POSITION BASED ROUTING IN VEHICULAR AD HOC NETWORKS

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Submitted for partial fulfillment of the requirements of the degree of MSCS to the Faculty of Engineering and Computer Science

NATIONAL UNIVERSITY OF MODERN LANGUAGES, ISLAMABAD

JANUARY 2019

NATIONAL UNIVERSITY OF MODERN LANGUAGES

FACULTY OF ENGINEERING AND COMPUTER SCIENCE

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THESIS TITLE: POSITION BASED ROUTING IN VEHICULAR AD HOC NETWORK

Submitted By: Samiya Shaheen

Registration #: MSCS-S-16-08

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CANDIDATE DECLARATION

I declare that this thesis entitled "*Position Based Routing in Vehicular Adhoc Networks*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Internet of Things (IoT) involves a large number of smart gadgets along with sensing capabilities to exchange the information across multiple networks. IoT enabled Vehicular Ad-hoc Network (I-VANET) comprises of a large number of vehicles that are connected with neighboring vehicles to exchange data with central repositories. In this scenario, network has a dynamic nature due to high mobility of vehicles or nodes in a smart city environment. Present routing protocols do not meet the challenging requirements for this scenario and position based routing protocols are considered to be a suitable solution. Position based routing protocols also encounter problems in city environment due to obstacles like buildings, trees that block line of sight communication among vehicles within a small area.

In this research work, we have proposed a Dynamic Position Based Routing (D-PBR) scheme. It considers the vehicle's position coordinates along with direction of movement parameters to decide about the next node towards the destination. In this scenario, we have considered the road junctions where different vehicles can join or leave to bring a change in the neighboring vehicle set. We have presented a Dynamic Next-hop Identification (DNI) algorithm that selects the best suitable next-hop vehicle available at the junction to forward the packet towards the destination vehicle. It calculates the distance and direction of neighboring nodes and then identifies the vehicles that can transmit the message in the direction of destination vehicle. It also maintains array-lists to store expected next-hop vehicles and then select the one vehicle. It considers least distance and more accurate direction as per current position of the vehicle that contains the packet for forwarding to the destination vehicle.

The work has been validated by simulations using NS 2.35 with TCL scripts and C code along with AWK scripts to extract results from trace files. Results show on the improvement over the existing RIDE protocol regarding end-to-end delay, residual energy, mean hop count, average throughput and average number of vehicles. The average number of vehicles for different densities decreases by 42.86% and mean hop count used for message exchange is decreased by 60% as compared to RIDE.

Keywords: Vehiclur Ad-hoc Networks (VANETs), Position based Routing, Next-Hop Identification, Road Side Unit, Junctions

I dedicate my thesis work to my parents and my teachers throughout my education career who have not only loved me unconditionally but whose good examples have taught me to work hard for the things that I aspire to achieve.

ACKNOWLEGEMENT

First of all, I wish to express my gratitude and deep appreciation to Almighty Allah, who made this study possible and successful. This study would not be accomplished unless the honest espousal that was extended from several sources for which I would like to express my sincere thankfulness and gratitude. Yet, there were significant contributors for my attained success and I cannot forget their input, especially my research supervisors, Dr. Muhammad Akbar and Dr. Ata Ullah, who did not leave any stone unturned to guide me during my research journey.

I shall also acknowledge the extended assistance from the administrations of Department of Computer Sciences who supported me all through my research experience and simplified the challenges I faced. For all whom I did not mention but I shall not neglect their significant contribution, thanks for everything.

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LIST OF ABBREVIATIONS

ACAR	Adaptive Connectivity Aware Routing
A-STAR	Anchor-based Street and Traffic Aware Routing
AODV	Ad Hoc On- Demand Distance Vector
CAR	Connectivity Aware Routing
DTN	Delay Tolerant Network
DBRP	Delay Bound Routing Protocol
D-PBR	Dynamic Position Based Routing
GPSR	Greedy Perimeter Stateless Routing
GeOpps	Geographical Opportunistic
GPCR	Greedy Perimeter Coordinator Routing
HSVNs	Hybrid Sensor and Vehicular Networks
IDTAR	Intersection-Based Distance and Traffic-Aware Routing
IGRP	Intersection-based Geographical Routing Protocol
IGR	Improved Greedy Routing
MANETs	Mobile Ad Hoc networks
OBUs	On Board Sensor Units
PDVR	Position Based Directional Vehicular Routing
PDGR	Predictive Directional Greedy Routing
PDR	Packet Drop Ratio
PBR	Position Based Routing
RIDE	Routing In Delay Tolerant Network
R2V	Roadside-To-Vehicle
RSU	Road Side Unit
VDTN	Vehicular Delay Tolerant Network
VCC	Vehicular Cloud Computing
VFC	Vehicular Fog Computing
VADD	Vehicle-Assisted Data Delivery
VANET	Vehicular Ad-hoc Networks
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
V2R	Vehicle-to-Roadside

CHAPTER 1

INTRODUCTION

1.1 Overview

In this chapter, VANETs are explored along with application scenarios and three types of architectures including cellular, ad-hoc and hybrid. After that, routing is defined for existing proactive, reactive and hybrid routing that are not suitable for VANET because VANET has extensive movability and rapid topology variations. Next, the position based routing is explored which is favorable for VANET. In the last sections, problem statement and thesis organization are stated.

1.2 Vehicular Ad-hoc Networks

A VANETs consist of vehicles that can coordinate with each other or with the related to the devices that are located on side of roads to achieve better transportation environment. These devices are called road side units (RSUs). It is applicable in write example application scenarios Right now many vehicles are utilized by many people. Mostly people have their own vehicles like cars, trucks, buses and many more for any purpose but the most concerning issue in regards to expended utilization of personal transport is the main cause in increasing number of death rate because of accidents at the roads; the cost and associated hazards are considered as major problem that is stood up to by the present society. Vehicles can remotely communicate with each other using a Dedicated Short Range Communication (DSRC). DSRC is basically IEEE 802.11a standard for low overhead operation which has been changed to IEEE 802.11p standard, which defines Wireless Communication Standard used for safety and for other applications in VANET. According to [1] vehicles can directly communicate with each other and this is called vehicle-to-vehicle (V2V) communication. Vehicles also communicate as vehicle to road side unit (RSU) and other devices that are connected along roads as shown in fig 1.1 it is called vehicle-to-infrastructure (V2I) communication.

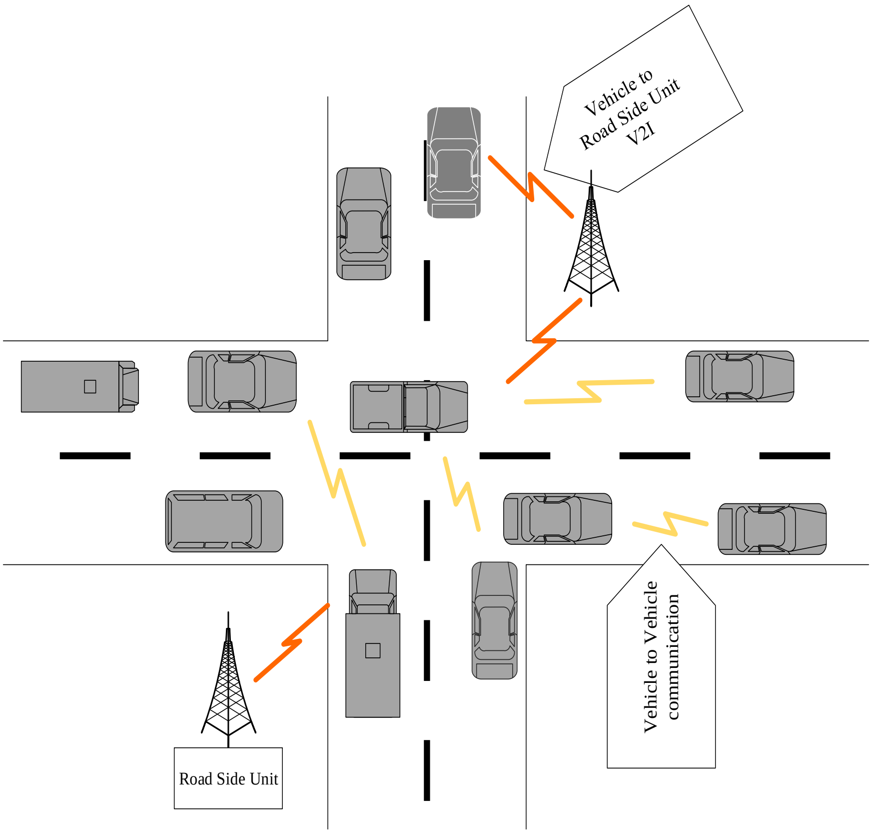


Fig. 1.1. VANET Architecture and application Scenarios

VANETs communication helps to reduce accidents. Safety messages are forwarded to inform other cars about traffic jam, information about any danger and post-mishap examination. Some messages are also shared for non-safety purpose such as information about passengers. The aim of exchange these information is to give security to human lives and to inform drivers about expected dangers. This field attracts many researches to work on different applications of VANET, protocols and simulation tools. A few challenges minimize packet drop ratio, reduce end-to-end delay, maximize throughput and reduce communication overhead are confronting by the researchers. These issues are tried to cover by many papers. Some researchers focus on routing protocols of VANET, while other researcher tried to discuss and overcame the issues behind routing protocols in VANET.

Routing is the way toward to discover optimal (shortest) path from one node to another node and then exchanging messages. Routing protocols ensure that information is exchanges effectively. During the transmission of information if route fails a recovery mechanism is executed to retransmit the data. Routing can be arranged into three types; I) Proactive routing: It keeps up a routing table for every node to keep data of each other hub in a system. Because of high mobility each node changes its position so tables are refreshed continuously as per change in topology of the system Reactive routing: It is on-request routing, it decreases the overhead of proactive routing and saves bandwidth of the system. It keeps a record of paths that are at present being used for the communication between nodes. Hybrid routing: this kind of routing gets after combining the proactive routing and reactive routing protocol. In VANET, delayed communication causes more chances for packet drop which is critical especially in road crisis and emergency scenarios. System topology in the VANETs is continuously changing, that results in extensive computation for route maintenance. It can result in reduced throughput, increased delay, and latency in packet delivery. Existing routing methods depend on topology that are not appropriate in VANET situation. In addition, the presence of hurdles like buildings and trees in the between the vehicles in a city environment is also main source of path failure [2].

Position based Routing (PBR) involves the coordinates of the vehicles to decide about the routing path identifications between source and destination. PR is a convenient scheme for routing in VANET because for the communication cars or nodes get information of the position of other cars in network from On board sensor units (OBUs) and also get the layout of road from an onboard digital map. Each vehicle has its own OBU and onboard digital map. Mostly position based routing protocols are based on greedy approach [2]. For PBR protocols, the destination location is required that is calculated by using location services, such as Grid Location Service (GLS). The packet is loaded with location address so the overhead is reduces because the nodes that retransmit the data packet do not need to use the location service again. The PBR protocol functionality may be divide in three different steps: path selection, forwarding and recovery. In PR decision of forwarding node is made by considering the packet's destination location. PR also considers the location of one hop neighboring node of source node. Destination node address is saved in the header of packet by the source node. Location of one hop neighboring nodes are found by sending beacon messages from source periodically to avoid congestion. Source node has its own radio range and vehicles that are in this range are considered as neighbor nodes. PR protocols do not keep the routing table like other routing techniques such as proactive and reactive routing. Path discover on the base of geographical location of nodes and there is no requirement of routing tables [3].

Literature contains a number of PBR schemes that are mostly greedy based approaches. Initially, some of the probabilistic, robust and promising schemes for highly dynamic environment were developed but such schemes were causing communication overhead and delaying in path finding due to fast speed and dynamic topology changes. There are a numbers of open problems in inter-vehicle communication when topology based routing protocols are used. It has been observed than position based routing discussed in literature review, not even a single protocol satisfies all needs for the routing in a VANET. In literature review different protocols such as, DTN, Non-DTN, DGR, PDGR, MLP-HSVNs and DBPR are discussed but all these do not fulfill the requirements of VANETs. It is difficult to model mobility and so it becomes important to do more research to model mobility and also to help the users in routing. For this purpose, we need some better analytical tools and better simulation tools. In this regard, the greedy approaches are considered suitable for such conditions but still these schemes lack in providing a reliable position based routing scheme that can also be applicable in Fog Environment.

1.3 VANET Architecture and Applications

In this section, we have discussed VANET architecture, applications and challenges. VANET has different characteristics such as dynamic network topology, boundless network size, frequently disconnected network, unlimited battery power and storage, road pattern restrictions and time sensitive data exchange. Some challenges that are caused by these characteristics such as network management, influence on environment and MAC design. Through wireless network current information of traffic condition is delivered among V2V communication and V2I communication. In real life, position of vehicles (nodes) is dynamic and there is no restriction on users to enter in the network or leave the network. The network topology is totally dynamic.

Vehicles (nodes) travel at a very high speed and physical structure is not fixed so, links between nodes connect and disconnect repeatedly. Due to this connectivity and disconnection of communication between vehicles is a big challenge. It is important for the drivers to keep information about the current traffic condition in its route to avoid road accidents and any other miscommunication. VANET provides linkage between all vehicles and road side units. Vehicles and RSUs connect to each other for communication and for this purpose VANET has specific architecture according to the type of communication. VANET face different challenges due to movement of vehicles is higher. VANET has different applications to help of passengers, drivers, and pedestrians regarding road safety, traffic efficiency and infotainment [4]. In this section we will discuss three categories of VANET architectures: cellular/WLAN, Ad hoc and Hybrid architectures as shown in figure 1.2. Differences between these three architectures are also highlighted.

1.3.1 Cellular/ WLAN

VANET contains both cellular and WLAN to make a network. It is called Pure cellular/WLAN infrastructure. The infrastructure consists of a cellular gateway or a WLAN/WIMAX access point that are fixed on road intersections to aggregate traffic information for routing data over the network. VANET comprises of both cellular network and WLAN to form a network. On the road side stationery or fixed gateways also provide connection between vehicles [5].

1.3.2 Ad hoc Architecture

Ad hoc network is a temporary network, it does not have a fixed topology. Ad hoc network has many characteristics. It is distributed, temporary, self-configured, and multi-hop network. There is no centralized control, each node can change it position and nodes do not rely on the existing network infrastructure. In network every node is capable to store, collect and forward the packet. Due to high mobility, network topology of ad hoc network is not fixed. Route maintenance is required if route is broken. This type of network has many limitations such as battery consumption, less bandwidth and limited channel capacity.

1.3.3 Hybrid Architecture

Hybrid architecture provides good coverage but provides broken transition when communicating with different wireless networks. In a hybrid architecture, for communication different access points are available like cellular gateways. Both architectures including cellular/WLAN node communicate with these infrastructures and ad-hoc architecture where nodes can communicate directly and no infrastructure is involved. Combination of both architectures is the best solution for a VANET [6].

In VANET vehicles communicate with each other using methods of communication. There are different methods of communication that are V2V, R2V and V2R. In V2V network vehicles connect to each other without relying on pre-established infrastructure. No need of any infrastructure because of high movement of nodes. The applications for V2V network are safety, security and dissemination applications. For V2V communication ad hoc architecture is needed. In V21 vehicles communicate with roadside infrastructure to get the information of traffic and other vehicles. Information and data collecting applications are part of this communication [7]. In V2R communication vehicles communicate to the road side units. RSUs provide information of surroundings like ATMs, banks, hotel parking areas and buildings that are in the range of RSUs. The information is stored in the database of RSUs and database is updated on regular bases by internet [8]. R2V communication is reverse process of V2R communication. In R2V communication RSU send information of other vehicles that are out of the range in the network. Ad hoc architecture is required for V2V communication. Similarly, for V2R and R2V communication cellular/WLAN architecture is suitable. In hybrid architecture V2V and R2V communication takes place. RSUs communicate with gateway and establish a connection between vehicles and internet server as shown in figure 1.2.

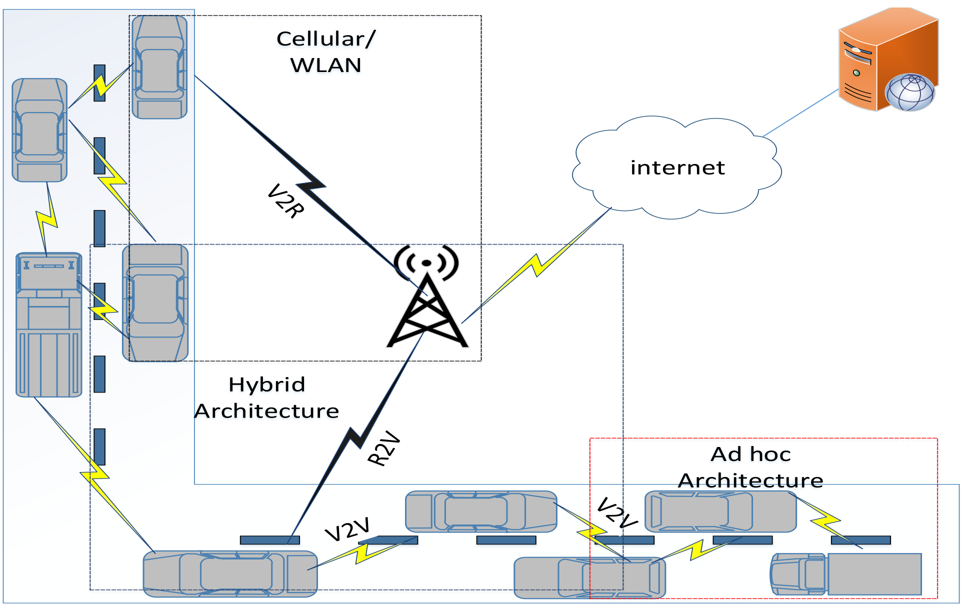


Fig. 1.2 VANET Architecture and its Types

VANET includes vehicles, RSUs, OBU, AU and sensors. Sensors can be OBU, AU or ECU. With the help of these sensors vehicles communicate to each other. Vehicles are equipped with dedicated short-range communications radio modules as well as Global Positioning System (GPS), by which vehicles can determine their geographical location. Vehicles are preloaded with digital maps, which provide street maps and traffic statistics at different times of the day in the area. Road side units have antenna, processors and read write memory. These units contain sensors that sense the traffic information from OBUs and communicate with gateway to make a connection between sensors and the internet. These units are mostly installed in high density vehicle areas, near gas stations, on junctions and on road sides. On Board Units are sensors that collect information and process it. These sensors send and receive packets from other vehicles and RSUs. Global positioning system (GPS) is also part of OBU. Other components of vehicles communicate with OBU to aggregate the information of vehicular statistics. Application Units are used to handle applications that are supported by OBU. AUs are mounted in the vehicles. RSU can also connect to the Internet or to another server which allows AU's from multiple vehicles to connect to the Internet. These all are hardware devices fixed on a vehicle [4]. Electronic control units control the engine, mirror and specifically perform entertainment of the unit. It also exchanges information with other vehicles [9].

There are different applications of VANET that are safety applications, traffic efficiency and management applications, and infotainment applications. In safety applications, the environment around vehicles is observed to ensure safety of users from the road accidents. These applications inform other users about the road condition, and curves. Information is stored in RSUs where any vehicle can get information from these RSUs whenever and wherever needed to avoid from road accidents, traffic jam issues, weather conditions and congestion. Vehicles transfer safety messages to other vehicles to warn them about occurrence of emergency events. If a collision occurs the information can be circulated to notify other vehicles about the accident and other vehicles can timely decide to change the route.

Traffic efficiency and management applications are also called convenience applications that enhance the comfort and ease for drivers. These applications facilitate the drivers to pre-plan the route in case of any emergency like traffic congestion etc. and also provide the facility to get information about parking areas whether a free spot is available or not [10]. Infotainment applications are non-safety applications that are a combination of informative and entertainment applications. These applications provide entertainment to the drivers through web access, drivers can access internet through RSUs. Drivers travel to different places but they may not have all the information of that area. Information of new area can be downloaded as digital maps for travel guidance. These applications also entertain the users without the help of internet, when a vehicles enters in an area then these application make announcement of petrol pumps, restaurants etc. for the help and guidance of new drivers [11].

1.4 Problem Statement

The main problem in position based routing schemes in that the direction of movement of the intermediate vehicle is not considered. It can cause a short path to become a long path if a vehicle is moving in the opposite direction. The main problem in these schemes occurs a data packet is transferred to the vehicle whose current position is near to the target vehicle but it is moving in the opposite direction. In this case data packet may not reach the destination. The previous schemes did not consider the parked vehicles [12].

1.5 Research Objectives

This research investigates the performance of PBR protocols in VANETs. The main objectives of this research can be categorized into following aspects:

1. To find the optimal path towards the destination vehicle by considering the direction and speed of vehicles.
2. To reduce the delay we considered the connectivity awareness for next hop identification with less delay.

1.6 Thesis Organization

Rest of thesis is organized as follows; Chapter 2 explains the literature about the DTN, non-DTN, directional greedy, PDGR and linear regression based PBR protocols present for the vehicular ad hoc network. Chapter 3 explains the methodology of our research work. We proposed a new architecture for PBR that overcomes the weaknesses of VCC and also helpful to share the load of cloud computing. Chapter 4 introduces our proposed routing algorithm for VANET which is scalable for VANET environment. The proposed algorithm manages the information of nodes of network. This algorithm consider three steps, direction of destination node, road junctions and parked vehicles. Chapter 5 illustrates the results and analysis along with description of simulation environment. Finally, Chapter 6 concludes our work and includes some possible future work area.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, a detailed literature review of existing schemes is given along with a comprehensive taxonomy of PBR protocols. The schemes described are greedy forwarding, improved greedy forwarding, directional greedy, predictive directional greedy forwarding, linear programing and linear regression. More schemes are discussed under these categories. In next section, position based routing is explored in city environment. Detailed discussion of PBR schemes is also presented. After that, comparative discussion of PBR schemes is presented in a tabular format. A number of challenges in VANETs are also presented.

2.2 Position based Routing in VANET

The main purpose of routing protocols is to find the optimal(shortest) path between network vehicles (nodes) with low overhead. Routing protocols are categorized according to the area and application [12] [13] [14]. If information is incomplete like information of traffic signals, road condition, and location of neighbor vehicles then chances of accident or any emergency are more [15]. Finding and maintaining routes in VANET is very difficult because of its dynamic nature of topology. In 2007, various traditional topology-based routing protocols were proposed but these are not suitable for vehicular network. In city environment various obstacles like trees and buildings can affect communication in high mobility vehicular network that restrict the applicability of topology-based routing protocols. In this environment, strong and secure routing system is critical demand of VANETs [16]. It also requires the optimization for energy consumption issues to improve the power utilization and reduce overheads. The related schemes are explored in [17]. In VANET, position of neighboring vehicles must be known for decide the path to send data from one vehicle to another.

Position based routing contains the geographic information of nodes. PBR is also known as “Geographic routing” because geographic information is required in this routing. Protocols that are used in position based routing use geographic information of nodes to identify the destination nodes. After that route is determined then send message or transfer data. PBR protocols have been proposed to deal with dynamic topology of VANETs, these protocols are based on geographic information. Each node has information of position of neighbor nodes to forward the data packet. A node makes decision to forward a packet on the basis of the location of itself, its next neighboring node and the location or position of the destination node. Current VANET schemes use transmitted nodes to send messages or data packets to destination. Mostly the dis-connectivity occurs because of some other specifications of VANETs such as high movement of vehicles that are constrained by roads and traffic lights that have greatly affected vehicle movement. Due to frequent disconnection of vehicles connectivity chance of local maximum may increase. Because of these problems, position based routing protocols are more suitable and useful for VANET than existing routing protocols designed for MANETs [18]. There are many position-based routing protocols proposed for VANETs. These protocols are described in this section. In position based routing, the vehicles connect with the nearest neighboring vehicles for forwarding the data packet to the destination. If there are no vehicles near the sender then it send packet to the nearest RSU. The RSU send that packet to its nearest vehicle as shown in figure 2.1.

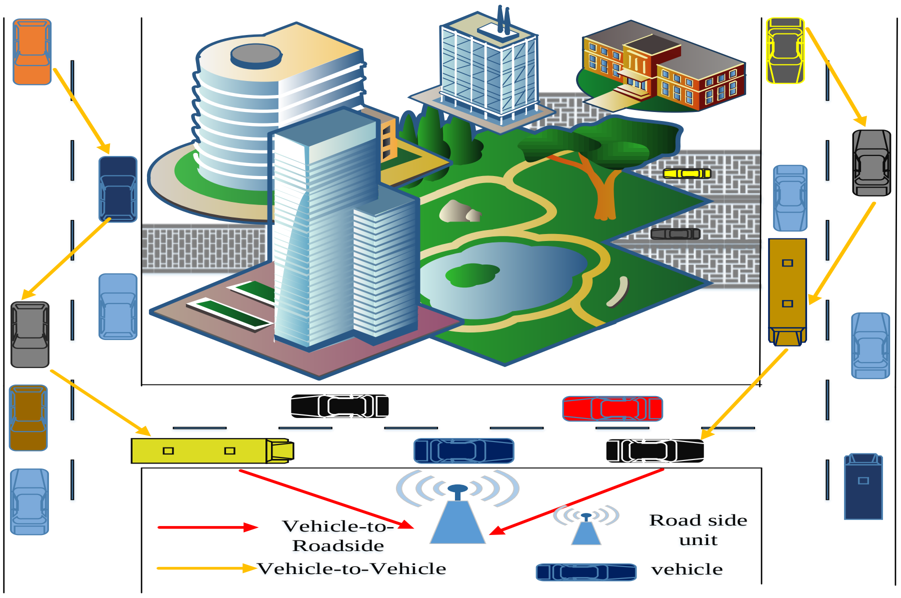


Fig. 2.1. Position Based Routing in a City Environment

Yellow arrows indicate V2V communication and red arrows indicate V2R communication. Vehicle find shortest path to send data packet. All vehicles have the information of other vehicles that are part of the network. In city environment vehicles cannot directly communicate to each other due to hurdles and obstacles. Position based routing helps in the case for establish a connection among vehicles. Vehicles get information of position of each vehicle and send message.

2.3 Overview of PBR

In this section, we have explored a number of PBR based schemes. We have discussed greedy approaches where message is transmitted to the nearest nodes towards destination at a particular location. Each node has information of its neighboring nodes to forward the data. These schemes also include improved greedy scheme where node looks up its neighbor table to check the current position of neighbor nodes and forwards message to the closest node towards destination. In direction based greedy schemes, only those nodes are considered which are moving towards destination and get nearer to the destination or its nearby nodes [19]. In predictive directional greedy forwarding schemes, source node keeps the information of two-hop neighboring nodes and then calculates the shortest distance for a vehicle that contains the destination in one-hop neighbors [20]. Moreover, linear programming and linear regression approaches are also discussed. Greedy approaches are further subdivided into Delay Tolerant Network (DTN), non-Delay Tolerant Network (non-DTN) and Hybrid as shown in figure 2.2. PBR protocols of Non-DTN category are not suitable for irregular connections of network and are applicable to high density traffic networks. Only DTN protocols are suitable for irregular network. Hybrid PBR protocols are a combination of Non-DTN and DTN routing protocols to achieve incomplete connections.

2.3.1 DTN based Routing Protocols

In these protocols, vehicles are communicated to each other for forwarding packets. The DTN protocols have limited transmission range and causes large delay due to the fact that distant vehicles are not connected with all vehicles in the region. Various DTN based protocols are described in this section.

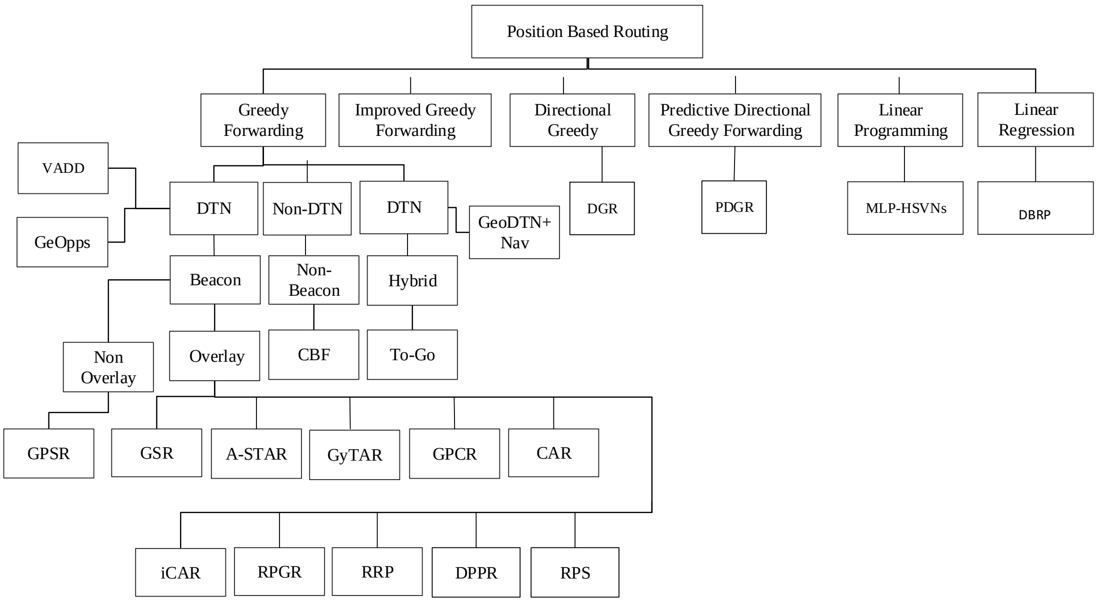


Fig. 2.2. Taxonomy of PBR Protocols

2.3.1.1 Vehicle-Assisted Data Delivery (VADD) Protocols:

In a VADD a carry and forward mechanism is used along with predictable vehicle mobility where source node decides to forward a packet at a junction. When packet reaches the junction, then the current vehicle decides for the next vehicle to forward the packet. It may cause a little delay in delivering the packet. In this scenario, a link road to junction is selected for forwarding the packet. To calculate the packet delivery delay, the parameters including density of vehicles on the road, vehicle speed and direction and distance of road are used. Linear system equations are used to solve the minimum delay. VADD protocols are further categorized as i) Location First Probe (L-VADD) protocol chooses the new vehicle that is very near to decide forwarding path even if that node is moving far from that path; ii) Direction First Probe (D-VADD) protocol selects the vehicle that is moving towards the decided path to forward, although that node may not be the closest to the selected forwarding path; iii) Multi-Path Direction First Probe (MD-VADD) protocol chooses several nodes that are moving towards the path that is select to forwarding and not even lose that node which provide less time to the destination node; iv) Hybrid Probe H-VADD formed by combining the L-VADD and D-VADD. H-VADD performs better as compared to GPSR and other variants of VADD [21].

2.3.1.2 Geographical Opportunistic (GeOpps) Routing Protocols:

In this scenario, source vehicle selects a set of nodes that are moving near to the destination node from the suggested route. The protocol computes the minimum distance from the destination vehicle to nearest point (NP) of vehicle's track. It also calculates the arrival time of message packet to the destination. But if there is any other vehicle that takes less time for delivering packet to the destination then packet is given to that vehicle and this procedure will stop when the packet is reaches the at destination. It needs position and information of direction to be made known to the network, therefore, secrecy might be breeched if intermediaries are compromised [22].

2.3.2 Beacon based Non-Overlay Routing Protocols:

Every node maintains information of position for itself and its nearby nodes in the way to the destination. Qabajeh et al. have proposed to transmit beacon or control messages to the direct neighbors to find position parameters. Figure 2.3 Illustrates the HELLO control message for neighboring nodes [23].

ID	POSITION	SPEED	CURRENT TIME	DIRECTION

Fig. 2.3. HELLO message Format

The non-DTN type protocols use greedy approach and do not consider the periodic connectivity of nodes by using the geographic forwarding approach [24]. They suffer from local maximum problem that occurs when no vehicle is present in neighbor of source node that is close to destination. To solve this issue a recovery scheme used. Many recovery schemes have been introduced in literature. In Overlay based protocols, recovery schemes are used to resolve the local optimal problem [24].

2.3.2.1 Greedy Perimeter Stateless Routing (GPSR):

Brad Kard has proposed a Greedy Perimeter stateless routing (GPSR) scheme. It uses greedy forwarding and perimeter forwarding. Source node transmits the message to the destination by using greedy strategy and sends packet to the nearest node that is close to the destination as illustrated in figure 2.4. Here x represents a source node, y as intermediary neighboring nodes that are selected recurrently and this process will stop when the packet meets its destination D [25].

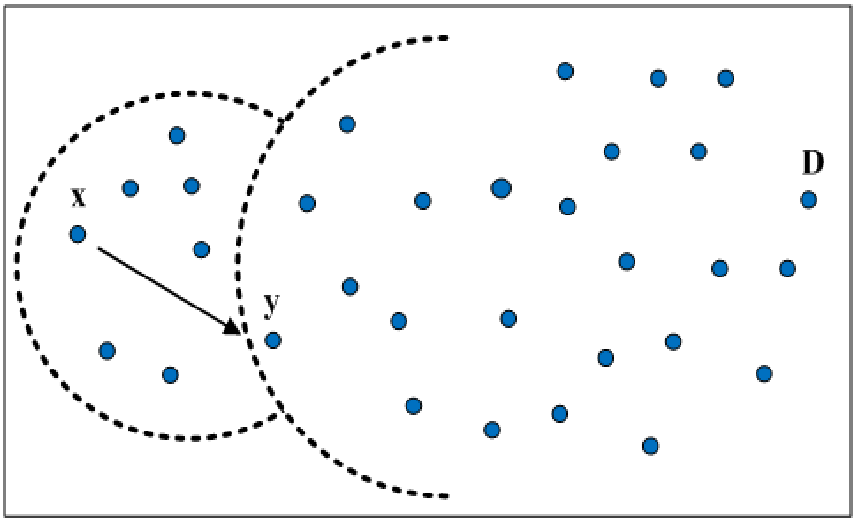


Fig. 2.4. Packet forwarding using greedy approach

In this scenario, the local maximum problem is resolved by using perimeter mode for forwarding. In this strategy numbers of hops are increasing and delay time is also increasing so it may cause unreliability of system. The protocol performs better in less obstacles scenarios [23]. Figure 2.5 illustrates the local maximum problem using where source node *x* has no node within its communication radius. It explores that there is no neighboring node towards the destination D. Nodes *w* and *y* are near to outer boundary but are out of communication range of *x*. In this scenario, the Right Hand Rule based greedy perimeter technique is used to resolve the local maximum problem [25]. In GPSR routing protocol, nodes process data in such a way that it is sent efficiently with less processing and computations. High mobility is a big issue in VANET so when different vehicles move with different speeds and data transmitted to the same node by multiple vehicles at the same time then network congestion occurs.

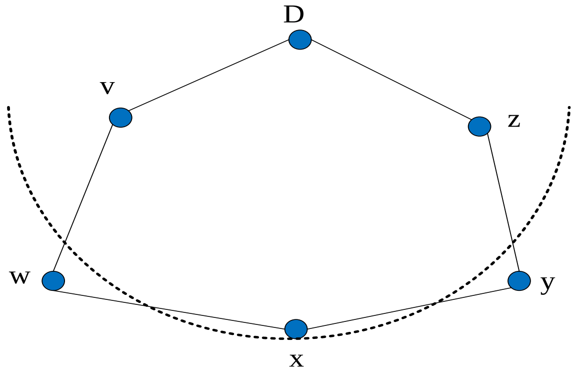


Fig. 2.5. Greedy forwarding failure [25]

It increases the count of data packets in node buffers and approaches the interface queue limits near to threshold values for packet drop. It also rises the transmission delay to reach the destination. E-GPSR routing strategy is applied to GPSR routing protocol which is based on the size of buffer to overcome this problem, by considering available size of node buffers in addition to position and routing parameters [26]. I-GPSR routing protocol is improved version of GPSR based on the orientation and speed of a vehicle. Its working is same as GPSR routing protocol but difference is that it sends messages to a vehicle which has high speed and going to towards the direction in which the receiver is moving. The four parameters that are packet delivery ratio, throughput, time delay and network load are tested on a same city by using these three different protocols that are GPSR, I-GPSR and E-GPSR. The city map is made in sumo and these parameters are tested on NS-2 simulator. I-GPSR shows better results than GPSR and E-GPSR. Packet delivery ratio can be got as *Received_Packets_count / Sent_Packets_Count.* Delay can be calculated as Delay = *Σ (Arrive_time – Sent_time) / Total_Messages_sent*. Throughput is calculated as *(Packet_count ∗ Size_of_Packet) / Total_Time*. Amount of data carried by a network is calculated as *Routing_packet / receive_packet* [26].

2.3.3 Beacon based Overlay Routing Protocols:

These protocols are executed on the nominated set of nodes that are overlaid on an existing network. These protocols involve the junctions where vehicles can change their directions to join new group of vehicles by leaving from existing neighboring vehicles [24].

2.3.3.1 Geographic Source Routing (GSR)

Ant´onio et al. [27], explored DSR that is Geographic Source Routing (GSR) scheme [28]. DSR uses Dijikstra's algorithm to use in city environment. GSR uses a map and a location based address scheme for packet delivery to the destination. All the nodes on this shortest path are included in the header of the packet. Each node transmits beacon and all nodes in the region build neighbor table. A neighbor is selected by receiving node according to whose progress is highest to the next hop. After arriving at the next hop, that hop is detected from the packet header and the location of the next hop is used as a new destination. In real time vehicular environment, GSR shows the advantages of map based approach. GSR achieve better results than AODV and GPSR in terms of PDR and delay. But the packets are directly discarded when it faces a local maximum problem.

2.3.3.2 Anchor-based Street and Traffic Aware Routing (A-STAR):

Seet et. al. have presented an *"Anchor-based Street and Traffic Aware Routing (A-STAR)"* for city environment [29]. The scheme uses the vehicular traffic data for city buses to analyze end-to-end links. It guarantees the high packet delivery in a highly dense area (city environment). The A-STAR uses a different approach to calculate the full path to forward data. In A-STAR Dijikstra algorithm is used to calculate the road path called anchor path. The number of bus lines pass by each road are considered for path. Road is marked as "out-of-service" if local maximum problem arises then it recalculates the road path from current node to the destination. Authors did not discuss about use of location service. It eliminates the disadvantages of GSR [28]by considering the traffic of vehicles on the streets [49]. A-STAR performs much better than GSR and GPSR in city environment because of its traffic awareness approach and a new recovery scheme. Bus lines are considered but due to many vehicles on the street, the road traffic density is not considered. Mostly the traffic of network is moved on the way to main streets (number of bus lines), which makes bandwidth overcrowding. Secondary streets are infrequently selected even these streets offer better connectivity and may provide optimum path [27].

Greedy Perimeter Coordinator Routing (GPCR) scheme improves the trustworthiness of GPSR with VANET. Basically GPCR works like GPSR, but the only difference is that GPCR chooses relay node by analyzing the knowledge about the road condition. GPCR considers junction based routing rather than selecting single node and considering its position. In GPCR, the vehicle at a junction forwards packet by analyzing traffic density on the adjacent node and connectivity of that node to the destination. If traffic density is low and connection is obviously week between nodes and destination so latency can increase due to local maximum problem. GPCR considers centered vehicles in junction as a special vehicles called coordinators to solve the hurdle problems on the junction. If density of node is low then transmission delay increases due to less connectivity [30].

2.3.3.3 Improved Greedy Traffic Aware Routing (GyTAR):

An *"Improved Greedy Traffic Aware Routing (GyTAR)"* protocol is applicable for city environment. Wireless routers are fixed on road junctions to increase connectivity of the nodes. When source node forwards the packet no path is constructed for packet forwarding. The fixed wireless router calculates the distance score towards different directions as given in equation 2.1. It helps in the selection of neighboring vehicle and next junction towards destination [31].

$$score(J) = \alpha * T_j + \beta * D_j \qquad (2.1)$$

Where,

α and β are weighted scores

T_j is traffic density

D_j is curve metric distance.

2.3.3.4 Intersection-Based Distance and Traffic-Aware Routing Protocol (IDTAR)

Abdelmuttlib Ibrahim Abdalla Ahmed et al. proposed "Introduced Intersection-Based Distance and Traffic-Aware Routing Protocol (IDTAR)" which is applicable for smart cities [32]. IDTAR has provided improved results as compared to GSR, GyTAR, and A-STAR. IDTAR has two main modules i) forwarding is intersection based, selection of suitable intersection to pass data packet to the destination, ii) greedy forwarding is used between two intersection points. To select the optimal intersection IDTAR considers the vehicle density and distance of intersection and destination. Then chooses intermediate intersection with these two factors, that is, density and distance. IDTAR selects intermediate intersection dynamically. After selection of intermediate intersection greedy forwarding is involved for forwarding packet between intersections. Recovery strategy is used by IDTAR to avoid local maximum problem is Re_compute-anchor-path. IDTAR gives 7.9% higher PDR than GSR, 3.8% higher PDR than GyTAR and 3.9% higher PDR than A-STAR.

2.3.3.5 Connectivity-Aware Routing (CAR):

Protocol does not use the location service to find the destination route as per author's claim [33]. Rather than depending only on the information of road condition, CAR familiarizes itself to the present condition of road to find a path with enough connectivity, to achieve less delay. For maintains communication it requires intermediaries and refines the path on the go. This protocol provides better data delivery rate and reduces delays but it causes an overhead during path discovery [33].

2.3.3.6 Intersection-based CAR (ICAR):

An intersection-based CAR (ICAR) has been proposed for infotainment and interactive applications where the road connectivity is estimated based on the vehicle position. It uses minimum link lifetime for road to manage utilization of the region and loads next region details as per mobility. Therefore, continuous position monitoring is essential. ICAR is compared with other routing schemes but not compared with CAR to show better comparison [34].

2.3.3.7 Adaptive Connectivity Aware Routing Protocol (ACAR)

An Adaptive Connectivity Aware Routing Protocol (ACAR) for Vehicular Ad Hoc Networks is proposed by Qing Yang et al [35]. In this protocol transmission quality for each road segment is calculated. In many routing protocols issues are still exist like due to high mobility of vehicles topology is not fixed with chances of dis-connectivity, poor link quality, vehicles density and hurdles in city environment etc. are encountered. To overcome these problems ACAR plays a vital role in VANETs. The advantages of ACAR are 1) adaptive route selection optimal path is calculated by using best quality link for transmitting the data. The algorithm chooses the next hop that reduces the rate of error in packet on route. 2) on-the-fly density collection, by this procedure the information of density of vehicle is calculated that is used by the adaptive route selection algorithm. 3) next hop selection, packet is forwarded through different hops in a road segment. Next hop is selected by the matrices that reduce the packet error rate (PER) of full path. For instance PER of node A to B is calculated as given in equation 2.2.

$$PER_{AB} = 1 - \frac{1}{ETX_{AB}}. \qquad (2.2)$$

Where ETX_{AB} is expected transmission count from node A to B.

2.3.3.8 Reliable Routing Protocol (RRP)

Reliable routing protocol (RRP) classifies more unfailing routes as it predicts the presence of relay nodes after the link expiry time. If the local maximum problem occurs or routing hole is faced due to unavailability of relay nodes then that data packet is retransmitted on different routes [36].

2.3.3.9 Driving Path Predication Based Routing (DPPR):

In *“Driving Path Predication Based Routing (DPPR)”* scheme, expected road selection towards the destination is achieved with better accuracy. In case of low vehicle density, the protocol utilizes nearby vehicles to carry packets to the roads where the density of vehicles is high. It reduces the delay of the packet and achieves better data delivery rate than its counter parts. Though, the other metrics like the delivery time, and the network overhead are not presented in this paper [37].

2.3.3.10 Reactive Pseudo-suboptimal-path Selection Routing Protocol (RPS):

In "*Reactive Pseudo-suboptimal-path Selection routing protocol (RPS)*", if any disjoint node appears then recently crossed junction is selected for refining a path towards the destination by analyzing current position information. RPS generates high network overhead and increases the chances of wireless transmission [38].

2.3.3.11 Acute Position based Routing (APR):

"Acute Position based Routing (APR)" protocol, considers a RSU at each intersection point to take decision about next vehicle selection towards the destination. In this scenario, if no path is available then RSU waits for the availability of some nearby vehicle and then transmits the packet towards the destination. It adopts the carry and forward strategy for recovery [39].

2.3.3.12 Position based Adaptive Routing (PAR):

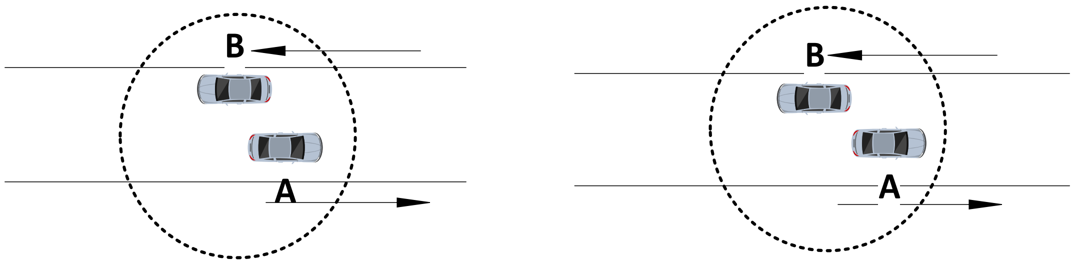
In *"Position based Adaptive Routing (PAR)"* scheme current condition and position parameters are adapted to select the routing path. In this scheme, the packet is forwarded to one-hop neighbors and then source node listens for any broadcast activity in its vicinity. In case of no progress, the packet is retransmitted. It also tracks the full path by involving the anchor nodes that are associated with junctions. Author claims to achieve better service ratio and PDR [40].

2.3.3.13 Routing in Delay Tolerant Network (RIDE)

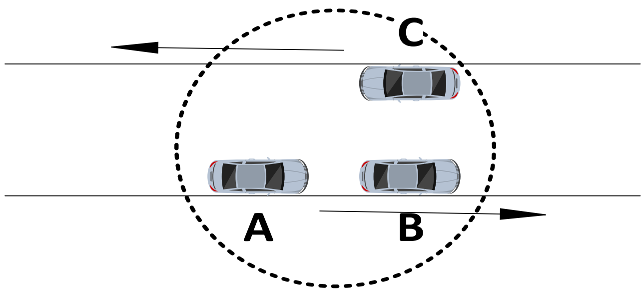
Zongjian He et al. introduced "Routing in Delay Tolerant Network (RIDE)". Main problem in VANETs is collecting data in highly dense area. This protocol is the situation in a city environment. RIDE uses carry and forward approach based on current traffic condition and knowledge of traffic condition. The main objective of RIDE is to minimize the communication overhead of network when data is collected by neighboring vehicles. It is explored that the data collection problem is NP-complete and it is a scheduling optimization problem. Under different application scenarios different solutions are used to solve the problem. Some of these are optical dynamic programming solution and a genetic algorithm based heuristic solution. In general evaluations certify that RIDE is better in terms of efficiency and usefulness as compared to counterparts [41].

2.3.4 Direction based Greedy Schemes for PBR

Directional Greedy Routing schemes utilize the greedy techniques and considered the movement of nodes. Directional greedy schemes are based on two strategies, i) Position First Forwarding: in this strategy nearest node to the destination is considered as a next hop. In this method direction of nearest node is preferred. There are also some drawbacks of direction based schemes. Node A is trying to send the data packet toward the node which is destination node. Destination node is moving along moving direction of A. While node B is moving in opposite direction to A. if we simply focus on geographical greedy forwarding scheme A will forward packet to B. as shown in fig 2.6 (a).



(a)



(b).

Fig 2.6 Routing Loop Scenario in (a) and Direction First Forwarding in (b)

A is not moving towards destination so B will forward data packet A and in this situation routing loop will occur because A is suitable nearest node for B. The process leads to end to end delay. This infers by adopting Location First Probe strategy alone cannot make routing efficient enough. ii) Direction First Forwarding: this strategy selects thee nodes that are moving towards destination node. In this selection chooses one node as next hop that is nearest to the destination. After choosing the nearest node the chance of looping becomes less. But there is still a problem. When A and B are moving in the same direction towards destination. On the other hand C is moving in opposite direction to A and B as shown in fig 2.6 (b). A and B are close to each other but C is moving in opposite direction of destination so when A forwards data packet towards destination it will choose b because direction first scheme is used and chance of delay may be increased [20].

This routing approach is used for the general case in VANETs, which means it is able to perform well in the extreme cases discussed above. It also considers the direction and position when it chooses the next hop. A mathematical model given in equation 2.3 is proposed to adjust the merits of position-first and direction-first forwarding. This model reflects the relationship between these two factors. The next hop is selected by calculating weighted score Wi.

$$Wi = \alpha\,(1 - Di/Dc) + \beta cos\,(\overrightarrow{v_\iota}, \overrightarrow{p_{\iota,d}}). \qquad (2.3)$$

Where,

α and β are weight factors,

Di is the shortest distance between node I to destination node,

Dc is the minimum distance between source node to destination or forwarding node too destination,

Di/Dc is the closeness of next candidate hop,

$\overrightarrow{v_\iota}$ is the vector for the velocity of node I,

$\overrightarrow{p_{\iota,d}}$ is the vector from the position of node i to the position of destination,

$cos\,(\overrightarrow{v_\iota}, \overrightarrow{p_{\iota,d}})$ is the cosine value for the angel made by these two vectors.

2.3.5 Road Perception based Geographic Routing (RPGR):

These schemes involve relative distance between vehicles, direction of motion, traffic density and nearby forwarder node to decide about the path towards destination. It also analyses the direction and traffic density when a packet is reaches at intermediate vehicle that is currently at intersection of roads. It also considers curve metric distance with destination and location of neighboring junctions [42]. Vasco et al. present a VDTN routing protocol called GeoSpray which is suitable for a smart city [43]. It begins with a multiple-copy approach by spreading a specific number of bundle copies to obtain alternate paths and then follows the forwarding scheme as shown in fig 2.7. It achieves robustness by limiting duplicates of same bundle transmitted on different paths along with controlled flooding. It uses active receipts to remove list of delivered bundles at intermediate nodes to avoid replication and improves storage utilization [43].

Topology-assisted Geo-Opportunistic Routing (TO-GO) is a geo-routing protocol that is hybrid of beacon and non-beacon based protocols. Range of transmission is large so fading and shadowing occur and due to large range attenuation chance of packet loss is high as well. Forwarding set technique is used to resolve the issue of fading. Three main steps of this protocols are: a next-hop prediction algorithm, the forwarding set selection and priority scheduling. Authors claim to achieve improvement than GPSR, GPCR and GpsrJ+ with 98 % PDR which is 40% higher than GpsrJ+ but delay is high [44]. The scheme is adaptable in smart cities.

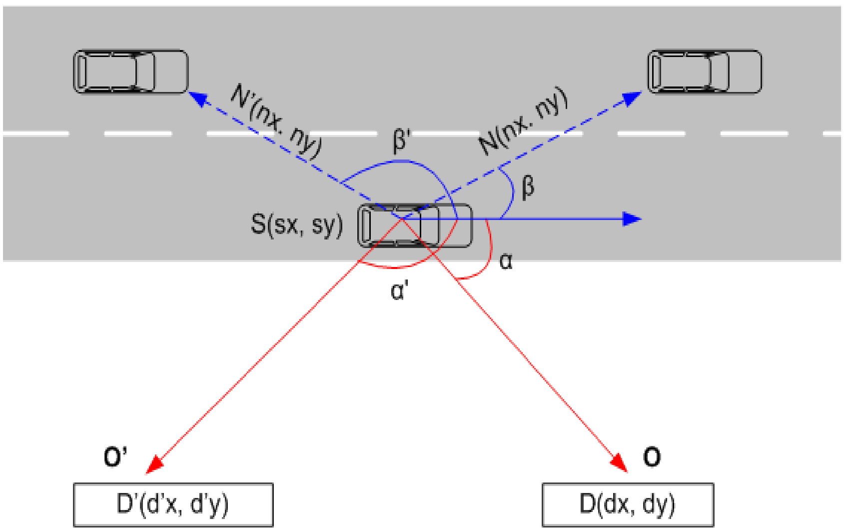


Fig 2.7. Direction and speed based next-hop selection

2.3.6 Predictive Directional Greedy Routing (PDGR)

In DGR, it only considers the current neighbor of source node when calculating weighted score for choosing next hop. In fact, a advance estimate by considering the source node's possible future neighbors can make routing more efficient. Node A and node B are moving in the same direction but node B is trying to overtake node A. when node A sends data packet to the destination in time t1, node B cannot be chosen by A as next hop according to DGR. After some time t2 B will be closer to destination so A will send packet to node B because node B is nearest to destination node. If node A forwards packet to the node B at time t1 it will increase the end to end delay. So DGR is improved with predictive direction greedy routing (PDGR) as shown in fig 2.8.

Weighted score in PDGR is not only calculated for source node or current node and its current neighbor nodes but also calculated for the future neighboring nodes that is possible upcoming neighboring nodes. The information of upcoming node is obtained from information of the two hop neighbors which can be calculated by beacon messages.

The PDGR algorithm has two parts. First part is to calculate the weighted score for current neighbors. Second part is used to calculate weighted score for the future neighbor nodes in short span of time but including the steps to get future position of the current neighbors and possible upcoming neighbors [20]**.**

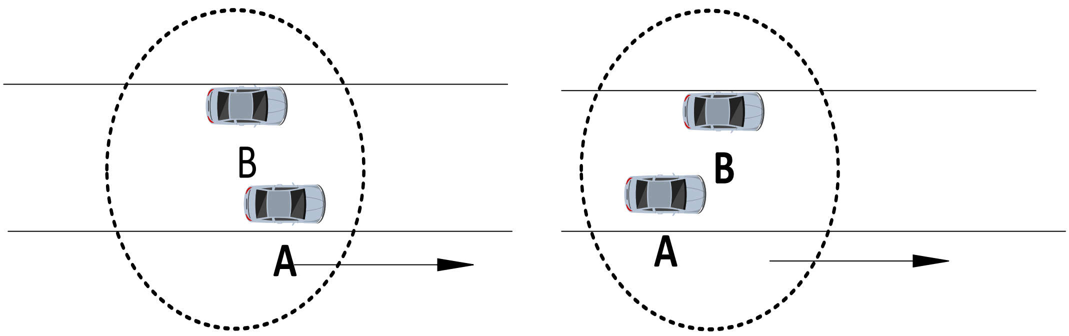


Fig 2.8. Overtaking Scenario

2.3.7 Linear Programming based PBR Protocol

In linear programming optimal path is obtained for formulating the given problems into mathematical model. One model for linear equation is network optimization.

2.3.7.1 Hybrid Sensor and Vehicular Networks (HSVNs):

Malika Sadou et. al. have proposed linear programming model in *"Hybrid Sensor and Vehicular Networks (HSVNs)"* [45]. It can overcome the problem of timely message delivery. This approach solves only small and medium sized problem of routing [45]. Linear optimization obtains the best results in a mathematical model whose requirements are shown by linear relationships like connections between vehicles.

2.3.8 Genetic Algorithm based PBR Protocol

J. Holland proposed a genetic algorithm (GA) in 1975 to improve the efficiency of complete NP problems [46] GA is a random search method that follows the method of natural selection (NS). NS is the central concept of evolution. Genetic algorithms are part of evolutionary algorithms that are used to optimize the complex algorithms, to train the text classification systems and the growth of artificial intelligent agents in randomized environment. GA provides the optimal solution. Some basic steps of GA are i) The First step of GA is to represent it. The solution is represented in form of string bits which contains same numbers of bits; ii) An initial population is normally generated randomly which should be spread over the search space to represent as wide a variety of solutions as possible; iii) The selection allows strings to be copied for possible inclusion in the next generation, where the standard for the selection is the fitness of all individuals; iv) The crossover is applied to two chromosomes and creates two new chromosomes by selecting a random position; v) Selection and crossover alone can generate a taggering amount of differing strings; vi) The stopping criterion can be set by the number of evolution cycles, the amount of variation of individuals between different generations, or a predefined value of fitness [46].

2.3.8.1 Genetic Algorithm Based QoS Perception Routing Protocol for VANETs (GABR)

Genetic algorithm based QoS Perception routing protocol for VANETs (GABR) is based on IBR with GA. For routing a packet over the network GABR predicts the direction of moving of a vehicle by selecting the next hope intersection dynamically. Vehicles are using carry and forward strategy to forward the packet over the network through road segment. GABR protocol combines source and destination by locating destinations. The advantage of this information is that source node knows about its destination and broadcasts the packet to the destination. After receiving the request from source node destination node responds and tells about the optimal routes towards destination. To start forwarding all optimal paths are examined by IBR. Subsequently, genetic algorithm is utilized in the global optimization of available paths to determine the path with optimal QoS. Optimal paths are calculated by the following steps:

(a) Code: A given route between the source and destination nodes is equal to an individual, i.e., the serial number sequence of intersections of the route is a chromosome, which can been coded directly. Therefore, this coding scheme avoids the route circulation due to that of the variation of length of the chromosome and the total numbers are less than the amount of intersections.

(b) Initialize the population: According to the route select strategy based on IBR, Gpaths are explored as an initial population and with the corresponding size.

(c) Selection: Pros and cons of individuals depend on the fitness value in GA, where the fitness value represents the QoS performance. With the increasing fitness, the QoS performance also correspondingly improved. An individual has more fitness value, which means that the individual is excellent and the corresponding path is optima [46]. Therefore, the fitness function is expressed as follows:

$$S = \alpha P_n + \frac{\beta}{D_{nth}} \quad (2.4)$$

Where,

α and β are weight parameters

P_n and D_{nth} indicated the connectivity probability and average delay of every individual node

(d) Crossover: Used to exchange the sub path of two individuals [46].

2.3.8.2 Intersection-based Geographical Routing Protocol (IGRP):

During *"Intersection-based Geographical Routing Protocol (IGRP)"*, a genetic algorithm based solution is presented. It considers the position based route finding as an NP complete optimization problem along with related position details, density and connectivity probability. A gateway is maintained to keep track of locations and active paths like a location server results explores the supremacy of IGRP over the GPSR and GPCR [47].

2.3.9 Linear Regression based PBR Protocol

In linear regression linear approach is used to estimate the time of vehicle the total time and travelling time to reach the destination. After estimating the total time and distance of destination node vehicle can move through a proper path [48].

2.3.9.1 Delay Bound Routing Protocol (DBRP):

A Delay Bound Routing Protocol (DBRP) is presented that uses linear regression to select the best location and slope by showing the connectivity of packet delivery time and travelling distance between vehicles. It has presented two schemes including greedy and the centralized approaches; the former is used for switching the route on the basis of local position details. The later analyzes the global details to decide about minimum cost path which can result into more accurate path due to availability of sufficient statistics. Results demonstrate a betterment in terms of PDR and increase in delay also increases the PDR [48].

2.3.9.2 Improved Greedy Routing (IGR):

Ting Lu et al. have proposed improved greedy routing (IGR) for vehicular fog computing (VFC) [49]. With the help of VFC communication among the vehicles and resource computation is improved. There are three basic points of IGR for routing: i) selection of junction, source node selects the junction for forwarding the packet. Position of nearest junction to source node is determined with the help of street map. There is possibility that there can be more than one neighboring junctions and source node gives score of each neighboring junction [49]. Selection of neighbor node is based on the given score. Source node forwards data to the junction with highest score. Score is calculated by considering Euclid Distance between source node to the destination and vehicle density between two junctions current and neighboring junction. Density of vehicles is calculated is given in equation (2.5).

$$\rho\left(Jcurrent, J_{next}^{(i)}\right) = \sum_{j=1}^{k^i} \frac{N_j}{N_{max}} \tag{2.5}$$

Number of nodes in a street segment can be obtained as $N_j = ceil\ (\frac{l_i}{R})$

Where,

l_i is the Euclid Distance

R is the transmission range of cars

$Ceil$ is the round up function.

Score of junction is calculated as given in equation (2.6). Improved greedy routing is used to send packet after selection of a junction. IGR maintains the routing tables for all neighboring nodes [49].

$$score\left(J_{next}^{(i)}\right) = \frac{\rho(J_{current}, J_{next}^{(i)})}{\frac{d_i}{d_{max}}} \tag{2.6}$$

Where,

$d_i$the Euclid distance between destination and the next junction

d_{max} is maximum distance between next junction and the destination.

2.3.10 Non-DTN based Routing Protocols

Non-Delay Tolerant Networks (Non-DTN) are used in city environment and in dense areas. The protocols use greedy approach to transmit packets towards destination from source. Packets are further forwarded to vehicles that are nearest to the destination. The chances of dis-connectivity in this type of protocols is very low [1] [50].

2.3.11 Non- Beacon Contention Based Forwarding (CBF)

Contention Based Forwarding (CBF) is non beaconing process to find out the location of neighboring nodes. Beaconing method is used in many greedy based forwarding to locate the neighbors. But because of high speed of vehicles the mobility of network is also high and beacon cannot find accurate position of neighboring nodes. This situation may cause network overload. CBF has the ability to deal with this situation. CBF follows greedy forwarding scheme to choose next forwarding hop. It is necessary to know real position of the neighboring nodes. This process is called distributed contention process [51].

When packet is forwarded by a source node to other nodes the after receiving the packet neighboring nodes start a timer. When timer of node expires earlier will defeat other opposing nodes. The timer depends on the distance towards the destination because that node will select next as a next forwarding hop. This is called progress. Progress on the way to destination can be calculated as given in:

$$Progress = \left\{0, \frac{dist(s,d) - dist\ (c,d)}{range}\right\} \qquad (2.7)$$

Where,
s is the source node
d is the destination node
c is the current node.

2.4 Hybrid Routing Protocols

Hybrid routing protocols are formed by combining the beacon and non- beacon protocols to forward packets by combining beacon and non-beacon approach to balance the consistency, robustness, strength and overhead. Two hop beacon information is used to select the next forwarding node by using greedy or recovery algorithm. Hybrid routing protocols are mixture of DTN and Non-DTN protocols to achieve partial network connection by adding boundary, DTN and non-DTN mode. Different routing protocols are used in VANETs and these protocols are designed to take care of special challenges of dynamic nature of network due to high mobility [52] [53].

2.5 Comparative Discussion

In this section we categories different PBR protocols. Advantages and disadvantages of each scheme are given in table 2.1. Most of them use greedy approach for forwarding packets but MLP-HSVNs is a PBR protocol that uses binary linear programming technique for forwarding data packet. Other protocols have main disadvantage that is higher delay. But GPSR is not a good scheme because neighboring table is not updated and it may cause the highest delay because there is no updated information of neighboring vehicles. The first neighbor changes its position and any new vehicle takes its position or may be a new vehicle will be near to source node but source node does not have updated information. It will send message to the older vehicles that is no more its neighbor. But at the same time GPSR is also good because it only considers one hop neighboring nodes and dynamically decides the packet forwarding. GeOpps is a good approach because this is not affected by the higher density of vehicles on a road. If there are many vehicles on road and source node wants to send messages to any other vehicle then it is not difficult to select the neighbor node.

Table 2.1 Overview of Position based Routing Schemes

Schemes	Basic Idea	Weaknesses	Strong points
VADD [21]	Carry and forward scheme	Higher delay	Higher delivery ratio
GeOpps [22]	Uses navigation system suggested routes to select the forwarding node nearest to destination.	Privacy is an issue due to navigation system	High density of vehicles do not affect the delivery ratio
GPSR [54]	Use greedy forwarding for sending packet but if this strategy fails use perimeter forwarding	Destination node address is never updated , neighbor's table contain the stale information	Only consider the location of one hop neighbor nodes and dynamically decide the packet forwarding
GSR [28]	Uses greedy forwarding and pre-selected path.	Higher routing overhead and neglect the sparse network	It is scalable and better packet delivery ratio as compared to AODV.

A-STAR [29]	Dijikstra's algorithm used for shortest path selection using anchor paths	Out-of-service issue at road side, Density of vehicles in streets not considered	High connectivity and packet delivery
GPCR [30]	Used greedy approach to forward the packet and pre-selected path is used for forwarding	Depends on junction nodes, problem with junction detection approach Fails on curve road Fails on sparse road	No external information is required No planarization problem
GyTAR [31]	Intersection based routing protocols reduced the end-to-end delay and control message overhead	Cannot avoid voids	Handles the network fragmentation
CAR [33]	Uses offline idealized location service,	Overhead during path discovery phases	Maximize data delivery rate and the average data packet delays
MLP-HSVNs [45]	Binary linear programming	Only solve small and medium size routing problems	Achieves distributed processing of routing details

2.6 Challenges in VANETs

VANETs are capable of provide numerous advantages to the society and industry but there are many challenges that remain need to be solved. Major challenges are presented describes in this section:

2.6.1 Mobility

Mobility is a big issue in VANETs. Due to high mobility of vehicles the maintaining and establishing communication is a challenging task. The infrastructure is not fixed and topology changes continuously due to high speed of vehicles and varied nature of road network. If a node sends data to a destination node and due to high speed of nodes data cannot reach its destination it may cause packet loss or delay in data delivery [55].

2.6.2 Accurate Positioning

In VANET for communicating with other vehicles it is very important to get information of other vehicles and its own location information. Vehicles equipped with sensors that help to get information of position of other vehicles and its own position. GPS is used for this purpose but some vehicles are not equipped with GPS while some are equipped with Global Navigation Satellite System (GNSS). GNSS is good for open areas because line of sight to satellite is necessary for its working but some vehicles may be passing through tunnels or underground roads [56].

2.6.3 Security

The messages that are sent to other nodes must be reliable and secure. Secure communication is a big challenge in VANET. When the data is sent from one node to another there are chances that message or packet can be altered by the hackers or attackers. When the message is received at a destination node, it may contain inaccurate information which may cause uncertain situation. Secure and efficient schemes are required for both V2V and V2I communication. We need novel encryption protocols that can operate at high speeds compared to traditional public key-based solutions which incur additional delays and overheads when encrypting messages from neighboring vehicles [56].

2.6.4 Data privacy

Sensitive information like vehicular tracking, vehicular status, digital footprint etc. needs be protected and kept private. Mostly people are not feeling secure. The challenge in data privacy is to exchange data while protecting personally identifiable information [56].

2.6.5 Delay

Forwarding a data packet in a timely manner is a big challenge because the nature of vehicular network is dynamic. Due to high mobility there is a chance of delay in packet delivery because vehicles have different speed and chance of link failure is high. The main purpose of this intelligent transport System is to provide safety to the drivers and passengers, avoiding road accidents etc. So, to achieve this aim we have to try to overcome this issue. Many researchers have proposed some approaches but delay in packet delivery is still issues. Position Based Routing faces many challenges [27]. Position Based Routing uses three schemes i) path selection ii) forwarding strategy iii) recovery strategy. Many Position Based Routing protocols use greedy based strategies but these may not be optimal for VANETs. Only two protocols GyTAR and GPCR have obstacles awareness. In these strategies overhead, latency and availability issues may occur. In safety applications, the rate of high rate of packet delivery and low latency is required that guarantees all data packets are forwarded at a proper time. It still suffers from large end-to-end delay and low packet delivery rate which makes it not appropriate for this type of applications.

2.7 Summary

In this chapter we have discussed PBR schemes. Different categories of PBR schemes are mentioned that are greedy forwarding, improved greedy forwarding, directional greedy, predictive directional greedy forwarding, linear programming and linear regression. The idea of position based routing in city environment is also given. Different PBR schemes are presented and a comparison of schemes is given. Comparative discussion is explored and challenges in VANETs are discussed. After comparative discussion of each scheme it is clear which scheme is good for VANETs and from which category.

CHAPTER 3

METHODOLOGY AND FOG ORIENTED POSITION BASED ROUTING ARCHITECTURE

3.1 Overview

This chapter explains the method of my research work. The fog oriented position based routing architecture is discussed in the second part. After that, the opportunities of proposed architecture for new application scenario are explained in the third part. .Finally, the fourth part mentions the challenges which the proposed architecture faces.

3.2 Fog Oriented Position based Routing Architecture

The Fog Oriented Position Based Routing Architecture is a newly introduced technology. It is useful for the end users and the edge of the network .it is also introduced as a new infrastructure for the VANETs. Vehicular Cloud Computing (VCC) is also proposed by some researchers, which is a cloud based architecture. The reason behind this concept is to group the individual vehicles that combine computing, sensing, communication and physical resources for their combination and dynamic allocation to the authorized users [21]. Because VCC cannot meet the requirements of VANETs, Vehicular Fog Computing is introduced to overcome its limitations. Vehicles are the main part of VFC infrastructure. Computation resources and the communication of these vehicles is used in VFC architecture. Moreover, VFC uses cooperative swarm of end users and end devices to handle significant and valuable amount of communication and computation. VFC also uses the features of slow vehicles and parked vehicles. The parked vehicles cause blockade of roads because there is no proper car parking arrangement. Another reason for traffic jam is slow vehicle movement. The VFC technology is used to utilize the resources of these types of vehicles. In VFC architecture end nodes are vehicles and mobiles as illustrated in figure 3.1. A communication scenario is depicted where vehicle 2 transmits packet m to the nearest node 4 to forward packet m to destination which is vehicle 17. Vehicle 4 checks its nearest node which is 5 that is moving in opposite direction that increases the chances of packet loss. The vehicle 4 forwards packet m to vehicle 6 which is nearer to the junction as well. After reaching the junction, vehicle 6 decides about forwarding the packet m to right vehicle which is in the direction of vehicle 17 that is, destination. The packet m is then forwarded to vehicle 11 via 10. At this stage vehicle 11 analyses to forward the packet to Fog server via RSU to further deliver the packet to destination that is far from this position. On the contrary, vehicle 11 can forward packet m via V2V communication and transmit to vehicle 13 which is at junction and then decides to forward it to vehicle 16 or vehicle 19. Vehicle 14 is across the junction and also in opposite direction so it will not be considered. Node 19 is near to vehicle 17 but it is in opposite direction and will get away from range of vehicle 17 that depends on the speed of vehicle 19. Therefore, Node 13 selects vehicle 16 as intermediary node to further forwarding the packet m to the destination 17.

3.3 Advantages of Proposed Architecture

Due to this FoG-oriented architecture of VANET, a number of new opportunities are explored that can originate the new application scenarios along with ITS. Following benefits and opportunities can be availed by utilizing our proposed architecture for vehicular routing in city environments.

3.3.1 Low latency

Data processing that occurs at the edge or near to the vehicle results in low latency. After processing faster result produced by ITS which can be delivered to all other vehicles and RSUs to make the better decision for selecting next hop vehicle. Sending and receiving messages by mobile phone is fast. When message sends from one car to another, if service of mobile phones is available then it is guaranteed that message delivers in timely manners and there is no chance of delay. In fog oriented VANET, involving mobile network make data transfer rate much better with less delay and also improve the response time among vehicles acting as guards, anchors or other intermediaries [57].

3.3.2 Local Resources

Smart vehicles has online connection with ITS. Smart vehicles have resource rich repositories to decide the next hop vehicle in the path. Next hop vehicle is based on speed, direction and density of nearby vehicles. It also ensures to maintain repository for vehicle, region, junction and road specific information.

3.3.3 Wide Connectivity across Networks

It improves the quick data sharing or emergency alerts across the networks like hospitals, fire brigade, and ambulance. Moreover, other services of ITS can also be availed to connect across different networks for video streaming, call sessions, weather predictions, road hazards in current track and coordination with companion vehicles.

3.3.4 Quality of Service

In FoG oriented architecture, ITS can ensure quality of information exchange by achieving less delays, more packet delivery ratios and increased throughput. The system can provide smooth, reliable and securely dependable communication for desired services in different applications. For the cellular network, the data will be transferred with better rates and less delays to improve the response time.

3.3.5 Efficient Bandwidth Utilization

Mobile phones can play a vital role to locally manage the request and working as an edge node to decrease the traffic on cloud servers and other devices in vehicles. On the move, vehicle can be linked with cell phones to access ITS deployed at FoG servers to efficiently communicate and utilize bandwidth in a better way. The vehicle or the FoG server can also communicate with cloud when necessary. Smart vehicle can reduce the amount of vehicle to vehicle communication by directly approaching the Fog server for next-hop identification and other emergency intimations. It improves the bandwidth utilization of the network with efficient accessibility.

3.3.6 Improved Energy Efficiency

Energy utilization is the challenging task to keep the FoG oriented architecture as green architecture. Though, the vehicle sensors can take a continuous amount of energy from vehicle battery but efficient energy utilization is beneficial for protecting our environment to keep it green. The system should also consider to eliminate the data for existing links that are no more connected to efficiently utilize the resources.

3.3.7 Improved Services Accessibility

FoG servers can provide a set of ITS based services for reducing delays. It also reduces the chances where vehicle has to unnecessarily wait for record saving at cloud servers. Similarly, more edge nodes can be identified in sub layers near to sensing devices of vehicles to perform caching for providing quick feedback.

3.3.8 Robustness

If there is chance of dis-connectivity between moving cars it can automatically recover when services are provided as mobile phones are involved in FoG oriented architecture. Moreover, the vehicle can handle the other trouble creating situations by adopting self-organization capabilities either locally by vehicle or intimated by the FoG servers.

3.4 Challenges of Proposed FoG oriented Architecture

There are many challenges faced by the new FoG-oriented VANET architecture to provide the dependable solutions. We have explored challenges in different application scenarios. During different vehicle communication environments, following challenges can be faced that should be catered to design new solutions for this FoG-oriented architecture.

3.4.1 Mobility Management

In VANET, it is difficult to smoothly and continuously communicate with ITS due to the high mobility of vehicles. In hilly areas mobile signals are not available everywhere it may also be reason. So V2V communication is best as well by using parked vehicles near anchor points using our architecture to ensure packet transmission in emergency scenarios and other services as well. It is an open challenge to propose ITS based solution to handle the mobility of vehicles with dependable connectivity by using FoG servers and RSUs in such regions.

3.4.2 Capacity Analysis

We have considered the capacity by evaluating set of services and applications supported by the ITS. Moreover, we also consider the amount of storage needed at FoG server and cloud as well. The main thing is the delivery of data in timely manners without any delay. Secondly, retrieve data from users and timely save at repositories with acceptable delay or no delay. To solve this issue, various patterns are used to put data on suitable FoG devices or nodes in linkage with ITS to maximize the throughput and minimize the latency. It is an open challenge for researcher to solve this issue in real time and non-delay tolerant applications, figure out the storage capacity limits and ensure timely selection of new storage ventures.

3.4.3 Reduce Communication Delay

During V2V communication, the chances of delays increases due to unavailability of intermediate nodes in the path. In this situation local maximum problem occurs and carry forward approach is adopted. Alternatively, by using our proposed architecture, the parked vehicles near by the anchor point or junction points can be utilized to reduce such delays. It opens a new set of challenges for the researchers to propose new mechanism that can effectively reduce or eliminate delays using ITS and FoG servers in combination, store the information of real time vehicles of a particular area and share with other neighboring vehicles. Moreover, if mobile service is not available in a region then more delays occur to deliver packets to destination. To resolve these challenges, authors must focus on effectively utilizing the ITS in hybrid architecture using V2V and V2I communication along with FoG server.

3.4.4 Security and Privacy

In our proposed architecture, security and privacy is quite challenging because vehicles have to rely on the intermediate nodes for sharing information. On the move, a large number of moving and parked vehicles are connected. In this scenario, malicious vehicles can pretend to offer efficient routes towards destination that can result in excessive packet drops in wrong direction. To resolve these issues, ITS can play a vital role to confirm the legitimacy of intermediaries. But, in case of inability to connect with ITS where V2V communication is involved. It becomes worst in case of

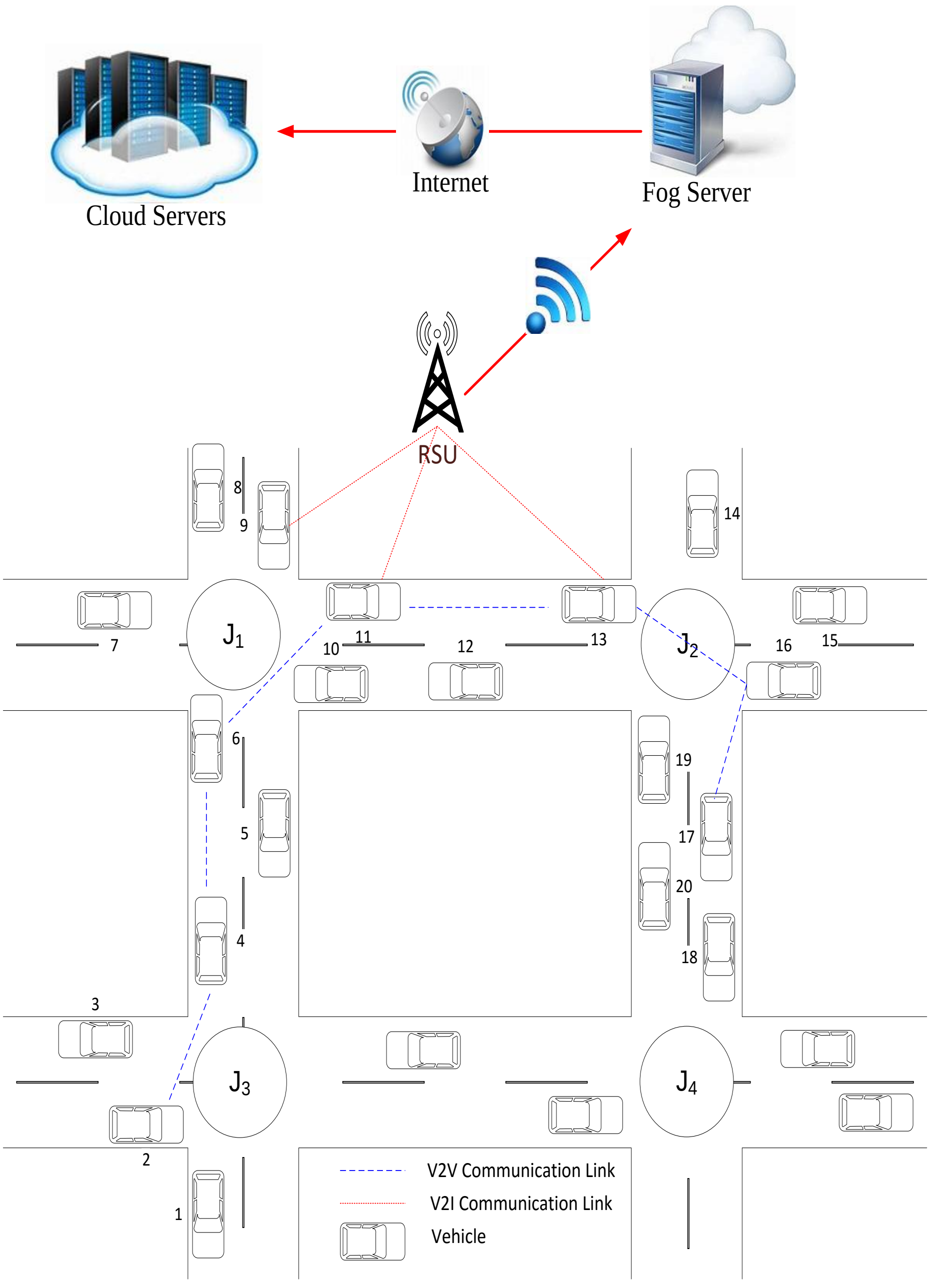


Fig. 3.1 Fog oriented Architecture for Position based Routing

local maximum problem when no neighbor is available and vehicle has to communicate via any available neighbor. It opens a large set of challenges for researchers to present dependable security solution in case of rapid connectivity with vehicles for short intervals as well. Moreover, the novel trust management systems are more important due to frequent involvement of intermediaries on the move. Vehicles can reconfirm the delivery of a packet if any malicious contact is identified. There could be a position specific intrusion detection system that is managed by ITS to identify malicious vehicles and inform to vehicles of that region. [58].

3.5 Summary

This chapter introduces proposed architecture for position based routing that is fog oriented position based routing architecture. This new architecture overcomes the drawbacks of VCC architecture and also share the burden of cloud computing. In next sections, different opportunities and challenges are discussed that can be faced by proposed architecture. The fog architecture provides many opportunities that are utilized by user to facilitate them in VANETs.

CHAPTER 4

DYNAMIC POSITION BASED ROUTING PROTOCOL

4.1 Overview

In this chapter, a novel PBR protocol is presented that dynamically manages the information regarding vehicle position along with neighboring vehicles. We have also discussed the role of anchor nodes and parked vehicles near road junction to manage connectivity aware routing. List of notation is also given to understand the technical terms and keywords. Finally proposed algorithm is discussed in a stepwise manner for three parts.

4.2 Dynamic Position Based Routing Protocol

To evaluate the proposed dynamic position based routing protocol D-PBR the main goal of our scheme is to increase the PDR, minimize the communication overhead and reduce the end to end delay. The proposed Dynamic Position based Routing Protocols is splits into three phases: i) Direction of destination node; we have considered the movement of vehicles in the direction of destination for selecting the path structure. ii) Road junctions for selecting next road; we have considered the road junctions like at signals to select the next road and the vehicle that can transfer the message towards the neighboring vehicle. iii) Parked vehicles for packed forwarding; for forwarding packet to the destination on time and avoiding any delay we have considered the parked vehicles to forward packet to the destination node. To achieve our goal different notations are used for D-PBR that are mentioned in table 4.1.

Table 4.1. Notations for D-PBR

Sr.	Notation	Description
1.	F	All nodes in the network except sink.
2.	NVs[ ]	List of Neighboring Vehicles
3.	DJ_V[ ],	Distance from source node to
4.	DJ_{PV}[ ];	Junction via Vehicles and Parked Vehicles
5.	PV[ ]	List of nearby parked Vehicles
6	JN[ ]	List of nearby Junctions
7	DV_D[];	Destination Vector
8	NJ_{Init}^{Vi}	Available Initial Next Junctions,
9	S	Speed
10	l_N: density	Density
11	Lg	Longitude
12	Lt	Latitude
13	V_D	Destination Vehicle
14	V_S	Source Vehicle
15	J_{next}^{Vi}	Next Expected Junction of a Vehicle

4.3 Proposed Dynamic Next-hop Identification (DNI) Algorithm

In this section, we introduced a next-hop identification algorithm that dynamically analyze the position and direction of vehicle towards the destination. It is helpful to increase the packet delivery ratio, reduce the communication overhead and reduce the communication overhead.

Steps (1) – (3): DV_D[ ] is the array of destination vector that is used to store the information of location of destination node. Information is got from fog server. When information of destination node receives source node broadcast the beacon message to the initial junction NJ_{Init}^{Vi} to get information of all vehicles that are located on initial junction. At the NJ_{Init}^{Vi} vehicles send response to the source node $V_{S.}$ After getting feedback from vehicles, Vs saves data of neighboring nodes such as, IDs, speed, density, available initial next junction, longitude Lg and latitude Lt of vehicles.

Steps (4) – (8): NVs[ ] is the array to store information of neighboring vehicles. For loop is used to fill the array, m is the number of vehicles. If the initial next junction has some vehicles and information of next expected junction then distance of neighbor node is calculated and result is save in DJ_V[ ].

Steps (9) – (13): PV[ ] store the information of parked vehicles. If initial next junction has some parked vehicles and information of J_{next}^{Vi} next expected junction then DJ_{PV}[ ] calculate the distance of source node Vs to parked vehicles PV. And after calculating this distance source node forwards data to the nearest parked vehicle.

Table 4.2. Dynamic Next-hop Identification (DNI) Algorithm

F; //all nodes in the network except sink.
NVs[ ]; //List of Neighboring Vehicles
DJ_V[ ], DJ_{PV}[ ]; //Distance from source node to Junction via Vehicles and Parked Vehicles
PV[ ]; //List of nearby parked Vehicles
JN[ ]; // List of nearby Junctions
DV_D[ ]; //Destination Vector with *S*: Speed, l_N: density, NJ_{Init}^{Vi}: Available Initial Next Junctions, Lg: Longitude and Lt: Latitude
V_D: Destination Vehicle
V_S: Source Vehicle
J_{next}^{Vi}: Next Expected Junction of a Vehicle
 	
Input: PV[ ], JN[ ], DV_D[ ], are arrays that store the input of parked vehicles, nearby junction and speed, density, longitude and latitude respectively.
 	
Output: Next-hop Vehicle V_{Nx} and junction J_{next}^{Vi} with Minimum Distance in the direction of Destination
 	
1: DV_D[ ] = Lookup_Dest_Info (V_D) //from FoG server
2: Broadcast ENQUIRY for NJ_{next}^{Vi}
3: Receive Reply from vehicles and Save values of IDs, *S*, l_N, J_{next}^{Vi} Lg and Lt in NV

```
for m = 1 to size (NVs) do
      If (NJ_next^Vi contains (NV[m].J_next^Vi)) then
          DJ_V[m] = calc_distance (V_S, NV[m]);
      End If
end for
for k = 1 to size (PVs) do
      If (NJ_next^Vi contains (PV[k].J_next^Vi)) then
          DJ_PV[k] = calc_distance (V_S, PV[k]);
      End If
end for

If (DJ_V[].count > 0 OR DJ_PV[].count > 0) then
   If (DJ_V[].min < DJ_PV[].min)
      V_Nx = Index Of Vehicle with DJ_V[].min
   Else
      V_Nx = Index Of Vehicle with DJ_PV[].min
   End If
End If

while (true)
   If (check_direction(V_Nx) to V_D then
      send (m) to V_Nx
      Break;
   else
      V_Nx = Index Of Vehicle with next minimum distance
end while
```

The proposed model is based on the weighted scores. Weighted score is calculated by using factors like speed of vehicle, location of neighboring vehicle, direction of movement of vehicles and connectivity of link between vehicles. Then weight of all factors is calculate and at the end destination node is selected. These factors are calculated by six units; speed of vehicles is calculated by Neighbor Node Selection (NNS), direction of movement by Measuring Distance (MD), location is traced by Moving Direction (MD) factor and link connectivity by Finding Stability Link (FLS). All these factors are calculated by Weighted Calculation to decide whether the data packet should be forwarded and which value is higher. At the end destination node is selected.

For junction based routing source vehicle chooses the next junction to send the packet to destination. Source vehicle gives score to each neighbor junction. The junction is selected according to the score, a higher score means better selection, and any junction which has higher score means the junction is near to the destination. The score is calculated by considering two factors i) Euclid distance and ii) density of vehicles between current and neighboring junction. The vehicle density between current junction and neighboring junction is calculated by the equation (4.1)

$$\rho\left(J_{current},\ J_{next}^{(i)}\right) = \sum_{j=1}^{k^i} \frac{N_j}{N_{max}} \tag{4.1}$$

Where,

$J_{current}$ is current junction,

$J_{next}^{(i)}$ is next candidate junction i.

k^i is the street segments between $J_{current}$ and $J_{next}^{(i)}$,

N_j is the number of vehicles in street segment j

N_{max} is the maximum nmbers of vehicles between current junction and neighbor junction.

N_j is calculated by the given equation (4.2).

$$N_j = ceil\ (\frac{l_i}{R}) \tag{4.2}$$

Where,

l_i is the Euclid distance between the current junction $J_{current}$ and the next candidate junction $J_{next}^{(i)}$

R is the transmission range of a vehicle

Ceil (·) is the rounding up function.

The score of junction is measured by the given equation (4.3)

$$score\left(J_{next}^{(i)}\right) = \frac{\rho\left(J_{current}, J_{next}^{(i)}\right)}{\frac{d_i}{d_{max}}} \tag{4.3}$$

Where,

d_i is the Euclid distance

d_{max} is the maximum distance from the candidate junction $J_{next}^{(i)}$ to the destination respectively.

4.3.1 Neighbor Node Selection

It is the process of identifying a neighboring node within the transmission range. Each node has its own table in which information about nearest vehicles is saved but this table should be update from time to time because vehicles change their positions frequently so this table is always dynamic. Every vehicle or node send a beacon message in every μ second, the table of a node is update periodically to inform about its presence. If node does not send its information through beacon message then it is automatically removed from the table in (α * μ) time (α is the number of beacons that is send by missing node and μ is time) [60].

4.3.2 Measuring Distance

GPS is used to calculate the distance between neighboring nodes and the destination node. Closest neighbor node selected. This closeness can be calculated with the help of formula (4.4) for MD [60].

$$MD = (1 - \frac{Nd}{Sd}). \qquad (4.4)$$

Where,

Nd is the distance of neighbor node and the destination node

Sd is the distance between source node and the destination node.

4.3.3 Direction of Movement

To find out the node that is moving towards the direction of the final node i.e. the destination node is found out using the equation (4.5) [60].

$$DM = \cos(\vec{v}_i, \vec{L}_{i,d}). \qquad (4.5)$$

Where,

$\vec{v}_i$ is the vector of velocity for the neighbor node i,

$\vec{L}_{i,d}$ is the vector of velocity for the neighbor node i

D is the destination node

Cos$(\overrightarrow{v\iota,\ L\iota,d})$ refers to cosine value for the angle made by the vectors.

4.3.4 Stability of Link

Link stability is defined as link expiry time, which means maximum time of connection which is maintained between any two neighboring nodes. In order to compute the link expiry time, the motion parameters of any two neighbors are considered. Let N1 and N2 be the two nodes within the transmission range R and ‘a1’, ‘b1’ and ‘a2’,’b2’ be the coordinates for nodes N1 and N2 with velocity V1 and V2 and direction and respectively. Let, after a time interval t, the new coordinates be a1 and b1 for N1 and a2 and b2 for N2. For time t, let d1 and d2 be the distances travelled by nodes N1 and N2 [60].

$$SL = \frac{R}{D} = \frac{R}{\sqrt{[\overline{(a_1 - a_2)} + t(v_1 cos\theta 1 - v_2 cos\theta 2)] + t[(b_1 - b_2) + (v_1 sin\theta 1 - v_2 sin\theta 2]}} \qquad (4.6)$$

Where,

SL is the link stability between any two nodes in the time t,

R indicates the transmission range

D is the distance between two nodes at time,

a_1, a_2, b_1, and b_2 are coordinates for nodes,

v_1 and v_2, is velocity.

4.3.5 Weighted Calculation

The weighted score is calculated by combining the distance, direction of motion and link stability factors of neighboring nodes. The packet will be forwarded to the destination node with the link with maximum score [60].

4.3.6 Destination Node Selection (DNS)

Using the formula in Equation 4.6 the weight score of each nearby nodes within the transmission range R is calculated. The node with the highest weight score is selected as the next forwarding hop which is having the higher possibility to reach the destination and packet is forwarded. DNS is responsible to select the next nearest node and sends the packet to the edge node. To prevent the common network disconnection and to increase the efficiency of the existing routing protocols the hierarchical clustering technique is used in DNS for packet forwarding [60].

4.4 Summary

In this chapter the proposed algorithm is presented. The name of proposed algorithm is dynamic position based routing protocol (D-PBR). This novel scheme dynamically manages information about the nodes in the network. D-PBR has three main phases that is, Direction of destination node, Road junctions for selecting next road and Parked vehicles for packed forwarding data packet. In this chapter parametric tables have also been discussed. Some other steps are also discussed which are helpful to solve main issues of the research work.

CHAPTER 5

RESULTS AND ANALYSIS

5.1 Overview

In this chapter, we have discussed about simulation environment, results and analysis. The routing protocols is dependent on different performance metrics. The effectiveness and efficiency of routing protocols can be measure by comparing with different routing protocols. We have presented the graphs to show improvement achieved by proposed scheme as compared to its counterparts.

5.2 Simulation Environment

For the simulation, NS2 is used which is an open-source simulation tool and we have run it on Ubuntu. It is a understated event simulator targeted at networking research and provides substantial support for simulation of routing, multicast protocols and IP protocols, such as UDP, TCP, RTP and SRM over wired and wireless (local and satellite) networks. Script written in TCL use a file extension TCL. TCL (additionally articulated tickle) remains for Tool Command Language. TCL is a dynamic open source language used for building web and desktop applications. Regardless of whether on Windows, Mac OS X, or Linux operating systems, TCL documents can be opened and altered by WISH and TCLSH. TCL file is used for deploying vehicles on a road model along with x, y, z coordinates. It also includes the code for message initiation from a source vehicle at certain time during the simulation. Moreover, we have also implemented the mobility scenarios for moving the traffic on both sides of the road with a certain speed. Nam is a Tcl/TK based animation tool for review arrange reenactment follows and certifiable packet trace data. The initial step to utilize nam is to produce the trace file. The detailed format is described in the TRACE FILE section. As a rule, the follow record is created by ns. AWK is a high level programming language which is utilized to process files content. AWK

Scripts are efficient in handling the information from the log (Trace files) which we get from NS2. List of simulation parameters are shown in Table 5.1.

Table 5.1. List of Simulation Parameters

Parameters	Values
MAC/PHY standard	IEEE 802.11p
Routing Protocol	GPSR, CAR
Mac Trace	OFF
Data Packet Size	1024 bytes
Antenna Type	Omni Antenna
Link Layer Type	Link Layer
Transmission Power at Vehicle	0.819 µJ
Receiving Power	0.049 µJ
Agent Trace	ON
Queue Type	Queue/DropTail/PriQue
Lanes Count	2
Velocity of Vehicle	70-120 km/h
Max Packet in Queue	50
Transmission Radius	400m
Channel Type	Wireless
Router Trace	ON
Density of Vehicles	10-50 vehicles
Movement Trace	ON

In our model many vehicles are moving in a city environment with two lanes along with road junctions. Vehicles speed ranges from 70 km/hour to 120 km/hour on different road segments containing two lanes. TCL code supports vehicle deployment using coordinates and mobility using detest function by including velocity as well. Moreover, V2V and V2I communication is also initiated from TCL but the "messages send" and "receive" functions are implemented in C language. PBR protocols is also implemented in C.

5.2.1 Average End to End Delay

This metrics define is time need for a packet transmission from source to destination throughout the network. It describes the delay created by the routing protocol. Main causes of the delay are route discovery and transfer time. When density id 10 vehicles per kilometer then average end-to-end delay is 0.0057 micro seconds as illustrated in figure 5.1.

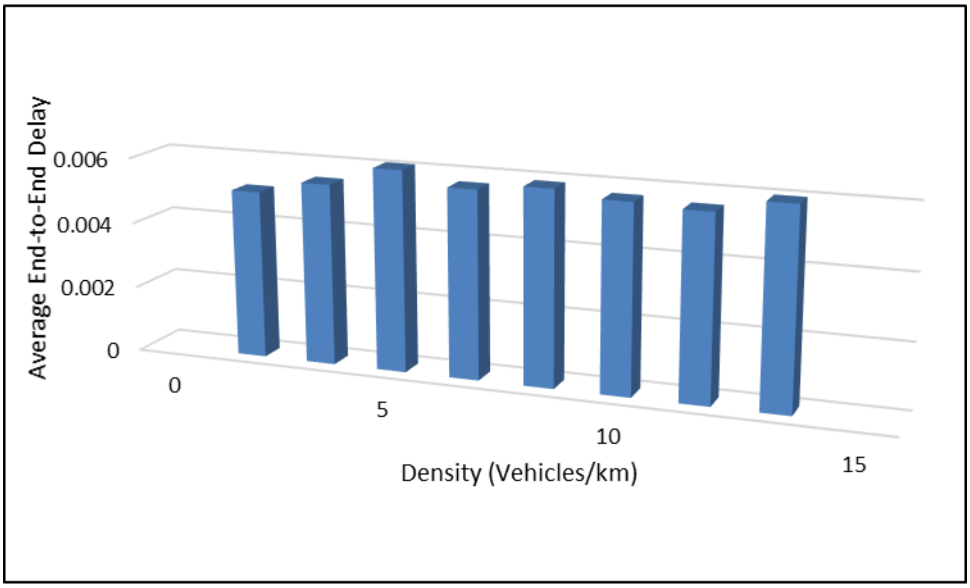


Fig 5.1. Average End to End Delay

5.2.2 The Residual Energy

A node sends packet to another node over the network. For this process node uses a specific amount of energy. Initial energy of node gets decreased. The reaming energy of node after sending or receiving the packet is the residual energy. In case of D-PBR when density id 7 vehicles per kilometer then residual energy is 999.97 kilojoule as shown in fig 5.2.

5.2.3 Mean Hop Count

Hop count is the total numbers of nodes used in the netwrok through which the message packet is passed from source node to destination node. Each node along the path is one hop. When density id 10 vehicles per kilometer then mean hop count of D-PBR and RIDE is 4 vehicles and 6 vehicles respectively that is 60% decreased in contrast to RIDE as shown in fig 5.3.

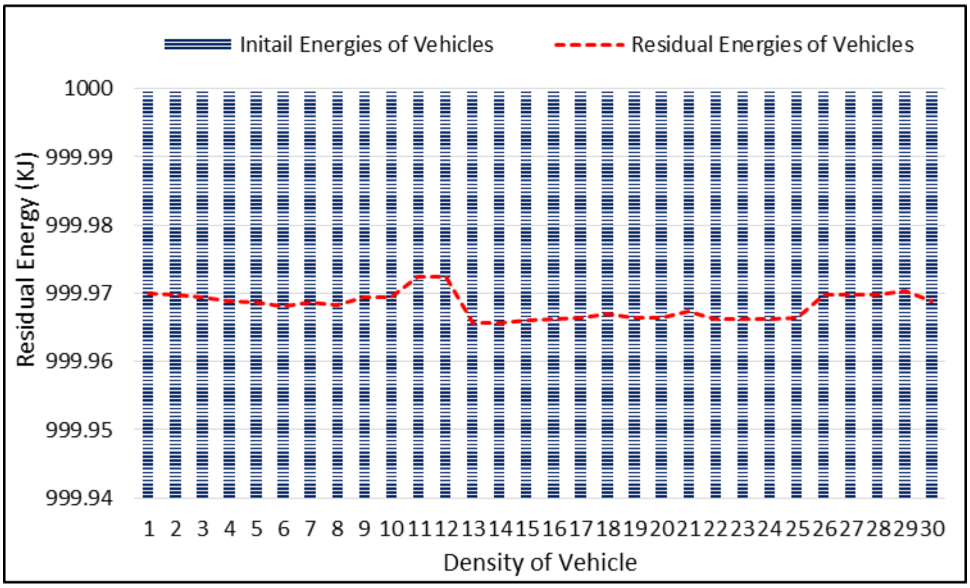


Fig 5.2. Residual Energy

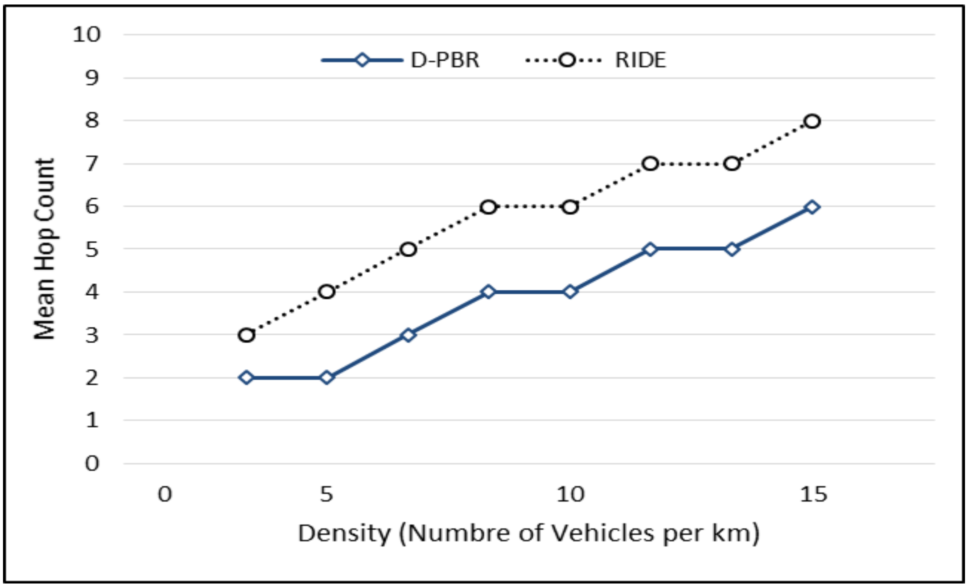


Fig 5.3. Mean Hop Count

5.2.4 Average Throughput

This metric is defined as ratio between the aggregate number of bits sent by the source node to the bits received by the by destination in a specific time span. When density id 10 vehicles per kilometer then average throughput is 170 kbps as shown in fig 5.4.

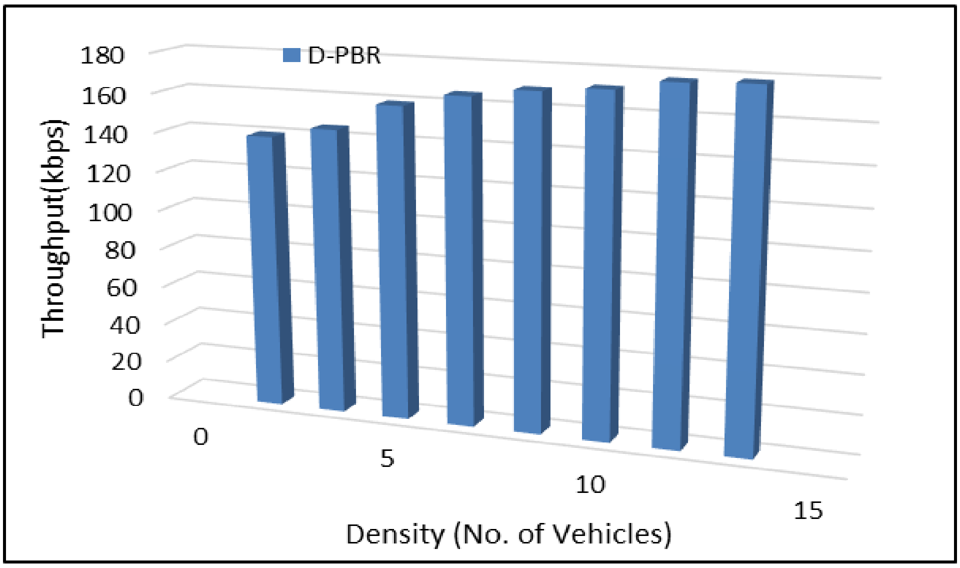


Fig 5.4 Throughput

5.2.5 Average Number of Vehicles

Fig 5.5 illustrates average numbers of vehicles involved in a network with respect to the change of vehicle density. Results illustrate that if density is 10 vehicles per kilometer, then average numbers of vehicles are 7 and 5 for RIDE and D-PBR respectively. The average number of vehicles decreases by 42.86% for D-PBR.

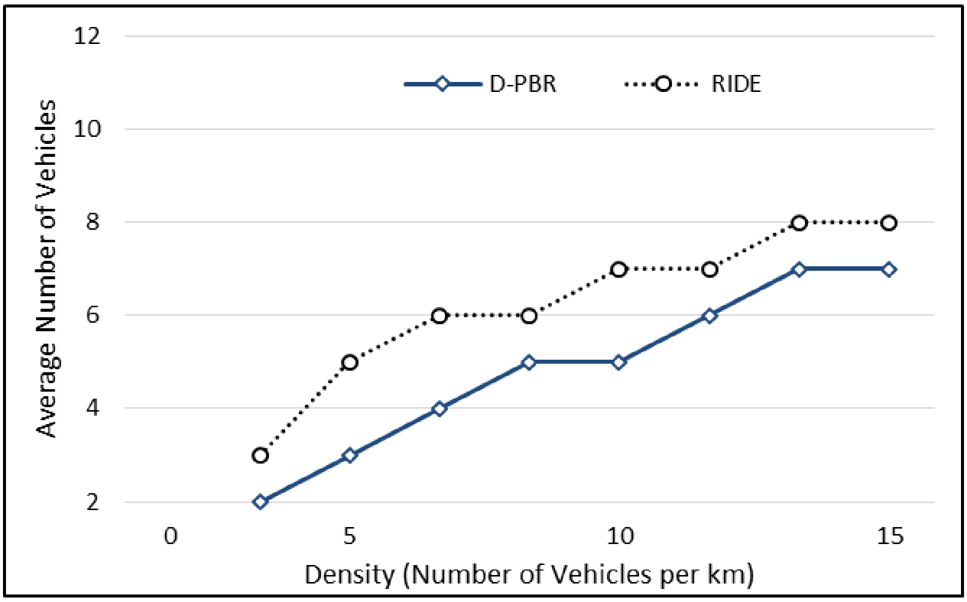


Fig 5.5 Average number of Vehicles

In above paragraphs we compare RIDE with our proposed scheme D-PBR. The mean hop count of D-PBR is decreases by 60% as compared to RIDE. When mean hop count decreases then routing will be efficient and no more time is required to reach packet to destination. Average number of vehicles also decreases by 42.86% in D-PBR as compared to RIDE.

5.3 Summary

In this chapter simulation environment and setup is discussed. Simulation tool used to extract the result is described. After description of simulation environment in next section results and graphs are discussed. D-PBR is compared with existing routing protocol RIDE. Different graphs are used to show the results in above sections. Performance metrics include end to end delay, residual energy, average throughput, and mean hop count. And these results show that D-PBR is more efficient than RIDE, the present position based routing scheme.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Overview

VANETs is an emerging field now a days. Many challenges have been identified in VANET by researchers. There are routing protocols have been developed to resolve these issues and challenges. In this thesis, performance of RIDE protocol is analyzed. It has been observed that RIDE protocol performs well in VANETs network but our proposed D-PBR provides minimum end to end delay which is the major requirement for a real time network.

The result of proposed algorithm which is D-PBR is well suited for city environment. D-PBR provides good network scalability. It also produces better delivery ratio as compared to other routing protocols for VANETS. VANET is not fixed, and keep on changing with moving vehicles, therefore, the fixed topology-based schemes are not suitable. To handle this issue, position based routing (PBR) protocols are useful for such networks. The main problem is that if the information is transmitted without considering the direction of a moving vehicle then the information may not reach the destination. In our research we consider direction of vehicles, and we also consider the junction based selection of vehicles for forwarding packets. We have designed a new fog based architecture for D-PBR that can reduce communication overhead and delays. To further improve communication and alternate delivery path, we have analyzed the impact of utilizing parked vehicles for junction based route identification.

In our research, we have focused on three things; first we have considered that the vehicle moving in the direction of destination must be selected for the next hop, Secondly, we have also considered the junction for better direction selection and thirdly, we have also considered the parked vehicles for packet forwarding.

6.2 Contributions and Achievements

In our research work we have focused on to minimize the communication overhead, end-to-end delay and improve message delivery ratio through reliability. We have introduced a new protocol which is D-PBR. In D-PBR we utilize the parked vehicles for forwarding message, we have considered the junction based selection of vehicles and also consider the direction of destination node to avoid delay in communication. It has been implemented the new architecture for VANETs.

6.3 Future Work

This work can be extended for clustered scenario of position based routing where one vehicle serves as head node. It will manage neighboring vehicles in the region to share connectivity aware routing information. Moreover, roads can be divided into segments with a head node in each segment.

REFERENCES

[1] S. Batish, M. Chahal and S. Sofat, "Comparative Study of Position Based Routing," *APRN Journal of Engineering and Applied Sciences,* vol. 10, no. 15, pp. 6414-6418, 2015.

[2] L. Jianqi, W. Jiafu, W. Qinruo, D. Pan, Z. Keliang and Q. Yupeng, "A survey on position-based routing for vehicular ad hoc networks," *Telecommun Systems,* vol. 62, no. 1, pp. 15-30, 2016.

[3] K. Ramin, I. Norafida, A. R. Shukor and N. Sara, "Non DTN Geographic Routing Protocols for Vehicular Ad Hoc Networks," *International Journal of Computer Science,* vol. 8, no. 5, pp. 86-91, 2011.

[4] E. Borcoci, "From Vehicular Ad-hoc Networks to Internet of Vehicles," in *NexComm 2017 conference*, Venice, 2017.

[5] P. Ranjan and K. K. Ahirwar, "Comparative Study of VANET and MANET Routing Protocols," in *International Conference on Advanced Computing and Communication Technologies*, 2011.

[6] R. Kumar and M. Dave, "A Comparative Study of Various Routing Protocols in VANET," *IJCSI International Journal of Computer Science,* vol. 8, no. 4, pp. 643-648, 2011.

[7] D. d. C. Felipe, B. Azzedine, V. Leandro, C. V. Aline and A. F. L. Antonio, "Data Communication in VANETs: A Survey, Challenges and Applications," 2015.

[8] Hiren, N. Kathiriya, A. i Kathiriya and Bavarva, "Review on V2R Communication in VANET," in *Proceedings of International Conference on Innovations in Automation and Mechatronics Engineering*, INDIA, 2013.

[9] K. AMIRTAHMASEBI and S. R. JALALINIA, Vehicular Networks – Security, Vulnerabilities and Countermeasures, 2010.

[10] K. Vishal, M. Shailendra and C. Narottam, "Applications of VANETs: Present & Future," *Communications and Network*, vol. 5, no. 1B, pp. 12-15, 2013.

[11] G. Samara, W. A. H. Al-Salihy and R. Sures, "Security Analysis of Vehicular Ad Hoc Nerworks (VANET)," in *International Conference on Network Applications, Protocols and Services*, Malaysia, 2010.

[12] H. Zongjian and Z. Daqiang, " Cost-efficient traffic-aware data collection protocol in VANET," *Ad Hoc Networks, ELSEVIER*, vol. 55, pp. 29-39, 2016.

[13] Marwa, I. Altayeb and Mahgoub, "A Survey of Vehicular Ad hoc Networks Routing Protocols," *International Journal of Innovation and Applied Studies* , vol. 3, no. 3, pp. 829-846, 2013.

[14] Meenu and Bhati, "Detailed Comparative Study of Various Routing Protocols in Vehicular Ad-hoc Networks," *International Journal of Engineering Research and General Science* , vol. 3, no. 2, pp. 444-451, 2015.

[15] J. Liu, J. Wan, Q. Wang, P. Deng, K. Zhou and Y. Qiao, "A survey on position-based routing for vehicular ad hoc networks," *Telecommunication Systems*, vol. 62, no. 1, pp. 15-30, 2016.

[16] S. Boussoufa-Lahlaha, F. Semchedinea and L. Bouallouche-Medjkounea, "A position-based routing protocol for vehicular ad hoc networks in a city environment," in *International Conference on Advanced Wireless, Information, and Communication Technologies*, 2015.

[17] B. Paul and M. J. Islam, "Survey over VANET Routing Protocols for Vehicle to Vehicle," *IOSR Journal of Computer Engineering* , vol. 7, no. 5, pp. 01-09, 2012.

[18] T. Darwish, K. A. Bakar and A. Hashim, "Green geographical routing in vehicular ad hoc networks: Advances and challenges," *Computers & Electrical Engineering,* vol. 64, pp. 436-449, 2017.

[19] R. S. RAW and S. DAS, "Performance Comparison of Position-based Routing Protocols in Vehicle-To-Vehicle (V2v) Communication," *International Journal of Engineering Science and Technology,* vol. 3, no. 1, pp. 435-444, 2011.

[20] J. Hung-Chin and H. Hsiang-Te, "Moving Direction Based Greedy routing algorithm for VANET," in *International Computer Symposium*, Tainan, Taiwan, 2010.

[21] G. Jiayu, X. Cheng-Zhong and H. James, "Predictive Directional Greedy Routing in Vehicular Ad hoc Networks," in *IEEE27th International Conference on Distributed Computing Systems Workshops* , 2007.

[22] Z. Jing and C. Guohong, "VADD: Vehicle-Assisted Data Delivery in Vehicular Ad Hoc Networks," *IEEE Transactions on Vehicular Technology,* vol. 57, no. 3, pp. 1910-1922, 2008.

[23] L. Ilias and M. Cecilia, "GeOpps: Geographical Opportunistic Routing for Vehicular Networks," in *IEEE International Symposium on a world of wireless, Mobile and Multimedia networks.*, Finland, 2007.

[24] 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.

[25] C. L. Kevin, L. Uichin and G. Mario, "Survey of Routing Protocols in Vehicular Ad Hoc Networks," Advances in Vehicular Ad-Hoc Networks: Developments and Challenges, 2010.

[26] K. Brad and H. T. Kung, "GPSR: Greedy Perimeter Stateless Routing for Wireless," in *International Conference on Mobile Computing and Networking*, USA, 2000.

[27] S. Kaur and K. Kaur, "An New Improved GPSR (I-GPSR) Routing Protocol For VANET," *Imperial Journal of Interdisciplinary Research* , vol. 2, no. 7, pp. 1190-1196, 2016.

[28] A. Fonsecaa and T. Vaz˜aoa, "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.

[29] C. Lochert, H. Hartenstein, J. Tian, H. Fussler, D. Hermann and M. Mauve, "A routing strategy for vehicular ad hoc networks in city environments.," in *Proceedings of the intelligent vehicles symposium*, Germany, 2003.

[30] B.-C. Seet, G. Liu, B.-S. Lee, C.-H. Foh, K.-J. Wong and K.-K. Lee, "A-STAR: A Mobile Ad Hoc Routing Strategy for Metropolis Vehicular Communications," in *International Conference on Research in Networking* , Berlin Heidelberg , 2004.

[31] C. Lochert, M. Mauve, H. Fusler and H. Hartenstein, "Geographic routing in city scenarios," *ACM SIGMOBILE Mobile Computing Communication Review*, vol. 9, no. 1, pp. 69-72, 2005.

[32] J. Moez, R. Meraihi, S. Sidi-Mohammed and G.-D. Yacine, "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. ACM,*, France, 2006.

[33] A. A. Abdalla, G. A. S. H. A. Hamid, S. Khan, N. Guizani and K. KO, "Intersection-based Distance and Traffic-Aware Routing (IDTAR) Protocol for Smart Vehicular Communication," in *13th International Wireless Communications and Mobile Computing Conference*, 2017.

[34] V. Naumov and T. R. Gross, "Connectivity-Aware Routing (CAR) in Vehicular Ad Hoc Networks," in *INFOCOM 26th IEEE*

International Conference on Computer Communications , Barcelona, Spain , 2007.

[35] G. Ajay and S. Kuldeep, "CAR: Intersection-based connectivity aware routing in vehicular ad hoc networks," in *IEEE International Conference on Communications (ICC)*, 2013.

[36] Y. Qing, L. Alvin, L. Shuang, F. Jian and A. Prathima, "Adaptive Connectivity Aware Routing for Vehicular Ad Hoc Networks in City Scenarios," *Mobile Networks and Applications,* vol. 15, no. 1, pp. 36-60, 2010.

[37] A. I. Saleh, S. Gameel and K. M. Abo-Al-Ez, "A Reliable Routing Protocol for Vehicular Ad hoc Networks.," *Computers & Electrical Engineering,* vol. 64, no. 1, pp. 473-495, 2017.

[38] Y. He, F. Zhang, Y. Li, J. Huang, L. Yin and C. Xu, "Multiple routes recommendation system on massive taxi trajectories," *Tsinghua Science and Technology,* vol. 21, no. 5, pp. 510-520, 2016.

[39] J. F. Bravo-Torres, M. López-Nores, Y. Blanco-Fernández, J. J. Pazos-Arias, M. Ramos-Cabrer and A. Gil-Solla, "Optimizing reactive routing over virtual nodes in VANETs," *IEEE Transactions on Vehicular Technology,* vol. 65, no. 4, pp. 2274-2294, 2016.

[40] G. Neha, D. Isha and S. Gaurav, "An Acute Position Based VANET Routing Protocol," in *International Conference on Micro-Electronics and Telecommunication Engineering*, 2016.

[41] A. Guleria and K. Singh, "POSITION BASED ADAPTIVE ROUTING FOR VANETs," *International Journal of Computer Networks & Communications* , vol. 9, no. 1, pp. 55-70, 2017.

[42] K. N. Qureshi, A. H. Abdullah and J. Lloret, "Road perception based geographical routing protocol for vehicular ad hoc networks," *International Journal of Distributed Sensor Networks,* vol. 2016, no. 2, pp. 1-16, 2016.

[43] N. S. Vasco, J. R. Joel and F. Farid, "GeoSpray: A geographic routing protocol for vehicular delay-tolerant networks," *Information Fusion*, vol. 15, pp. 102-113, 2014.

[44] C. L. Kevin, L. Uichin and G. Mario, "TO-GO: TOpology-assist Geo-Opportunistic Routing in Urban Vehicular Grids," in *Proceedings of the 6th international conference on wireless on-demand network systems and services*, 2009.

[45] S. Malika and B.-M. Louiza, "Efficient Message Delivery in Hybrid Sensor and Vehicular Networks Based on Mathematical Linear Programming," *Computers & Electrical Engineering*, vol. 64, pp. 496-505, 2017.

[46] Z. Guoan, W. Min, D. Wei and H. Xinming, "Genetic Algorithm Based QoS Perception Routing Protocol for VANETs," *Wireless Communications and Mobile Computing* , pp. 01-10, 2018.

[47] S. Hanan, L. Rami, N. Kshirasagar, B. Raouf, N. Amiya and Nishith Goel, "Intersection-Based Geographical Routing Protocol for VANETs: A Proposal and Analysis," *IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY*, vol. 60, no. 9, pp. 4560-4574, 2011.

[48] C. Yuh-Shyan, H. Chih-Shun and S. Yi-Guang, "Linear Regression-Based Delay-Bounded Routing Protocols for Vehicular Ad Hoc Networks," in *Linear Regression-Based Delay-Bounded*, Taiwan, 2010.

[49] L. Ting, C. Shan and L. Wei, "Fog computing enabling geographic routing for urban area vehicular network," *Peer-to-Peer Netw. Appl*, pp. 01-07, 2017.

[50] A. Soni and D. K. Xaxa, "Position Based Routing protocols in VANET for Better Link Quality: A Survey," vol. 4, no. 4, 2015.

[51] F. Holger, H. Hannes, W. Jörg, M. Martin and E. Wolfgang, "Contention-Based Forwarding for Street Scenarios," in *In 1st International workshop in intelligent transportation*, 2004.

[52] U. R. Sabih, A. K. M, A. Z. Tanveer and Z. Lihong, "Vehicular Ad-Hoc Networks (VANETs) - An Overview and Challenges," *Journal of Wireless Networking and Communications,* vol. 3, no. 3, pp. 29-38, 2013.

[53] V. Jindal and P. Bedi, "Vehicular Ad-Hoc Networks: Introduction, Standards, Routing Protocols and Challenges," *International Journal of Computer Science,* vol. 13, no. 2, pp. 44-55, March 2016.

[54] B. Karp and H. T. Kung, "GPSR: Greedy Perimeter Stateless Routing for Wireless," in *Proceedings of the 6th annual international conference on Mobile computing and networking*, Boston, Massachusetts, USA , 2000.

[55] J. M, D. C. Chanrasekar and D. K. Jayasudha, "A New Approach on Step CLlustering Based Greedy Routing in Vehicular Ad Hoc Networks," *Journal of Theoretical and Applied Information Technology,* vol. 95, no. 2, pp. 310-318, 2017.

[56] B. T. Sharef, R. A. Alsaqoura and M. Ismail, "Comparative Study of Variant Position-Based VANET Routing Protocols," *Procedia Technology,* vol. 11, pp. 532-539, 2013.

[57] B. Flavio, M. Rodolfo, Z. Jiang and A. Sateesh, "Fog Computing and Its Role in the Internet of Things," in *Proceedings of the first edition of the MCC workshop on Mobile cloud computing,* Helsinki, Finland, 2012.

[58] M. Mukherjee, R. Matam, L. Shu, L. Maglaras, M. A. Ferrag and N. Choudhury, "Security and Privacy in Fog Computing: Challenges,"

Intelligent Systems for the Internet of Things , vol. 5, pp. 19293-19304, 2017.

[59] N. Takayuki, S. Ryoichi, T. Takahashi and B. M. Narayan, "Service-Oriented Heterogeneous Resource Sharing for Optimizing Service Latency in Mobile Cloud," in *Proceedings of the International Workshop on Mobile Cloud Computing & Net-working*, Bangalore, India., 2013.

[60] H. Pengfei, D. Sahraoui, N. Huansheng and Q. Tie, "Survey on fog computing: architecture, key technologies, applications and open issues," *Journal of Network and Computer Applications,* vol. 98, pp. 27-42, 2017.

[61] M. JAGADEESAN, C. CHANDRASEKAR and K. JAYASUDHA, "A New Approach on Step Clustring Based Greedy Routing in Vehicular Ad hoc Networks," *Journal of Theoretical and Applied Information Technology* , vol. 95, no. 2, pp. 310-318, 2017.