Destination Oriented Routing Protocol for VANETs

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Dedication

I dedicate this work to my Parents, Asma, Misbah, Samee, Ayesha and my Chachu who always supported and encouraged me to work hard and make a change.

Certificate of Originality

I hereby declare that this submission titled "Machine learning based Intelligent Transport System (Routing algorithm) for VANETS " is my own work. To the best of my knowledge it contains no materials previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any degree or diploma at NUST SEECS or at any other educational institute, except where due acknowledgement has been made in the thesis. Any contribution made to the research by others, with whom I have worked at NUST SEECS or elsewhere, is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except for the assistance from others in the project's design and conception or in style, presentation and linguistics, which has been acknowledged. I also verified the originality of contents through plagiarism software.

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Abstract

Vehicular Adhoc Network (VANET) has went through some major technological advancements in the last ten years. VANET is now considered a crucial component of ITS (Intelligent Transportation System). Due to the presence of environment limitations such as mobility, reliable routing and sparse connectivity, effective message delivery and efficient use of bandwidth is a major issue in VANET. These problems cause frequent topological changes in the network which consequently affects network performance. In our proposed Destination Orientation Routing (DOR), vehicle destination is adopted as an important factor for the formation of network topology and delivery of messages. The vehicle shares its destination with the neighboring nodes. Then by using their destination, a topology is formed between the vehicles which are in close proximity to each other. Such topology formation based on destination increases network stability and improves overall packet delivery ratio between the communicating vehicles.

Chapter 1

Introduction

According to the year 2020 annual road safer report released by World Health Organization (WHO), road accidents were the reason of the death of nearly 1.35 M people each year globally [38]. Furthermore, as per estimates around more than 60 percent of the vehicles are owned by the people whose income are low-or-middle income countries and the same time, around 93 percent of all global road-related injuries and deaths worldwide are caused in these countries. There is an increasing need to find the ways to reduce the traffic accidents so that previous lives can be saved.

Vehicular-Ad-hoc-Network (VANET) has become the vital study areas with the main focus on increasing the road safety by allowing the vehicles share the information with each other on the road. VANET is type of self-serving and self-organizing network consisting of vehicles as network nodes. One of the biggest advantages of VANET is that in this type of networks vehicular nodes can connect with each other independent of any centralized control. VANET's involves mobile nodes i.e. vehicles which are equipped with the instruments which are used for communication known as On-board Units (OBUs). These sensors are the main components for the connectivity among nodes. Moreover, if needed, Road Side Units aka RSU can be used by the vehicles to perform indirect communication which are permanently installed on the both ends of the road and work as access points for getting information. Since, VANET allows the sharing of the information by the mobile nodes. It can play its role in ensuring road safety by allowing the vehicles to share the road-safety-information with other vehicles in an ad-hoc network or every vehicular node can be connected with the internet services via RSUs and share the safety-information with other mobile nodes without the need of any adhoc network. According to Yong et al. [15], the VANET architecture is made up of vehicle and infrastructure components. The vehicle's workings are made up of the circuits known as On-Board-Unit (OBU) and the application that will allow the OBU to communicate. Furthermore, infrastructure components are RSUs that are often linked to the internet.

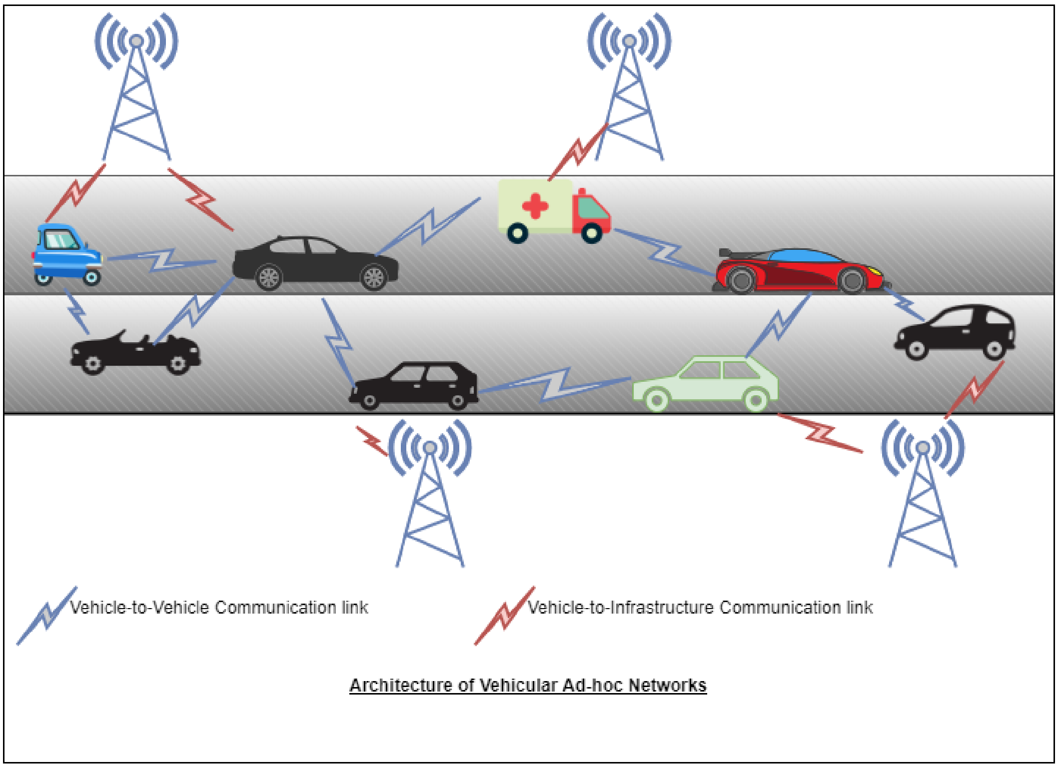

Figure 1.1: VANETs Architecture

The communication in the VANETs is categorized as Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). In V2V communication, the vehicle creates an adhoc vehicular network among the nearby vehicles and then share the information with the other vehicles in the network. In V2V, each vehicle wirelessly exchanges the information about the speed, location, direction and on the basic of this information, it is determined which vehicles can be part of the ad-hoc network. Then, these vehicles share the road safety information in form of BSM (Basic Safety Message) This aids in the prevention of accidents, the reduction of traffic congestion, and the improvement of the environment However, the biggest benefits may be realised only when all cars can interact with one another. In V2V, the communication messages can be delivered with the vehicles located in a specific range such as 300 meters. This range depends on properties of the antenna embedded onto OBU of the vehicle. The vehicles which are in the communication range, can intercept these safety messages and then interpret these messages to detect any dangers and reduces the possibility of any traffic accidents. V2V can also extend the communication by using the radars or cameras for the detection of any crash hazards. This new technology not only assists drivers in surviving a collision, but it also assists them in avoiding the collision entirely.

V2V results into an Intelligent Transportation System which if implemented properly, has the potential of significantly decreasing the accidents. The increase in road accidents in developing and underdeveloped countries highlights the need for ITS to modernize the present transportation infrastructure. In Vehicle-to-Infrastructure (V2I) communication, instead of sharing the information with each other, each vehicle shares the information through some access point which is installed on the road side. This access point is commonly known as RSU (Road Side Unit). RSU aggregates the information it receives from all the vehicles and sends it to a central server which connects to all the RSUs. The central server then uses this information to determine the most optimal and safest routes from one location to other location. This information is then shared with the vehicles through the RSUs to help them make informed decisions about their journey. For example, If a vehicle desires to find the shortest route from its current position to a specified destination, it requests the central server through RSUs, which should always contain an accurate representation of the transportation system. The biggest advantages of V2I is that central server has global view of the traffic and hence it can make best use of available information for decision making. However, the biggest limitation of V2I is single point failure and decision making of each vehicle is dependent on the server which, if goes down, takes the whole V2I network down.

1.1 Routing in VANETs

VANET is a sub type of adhoc networks, the key point which differs it from the MANETs is it's mobility pattern which changes fluently and rapid change in the existing topology. Commonly used protocols of adhoc networks are used in the MANETs and later they are tested in the vehicular adhoc networks. We need a method for assigning unique-logical-addresses to cars, nevertheless existing routing protocols do not assurance that the allocation of identical or same logical addresses would be discouraged in this adhoc networks. As a result, in an extremely VANET environment, many current address

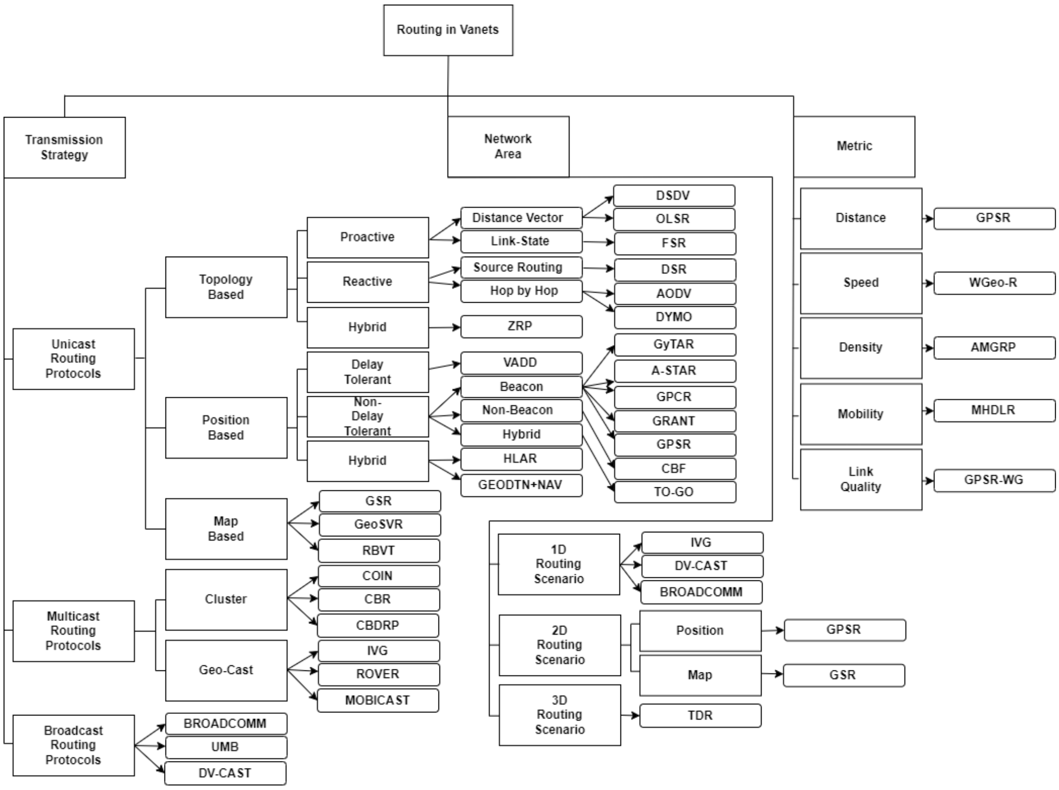

Figure 1.2: Taxonomy of VANETs Routing Protocols

assignment procedures which are useful in MANETs are not often acceptable. VANETs issues such as configuring the number of nodes at different time spans, demographics, patterns in the mobility, arbitrary random changes in vehicles joining and leaving the network, and the undeniable fact that the road's dimensions are typically less than the communication handling range; all of these make use of the adhoc routing protocols quite inappropriate and misleading.

1.2 Topology based

This protocol is dependent on the underlying network's topology [16] [7]. This protocol keeps routing tables for storing link information and passes packets from source cars to destination vehicles depending on this data. It makes routing decisions based on global information. Many existing algorithms in this category attempt to strike a balance between being aware of possible paths and minimizing control overhead. The overhead in this case refers to the bandwidth and time required to route the message. These routing methods choose the routing path for the required destination founded in the stored link information or the information retrieved when needed. Maintaining a route database or finding the path is required before forwarding the data to the destination. Topology-based routing protocols necessitate additional node topology during the routing process. Because of the high mobility in the VANET scenario, which results in recurrent network segmentation and route breakage, topology re-computation is required. The protocol is slower than any other VANET routing protocol.

1.3 Proactive Routing

Proactive routing refers to information routing [16]. Every node keeps a routing table that represents the topology, with each record representing the next relay node towards the destination. As a result, the need for discovering route in demand is eliminated because the route for the destination is always recorded in the table. Routing information tables are continuously updated and exchanged between nodes. The routing table can be updated in two ways: periodically and triggered. Size of the routing table grows with the number of increased nodes in the topology, resulting in an increase in load. Regardless of the communication demands, a table containing the next forwarding hop is kept, which means that unused pathways must be kept, thus limiting available bandwidth. Destination-Sequenced-Distance-Vector-Routing (DSDV), Optimized-Link-State-Routing(OLSR) and Fisheye-State-Routing (FSR) are much known examples. The advantage of using proactive routing is that there is no more need for route discovery and as result, the latency is decreased. This is very useful for real time application where we want the latency to be as reduced as possible. However, the drawback of using proactive routing is that it requires more resources and it increases the overall overhead.

1.4 Reactive Routing

This protocol [7] [11], commonly known as the On Demand Routing Protocol, constructs the path only when a node wishes to communicate. This significantly reduces the network's load. The protocol discovers the route during the route discovery phase by flooding packets into the network. When the query packet arrives at the destination node, the source receives the route information as reply in returned unicast communication. Routing protocols are further classed as source routing or hop to hop protocol. Only the relay node next to it and destination vehicles are specified in the former. In the latter, entire route information is included in the data packets. In terms of throughput and time, hop-by-hop routing is superior. This protocol's examples include Ad-hoc-On-Demand Distance-Vector (AODV) and Dynamic-Source-Routing (DSR). These types of routing protocols are quite efficient in nature of vanet because they do not hold any routing table as a result their overhead is also less. They saves bandwidth due to the absence of beacon. Meanwhile communication flow may disturb due to the excessive flooding, latency and delay can also be observed in search of route discovery and maintenance of such routes.

1.5 Hybrid

Such protocols are enriched with the qualities of proactive and as well of reactive routing protocols. Members of topology formed by these protocols keep the routing information of those nodes which are within the zone. For the nodes outside their zone they need to reactively calculate the path for the transmission of data. Zone-Routing-Protocol (ZRP) is the only known example of such hybrid protocols.

1.6 Position Based

This protocol, also known as Geographic routing, is the most promising of all VANET algorithms since it uses the geographical parameters for position information of every vehicle to provide routing [17] [32]. GPS, a location service, is required by the protocol. Every node knows where it is with relation to its neighbors and the destination thanks to GPS. The protocol is capable of finding the best optimal path for the destination location using GPS data. It neither maintains the routing table nor communicates status information to its neighbors. It don't require a path from the source to destination because in this type of routing forwarding is achieved by sending the data to nearest nodes by using the greedy algo. The disadvantage of this strategy is that it may fail if no such node is available. This is known as a local optimal state, and it should be addressed with using a recovery approach. Greedy forwarding performs poorly in urban environments with barriers. This algorithm, on the other hand, ensures reliable road-way routing. This protocol has three variations based on delay tolerance: delay tolerant, non-delay tolerant, and hybrid protocols. Few are the position based protocols which uses position coordinates for information spreading Connectivity-Aware-Routing (CAR) and Vehicle-Assisted-Data-Delivery (VADD) are known protocols. Such protocols are suitable for scalability with lesser overhead because of no need of the route discovery and management requirements. They are also greatly suitable for highly mobile environments. Furthermore, such protocols lost their worth in the tunnels and geographical areas where GPS services are unavailable.

1.7 Broadcast Based

This type of routing is frequently used in VANET to notify cars of emergency situations [2], [5]. This strategy is utilized if data packet to be sent to a node which is not connected directly to the source vehicle. Using flooding, a packet is sent to every node in the network. The delivery of packets is thereby ensured, but bandwidth is wasted. Broadcast performance is improved in environments with a modest number of nodes. However, the disadvantage of using broad-based routing is that more bandwidth is consumed due to flooding. Moreover, duplication of same packet is another issue. Distributed Vehicle CAST (DVCAST), BROADCOMM and Urban-Multihop-Broadcast (UMB) are known variants of this category.

1.8 Cluster Based

In cluster-based routing [12]. the protocol creates several distinct clusters in the network in a dispersed manner. The cluster formation is based on mobility metrics to preserve cluster stability, eliminating the cluster's reliance on topology. In each cluster-based topology, a cluster head is selected node based desired settings such as signal strength and time in cluster which permit communication in and outside the cluster over the prevailing unidirectional communication links. The approach effectively decreases traffic due to flooding during route finding using the clustering technique. Cluster-based routing in VANET is ideal for environments with high routing and scalability demands. Due to these characteristics, routing overhead is minimized which results into good packet delivery ratio. Clustering-for-Open-IVC-Networks(COIN), Constantbit-rate (CBR), Cluster Based Directional Routing(CBDRP), and more variants are examples of this kind. However, this routing ignores other parameters of the nodes such as velocity of mobile node and direction.

1.9 Geo-Cast Based

Geo-cast is a type of multicast communication in which a specific region serves as the destination and nodes it that particular area works as member of it [6] [1]. Unlike multicast, which delivers a packet to a random node, geo-cast transmits a packet to every node within a preset geographical area. The primary goal of the geo-cast protocol is guaranteed delivery at a cheap cost. This protocol is classified into two types based on the destination region. First one considers the closed destination which are closed to the source and second varies that destination is not as much closer to the source node as it's at a bit distance and rely on the relay node for communication. The latter set of the routing techniques is supplementary subdivided in flooding and unicast. Messages are sent to the destined locality by every vehicular node in the forwarding locality in the first subcategory. In the second type, however, a path to the destination is found and then forwarding region is selected to forward the message to the ultimate destination geo-area. Henceforth unicast has less bottleneck and operating cost as compared to the multicast. Nonetheless, flooding is used for information dissemination in the destination location. A major issue with this kind of protocol is make sure the packet spreads and reaches the long distance destination. Such networks are good enough for reliable delivery of data in the unpredictable topologies they don't produce greater overheads because of no route keeping services. Such protocols are not recommended for greater networks because transmission delays can be spoiled by the disconnection in the networks. intervehicle geocast (IVG) and ROVER are geocast routing protocols.

IVG geo hlar hybrid geo GeoDTN+nav hybrid geo, A-stargeo non delay, GSR map

Chapter 2

Literature Review

Hussain et al. [23] examined the end-to-end response in the Internet of Vehicles scenario as well as the excellence of the provided services. The accumulation is essential for the communication of vehicle which are processing the Realtime data and providing the integrating. The increased vehicle load on the network will be caused by the additional nodes that are linked and communicating. As a result, IoV requires end-to-end distribution of data without compromising the parameters of bandwidth utilization, delay, jitter and latency in the transmission which are essential for a healthy communication. QoS is used in IoV to improve network service and meet consumer requirements. The QoS factors provide devoted bandwidth and lower packet loss features, which are some key purposes of Vanets. Because the cars are dynamic in mobility and move from one location to other location with rapid change and fast speeds, the network requirements are unpredictable. However, managing and integrating all of these capabilities in the system while providing the dynamics is quite complex. When the vehicle network is autonomous, the fundamental difficulty is that when the vehicles move from one communication range may face packet loss. End-to-end services function in tandem with this kind of network. Mobile cars are viewed as nodes that transforms vigorously in response to changing conditions. They conclude that by using QoS parameter they will be able to propose a efficient QoS enabled protocol.

In [9] Cheng et al. examined specifics of the IoV-based-routing-algorithms. In order to achieve IoV, the IoV employs a generic protocol. Initially, they classify transmission schemes into three categories: broadcast, unicast, and geocast. They addressed routing protocols in the unicast category throughout much of the study. This category's applications include emergency vehicle preemption and road condition information. The last category employs the balancing kind of routing algorithms. They categorizes the information in vehicular networks into four groups depending on these details: map, location, path-based, and based on topology. However, spatial structure of those protocols thwarts them from prognostication topological gaps in the dispensing nodes. Furthermore, a few routing protocols only function in 1D and 2D scenarios and perform poorly in real-time 3D circumstances. They also examined the dependability of the vehicles' exchange of messages. A heterogeneous vehicular network technique is required for this communication. As a result, the researcher requires well-defined protocols to handle the challenges presented by the diverse nature of Vanets and the vast size. Ultimately, they advise the scholars to validate their findings in small set of the homogenous node's networks. Large-scale network of the heterogeneous nodes depends on the road side information.

Kayarga et al. [34] studied the model of IoV and examined it's technology in various applications. They primarily focus on bioinspired algorithms that are employed amongst vehicles, things, and humans. The IoV includes multiple processes for integrating vehicular nodes into the IoV ecosystem network using wireless based access network technology for these numerous uses. The IoV features such aspects which are as follows including encoding, virtual network, and data awareness that play a key part in transferring of the control data packets to the IoV in order to sustain this technology. Each topology in intervehicle networks is also preserved using this method. The primary routing topology is based on ad hoc networks. For wireless vehicle communication, this technology is more effective. It is also crucial for an IoV that is believable and managed. IoV's solution considers vehicle communication in a complicated city. By utilising a set of complex technologies in IoV they develop the ability of IoV communication. As resultant product, communication among the vehicles with hefty data volumes can increase load on the networks. To achive the efficient product in the global network of vehicular nodes highly effective and efficient techniques of optimizations are required. Furthermore, numerous issues are also arising as the number of communicational nodes are rising in the intelligent transport systems and number of sensing nodes are also rising in the smart cities. Tuyisenge et al. [20] also conducted a survey of the IoV on the market prospects for municipal transportation communication systems. It has significant challenges and problems, including traffic congestion, safety issues, pollution, and commercialization. This is all predicted, and it is clear that the IoV component will generate a massive amount of data and massive real-time IoV applications that will necessitate rapid routing. They also examined the existing protocols for IoV vehicle communication, such as IEE, 3GPP, and VANET, and employed protocol stack analysis. They ultimately present some information regarding future study linked to the mechanism of IoV between diverse networks based on the results of this survey.

Ksouri et al. [36] reviewed appropriate strategies of the routing in VANET and multi-optimization algorithms. They propose novel routing standards for the lively ecosystem of the Vanets. As per many surveys, new advances of IoV applications, as well as the introduction of autonomous vehicles creating new point of concerns of security and QoS in such kind of Adhoc networks. To keep the macro classification, their classification is based on the forwarding criterion. This type of classification is a third family in the routing protocol. It is known as "hybrid routing," and it is a blend of geographical routing and topology-based modelling. This process's function symbolizes the fusion of two routing processes. They then discussed geographical routing approaches which depends on the environment of the vehicle's, this VANET routing model can take certain route materials. This architecture is more than suitable for the networks which are of type of large scaled, as well as boosting node's security with the safety of users later they examine the progress. Next stage is critical where packet travel from one locality to another locality. It is divided into two stages: selection of forwarding node is considered as one step and in second it will handle the replying requests for the nodes. They then go over the routing enhancement strategies that are utilised to improve the entire way of routing which includes the selection of more reasonable head of the cluster, which is best relay node and what way is used for path selection. By considering such point of interests they were able to optimize the routing algorithm which really outperforms in VANETS.

In the past ten years, Vehicular Adhoc Network (VANET) has seen considerable scientific advancement. It is now considered as one of the key component in the building up an Intelligent Transportation System [10]. To provide a successful, reliable data and message delivery considering the challenging environment of VANETs such as rapid mobility, speed variance, signal fading many algorithms have been proposed already [8],[3]. The terms "mobility" and "speed" allude to the change in velocity of moving objects, that causes frequent topological changes. While signal fading relates to antenna type and propagation loss, which causes sporadic connectivity since it might occur outside of the transmission range or as a result of obstructions. The choice to transmit data is often the fundamental and central function of a routing system for the actual data delivery.

In VANETs routing is categorized in many type:

The fundamental design of the relative angle forwarding approach is compass routing. Since the lesser angle will probably head to a position nearer the end point, the method is not loop-free. In dense networks, the compass approach has a exceptional delivery rate of data, but in sparse mode of network, it has a low delivery rate. The Compass II (facial routing), which adds the capability of choosing intermediate nodes, enhances the fundamental method. By lowering the spatial distance of packet transmissions, this feature eliminates looping [4].

In ConeBased Topology Control (CBCT) [1] forms a cone area using an angle as a parameter. The cone area specifies an anticipated transmission region with a given degree. Necessary connection is defined by the degree of = 5(PI)/6 and = 2(PI)/3. Using those two degrees involves trade-offs, but the comparative angle has a big impact on maintaining the connectivity and shrinking the communication range.

The route will be disrupted by constantly altering topology and nodal congestion. Routing in the Vehicle Ad hoc Networks is always a challenging job due to network physical characteristics like as high nodal mobility, frequently evolving network topology, and significantly subdivided network segments. [19].

The effectiveness of a routing protocol is determined by both internal characteristics such as node movement and other external factors which involves signal blocking barriers and path metrics. It necessitates a extremely adaptable strategy to dealing with complicated scenarios by selecting the appropriate plan of action for the process of routing and forwarding and employing requisite adaptability and transmission models. Communication among V2I is always considered as most challenging scenario in the routing in vanets [25].

Routing protocols are crucial in ad hoc networks since they are in charge of establishing and managing routes that enable multi-hop communication and extend the network's coverage area. Furthermore, VANET routing protocols are configured for various situations while taking into account the vehicle network's core aspects and inadequacies, such as node mobility, congestion, and bandwidth restrictions [13].

CBR aka Cluster-based-routing methods offer consolidated control and it's quite effective for avoiding dispersion in extremely clogged networks. Protocols designed for low-latency operations rely on the provided information or the information provided by the topology. After all, there are various ways for determining the ideal protocol for effective QoS routing based on various criteria such as like latency in end-to-end communication, network stability, low collision rate, external interference, and so on. [35].

Although application-oriented categorization diverge, generic criteria have been utilized to study and classify them more usual manner. VANET routing protocols are categorized as V2I or V2V changing on whether the vehicles uses networks to relay packets to the terminal node as destination[24].

In VANET, routing can be classified into several important categories, which are: Position, Broadcast, Multicast/Geo-cast, and Cluster-Based Protocols are all examples of routing protocols. A typical categorization of routing protocols is always based on which transmission tactic is suggested, with protocols classified as unicast, multicast, broadcast, or geocast [14].

There are various approaches for constructing a network system. Data transfer between vehicles is one of the most problematic issue in VANET planning ever since it necessitates the development of complicated routing protocols. Because of the relatively complex architecture, traditional MANET in-routing varies from VANET routing [31].

A location-based protocol bases routing rulings on the car's geological coordinate's location [30]. This does not require the construction or management of a road, but rather the use of geographic means to determine the direction of the common interest point. Global Positioning System routing protocols are DREAM-Location-Services, Reactive-Location-Services. and Simple-Location-Services are all positions extensively used by providers [29]. Place-based routing techniques are becoming increasingly important with the introduction of GPS-based location services.

It is the highly commonly used protocol for routing in VANETs, particularly in safety-critical applications. Where in broadcast mode, packets are sent to all network nodes, and every node will keep re-broadcasts the message to other network vehicles[33]. Flooding is widely used technique of routing protocol in the broadcasting. Product of blind flooding leads to the broadcast storms which will overload channel's available bandwidth, causing channel overcrowding and lowering transmission competence[18]. It's also utilized in VANET to communicate road traffic, climate conditions, and road or roadside accidents, as well as send marketing and broadcasts.

Adhoc network grouping can be defined as fundamental segmentation of categorised nodes in hierarchy into multiple classes. A number of nodes identify themselves as cluster members [19][21]. Cluster-heads are dedicated nodes that are in charge of routing jobs, messages among cluster communication, organising intra-cluster traffic, and allocating and managing the channels to the members of the cluster. Within clusters, cluster routing is always preferred. Numerous nodes distinguish themselves as members of the specific cluster, and the cluster head may broadcast messages to the cluster [26]. Large-scale networks can be created with good scalability, however lags and network overhead are encountered when establishing rapid-mobility vehicular clusters.

Multicast routing allows messages to be delivered from a single hub to a collection of nodes with same point of interest. Geocast based routing is simply a location-aware multicast routing technique that aims to distribute info from the given source vehicle to all other nodes which are within a particular terrestrial region [19][28]. Geocast is a multicast facility that serves a specific geographic region. Typically, it selects the forward zone where it relays packet inundating to reduce the message overhead and it will also cut the network latency caused by flooded data packets all over the place [22].

In [37] Singh et al. empasises on a metric based protocol, for applications including health monitoring, the WGeoR protocol predicts node movement direction using speed metrics. That vehicle's degree refers to any vehicles that are within communication range. Because of the high density in hop-by-hop selection, many network disconnections may be avoided and density metrics can be used to predict route dependability.

The DSQR protocol [27] based its forwarding decisions on mid-area node selection; to choose the optimal next forwarder node toward the destination node, it assesses the direction and distance of neighbour nodes as well as link quality. For next-hop selection distance is a crucial factor. GPS is used to calculate node positions, and the Trigonometric theorem is applied to measure the distance between sources and their neighbouring nodes. This idea focused on multilevel flyovers, bridges, tunnels, and over underpasses while taking into account the use of a 3D environment for distance estimation. DSQR takes into account MAC channel-quality measurement. Signal strength and average link quality (ALQ), which take into account both past and present channel quality, are used by DSQR to assess channel quality. The middle and edge of the transmission range are defined by DSQR using node distance. It lowers the likelihood of the following forwarder breaking, packet errors, and latency to give mid-area nodes a greater priority. The source node uses the carry forwarding strategy if there isn't a vehicle node in the middle.

Table 2.1: Comparative Analysis of VANETs Routing Protocols

Year	Category	Protocol	FA	RA	NS	DM	MM	PM	Tools	Delay
2000	GeoNDNT	GPSR	G	F	H	Y	MTS	PS	NS-2	M
2002	HB	ZRP	MHF	MHF	C	N	U	U	NS-2	M
2003	R	AODV	MHF	SF	C&H	N	IMG	PS	NS-2	M
2004	GeoNDNT	A-STAR	G	F	C	Y	IMG	RB	NS-2	L
2004	Cluster	CBLR	MHF	F	C	Y	RWP	RB	NS-2.29	L
2004	BC	UMB	MHF	F	C	Y	FW	RB	WS&MATLAB	L
2005	BC	BROADCOMM	G	F	H	Y	RWP	RB	-	M
2007	P	DSDV	MHF	MHF	C	N	RWP	RP	NS-2	L
2007	R	DSR	MHF	SF	C	N	RPG	PL	NS-2	M
2007	BC	DVCAST	O	SF	H	N	RWP	FS	NS-2	M
2007	Geocast	ROVER	G	F	C	N	RWP	RB	OMNET++	M
2008	GeoDNT	VADD	O	SF	C	Y	U	U	NS-2	L
2010	GeoHB	GeoDTN+Nav	HB	PF	H	Y	VMS	RB	NS-2	L
2010	Cluster	CBDRP	MHF	SF	C	Y	RWP	RB	NS-2	M
2012	GeoHB	HLAR	G	PF	H	Y	RWP	RB	NS-2	L
2012	Geocast	IVG	G	SF	C	Y	RWP	RB	Omnet++	M
2019	Geocast	EGPSR	G	F	H	N	U	U	NS-2	L
2020	MB	DSQR	G	SF	C&H	N	MOM	PS	NS-2.34	L
2021	MB	W-GeoR	G	PF	C	Y	RWP	TWG	NS-3.23	L

FA: Forwarding Approach	RA: Recovery-Approach	NS: Network-Scenario
DM: Digital-Map	MM: Mobility-Model	PM: Propagation-Model
BC: Broadcast	C: City	F: Flooding
FS: FreeSpace	FW: Free Way	GeoDNT: GeographicDNT
GeoHB: Geographic Hybrid	GeoNDNT: GeographicNonDNT	G: Greedy
H: Highway	HB: Hybrid	IMG: IDMonManhattanGrid
L: Less	MB: Metric Based	MHF: Multi Hop Forwarding
M: More	MOM: Move Mobility	O: Opportunistic
PL: PathLoss	P: Proactive	PF: Perimeter Forwarding
PS: Probabilistic Shadowing	RP: Radio Propagation	RWP: Random Way Point
RPG: ReferencePointGroup	R: Reactive	RB: Road Blocking
TWG: Two: way: Ground	U: Unknown	VMS: Vanet Mobsim

Problem Statement and Contribution

The problem with above discussed routing schemes is that none of these have focused on the destination of vehicles as an important factor for neighbor node selection for the topology creation. It is understood that if the topology creation is influenced by the destination of the neighboring vehicles, it can have a more positive effect on the topology formation and consistency and may allows the vehicles to stay connected with each other for a longer period of times since these vehicles are moving in the same direction and having the close proximity of their destinations. Hence, each vehicle selects the neighboring node on the basis of its current location and destination. The resulting network topology will be more consistent requiring less frequent topology changes but will also increase overall network efficiency. To the best of our knowledge, there is no protocol which considers destination as an important factor for the selection of nodes in network topology.

Chapter 3

Proposed Solution

In our work, we propose a new routing approach for VANET which adopts the vehicle destination as one of the important factor for the selection of neighboring vehicle and path selection. To the best of our knowledge, in none of the previous works which we discussed in the literature, any routing approach has used the destination.

In our proposed work, we introduce a new routing metric Communication Compatibility Metric (CCM) which is the sum of the three other perimeters Communication Feasibility Metric (CFM), Location Compatibility Metric (LCM) and Destination Compatibility Metric (DCM). CFM is calculated by using the following formula. In our proposed scheme communication range is 250m, location distance is the distance between vehicle and any vehicle which is within the communication range, and it must be between 0 and 250 meters.

$$CFM = \left(\frac{(R - LocationDistance(L_{ij})}{RelativeVelocity(\delta v_{ij})}\right) \tag{3.0.1}$$

whereas R = Range of Communication

In the above equation 3.0.1, R represents the maximum communication range in a peer to peer connection between two neighboring vehicles. The location distance Lij is the distance between the current locations of the two neighboring vehicles i and j at time T and Vij is relative velocity of vehicle i with respect to vehicle j at time T. To calculate the relative velocity, we used the following formula:

$$\delta V_{ij} = \sqrt{(V_i - V_j)^2 + 1} \tag{3.0.2}$$

Our second metric Destination Compatibility Metric (DCM) takes the destination of the neighboring vehicles into consideration. To determine the value of DCM, we first find out the destination difference (Dij) between vehicles i and j. Dij is the distance between the destination of ith node and jth node and every vehicle is calculating it locally after certain interval. The vehicle i will receive the vehicle parameters of vehicle j in response of the BSM packet which it will broadcast. Each node in communication range R of vehicle i will send a response packet in which it will send its parameters such as location, velocity, direction. However, in our proposed scheme, the vehicles will also send their destination location in response of any received hello packet. DCM can be calculated as following.

$$DCM = (\frac{D_{max} - D_{ij} + 1}{Dmax}) * 10 \tag{3.0.3}$$

In the above formula, Dij represents the distance between the destination location of vehicles i and j. Dmax represents the maximum allowed difference between the destinations of vehicles i and j. If the destination difference between any neighboring two vehicles i and j is greater than Dmax then according to our proposed scheme, we do not allow a end-to-end communication between the two. In other words, for the DCM to have an acceptable value in our case, Dij $<$ Dmax all the time.

Location Compatibility Metric (LCM) is our last parameter for the calculation of our CCM. It is calculated by using the communication range R between vehicles i and j and location distance. The formula for calculating DCM is give below:

$$LCM = (\frac{R - L_{ij} + 1}{R}) * 10 \tag{3.0.4}$$

According to our proposed scheme, as soon as a vehicle i enters the simulation environment, it broadcasts a beacon which is received by all the vehicles in its communication range R. In the response of the beacon, each vehicle in the communication range prepares a response packet containing its location, direction, velocity and destination and sends it back to the broadcasting vehicle. Suppose a vehicle unicasts a response packet back to vehicle i. After receiving the packet, the vehicle i will first check the direction value of the vehicle j to check if the vehicle j is moving in the same direction as vehicle i. For this purpose, the vehicle i takes into consideration its own direction angle i and the direction angle j vehicle j and then determines the movement direction of vehicle j by using the following formula:

$$\delta\theta_{ij} = (\theta_i - \theta_j + 180)\%360 - 180 \tag{3.0.5}$$

If the value of ij is less than 60 then vehicle i and j will be moving into same direction. Otherwise, both vehicles will be moving in the different direction. For selection as a neighboring, the vehicle i will only consider those vehicles which are moving in the same direction as vehicle i itself. For any neighbor of vehicle i, if ij < 60, that node is included in the list of its neighbor nodes list. Next, for each node in the its neighbor nodes list, the vehicle i will calculate the CCM value. After calculating the CCM, the vehicle i will select only that nodes as the best next hop node which is not only going in the same direction but also has the highest CCM value as compared to other nodes in the its neighbor list. For our proposed solution, we have set the maximum communication range of 250 meters which means R = 250. Moreover, we have set the maximum allowed destination distance to be 1000 meters. In other words, if the destination distance between vehicle i and j is greater than 1000, then vehicle j will not be included in the neighbor list of vehicle i. Hence, the decision of a vehicle to select a next hop at any point depends on many different factors such as vehicle location, direction, velocity and most importantly the final destination of the vehicle. This gives the vehicle more chances to select the best possible next hop node considering its destination.

Below given image shows the step by step working of our proposed algorithm using a flow chart. The below given flow charts only shows the process after some vehicle, say i receives a response packet from any node in its communication range. As soon as the vehicle i receives the response packets, it reads the vehicle parameters such as location, direction, velocity and direction. Let's assume that the vehicle i received the response from vehicle j. As a first step of neighbor selection, the vehicle i determines the direction of the vehicle j by using the equation (v). As a result of the equation, if the calculated value is less than 60 then it is assumed that vehicle j is heading into same direction as vehicle i and it is included into its neighbor list. If relative direction angle is not less than 60 then it is assumed that vehicle j is moving in a different direction as compared to vehicle i and hence vehicle j is discarded and not included in the neighbor list of vehicle i.

In the next step, the vehicle i using the distance of the vehicle j to calculate the destination distance Dij and then compares it with the maximum threshold value Dmax. Dmax is the maximum allowed distance between the destinations of vehicle i and j. In other words, after calculating the destination distance between vehicle i and j, if it is found that the direction distance between i and j is greater than maximum allowed destination distanced Dmax, then vehicle j is not considered as a neighbor for vehicle j. Otherwise, in the next step, the vehicle i calculates the value of DCM for vehicle j.

In the second stage, the vehicle i uses the velocity of the vehicle j to calculate the relative velocity Vij by using the equation (ii). The relative velocity is then used in the next step to calculate the value of our CFM. In the next step, the relative velocity for vehicles i and j is calculated and then by using this velocity, the value of CFM is calculated. As for any other routing algorithm, the current location of the vehicles plays a very important role in the selection of neighbor. The closer the vehicle in the neighbor, the more chances it has to become part of the local topology. Therefore, in our proposed algorithm, we consider the current location of the neighboring vehicles to calculate the value of CFM.

Finally, we calculate the value of CCM by adding the values of LCM, DCM and CFM. The vehicle i periodically calculates the CCM value for each node in its neighbor list. Then, its selects the node with highest CCM value as the best node for forwarding.

The 3.1 represents the working on our proposed algorithm. The vehicle i broadcasts a Hello packet which is received by all the nodes in its communication range. Each node which receives the Hello packet prepares a response packet containing its vehicle parameters such as current location, velocity, direction, destination and sends back to vehicle i. The vehicle i then extracts the vehicle parameters from each incoming packet. For each incoming packet, it first checks the direction angle of the vehicle and then by using the equation 3.0.5, determines if the vehicle has the same direction as itself or if it is going in a different direction. Any vehicle not having the same direction as vehicle i, will be ignored. For vehicles having the same direction as vehicle i, the next step is to calculate the Location Compatibility Metric (LCM) and Destination Compatibility Metric (DCM). Based on these metrics, the vehicle i calculates the Communication Compatibility Metric for each of the vehicles which are in its communication range and are going in the same direction as vehicle i. After calculating the CCM, vehicle i selects the vehicle with the highest CCM as its next hop for forwarding of data. In the figure

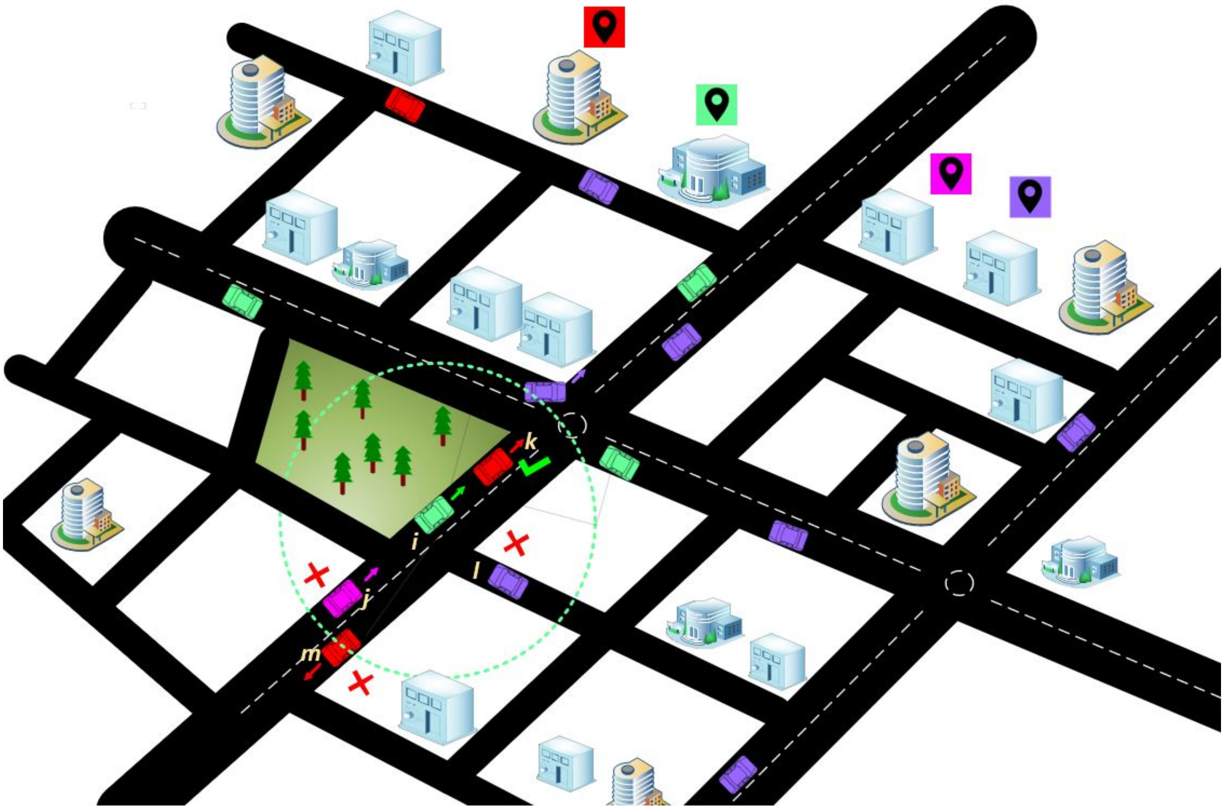

Figure 3.1: Route calculation

3.1, the tick sign with vehicle k shows that vehicle k had highest CCM value for vehicle i therefore vehicle i selects vehicle i its next hop node for data forwarding.

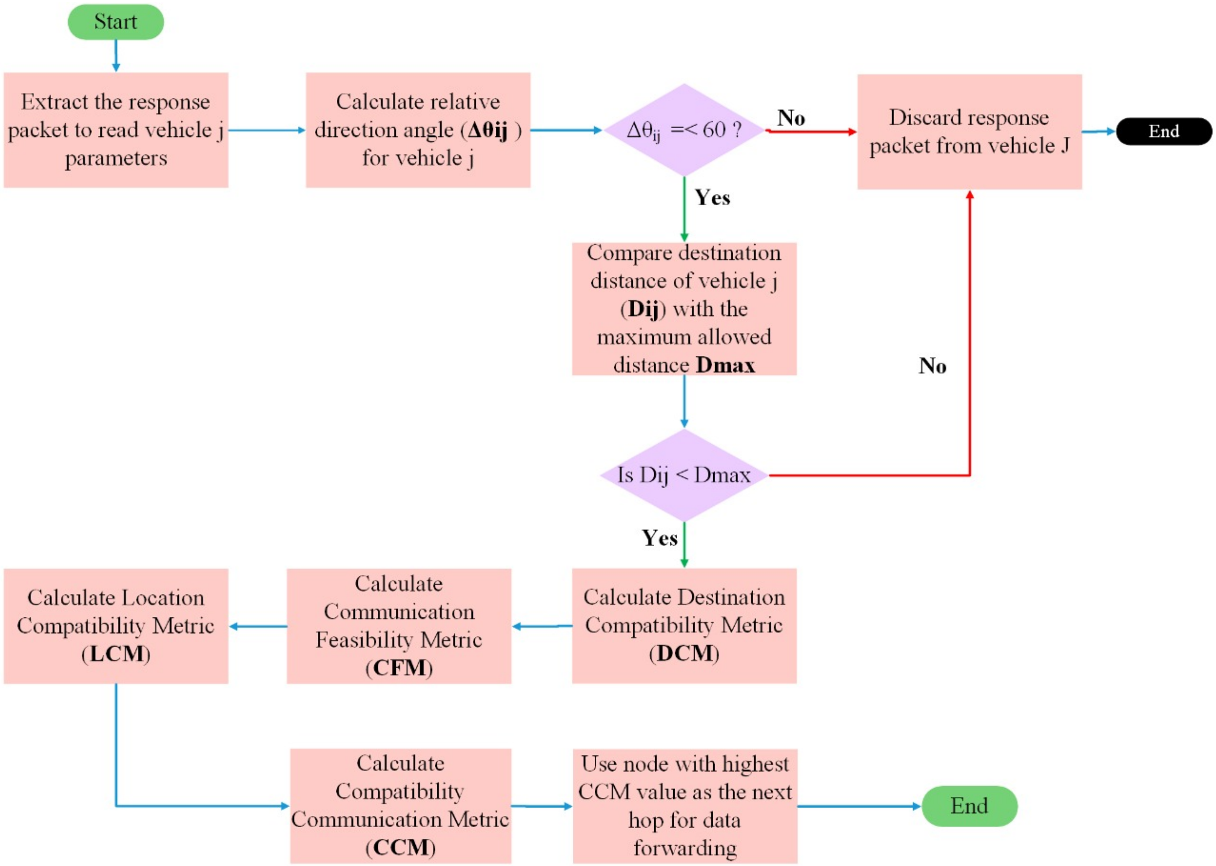

Figure 3.2: Flow of Route calculation

Chapter 4

Implementation

Simulation Work

The simulation environment for our proposed algorithm is based on NS-2.35 implementation. The scenario was implemented on a 2.5x2.5 square km of chunk of map of F-10 sector of Islamabad which is the capital city of Pakistan[39]. The map is shown in the figure 4.1. Moreover, we have used network traces which were taken from SUMO, which is a highly portable open-source designed as simulation packet for continuous traffic. For our simulation, we assumed that there were no barriers or distortion in the signal transmission between vehicles and the vehicles could freely send packets in their communication range without any barriers. The chunk of map we used for our simulation environment which we obtained from OSM is below:

For our simulation work, we set the maximum communication range of 250 meters and destination distance range of 1000m. The destination distance is the distance (in meters) between the final destinations of the two vehicles which want to become the neighbors. To implement our proposed algorithm, we have modified the AODV protocol and named it as AODV-KAL. We ran our simulation for 600 seconds by periodically increasing the number of vehicles on the map. In our simulation, each vehicle sends a BSM after every 1.5 seconds. The other details of simulation parameters are given in the table below:

The below given figure shows the view of the simulation in process. Each number shown in the figure represents a vehicle in the network. The circles represent the broadcast of packets by different vehicles.

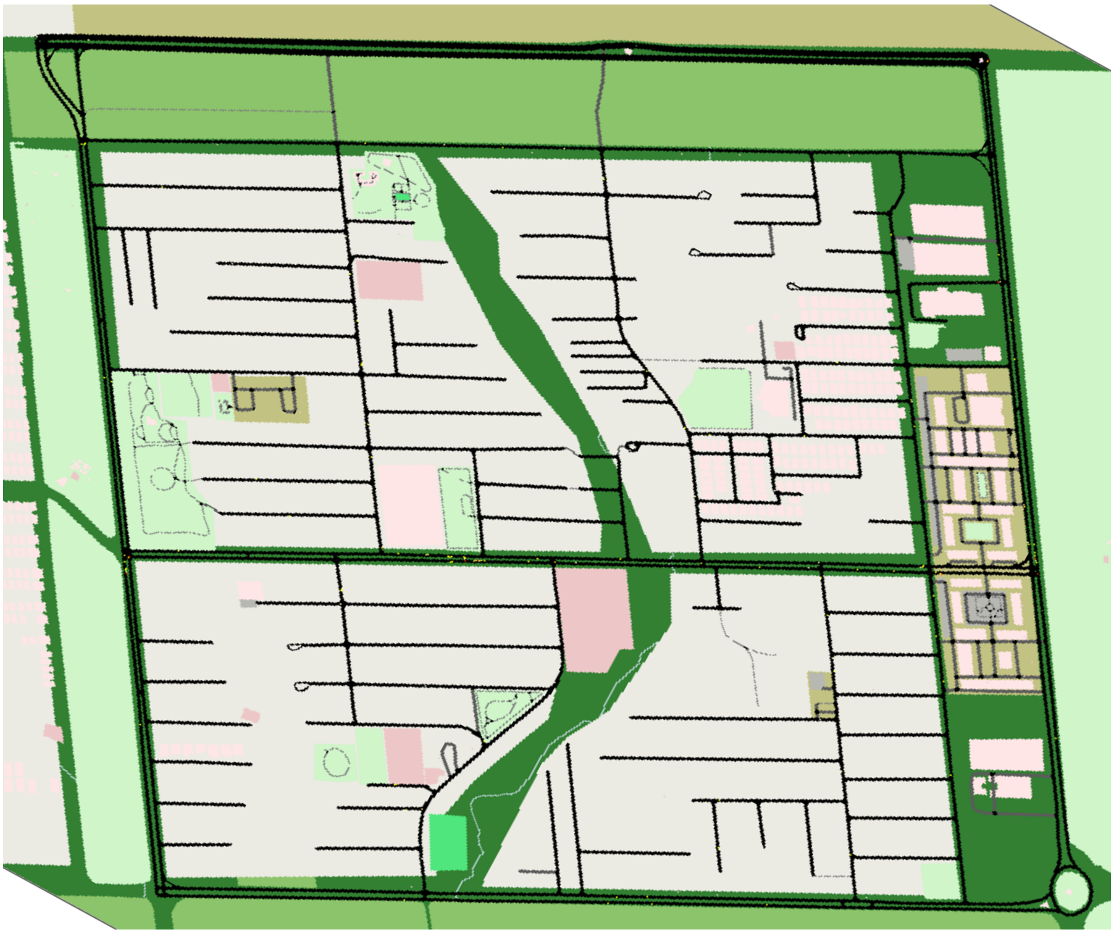

Figure 4.1: Map of F-10 with mobile nodes

Table 4.1: Simulation Parameters

Parameter	**Value**
Mobility Model	Random Traces (OpenStreetMap)
Area	Sector F-10, Islamabad
Map Size	2.5km x 2.5km
Simulation Time	600sec
Vehicle Number	50, 100, 150 and 200
Transmission Range (Lij)	250m
Destination Range (Dmax)	1000m
Physical Layer	IEEE802.11p
Packet Type	UDP
Routing Protocol	AODV, eGPSR, AODV-kal
Hello Messages	1.5 sec

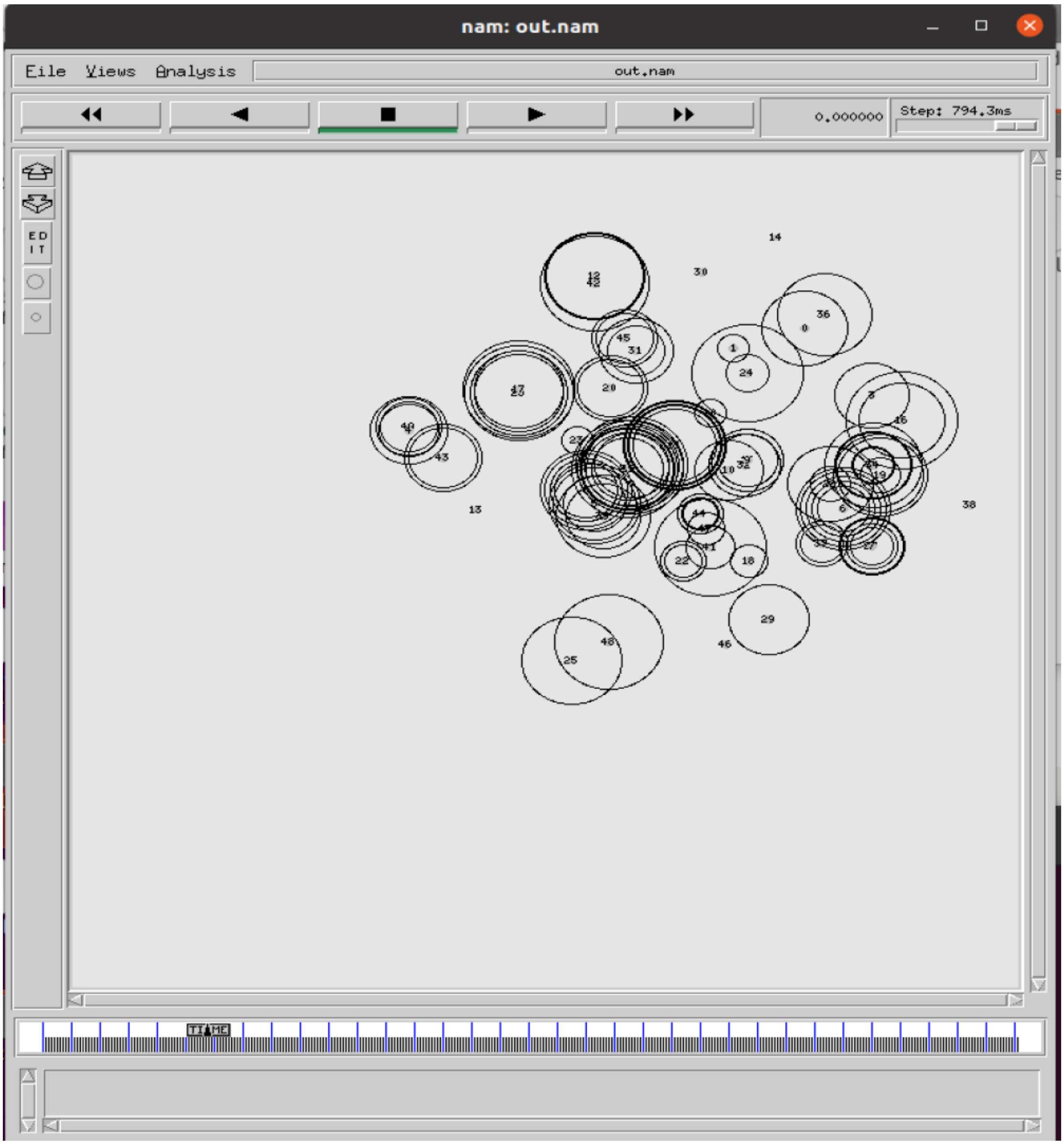

Figure 4.2: NAM Traces

Chapter 5

Discussion

5.1 Results and Analysis

For the performance comparison of our proposed algorithm, we selected two algorithms. One, a legacy VANET routing protocol AODV and another recently proposed routing algorithm eGPSR. For the comparison and analysis of results, we implemented eGPRS, AODV as well as our proposed algorithm AODV-Kal. To make it sure that the results are consistent and accurate, we have used the same simulation environment and repeated by simulation by gradually increasing the number of vehicles and communication links. For comparison of our proposed algorithm with the existing algorithms, we selected overhead and end-to-end delay as a performance metrics.

5.2 Packet Overhead Comparison

5.2.1 Packet Overhead with 50 mobile nodes

The below given 5.1 shows the simulation results for overhead. In our case, overhead represents the number of packets which were sent by the nodes during neighbor discovery and route discovery process. Initially, we used 50 vehicles on the map and repeated the simulation by gradually increasing the communication links. As we can see from the given graph that when using 50 vehicles in our simulation, the overall overhead of our proposed algorithm is more than both AODV and EGPSR. This is due to the less traffic density and when there are less nodes on the map, it is difficult for the node to make a node selection based on the destination only. It means that in case of a smaller number of vehicles, it is very difficult for a vehicle to find a vehicle which is not only in its communication range but moving towards the same direction or having the close proximity of destination. Hence, due to this reason, the overall overhead increases in the network due to small traffic density. We can see that if even if we increase the communication links, it does not have any effect on decreasing the overall overhead. Hence, from the given result, we can assume that our proposed algorithm doesn't perform well in the situation when there are less vehicles on the map.

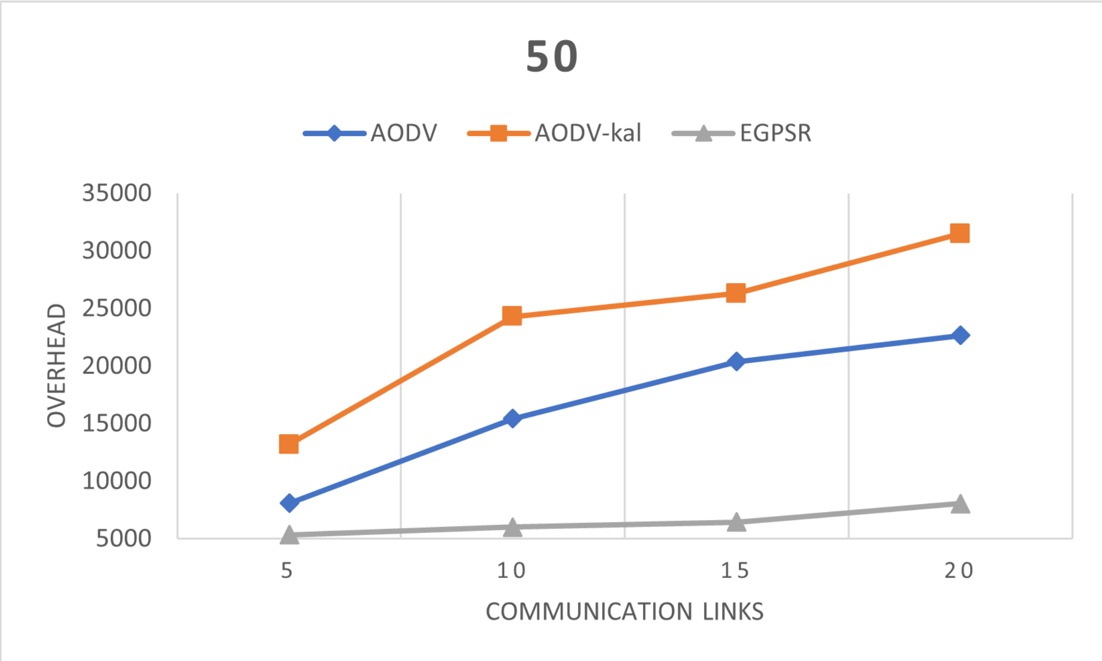

Figure 5.1: Packet Overhead with 50 mobile nodes

5.2.2 Packet Overhead with 100 mobile nodes

The below given 5.2 shows the simulation results for overhead in which we used 100 vehicles on the map. Initially, we started the experiment by using 5 communication links and repeated the simulation by gradually increasing the communication links. From thhe graph, it is evident that when using 100 vehicles, the overall overhead of our proposed algorithm is much improved as compared to 50 vehicles for the same experiment, when comparing the results with AODV. This is due to the reason that when we increase the vehicles on the map, the traffic density increases and it becomes denser. Due to this reason, there is a high chance that a vehicle may be able to find sufficient neighbor vehicles in its surrounding and the number of dropped packets decreases. As a result, the

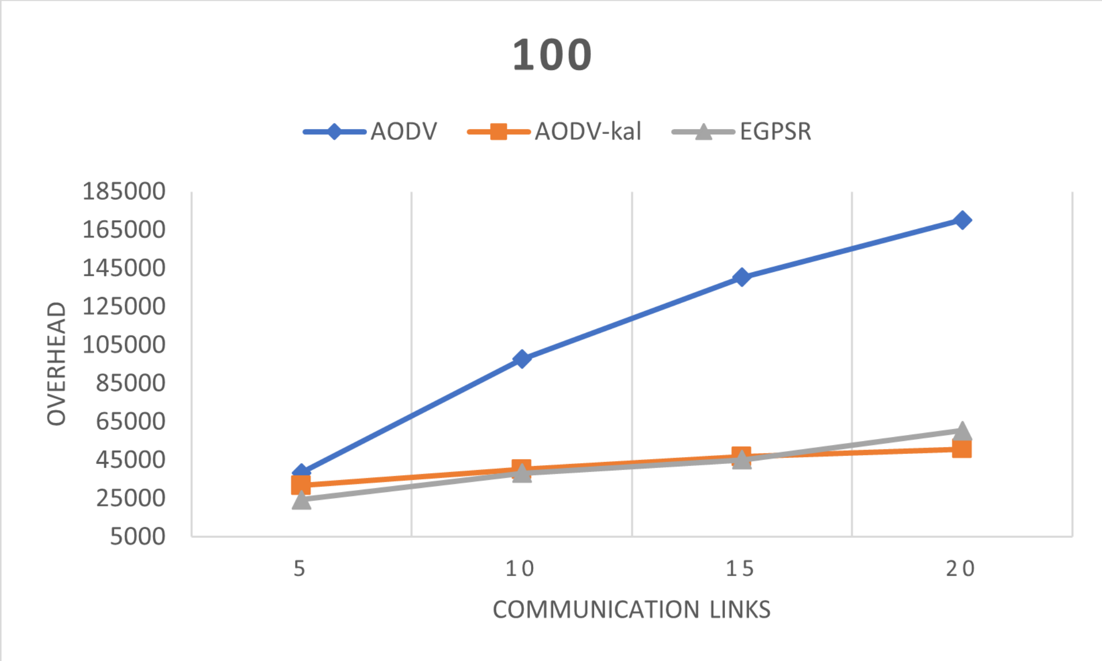

Figure 5.2: Packet Overhead with 100 mobile nodes

overall overhead also reduces with the increased number of communication links. Hence, we conclude that our proposed algorithm performs better as compared to AODV for a dense traffic environment. For 5 communication links, the overhead of our proposed algorithm is improved by 53% as compared to AODV. However, when comparing with eGPSR, its under-performs by margin of around 5% which is negligible.

5.2.3 Packet Overhead with 150 mobile nodes

We repeated the experiment by increasing the vehicles to 150 vehicles and the communication links between the vehicles. From the graph shown in the 5.3, we have see that the results of our proposed solution are better when comparing with both AODV and eGPSR. As compared to AODV, the overhead in our proposed algorithm is improved by 79% and 47% for AODV and eGPSR respectively. Hence, our proposed solution outperforms both algorithms when the traffic density is further increased. It is because of the reason that as the number of nodes increases in the topology, there is very high chance that a vehicle may be able to find some vehicles in its neighborhood which are likely to have its destination in the close proximity of its destination and so these vehicles are more likely to create a communication link. In the presence of such situation, the topology becomes more stable resulting into a reduced overhead.

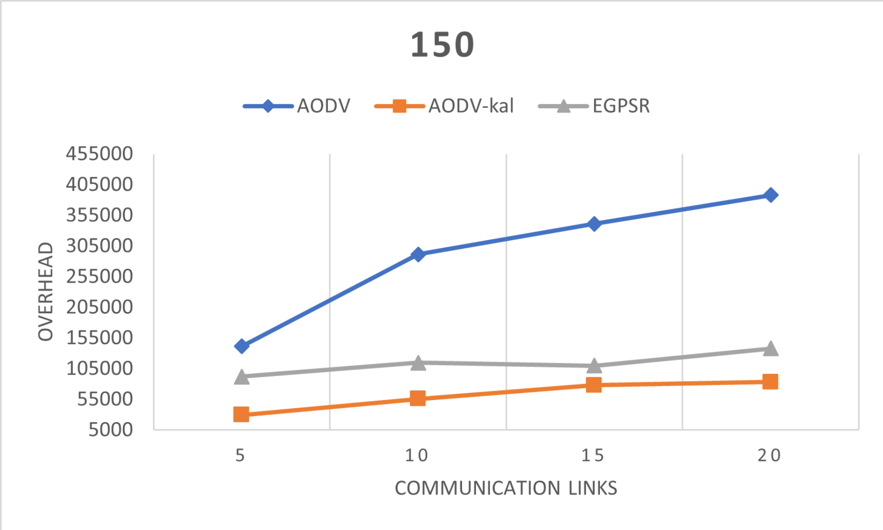

Figure 5.3: Packet Overhead with 150 mobile nodes

5.2.4 Packet Overhead with 200 mobile nodes

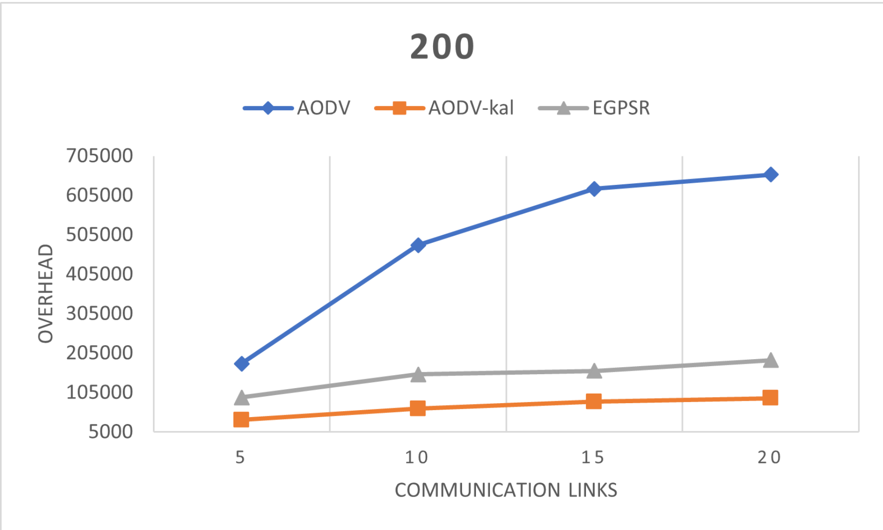

Figure 5.4: Packet Overhead with 200 mobile nodes

We carried out the experiment again, this time with 200 vehicles and communication lines between them. We can observe from the graph in 5.4 that the outcomes of our suggested method are superior to both AODV and eGPSR. The overhead in our suggested algorithm is reduced by 84% and 54% for AODV and eGPSR, respectively, compared to AODV. In light of this, our suggested method performs better than both algorithms as the traffic density is increased. The reason for this is that as the topology's node count grows, there is a very high likelihood that a vehicle will be able to locate other vehicles in the area that are likely to be headed in the same general direction as it, increasing the likelihood that these vehicles will establish a communication link. When such a condition exists, the topology becomes more stable, which lowers overhead.

5.3 End to End Delay Comparison

In this section, we computed the results for end to end delay for vehicular adhoc networks and compared it with existing protocols AODV and eGPSR. End-to-end delay is measured in the milliseconds (ms). To perform the evaluation we executed the simulation for numerous times with different communication links and gradually increasing number of nodes.

5.3.1 End to End Delay with 50 mobile nodes

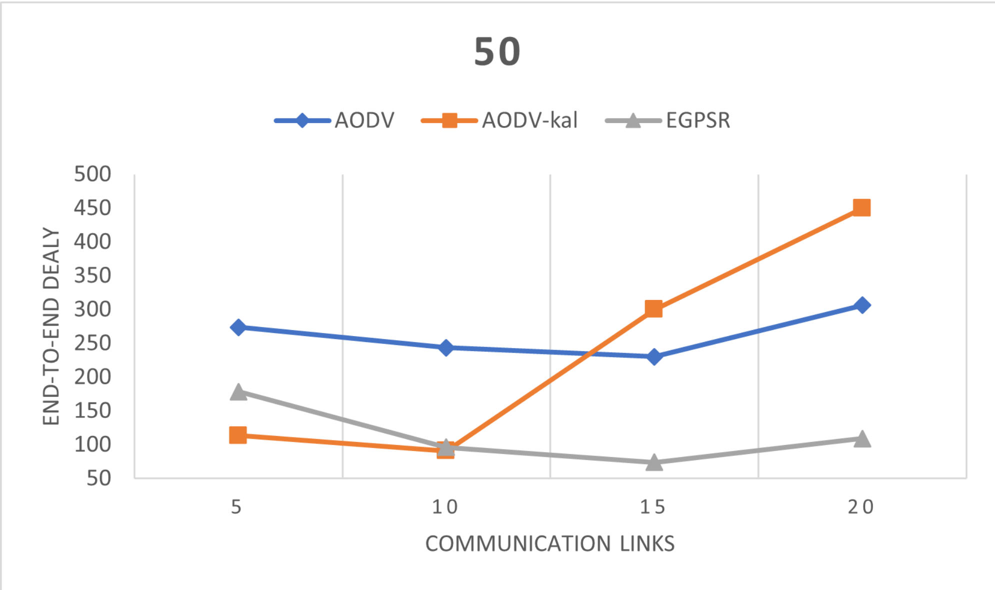

Figure 5.5: E2E Delay with 50 mobile nodes

5.5 depicts the end to end delay performance of AODV, AODV-kal and eGPSR with 50 number of mobile nodes and 5, 10, 15 and 20 communication links. In this scenario our protocol did not performed well as the number of nodes are far from each other and can not find the right neighbours to send and receive data packets. In earlier stage stages our protocol performed 11% better the AODV and 20% efficient as compared to EGPSR but later the efficiency reduces as the gap increase among the nodes.

5.3.2 End to End Delay with 100 mobile nodes

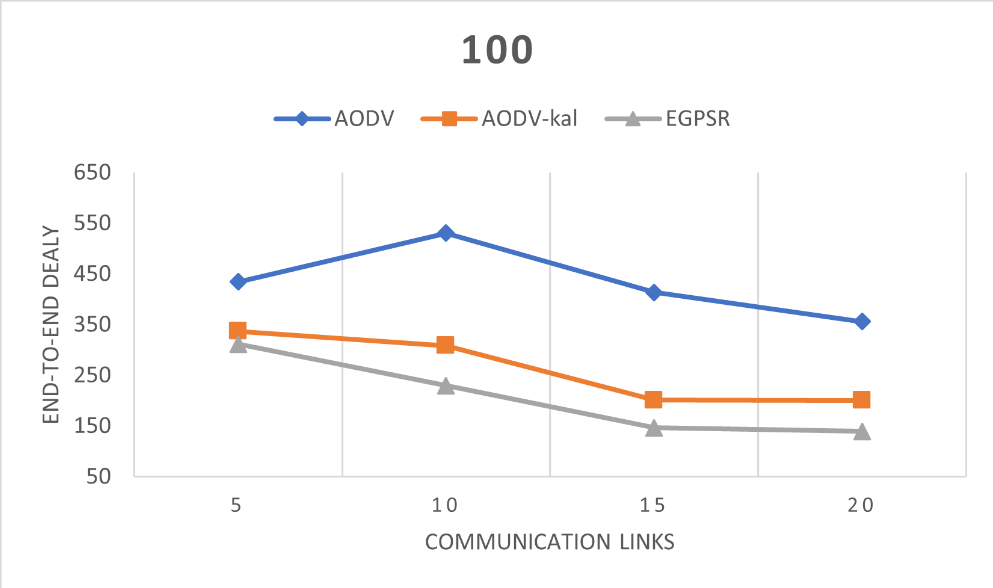

Figure 5.6: E2E Delay with 100 mobile nodes

Figure 5.6 portray the simulation results of 100 mobile nodes with a number of communication links implemented for communication. Our proposed scheme start performing better as compared to AODV and improved the delay around 39% but it's unable to find the best scenarios where it can outperform. We can ignore such delays as the number of nodes increases in the map end to end delay will be keep going downwards.

5.3.3 End to End Delay with 150 mobile nodes

In fig 5.7 we simulated on the same map but using different number of nodes and communication links. In this environment, initially our scheme was unable to perform as the number of nodes were active in the simulation but as the number of active nodes rises our proposed model started to work efficiently. As the number of mobile nodes increases and more communication feasibility exists for the information exchange perspective. Our scheme performance was 12% effective as compared eGPSR and around 60% less delay friendly.

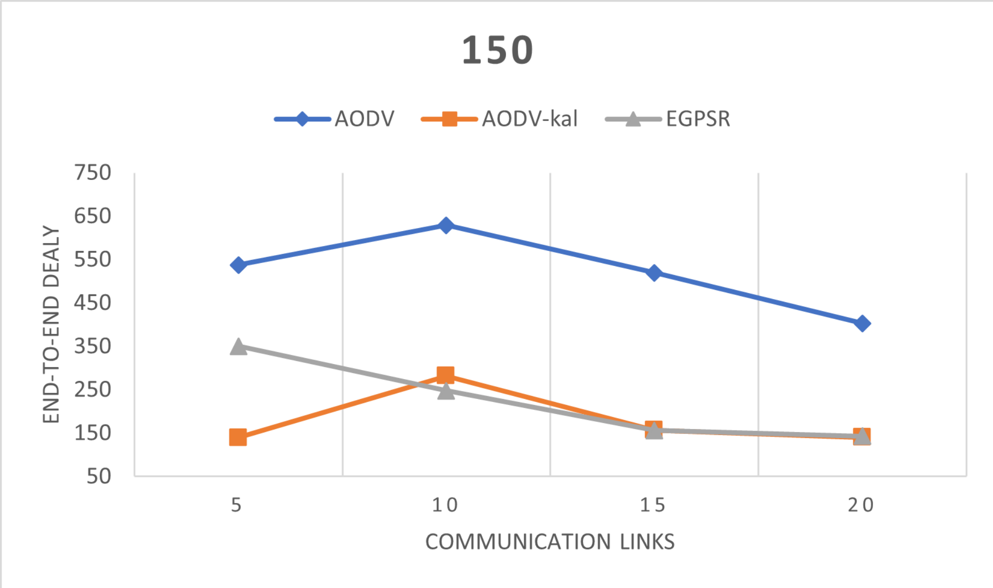

Figure 5.7: E2E Delay with 150 mobile nodes

5.3.4 End to End Delay with 200 mobile nodes

In fig 5.8 simulation results of 200 nodes with multiple communication link exist as the nodes are enough to form topology and choose best next neighbour performance of our AODV-kal improves significantly. These results illustrates the effectiveness of the scheme over 200 nodes in a territory. Performance in term of end to end delay is 16% good with respect to EGPSR and 62% as compared to AODV protocol.

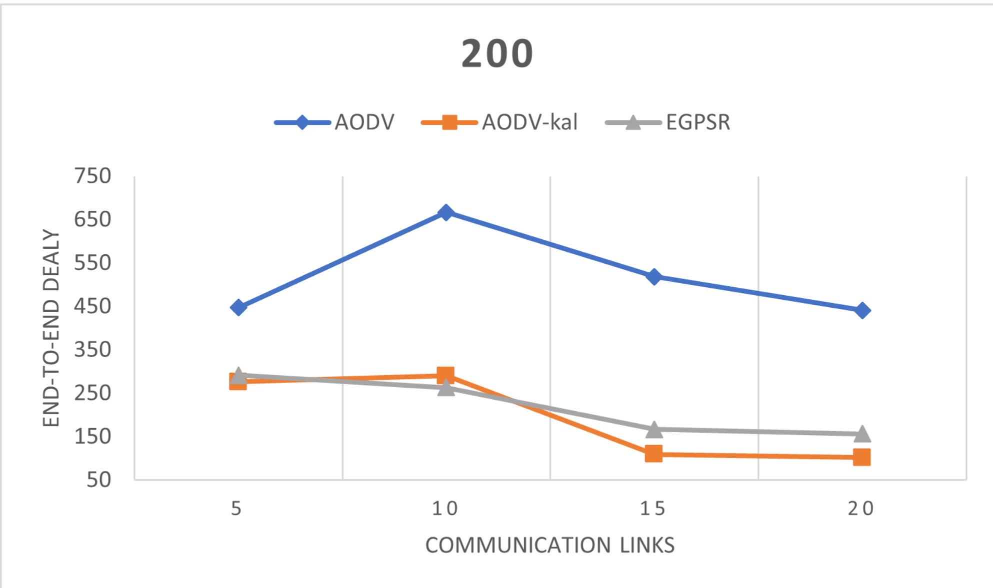

Figure 5.8: E2E Delay with 200 mobile nodes

Chapter 6

Conclusion

In this work we proposed a destination-oriented routing protocol for VANETs. We assumed that our vehicular nodes are sharing an extra parameter of destination along with location, direction and velocity of the vehicle. In this work we introduced a new routing metric Communication Compatibility Metric (CCM) which is the sum of three other calculated metrics Communication Feasibility Metric (CFM), Location Compatibility Metric (LCM) and Destination Compatibility Metric (DCM). In CFM we checked the feasibility of the communication that is it in the suitable range for communication with respect to the location distance and relative velocity of the vehicles. In our second metric DCM we narrowed down the destination parameter as we already shared the destination parameter with the neighboring nodes we specifies is it suitable to start communicating using these neighbors will stay for longer time or not as result our topology persists for longer time period. In the third and last metric used in CCM which is LCM we preferred the nodes which are in the close proximity so we can start forming a topology among them by selecting favorite node for forwarding the data need to be selected by the sum of all of these metrics.

We computed the results by running the simulation by a number of time with different parameter using such as using same scenario with 50, 100, 150, and 200 mobile nodes with multiple sets of communication links i.e. 5, 10, 15, and 20. We considered the end to end delay and routing overhead as a matter of performance evaluation metric for our proposed scheme. Our proposed scheme did not outperform in the presence of a very small number of mobile nodes but as the number of nodes increase along with the number of communication links our proposed scheme achieves what is proposed for. By using 100, 150 and 200 nodes in the 2.5x2.5 km2 area our scheme was able to achieve upto 70 percent lesser overhead as compared to the existing routing protocol AODV and 31 percent lesser over head as compared to eGPSR. Meanwhile our scheme also performed very well in the end to end delay, as compared to AODV it performed upto 56 percent lesser delay and 5 percent lesser delay as compared to eGPSR routing mechanism.

6.0.1 Future Work

In future work, we will implement the communication of the mobile nodes with the roadside units. So, we can use the data to implement newer Machine Learning models with the data received from the vehicular nodes. It will help reduce the overheads with more accuracy.

Bibliography

[1] Fan Li and Yu Wang. "Routing in vehicular ad hoc networks: A survey". In: *IEEE Vehicular Technology Magazine* 2.2 (2007), pp. 12–22. ISSN: 15566072. DOI: 10.1109/MVT.2007.912927.

[2] Ozan Tonguz et al. "Broadcasting in VANET". In: *2007 Mobile Networking for Vehicular Environments, MOVE* (2007), pp. 7–12. DOI: 10.1109/MOVE.2007.4300825.

[3] Jing Zhao and Guohong Cao. "VADD: Vehicle-assisted data delivery in vehicular Ad hoc networks". In: *IEEE Transactions on Vehicular Technology* 57.3 (2008), pp. 1910–1922. ISSN: 00189545. DOI: 10.1109/TVT.2007.901869.

[4] Christian Poellabauer Waltenegus Dargie. *Fundamentals of Wireless Sensor Networks: Theory and Practice*. 2010, pp. 166–186. ISBN: 978-0-470-97568-8.

[5] Uma Nagaraj and Poonam Dhamal. "Network and Complex Systems Broadcasting Routing Protocols in VANET". In: 1.2 (2011), pp. 13–20.

[6] Salim Allal and Saadi Boudjit. "Geocast routing protocols for VANETs: Survey and guidelines". In: *Proceedings - 6th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, IMIS 2012* (2012), pp. 323–328. DOI: 10.1109/IMIS.2012.133.

[7] Kashif Naseer Qureshi and Abdul Hanan Abdullah. "Topology based routing protocols for VANET and their comparison with MANET". In: *Journal of Theoretical and Applied Information Technology* 58.3 (2013), pp. 707–715. ISSN: 18173195.

[8] Ying He et al. "A link state aware hierarchical road routing protocol for 3D scenario in VANETs". In: *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 8662 LNCS (2014), pp. 11–20. ISSN: 16113349. DOI: 10.1007/978-3-319-11167-4{_}2.

[9] Jiujun Cheng et al. “Routing in internet of vehicles: A review”. In: *IEEE Transactions on Intelligent Transportation Systems* 16.5 (2015), pp. 2339–2352. ISSN: 15249050. DOI: 10.1109/TITS.2015.2423667.

[10] Amelia C. Regan and Rex Chen. *Vehicular ad hoc networks*. 2015, pp. 29–35. ISBN: 9781782422112. DOI: 10.1016/B978-1-78242-211-2.00002-7.

[11] Awos Kh Ali, Lain Phillips, and Huanjia Yang. “Evaluating VANET routing in urban environments”. In: *2016 39th International Conference on Telecommunications and Signal Processing, TSP 2016* (2016), pp. 60–63. DOI: 10.1109/TSP.2016.7760829.

[12] Priyanka Batavia et al. “Study of Broadcasting Protocols in Vehicular Ad-Hoc networks”. In: *International Journal of Engineering Trends and Technology* 36.8 (2016), pp. 439–445. DOI: 10.14445/22315381/ijett-v36p279.

[13] Tasneem Darwish and Kamalrulnizam Abu Bakar. “Lightweight intersection-based traffic aware routing in Urban vehicular networks”. In: *Computer Communications* 87 (2016), pp. 60–75. ISSN: 01403664. DOI: 10.1016/j.comcom.2016.04.008. URL: http://dx.doi.org/10.1016/j.comcom.2016.04.008.

[14] Huma Ghafoor and Insoo Koo. “Spectrum-Aware Geographic Routing in Cognitive Vehicular Ad Hoc Network Using a Kalman Filter”. In: *Journal of Sensors* 2016 (2016). ISSN: 16877268. DOI: 10.1155/2016/8572601.

[15] Xie Yong et al. “Efficient and secure authentication scheme with conditional privacy-preserving for VANETs”. In: *Chinese Journal of Electronics* 25.5 (2016), pp. 950–956. ISSN: 10224653. DOI: 10.1049/cje.2016.08.027.

[16] R. Brendha and V. Sinthu Janita Prakash. “A survey on routing protocols for vehicular Ad Hoc networks”. In: *2017 4th International Conference on Advanced Computing and Communication Systems, ICACCS 2017* 6.2 (2017), pp. 94–103. DOI: 10.1109/ICACCS.2017.8014615.

[17] Neha Goel, Gaurav Sharma, and Isha Dhyani. “A study of position based VANET routing protocols”. In: *Proceeding - IEEE International Conference on Computing, Communication and Automation, ICCCA 2016* October (2017), pp. 655–660. DOI: 10.1109/CCAA.2016.7813803.

[18] Ajay Guleria and Kuldeep Singh. "Position based adaptive routing for VANETs". In: *International Journal of Computer Networks and Communications* 9.1 (2017), pp. 55–70. ISSN: 09749322. DOI: 10.5121/ijcnc.2017.9105.

[19] Kashif Naseer Qureshi et al. "Cluster-based data dissemination, cluster head formation under sparse, and dense traffic conditions for vehicular ad hoc networks". In: *International Journal of Communication Systems* 31.8 (2018), pp. 1–16. ISSN: 10991131. DOI: 10.1002/dac.3533.

[20] Livinus Tuyisenge et al. *Network Architectures in Internet of Vehicles (IoV): Review, Protocols Analysis, Challenges and Issues*. Vol. 11253 LNCS. Springer International Publishing, 2018, pp. 3–13. ISBN: 9783030050801. DOI: 10.1007/978-3-030-05081-8{_}1. URL: http://dx.doi.org/10.1007/978-3-030-05081-8_1.

[21] Xiaolu Cheng and Baohua Huang. "A center-based secure and stable clustering algorithm for VANETs on highways". In: *Wireless Communications and Mobile Computing* 2019 (2019). ISSN: 15308677. DOI: 10.1155/2019/8415234.

[22] E. Gurumoorthi and A. Ayyasamy. "Cache Agent Based Location Aided Routing Protocol Using Direction for Performance Enhancement in VANET". In: *Wireless Personal Communications* 109.2 (2019), pp. 1195–1216. ISSN: 1572834X. DOI: 10.1007/s11277-019-06610-9. URL: https://doi.org/10.1007/s11277-019-06610-9.

[23] Shaik Ashfaq Hussain et al. "A Review of Quality of Service Issues in Internet of Vehicles (IoV)". In: *Proceedings - 2019 Amity International Conference on Artificial Intelligence, AICAI 2019* (2019), pp. 380–383. DOI: 10.1109/AICAI.2019.8701299.

[24] Chong Zhao et al. "An analytical model for interference alignment in broadcast assisted vanets". In: *Sensors (Switzerland)* 19.22 (2019), pp. 1–27. ISSN: 14248220. DOI: 10.3390/s19224988.

[25] Ayesha Amjid, Abid Khan, and Munam Ali Shah. "VANET-Based Volunteer Computing (VBVC): A Computational Paradigm for Future Autonomous Vehicles". In: *IEEE Access* 8 (2020), pp. 71763–71774. ISSN: 21693536. DOI: 10.1109/ACCESS.2020.2974500.

[26] Xiang Bi et al. "A new affinity propagation clustering algorithm for V2V-Supported VANETs". In: *IEEE Access* 8 (2020), pp. 71405–71421. ISSN: 21693536. DOI: 10.1109/ACCESS.2020.2987968.

[27] "Distance and signal quality aware next hop selection routing protocol for vehicular ad hoc networks". In: *Neural Computing and Applications* 32.7 (2020), pp. 2351–2364. ISSN: 14333058. DOI: 10.1007/s00521-019-04320-8. URL: https://doi.org/10.1007/s00521-019-04320-8.

[28] Luis R. Gallego Tercero, Rolando Menchaca Mendez, and Mario E. Rivero-Angeles. "Spatio-temporal routing in episodically connected vehicular networks". In: *Computacion y Sistemas* 24.4 (2020), pp. 1539–1559. ISSN: 20079737. DOI: 10.13053/CYS-24-4-3467.

[29] Meriem Houmer et al. "SE-GPSR: Secured and Enhanced Greedy Perimeter Stateless Routing Protocol for Vehicular Ad hoc Networks". In: *International Journal of Interactive Mobile Technologies* 14.13 (2020), pp. 48–64. ISSN: 18657923. DOI: 10.3991/ijim.v14i13.14537.

[30] Raj K. Jaiswal. "Position-based routing protocol using Kalman filter as a prediction module for vehicular ad hoc networks". In: *Computers and Electrical Engineering* 83 (2020), p. 106599. ISSN: 00457906. DOI: 10.1016/j.compeleceng.2020.106599. URL: https://doi.org/10.1016/j.compeleceng.2020.106599.

[31] Ravie Chandren Muniyandi, Faizan Qamar, and Ahmed Naeem Jasim. "Genetic optimized location aided routing protocol for VANET based on rectangular estimation of position". In: *Applied Sciences (Switzerland)* 10.17 (2020). ISSN: 20763417. DOI: 10.3390/APP10175759.

[32] Ankita Srivastava, Arun Prakash, and Rajeev Tripathi. "Location based routing protocols in VANET: Issues and existing solutions". In: *Vehicular Communications* 23 (2020), p. 100231. ISSN: 22142096. DOI: 10.1016/j.vehcom.2020.100231. URL: https://doi.org/10.1016/j.vehcom.2020.100231.

[33] Tianjiao Zhang and Qi Zhu. "EVC-TDMA: An enhanced TDMA based cooperative MAC protocol for vehicular networks". In: *Journal of Communications and Networks* 22.4 (2020), pp. 316–325. ISSN: 19765541. DOI: 10.1109/JCN.2020.000021.

[34] Tanuja Kayarga and S. Ananda Kumar. “A Study on Various Technologies to Solve the Routing Problem in Internet of Vehicles (IoV)”. In: *Wireless Personal Communications* 119.1 (2021), pp. 459–487. ISSN: 1572834X. DOI: 10.1007/s11277-021-08220-w. URL: https://doi.org/10.1007/s11277-021-08220-w.

[35] M. Ye, L. Guan, and M. Quddus. “TDMP: Reliable Target Driven and Mobility Prediction based routing protocol in complex Vehicular Ad-hoc Network”. In: *Vehicular Communications* 31 (2021). ISSN: 22142096. DOI: 10.1016/j.vehcom.2021.100361.

[36] Chahrazed Ksouri et al. “Towards general Internet of Vehicles networking: Routing protocols survey”. In: *Concurrency and Computation: Practice and Experience* 34.7 (2022), pp. 1–35. ISSN: 15320634. DOI: 10.1002/cpe.5994.

[37] “W-GeoR: Weighted Geographical Routing for VANET’s Health Monitoring Applications in Urban Traffic Networks”. In: *IEEE Access* 10 (2022), pp. 38850–38869. ISSN: 21693536. DOI: 10.1109/ACCESS.2021.3092426.

[38] https://www.who.int/health-topics/road-safety. *Road traffic injuries.*

[39] OSM. “OpenStreetMaps”. In: (). URL: https://www.openstreetmap.org/node/66347043.

Appendix A

First Appendix

The separate numbering of appendices is also supported by LaTeX. The *appendix* macro can be used to indicate that following chapters are to be numbered as appendices. Only use the *appendix* macro once for all appendices.