Research Thesis

Improved Segment based Geographical Routing (ISR) Protocol for Vehicular Ad-hoc Networks

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Acknowledgment

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First, I Thanks to **ALLAH ALMIGHTY** for the wisdom and perseverance that HE has been bestowed upon me during this research, and indeed, throughout my life: I can do everything through HIM who gives me strength".

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ABSTRACT

Vehicular Ad hoc Networks (VANETs) have adopted the smart abilities of wireless networks and make the data communication possible through vehicle nodes. These networks support various types of applications related to safety and infotainment. The routing protocols have adopted for data communication and handle the high mobility of nodes plus dynamic and unpredictable topologies in the network. Due to these limitations, the data communication become unreliable which causes data loss and link disconnections. Still, these issues need to address through smart and network aware routing protocols. Connectivity among vehicle nodes is one of the main and significant requirements in these networks. Geographical routing protocols are best to deal with these networks due to their location information exchange strategy to find the destination in the network. This research proposed an Improved Segment based Geographical Routing Protocol (ISR) which only need position information of the vehicle nodes for routing decisions. The research aims to improve connectivity and reduce network overhead in the network. The proposed protocol is considering traffic density, distance, and direction of nodes for the next forwarder and route selection. This protocol is viable for urban traffic conditions. The simulation results show that the proposed protocol performed better in terms of packet delivery ratio, end-to-end delay, and network overhead compared to state of art protocols.

CHAPTER 1

INTRODUCTION

1.1 Overview

In a very first chapter we present background study of the Vehicular Ad hoc Networks (VANETs) and describes the routing issues. It briefly describes applications and routing process in these networks. This chapter presents the purpose of this study and gives an overview of thesis followed by problem background, problem statement, research questions, research objectives and ends with thesis organization.

1.2 Vehicular Ad hoc Networks

Vehicular Ad hoc Networks (VANETs), enables data communication among vehicle nodes with or without using preexisting infrastructure which helps drivers to drive safely. This field has gained popularity among researchers because of its different types of applications. Designing of routing protocols is still a challenge because of the high mobility of nodes and dynamic and unpredictable network topologies. Because of these constraints, the exchange information becomes outdated which results in the disconnection and packet dropping issues. These issues have been addressed in different routing protocols [1].

The data communication is possible with or without roadside units. This type of data communication makes this area is one of the subclass of ITS (Intelligence Transportation System) for the transportation domain. Mostly, the applications in this area offer convenience and improve road safety. In addition, the safety applications contain the needed information for alerting the drivers in case of any accidents, traffic congestion, repair work, emergency braking, available parking spaces, the presence of police radar and emergency response vehicles [2]. The vehicle nodes are taking advantage of new and intelligent technologies and reduces the cost of wireless devices. Indeed, by the installation of sensor nodes in vehicles, or at the edges of roads and in control centers, vehicular communications can warn or alert the drivers for possible dangers in advance.

In addition, in order to improve data communication and road safety, these networks offer new services to road users for more convenience and road safety. Several research projects related to road safety have been proposed where different electronic devices are installed in vehicle nodes to develop such a network such as radars, cameras, and GPS tracking system [3].

Vehicle nodes contains On-Board Equipment (OBE) which is installed in the vehicle and able to communicate with other OBE units and Road-Side Unit (RSU) RSU refers to node or base station installed on the road-side and provides connectivity among vehicle nodes to access the network easily and further connected to the main station. Two types of communications happened in VANETs. Vehicle-to-Vehicle (V2V) and Vehicle –to-Infrastructure (V2I). The main goal of VANET is to providing well organized data communication among vehicles and RSUs. The movement of nodes in VANETs are periodic and having a merging network. Figure 1.1 shows the components and V2V communication and V2I communication by RSU [4].

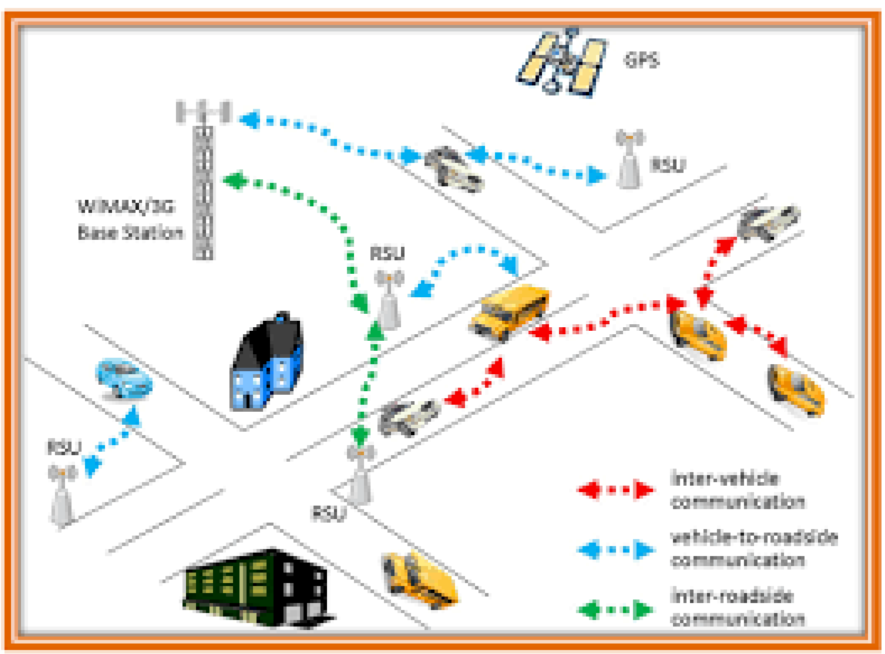

Figure 1.1: VANET Components and Communication

Vehicular network's performance is majorly depending on the routing protocols which are used in the network for data routing. Routing protocol have categorized into five types including topology-based, geographic-based, cluster-based, broadcast and geocast routing protocols. Vehicle nodes movement in VANETs are typically restricted in two-way roads and streets. So, routing protocols that use physical information of the nodes received from GPS and street maps are best to consider for routing decisions [5].

1.3 Problem Background

VANETs have unique characteristics such as dynamic topologies, high mobility of nodes. Therefore, to improve the routing services in this area, the routing protocol should be more feasible and smarter for routing decisions. There are still various challenges for the deployment of VANETs applications, such as instable movement of traffic amongst multi-path topologies, and inefficient network deployment. High mobility of vehicles nodes and unpredictable network topologies makes the VANETs are highly dynamic network.

In [2], the authors discussed some previous known routing protocols for VANETs like DSDV, OLSR, GPSR, GSR, and A-STAR. In DSDV two types of packets are used to send the information, incremental and dumb packet. The dump packet contains the initial routing information and the incremental packet contains the updates. It offers a loop-free routing protocol. The network topology is changing very frequently, due to this number of incremental packets also increases and leads to network overhead. In OLSR, whenever topology changes' its MPR (multipoint relay) responsibility increases to update the information for selected nodes. In the broadcast scenario, it reduces the packet retransmission.

The basic idea of geographical type routing is GPSR (Greedy Parameter Stateless Routing) [2]. GPSR uses two mods particularly, the greedy and perimeter mode. When a data is delivered to the node which is near to the destination and in the transmission range of source node is called greedy mode. When source node is near to destination and its neighbors are far away in those cases, the protocol switches to perimeter mode. It's not performed well in an urban environment and it's only considered distance metric, not direction which leads to wrong packet forwarding and increases packet loss.

GSR uses topology and position information for forwarding the data packets from source to destination. To find the shortest path between source and destination, the protocol uses the Dijkstra algorithm. A-STAR is used to overcome the problem that arises in GPRS and GSR. Its working is very much similar to GSR. Only changes calculate the topology information which uses actual traffic awareness which was not available in GSR [5]. Improved Geographical Routing (IG) [33] uses different metrics at the intersection and between intersections. Beacon messages are used to get the position of vehicles. The protocol uses distance and link quality between vehicles to transfer the data packet. It uses distance and link quality between the intersections and uses density when at an intersection. It does not take direction metric which causes the face routing and protocol suffers from low packet delivery ratio.

In addition, traffic density changes frequently and lead to disconnection issues in the network. This disconnection mostly happens in the sparse network where the distance between vehicles is more compared to high dense area, furthermore, the obstacles are another issue for disconnection. It’s easy to find the path to communicate in a highly dense network. In opposite, in low vehicle density’ frequent network disconnections happen and resulting network overhead. The vehicle takes a long time for data delivery or sometimes they drop the packet. In geographical routing, nodes always find the neighbor nodes which are closer to the destination and transmit the data packet as shown in Figure 1.2. The situation where S node wants to send the data to node D, and it chooses node A to forward the data because node A is closest to node D in the transmission range of node S [6].

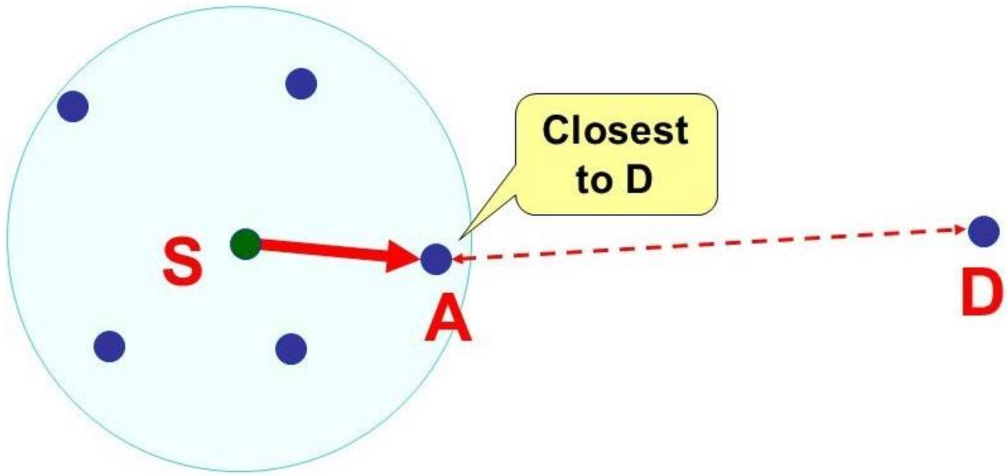

Figure 1.2: Greedy Forwarding

Limitation of greedy forwarding is that it does not always work. Figure 1.3 shows that there may be a situation where node may not find the closest node to the destination to forwarding the data than itself. This approach fails in that situation and it is called dead end or void.

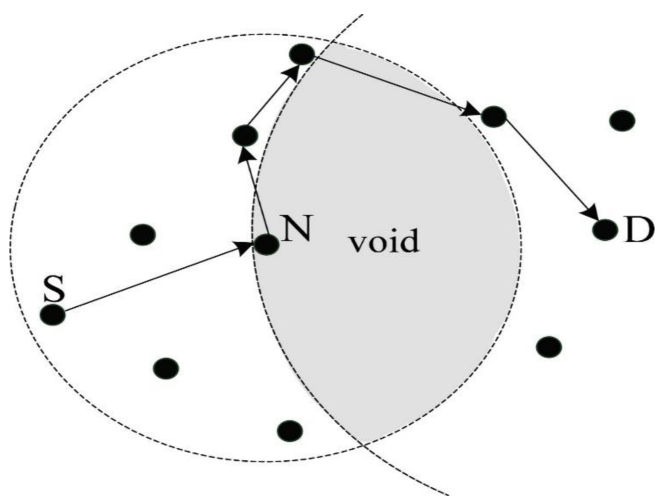

Figure 1.3: Void Situation

Due to the dynamic nature of the VANETs, packets can send in wrong direction because of routing loop induced by right hand rule which is used to overcome the problem of void scenarios, resulting the higher delays. To address these issues, a robust enhanced geographical routing protocol must be aware with more appropriate routing metrics to address disconnections issues with low overhead for data routing [7].

1.4 Problem Statement

Vehicular networks have suffered from high mobility of nodes in dense or sparse traffic conditions which cause disconnectivity and overhead issue in VANETs. Many geographical routing protocols are based on greedy forwarding where the source node selects relay node near destination within its communication range to forward the data. Due to high mobility of the nodes and changing its position and protocol has disconnection issues and also cause of routing overhead due to frequent beacon messages.

1.5 Research Questions

The research designs an Improved Segment based geographical routing protocol (ISR). To achieve the research objectives the below questions are precisely identified and will be answered through this research.

- How to improve disconnectivity issues in VANETs?
- How to minimize network overhead in VANET?

1.6 Research Objectives

To achieve the main aim of this research by designing a new segment based geographical routing protocol, following are the main research objectives.

- To design a geographical routing protocol to improve the network connectivity in order to achieve higher packet delivery in urban environment with low delay and high throughput.
- To design a segment based geographical routing protocol to minimize network overhead. By considering more feasible routing metrics for VANETs.

1.7 Motivation

Vehicular networks applications offer extensive safety and infotainment services. All the applications need stable routing without any delay and disconnection issues among vehicles. In geographical routing, there is no need for maintenance and these protocols do not require large bandwidth. Forwarding decision in geographical routing is considered by source node, neighbor node and destination node position. These protocols are more feasible compared to topology-based routing.

1.8 Thesis Organization

The remaining research is based on the following characters:

Chapter 2 discusses the literature review of existing geographical routing protocols

Chapter 3 discusses research methodology to design the objectives.

Chapter 4 presents the proposed design for geographical routing protocol.

Chapter 5 discusses the simulation results.

Chapter 6 concludes the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter presents the overview of Vehicular Ad hoc Networks (VANET) and its applications for safety and infotainment purposes. The data communication is based on well-designed routing protocols which are based on different strategies. The types of routing protocols and their functions are also discussing in this chapter. In last, the comparison analysis illustrates with the help of tabular comparison and discussion.

2.2 Routing Protocols for VANETs

Different routing protocols have been proposed for VANETs. The routing means "Routing is a mechanism to establish and select the best path in order to send the data from source to destination". Due to the unique characteristics of VANETs, such as rapid changes in network topologies and high mobility of nodes, most of these protocols are not so feasible to deal with these characteristics. Therefore, still, the improvement of existing routing protocols is taken into a place for data routing [8]. There are five main categories of routing protocols including Topology-based routing protocols, Geographic routing protocols, Cluster-based routing protocols, Broadcast routing protocols, and Geocast routing protocols.

Topology-based routing protocols are based on the received information and update their routing tables and further classified into Reactive and Proactive types. Geographical routing is transferring the data by using the position information of vehicle nodes. Geographical routing needs additional resources like GPS (Global Positioning System) to get the node position information of neighboring and its own for routing. Cluster-based routing protocols create a virtual arrangement of nodes known as the group. Each group has one group leader who is responsible for data communication between different other groups. Intra-Nodes data communication is done via local links. There are two main types of applications including safety and infotainment. Safety applications are containing information like accident detection, weather alert, and other disasters alerts. Flooding method has adopted to update the nodes information in the network. Geocast routing protocol broadcasts the data by using a directional broadcast region called Zone of Relevance (ZOR), to overcome the flooding in the whole network.

There are various issues related to data routing have been considered in VANTE [9]. The main objective of routing protocols is to use vehicle nodes as relay nodes to send the data to the destination. The constraints like disconnections, data delay and packet dropping are the main challenges in data routing. However, they also have definite features like high mobility of nodes and access to physical information of the nodes for data routing. In position-based routing protocols, position information to all vehicle nodes are acknowledged geographically through GPS. Geographical routing does not need any routing table exchange information and share with other nodes and then routing decisions are made on the nodes position information.

In [2], discussed some previous known routing protocols like DSDV, OLSR, GPSR, GSR, and A-STAR. In DSDV two packets are used to send the information called incremental and dumb packets. The dump packet contains the initial routing information and the incremental packet contains the routing updates. It offers a loop-free routing protocol. In VANETs, the topology is changing very frequently, due to this' the number of incremental packets and network overhead increase. In OLSR, whenever network topology changes, its MPR (multipoint relay) responsibility is increasing to update the information to selected nodes. In a broadcast scenario, it reduces the packet retransmission.

Another well-known protocol GPSR proposed in [6], where every node knows about its present and neighboring nodes geographic position. The greedy technique is used to send the packets to the destination and if it doesn't work then it uses perimeter forwarding. It works only for highways not for the urban scenario. It doesn't perform well in urban situations due to various obstacles like building shadow and trees etc. GPSR designs to overcome that problem of GSR where it uses topology and position information for forwarding the data packets from source to destination. To find the shortest path between source and destination protocol this protocol uses the Dijkstra algorithm.

In [10], a multi-hop routing protocol presented, protocol achieved high end-to-end packet delivery ratio with low overhead that can find the robust paths in urban VANETs. The chances of disconnections are minimized by MURU by using vehicle mobility information in VANETs. The matric which is used for path selection from source to destination is Expected Disconnection Degree (EDD). MURU does not suffer much overhead because of fully distributed infrastructure, therefore MURU is extremely accessible for VANETs. MURU is a reactive routing protocol based on movement and adapted for urban environments. It uses a metric called level disconnection which is expected to measure the quality of the path. This metric is calculated using the information on the prediction of the speed and the path of each vehicle. MURU is optimized with a power reduction mechanism to minimize the network overhead of bandwidth by removing excessive control messages. However, when nodes density increases the end-to-end delay decreases.

In [11], the author presented A-STAR which is similar to Geographic Source Routing (GSR) by adopting an anchor of street features. However, unlike the anchor, GSR calculates the paths which are depending on the traffic. A weight is assigned to each road function to its quality that is a small or large street that is examined by several buses. Road information is provided by the bus which gives an idea of the traffic load in each street of the city at different times. It uses the main streets because the connectivity on these streets may be higher due to the high density of nodes and more stable due to the presence of a regular city bus. When choosing a road with a high density without its width and leads to delays in the case of a large-scale road.

In [12], a routing protocol MORA is presented, in which uses nodes position, and movement of vehicle nodes to adjust the retransmission decisions in the context of vehicle nodes and thus face the high mobility of nodes and the relatively frequent changes in the topology. A function is developed by this approach which depends on the transmission distance between source and destination and the moving direction of the vehicle nodes.

The source node has a package including a route request to the destination node and the source node which response with a road package including moving information.

In [13], the author proposed a VANET Routing Protocol named (ETAR). For exchanging the data packets, this protocol uses the most appropriate route which is based on lights and vehicle nodes density. This protocol finds the density and connectivity of the vehicle nodes through modified hello packets. Three steps are used to delivering the data to their destinations, first is Path Selection, then the greedy approach is used to send the data and, in the case, where the greedy approach is not suited then Carry and Forward method is used to send the data. The protocol is evaluated by two parameters, End-to-End Delay (EED) and Packet Delivery Ratio (PDR).

In [14], the authors proposed a Perception Based Geographical Routing Protocol for VANETs named (RPGR). To select the next hope it considers central node, distance and direction of the vehicle as routing metric. In this protocol, each vehicle continuously broadcasts the beacon message to get the information of other vehicles. It considers central vehicle for forwarding the data packets rather to select the outermost vehicle because it has higher chances to exit from the transmission range. It uses carry and forward approach to address the disconnectivity problem. The RPGR has been evaluated with these previous states of the art protocols like GeoSVR, SDR, and GMGR. The outcomes show that RPGR dominates as far as Path Length (PL), PDR, EED and Packet Size (PS).

In [15], the author proposed a Beaconless routing Protocol for VANETs for city atmosphere. In this protocol, they used beaconless technique for data transmission. Whenever a vehicle wants to send the data, it uses modified frames of the IEEE 802.11 protocol. At the time of packet transmission protocol considered vehicle direction and link quality as a routing metrics. Two types of data forwarding techniques are used in this protocol, between the intersections, and at the intersection. When a node is between intersections it simply forwards the progress and checks link quality and if the node is at an intersection it uses directional greedy mode for forwarding the data packet. The outcomes show that this protocol outclasses in terms of PDR and EED, after comparing with two beacons and two beaconless protocols.

Dynamic Vehicle Ontology Based Routing protocol (DVOR) proposed in [16]. In this approach, the shortest path routing scheme is used at the time of congestion, it decreases the waiting time for vehicles. To discover the best path, protocol get helps from RSU and check activity files. It mainly focused on time of Trip Duration, due to this' the waiting time is automatically reduced. This protocol provides the node updated information about traffic condition at shortest possible time. After simulation, the parameters Mean Delay (MD), PDR and Trip Duration are evaluated and compared with these two-routing protocol OLSR and DSDV.

The author's proposed in [17] routing protocol for point to point data transmission in VANETs. The protocol is based on unclear constraint Q-learning algorithm. It uses AODV routing protocol to find multiple route from source to destination. They proposed the point to point AODV protocol to find the best route by using Q-learning based algorithm. To check the link is good or not it considers available Bandwidth, Delay and Packet collision probability. The performance is almost 20% increase by existing protocol. Simulation result shows that the protocol performs best with an increase in PDR and decrease overhead and EED.

The authors proposed in [18], Bipolar Traffic Density Awareness Routing Protocol [BTDAR]. BTDAR has two variants one for dense network BTDAR-R, and BTDAR-P for sparse network. For dense network the protocol uses multi-hop forwarding technique and for sparse network it uses carry and forward technique. Many relay nodes are used between source and destination to improve the quality. Beacon messages are used for exchange information of neighbor nodes. Simulation results showed that the protocol perform well and increases the PDR and decreases the Packet Delivery Delay (PDD).

The authors proposed in [19] Routing protocol based on ETCOP (SRPE). In this model a wiener procedure is used to measure the chances of link availability, they use opportunist routing scheme using signal fading mobility of vehicle and also considers the vehicle states whether it is stable or unstable according to the actions of the vehicles. Routing decisions are taken at the intersection without acting on topology information. Different combinations of link are used to send packets to achieve high throughput in less resource network. Performance is evaluated by changing number of vehicles and CBR connection pairs.

The authors proposed in [20] a reactive routing protocol MYLAR1. To send data and maintain connection it uses three packets which are route request, route reply and route error packets. Route request packets are further classified into two types. To get the information of the destination the used modified route request packet. And at the time of route breakage the original route request packet is used. To reduce the size of modified route request packet they remove the redundant fields, flooding variable field and zone variable field, due to this the network overload is decreased resulting network performance is increased.

The authors proposed in [21], a routing protocol for VANETs is Directional-Location Aided. It combines directional and location aided routing. Greedy approach is used in this protocol to select the next hop considering direction and location of the vehicle. To select the next node, it uses DIR technique and for discovery it uses LAR technique. It is more suitable in urban environment. Through investigation, protocol gives the relationship between link lifetime, average hop counts and path throughput.

The authors proposed in [22] an improved version of AODV routing protocol for VANETs. Protocol uses three parameters to find the route for data transmission. It simply varying the parameter (Hello Interval, Hello Message Loss and Active route timeout) of simple AODV protocol. By doing this it shows better quality of service (QOS) then simple AODV. Results show that improved AODV performed better than AODV and improve the parameters like PDR, EED and Throughput.

The authors proposed in [23] location based efficient reactive protocol for VANETs. In this protocol they combine the features of geographical and reactive routing protocols. They modified AODV as Expected transmission count AODV-ETX to find the best route. The protocol continuously broadcast small beacon messages to get the information of other vehicle links quality. It also uses TTL in RREQ packet to reduce overhead in the network. Results show that it performed better with doing modification and increase the network throughput.

The authors proposed in [24] clustering based AODV-R. In this protocol they use Ant colony optimization for VANETs, it considers such routes which has shortest distance by using hop by hop and dijsktra algorithm and by using clustering it reduces the overhead of the network. By combination of ACO and clustering the protocol performs better. It is implemented in MATLAB and the results shows that it performs better than existing protocol and improve the packet delivery ratio and reduce network overhead and end to end delays.

The author's proposed in [25] re-routing algorithm for VANETs to control congestion. This protocol control congestion by comparing traffic density with threshold value if density is greater, then choose alternative path or else maintain the same path. In this protocol each packet is also encrypted. The simulation results show that the protocol chooses best path for transmission and reduce overhead. The simulation is done on visual studio using #c language.

The author's proposed in [26] efficient cluster-based protocol for VANETs to enhanced bandwidth named (EBECM). This protocol is variant of BEAM which is not performed well in emergency situation and vehicle may be colliding, to overcome this issue they proposed cluster-based protocol. In this protocol all messages can share between cluster head and RSU to deliver information among all vehicles. In previous protocol only, multicasting group member can get emergency messages but in this all vehicles can get the messages either it is group member or not.

The authors proposed in [27] novel routing protocol for VANETs. In this protocol they proposed nearby forwarding and backward agent algorithms. By combination of both these the protocol chooses best path to forward the data considering road density to avoid disconnectivity and backward agent selects the neighbor to forward packet in restrain ranges. The simulation is done on NS2 and results shows that it performs well with high packet delivery with low latency.

The authors proposed in [28] an improved cross layer cooperative routing protocol for VANETs. In this protocol they introduced piggyback mechanism to reduced network overhead and choose the route for transmission whose delay time is smaller. The metric used for selecting route is combination of two parameters, power of node and its stability and whenever there are two routes available whose metric weight is same, then protocol chooses the route who has minimum hops. The simulation is done on NS2 and the results show that the protocol performs well and improve PDR and reduce EED and network overhead.

The authors proposed in [29] a location error resilient geographical routing for VANETs. In this protocol they solve the location error issues, GPS calculate wrong location information due to loss of satellite signal because of multi-floor bridges, tunnels and flyovers. In this paper they calculate the future location of the vehicle using Kalman filter and choose next forwarding vehicle based on least error in location information. To apply these the protocol reduces the impact of location error on the performance of protocol.

The authors proposed in [30] a routing protocol Prediction based geographical routing protocol (PGR) which improves the routing strategy of GROOV through predictions. It redesigns the forwarding and repair algorithm of GROOV protocol, it's not using pure greedy forwarding it enhances prediction before an intersection and thus saves one hop in some cases. It reduces the hops while maintaining a relatively high packet delivery ratio. Simulation results show that it performs well in term of hop counts, network latency and packet delivery ratio in both scenarios like dense and sparse VANETs.

The authors proposed in [31] a Multi-metric Routing Protocol (AMGRP), it enhances the existing GPSR routing protocol, and it adopts Analytical Hierarchical Process AHP) considering multiple metrics to such as link lifetime, node density and node status to find the route. It routes the data packets to more directed nodes in a less congestion and more stable routing path. Simulation results show that it performs better with AHP and reduces the network overhead and decreases the hop count.

The authors proposed in [32] a geographical routing protocol, which uses distance, direction and traffic density as routing metrics to forwarding data to destination. It performs well in urban scenario where high mobility and dynamic topology is always a challenge, it operates in two modes between the intersection and at the intersection. The simulation results show that proposed protocol perform well in terms of data delivery, network delay when it is compared with existing geographical routing protocols.

Improved Geographical Routing (IG) [33] uses different metrics at intersection and between intersections. Beacon messages are used to get the position of vehicles. The protocol uses distance and link quality between vehicles to transfer the data packet. It uses distance and link quality, when node is between intersections and uses density when at intersection. It does not take direction metric which causes the face routing and protocol suffers from low packet delivery ratio. Beacon reception ratio in order to improve greedy forwarding. Simulation results shows protocol improves packet delivery and decreases delay in network

TASR [34] proposed as a segment-based routing protocol for VANETs. It considers real time traffic information for selection of route. To calculate the strength of segment a metric called Estimated Connectivity Degree (ECD) is presented, this metric considers traffic density and their position. Routing decisions are depending on the information of segments. Each segment has two Head Node which is presented on the corners of the segment. Each vehicle sends hello messages containing traffic density and their position within segment. This protocol achieves low overhead, high packet delivery ratio with minimum delay.

VBRP [35] proposed as a segment-based routing protocol. In this protocol the virtual backbone is distributed in each segment which is based on stability index. It considers the link stability between vehicles and their mobility. In addition, they introduce RSU which assist to take routing decisions and help protocol to overcome local maximum problem and improve data transmission efficiency. In this protocol the transmission is depended on backbone nodes, a normal node only receive data while all the transmission through backbone node which receive and sends also. The simulation results show that this protocol outperforms in terms of packet delivery ratio and end to end delay.

EGSR [36] proposed as an ant based geographical routing protocol. To select the route from source to destination the source node selects the route which has minimum weight for complete route. It uses a small control packet in every street to calculate a weight which is proportional to network connectivity. To control the broadcast storm, it uses efficient broadcasting ants in network. The simulations results show that the performance of protocol is better in term of Packet delivery ratio and end to end delay

2.3 Discussion

While comparing VANETs routing protocol, after analyzing the throughput, the rate of delivery and the average delivery of packets, it is shown that without GPS routing protocol does not work efficiently in VANETs environment. GPSR [6] is the most common routing protocol for VANETs, it's not able to perform without GPS and not suitable for city environment. GSR overcome the issue of GPSR and performed well in city, packet delivery is not well in sparse network. A-Star [11] overcome the GSR problem but not improved packet delivery ratio. MURU [10] minimizes the disconnection issues by using information of speed of vehicle. ETAR [13] uses traffic density and lights to take routing decisions and improves the packet delivery. RPGR [14] perform well in high traffic density. B-PFP [15] used link quality and direction of vehicle at the time of transmission. DVOR [16] discovers the shortest route with less delay, high packet delivery ratio and minimize waiting time for nodes at traffic jams using activity files. SRPE [19] using ETCoP metrics to achieve minimum transmission cost. MYLAR1 [20] minimizes the overhead of the network using location and speed of the network. D-LAR [21] reduces network overhead by using location and speed of the vehicle as a routing metrics. Improved version of AODV [22] increase timeout period of the active route by using speed and direction of vehicle. In [23-24] they improved the working of AODV in [23] they combine the geographical and reactive routing protocol and in [24] use dijsktra algorithm to find the best route. In [25] they proposed a secure protocol to control congestion. In [26] they overcome the scenario of emergency situations of BEAM protocol where all vehicles not getting the desired information. In [27] they proposed two different algorithms with the help of them they find a best route for transmission with high packet delivery with low latency. In [[28] they reduce network overhead by introducing piggyback mechanism in AODV. In [29] they reduced the location error issues by using Kalman filter. In [30] they reduce a hop count while maintaining a relatively high packet delivery ratio through redesign GROOV algorithm. In [31] they enhance the existing GPSR routing protocol consider multiple metrics to find the best route. In [32] they proposed a protocol which operate in two modes to enhance the performance.

Table 2.1: Parameters for geographical routing protocols

S/N	Technique	Year	Direction	Position	Link Quality	Velocity	Distance	Road Topology	Traffic Density
1	**GPSR**	**2000**		✓			✓		
2	**A-Star**	**2004**		✓			✓		
3	**MURU**	**2006**	✓			✓		✓	
4	**MORA**	**2006**	✓	✓					
5	**Novel Routing Protocol**	**2012**		✓		✓			
6	**ERLAR**	**2013**		✓					
7	**ETAR**	**2015**		✓				✓	✓
8	**B-PFP**	**2015**		✓	✓			✓	✓
9	**DVOR**	**2015**		✓					✓

10	**PP-AODV**	**2015**			✓				
11	**BTDAR**	**2015**		✓	✓	✓			
12	**MYLAR1**	**2015**		✓					
13	**DLAR**	**2015**	✓	✓					
14	**EBECM**	**2015**	✓	✓		✓			
15	**RPGR**	**2016**	✓				✓		
16	**AODV-R**	**2016**		✓	✓				
17	**PGR**	**2016**	✓	✓		✓			
18	**SPRE**	**2016**	✓	✓		✓			
19	**CLCR**	**2016**		✓	✓				
20	**LER-GR**	**2017**		✓		✓			
21	**AMGR**	**2017**		✓	✓				✓
22	**RAGR**	**2017**	✓	✓				✓	✓
23	**TASR**	**2018**		✓					✓
24	**VBRP**	**2018**	✓	✓		✓			

2.4 Summary

This chapter presents the detailed literature review of latest geographic routing protocols and their issue. The protocols which are not considering distance metric suffer from link failure because they select the border node and the node exit their transmission range. Direction metric is necessary in geographical routing protocols as discussed in the above protocols, without direction metric protocol suffers from looping issue. Due to dynamic topology, above protocols which are not considering traffic density metric suffer from maximum number of hops or disconnectivity issue caused by dense or sparse traffic in the network.

CHAPTER 3

Research Methodology

3.1 Overview

This chapter discusses the detailed research methodology to be adapted to design and develop the proposed geographical routing protocol. It gives an overview of operational and systematic research framework to achieve the research objectives. The research framework process begins with problem investigation research design development and performance evaluation. The problem background, identification and formulation are based on literature review which is discussed in Chapter 2 and further elaborates in phase 1. The second phase discusses the research design and development of proposed protocol. The final phase provides the test and comparison with state of art protocols.

3.2 Research Framework

This research work is carried out according to the research framework as shown in Figure 3.1. In the first phase of the framework, the problem is identified and critically investigated. In the second phase, the details of the methodology which is used to design and develop the proposed protocols and scheme are discussed. Finally, in the third phase performance evaluation conducted to assess the proposed protocol and congestion scheme in realistic vehicular urban scenarios. The thesis is based on research methodology as one of the significant methods to achieve the research objective. The detail of research methodology is explained in the following sections.

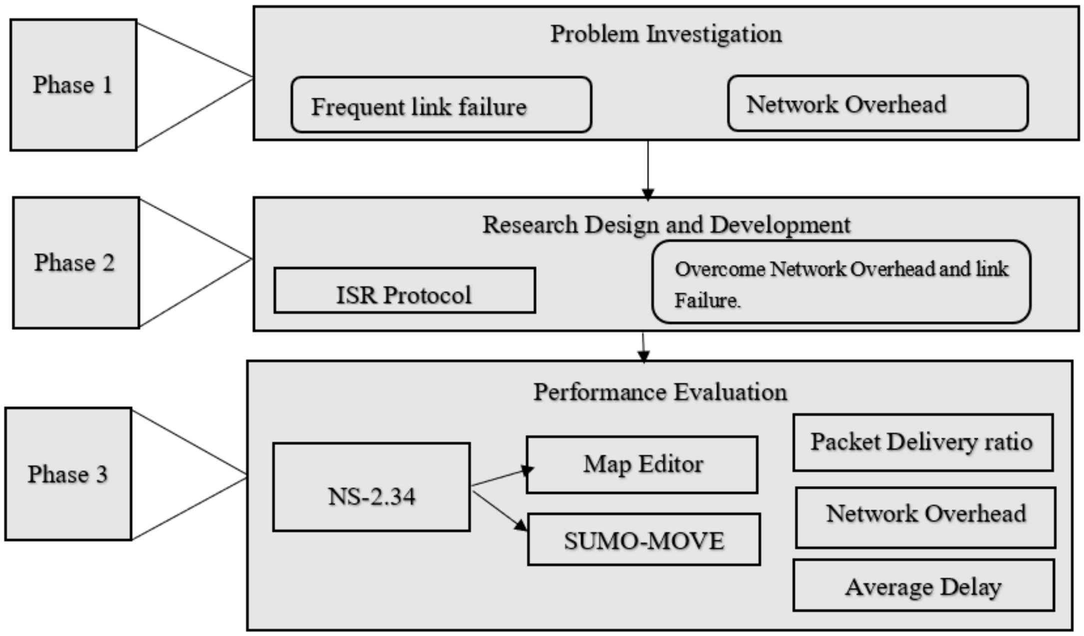

Figure 3.1: Research Framework

3.3 Problem Investigation

In this phase, the research problem is investigated through the literature review of different previous protocols. In these protocols, the packet carrier node routes the data packet by considering the position of destination node. More specifically, the source route data packet is use for direct neighbor node whose distance to the specify destination is the shortest compared to another neighbor node. In within the radio coverage of the source node there is no such type of node, face routing is enabled to recover the data packets and then forwarded towards the destination in sequence. Moreover, geographical routing protocol nominates the node which is closest to destination for data forwarding. The problem of this mechanism is that when the distance between source and the forwarder is increases, the degree of attenuation also increases, it is a well-known undeniable fact that the signal loss becomes higher over longer distance. So, the network suffers from the packet delivery rates and overhead increases. Most of geographical routing protocols are not aware of appropriate metrics, which leads to packet dropping and increase the delay and overhead in the network.

3.4 Design and Development

In the second phase, the proposed solution of the problem will be simulated on simulation tool called NS-2.34 with mobility module SUMO. It was developed in 1981 as event driven an open source simulator. The simulator support network and MAC layer operations. It provides user an executable TCL file, and it is used to plot graphs for animations. Further the simulator provides a tool called NAM (Network Animator) to execute animation files having extension NAM file. NS-2.34 working with two languages OTCL (Object oriented Tool Command Language) and C++. C++ provide user facility to define internal working mechanism (executable at the backend) of the simulation's objects, while having OTCL provide facility to setup simulation scripts and configuration of objects (executable at the front end) and discrete events [37].

3.5 Performance Evaluation

This phase evaluates the simulation results and compare with existing protocols. The results will show the effectiveness of proposed routing protocol in terms of PDR, and Network Overhead

3.5.1 Simulation Setup of proposed protocol

To select the simulation setup which is very important factor to analyze and validate the research objectives. In this study, NS-2.34 is used with mobility generator (MOVE). MOVE is used for simulation of urban mobility (SUMO). It has two main modules, vehicle movement editor and road map editor. The road map editor gives information about roads such as number of lanes, roads, junctions, traffic lights setup. Vehicle editor is used to set speed number of vehicles in networks and probability of movement of vehicle. The trace file is made by MOVE and it is directly used in NS-2 after set all required parameters. The simulator support network and MAC layer operations. It gives user executable TCL scripts as an argument. A simulator trace file is used to generate after the execution of TCL file, and it is used to plot the graphs for animation. NS 2.34 is working with two languages OTCL (object-oriented command language) and C++. C++ provides a user facility to define external mechanisms (executed at the backend) of the simulation objects, while OTCL provides the facility to setup the simulation scripts and configuration of scripts (executed at front end) [38].

VANETs operates on roads for connecting intersections. The proposed ISR protocol is designed for urban situations including possible obstacles and dense traffic. These environmental conditions are considered in the design of proposed ISR.

- **Physical Layer:** The simulation setup of physical layer is based on Nakagami radio propagation model to determine the fading features of wireless channels among vehicles (Nakagami, 1960). According to [39], this data is more realistic for data output and feasible for real time vehicular communication. Furthermore, all vehicles are communicating with a default radio coverage of 300 meters.
- **Mobility and Traffic Model:** The speed of vehicles nodes is set to 40-km/h with rectangular area 2km * 2km. city of Oldenburg (Oldb), Germany, map is used with 370 road segments and 124 intersections [40].Constant Bit Rate (CBR) is a source of simulation [41].The vehicular density varies from 100 to 350 vehicle nodes and beaconing is set with 0.5 second intervals.
- **Network and Media Access Control Layers:** The radio range is set with 300 m and packet size 512 bytes, 2MB/s data rate [42, 43].IEEE 802.11 is used for MAC layer with 3 Mbps channel bandwidth [44]. Furthermore, in the simulation, the process of packet forwarding continues until the packet reaches to destination or pass over 10 hops (TTl = 10 hops)
- **Simulation Time:** The time for simulation is set at 500s for each round, where the settling time is set at 40 seconds to avoid the transmit behaviors from the results. The confidence interval is set 95%.
- **Positioning and range**: Global Positioning System GPS) receiver is installed in each vehicle and. Communication range of vehicles is at least 300 meter which helps them to determines its position. Moreover, this communication range covers the area of segment as well. Vehicles exchange their information such as position and direction with each other that are in the transmission range to maintain the neighbor table. HELLO messages help them to update these tables periodically.

- **Cooperative Awareness Messages (CAM)**: Vehicle nodes send CAMs as characterized in the ETSI standard [45]. It contains the information like their physical location, destination (if applicable), current velocity and direction. The header of CAM contains an ID and location of source, packet generation time and expiration time.

For the experiments, the test space is set to 2×2 km within the city of Oldenburg (Oldb), Germany shown in Figure 3.2. In the chosen test area, the red circles are marked on junctions and segments and black lines, severally. We realistically thought about the obstacles to exist among all the road segments wherever no Line-Of-Sight (LOS). As represented in Table 3.1 300 vehicle nodes are used in the simulations. The typical speed of those nodes is 40km/h.

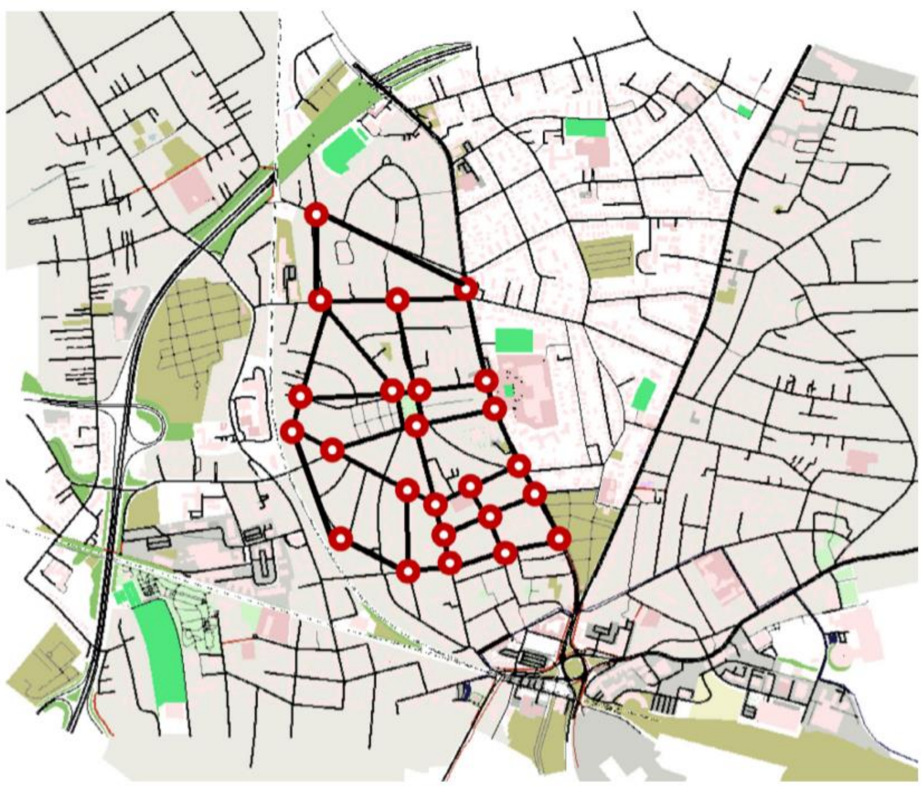

Figure 3.2: Street graph representation of the city of Oldenburg in SUMO

Table 3.1: Simulation Setup

Parameter	**Value**
Network Simulator	NS-2
Simulation Area	2km $\times$ 2km
Traffic type	CBR
Simulation Time	500s
MAC protocol	IEEE 802.11p
No of Vehicle Nodes	100 to 350
Packet Size	512 bytes
Transmission range	300 meters
Vehicle speed	40 km/hr.
Mobility Model	SUMO-MOVE

CHAPTER 4

Improved Segment Based Geographical Routing Protocol

4.1 Overview

This proposed Improved Segment based Geographical Routing Protocol (ISR) addresses the staleness issue of geographical routing protocol's in VANETs. This chapter presents the complete design of proposed protocol.

4.2 Improved Segment Based Geographical Routing Protocol

ISR uses segments to perform the data routing in urban VANETs environment. The proposed routing protocol is based on these metrics Position, direction, traffic density and link quality in the networks. ISR (Improved Segment based Routing) partitioning the road into segments and work with physical location of the nodes. Decision of routing are totally depends on the segment information with a look-ahead of next segment information. The next segment will be selected which has high traffic density. Its operation is proposed to improve the success rate of routing protocol owing to its dynamic assessment of the abilities of multihop forwarding of road segments and the connectivity for the existing network.

4.3 Segmentation Formation

The proposed routing protocol is based on these metrics distance, direction, and link quality and traffic density in the networks. When source nodes find destination out of his communication range the protocol divided the path into small segments with the help of GPS. Each vehicle equipped with On Board Unit (OBU) and digital maps are loaded which comprises of street level maps and traffic statistics as mentioned in [36].

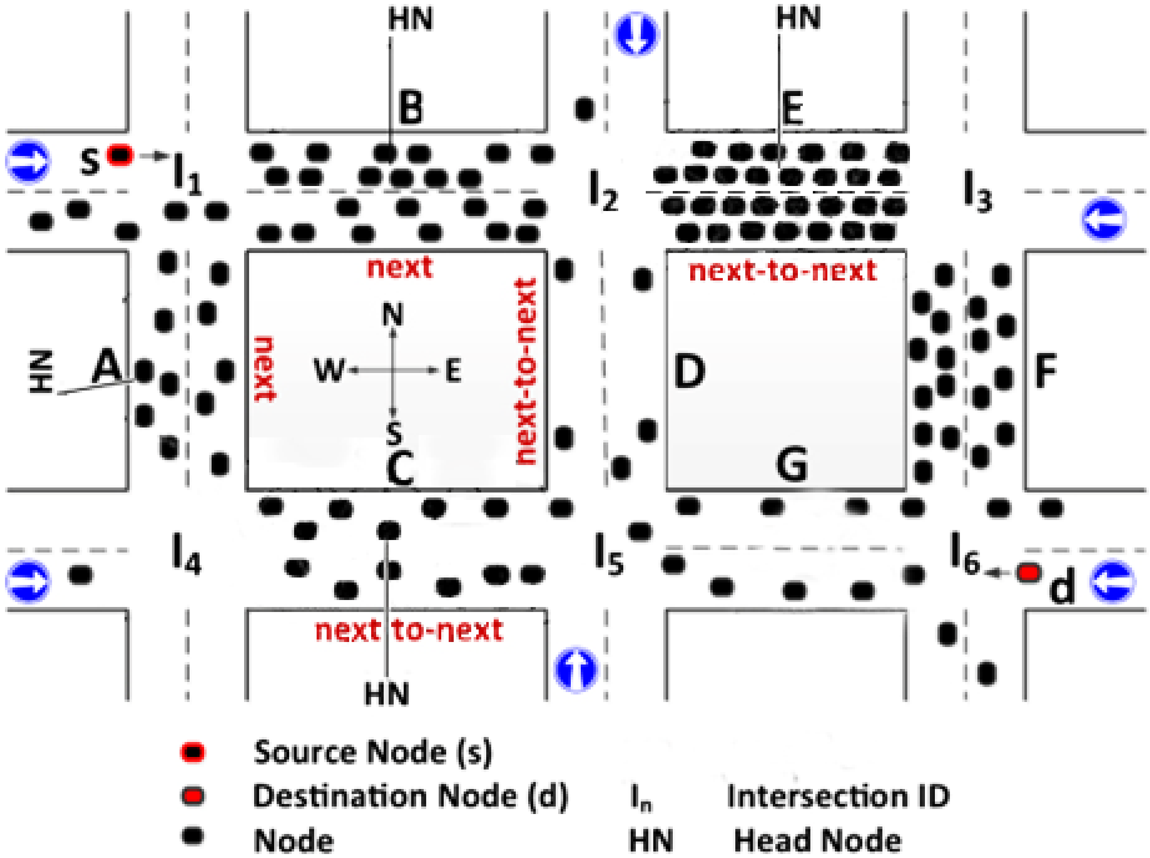

Figure 4.1: Trajectory Model for ISR Protocol

4.4 Head Node Election Process

ISR uses segments to perform the data routing in urban VANETs environment. The proposed routing protocol is based on these metrics position, direction, traffic density and link quality in the networks. When source nodes finds destination out of his communication range the protocol divided the path into small segments and after that head node election will be process in each segment. Each node multicast its position direction and link quality to its neighbors within segment. Then protocol checks the position and direction of each vehicle for electing HN. Direction will be calculated with the help mentioned eq (4.3) protocol check the position of node at time t and t+1. If distance of node decreases towards destination.

$$Distance(t) = at\ time\ t \qquad (4.1)$$

$$Distance(t+1) = at\ time\ t+1 \qquad (4.2)$$

$$Distance(c) = eq(4.2) - eq(4.1) \qquad (4.3)$$

And position will be calculated with the help of Pythagoras theorem as mentioned in eq (4.4)

$$Distance = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \qquad (4.4)$$

And when there is a tie between nodes who has same direction and presented in central position then protocol checks the link quality of nodes as mentioned in [9].

4.5 Score function for CH Selection

After explanation of the routing metrics, this section presents the score function for Head Node selection. The first metric is position, where vehicle node is presented in central position. The progressive distance toward destination is one of the significant routing metric in geographical routing protocol. The next routing metric is direction towards the destination where the next forwarder select only which is moving towards destination to avoid looping issues.

$$\text{Weighting factor} = \text{Position} \times \text{Direction} \qquad (4.5)$$

And the third metric is link quality when there is a tie between nodes on above two metrics protocol checks the link quality of the nodes and choose the best node between them as Eq (4.5) shows the weighting factor score.

$$\text{Weighting factor} = \text{Position} \times \text{Direction} \times \text{Link Quality} \qquad (4.6)$$

In above equation (4.5) and (4.6), the weighting factor for selecting HN must be equal to 1. When there is only a single node presented in central position it will be elected as HN using eq (4.5) and if there is tie between nodes then eq (4.6) will be executed for electing HN.

4.6 Head Node selection Flowchart and Algorithm

The below Figure shows the flowchart of Head Node election process. An HN performs the following operations:

- HN multicast its unique ID to its segment members after election and its neighboring HN.
- It collects the Segment Information (SI), which contains other vehicle information, feeding it to available HN neighbors.
- The HN chooses the N2N segment that is based on the collected information as explained above.
- After moving out of segment then protocol will reinitiate the election process for selecting new HN.

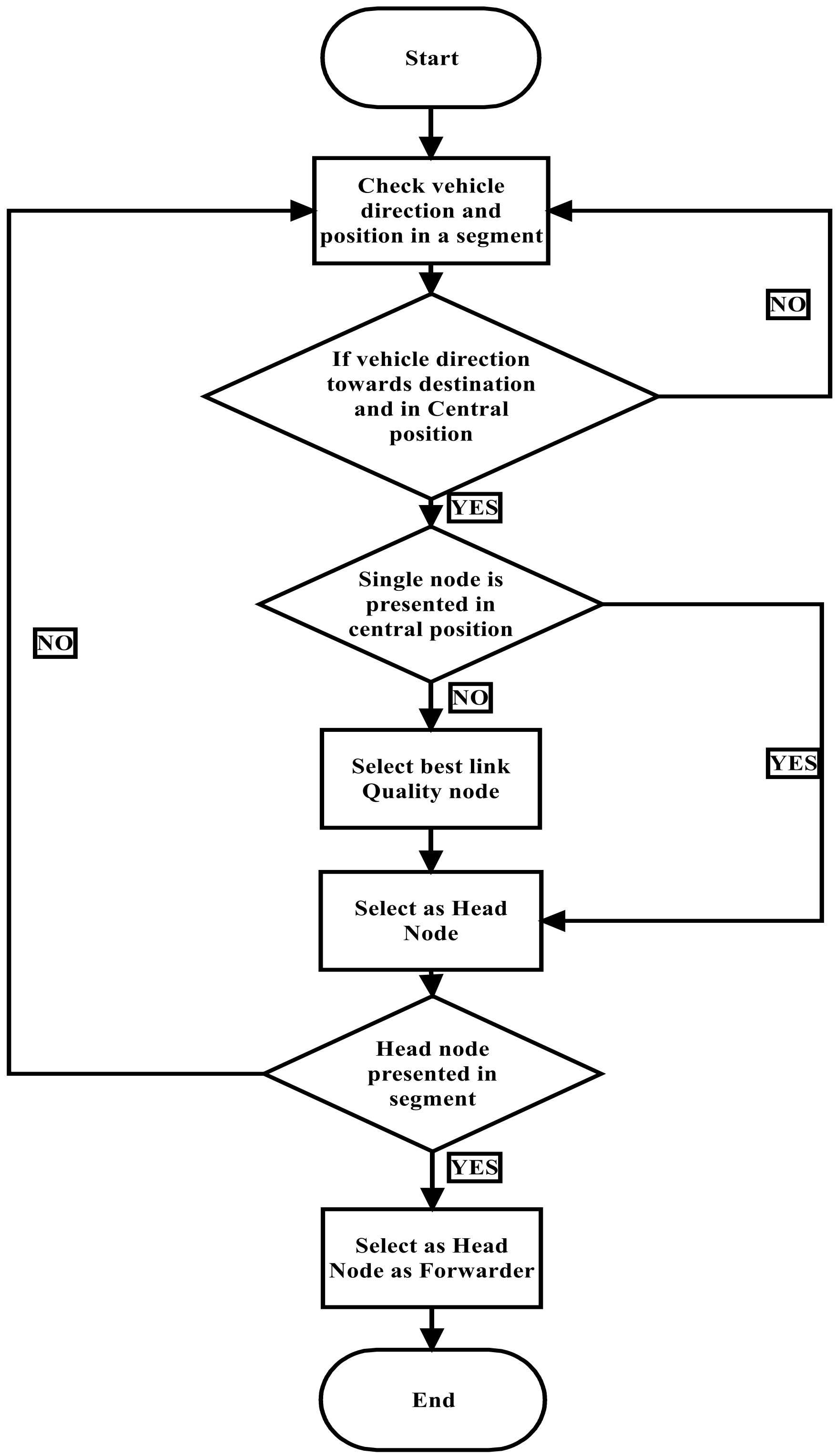

Figure 4.2: Flow Chart of Head Node Selection

Algorithm 1 shows the process of Head Node Election.

ALGORITHM 1: Head Node selection

Input: Position of node

Output: Head Node

For each segment
    do
    Compute $Center_{point}$ for i
    Length $Center_{point}[i] = Center_{point}[i]$;
    J(i) = Nodes nearest to $Center_{point}[i]$;
    For each J(i)
        Compute direction through Distance(c)
        If
            Distance(c) < Distance
            Select node(i) as HN
        End if
    End for
    If
        nodes > 1
        Check link quality of nodes
    End If
    Call Weighting factor as mentioned eq (4.6)
End for

4.7 Proposed Protocol Flowchart and Algorithms.

Below flowchart shows the proposed protocol routing process at or between intersections.

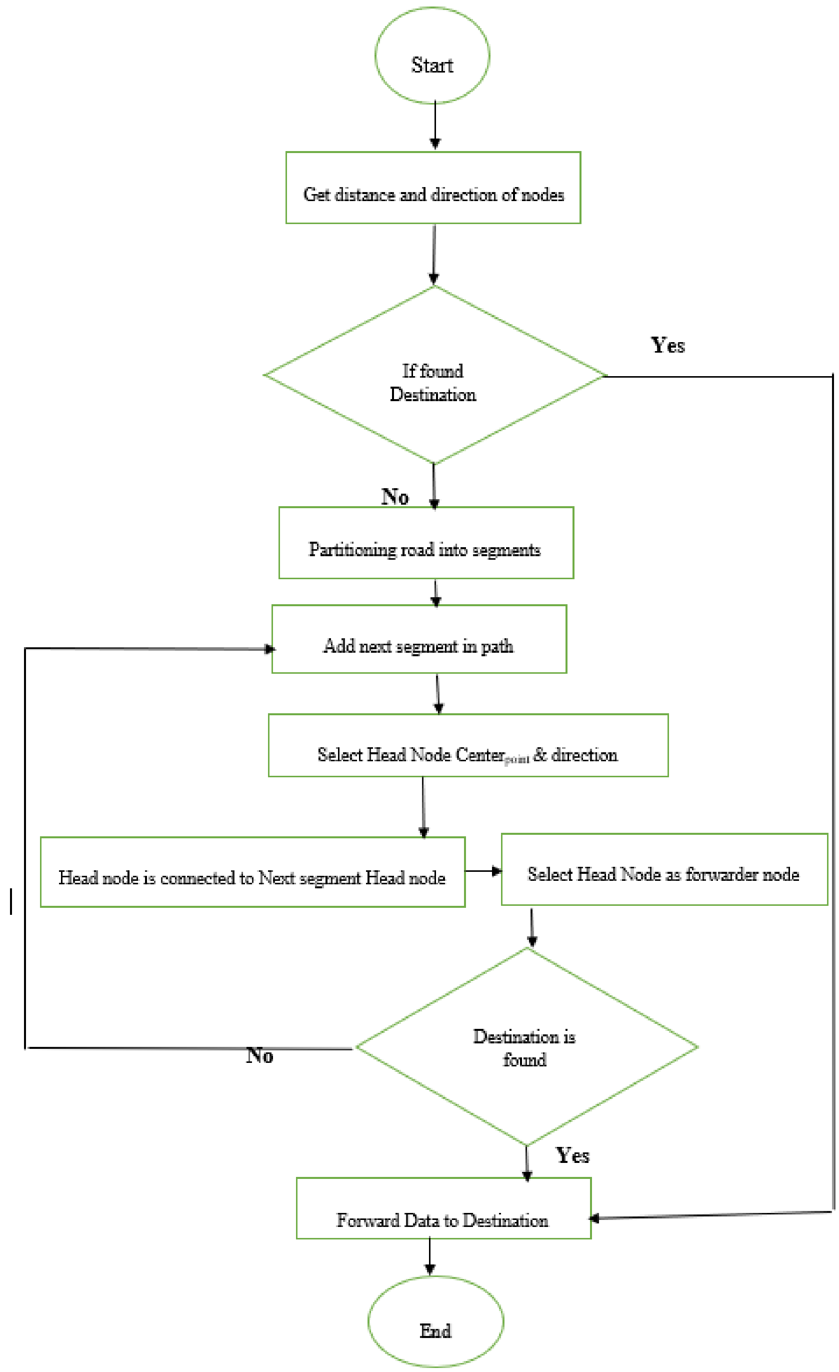

Figure 4.3: Flow Chart of Routing Process

4.7.1 Direct Communication

When destination node and source node is in range of each other or in same segment, it directly sends the data to destination. Algorithm 1 shows the process of direct communication. The protocol gets the location of nodes through GPS which is equipped with all vehicles.

Terminologies:

Table 4.1: Notations used

Notations	**Description**
s, d	IDs of the source nodes and destination nodes
S_{next}	Next Segment
HN_i	Head Nodes for segment *i*
$N\text{SH}_i$	Next segment Head Node where $i = 1, 2, 3, \ldots, n$
S_s	Segment where *s* is located
S_d	Segment where *d* is located
RD	Route Discovery packet
n_i	Intermediate node

ALGORITHM 2: Direct Communication

Input: *Position of nodes.*

Output: *Send packet*

1: **if**

2: ($ni == d$) & $ni \in [Ss \vee Snext]$

3: Send packet $P \rightarrow d$

4: **else**

5: Algorithm 3

4.7.2 Communication through Segmentation

To commensurate with the dynamicity of the vehicle, ISR selects appropriate segments intelligently. The node which is nearest to central point and his directions towards destination is considered as Head Nodes (HN). The segment nodes information is distributed in or out of the segment respectively. After the election process the HN act as a forwarder and sends data only to its neighbor HN. ISR gives a solution to reduce the transmission overhead for each node to eliminate broadcasting in the whole network.

The details segment selection shows in Algorithm 3.

ALGORITHM 3: Divide network into segments

Input: $S_s \neq S_d$

Output: Transmit data

```
if
        RD not seen before
        if
                Ss ≠ Sd
                Add HNi segment to path
                Select Head Node (as Algorithm 1)
                if
                                HNi are connected to NSHi
                                select HNi as forwarder
                End if
                Transmit packet P → ni s.t. ni= d ∨ ni∈Sd
        End if
End if
```

4.8 Summary

This chapter discussed the Segment based protocol for VANET called ISR. Proposed protocol is selecting the route for data forwarding. This protocol is based on multi-metric mechanism and adopted the distance, direction and traffic density for its routing decision. The proposed protocol adopted 802.11p standard to initiates the routing decision. Proposed protocol uses distance, direction and traffic density metric for routing and always select the best and feasible route for data delivery.

CHAPTER 5

Results and Discussion

5.1 Overview

This chapter discusses the simulation results performed on Improved Segment Based Geographical Routing Protocol. This protocol compares its results with two state of the art protocol one is cluster-based routing protocol (TASR) and one is simple geographical routing protocol (VBRP).

5.2 Experiment Results

The experimental results of ISR in terms of Packet Delivery ratio (PDR) and End-to-End delay with number of vehicle nodes and their speed are discussed.

The elaborate description of these metrics is as follows:

(i) Packet delivery ratio (PDR) is defined as the ratio of data packets received at destination successfully over total number of packets which are sent from source. It shows successful transmission rate of routing protocol.

(ii) The end-to-end delay is defined as how much protocol takes time for sending data to destination from source. Basically, it is the sum of sending buffer, retransmission, medium access delay due to interface queue, propagation delay, and relay election delay.

5.2.1 Number of nodes Analysis

The first experiment is with number of vehicle nodes to analyze the data delivery ratio of proposed routing protocol and compared the results with one clustering protocol Traffic Aware segment based routing (TASR) [36] protocol and one beacon based A reliable and Efficient routing protocol based on virtual Backbone in Vehicular ad-hoc networks (VBRP) [37].

The TASR protocol is cluster-based routing protocol but their cluster heads are presented on the corners of the cluster which will be outdated due to high mobility. On the other hand, the VBRP protocol is position based protocol has a network overhead issue due to continuous beacon messages in whole network.

Figure 5.1 shows the Packet Delivery Ratio (PDR) in accordance with different number of vehicle nodes in the network. Figure shows the trend that ISR has increased data delivery consistently due to increasing connectivity probability with more vehicle in dense networks. The existing TASR has better results than VBPR because of cluster mechanism. The VBPR protocol is based on greedy forwarding mechanism which is not appropriate for VANET. This is the main reason that VBPR is behind TASR and ISR.

The results indicate the better results of proposed protocol compared to existing routing protocols. The proposed ISR protocol data delivery ratio has increased more due to increasing connectivity probability with more traffic density in urban environment.

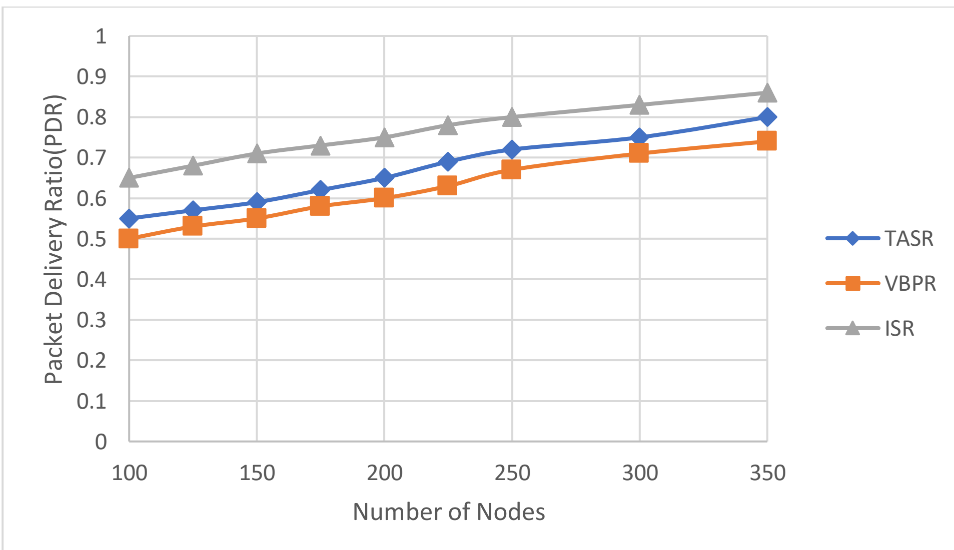

Figure 5.1: Packet delivery ratio with number of nodes

Another performance metric has analyzed that is End to End delay as shown in Figure 5.2. The delay of proposed protocol ISR consistently increased due to its routing metrics calculations. However, the existing protocols have more delay compared to proposed protocol. This result also indicated that both the Clustering protocol has less delay compared to other protocol because more traffic has more beacon overhead and the next forwarder selection is difficult. The TASR protocol steeply increased the delay because, this protocol initiates the decision based on distance, direction and signal strength. Although, sometime the more congested road nodes have strong signal strengths but have more delay due to number of vehicle nodes. The proposed protocol addresses this issue by selecting the maximum traffic density road segments.

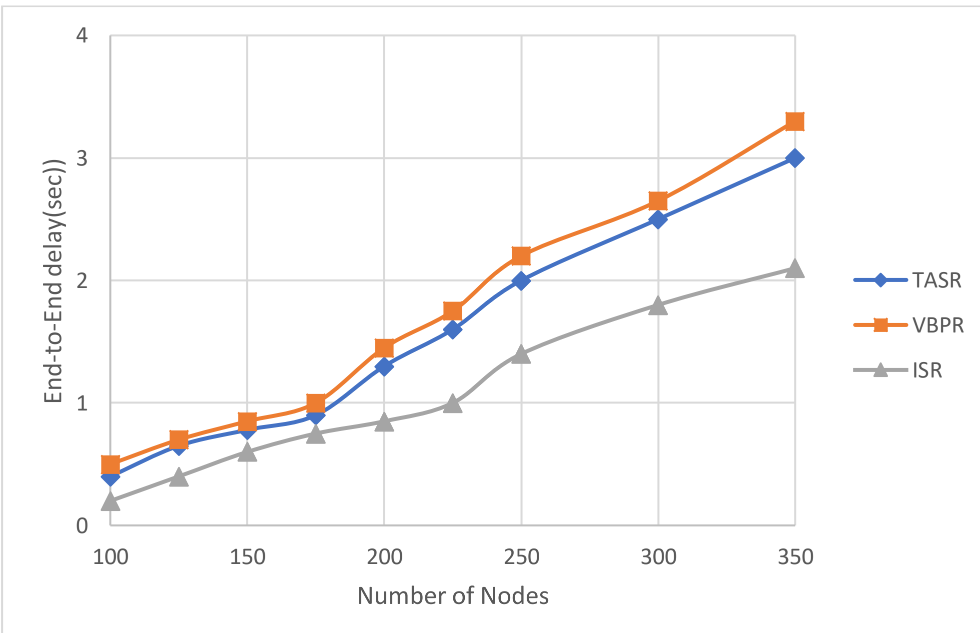

Figure 5.2: End-to-End delay with number of nodes

This result indicates that proposed ISR protocol has better results compared to TASR and VABR protocols. Whenever, the traffic density is high in the network the delay is more due to various number of nodes. Compared to VABR protocol, the Clustering TASR and ISR have less delay because more traffic has more beacon overhead and the next forwarder selection is difficult. The TASR protocol steeply increased the delay because, this protocol initiates the decision based on distance, direction and Vehicle Density. Although, sometime the more congested road nodes have strong signal strengths but have more delay due to number of vehicle nodes. The proposed protocol addresses this issue by selecting the maximum traffic density segments.

5.2.2 Speed of Vehicle Analysis

This section shows the results based on vehicle node velocity in terms of packet delivery ratio and average delay in the network. Figure 5.3 shows the data delivery ratio of the ISR, TASR and VBPR routing protocols. A prompt result is that the vehicle speed cause of low PDR in the network. However, the proposed ISR has better results due to removal of beacon messages in the whole network. This mechanism also helps to reduce the consumption of bandwidth and less memory to store the neighbor node information. In addition, the multi-metric protocol supports the protocol to select appropriate next forwarder node for data delivery towards the destination. On the other hand, the TASR protocol has one mechanism where this protocol determines the distance, direction and vehicle density metric to select the next forwarder. In addition, the VBPR protocol uses Beacon messages in the whole network which increase the network overhead which leads to packet dropping issues. The high speed also causes of staleness of neighbor node information. The result shows that proposed protocol even has better packet delivery ration when the vehicle nodes speed set to 35 and 40 respectively.

Basically, the PDR decreasing trend indicates that the vehicle speed cause of low data delivery in the network but ISR still has better results due to removal of beacon messages in the whole network for next forwarder node selection. This strategy supports to consume less bandwidth compared to Position based routing protocols. The TASR protocol also has less packet drops compared to VBPR due to its multi-metric and Clustering strategy. In addition, the high speed also causes of staleness of neighbor node information. The result shows that ISR has better results when the vehicle nodes speed set between 50 to 60 in the network and it's gradually decrease when speed reaches to 100km\hr.

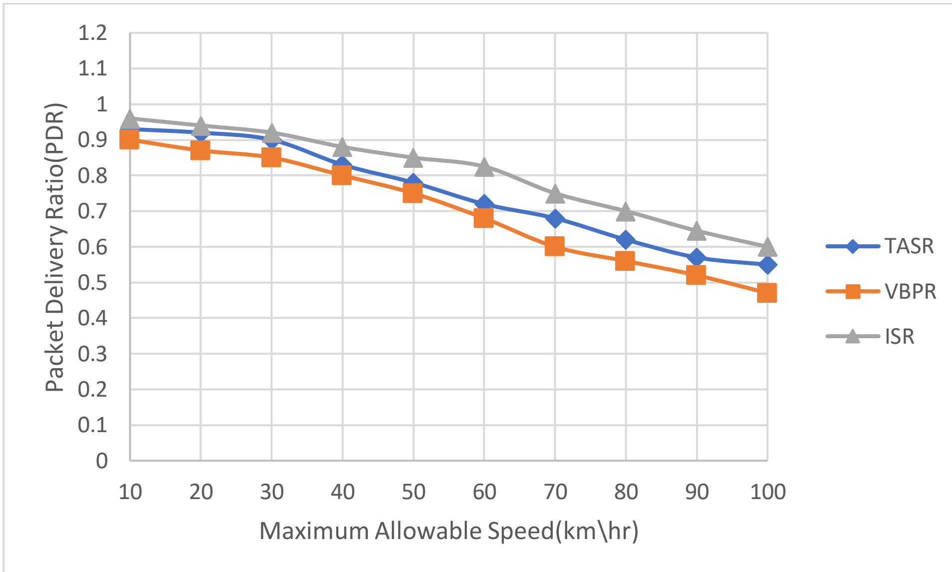

Figure 5.3: Packet delivery ratio with vehicle speed

Figure 5.4 shows the average delay results with vehicle speed analysis. The results indicate that proposed ISR protocol has less delay compared to TASR and VBPR. Whenever, the vehicle speed reaches to 35 and 40 the delay is more due to high velocity of nodes where the information is outdated, and next forwarder selection is difficult. Compared to VBPR protocol, the TASR and ISR have less delay. The high velocity has more chances for packet dropping. On the other hand, the TASR protocol steeply increased the delay because, this protocol initiates the decision based on distance, direction and Vehicle density. Although, sometime the more congested road nodes have strong signal strengths but have more delay due to high speed. The proposed protocol addresses this issue by selecting the maximum traffic density segment.

The proposed routing protocol ISR has better results in terms of delay compared to TASR and VBPR even though the vehicle speed set at 40 to 60 km/hour. The proposed protocol is best option for urban areas where the vehicle speed at normal level. On the contrary, the existing protocols have suffered when the vehicle speed increases in the network. The Clustering protocols (TASR and ISR) have less delay compared to VBPR because high speed of vehicle nodes lead to packet dropping and protocols again check the neighbor node information to initiates the routing decision. On the other hand, the TASR protocol steeply increased the delay because, this protocol initiates the decision based on distance, direction and Vehicle Density. Although, sometime the more congested road nodes have strong signal strengths but have more delay due to channel congestion.

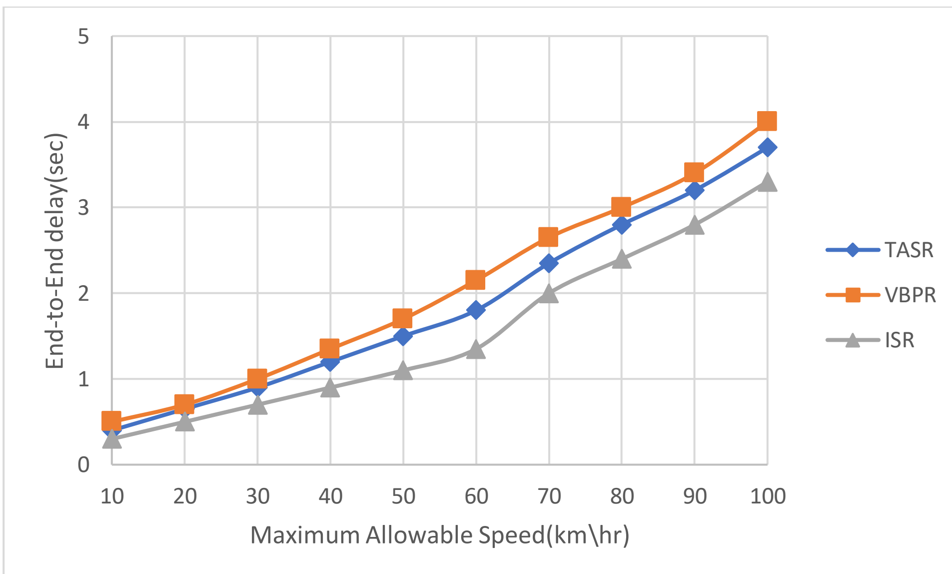

Figure 5.4: End-to-End delay with vehicle speed

5.3 Summary

This chapter has presented the comparison of Segment based geographical routing protocol for VANET with one Clustering and one position-based protocols. The simulation results have shown that in the urban environment cluster based geographical protocols are the best option as they have minimum delay as compared to other position-based protocols.

Chapter 6

Conclusion and Future Work

6.1 Conclusion

In this work an efficient routing protocol has been presented for VANETs with minimum overhead. Main challenges involved in designing of efficient, stable, robust routing protocol has been addressed and resolved.

An extensively study of existing routing protocol has been done in terms of their operation, framework and limitation. Modifications in the existing routing techniques have been made and new routing protocol has been developed with an objective to resolve the following limitations:

- Disconnectivity issue for urban areas due to dynamic topology.
- Minimize delay in geographical routing protocol.
- Minimize Overhead in geographical routing protocol.

A critical examination of these limitations led to the designing of Improved Segment based geographical routing protocol. ISR has been simulated using NS-2.34 simulator and the performance of the protocol has been compared with existing protocol. Simulation results show that ISR has high data delivery ratio in terms of total number of nodes.

6.2 Future Work

The research work has been carried out in this thesis, to find the solutions of the problems which are discussed in literature review. It has been found that the research regarding beaconless geographical routing protocol is still to go a long way. For future work, compare the proposed protocol by adding more parameters and compare other beacon based and beacon less geographical routing protocols with the proposed one.

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