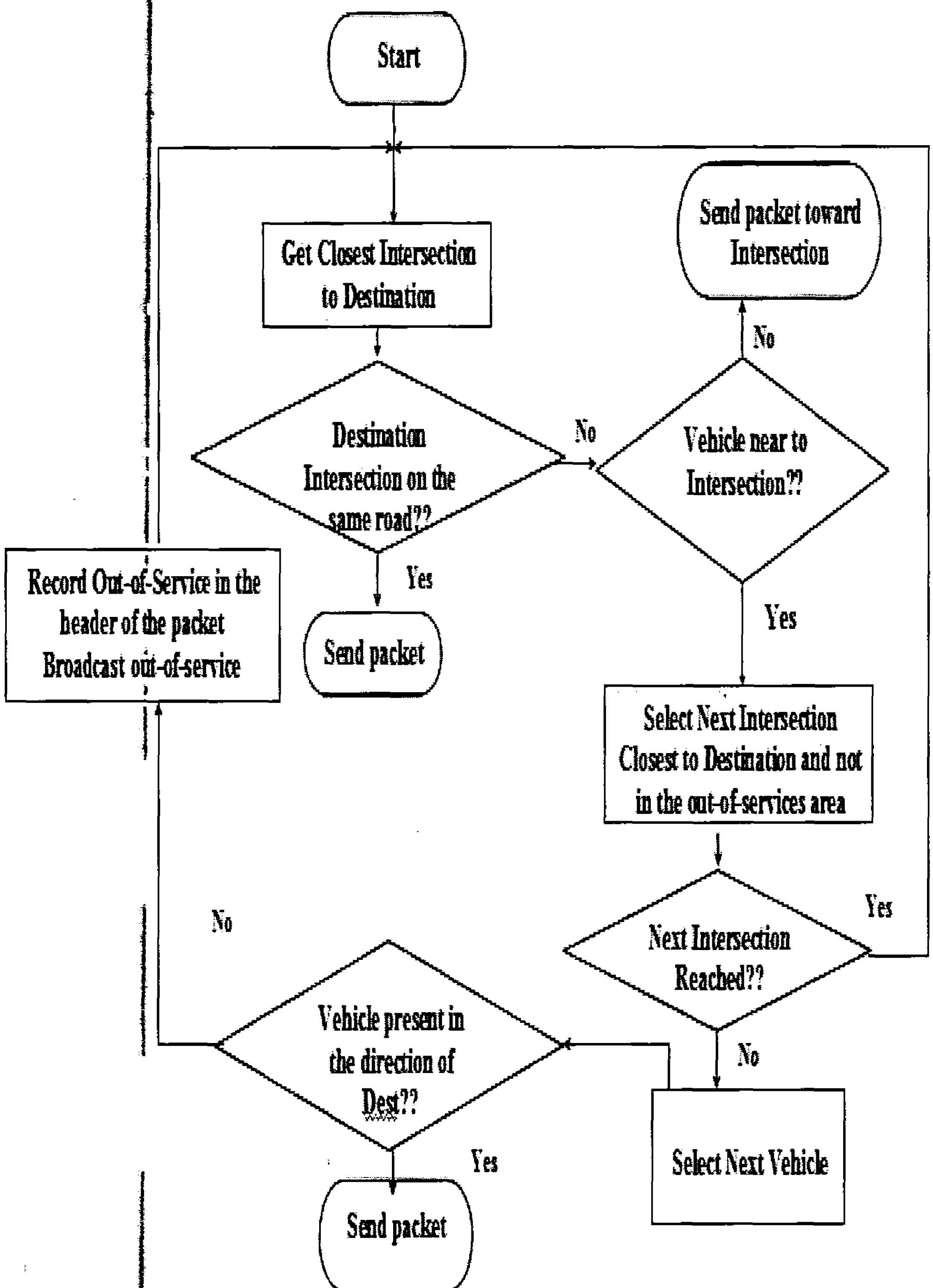

Figure 5.1: Intersection-based Distance and Traffic Aware Routing

5.2 Forwarding Data between Two Junctions

The idea of this module borrowed from GSR[117] .When destination junction is determined, the greedy method will be used to forward packets between the two involved junctions, the current junction, adds location of next junction to data packets. Every member vehicle maintains neighbours-table in which the position of each neighbouring vehicle will be recorded. Each vehicle updates its neighbour-table by exchanging hello messages periodically with other vehicles.

5.3 Recovery Strategy

The idea of this module borrowed from A-STAR [126]. Where, *Re-compute-anchor-path* adopted to recover from Local Maximum Problem. With *Re-compute-anchor-path* a new anchor path will be computed from the vehicle (anchor) in which Local Maximum Problem occurred. The packet is recovered by traversing the new anchor path. The street at which Local Maximum occurred will be marked as "out-of-service" for the time being, and this information will be broadcasted to the network. Vehicles update their local map with out-of-service before making forward decision. The streets marked out-of-service do not use for computation/re-computation of anchor for specified duration. IDTAR define threshold value (RecTime) to limit the number of times a packet can be recovered.

Summarized Pseudo Code Of IDTAR:

Let N_s: be source of a packet and N_d to be the destination

Let N_r: be a vehicle receiving a packet *pkt* for destination N_d

Let N_{neig}: be the set of *vehicles* neighboring N_r

Let *ttl* : represent live time of *pkt*

Let *Tmax* : represent the maximum hops *pkt* is allowed to traverse

Let *mRcvTim* : represent the maximum number of times *pkt* is allowed to be recovered

Let *RcvTim:* represent the number of times *pkt* has been recovered

Let J : Group of neighboring junctions

Let j : the next candidate junction .

Let i : the current junction

Let R : Road between i and j

Let D_j : the curvemetric distance from the candidate junction j to the destination.

Let D_i the curvemetric distance from the current junction to the destination.

Let D_p : determines the closeness of the candidate junction to the destination vehicle

Let N_V : total number of vehicles between i and j,

Let N_c : number of cells between i and j,

Let N_{avg} : average number of vehicles per cell

Let N_{con} : constant which represents the ideal connectivity degree we can have within a cell.

from GyTAR[104] and ASTAR[126]

If $N_r \neq N_d$ of *pkt* and ttl < *Tmax*

Get_Junction:

//Get next intersection j where it has highest

for $j \in J$

if R between I and $J \neq$ out-of-service

$D_p = D_j / D_i$

$N_{avg} = N_v / N_c$

$score(j) = \alpha \times [1 - D_p] + \beta \times [\min(N_{avg} / N_{con}, 1)]$

If ($score(j)$ is maximum score and R between N_r and j $\neq$ out-of service)

Set j as Next Junction

from GyTAR[104]

//compute the next vehicle *n* along the anchor path

do

If ($\exists\, n \in N_{neig}$: *n* resides on *R* and has shortest distance along *R to j* and)

Send *pkt* to *n*

until *n is in j* *then* *i=j*

goto Get_Junction

else

Mark the street where *n* resides as "out-of-service"

Record the "out of service" information in the header of *pkt* and mark *j* as blocked)

goto *Get_Junction:*

from ASTAR[126]

5.4 Simulation Setup and Scenarios

This section describes the simulation parameter and setting which has been employed in the experiments then the city scenarios explained.

5.4.1 Simulation Setup

We consider different vehicle densities under which the performance of each protocol is evaluated. Speed of vehicles and cars is up to 60 km/h.

Table 5.1: Summary of parameters settings in the simulation

Parameter	Setting
Simulator name	Glomosim
Mobility model	VANETMOBISIM
Packet sending rate	4 packets / second
Traffic model	10 CBR connections
Data packet size	128 Bytes
Map size	2500x2000 m^2
Number of nodes	100-300, in steps of 50
Simulation time	200 Seconds
MAC protocol	IEEE 802.11
Radio propagation model	TWO-RAY

5.4.2 Simulation Scenarios:

Simulation has taken different city map scenarios in each of which different number of roads and intersections these scenarios detailed as follows:

5.4.2.1 First City Scenario

In this scenario, to model city map similar to geometric shapes of modern cities. I designed as grid map in which 24 Intersections Connected with 76 road segments as shown by Figure 5.4.

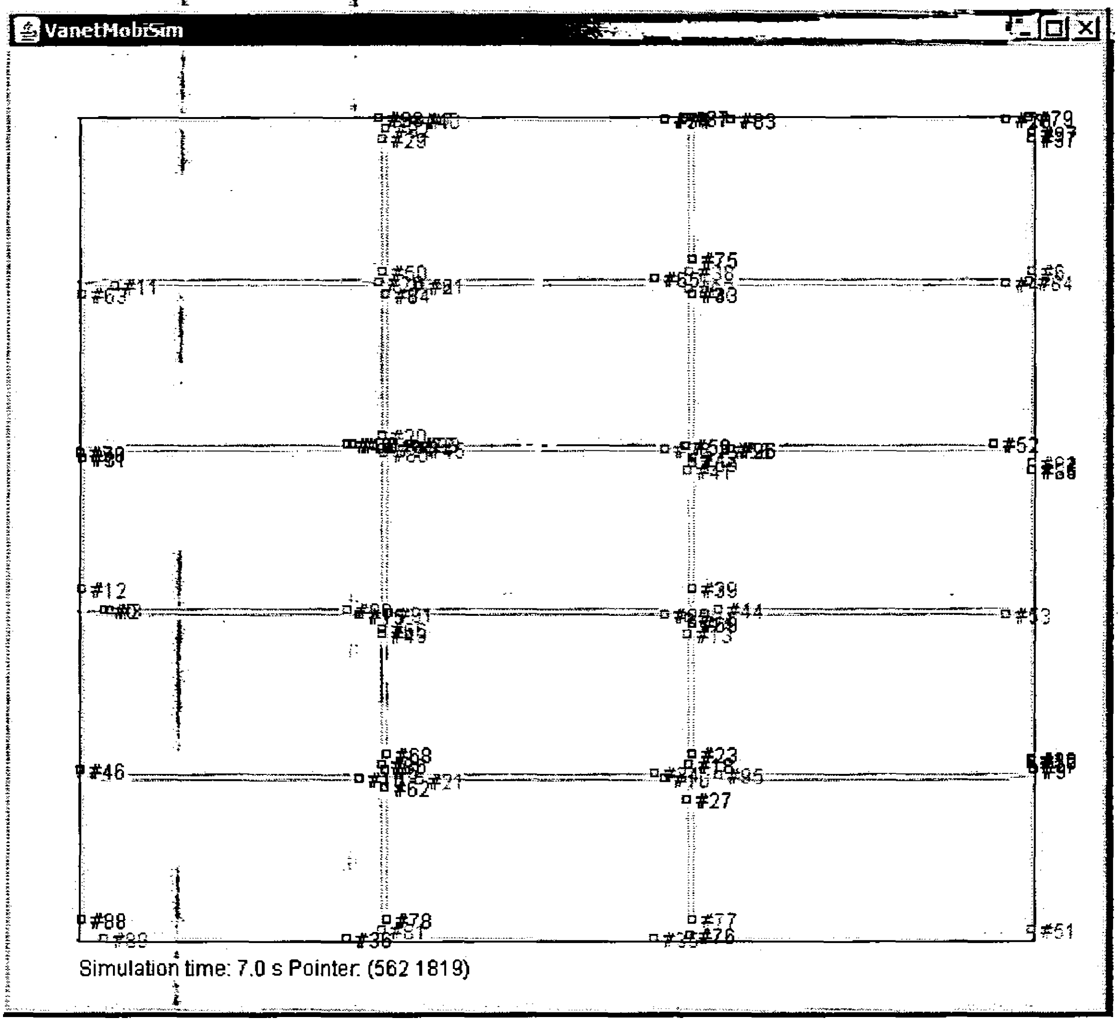

Figure 5.2: First City Scenario

5.4.2.2 Second City Scenario

In this scenario, to make considerable difference from first scenario I removed 4 intersections consequently 14 road segments has been removed, then I rearranged the distances between the intersections. So, second city scenario became 20 Intersections Connected with 62 road segments as shown by Figure 5.3.

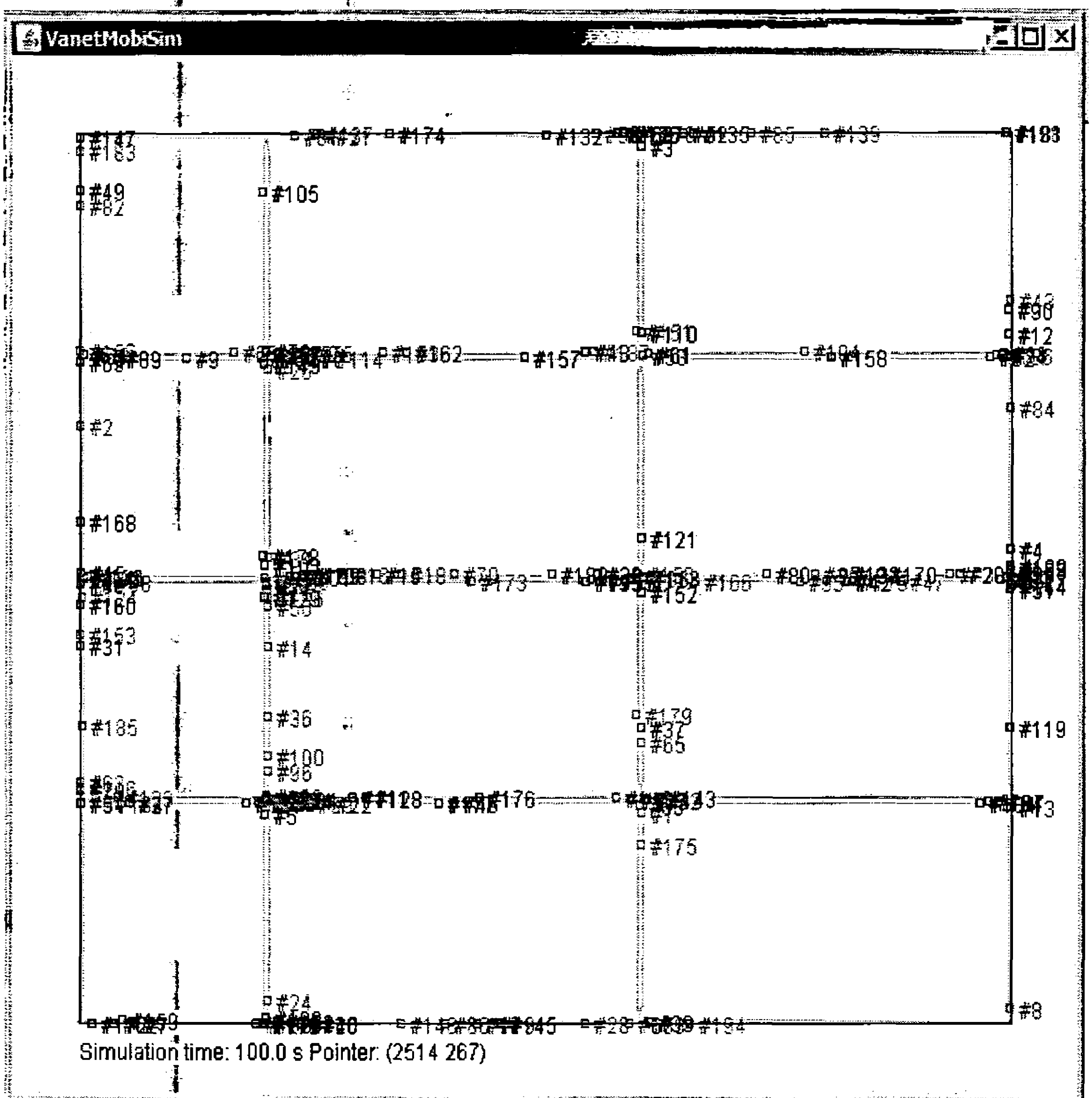

Figure 5.3: Second City Scenario

5.4.2.3 Third City Scenario

In this scenario, to make considerable difference from second scenario I removed 4 intersections consequently 14 road segments has been removed, then I rearranged the distances between the intersections. So, Third city scenario became 16 Intersections Connected with 48 road segments as shown by Figure 5.4.

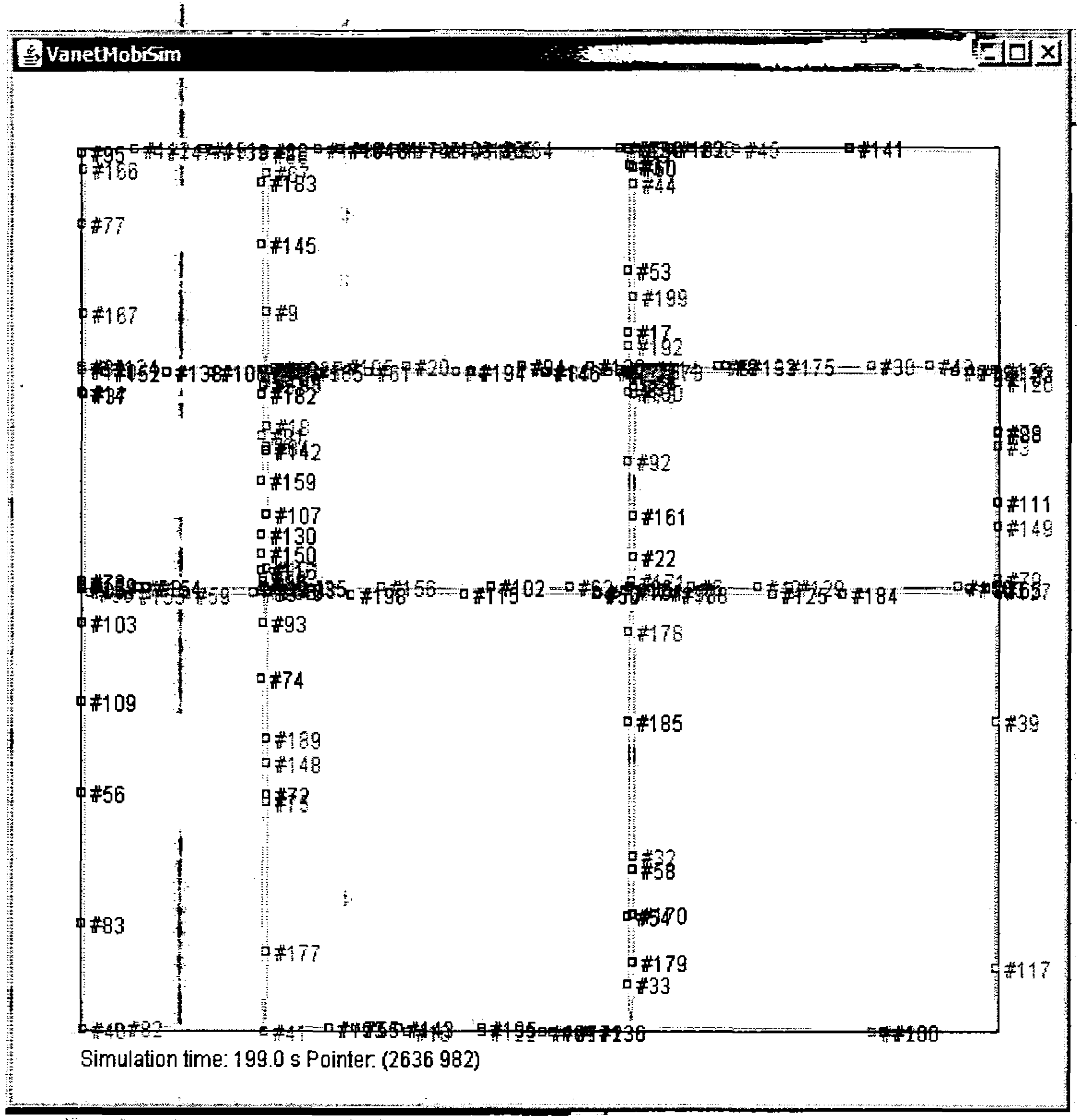

Figure 5.4: Third City Scenario

Chapter 6

Simulation Results and Analysis

6 Simulation Results and Analysis

Performance of IDTAR and other relevant protocols are implemented in Glomosim simulator. Four protocols are analyzed and compared: i) GSR[117], ii) ASTAR-SR[126] iii) GyTAR [104] iv) IDTAR.

Performance result for each simulated vehicles density taken as the average of three runs. The interest factors are:

- Packet delivery ratio: the average of packets number, which delivered from the source to the destinations.
- End-to-end delay: the average time packet takes to travel from its source to destination.

This study does not consider Results of control overhead.

The experiments have been carried out in three different networks of road in city environments ,each of which consist of different number of intersections and number of roads , detailed as follows

6.1.1.1 Results of First City Scenarios

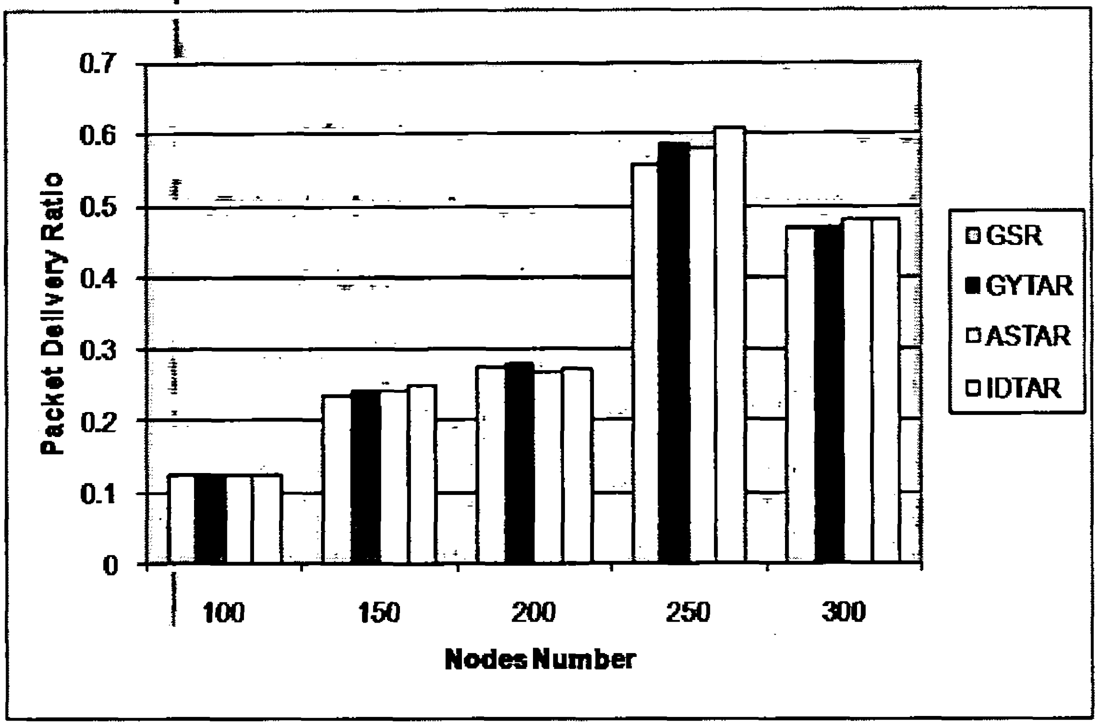

Figure 6.1: Packet Delivery Ratio in First City Scenario

Figure 6.1 show that IDTAR gives the highest packet delivery ratio, with improvement of 4.4% over than GSR[117], 1.9% than GyTAR[104] and 2.6% than A-STAR-SR[126]. This is because IDTAR determines the path dynamically (road after road), considering vehicle density in road and distance. Therefore, a packet will pass closer towards the destination via streets which have sufficient vehicles to provide connectivity. Observed, that packets delivery ratio increases with increment of vehicle number until it reach 250 then it decreases due to congestions in intersections, because the vehicles not well scattered in roads to provide good connectivity .

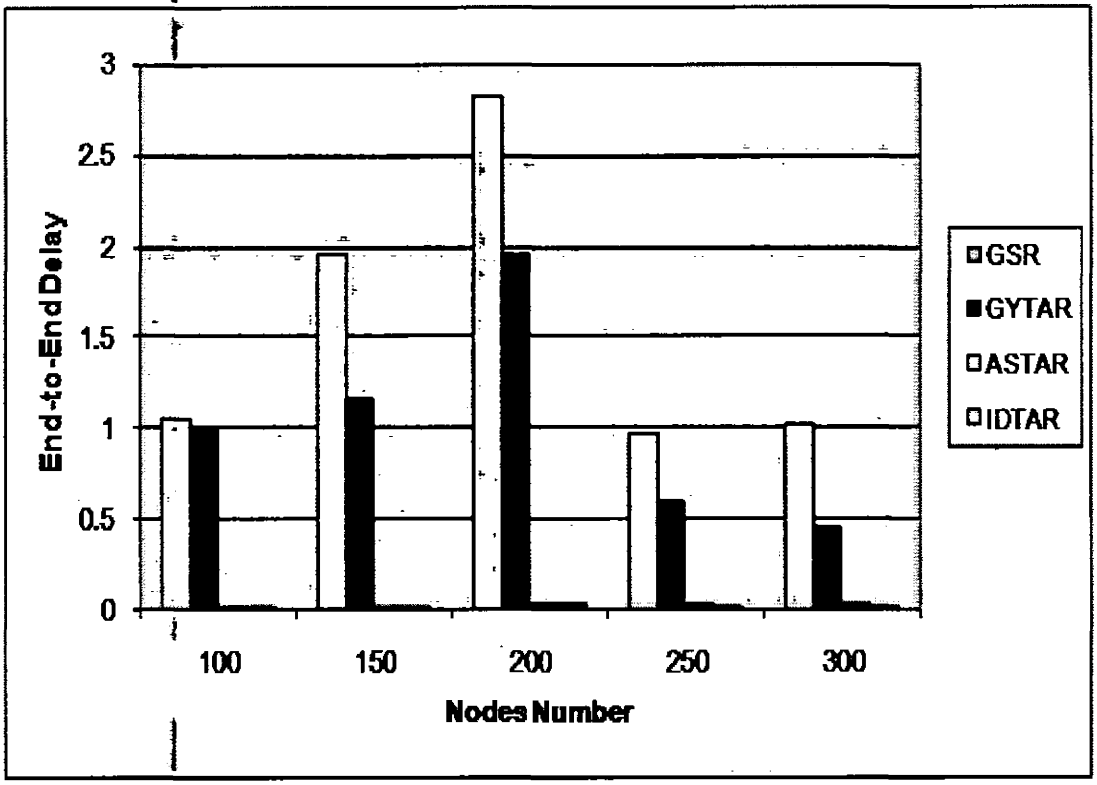

Figure 6.2: End-to-End Delay in First City Scenario

Figure 6.2 show that IDTAR achieves the lowest End-to-End, with improvement of 99.3% lower than GSR[117], 99% than GyTAR[104] and 38.9% than ASTAR-SR[126]. This is mainly because in IDTAR, adopt Re-compute new anchor to recover from Local Maximum Problem. Where, GSR [117] and GyTAR[104] use Carry-and-forward Strategy to recover from *Local Maximum Problem*[107]. Observed, A-STAR-SR[126] achieves low End-to-End Delay like IDTAR and both uses same recovery Strategy. Consequently, in this scenario Re-compute-anchor-path performs better than Carry-and-forward.

6.1.1.2 Results of Second City Scenarios

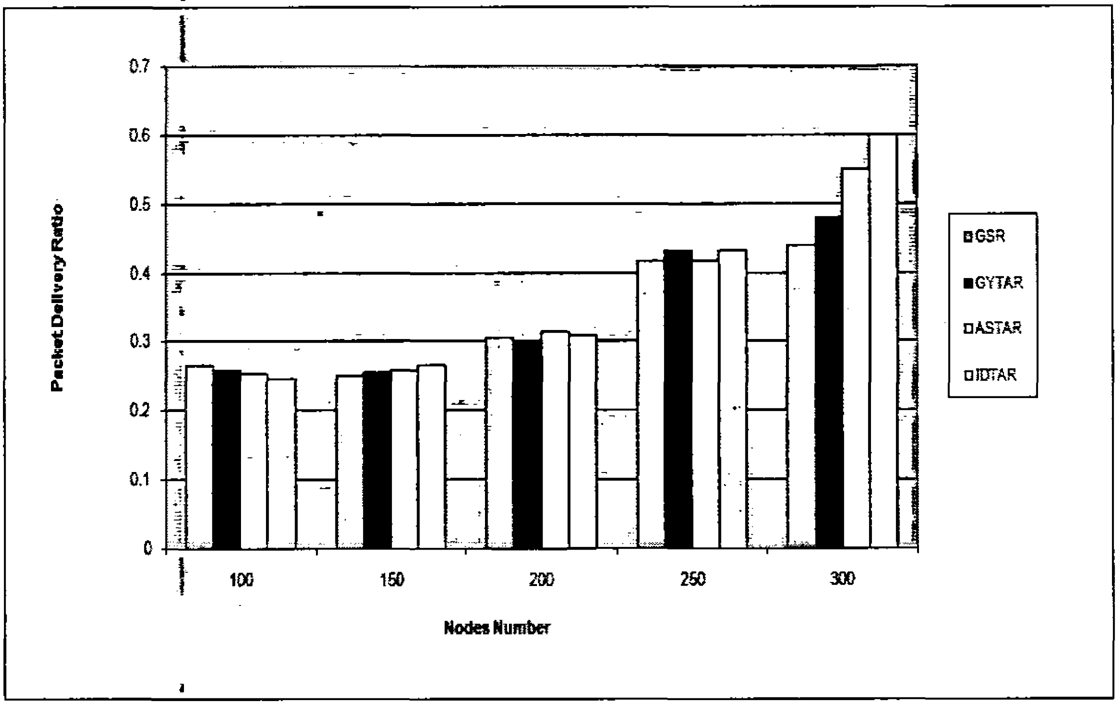

Figure 6.3: Delivery Ratio in Second City Scenarios

Figure 6.3 show that IDTAR gives the highest packet delivery ratio, with improvement of 10.2% than over GSR[107], 7.2% than GyTAR[104] and 3.1% than ASTAR-SR[126]. This is because IDTAR determines the path dynamically (road after road), considering vehicle density in road and distance. Therefore, a packet will pass closer towards the destination via streets which have sufficient vehicles to provide connectivity. It is observed that packets delivery ratio proportionate to vehicles number.

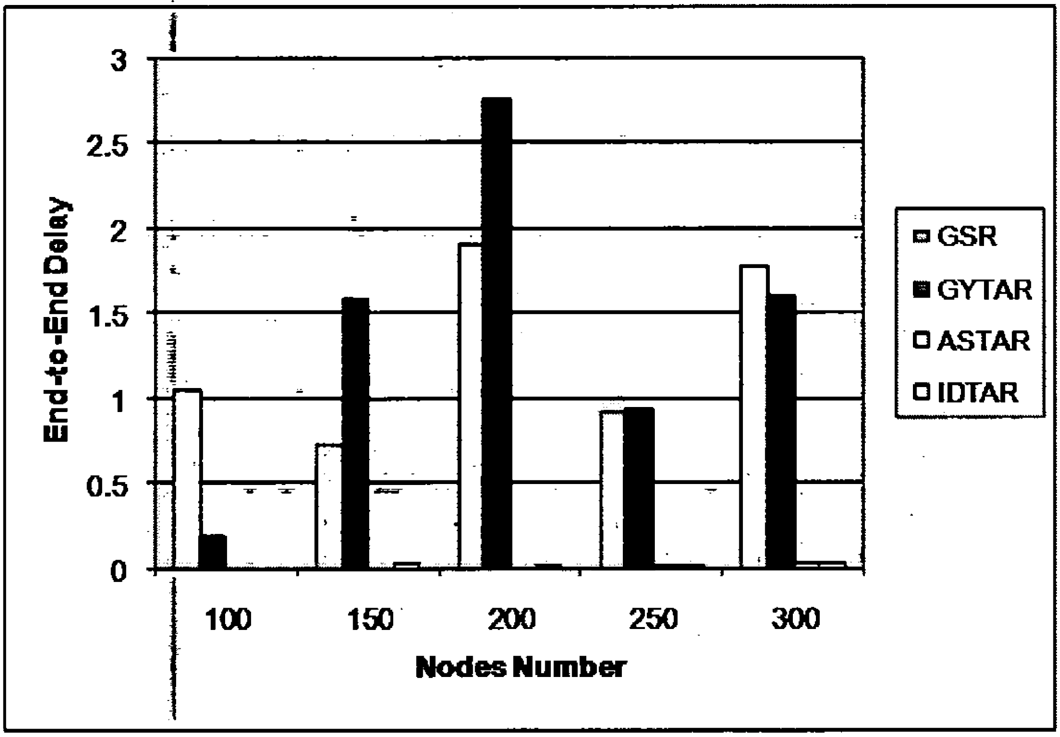

Figure 6.4: End-to-End Delay in Second City Scenario

Figure 6.4 show that IDTAR achieves the Lowest End-to-End Delay, with relative improvement of 98% lower than GSR[117], 98% than GyTAR[104], but 13% greater than A-STAR-SR. This is mainly because in IDTAR, adopt Re-compute-new-anchor to recover from Local Maximum Problem. Where, GSR[117] and GyTAR[104] use Carry-and-forward Strategy to recover from *Local Maximum Problem*[107]. Observed, A-STAR-SR[126] achieves low End-to-End Delay like IDTAR and both uses Same Recovery Strategy, therefore, Re-compute-anchor-path better than Carry-and-forward Strategy in term of performance in this scenario.

6.1.1.3 Results of Third City Scenarios

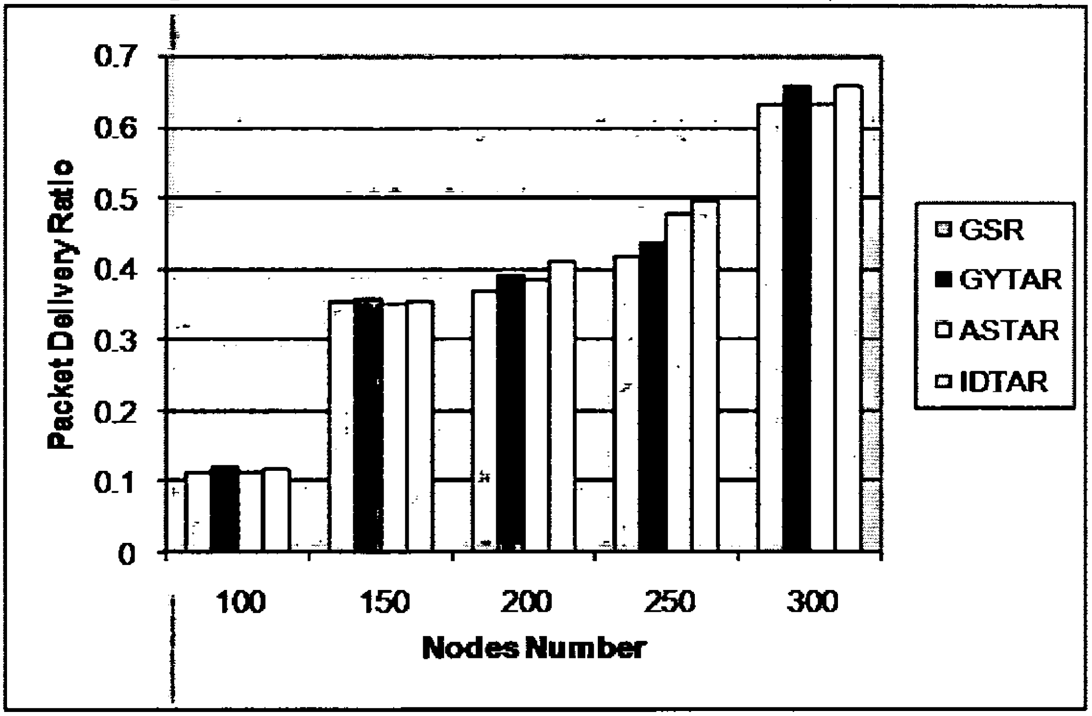

Figure 6.5: Packet Delivery Ratio in Third City Scenarios

Figure 6.5 shows that IDTAR gives the highest packet delivery ratio, with improvement of 7.9% over than GSR[117], 3.8 % than GyTAR[104] and 3.9% than A-STAR-SR[126]. This is because IDTAR determines the path dynamically (road after road), considering vehicle density in road and distance. Therefore, a packet will pass closer towards the destination via streets which have sufficient vehicles to provide connectivity. It is observed that packets delivery ratio proportionate to vehicles number.

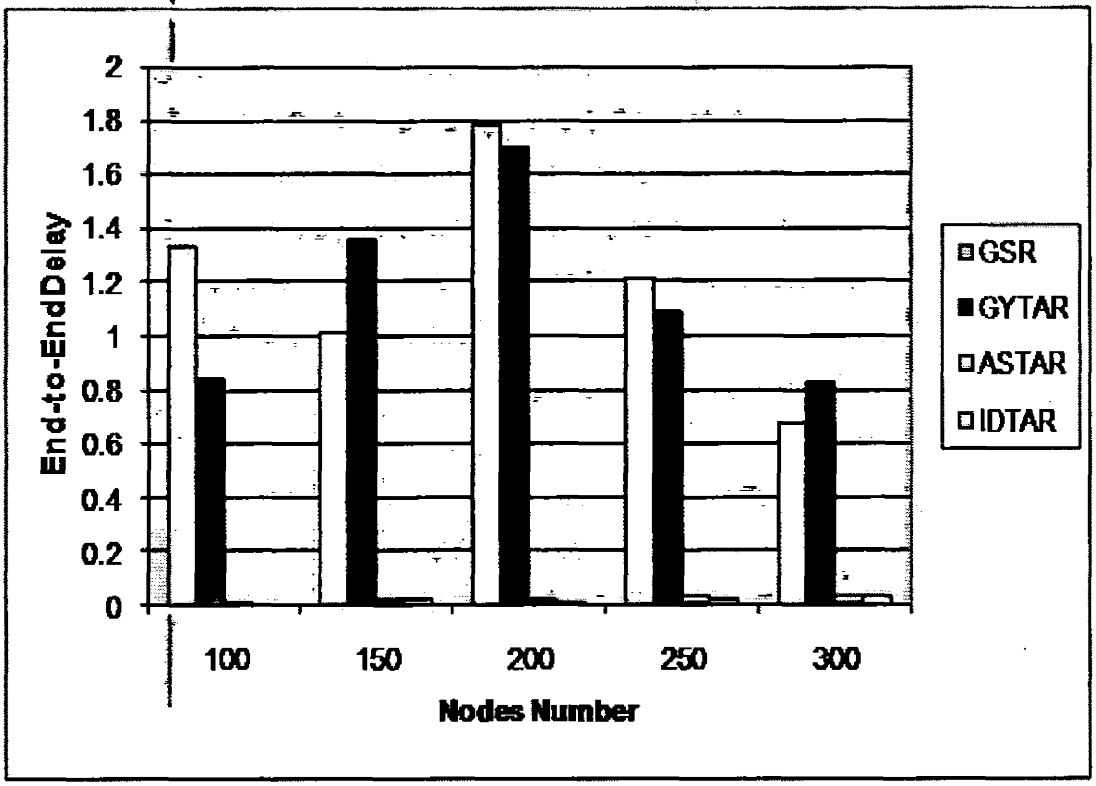

Figure 6.6: End-to-End Delay in Third City Scenarios

Figure 6.6 shows that IDTAR achieves the Lowest End-to-End Delay, with improvement of 98% lower than GSR[117], 98% than GyTAR[104], but 8% greater than A-STARR-SR[126] . This is because IDTAR, adopt Re-compute new anchor to recover from Local Maximum Problem. Where, GSR[117] and GyTAR[104] use Carry-and-forward Strategy to recover from *Local Maximum Problem*[107]. Observed, A-STAR-SR and IDTAR achieves low End-to-End Delay and both uses Same Recovery Strategy therefore Re-compute new anchor better than Carry-and-forward Strategy in term of performance.

4.2.2.4 Impact of Intersections Number on Overall Performance

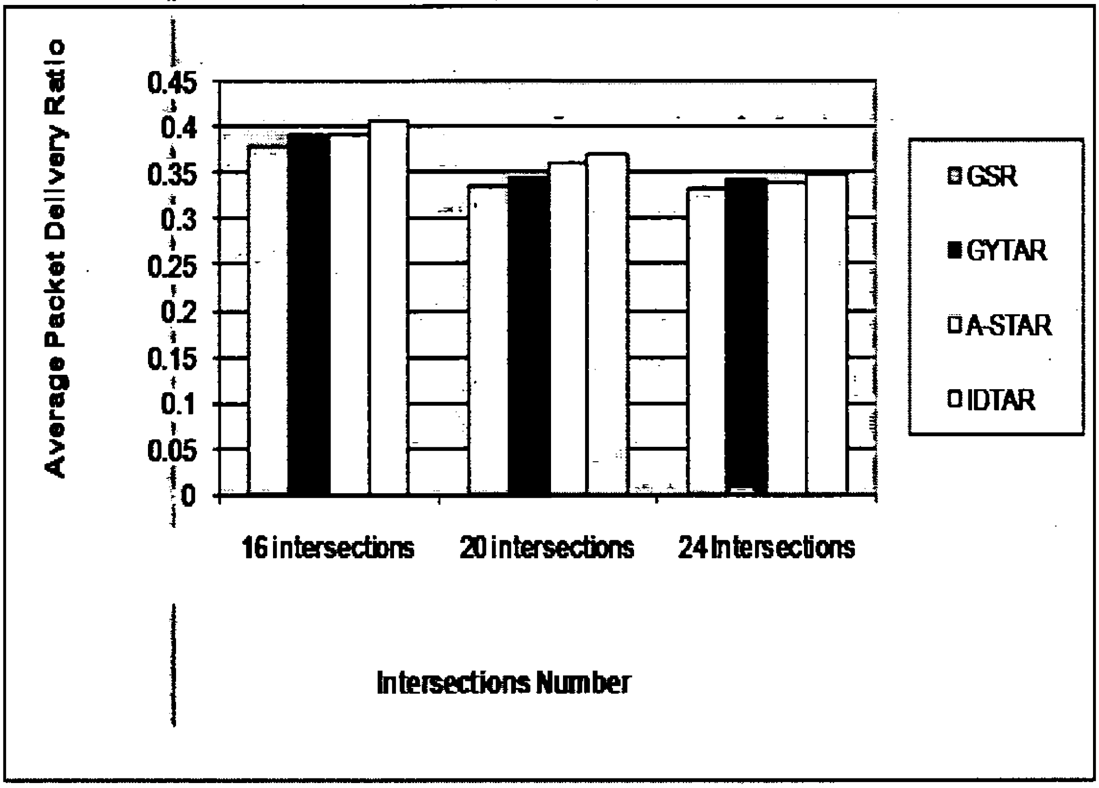

Figure 6.7: : Impact of Intersections Number on Packet Delivery Ratio

Figure 6.7 show that Intersections Number has impact on Overall Packet Delivery ratio, where increment of intersection slow-down the performance of the four protocols.

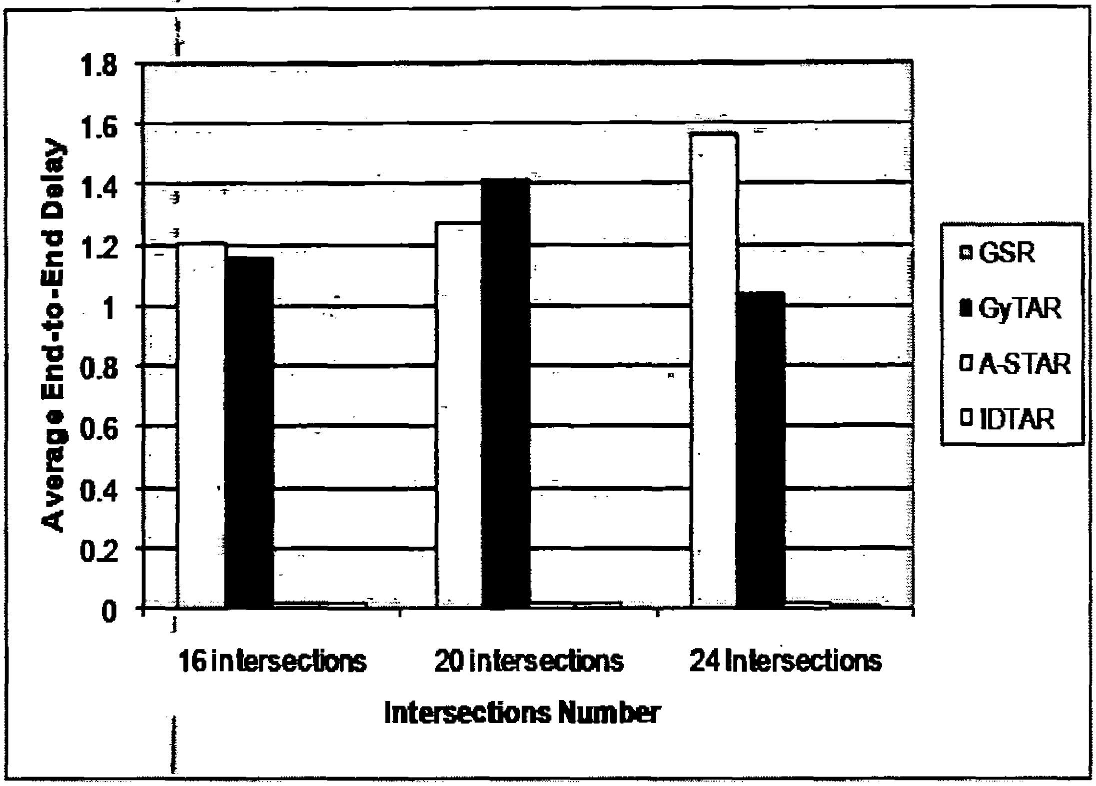

Figure 6.8: Impact of Intersections Number on End-to-End Delay

Figure 6.8 show that Intersections Number has impact on , where increment in Intersection Number increase the Overall End-to-End Delay of GSR and A-STAR-SR and Decreases End-to-End Delay of GyTAR and IDTAR.

Chapter 7

Conclusion and Future Work

7 Conclusion and Future work

This chapter summarizes the overall conclusions of the thesis and then it identifies the gap which is left for future works.

7.1 Conclusions

The contributions of this thesis can be divided in to three parts as follows:

- The introduction of a new effective position-based routing protocol for VANETs named Intersection-based Distance and Traffic Aware Routing protocol (IDTAR), where it considers both Distance and real time vehicle density information to route data in VANETs. IDTAR is position-based routing protocol designed for city environments.
- performance analysis and evaluation conducted within various city scenarios , simulation results showed that IDTAR performs better than GSR, GyTAR and A-STAR-SR in terms of packet delivery ratio and data packet end-to-end-delay so legacy protocols has been analyzed as well .
    - In the First City Scenario, IDTAR gives the highest packet delivery ratio with improvement of 7.9% over than GSR, 3.8 % than GyTAR and 3.9% than ASTAR. IDTAR achieves the Lowest End-to-End Delay the relative improvement of lower 98% than GSR, 98% than GyTAR , but 8% greater than ASTAR-SR .
    - In Second City Scenario, IDTAR gives the highest packet delivery ratio with improvement of 10.2% over than GSR, 7.2% than GyTAR and 3.1% than ASTAR . IDTAR achieves the Lowest End-to-End

Delay with improvement of 98.3% lower than GSR, 98.4% than GyTAR , but 13% greater than ASTAR.

- In Third City Scenario, IDTAR gives the highest packet delivery ratio with improvement of 4.4% over than GSR, 1.9% than GyTAR and 2.6% than ASTAR. IDTAR achieves the Lowest End-to-End Delay with improvement of 99.3% lower than GSR, 99.0% than GyTAR and 38.9% than ASTAR.

- The impact of roads and intersections numbers on the performance of position-based routing protocol has been analyzed, where increment of roads intersections number over specific limit slow-down Overall Packet Delivery Ratio increment of the four protocols and increases it overall End-to-End Delay

7.2 Future Work

As discussed in Section 2.3.5 there are many radio propagations models, this thesis employed Two-Ray model, for future work the same experiments should be done using different radio propagation model , then the result should be analyzed and compared to measure the impact of radio propagation models on the performance of Position-based routing.

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