Beaconless Traffic Aware Geographical Routing Protocol

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Abstract

Vehicular Ad hoc Networks (VANETs) aretaking advantage of moving vehicle nodes for data communication. VANETs support many applications related to safety, infotainment and accident detection. The routing protocols are using for data communication in the presence of high mobility nodes and dynamic topologies. Due to high mobility and unpredictable topologies, the data communication becomes unreliable which causes data loss, delay and link disconnections among vehicle nodes. To address these routing limitations, various types of routing protocols have developed. In all existing routing protocols types, geographic routing protocols are one of the efficient type due to its low overhead processes. Geographical routing protocols are able to handle vehicular environment constraints. However, with many advantages geographic routing protocols are not considering many constraints of vehicular environment. Geographical routing protocols should have well defined routing metrics to deal with high mobility and other data loss and link disconnection issues. This research designs a Beaconless Traffic Aware Geographical Routing protocol by considering traffic density, distance and direction for next forwarder node and route selection. The protocol is feasible for urban dense and sparse traffic conditions and addresses delay, disconnection and packet dropping issues. Proposed protocol has simulated with state of the art routing protocols. The simulation results indicated that proposed protocol is higher performance in VANETs.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Vehicular ad hoc network (VANET), enables communication between vehicles with or without using any infrastructure which enable drivers to drive safely [1]. VANET has gained popularity among researchers because of its various different types of safety and infotainment applications. Designing of routing protocol which can accommodate high mobility environment is still a challenge. Due to high mobility and dynamic topology, information becomes outdated which results in disconnection and packet dropping issues among vehicle nodes. These issues have been addressed in different routing protocols.

Routing protocols have characterized into different types such as table driven or topology and geographic based routing[2]. In topology based routing, the information stores in routing tables.These protocols face data communication and delay issues. These type of routing is categorized into two types proactive and reactive. Proactive type haslow delay because routes are known before the packets need to be forward. Proactive protocols have high overhead due to many route update requests. On the other hand reactive protocols have high delay because the routes have to be discovered when the source node initiates the route request. Reactive protocols determine routes when there is data to send.

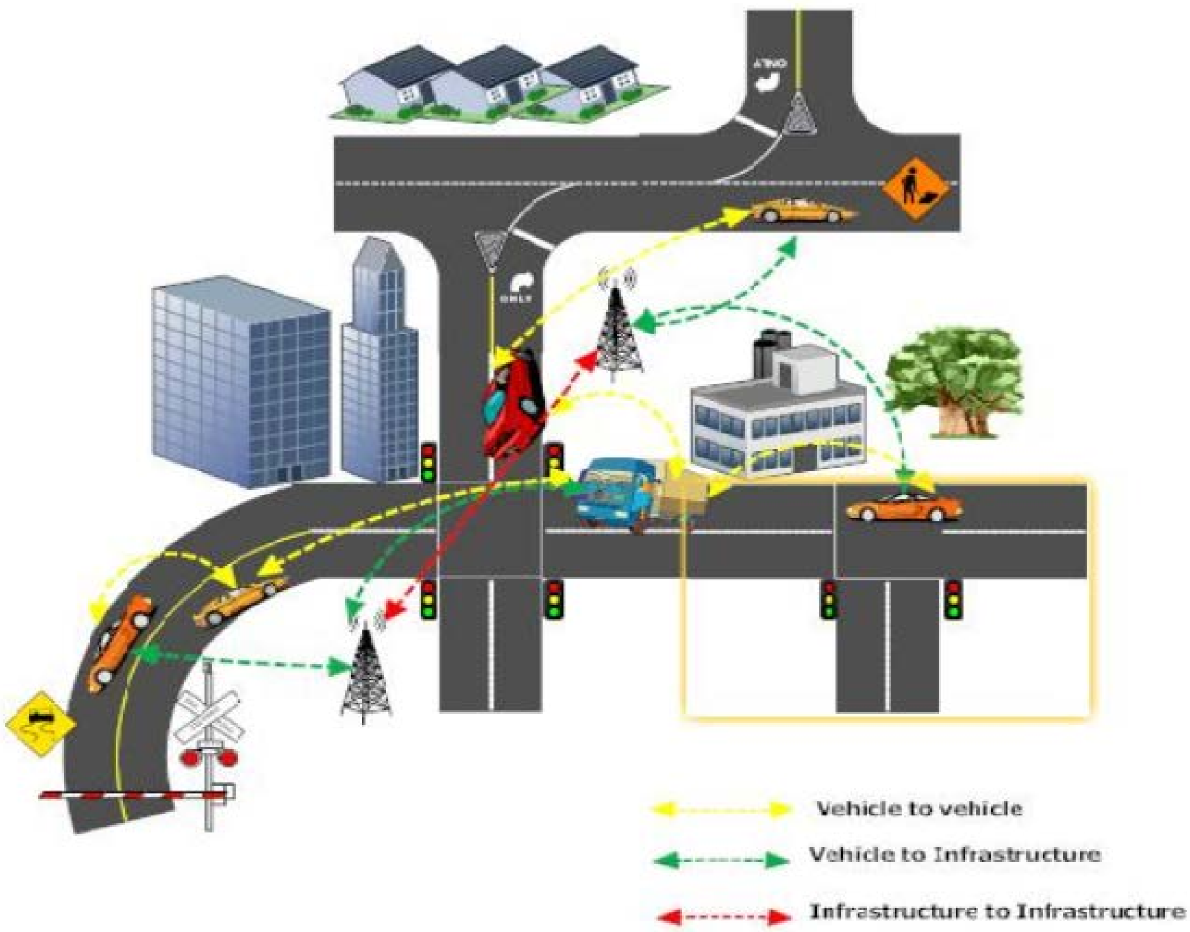

Figure 1.1: Vehicular ad hoc network overview [2]

Geographical routing protocolsuse neighbor nodes information only which are in its transmission range. Data forwarding in these types of protocols depend on node location information for data forwarding decision. Hello messages are used to find the position information of neighbor node in beacon based geographic routing protocol. In beacon less geographical routing protocol modified control packets are used. Geographical routing protocols use Global Positioning System (GPS) information[3]. GPS is used to give the exact information about the vehicle position. For dynamic topologies, geographic routing protocols are considered to more feasible and efficient [2, 4, 5].

1.2 Problem Background

The basic idea of geographical type is evolved from GPRS (Greedy Perimeter Stateless Routing)[6]. GPSR uses two model particularly, the greedy and perimeter mode. When a datapacket is delivered to the node which is closest to the destination it is called greedy mode. On the other hand, when greedy mode fails thenprotocols use perimeter mode. Various routing issues occur when source node is near to the destination and its neighbors are far away from destination. In such cases the protocol switches to the perimeter mode which uses right hand rule. All nodes send information to the neighbor’s clock wise when they send the information in anti-clock wise, this mechanism is called right hand rule. The GPSR suffers from face routing issue and protocols arenot working well in un even traffic distribution. The GPSR only takes distance metric and does not consider direction metrics, which leads to wrong packet forwarding decision and increase packet loss.

Geographic source routing (GSR) [7],utilizeslimited wayto forward the data towards the destination by using digital map and not efficient due to static map strategy. It does not take real time traffic information while planning the path to the destination. GSR works well in highly dense area due to its shortest path algorithm but the protocol does not work well in light traffic area.Improved Greedy traffic aware geographic routing (GyTAR)[8],uses speed, direction plus density as routing metric to evaluate the protocol. There are two modes of operations in GyTAR: routing at intersection and routing at road segment. At road segment GyTAR reactively selects the neighbor intersection, when there is change in traffic density or distance to destination. GyTAR does not consider changes in the length of road segment in urban environment. GyTARuses traffic density as metric which is very costly in terms of bandwidth when beacon messages are exchanged. GyTARstores the vehicle nodes information in routing tables.

Traffic aware geographic aware routing (TARGET) [9], selects the junction dynamically. Each junction has monitor node which calculates the nodes between two junctions. Packets are forwarded between two junctions based on the destination junction position. If the packet is not delivered to the junction due to link break between two junctions then packet came back to the source junction which causes computational complexity and the protocol has low packet delivery ratio. TARGET considers road transmission delay and cause of link disconnectivity. However, transmission delay can also cause of network load.

Improved Geographic Routing (IG) [10], uses different metrics at interaction and between intersections. IG uses beacon messages to know the position of vehicle nodes. IG uses distance and link quality between vehicle nodes to transfer the data packets. When vehicle is in between intersections then uses distance and link quality when node is located at the intersection then uses traffic density metric. Road environment is dynamic in nature which cause high complexity issue in geographical routing protocol. IG also does not take direction metric which causes the face routing and protocol suffers from low packet delivery ratio.

Connectivity-aware intersection based routing (CAIR) [11], uses link quality, direction of nodesand traffic density asrouting metrics. Greedy approach is used for data forwarding.When these metrics are taken in CAIR, the protocol leads to packet drop issues. CAIR uses carry and forward approach for data routing which leads to packet delay issue. Junction based routing (JBR) [12], uses direction and transmission range as routing metrics. Junction nodes are more importance because they are used to forward the data packets.JBR suffers from face routing issue as protocol does not take direction metrics for forwarding the data packets. JBR uses selective greedy forward approach to forward the packets.

Road selection based routing[13], uses distance, velocity and transmission range as routing metrics. The protocol suffers from disconnectivity issue due to the dynamic vehicular environment, network traffic becomes sparse or dense which causes more hops or link disconnectivity issue. The protocol also suffers from looping issue as there will be two-way traffic which cause looping for data forwarding.Vehicle Density and Load Aware Routing [14], uses traffic density, distance and load as routing metrics to forward the data packet. VDLA recalculate traffic density in a network to address local maximum issue. Recalculation of traffic density results in high packet delivery ratio and high network overhead.

For solving the aforementioned routing issues, geographical routing usesmore appropriate routing metrics including vehicle direction, vehicle speed,road segment, traffic density, distance and intersections into consideration [15, 16].With many advantages of geographical routing protocols, still protocols havepacket delay, disconnectivity and throughput issues. To overcome these issues, we conduct this study to design a beaconless geographical protocol to handle high mobility of vehicle nodes and changing topologies of VANET.

1.3 Problem Statement

Vehicular networks suffer from high mobility of nodes in dense or sparse traffic conditions which cause delay and disconnectivity issue in VANETs. Many geographical routing protocols are based on greedy forwarding where the source node selects the relay node near from the destinationnode within its communication range to forward the data. Due to high mobility of nodes, the selected node has change its position and protocol has disconnection issues. Another problem of geographical routing is delay due to computational complexities and lengthy routing decisions.

1.4 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.

1.5 Research Questions

This research design an enhanced geographical routing protocol. To achieve the research objectives, the below questions are precisely identified and will be answered through this research.

1. How to improve disconnectivity issues in geographical routing protocol.
2. How to minimize delay in geographical routing protocol?
3. How to improve data throughput in geographical routing protocol?

1.6 Research Objectives

To achieve the main aim of this research by designing a new beaconless geographical routing protocol, following are the main research objectives:

1. To design a geographical routing to improve the disconnectivity issues for urban area, with low delay and high throughput in VANETs.
2. To design a light weight geographical routing protocol by considering more feasible routing metrics for VANETs.

1.7 Thesis Organization

The remaining research is based on the following chapters:
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

1.8 Summary

This section has given the background information and significance of VANETs. Following to that, the motivation, major research problems, research questions, objectives and thesis organization of this research are discussed. A generic design research approach methodology is explained to analyze the existing problems to propose a new solution.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

VANETs allow vehicle nodes to communicate with each other. Vehicle nodes have On Board Units (OBU) which allow them to communicate with other vehicle nodes. Road side units have deployed on the roads to allow communication among vehicle nodes and road side units. Vehicle nodes in VANETs communicate with each other to help other vehicle nodes to avoid accidents. VANETs have number of traffic management application. The applications are providing safety and infotainment services or used to transfer the files between vehicle nodes.With many advantages vehicular networks suffer from routing problems.Vehicular networks require an efficient routing protocol for data communication.

Mainly, the protocols arecategorized into two types including topologyandgeographical basedrouting protocols. In first topology type, vehicle keeps the nodes information in routing tables which cause maintenance issue in terms of reestablishing the connectivity. However, geographic routing protocols only store information about their neighbors who are in their transmission range. For dynamic topologies, geographic routing protocols are considering to more feasible and efficient type[2, 4, 5].Figure 2.1 shows the basic infrastructure of VANET.

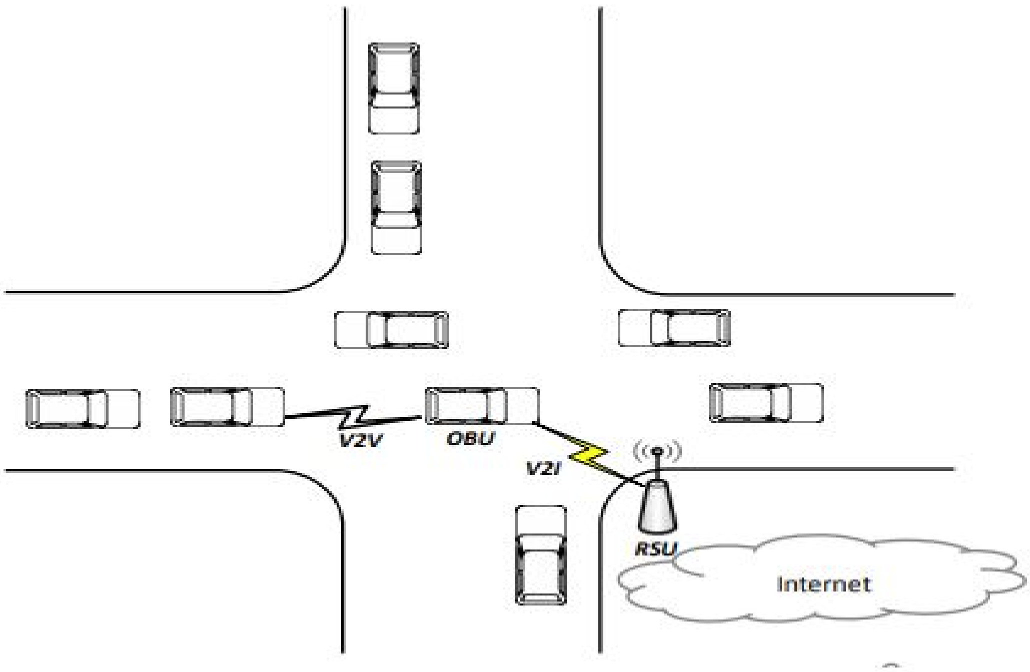

Figure 2.1:VANET Structure [17]

Various geographical protocols have designed whichmajority of those protocols are trying to achieve minimum packet delivery ratio. Those proposed protocols also target to attain low network overhead, low end to end overhead. Next section presents the detail overview of protocols and discuss their issues or challenges.

2.2 Greedy Perimeter Stateless Routing (GPSR)

Greedy Perimeter Stateless Routing (GPSR) [6], is ageographicalbased protocol developed originally for MANETs (Mobile ad hoc Networks). GPSR utilizes position data of one hop neighborsand exchange beacons to make greedy forwarding towards the destination position. GPSR requires one-hop topology information and destination location to make a local forwarding decision. This protocol uses greedy forwarding strategy for select the next forwarder as the progressively closest immediate neighbor to the final destination. Whenever, greedy method does not work then GPSR switches to recovery mode around the perimeter of the failing region. As many other geographic routing protocols, GPSR does not specify a location service to obtain the destination position. GPSR performs well in high mobility networks like VANET and not required full path finding or maintaining operations. However, greedy routing in the VANETs causes multiple local minimum events where GPSR uses perimeter mode for recovery, in which a packet crossesfrom planner sub graph of connected VANET, until success a node that is near to destination than the position that the perimeter mode started at, where greedy forwarding is resumed. This causes a major increase in the number of intermediate forwarders and, accordingly, the end-to-end packet delivery delay.

2.3 Improved Greedy Traffic Aware Routing (GyTAR)

GyTAR[8], takes real time road traffic variation which includes vehicle speeds and directions plus intersection. GyTAR uses road segments and junctions as road map. In GyTAR each cell is based on equal size. The protocol uses cell density packets (CDP), when vehicle leaves the road. CDP is forwarded to another intersection through the anchors known as cell centers. GyTAR works with two modules, routing at the junction and between two junctions. For junction selection,source nodedeterminesthe destination position and givethe score to each junction in the network by considering the traffic density. Then the high score junction will be forwarding junction. In GyTAR, every vehicle stores the neighboring table in which direction, position and velocity information is stored. When beacon messages are exchanged, vehicle nodes update the information about vehicles in the neighboring table. In GyTAR, every nodeposition is determined by receiving hello packets, thus node predicts the node distance toward the destination and selects the next hop neighbor. The protocol uses carry and forward strategy when node is in local optimum issue. Each node carries the data packet until node enters its transmission range.This protocol forwards the data packets from adjacent intersection to final destination. The protocol considers only adjacent intersections when forwarding decision is made at each intersection. This limited vision can cause routing of packets from un optimized routes or causes of packets bounced back.

2.4 Geographic Source Routing (GSR)

In order to address the node level routing challenge in the highly dynamic topology of VANETs, GSR [7] uses source position based routing. By utilizing map information and planning the routes by the means of consecutive junctions, GSR overcomes the problem of traversing high intermediate forwarders presented in GPSR.GSR uses Dijkstra’s algorithm to finds the shortest path between source node and destination node. The graph is extracted from the city road map with bidirectional edges representing roads, and graph-nodes representing road intersections.Data packets are transmitted between nodes which has complete route information from source to destination node. Intermediate forwarders use greedy routing to select the next-forwarder in order to deliver the data packets independently to the next-junction indicated in their routes. Although GSR is using a shortest path algorithm, the connectivity of these paths are not ensured. GSR does not use statistical or real-time traffic information to rate the map, while planning the path, which affects its performance. In dense networks and limited data traffic streams, GSR performs well and shows low delivery latency. However, in light traffic areas, GSR fails to discover connected routes and shows low packet delivery ratios. Moreover, as GSR applies static routing, it can easily cause data traffic congestions on some road segments.

2.5 Traffic-Aware Geographic Routing (TARGET)

As proposed in [9], traffic aware geographic routing (TARGET), divides the nodes in two categories: junction node and ordinary node. Each junction has its own monitoring method which is responsible for communication with other nodes and share traffic information with them. Number of vehicle nodes are calculated when two monitor nodes exchange detective packets.Data packets also store the forwarding node position information and counts number of nodes existing in between two junctions. In TARGET, junctions are selected dynamically. Source node junction selection is selected on the basis of source node. Whenever, source node is not located then it finds shortest path using Dijkstra and selects the junction which is near to the destination. If the source node is at the junction, then source node looks for the junction which is closer to the destination. If monitor nodedoes notreceive any data packet from neighboring junction in specific time frame, monitor node considers the link is broken and exclude the junction from the list.

Monitor nodes check if there is at least one junction which is closer to the destination among all other junctions, monitor node enters the greedy approach. If there is no junction closed to the destination node,then protocol enters the perimeter mode. When junction has been selected then the packets are transferred greedily between the junctions. If data is not delivered to the junction, then packet comes back to last junction and monitor node marks that the junction unconnected. TARGET protocol has better data delivery because GPSR does not take traffic into account.

2.6 Intersection-Based Connectivity Aware Routing (iCAR)

Firstversion of intersection based connectivity aware routing protocol (iCAR) is presented in [18]. The iCAR addresses the real-time packet delivery delay and traffic density and for each road. The iCAR combines real time traffic information and static map for better performance in the city environment. iCAR sends control packets (CP) to calculate real time traffic. The iCAR usescontrol packets to collect traffic density and connectivity.The iCAR is based on unicast routing and maintain connectivity by generating control packets at every intersection.In iCAR, when node reach at intersection, then the next road with high traffic density is selected which makes it suitable for urban areas. The iCAR has less data delivery delay issues because high traffic density results in maximum number of hops.

Control packets (CP) are used in iCAR which uses for maintaining connectivity information at each intersection.Score has assigned to each road segment and are exchanged between vehicles in beacon message. CP is used to determine the vehicle information when it is traversed along the road and determine connectivity among the vehicle nodes.iCAR uses greedyapproach for data forwarding between two junctions. The nodes position is determined by the exchange of beacon messages, however nodes can move out of each other transmission range which causes retransmission. This problem can be escaped by using the available forwarders node of the last report based on speed and position.If there is no forwarder node found, protocol uses store and forward approach to forward the data packets.The first version of connectivity aware routing protocol has the routing problem, the second version of connectivity aware routing protocol (iCARII) [19], addresses the routing problem by increasing delivery delay. Nodes in iCARII updates their locations periodically. The protocol uses node to node beacon messages. Nodes uses the roadside units and board units to access the internet.

2.7 Junction Based Routing (JBR)

Junction based routing is proposed in [12], which exploits the junction nodes. The protocol uses the greedy forward approach for the junction nodes which are located near the destination. Nodes located at junctions are coordinator nodesand the nodes placed between the roads are simple nodes. The protocol broadcasts hello packets by every node in which coordinates of nodes are present. If packet is not transmitted after some time then entry for the node will be deleted and if hello message is received after some time then entry for the node in the neighbors list will be updated. Selectively greedy method forwards the data packet by selecting the node which is farthest from the source node.If packet has to be forwarded by simple node then the node searches the neighbor list closer to the destination and divide the nodes into coordinator and simple node. If there are available coordinator nodes then they are queued priority wise. The protocol uses distance metric to select the next hop closets to destination. When there is not any coordinator node then simple node will forward the packet. The protocol suffers frompacket delayissue because traffic density has not been considered as metric which cause maximum number of hops in the network.

2.8 RTS/CTS Protocol

RTS/CTS (request-to-send/clear-to-send)[20], is four-way handshake method for session data transmission and designed based on CSMA/CA (DCF Carrier Sense Multiple Access/Collision Avoidance) based IEEE 802.11 protocol. Basic purpose of RTS/CTS frames to address the hidden terminal issue in VANETs. The hidden terminal issue refers to the area where more than one node is located to receive the packets and collision occurs. The control frames address the hidden terminal issue where source node locates the communication channel for specific time period and selects random bakeoff timer. After receiving the packet, the receiver node acknowledges by CTS packets to all its neighbors. Afterwards, the neighbor of source node updates NAC (Network Allocation Vector) for time interval. In this time interval, the neighbor nodes defer data till transmission session completion. After receiving CTS packets, the data transmission initiates. In last, the acknowledgement frame has completed the data transmission between source and receiver nodes in the network.

2.9 Intelligent Beaconless Geographical Routing (IB)

As proposed in [17], intelligent beaconless geographical routing (IB) is infrastructure less protocol. Data packets are sent using beaconless strategy. To forward the data packet, IB makes data forwarding decision between or at intersection. At the intersection packet carrier node sends RTS to all its neighbors nodes to decide about data forwarding. The forwarding decision is based on three metrics: distance, signal strength and direction. When best intersection has been selected, forwarder node tries to catches the channel between the intersections using direction and signal strength, packet is being forward to the candidate node. When the best node accesses the channel, other nodes cancel their transmission. IB protocol suffers from variation in traffic density. In high traffic density, IB suffer from delay by increasing number of vehicle nodes. If traffic density is low IB suffers from disconnectivity ratio and low packet delivery ratio.

2.10 Connectivity-Aware Intersection Based Routing

In [11], CAIRis presented which is based on lower delay, higher probability of connectivity and uneven distribution of vehicles.The protocol uses topology, traffic, geographic and localization information.In CAIR, each node broadcasts a hello message, each node maintains its neighbor list and know its neighbor position. By exchange of neighbor list, every node may aware about it is known intersection node or not. At intersection, node will broadcast hello packet to update its neighbors. Based on the vehicle speed location information extracted from beacon messages, the forwarder node predicts its future location of its neighbors and takes the node greedily by considering the distance metric for data forwarding. CAIR uses routing recovery method when there is no neighbor node near with destination. This is called local maximum issue. The protocol uses store-carry-forward policy to overcome this issue. Store-carry-forward method work in a way that node carry the packet along the road and forwards the packet when other node enters its transmission range.

2.11 Improved Geographical Routing (IG)

Improved geographical routing protocol[10], establishes communication between vehicles. IG works in two modes; between intersection and at intersection. The protocol exchange beacon messages to know the nodes position. After exchange of beacon messages, the relay node checks its location at the intersection or not. If it is between the intersections,then the source node computes the forwarding progress (FP). FP measures through computing the distance of source node and intermediate node towards the destination. If intermediate node has higher value of forwarding progress,then source node will select the intermediate node which is closer to destination node. After computing FP, source node computes the Beacon Reception Rate (BRR). BRR is used to determine link quality between two vehicles. It is measured with how many packets have been received and transmitted at some interval by the vehicle. Packet carrier node gives high value to the vehicles that move in the similar way. IGlink quality,destination and link stability before sending the packet to an intermediate node. When forwarder node reaches to intersection then distance and traffic are used for data forwarding.Distance and direction is taken as routing metrics when node is at intersection to forward the data packet.IG uses different metrics when a single metric is not useful in harsh vehicular environment for packet forwarding.

2.12 Vehicle Density and Load Aware Routing (VDLA)

VDLA[14], is based on geographic routing protocol. Mostly geographic routing protocols forward the packet along the road and make routing decisions when packet reach at destination. The protocol make routing decision before a packet reach at junction. VDLA also considers a traffic density and load. By considering traffic density and network traffic load, VDLA prefers the path with low density and selects the path with the higher network connectivity. VDLA reduces the transmission delay by maintaining the network load along the paths. All the routing decisions are made before the junction in VDLA. The protocol decreases the congestion by avoiding disconnected roads. VDLA use Network Information Collection Packet (NICP) and transmit it from one node to other. NICP consists number of node, the entire length of buffer queue and total neighbors. NICP provides the shortest route in the network by calculating the weighting score for every adjacent road section vehicle node which reduces the network load, if two nodes enter at the junction at the same time. To address local maximum issue in VDLA, protocol provide the optimal route in a network by recalculating traffic density in a network. Recalculation of traffic density has low data delivery. To overcome the overhead issue, the route lifetime and timer is necessary in VDLA.

2.13 Reliable Beaconless Routing Protocol (RBRP)

As proposed in [21], Reliable beaconless routing protocol (RBRP) presents a self-adaptive scheme to forward the data packet. RBRP use beaconless routing strategy for data forwarding. To forward the data packet, the protocol takes distance, link quality and load of a node as metrics. The distance metric make use of normalization method used in VIRTUS [22]. The protocol uses link quality and distanceas routing metrics. When link quality is not good, then source will not send data to the candidate node and protocolinitiates the whole process again to forward the data packet. The protocol also takes the direction metric in which all nodes moving towards the destinations are considered and nodes moving in the opposite direction are discarded. The protocol does not take traffic density in to account which leads to increase the maximum number of nodes and increases network delay.

2.14 Road Selection Based Routing Protocol (RSBR)

RSBR[13],aims to forwards the data from source to destination. The protocol predicts the network gap in a path earlier to increase the system performance. The protocol selects the best route at the junction towards the next junction. Each road has ratings, which helps to find the best road between the junctions. The protocol assumes that every node has routing table using GPS service to know their own location and forwards data to that vehicle which has same direction with destination. The protocol selects the road with best road rating which helps to solve the network gap problem. TRSBR uses less number of nodes for data forwarding to the destination. Theprotocol initiates to start short route using Dijkstra algorithm. Then the source vehicle forwards the data to the nearest node. The protocol activates the Multihop communication when source node reaches tojunction and forwards the data to the static vehicle on the junction. As static vehicle receives the data and forwards it by calculating road ratings. Road rating is calculated using number of vehicle nodes and junction information. The road with less number of vehicle and low connectivity will have high road rating and road with more vehicle and strong connectivity will have low road rating. The protocol selects the road with the low road rating.

The protocol uses recovery phaseto save the system from the network gap which is created between the junctions. A network gap can be generated in any direction. The road with the low road rating uses network gap to forward the data in same direction. The protocol presents a speed adjustment method for recovery to solve gap issue. The protocol assumes that a vehicle moves with the constant speed between the junctions until some situation occurs,whenever vehicle increases or reduces their speed. Sufferer vehicle forwards the data to the backward or forward vehicle, when vehicle have the greater speed then the sufferer vehicle. The protocol can be evaluated by calculating three metrics including delay, and network gap. Number of nodes are also used to decrease the network gap, as number of vehicles in the path increases then network gap will be zero, with the increase of distance network gap will also increase. When number of vehicle nodes increase the delay increases. The delay depends on the density of vehicle nodes and less number of vehicles can also generate network gaps.

2.15 Greedy Probability based routing

As proposed in [23], Greedy probability based routing protocol for incompletely predictable vehicular ad hoc network (IPN) is beacon based protocol and take node speed and traffic density as parameters. IPN is not suitable due to unpredictable vehicular environment. The networks in which node movements are limited and have known trajectories are called incompletely predictable VANET. So to route the packet anti pheromone and greedy algorithm is required in vehicular network. In anti-pheromone if route lengths remain constant and source needs to send the data packet to different neighbors, then anti pheromone would chose the node which is less used. IPN have APh information added to ACK which indicates, how many times node have been used to send the packet. Node with less APh is selected. IPN use selective greedy approach to select the next forwarder and take node density and distance into an account to forward the packet. IPN use beacon messages to share nodes information. IPN does not take direction in to account so these types of protocol suffer from looping issue.

2.16 Beaconless Packet Forwarding Routing

In [24] Beaconless Packet Forwarding strategy (BPF), was presented as protocol aims to modify handshake messages for better performance. The protocol takes distance and link quality as routing metrics.To update the nodes location, beacon messages are exchanged in a network. In beaconless protocols, RTS/CTShave been modified for data forwarding. The protocol sends source and destination address with RTS in its transmission range. The candidate node calculates the routing metrics: distance and link quality to forward the packet. The protocol prefers to select the border node which has better link quality as a forwarder node. When the relay node has been selected, then relay node sends CTS to the source to sends the data packet. When the packet reaches to the relay node, the relay node initiates the sameprocess to forward the data packet. BPF protocol does not take traffic density and direction as a routing metrics due to which BPF suffers from looping issue and disconnectivity issue as there will be two way traffic and protocol suffers from packet delay issue. Traffic density should be considered in BPF so that protocol does not suffer from disconnectivity issue and maximum number of hops due minimum and maximum number of hops respectively.

2.17 Opportunistic Beaconless Routing

In [25] Opportunistic Beaconless Packet Forwarding strategy (OBPF), was presented as protocol aims to packet delay and data delivery ratio. The protocol takes distance, direction and link quality as metrics. OBPF is designed for inter communication between vehicles and does not use and road infrastructure to communicate between the vehicles. OBPF takes routing decision at or between intersections. OBPF modifies the RTS message with source and destination nodes address and add flag which determine the nodes position at or between intersections. If the node is at the border or located near with the destination and has the good link quality and it moving direction towards destination node, then it will be selected for relay node. If no node satisfies the criteria, then it will be selected as relay node.OBPF suffers from disconnection issue if nodes are very far or located at the border as the protocol does not take traffic density metric. The protocol also suffers from maximum number of hops issue as there will be an area where large number of nodes exist so the number of hops required to forward the data packet will increase which will result in increase of packet delay.

2.18 Connectivity Aware Intersection Based Shortest Path Routing Protocol

In [26], CISRP is presented which uses distance, traffic density and vehicle speed to forward the data packet. This protocol calculates the average distance between nodes and closer distance node is selected. CISRP computes the average velocity of all the vehicle nodes in its communication range and take its average. The node which has its velocity closer to the average velocity will be selected. CISRP does not take traffic density in to account, neither at nor between intersections. The negligence of this metric cause maximum number of hops issue and link failure issue which affects the packet delay and the packet delivery ratio. CISRP also suffers from the face routing issue due to two way traffic as distance metric is not considered.

2.19 Discussion

Various geographical protocols have been presented and they are using different metrics to evaluate their performance. Due to the dynamic topology, geographical routing metrics should have well defined routing metrics to handle high mobility and disconnection issues. Three important metrics for geographical routing are traffic density, direction and distance. The protocols which does not consider distance suffer from out dated information and link failure as node goes out of the reach when communication starts. Direction metric is very useful in evaluating geographical routing protocols as nodes which do not consider direction face looping issue. The protocols which are not considering traffic density metric, they suffer from maximum number of hop issue due to dense network and link failure issue when there is sparse traffic in the network.

Table 2.1: Parameters for Geographic routing protocols

Protocols	**Year**	**Distance**	**Direction**	**Traffic Density**
Greedy Perimeter Stateless Routing (GPSR)	2000	✓	✗	✗
Improved Greedy Traffic Aware Routing (GyTAR)	2007	✓	✗	✓
Geographic Source Routing (GSR)	2009	✓	✓	✗
Traffic Aware Geographic Routing (TARGET)	2012	✓	✗	✓
Intersection Based Connectivity Aware Routing (iCAR)	2013	✓	✗	✓
Junction Based Routing (JBR)	2013	✓	✓	✗

Intelligent Beaconless Routing (IB)	2013	✓	✓	×
Connectivity-aware Intersection Based Routing (CAIR)	2014	×	✓	✓
Improved Geographical Routing (IG)	2014	✓	×	✓
Vehicle Density and Load Aware Routing (VDLA)	2014	✓	×	✓
Reliable Beaconless Routing Protocol (RBRP)	2014	✓	✓	×
Road Selection Based Routing (RSBR)	2015	✓	×	×
Greedy Probability Based Routing	2016	✓	×	✓
Beaconless Packet Forwarding Routing (BPF)	2016	✓	×	×
Opportunistic Beaconless Routing (OBPF)	2016	✓	✓	×
Connectivity Aware Intersection Based Shortest Path Routing Protocol (CISRP)	2018	✓	×	×

2.20 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

1.1 Overview

This chapter discusses the detailed research methodology to be adopted to design and develop beaconless geographical routing protocol. It gives an overview of the 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 based on literature review, which are discussed in Chapter 2, are presented in the first phase. The second phase discusses the research design and development of the proposed protocols. The final phase provides the procedure to test and evaluate the performance of this work with state-of-the-art protocols[17, 23].

1.2 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 frame work, the problem is identified and critically investigated. In the second phase, details of the methodology used to design and develop the proposed protocols and scheme are discussed. Finally, in the third phase, performance evaluation and conducted to assess the proposed protocols and congestion scheme in realistic vehicular urban scenarios. This thesis is based on research methodology as one of the significant method to achieving the objective of research. The details of research methodology are explained as in the following section.

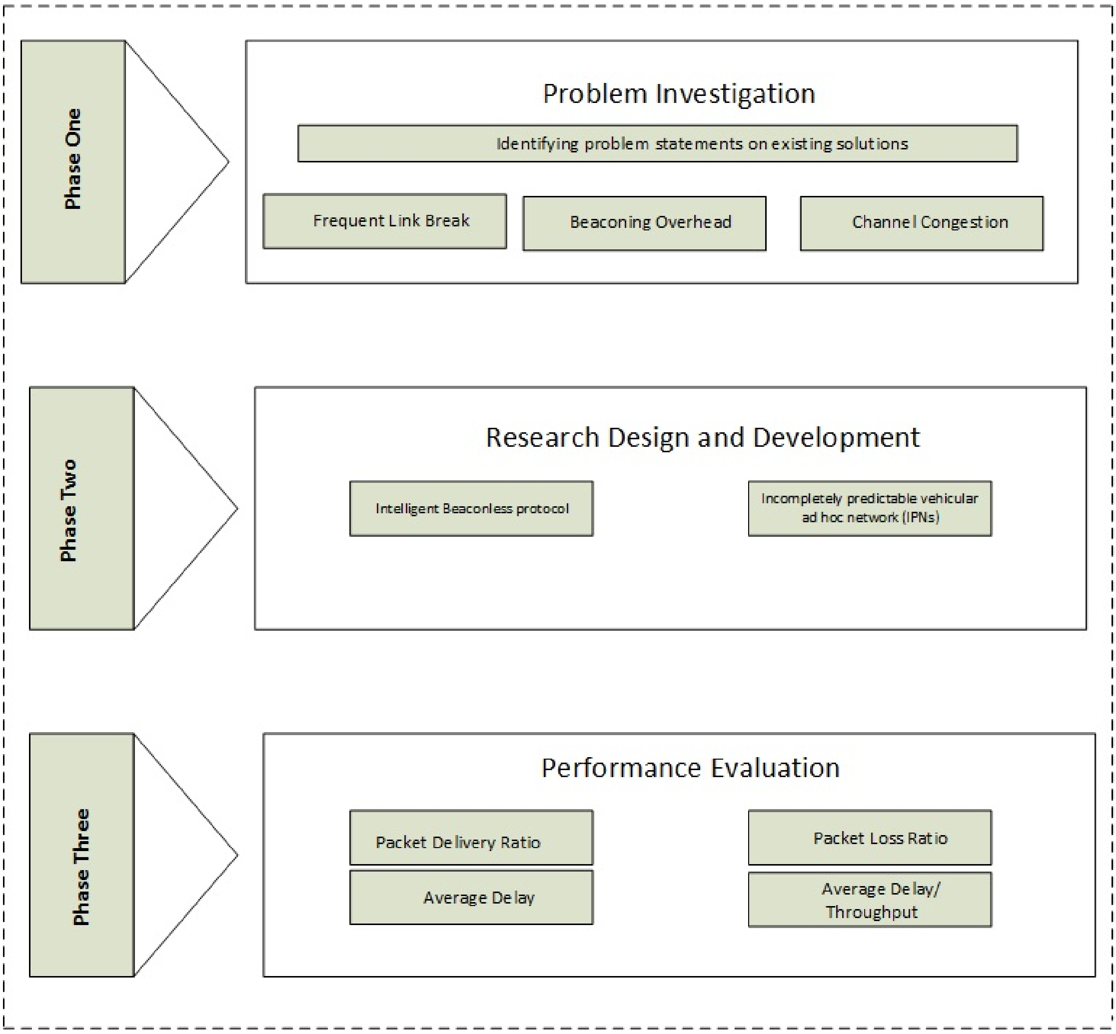

Figure 3.1: Research Framework

1.3 Problem Investigation

The problem is investigated by conducting a detailed literature review by using resources such as journal articles, conference proceedings, previous research in the relevant domain, and other online resources. These were used to formulate chapter two, which is divided into three parts and reviewed literature on geographical routing protocols and beaconless protocols. This process gives an insight into the research background, problem investigation and its analysis.

i. In VANET, rapid and dynamic topologies, high mobility, lead to network disconnection of links, and packet loss issues. Geographical routing is one of the type of considering a better protocol due to its position awareness services. Most of geographical routing protocols greedily find the next forwarder, in which they look for a closer node with the destination. If a closer neighbor node does not exist in radio range of scenario node, then protocol faces forwarding failure issue. This issue is known as void region in greedy-based forwarding [27].Right hand rule is used to address void region issue where sender node selects next forwarder to the node which creates the next link in anti-clock wise direction starting from the incoming link.Right hand rule follows perimeter path of the polygon which covers void region. Due to the increment in number of hops in perimeter-based right Hand rule, end-to-end delay considerably increase which need to be addressed with better next forward node selection strategy in geographical routing. Due to higher possibility of formation of loops in right hand rule, complete disconnectivity with the neighbor node resulting in packet loss is another issue of greedy geographic routing protocols.In addition, these greedy based routing protocols are selecting a node at the border of radio range as a next forwarder node due to the closeness to the destination.

1.4 Performance Evaluation

The selection of simulation is very important factor to analyze and validate the research objectives. In this study, the NS-2.34 is used with a mobility generator (MOVE). The NS-2.34 was developed in 1981 as event driven an open source simulator. The simulator supports network and MAC layer operations. It provides user an executable TCL scripts as an argument. A simulator trace file is generated after the execution of 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 an extension NAM file. NS-2.34 working with two languages OTcl (Object oriented Tool Command Language) and C++. C++ provides a user facility to define internal working mechanisms (executed at the backend) of the simulations objects, while OTcl provide facility to setup simulation scripts and configurations of objects (executed at front end), and discrete events[28].

1.5 Simulation Setup of Proposed Protocol

In this section, the simulation setup-in is presented to evaluate the proposal Beaconless traffic aware geographical routing protocol (BTA-GRP). The simulation parameters are as following:

- **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 [29], 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 40-70 km/h with rectangular area 3,968 * 1251 m. Washington DC, USA, map is used with 370 road segments and 124 intersections[30].Constant Bit Rate (CBR) is a source of simulation[31].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[32, 33].IEEE 802.11 is used for MAC layer with 3 Mbps channel bandwidth[34].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%.

The BTA-GRP is evaluated with two routing protocols Intelligent Beaconless protocol (IB) and Incompletely Predictable Vehicular Ad hoc Network (IPN) for evaluated the protocol performance. The detail of metrics are as following:

- Packet Delivery Ratio (PDR) shows the ability of successfully transmitting data packets between the source and destination.
- Network delay presents the complete time of data transmission from source to the destination node.

Table 3.1: Simulation Parameters

Parameters	**Values**	**Parameters**	**Values**
Traffic Type	CBR	Simulation Time	500s (each round)
MAC protocol	IEEE802.11p	Mobility model	MOVE
No of Vehicle Nodes	100 to 350	Vehicle speed	40-70 km/h
Packet Size	512 bytes	Antenna Model	Omni directional
Transmission Range	300 m	Intersections	10
Total area of simulation	3500×3500 m^2	Propagation model	Nakagami radio propagation model

1.6 Summary

This chapter presents the detail simulation setup of proposed protocols and scheme for VANET. The research methodology has three main phases, where the first phase presents the problem investigation. In the second phase, the design of Beaconless Traffic Aware Geographic Routing Protocol (BTA-GRP) is presented with design model. In the third phase, the methodology of experiments (simulation set-up) and performance evaluation metrics are discussed.

CHAPTER 4

BEACONLESS TRAFFIC AWARE GEOGRAPHICAL ROUTING PROTOCOL

4.1 Overview

This proposed Beaconless Traffic Aware Geographical Routing Protocol (BTA-GRP) addresses the staleness issue of geographical routing protocol's in VANETs. This chapter presents the complete design of proposed protocol using RTS/CTS control packets. The RTS/CTS packets have modified based on appropriate routing metrics for selection of next node in the network.

4.2 Proposed Protocol Design

BTA-GRP uses RTS/CTS modified frames to perform data routing in urban VANETs environment. We have some assumptions to test proposed protocol in simulation such as all the vehicle nodes are equipped with GPS system and vehicle nodes also aware about digital map. In digital map, the vehicle nodes position, coordinates of intersections and road segments. The proposed routing protocol is based on three metrics, distance, direction and traffic density in the networks.

4.2.1 Distance

Distance has considered one of the important metric for design a geographical routing protocol. In this type of routing, the packet carrier node routes the data using source and destination position information. This type of method also called greedy packet forwarding. The greedy forwarding is based on distance metric in which nodes which is located at border is selected within its communication range. If, there is no node available on border then, this type of protocol faces delay or disconnection issues. The proposed BTA-GRP usedistance as one of the metric because distance has less or more among vehicle nodes. By distance, proposed protocol measure the distance of nodes which are not very far or not very near. This is well known fact that when distance is short between vehicle nodes then the number of hops will increase. When the distance is more than the link failure probability increase. In order to address this issue, proposed protocol select the node which is located with maximum distance. This matric increases the reliability of packet forwarding in VANET. The position of vehicle nodes is known through GPS services. For distance calculation, the Pythagoras theorem is used as shown in Figure 4.1.

$$Distance = \sqrt{(a_1 - a_0)^2 + (b_1 - b_0)^2} \quad (1)$$

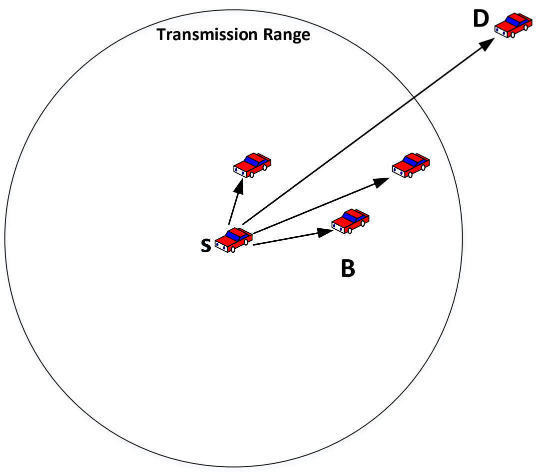

Figure 4.1: Distance calculation

In Figure 4.1, the distance is calculated where node A denotes as a source and node D denotes destination in the network. After the distance calculation, the node B is selected with maximum range vehicle node for data forwarding. The distance evaluates and prefer maximum distance vehicle node within the source communication range. The distance metric is calculated in Equation 2.

$$Distance = max\left[\log\left(\frac{SD}{SN}\right)\right] \quad (2)$$

In Equation 2, the Distance calculated and the maximum distance evaluates between Source node to Destination (SD) and Source node to Neighbour Nodes (SN).

4.2.2 Direction

After distance calculation, the second metric is direction. Without direction metric the protocols face looping issues because traffic is multidirectional in VANET. Direction is more suitable routing metric for stable and reliable routing. The direction of the vehicle node is constrained by the roads. In straight highway environment, the vehiclesmove in same or opposite direction. The BTA-GRP selects the direction of source node to the destination because in VANET, all vehicle nodes are aware about its own and neighbor nodes direction. So the proposed protocol first checks the distance of neighbor node and select maximum distance node then select then check the direction of selected node and send data packet to the node which is moving towards the destination. The direction based method of proposed protocol shows in Figure 4.2, where the line shows the direction of nodes towards the destination. At first stage, the source vehicle node calculates the angle ϴ = DSA which is made between the vectors of neighbor nodes vector SD and AD. After angle of neighbor calculation, the vehicle node which has smallest angle towards destination is selected for data forwarding. This process will continue till the data packets will reach to destination in the network.

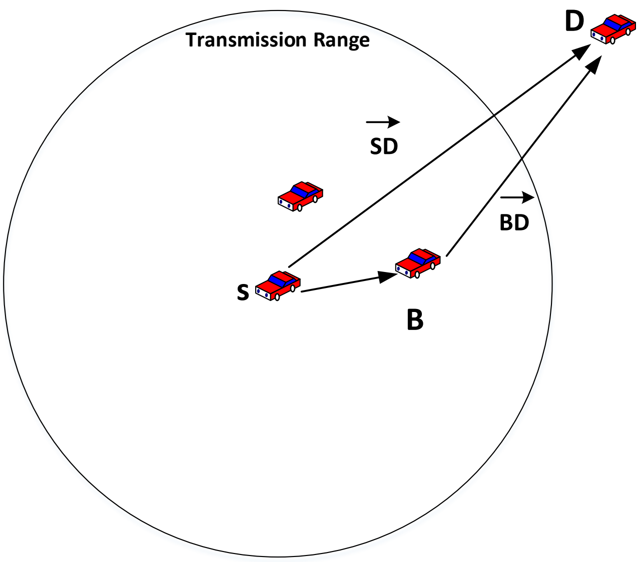

Figure 4.2: Direction calculation

The direction is calculated in Equation 4, where the direction weight value factor is calculated with travel vehicle direction $(\overrightarrow{Direction_n})$and direction of packet transmission$(\overrightarrow{Direction_{packet\ \ transmission}})$.

$$Direction_{WeightValue} = [(\overrightarrow{Direction_n}, \overrightarrow{Direction_{packet\ \ transmission}})] \qquad (3)$$

4.2.3 Traffic Density

Traffic density metric is initiated when source node reach to intersection area, then source node collects the traffic status and then forward the data to destination or next intersection. At intersections the Road Side Unit (RSU) is used to update the traffic status and broadcast Collector Packet (CP) within the range of intersection using digital map for traffic density information.

CP packet uses for traffic and network status and contains some information or fields as shows in Figure 4.3. The first field has holding the forwarder node address. The second field has next forwarder address at intersection which is assigned by RSU for forwarding the data further. The next field is about vehicular density information Traffic density ($T_{Density}$) which has accumulative number of vehicles located on the roads or moving on roads. Proposed protocol uses direction metric that's why source node neglected the opposite direction vehicles nodes. RSU already has all the roads IDs through digital map in the network.

Forwarder Vehicle Node Address	**Next Forwarder Vehicle Node Address**
Traffic density ($T_{Density}$)	**Duration timeline ($D_{Timeline}$)**
Number of Hops	
Originial Flag	**Time Stamp**

Figure 4.3: CP packet structure

The CP also has Duration timeline ($D_{Timeline}$) which refers to a duration which remains until next update. This time is set based on estimated period of time where a network disconnection is expected to occur. CP packet also has number of hops section, original flag section which make differentiate with normal beacon and CP message. The last field is time stamp for registration the generation time of CP.

After receiving the CP packet from RSU, the candidate vehicle node calculates the traffic density to select the next forwarder node towards the destination. The candidate node initiates the received values from CP and calculate the road density using Equation 4.

$$\mathrm{TD_{Value}} = \frac{2 * \mathrm{T_{Density}}}{3 * No.of\ vehicle\ nodes * N_{con}} \qquad (4)$$

$$TDV = \begin{Bmatrix} \frac{1}{\mathrm{TD_{Value}}} \mathrm{TD_{Value}} > 1 \\ otherwise \end{Bmatrix} \qquad (5)$$

The candidate node selects the higher density road because it has high data delivery ratio and less delay as discussed in[35]. Therefore the proposed protocol selects higher weighting factor which is equal to $\frac{2}{3}$given for $\mathrm{T_{Density}}$. Equation 4 shows that roads with higher traffic density and N_{con} shows the constant connectivity degree. Based on Equation 5, if the $\mathrm{TD_{Value}}$ is higher than required density the Traffic Density Value (TDV) parameter scaled to 1, otherwise TDV is in the range 0.0, 10.0 based on Equation 3.

4.3 Score Function for Routing Decision

After explanation the routing metric, this section presents the score function for routing decision. The candidate (Source) node calculate the distance and direction between two intersections by calculating the score function. The first metric is distance, where the maximum distance vehicle node is selected as a next forwarder. 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. Equation 6 shows the distance and direction weighting factor score, respectively.

$$Next\ Forwarder\ Score = \alpha_1 + \alpha_2 \qquad (6)$$

In above Equation 6, the weighting factors for distance and direction indicate and the factors must be equal and the calculated next forwarder vehicle score is 1, 0 and all values in this range. This value is calculated and send through CTS control packet to source node. Then source node selects the next forwarder on the basis of this scope.

When the source node reaches to intersection, then it receives the CP packet. The CP packet is calculated as showed in Equation 4 and 5. Then select the next road towards destination and again the first metrics (Distance and Direction) calculation initiated.

4.4 Proposed Protocol Routing Process

The proposed routing protocol BTA-GRP adopts RTS/CTS control packets for the nodes which are located at or between intersections. When the node reaches to intersection then from RSU, source node again determines the traffic density and select the road with maximum vehicle nodes towards the destination. For first process, the source vehicle node calculates the distance of neighbor nodes which are in its transmission range and select the node which has more time to leavethe transmission range and address the greedy forwarding issues in the network. The second routing metric is direction which is used to avoid looping problem due to bi directional vehicle nodes traffic in urban areas. By direction metric, source node neglects the opposite direction vehicles and select the vehicle as a next forwarder which direction towards the destination node. These routing metrics support the source node between two intersections. Intersection is an area where different roads are linked towards different destinations. At the intersection, another important route decision is needed to avoid the packet dropping due to more traffic and less traffic situations. In urban areas, the RSU are available at intersections to update the traffic conditions based on map segmentation method, where they count the vehicle nodes and this information broadcasted through short messages to the intersection area vehicle nodes. The proposed protocol adopts this method and select the next road which has maximum vehicle nodes and improve packet throughput and delivery.

Basically, proposed protocol overcome the beaconing by using RTS/CTS control packets and improve the data delivery and decrease the network overhead. Through traffic density updating, proposed protocol improves the data delivery and delay issues. The next section illustrates the proposed protocol flowchart and algorithm. In CTS packet, the metric score function value is added to imitate the routing decision in the network.

4.5 Proposed Protocol Flowchart and Algorithm

The below Figure 2 shows the flowchart of proposed protocol routing process at or between intersections. The doted rectangles show the proposed protocol process at the intersection and between two intersections.

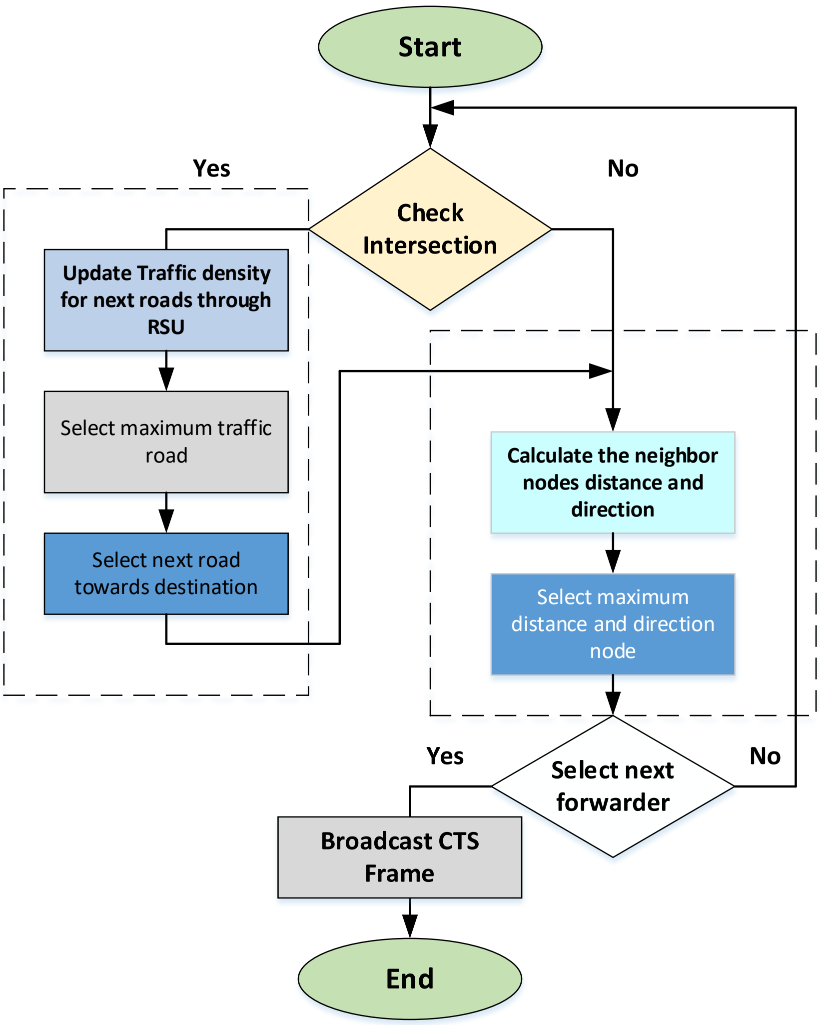

Figure 4.4: Flow chart

Algorithm 1 shows the process line by line where line 1 indicates that source node broadcast RTS frame instead of beacon messages. After RTS the protocol check the source node position by intersection flag and if it is 1 then initiated further process. Upon receiving the RTS packets by neighbor nodes of source node the distance and direction has calculated as show in line no 4, 5 and call the score function and weight the values to select the next forwarder. When the source node is at intersection area, then it will check the traffic density updates through RSU as shows in line no 8, 9. In last protocol broadcast CTS packet and start data forwarding in the network.

Algorithm 1: Routing process of BTA-GRP

```
1   Broadcast RTS frame to neighbor nodes
2   IfRTS received then
3   If Intersection check=1then
4       determine Distance
5       determine Direction
6   Call score function
7   Else
8       Receive traffic density update from RSU
9       Calculate the maximum traffic density
10  end if
11  Broadcast CTS frame
12  end if
13  end if
```

4.6 Summary

This chapter discussed the beaconless protocol for VANET called BTA-GRP. 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 802.11 b standard and RTS/CTS control frames, initiates the routing decision when source node located in between two intersections and when at the intersection. Proposed protocol uses distance, direction and traffic density metric for routing and always select the maximum distance and maximum traffic road for data route.

CHAPTER 5

Simulation and Results

5.1 Overview

This chapter discusses the simulation results performed on Beaconless Traffic Aware Geographical Routing Protocol. This protocol compares its result with one beaconless and one beacon based geographical routing protocol.

5.2 Experiment Results

The experimental results of BTA-GRP in terms of data delivery ratio, network delay, overhead and data throughput with number of vehicle nodes and vehicle speed analysis are discussed.

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 beaconless Intelligent Beaconless (IB) [17] protocol and one beacon based Greedy Probability-Based Routing Protocol for Incompletely Predictable Vehicular Ad-hoc Network (IPNs) [23] 20].

The IB protocol is beaconless but only consider distance, direction and signal strength and neglected the traffic density metric, which is one of the important metric for the nodes located at intersection. On the other hand, the IPNs protocol is prediction based protocol and due to unpredictable VANET environment and not suitable for VANETs.

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 BTA-GRP has increased data delivery consistently due to increasing connectivity probability with more vehicle in dense networks. In addition, when the number of nodes reach to 60, the proposed protocol trend becomes flat due to RTS/CTS handshaking method. The existing beaconless routing protocol IB has better results than IPN because of RTS/CTS mechanism. The IPNs protocol is based on greedy forwarding and prediction mechanism which is not suitable for VANET. This is the main reason that IPN is behind IB and BTA-GRP.

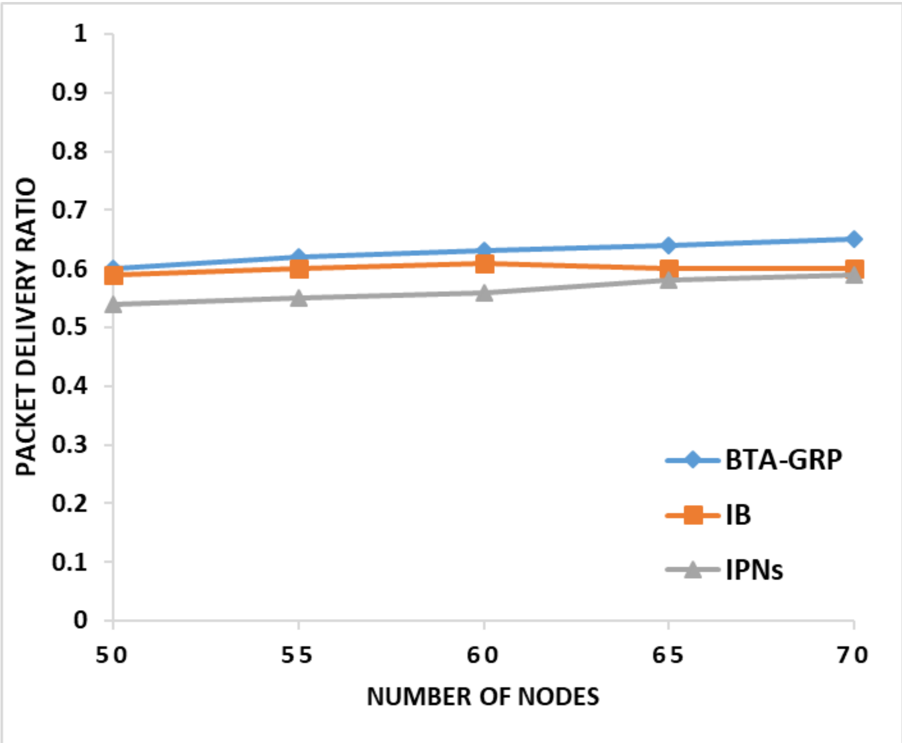

Figure 5.1: Packet delivery ratio with number of nodes

Figure 5.2 illustrates data delivery with more number of nodes. The results indicate the better results of proposed protocol compared to existing beaconless and beacon based routing protocols. The proposed BTA-GRP protocol data delivery ratio has increased more due to increasing connectivity probability with more traffic density in urban environment. In addition, when the number of nodes reach to 80 and 85 the PDR has increased. These results are because of controlling handshaking mechanism (RTS/CTS), the trend of existing beaconless protocol IB also has better results compared to IPNs due to its beaconless strategy. The IPNs protocol has minor difference compared to IB due to its mechanism support in more traffic density where protocol predicts easily to find next forwarder in the network.

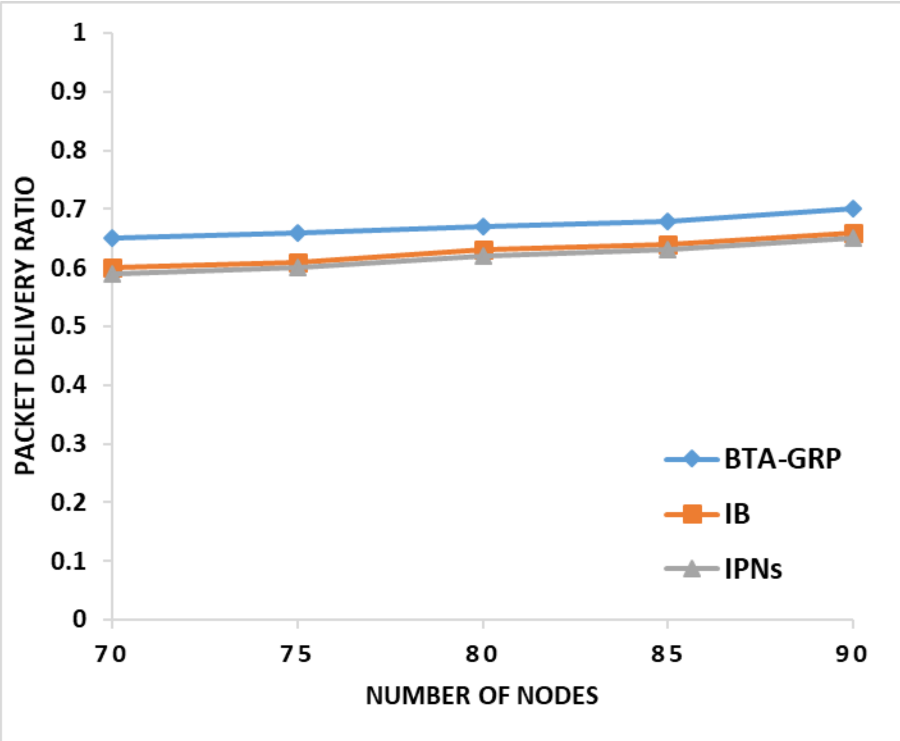

Figure 5.2: Packet delivery ratio with number of nodes

Another performance metric has analyzed that is average delay as shown in Figure 5.3. The average delay of proposed protocol BTA-GRP consistently increased due to its routing metrics calculations and waiting time of CTS packets. However, the existing protocols have more delay compared to proposed protocol. This result also indicated that both the beaconless protocol has less delay compared to beacon based protocol because more traffic has more beacon overhead and the next forwarder selection is difficult.The IB protocol steeply increased the delay because at the intersection, 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 address this issue by selecting the maximum traffic density road at the intersection.

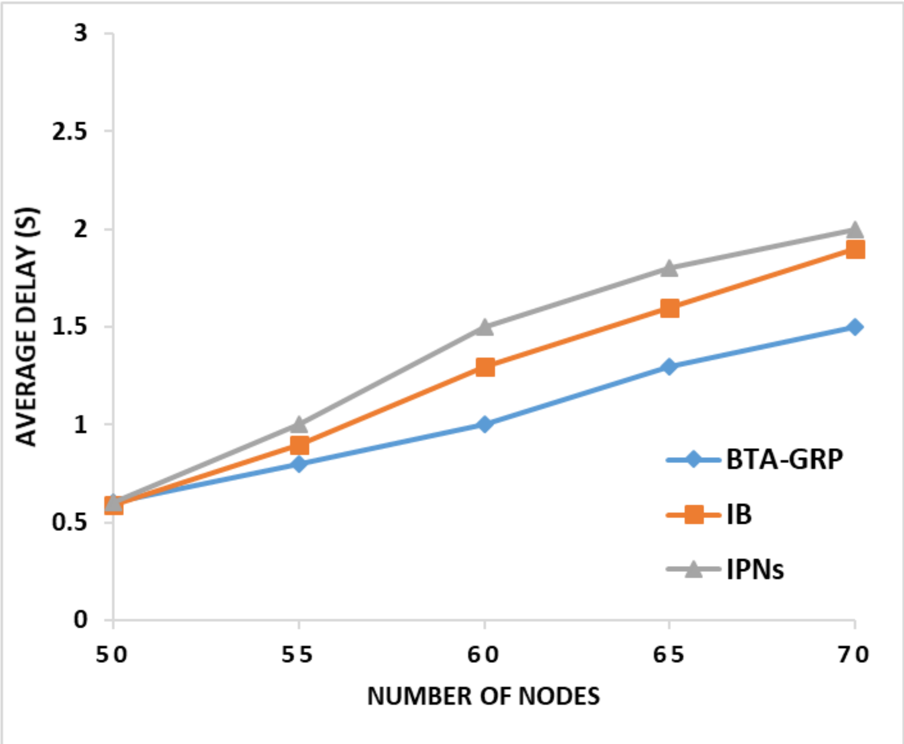

Figure 5.3: Average delay with number of nodes

Figure 5.4 shows the average delay analysis with more number of nodes. This results indicate that proposed beaconless BTA-GRP protocol has better results compared to IB and IPN protocols. Whenever, the traffic density is high in the network the delay is more due to various number of nodes. Compared to beacons based IPNs protocol, the beaconless IB and BTA-GRP have less delay because more traffic has more beacon overhead and the next forwarder selection is difficult. The IB protocol steeply increased the delay because at the intersection, 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 address this issue by selecting the maximum traffic density road at the intersection.

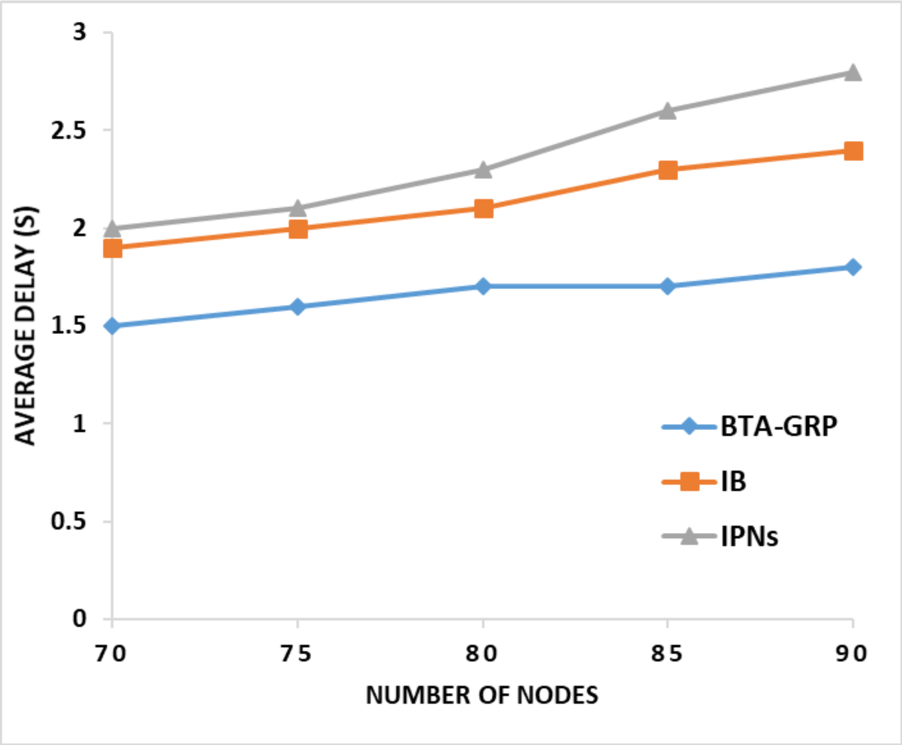

Figure 5.4: Average delay with number of nodes

Figure 5.5 shows the data overhead analysis with more number of nodes. This results indicate that proposed beaconless BTA-GRP protocol has better results compared to IB and IPN protocols and has less overhead. Whenever, the traffic density is high in the network the overhead is more due to various number of nodes. Compared to beacons based IPNs protocol, the beaconless IB and BTA-GRP have less overhead because more traffic has more beacon overhead and the next forwarder selection is difficult. The IB protocol steeply increased the overhead because at the intersection, 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 overhead due to number of vehicle nodes. The proposed protocol address this issue by selecting the maximum traffic density road at the intersection.

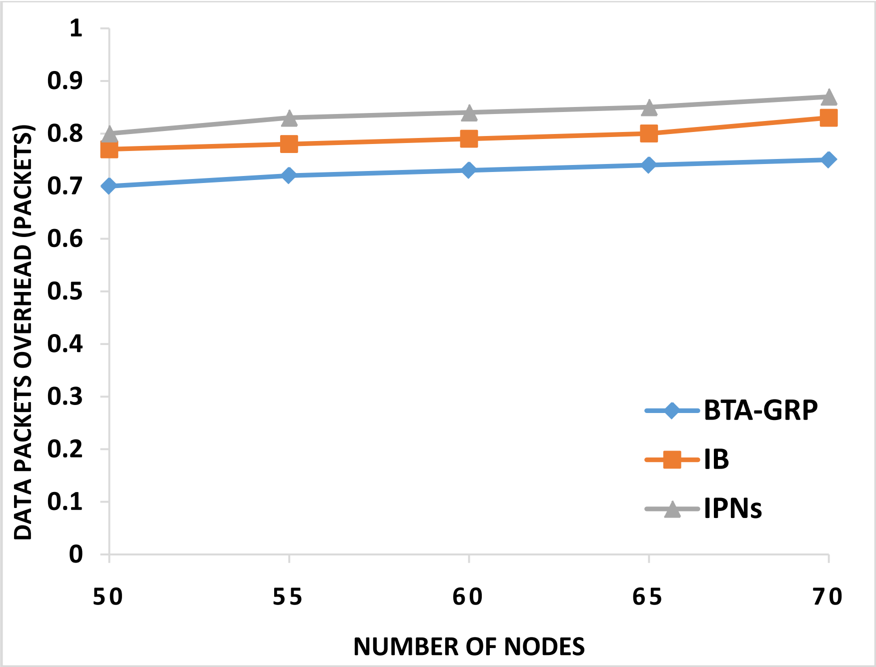

Figure 5.5: Data Overhead with number of nodes

Figure 5.6 shows the data overhead analysis with more number of nodes. This results indicate that proposed beaconless BTA-GRP protocol has better results compared to IB and IPN protocols and has less overhead. Whenever, the traffic density is high in the network the overhead is more due to various number of nodes. Compared to beacons based IPNs protocol, the beaconless IB and BTA-GRP have less overhead because more traffic has more beacon overhead and the next forwarder selection is difficult.The IB protocol steeply increased the overhead because at the intersection, 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 overhead due to number of vehicle nodes. The proposed protocol address this issue by selecting the maximum traffic density road at the intersection.

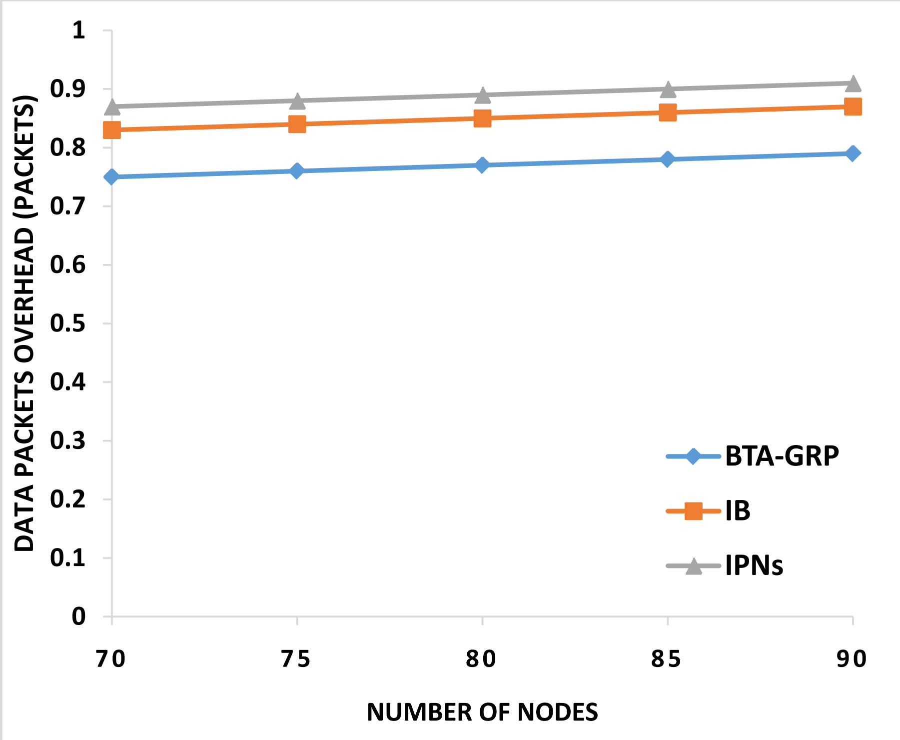

Figure 5.6: Data Overhead with number of nodes

5.2.2 Vehicle Speed Analysis

This section shows the results based on vehicle node velocity in terms of packet delivery ratio and average delay in the network. Figure 5.7 shows the data delivery ratio of the BTA-GRP, IB and IPNs routing protocols. A prompt result is that the vehicle speed cause of low PDR in the network. However, the proposed BTA-GRP has better results due to removal of beacon messages and add RTS/CTS handshaking method for routing decision. 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 IB protocol has one mechanism where this protocol determines the distance, direction and signal strength between two intersections and at the intersection. In addition, the IPNs protocol uses prediction 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.

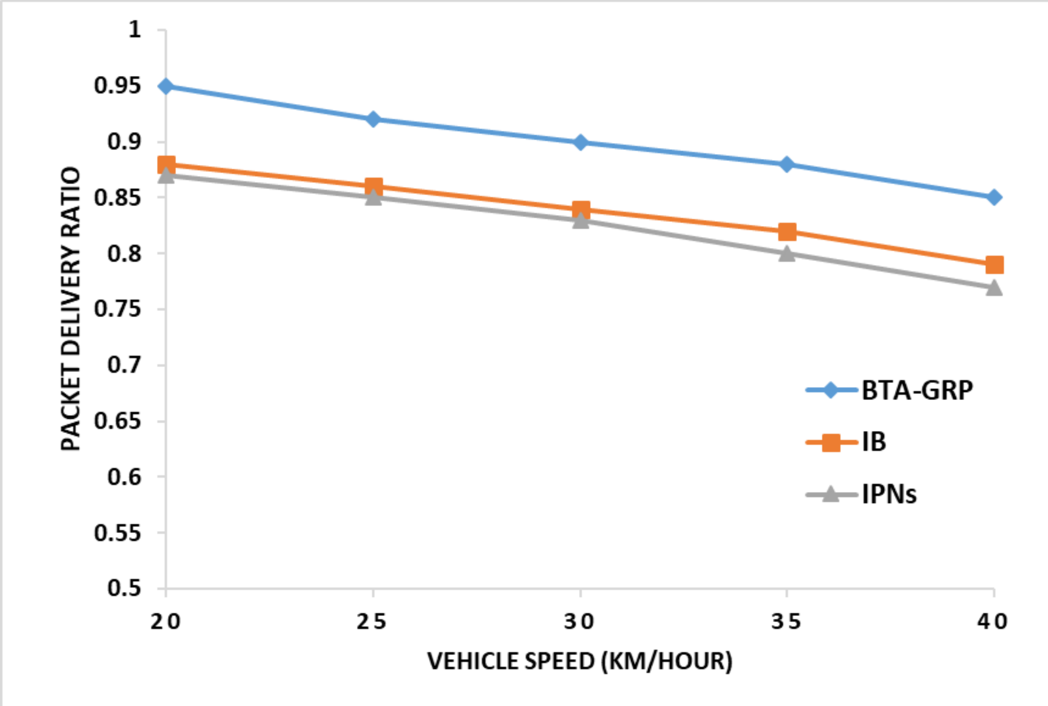

Figure 5.7: Packet delivery ratio with vehicle speed

Figure 5.8 shows the PDR analysis in the presence of different vehicle speed. As per previous graph, again the proposed protocol BTA-GRP has better results compared to IB and IPNs protocols even when the vehicle velocity reached to 55 and 60 km/hour. Basically, the PDR decreasing trend indicates that the vehicle speed cause of low data delivery in the network but BTA-GRP still has better results due to removal of beacon messages for next forwarder node selection. The beaconless strategy supports to consume less bandwidth compared to beacon based routing protocols. The IB protocol also has less packet drops compared to IPNs due to its multi-metric and beaconless strategy. In addition, the IPNs protocol uses prediction which leads to packet dropping issues and that's why the graphs show when the vehicle speed reaches to 55 and 60, the protocol suffers with packet delivery ratio. In addition, the high speed also causes of staleness of neighbor node information. The result shows that BTA-GRP has better results when the vehicle nodes speed set between 40 to 60 in the network.

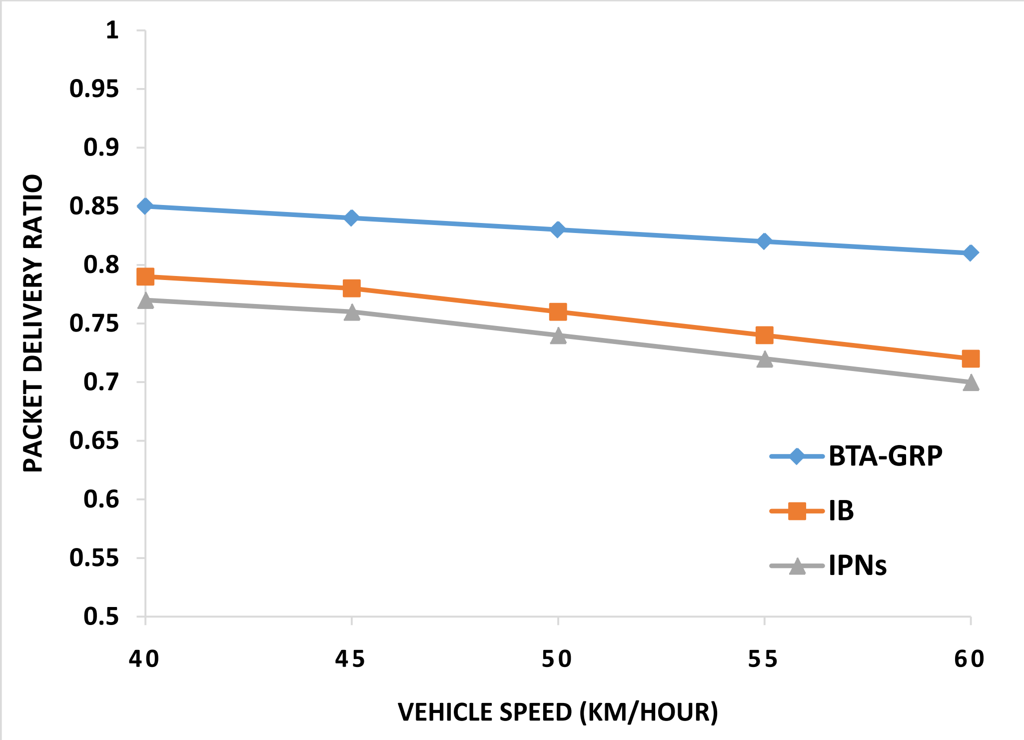

Figure 5.8: Packet delivery ratio with vehicle speed

Figure 5.9 shows the average delay results with vehicle speed analysis. The results indicate that proposed beaconless BTA-GRP protocol has less delay compared to IB and IPNs. 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 beacons based IPNs protocol, the beaconless IB and BTA-GRP have less delay. The high velocity has more chances for packet dropping. On the other hand, the IB protocol steeply increased the delay because at the intersection, 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 high speed. The proposed protocol address this issue by selecting the maximum traffic density road at the intersection.

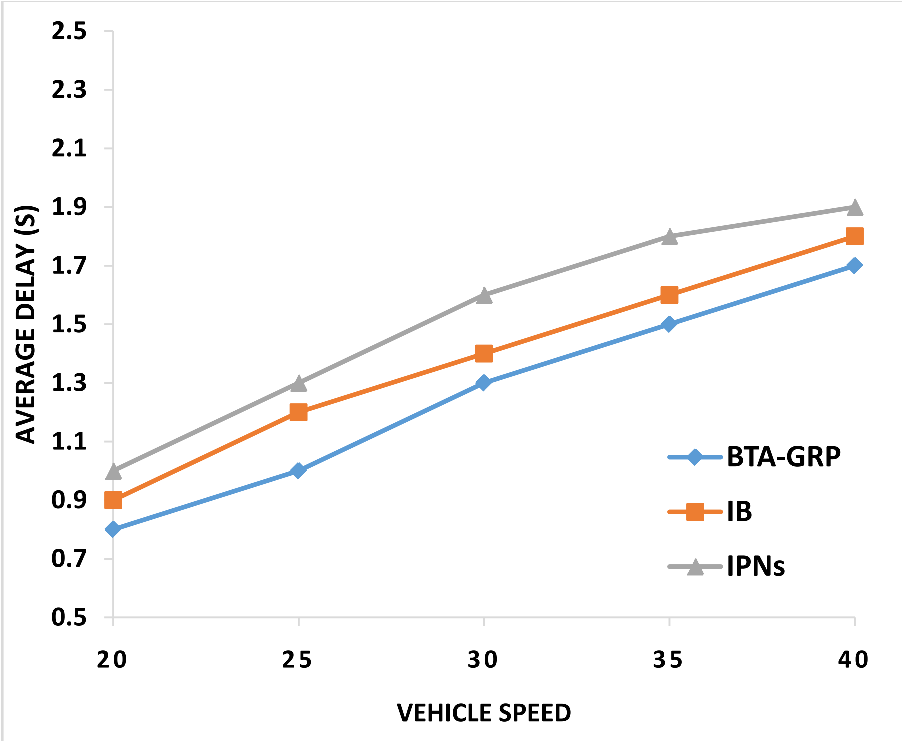

Figure 5.9: Average delay with vehicle speed

The graph Figure 5.10 shows the delay trend with more vehicle velocity in urban environment. The proposed routing protocol BTA-GRP has better results in terms of delay compared to IB and IPNs 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 beaconless protocols (IB and BTA-GRP) have less delay compared to IPNs 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 IB protocol steeply increased the delay because at the intersection, 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 channel congestion.

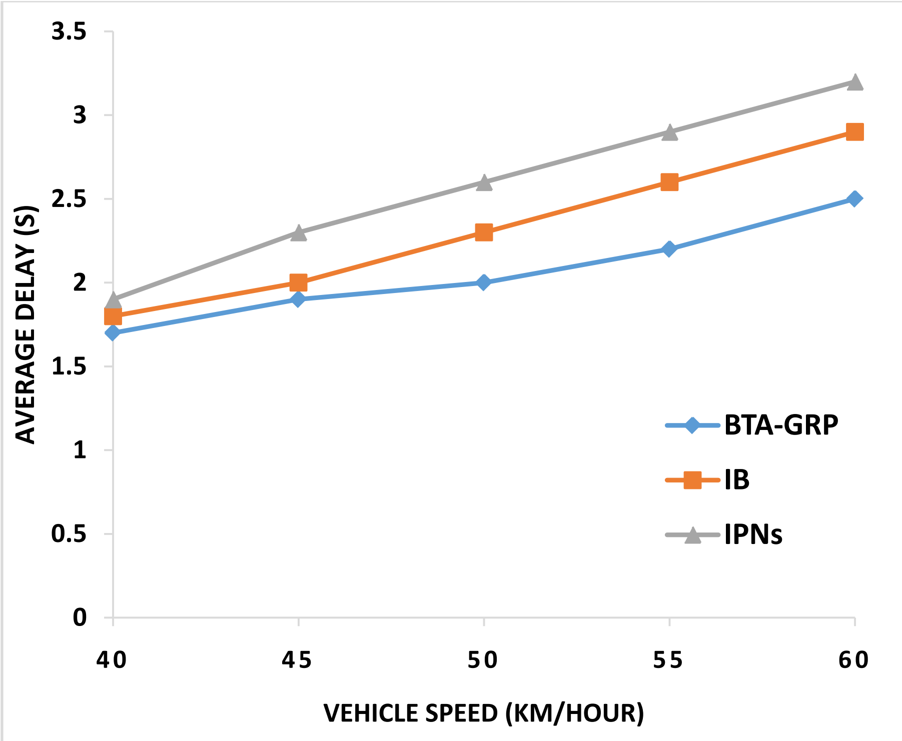

Figure 5.10: Average delay with vehicle speed

The last graph Figure 5.11 shows the data packets overhead trend with more vehicle velocity in urban environment. The BTA-GRP has better results in terms of network overhead compared to IB and IPNs 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 beaconless protocols (IB and BTA-GRP) have less overhead compared to IPNs because their RTS/CTS mechanism. The IB protocol steeply increased the overhead because at the intersection, 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 channel congestion.

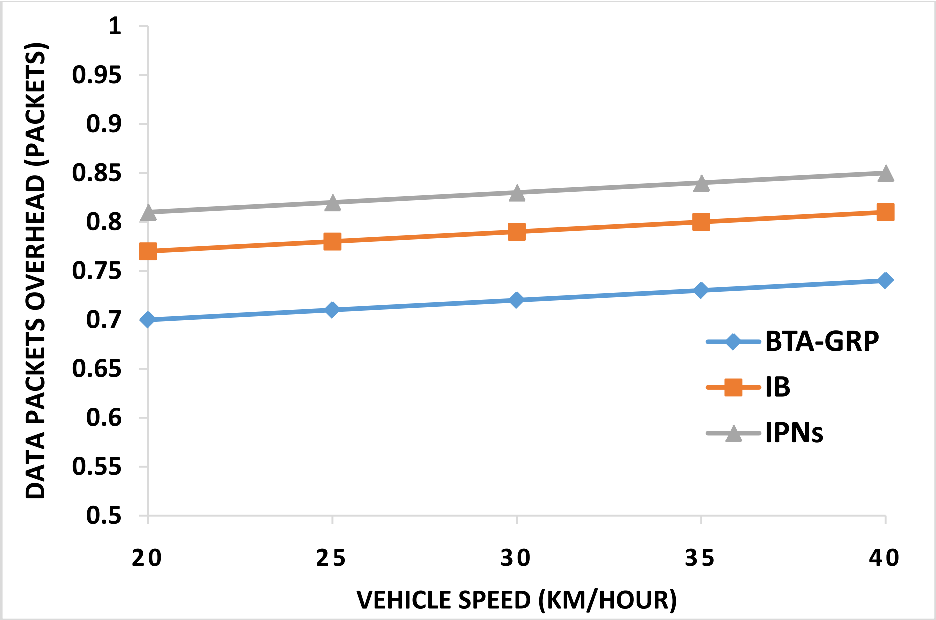

Figure 5.11: Data packets overhead with vehicle speed

The last graph Figure 5.12 shows the data packets overhead trend with more vehicle velocity in urban environment. The BTA-GRP has better results in terms of network overhead compared to IB and IPNs 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 beaconless protocols (IB and BTA-GRP) have less overhead compared to IPNs because their RTS/CTS mechanism in the network.

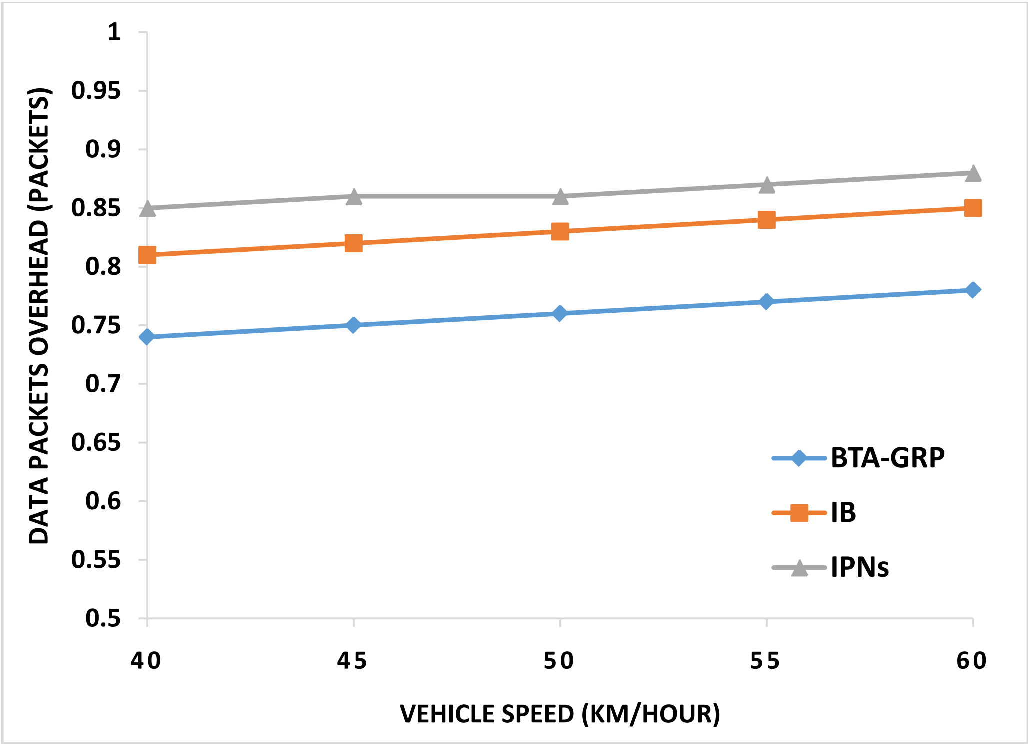

Figure 5.12: Data packets overhead with vehicle speed

After evaluating the proposed protocol BTA-GRP with state of the art existing routing protocols, Table 5.1 presents the difference of results and protocols comparison.

Table 5.1: Results comparison of BTA-GRP, IB and IPNs

Packet Delivery Ratio				**Average Delay**				**Network Overhead**			
No of Sensor Nodes	**BTA-GRP**	**IB**	**IPNs**	**No of Sensor Nodes**	**BTA-GRP**	**IB**	**IPNs**	**No of Sensor Nodes**	**BTA-GRP**	**IB**	**IPNs**
50	0.6	0.59	0.54	50	0.6	0.59	0.6	50	0.7	0.77	0.8
55	0.62	0.6	0.55	55	0.8	0.9	1	55	0.72	0.78	0.83
60	0.63	0.61	0.56	60	1	1.3	1.5	60	0.73	0.79	0.84
65	0.64	0.6	0.58	65	1.3	1.6	1.8	65	0.74	0.8	0.85
70	0.65	0.6	0.59	70	1.5	1.9	2	70	0.76	0.83	0.87
75	0.66	0.61	0.6	75	1.6	2	2.1	75	0.77	0.84	0.88
80	0.67	0.63	0.62	80	1.7	2.1	2.3	80	0.78	0.85	0.89
85	0.68	0.64	0.63	85	1.7	2.3	2.6	85	0.79	0.86	0.9
90	0.7	0.66	0.65	90	1.8	2.4	2.8	90	0.76	0.87	0.91
Vehicle Velocity	**BTA-GRP**	**IB**	**IPNs**	**Vehicle Velocity**	**BTA-GRP**	**IB**	**IPNs**	**Vehicle Velocity**	**BTA-GRP**	**IB**	**IPNs**

20	0.8	0.9	1	20	0.6	0.59	0.6	20	0.7	0.77	0.81
25	1	1.2	1.3	25	0.8	0.9	1	25	0.71	0.78	0.82
30	1.3	1.4	1.6	30	1	1.3	1.5	30	0.72	0.79	0.83
35	1.5	1.6	1.8	35	1.3	1.6	1.8	35	0.73	0.8	0.84
40	1.7	1.8	1.9	40	1.5	1.9	2	40	0.74	0.81	0.85
45	1.9	2	2.3	45	0.6	0.59	0.6	45	0.75	0.82	0.86
50	2	2.3	2.6	50	1.6	2	2.1	50	0.76	0.83	0.86
55	2.2	2.6	2.9	55	1.7	2.1	2.3	55	0.77	0.84	0.87
60	2.5	2.9	3.2	60	1.7	2.3	2.6	60	0.78	0.85	0.88

Table 1 shows the all results of simulations and indicated that BTA-GRP has better results in terms of PDR, network delay and network overhead compared to state of the art protocols.

5.3 Summary

This chapter has presented the comparison of beaconless geographical routing protocol for VANET with one beaconless and one beacon based protocols. The simulation results have shown that in the urban environment beacon less geographical protocols are the best option as they have minimum delay as compared to beacon 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 have 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.
- Improve data throughput in geographical routing protocol.

A critical examination of these limitations, led to the designing of beaconless traffic aware geographical routing protocol.

BTA-GRP has been simulated using NS-2.34 simulator and the performance of the protocol has been compared with existing beaconless and beacon based geographical routing protocol. Simulation results show that BTA-GRP has high data delivery ratio in terms of total number of nodes and nodes speed.

6.2 Scope of Future Work

The research work has been carried out in this thesis, in order 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 also compare other beacon based and beacon less geographical routing protocols with the proposed one.

REFERENCES

[1] M. J. Piran, G. R. Murthy, and G. P. Babu, "Vehicular ad hoc and sensor networks; principles and challenges," *arXiv preprint arXiv:1108.2776,* 2011.

[2] K. N. Qureshi, A. H. Abdullah, and R. Yusof, "Position-based routing protocols of vehicular Ad hoc networks & applicability in typical road situation," *Life Science Journal,* vol. 10, no. 4, pp. 905-913, 2013.

[3] S. M. Bilal, C. J. Bernardos, and C. Guerrero, "Position-based routing in vehicular networks: A survey," *Journal of Network and Computer Applications,* vol. 36, no. 2, pp. 685-697, 2013.

[4] A. Fonseca and T. Vazão, "Applicability of position-based routing for VANET in highways and urban environment," *Journal of Network and Computer Applications,* vol. 36, no. 3, pp. 961-973, 2013.

[5] A. Bazzi and A. Zanella, "Position based routing in crowd sensing vehicular networks," *Ad Hoc Networks,* vol. 36, pp. 409-424, 2016.

[6] B. Karp and H.-T. Kung, "GPSR: Greedy perimeter stateless routing for wireless networks," in *Proceedings of the 6th annual international conference on Mobile computing and networking*, 2000, pp. 243-254: ACM.

[7] L. Liu, Z. Wang, and W.-K. Jehng, "A geographic source routing protocol for traffic sensing in urban environment," in *Automation Science and Engineering, 2008. CASE 2008. IEEE International Conference on*, 2008, pp. 347-352: IEEE.

[8] M. Jerbi, R. Meraihi, S.-M. Senouci, and Y. Ghamri-Doudane, "GyTAR: improved greedy traffic aware routing protocol for vehicular ad hoc networks in city environments," in *Proceedings of the 3rd international workshop on Vehicular ad hoc networks*, 2006, pp. 88-89: ACM.

[9] X. Li, "Traffic-aware geographical routing in vehicle ad hoc networks," in *Future Wireless Networks and Information Systems*: Springer, 2012, pp. 755-759.

[10] K. Z. Ghafoor, J. Lloret, A. S. Sadiq, and M. A. Mohammed, "Improved geographical routing in vehicular ad hoc networks," *Wireless Personal Communications,* vol. 80, no. 2, pp. 785-804, 2015.

[11] C. Chen, Y. Jin, Q. Pei, and N. Zhang, "A connectivity-aware intersection-based routing in VANETs," *EURASIP Journal on Wireless Communications and Networking,* vol. 2014, no. 1, p. 42, 2014.

[12] S. Tsiachris, G. Koltsidas, and F.-N. Pavlidou, "Junction-based geographic routing algorithm for vehicular ad hoc networks," *Wireless personal communications,* vol. 71, no. 2, pp. 955-973, 2013.

[13] S. K. Bhoi and P. M. Khilar, "A road selection based routing protocol for vehicular ad hoc network," *Wireless Personal Communications,* vol. 83, no. 4, pp. 2463-2483, 2015.

[14] C. Zhao, C. Li, L. Zhu, H. Lin, and J. Li, "A vehicle density and load aware routing protocol for VANETs in city scenarios," in *Wireless Communications & Signal Processing (WCSP), 2012 International Conference on*, 2012, pp. 1-6: IEEE.

[15] C. Li, C. Zhao, L. Zhu, H. Lin, and J. Li, "Geographic routing protocol for vehicular ad hoc networks in city scenarios: a proposal and analysis," *International Journal of Communication Systems*, vol. 27, no. 12, pp. 4126-4143, 2014.

[16] S. Parvin, M. A. Sarram, G. Mirjalily, and F. Adibnia, "A survey on void handling techniques for geographic routing in VANET network," *International Journal of Grid & Distributed Computing*, vol. 8, no. 2, pp. 101-114, 2015.

[17] K. Z. Ghafoor, K. Abu Bakar, J. Lloret, R. H. Khokhar, and K. C. Lee, "Intelligent beaconless geographical forwarding for urban vehicular environments," *Wireless networks*, vol. 19, no. 3, pp. 345-362, 2013.

[18] N. Alsharif, S. Céspedes, and X. Shen, "iCAR: Intersection-based connectivity aware routing in vehicular ad hoc networks," in *Communications (ICC), 2013 IEEE International Conference on*, 2013, pp. 1736-1741: IEEE.

[19] N. Alsharif and X. S. Shen, "iCARII: Intersection-based connectivity aware routing in vehicular networks," in *Communications (ICC), 2014 IEEE International Conference on*, 2014, pp. 2731-2735: IEEE.

[20] A. Yadav, Y. Singh, and R. Singh, "Cross layer design for power control and link availability in mobile adhoc networks," *Int. J. Comput. Netw. Commun.(IJCNC)*, vol. 7, no. 3, pp. 127-143, 2015.

[21] Y. Chen, C. Li, X. Han, M. Gao, and L. Zhu, "A reliable beaconless routing protocol for VANETs," in *Computer and Information Technology (CIT), 2014 IEEE International Conference on*, 2014, pp. 94-99: IEEE.

[22] C. Rezende, H. S. Ramos, R. W. Pazzi, A. Boukerche, A. C. Frery, and A. A. Loureiro, "Virtus: A resilient location-aware video unicast scheme for vehicular networks," in *Communications (ICC), 2012 IEEE International Conference on*, 2012, pp. 698-702: IEEE.

[23] J. Shen, C. Wang, A. Castiglione, D. Liu, and C. Esposito, "Greedy Probability-Based Routing Protocol for Incompletely Predictable Vehicular Ad-hoc Network," in *International Conference on Security, Privacy and Anonymity in Computation, Communication and Storage*, 2016, pp. 208-217: Springer.

[24] K. N. Qureshi, A. H. Abdullah, and F. Ullah, "Beaconless Packet Forwarding Approach for Vehicular Urban Environment," *Bulletin of Electrical Engineering and Informatics*, vol. 5, no. 2, pp. 253-262, 2016.

[25] K. N. Qureshi, A. H. Abdullah, J. Lloret, and A. Altameem, "OBPF: Opportunistic Beaconless Packet Forwarding Strategy for Vehicular Ad Hoc Networks," *KSII Transactions on Internet & Information Systems*, vol. 10, no. 5, 2016.

[26] D. K. N. Venkatramana, S. B. Srikantaiah, and J. Moodabidri, "CISRP: connectivity-aware intersection-based shortest path routing protocol for VANETs in urban environments," *IET Networks*, vol. 7, no. 3, pp. 152-161, 2018.

[27] S. Sadhu and T. K. Maiti, "Cellulase production by bacteria: a review," *British Microbiology Research Journal*, vol. 3, no. 3, p. 235, 2013.

[28] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, "Sumo–simulation of urban mobility," in *The Third International Conference on Advances in System Simulation (SIMUL 2011), Barcelona, Spain*, 2011, vol. 42.

[29] J. Alme *et al.*, "The ALICE TPC, a large 3-dimensional tracking device with fast readout for ultra-high multiplicity events," *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 622, no. 1, pp. 316-367, 2010.

[30] K.-c. Lan and C.-M. Chou, "Realistic mobility models for vehicular ad hoc network (VANET) simulations," in *ITS Telecommunications, 2008. ITST 2008. 8th International Conference on*, 2008, pp. 362-366: IEEE.

[31] Y. Chen, S. Y. M. Lee, S. Li, and C.-R. Huang, "Emotion cause detection with linguistic constructions," in *Proceedings of the 23rd International Conference on Computational Linguistics*, 2010, pp. 179-187: Association for Computational Linguistics.

[32] M. Torrent-Moreno, J. Mittag, P. Santi, and H. Hartenstein, "Vehicle-to-vehicle communication: fair transmit power control for safety-critical information," *IEEE Transactions on Vehicular Technology,* vol. 58, no. 7, pp. 3684-3703, 2009.

[33] J. Nzouonta, N. Rajgure, G. Wang, and C. Borcea, "VANET routing on city roads using real-time vehicular traffic information," *IEEE Transactions on Vehicular technology*, vol. 58, no. 7, pp. 3609-3626, 2009.

[34] B. Aubert *et al.*, "Observation of the χ c 2 (2 P) meson in the reaction γ γ→ D D¯ at BABAR," *Physical Review D*, vol. 81, no. 9, p. 092003, 2010.

[35] M. Jerbi, S.-M. Senouci, R. Meraihi, and Y. Ghamri-Doudane, "An improved vehicular ad hoc routing protocol for city environments," in *Communications, 2007. ICC'07. IEEE International Conference on*, 2007, pp. 3972-3979: IEEE.