International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August 2019

A Systematic Classification of Routing In Vehicular Ad Hoc Networks

Sandeep Kad, Vijay Kumar Banga

Abstract*: *Vehicle ad hoc network (VANET) is a promising aspect in intelligent transportation system (ITS) which is getting considerable attention from researchers. In this vehicles formulate a self-organized network with an aim to provide better traffic safety as well as enhance the travelling comfort for the commuters. VANET does not depend upon fixed infrastructure. In contrast to MANETs, the node positions in VANETs keep on changing very rapidly thus it becomes a big challenge to route the information to its destination. In this paper we have surveyed different aspects highlighting architecture, applications, communication technologies, routing protocols, mobility models & simulating tools of VANETs. Finally some research gaps are listed which if addressed can result in an improved overall driving experience.

Keywords: Dedicated short range communication (DSRC), Intelligent transport system, Mobility models, Routing protocols, Vehicular ad hoc network

I. INTRODUCTION

Keeping in view the speed and number of vehicles on road, safety of the commuters is of utmost importance and VANET being an important component of ITS leads to promising possibilities that enhances safety and comfort of travelers [1]. Drivers can be alerted well in advance about the traffic density and road conditions [2] etc. The issues that contributes to the need of the development of VANET is the growing traffic problems faced by the majority of the nations across the globe, resulting in lowering of operational efficiency and increase in air pollution. According to the report, due to vehicular accidents, there have been more than 32 thousand fatalities causing 3.9 million injuries [3]. Due to traffic jams travelers in the United States alone wasted 6.9 billion hours on roads with additional fuel consumption of 3.1 billion gallons leading to monetary loss of about $160 billion [4]. VANET is relatively a new member in the family of wireless environment.

Revised Manuscript Received on August 30, 2019.
* Correspondence Author
Sandeep Kad*, Research Scholar, Department of Computer Science and Engineering, IKG Punjab Technical University, Kapurthala, India. kadsandeep@yahoo.com
Vijay Kumar Banga, Department of Electronics and Communication Engineering, Amritsar College of Engineering and Technology, Amritsar, India. vijaykumar.banga@gmail.com

In contrast to MANETs, nodes in VANETs travel on the road instead of moving randomly i.e. the mobility of vehicular nodes is confined by road network and traffic conditions [2]. VANET comprises of vehicles as nodes which are capable of wireless communication so that useful information can be exchanged as and when required [5]. This exchange of information (e.g. warnings about road accidents, low bridges, snow or slippery road, pollution and other road conditions etc.) creates an awareness amongst the drivers about the environment in its periphery and the intentions of other vehicle drivers on the wheels [6]. VANET architecture includes communication between vehicles called V2V, communication of vehicles with infrastructure deployed on the roadside which is often referred to as V2I and hybrid communication comprising both vehicular nodes and road side infrastructure as well. VANET components include of application unit (AU), on board unit (OBU) and road side unit (RSU). OBU is installed on the vehicles that supports communication amongst the vehicles and RSU's using wireless access vehicular environment (WAVE). It provides wireless access using radio technology and assists in controlling control congestion, transfer information, secure data and IP mobility. AU is installed in vehicles separately or it may reside as a single unit within OBU. It uses communication capabilities of OBU. Vehicles are also equipped with sensors that can collect a variety of information to be shared with others [6]. V2V is a kind ad hoc environment where vehicles communicate with one another. Due to economical limitations, physical infrastructure like access points and communication towers cannot be deployed at all the places. Fig. 1 depicts a V2V environment. Vehicles by means of equipment fitted on them like OBU's and sensors collect information relating to road conditions like accidents, jams etc. and disseminate this information to other vehicles so that they are well aware in advance and can take an alternative path towards their destination. The vehicular nodes can communicate even out of the line of sight or beyond its communication range by building a multi-hop network of vehicles with several other vehicles fitted with OBU's and other necessary equipment.

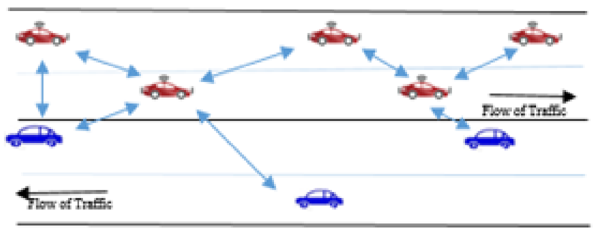

Fig. 1. V2V communication

In V2I communication, vehicles communicate with infrastructure deployed on road side generally referred to as RSU's for disseminating or gathering information. In these systems, for accessing internet wireless access points (WAP)

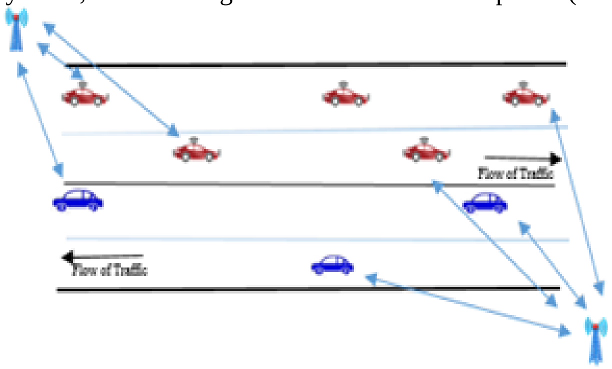

Fig. 2. V2I communication

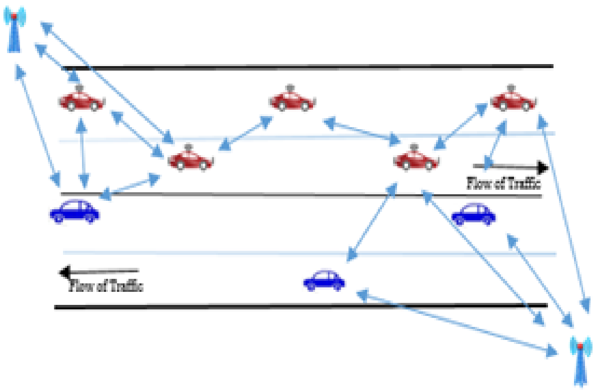

Fig. 3. Hybrid communication

and cellular gateways are deployed permanently at traffic junctions and along the highways. Thus V2I communication provides link with high bandwidth. RSU deployment depends upon the communication protocol i.e. they may be evenly distributed or may be deployed at intersection points only or at region borders. The communication is quite smooth due to the presence of infrastructure, but for a vehicle to be connected to RSU at all times is something which is unrealistic. Fig. 2 depicts V2I communication. Hybrid communication comprises of both V2V and V2I communication in VANET. WAP and cellular towers are deployed on the road side. Depending upon the distance, vehicles can communicate with RSU's directly (i.e. single hop communication) or indirectly through intermediary vehicles (i.e. multihop communication) in case RSU is outside the communication range of vehicle, thus enabling communication at longer distances. Fig. 3 depicts hybrid communication.

The information dissemination in VANETs can be a (i) push model (ii) pull model (iii) hybrid model. In the first case the information to be disseminated is broadcasted periodically whereas in pull model data is disseminated whenever demanded, in the case of hybrid model both push/pull approaches are used to aid number of applications [5].

A. VANET characteristics

VANET characterization can be done on the basis of simulation studies or real time experiments. The effects of frequent topological changes or network partitions on a large scale can be observed through simulation studies whereas the impact of interference due to many factors can be visualized through experimental studies. VANETs characterization includes:

1) High mobility

The vehicle flow on highways is at extremely high speed as a result the communication period between vehicular nodes is relatively very small. Moreover, vehicular movement at high velocity leads to frequent variation in topology because of this, the routing table possessing neighbor information becomes outdated quite often. Thus the routing protocol which depends upon tables for routing decisions may lead to erroneous situations [7].

2) Dynamic topology

VANET topologies are highly dynamic in nature. The reason behind this is the environment which might be very sparse for ex. rural area where vehicle density is extremely low, or it may be dense environment like in cities where vehicle density varies during peak/off peak hours and traffic jams etc. The span for which vehicles are connected for communication depends upon the radio transmission range and the vehicular nodes direction of movement. The frequent variations in link connectivity leads to frequent disconnections. Thus the routing protocol needs to address both sparse and dense environment issues due to high speed node mobility [8].

3) No power constraints

This is not an issue in VANET as the vehicles are able to continuously feed power to infrastructure within vehicles by means of battery equipped in them which keep on charging as the vehicle is on move [9].

4) Delay constraints

Due to various safety related applications in VANET, delay in delivery of information might result in accidents. Thus delivery of information in case of time critical scenarios needs to be prompt[6].

5) Mobility patterns

Mobility patterns of vehicles is largely predictable as it solely depends upon the road networks thus routing protocols can utilize this information for better data dissemination [10].

6) Network scale

The network scale is largely dependent upon the environment which may be dense or sparse. In dense environment like cities the high vehicular density may lead to traffic jams. This will result in scarcity of resources due to the ongoing demand. On the other end in sparse environment the number of vehicles is quite less and may be outside the communication range which may lead to link failure [11].

7) High computational ability

Vehicular node is armed with sensors and other computational facilities such as processor, memory, global positioning systems (GPS) etc. Thus an efficient computation process assists in gathering accurate information about position, speed and directional movement of vehicles [9].

Retrieval Number F8779088619/2019©BEIESP
DOI: 10.35940/ijeat.F8779.088619
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

B. VANET applications

In general VANET applications can be characterized on the basis of their functionalities, the most important of which is safety and apart from this, convenience and commercial aspects are important as well. DSRC focuses on variety of applications. As per vehicle safety communication project report [12] there are 34 safety applications of VANETs for DSRC. Safety applications primarily focuses on commuters security to lower the chances of road accidents [13] by avoiding intersection collision, alert for the traffic signal, lane change, curve speed, cooperative forward collision alert, assistance in turning, stop sign movement assistance public safety, sign extension, slippery roads, potholes on roads [7]. Table I depicts few safety applications.

Table- I: Safety applications

Safety Applications	Architecture	Purpose
Traffic signal breach	V2I	To reduce collision at intersection
Emergency braking light	V2V	Warns trailing vehicle about sudden brakes by immediate leading vehicle
Curve ahead speed caution	V2I	Warns the driver about the curve and guides using information like vehicle characteristics, weather conditions and geometry of the curve.
Lane changing alert	V2V	Keeps the driver informed if there is any potential risk involved during the lane changing

The non-safety applications increases the convenience by providing facilities like instant messaging with which driver of one vehicle share information with other vehicles, traffic management, parking lot payment, electronic toll collection system which allows driver to pay toll online rather than stopping at designated place and waiting in long queues, guiding and navigating the route thus assisting a driver regarding travel plans. The RSU can share information updates related to road conditions and parking constraints. Apart from this number of entertainment features like transferring of music and videos for entertainment of commuters has been the part of vehicular communications [14]. These applications consume high bandwidth and require significant network resources.

C. VANET communication

VANET communication is possible with a number of wireless access technologies that provide radio interface amongst vehicles and infrastructure. As discussed, these communications support both safety and non-safety applications. These technologies may utilize centralized infrastructure or they may operate with ad hoc means to provide communication amongst the vehicular nodes. The standards of communication addresses the requirements of interconnectivity and interoperability.

1) DSRC

DSRC or IEEE 802.11p [15] provides assistance in supporting V2V and V2I communication. WAVE enables wireless communications to disseminate information for both V2V and V2I architecture. It functions and operates in the rapidly changing environment where information dissemination is done without joining basic service set (BSS) [13]. It has a high data rate with minimal delay in small range communication. The first generation of DSRC operated at 915 megahertz supporting 0.5 Mbps transmission rate. In 1997, the second generation of DSRC was started additional bandwidth of 75 megahertz (5.850 gigahertz to 5.925 gigahertz) in 5.9 GHz band [11] was allotted. This 5.9 gigahertz band of DSRC has overcome many limitations of 915 MHz DSRC like more bandwidth is available, supporting high data rates between 6 Mbps to 27 mbps [12][16]. As shown in Table II, this 5.9 Gigahertz DSRC spectrum comprises of 7 channels, (10 Megahertz each) where channel 178 is reserved for control and 6 channels are service channels. Synchronization is done to monitor and guard intervals between control and service channels. In case, 2 service channels are clubbed then data rate to the tune of 54 Mbps can be attained. DSRC accommodate vehicle's with velocity of up to 200 km per hour and communication range of 300m (up to 1000 m) [13].

2) Wireless LAN / Wi-Fi /WiMAX connectivity

To enable V2V or V2I communication wireless access can be provided by means of WLAN or Wi-Fi through 802.11a supporting devices. IEEE 802.11a supporting hardware operates at 5 MHz, with data rate up to 54 Mbps within communication range of 140 m. WiMAX technology provides multiple physical layer (PHY) and medium access control (MAC) options, better transmission range at high data rates with improved quality of service (QOS) supporting VoIP and multimedia. As shown in Table III, DSRC has specified regional standards (Europe, Japan and United States). Also Fig. 4 depicts WAVE reference architecture. Its operational functionality and complexity is handled by IEEE 1609's upper layers. WAVE uses OFDM i.e. orthogonal frequency division multiplexing for splitting the signals and providing communication capability between 3 Mbps and 27 Mbps in 10 MHz channels [17]. The cellular technology system uses limited available frequency. It includes Global System for Mobile, General Packet Radio Service, and Enhanced Data Rate for GSM Evolution, Universal Mobile Telecommunication System, High Speed Downlink Packet Access, and Code Division Multiple Access 2000. Table IV indicates the comparison of communication technologies.

II. MEDIUM ACCESS CONTROL

MAC layer determines access to physical media amongst all the nodes for communication. The protocols in MAC are classified into i) contention based, ii) contention free and iii) hybrid. In first case, protocols compete for gaining access to the communication medium. They keep on sensing the carrier or use back off schemes. Thus the safety messages where real time communication is required, contention based schemes are not preferred. IEEE 802.11 a/b/g standards are based on carrier sense multiple access / collision detection (CSMA/CD) approach. An improved 802.11 based MAC scheme [18] enhances fairness for V2I communication.

As vehicles are moving at varying speed, so their connectivity with RSU is not the same. Vehicles with slow speed remains connected for a longer period of time with RSU as compared to vehicles with faster speed. This approach adjusts Distributed coordinated function (DCF) as per node speed. The contention window for vehicle nodes with higher speed is adjusted so that a fair

Table- II: Channel assignment in DSRC (as per IEEE 802.11p standard) [15]

			Channel 175			Channel 181		
Channel	Reserved	Channel 172	Channel 174	Channel 176	Channel 178	Channel 180	Channel 182	Channel 184
	5 MHz	10 MHz	10MHz	10 MHz	10 MHz	10 MHz	10 MHz	10 MHz
Utilization		medium power safety application	both the channels are set aside for power applications		control channel, for safety application broadcast amongst vehicles	both channel for low power configurations		high power service channel, coordinates intersection applications

Table- III: Comparison of the VANET standards [19]

Feature	USA(DSRC/WAVE)	Europe(ETSI)	Japan(ARIB)
Radio frequency band	5.9 GHz	5.8 GHz	5.8 GHz
Radio frequency bandwidth	75 MHz	50 MHz	80 MHz
Channel Bandwidth	10 MHz	10 MHz	5 MHz
Number of channels	7	5	uplink-7, downlink-7
Modulation type	OFDM	OFDM	ASK,QPSK
Radio access type	CSAM/CSAD	DCC access	TDMA-FDD
Communication Range	1000 m (approx.)	1500 m (approx.)	< 30 m
Type of Communication	Half duplex	Half duplex	OBU-half duplex; RSU-half/full duplex
Speed of vehicle	Up to 200 Km/h	Up to 200 Km/h	Up to 180 Km/h

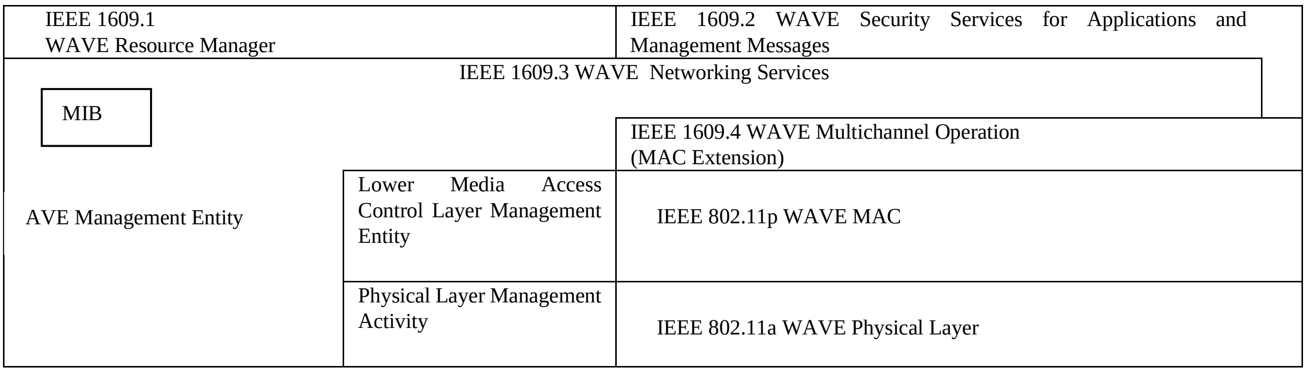

Fig. 4. WAVE reference architecture [20]

Table- IV: Comparison of the VANET standards [19]

Technology	Generation	Data Rate	Schemes	Frequency Band
GSM	2G	10 Kbps	FDMA and TDMA	890 MHz- 915 MHz (U)
				935 MHz – 960 MHz (D)
GPRS	2.5G	50 Kbps	TDMA	890–915 MHz, 1710–1785 MHz (U)
				935-960 MHz, 1805–1880 MHz (D)
EDGE	2.5G	200 Kbps	TDMA	-
UMTS	3G	384 Kbps	CDMA	700 MHz-2600MHz
CDMA 2000	3G	384 Kbps	CDMA	410 MHz - 470 MHz
WiMAX	4G	100-200 Mbps	OFDM	2.3 GHz-5.8 GHz
LTE	4G	100-200 Mbps	OFDM	450MHz-4.99GHz

U-Uplink, D-Downlink

access to the channel is done. Yang [21] proposed different priority levels for enhanced CSMA based protocols where messages with higher priorities are given early access as compared to the one with lower priorities. Bilstrup [22] proposed self-organizing time division multiplexing access (STDMA) to ensure timely delivery of safety messages. Fig. 5 depicts categorization of MAC protocols. In comparison to contention based approaches where nodes randomly tries to access the medium, in contention free approaches frequency, time, code and code are used for collision free transmission. Cooperative MAC for broadcast in clustering by Yang [23] is a scheme where if some member is unable to receive the information,

Retrieval Number F8779088619/2019©BEIESP
DOI: 10.35940/ijeat.F8779.088619
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August 2019

then any of the cluster member can assist and forward the information to that member. This assisting node also maintains a list all those members who were unable to get the information earlier and shares this with the cluster head as well.

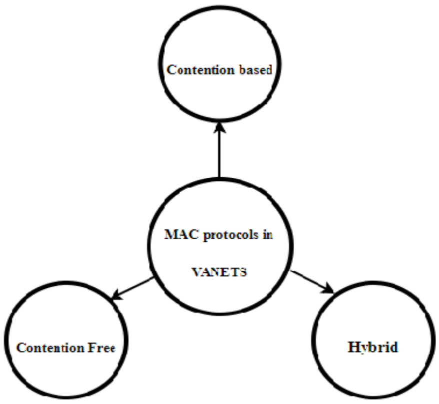

Fig. 5. Classification of MAC protocols

The cluster head nominates this assisting node with a cooperation task in free slots for non-receiving nodes. Hybrid approaches combines both contention based and contention free schemes. In multichannel token ring protocol (MCTRP) [24] for inter vehicle communications, nodes moving at similar speed are grouped together as rings and the initiating node in the group becomes leader and CSMA/CA is used to control the communication within the group members and TDMA is used in controlling access to medium for intra ring communication. Though this approach has low latency, but there are some disadvantages as well, like in case if, the initiating node leaves the ring, then the group dissolves and reformulation of group needs to be done again. Xie *et al* [25] proposed VMMAC scheme with the aim to improve bandwidth utilization. This scheme performs well for directional transmission with single lane roads. Clustering based Cooperative MAC approach [26] utilizes unused timeslots for retransmission of packets which were lost. A cluster oriented MAC scheme [27] maintains veracity of safety messages and bandwidth exploitation. The scheme divided access time of channel without any overlapping of time frames. The length of the time frame depends upon vehicle density in the cluster.

III. ROUTING PROTOCOLS - AN OVERVIEW

VANET has got huge attention from researchers in recent times. As vehicles move at high velocity, topology keeps on changing very rapidly. Vehicular density is also varying that leads to sparse or dense network situations. Both these factors play a decisive role in routing which impacts packet deliver ratio (PDR), delay and other parameters as well. To improve PDR and delay, road side infrastructure such as deployment of access points at different places along the road assists in providing communication between vehicles. The infrastructure laid along the road like RSU's forward the information to vehicular nodes that are inside transmission range of RSU. The protocols supporting this approach are referred to as V2I routing protocols whereas in V2V based routing, communication is focused on vehicles instead of infrastructure. These protocols can be categorized as shown in Fig. 6.

A. Topology or ad hoc routing protocols

Ad hoc routing schemes (Topology based) uses information related to links between vehicles to transfer messages from source vehicle to terminus vehicle. Routing tables are maintained to keep track of nodes in the topology. Routing tables needs to be updated quite frequently as vehicles are moving constantly. On the basis of routing table updation, these approaches are further categorized into (i) proactive routing, (ii) reactive routing and (iii) hybrid routing.

1) Proactive routing protocols

These approaches maintain and update information for every vehicular nodes even if the paths are not used. This information is shared with the all the neighbors so that other nodes can update their routing tables as and when the topology changes. This updating process takes place periodically irrespective of network size, load and bandwidth constraints. These protocols are quite unsuitable in scenarios that involve high mobility like VANETs.

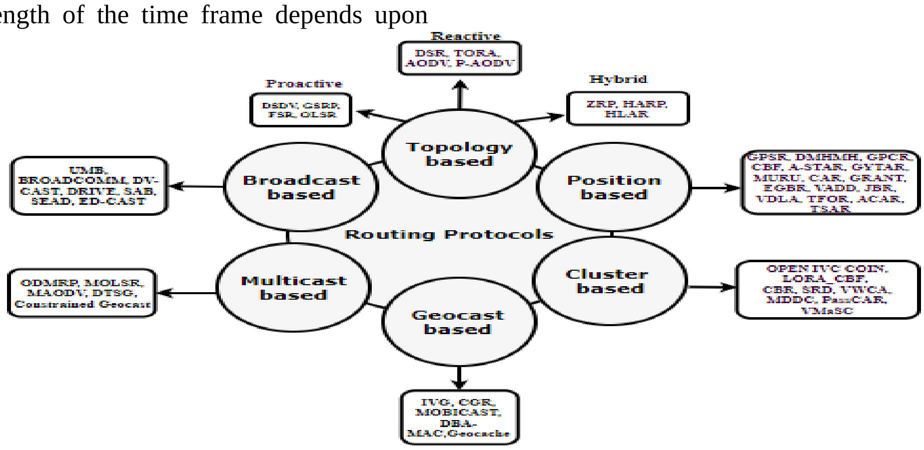

Fig. 6. Classification of routing protocols

The choice of the route in these protocols usually depends upon the shortest path algorithms. In destination sequenced distance vector (DSDV) [28] approach every nodes maintains information table about next hop and share this table with their neighbors. DSDV provides routes that are free of loops and forwards complete packets or incremental packets. The difference between the two lies in the content which is forwarded where the former forwards the complete route information whereas the later forwards the updates only resulting in lower bandwidth requirements and high overheads. The limitations of DSDV is that it does not provide multiple routes towards destination and also has no control over network congestion which results in lowering network efficiency. In global state routing protocol (GSRP) [29], all the nodes prepare a neighbor list comprising information about next hop, topology and distance. It keeps knowledge of full network topology just as in LSR and prevents the flooding of routing details. The table in the LSR maintains the information that it has received from its neighboring nodes and is periodically shared with the nodes that are in its close vicinity. Fisheye state routing (FSR) [30] approach minimizes the bandwidth utilization by reducing the routing table updating overhead for large networks. The link state entries are exchanged with the neighbors whose frequency depends upon the how far the destination is i.e. it swaps information about those nodes that are in its close vicinity at a higher frequency instead of all the nodes. Therefore the information about the nodes that are close is updated whereas with the increase in distance the precision is comparatively less. Every node stores information pertaining to neighboring nodes in vicinity and has three tables comprising about topology, next hop and distance (to keep track of the distance between two nodes). As the network size grows, update message utilizes more bandwidth. To keep it in control, as shown in Fig. 7 different shades depicts the scope in FSR i.e. the number of nodes that are reachable within a given number of hops (1, 2 or > than 2) from the central node 11.

2) Reactive routing protocols

These approaches maintain the route only when it is required. This results in reduced network overhead but in comparison to proactive protocols, these protocols are slower as during restructuring or failure they react slowly. These protocols keep updating their own routing information as well as about the neighboring nodes. To discover the routes, request messages are flooded in the network. Dynamic source routing (DSR) [31] approach comprises of i) route discovery and ii) route maintenance phases. Initially, the source node intends to transfer information to destination with no prior information about the path. The host dynamically discovers the path neighbors directly or via intermediaries by broadcasting route request. In second phase, whenever a source node detects a broken path, it tries to look for an alternative route. When a node intends to disseminate information, it prepares a path and copies it in packet header which is transmitted to the first hop on the way to destination. Upon receiving the packet if this node is not the final target, it passes the packet according to route plan. Temporally ordered routing algorithm (TORA) [32] routing approach limits the message dissemination in extremely dynamic scenario. It is

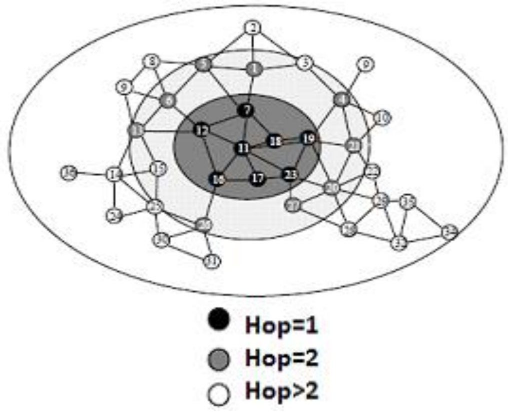

Fig. 7. Fisheye state routing

based upon link reversal routing algorithms. In this approach every node itself initiate a query to gather route information for a particular destination and maintains that route and finally clears the route when it no more exists. It constructs a directed cyclic graph from root of the tree. Information moves from the top node to the bottom node in the tree. All the nodes create directed cyclic graph by sending a query message. The receiving nodes on getting the query message replies with a message if it has downstream link to destination, otherwise they discard the query message. This approach provides routes between all the nodes thereby lowers the control overheads. On the other end, it adds to routing overheads in maintaining routes to each node on the network. In VANET, to preserve all these routes, it is difficult as VANETs are highly dynamic. Ad hoc on demand distance vector routing (AODV) [33] is loop free approach as it avoids the loop to infinity problem and responds quickly in case topology occurs in ad hoc network. AODV quickly adapts dynamic link situations and has low processing overheads as it lowers the flooding of information. It has lesser memory requirements as the entries in the routing table are minimized because the information about the recent active routes and the next hop only is preserved. Every time it uses sequence numbers of destination to ensure freedom from loops. In case there is breakage in link, the affected nodes are notified to invalidate the paths using lost links. Some delays are caused due to route discovery as in case of route failure, new route discovery leads to further delays resulting in increased network overheads and low data transmission rates. Prediction based AODV (PRAODV) [34] protocol is an extension of AODV. In comparison to AODV where the alternative route is chosen upon link failure, whereas PRAODV constructs well in time before the approximated lifetime of the route is over. The route reply packet (RREP) also carries speed and location of the packet. All the intermediary hops that encounters the packet modifies the content of this packet according to their own location and speed. This is done when predicted value of the current node is less than previous predictions of any link on this route. The purpose of this is to calculate the most correct value that is lowest for all the links on this route. The protocol's performance largely depends upon the preciseness of prediction method.

In static-node-assisted adaptive data dissemination in vehicular networks (SADV) [35] information is forwarded to the static nodes deployed on road side or junctions in the absence of vehicles for delivering packets. This information is stored by the static nodes till the time the best route is available. SADV has minimized information delivery delay using multipath routing mechanism particularly in sparse environments where connectivity issues exists.

3) Hybrid protocols

They combine both reactive as well as proactive protocols with the aim to minimize routing overheads and delays in the route discovery for which the nodes are divided into zones. These approaches are not effective in scenarios where highly dynamic nodes are involved. Zone routing protocol (ZRP) [36], is a first protocol falling in this category. ZRP bifurcates the network into different sectors. Each node must be aware about the topology in its periphery, updating of nodes if any, takes place only in case topological changes takes place inside their own zone. Hybrid ad hoc routing protocol (HARP) [37] splits the network into non overlapping regions. In this protocol, routing is performed at intra region and inter region level based upon whether or not the destination is in the same region in which intermediary node resides. Hybrid location based ad hoc routing (HLAR) [38] approach merges modified AODV and greedy forwarding geographic routing approaches. In this approach instead of the minimum hop count, AODV uses an expected transmission count to know the best possible route. In this approach, the route discovery begins when the demand arises. In case no path is found from initiating node to terminating node, the initiating node includes its own location and the destination nodes location coordinates in route request packet (RREQ) and searches its own information table to check if any neighboring node is closer to destination node. In case, no such node is found, RREQ packet is flooded to all neighbors. Table V depicts comparison of ad hoc routing protocols.

B. Position based routing

In position or geographical routing basically the movement of vehicles in VANET is confined to the road and streets therefore, routing process using geographical information makes sense. The study by various researchers reveals that in comparison to topology based routing scheme like DSR and AODV, the position based routing schemes performs is better both in urban and highway scenarios. The nodes can get the information about their own position and neighboring nodes through GPS which assists in routing decisions and the vehicular node decides forwarding of the packet on the basis of its own location, neighboring node's location and destination's location. In case no neighbor is found nearer to the destination in comparison to the forwarder itself, then this strategy fails, this is called local optimal. Greedy parameter stateless routing (GPSR) [39] uses two approaches for disseminating packets, first is greedy forwarding where the node by using position information directly disseminates the information to nodes in its vicinity which is nearest to destination and the second method is perimeter recovery mode which is used when a local optimal situation arises, planarized graph for the node is constructed and packets are transferred as stated by right hand rule. Disseminating messages among highly mobile hosts (DMHMH) [40] is a scheme in which the packet collision are minimized and rebroadcasting is reduced. In this approach rebroadcasting is not carried out immediately instead the node waits for specified time to take the decision for rebroadcasting. This waiting period depends upon the interspace between the node and the sender i.e. lesser the distance from the sender, more is the waiting period for the rebroadcast. Generally the nodes in the border region carry the rebroadcast process. During the waiting period, if a node does not gets a duplicate copy from another node in its vicinity then only it transmits the information further thus suppressing broadcast storm. In greedy parameter coordinator routing (GPCR) [41] the nodes passes the message to the node available at the junction (called the coordinator) instead of the node that is within the range but is across the junction as this may lead to a local maximum. Greedy approach is used for packet forwarding and recovery mode is employed in case the local maximum situation arises. Due to high rise structures and build up in the city environment, a position based routing suffers. Traffic density is high on some roads as compared to the other, also vehicles have mobility constraints, due to road patterns which results in a weak signal reception and ends up into poor connectivity among vehicles. Contention based forwarding (CBF) [42] protocol involves broadcasting of packets to all the nodes that are directly in the vicinity of sender node and thereafter decision for transferring of packet by a node is carried keeping in view the distributed timer-based contention. Recovery procedure of CBF uses perimeter routing in case no greedy next hop is available. Sometimes due to hidden node issues, network congestion might be there. Anchor based street and traffic aware routing (A-STAR) [43] an urban scenario based approach, uses statistically dynamically related maps. Street maps assists in computing the order of junctions through which message travels to the final destination. It makes use of local recovery strategy instead of greedy approach or perimeter mode as the former is more suitable in the city environment. The authors have compared this approach with GSR and GPSR in terms of PDR and delay and it is observed that at lower traffic density 20% more packets are delivered as compared to higher density and there is an improvement of about 6% in terms of delay. A-STAR has improved outcome than GPSR but at lower density GSR is better. Greedy traffic aware routing (GYTAR) [44] performs well within city environment. The selection of an intersection through which the message travels is chosen dynamically depending upon the traffic density at that time and curve metric distance. In case of occurrence of local optimum, carry-forward approach is used. The results of this approach are compared to DSR and location aided routing (LAR) in terms of PDR and control overheads and it is observed that GyTAR outperforms other two approaches as it does not keeps track of the complete route at once but keeps on determining the relay path progressively. Also GyTAR has 'Hello' messages that adds the control overheads whereas other approaches have three control messages which increases the control overhead.

Table- V: Comparison of ad hoc based routing protocol

Protocol	PDR	Latency	Overhead	Bandwidth Utilized	Pros/Cons
DSDV	H	L	H	H	Route discovery not required initially, lower delay in real time applications, regular updates in routing tables required, more bandwidth required
DSR	H	H	L	L	No beaconing, route creation done only when it is needed, route cache information utilized efficiently to reduce overheads and collisions, broken links cannot be maintained locally, high delays in comparison to the table driven approaches, performance degradation in a highly dynamic VANET environment
TORA	H	H	H	H	Creates directed acyclic graph when required, not scalable and suitable for vehicular environment, causes routing overheads as it maintains routes to all network nodes
GSRP	L	L	H	H	Generates better optimal paths, more bandwidth consumption, higher operational cost, large message size leads to more time consumption
AODV	L	H	H	H	Link failures are handled efficiently, minimized route redundancy, low memory requirement, supports large networks, high bandwidth utilization, connection initiation process takes time
OLSR	M	M	H	H	Suitable where delay requirement is low and where there are rapid changes of source-destination pair, broken link discovery requires more time, routing table is updated in case of link failure not done as no control messages triggered for link failure, overhead is high when number of nodes increases
FSR	L	H	H	L	Due to partial information sharing about updates with neighbors, low bandwidth consumption, little awareness about far away nodes, higher processing overheads as network size increases, route formation information incomplete
HARP	M	H	L	L	Handles path failures during information transmission itself, election overheads
PRAODV	L	ND	H	M	Keeps track of life time of route and accordingly new routes are constructed, control overheads are higher due to prediction mechanism
SADV	L	H	H	ND	Adapts varying traffic densities dynamically, periodic beacon by vehicles and static nodes adds overheads, each node must have digital street maps
HLAR	M	L	ND	M	Intermediate nodes can repair the broken links locally, do not guarantees best reliable route as relay nodes lacks information about reverse link to source
ZRP	ND	ND	L	L	Large overlapping of routing zones, networks division into zones can be done on the basis of transmission power, strength of signal and speed, affected by frequent topology changes and dynamicity of VANET, zone size needs to be fixed before implementation, nodes maintain information of its own routing zone thus control overhead are less, multiple route identification with no looping problems

L-Low, M-Medium, H-High, ND-Not Determined

Multihop routing protocol for urban VANETs (MURU) [45] is distributed, on demand multihop routing scheme for city scenarios where the source vehicle initiates route discovery by creating route_request message. All the intermediary nodes calculate an estimate for the quality of link at receiver using expected disconnection degree (EDD) metric. To calculate EDD, speed and trajectory of vehicular movement is taken into consideration. The source vehicle initiates a route request and every intermediary vehicle calculates EDD. The route with lowest EDD is chosen. The authors have evaluated the approach in terms of PDR, delay and control overhead and comparison is done with DSR, AODV and GPSR. It has been observed that with the rise in vehicle density, MURU has higher PDR and lower average overhead and lower delay. Connectivity-aware routing (CAR) [46] is a V2V based communication approach that is suitable highway and urban environment. “Guards” track the current location of destination even if the destined node had covered substantial distance from its initial location over a period of time. These guarding nodes adds up some information to the packets or redirects the packets to deliver it to the destination. The comparison is done with GPSR and GPSR+AGF on basis of the parameters like PDR, average delay and routing overhead. It has been observed that CAR performs exceedingly well in comparison to GPSR whereas the performance is moderate in GPSR+AGF. The delay in CAR has shown drastic improvement in comparison to others in both city and highway scenario. Low routing overhead because of adaptive beaconing is observed in comparison to GSPR. In Greedy Routing and Abstract Neighbor Table (GRANT) [47] approach the plane is splitted into areas, and for each area there is one representative neighbor. The information about the representative neighbor for each area is stored in abstract neighbor table (ANT). In case there is no neighbor for an area, the entries for such area are empty in ANT. Whenever a node sends beacon packets, ANT is appended with it. Upon receiving this beacon, receiving node can calculate the area that the sending node and its neighbor belongs to. As GRANT uses extended greedy routing, this provides every node an information in advance about the best route to follow. In edge node based greedy routing (EGBR) [48] scheme message may be forwarded in a unicast manner. The next hop selected is the one that is on the edge in the direction of destination as per transmission range from the sender. EGBR involves less intermediary nodes for transmitting information from the source to destination with high throughput.

Vehicle assisted data delivery protocol (VADD) [49] proposed store and carry forward concept where the vehicles on the move carries the packet till the time another vehicle comes in its vicinity and the packet is forwarded. VADD has performed exceedingly well in terms of PDR, with lower data delay and control overheads.

In junction based routing (JBR) [50] approach the nodes are identified as i) coordinator node - node located near junction and ii) simple nodes- nodes placed anywhere between two junctions on the road. Every node periodically broadcast hello message and shares its positional coordinates as well as its identification category. Before passing a message to destination, the simple node verifies the neighbors in the vicinity of destination. In case destination is not in its communication range. Preferably coordinator node if available is selected as forwarding node. In case if multiple coordinators are available, the one that is closest to the destination is chosen. Further in recovery strategy for a simple node when local optimum is attained, neighbor list is searched and divided into simple node and coordinator node. The distance of last node from current node and as well as the node under consideration is also evaluated for forwarding the packet. In recovery strategy, where coordinator just forwarded the message, the divergence between the vehicle which was placed in recovery strategy and the terminus vehicle is calculated. This is done for every selected simple node. The selection of next hop is made where the angle is smallest. The authors assessed JBR with modified GPCR on metrics like PDR, delay and hop count. This approach is evaluated by varying the communication radius and it is observed that the delay is higher in case of JBR in comparison to GPCR when the communication radius is low, but when the communication radius is increased the JBR outperforms GPCR. It is because of better selection approach for next hop. JBR outperforms GPCR in terms of PDR irrespective of the variation in the communication radius. It has also been observed that JBR performs drastically well when the communication range is highest. Vehicle density and load aware (VDLA) [51] routing uses junction based geographical approach which aims at searching a robust route with high packet delivery ratio and lower delays. In this approach firstly traffic load and vehicle density is obtained for each road segment and junctions. As the packet is forwarded, the decision about the selection of junction is done dynamically and sequentially. Density of vehicles, traffic load and distance to destination is taken into account while decision is to be made. The performance of VDLA approach is assessed using PDR, hop count and delay where the results are compared with GPCR. It has been observed that with the rise in traffic density, VDLA has lower hop count. Also delay is extremely lower in comparison to GPCR due to lesser hop count and low probability of packet contention, and PDR in this approach is higher in comparison to GPCR because VDLA chooses a path where the number of vehicles are such that they provide connectivity with the light network load that reduces contention.

Traffic flow-oriented routing (TFOR) [52] is a junction based geographic approach suitable for city scenarios. The protocol involves mechanism for selecting of junction followed by routing between junctions on the basis of two hop neighbor information, while making selection for junction dynamically, also the protocol keeps in consideration the directional and non-directional traffic flow. The sender vehicle utilizes digital maps to locate the neighboring junctions and thereafter determines the curve-metric distance from the neighboring junction to the destination vehicular node. The junction which is nearest to the destination is chosen. The authors have compared TFOR with E-Gytar, GPSR and GSR on the basis of PDR, delay and routing overheads. It has been observed that, irrespective of varying traffic densities, the TFOR outperforms all the other protocols by a margin of over 7%, 9% and 16% for PDR and 7.5%, 12% and 15.3% for delay as compared to E-Gytar, GSR and GPSR respectively. One of the reasons for this is that TFOR considers both directional and non-directional traffic available towards the path of destination. Anchor based connectivity aware routing (ACAR) [53] protocol takes into consideration buses and cars as nodes, irrespective of whether they are moving clockwise or anticlockwise. The protocol gathers the information about its neighbors through a route request and reply beacon messages and thereafter shortest path is preferred to move the information. In case of non-availability of node i.e. in sparse scenario, store and carry forward mechanism is implemented. The performance of ACAR is evaluated on the basis of PDR, packet delay, distribution of route length, routing overhead, hop count and the results are compared with A-STAR. It has been observed that with the rise in traffic density the PDR also improves whereas the delay is higher when traffic density is low in comparison to ACAR, but at higher densities it is almost same. The hop count is always on the lower end in comparison to A-STAR which is because of the assumption made by authors regarding position and direction of vehicles. Routing overhead is on the higher side as vehicles shares their position updates with the neighbors continuously to maintain connectivity.

Traffic aware segment based routing (TASR) [54] is a fully distributed approach where information about the road segment plays a decisive part in making routing selection. The protocol calculates the connectivity of the network and multihop forwarding dynamically i.e. from traffic density information and route selection, expected connectivity degree (ECD) is computed. ECD identifies the quality of connection from initiator to receiving nodes. TASR controls transmission overheads for each intermediary node to avoid broadcasting in the entire transmission area. The approach is evaluated in comparison to MURU and VLDA. The evaluation is done by variation in the velocity, number of vehicles and data sending rates. TASR outperform others in terms of latency, delay, PDR, hop count and data packet error rate. The average latency is lower when the vehicles are moving at slower speed, delay is low when traffic flow in the network is less but this gap further widens in comparison to VDLA and MURU when traffic density increases. PDR is a higher when the vehicle velocity is less. TASR shows the lowest packet error rate in comparison to VDLA and MURU.

This error rate increases with rise in velocity of vehicles. Table VI depicts comparison of position based routing protocols.

Table- VI: Comparison of position based routing protocols

Protocol	Vehicle Density	PDR	Latency	Number of Hops	Bandwidth Consumption	Pros/Cons
GPSR	L	H	M	L	L	Suitable for static ad hoc environment, packet forwarding decision made dynamically, largely affected due to obstacles in cities, updated information about neighbors not available in sender nodes routing tables, fails to consider impact of high mobility
GPCR	H	L	ND	H	M	Does need global or external information, highly dependent upon junction nodes, end to end connectivity issue in sparse environment
GSR	H	M	M	L	L	Scalable, higher routing overhead due hello messages. Connectivity issues at lower densities
A-STAR	M	L	ND	H	L	Suitable for both dense and sparse environment, relies on static information to discover path which results in connectivity issues in city streets
CBF	H	H	H	L	L	Eliminating beacon messages results in saving bandwidth, lesser packet collisions, performance on highways not good
GYTAR	M	L	M	L	M	Can handle high mobility, changing topology, frequent disconnection efficiently, dependent upon RSU's, to select routing paths it requires accurate traffic information system
MURU	H	H	M	M	L	Link stability is determined priorly, does not perform well with low vehicle density, small broadcast area is cause of concern if next hop falls out of transmission range
CAR	M	L	H	ND	L	Stores information about paths available between source and destination, unnecessary nodes might get selected as anchor, cannot adjust with different sub path when traffic environment changes
VADD	H	H	L	M	L	High PDR, suitable in case of multihop data delivery, delay is high in case topology and traffic density changes
GRANT	ND	ND	ND	ND	ND	Better performance in comparison to many other greedy routing in urban environment. Due to beacon messages overhead is high
EBGR	H	M	L	ND	ND	No. of hops from source to destination minimized, high throughput, drastic variation in PDR as vehicle density varies
VDLA	H	H	L	L	ND	Major routing decisions are done before packet reaches junction, high mobility of nodes may lead erroneous information
JBR	H	H	L	H	ND	Coordinator selection approach for packet forwarding is efficient, for better performances higher transmission ranges are required
ACAR	L	M	M	L	ND	Utilizes both greedy, store and forward approach, performs only when vehicles are moving, higher overheads
TFOR	H	H	L	L	ND	Performs well for safety as well comfort applications
TASR	H	H	L	L	ND	Establishes and sustains robust communication, overheads in terms feedback information about route error to sender

L-Low, M-Medium, H-High, ND-Not Determined

C. *Cluster based routing*

It involves creating clusters for the nodes that are in a close vicinity. The cluster head (CH) within the cluster ensures communication between the members of the cluster and across clusters as well. Some approaches allows direct communication between members, whereas communication across clusters is through cluster heads. The cluster head (CH) manages the information about the nodes in its cluster as well as gateways (GW). Cluster based routing improves scalability. Various clustering protocols have been proposed regarding the CH selection and routing process. Open IVC COIN [55] is clustering based approach where cluster head is selected considering vehicle dynamics like mobility of node, distance between nodes and intention of the driver. To make communication possible for longer periods, relative mobility between the cluster heads and nodes of the cluster should be low. Simulation results reveals that the average cluster lifetime is increased by 192 % and cluster membership changes are reduced by 46% in COIN. LORA_CBF [56] protocol uses greedy forwarding scheme for transferring information. Here, the nodes are either cluster member (CM) or CH or GW. Only CHs or GW nodes are responsible for packet forwarding. Location Request (LREQ) messages are forwarded by source (either CH or GW) in case destination's location is unknown. Upon receiving location reply (LREP) message, CH verifies if the destination vehicle is the part of the same cluster. This approach is robust in overheads and packet delivery. In cluster based routing (CBR) [57] approach the geographical area is split into square lattice. On the basis of geographical information each node calculates best possible neighboring node so that messages can be passed on to the next hop. The routing overhead in this approach is lesser as route discovery is not required. In case RSU is present in the grid, it is chosen as CH. Cluster head broadcast the information about cluster coordinates and its own presence to its neighbor. In case cluster head leaves the cluster it broadcast a message about its exit as well as information about the cluster, this information is stored by intermediate node till the time new cluster head is formed. Vehicular weighing clustering algorithm (VWCA)[58] describes the procedure for electing the best possible node as the cluster head so that network can work in an efficient manner. To do so, a distrust value for each vehicle on basis of message forwarding is taken into consideration. Two lists i) a white list and ii) a black list are maintained by each vehicle.

Further, the vehicles can adjust their transmission range dynamically in case there are no neighboring nodes for which adaptive allocation of transmission range (AATR) technique is proposed. Monitoring of malicious vehicle (MMV) algorithm is used for evaluating distrust value that decides the priority which is to be given to the vehicles. Simple and robust dissemination (SRD) [59] approach can disperse data both for dense as well as sparse environment using limited topology information. To optimize the suppression technique in dense scenarios, only a subset of vehicles participate in the rebroadcast whereas in case of sparse environment, store-carry-forward concept is implemented. SRD results in a high PDR with low delay in varying traffic conditions. Multiagent driven dynamic clustering (MDDC) [60] is an approach that considers heavy weight static and light weight mobile agents like speed of the vehicle, direction, pattern of movement and degree of connectivity with other vehicles while forming a cluster on the road between two intersections. The clusters members are classified keeping in consideration relative speed and direction of movement of vehicles, whereas for the selection of cluster head, the degree of connectivity and time to leave the intersection is considered. Cluster members (CM) that follows similar mobility pattern as announced by CH can reconnect once they pass the intersection. Passive cluster aided routing (PassCAR) [61] protocol performs well in one way multilane highway scenario. The protocol involves three stages i) route discovery ii) route reply and iii) data transmission. Initially PassCAR identifies suitable members for stable and reliable cluster. The candidate nodes determine the priority of their own to be a participant on the basis of node degree, expected transmission count and lifetime of link. PassCAR protocol claims to have high PDR and high throughput. Vehicular multihop algorithm for stable clustering (VMaSC) [62] is a multihop approach using long term evolution for broadcasting safety related information. In this approach the cluster head selection is based upon relative mobility metric that is evaluated on the basis of average relative speed with regard to the nodes in the neighbor. The vehicular node operates in one of the five states i.e. initial, state election, CH, isolated CH and CM. Authors have implemented the proposed approach using NS3 and SUMO. To validate the proposed approach comparison is carried with multihop clustering algorithm NHop and MDMAC in terms of metric such as CH duration, CM duration, CH change rate, CH overhead. This approach results in high PDR at varying vehicular densities. Due to better cluster stability delay is minimal with low cluster overheads. CPB [63] approach forms clusters considering the direction of movement of vehicular nodes. The CH selection is carried on the basis of link connectivity and the probability of packet transmission successfully. The packet forwarding probability by cluster head depends upon the count, a copy message is received by CH. In case a copy of the packet is received multiple times (above a threshold value), the cluster head just ignore the packet instead of forwarding. The approach is compared with Jin's model and weighted-p-persistence scheme in terms of PDR, information coverage and transmission delay. At lower densities the performance of CPB in terms of information coverage is low but with rise in traffic density, the performance is significantly improved. Similarly the delay is less at low density. PDR is evaluated at varying speed as well as traffic density and CPB performs better in comparison to the other approaches. CRLLR [64] approach utilizes Ant Colony Optimization for deciding the number of clusters, making cluster head selection as well as for reliable routing path. The information to be disseminated is aggregated to nearby authenticate on board units rather than all OBU's transferring data. In the absence of routing information in routing table, all the route requests are sent to cluster head by vehicular nodes which the CH forwards to the gateway nodes. Table VII depicts the comparison of cluster based routing protocols.

D. Geocast based routing

It aims is to a deliver packet within a specific geographical region. Geocast is a kind of multicast within a specific region. Many of the geocast approaches are based on direct flooding that controls message overhead and congestion in the network by specifying a forwarding region and restricting the flooding within it. Inter-vehicle geocast (IVG) [65] disseminates information relating to accidents and natural calamities with vehicles on highways that are moving towards the site of incident. The GPS assists in confining the delivery of messages in the specific area. Cached Geocast Routing (CGR) [66] is an approach that adds cache to the routing layer which holds the packet that cannot be forwarded by a node at distant location because of local minimum upon arrival of neighbor in range, the message in the cache can be forwarded to this newly identified node. In this approach the distance based continual updations in neighbor are considered Mobicast protocol [67] works well for applications involving spatio-temporal coordination. It considers both space as well as time for geocast routing. This approach aims to disseminate message to every node that is in the zone of relevance at time t. It works well for applications involving spatio-temporal coordination. Dynamic backbone assisted medium access control (DBAMAC) [68] protocol supports geocast communication on a highway scenario for various VANET applications. It ensures faster dissemination of messages by combining reactive and proactive approaches. On the basis of stability and channel link quality a virtual back bone is created, and messages are forwarded over multihop backbone. In the absence of backbone, a recovery forwarding contention based approach is used. Geocache [69] protocol cooperatively shares information relating to road congestion This information is utilized in making the decision dynamically to select best possible route to destination. As the information is stored within the cache instead of fetching from other nodes, this results in lowering the network overhead as information exchange reduces significantly. Authors have implemented the approach with varying traffic generation scenarios for an urban environment. The scheme is evaluated on the basis of response time i.e., the delay in requesting and receiving information by the vehicle, the number of broadcast and information accuracy. Geocache reduces the response time to a large extent.

This scheme performs better, with increase in cache time as the message generation per vehicle reduces. Table VIII shows comparison of Geocast Routing protocols.

Table- VII: Comparison of cluster based routing protocols

Protocol	Vehicle Density	PDR	Cluster Life	Throughput	Bandwidth Consumption	Pros/Cons
COIN	M	M	H	L	L	Provides better cluster stability, high overhead for achieving cluster stability
CBR	H	H	H	H	ND	Minimizes on demand route discovery traffic, scalable for large networks, speed and direction not taken into consideration
SRD	H	H	M	H	H	Supports both dense and sparse scenarios, addresses broadcast storm problem efficiently, Not reliable for safety messages
VWCA	M	H	H	ND	H	Improved network connectivity while electing cluster heads, performance in city environment is low
MDDC	M	M	H	M	H	Traffic management is robust and agile, high communication and computational overheads
PassCAR	H	L	M	M	L	Support high speed vehicles, lower transmission overheads, throughput decreases drastically when vehicle velocity increases
VMaSC	H	H	H	H	L	Efficiently disseminates information with minimal usage of architecture, performance issues in urban scenarios with lower vehicle density
CPB	H	H	H	H	L	Provides better cluster stability, forwarding probability is adjusted according to the traffic density, information is low at lower density
CRLLR	H	ND	H	M	H	Control excessive route discovery requests

L-Low, H-High, ND- Not Determined

Table- VIII: Comparison of geocast routing protocols.

Protocol	PDR	Latency	Control Overheads	Bandwidth Consumption	Pros/Cons
IVG	M	H	H	L	Reliable and stable, keeps restriction on number of broadcasts, performs well in fragmented network, requires accurate GPS information, operates in highway scenario only
CGR	H	L	H	ND	Reduced network disconnection as messages can be stored in cache, keeping information about neighboring nodes increases transmission overheads
Mobicast	L	H	H	L	Performs well in fragmented network, complex computation for zone of forwarding using dynamic topology
DBA-MAC	H	L	L	L	Provides efficient and real time information dissemination, eliminates back-off overheads, reliable
Geocache	H	L	L	L	Lesser number of broadcasting messages and lower response time, with increase in congestion response time increases

L-Low, H-High, ND- Not Determined

E. Multicast based routing

It involves communication from single sender node to multiple destination nodes lying in specific region. Multicast communication results in low transmission control overheads as well as power consumption [56]. Due to higher mobility and frequent topology change in VANETs, multicast protocols in VANETs are required to adapt these vehicular network characteristics. On-demand multicast routing protocol (ODMRP) [70] is a robust and scalable approach in which nodes are grouped and multicast routes are formed, the update is done on request by source rather than periodically. When a sender has some information to disseminate, it floods a Join_Query message periodically in the network, and in case a node that is not the member of multicast group receive the Join_Query, then the approach verifies whether the node is redundant or not. If it is not, the protocol stores the identity of this node and again broadcast the message. ODMRP has high control overheads and scalability issues as well. The efficiency of ODMRP is also affected when the information is propagated by multipath routes to destination. Multicast optimized link state routing (MOLSR) [71] is source based scheme that forms a multicast tree and a table comprising of a pair (source node, multicast group) is maintained that has no centralized entity. It provides a shortest possible path from the source node to all the members of this multicast group. In Multicast Ad hoc On-Demand Distance Vector (MAODV) [33] approach whenever a node wants to join multicast group it performs broadcast, all the recipient members of multicast group replies in unicast mode to sender. In case multiple replies are received by the sender of broadcast message, it chooses the one with the shortest path. MAODV has more overhead, a low PDR and longer delays. Dynamic Time Stable Geocast [72] routing protocol performs well in low density environment as well. In the region where the information is to be shared, the information is stored by the vehicle for some time which can be varied. The approach performs in two phases i) pre-stability period - during which the information is to be disseminated in the region of concern ii) stability period - the period in which information is kept alive i.e. the information is stored, carry and forwarded so that it can be disseminated when a relevant vehicle comes in the communication range.

This protocol suffer from overheads, as information delivery time is to be adjusted, and transition from one phase to another is also to be considered. Constrained geocast [73] supports cooperative adaptive cruise control wherein vehicular speed is automatically controlled. The future prediction of vehicle position is done on the basis of current scenario. The protocol operates reliably as the traffic density rises however, the network overhead increases. Table IX depicts comparison of multicast routing protocols.

Table- IX: Comparison of Multicast Routing Protocols

Protocol	PDR	Latency	Control Overheads	Pros/Cons
ODMRP	H	ND	H	Uses control packets to deliver more information to multicast members, ODMRP suffer from problem of scalability, data packet reaching destination through multiple paths reduces the efficiency
MAODV	L	H	H	Longer delays, establishing broken links in high mobility scenario is time consuming, single point of failure in case multicast group leader fails
DTSG	H	L	H	Not affected by vehicle speed, Additional overhead due to switching between stability phases
Constrained Geocast	ND	ND	H	Reliable in the environment where vehicle density is high, higher mobility of nodes result in network fragmentation

L-Low, H-High, ND- Not Determined

F. Broadcast based routing protocols

They are generally used for sharing information with vehicles relating to traffic and road conditions, weather, emergency situations and advertisements etc. Mostly broadcasting is implemented through flooding where each node rebroadcast the information in the vicinity except the sender. Flooding ensures delivery of the message to destination nodes. Flooding works efficiently when the network size is limited, otherwise the performance drops significantly. The bandwidth requirements are increased in flooding resulting in contentions and the collisions that increases overheads [17]. Selective flooding is used to avoid congestions in the network. Urban multi-hop broadcast (UMB)[74] protocol overcomes the issues related to broadcast storm, interference and hidden nodes. A transmitter node moves the packet to farthest node in the broadcast direction without any prior information. At the intersection, repeaters installed initiate directional broadcast. Authors have evaluated the proposed work on the basis of metrics like success percentage, packet dissemination speed and load generated per broadcast. It has been observed that UMB approach attains almost 100% success rate when packets are less, but the performance starts degrading when packet generation rate increases. In comparison to flooding protocols where load generated rises with the increase in number of vehicles, UMB's load generation remains almost same. BROADCOMM [75] approach splits the highway into virtual cells that are of similar length. The nodes are in such a way that at first level includes all nodes in a cell, second level is represented by cell reflector with some of the nodes located close to the middle of the cell. Cell reflector act as CH for a specific time interval and handles messages from the members of its own cell as well as of neighboring cells. Authors have evaluated the approach in terms of parameters like broadcast delay and routing load and comparison is carried with DOLPHIN and it has been observed that the broadcast delay for both the approaches is almost same when vehicles are at a close distance but when the gap between the vehicles increase, the delay for BROADCOMM is far less in comparison to DOLPHIN. In distributed vehicular broadcast (DV-CAST) [76] approach all the vehicular nodes uses flag variable to keep track of duplication of packets. In this vehicles are categorized as well connected, sparsely connected or totally disconnected to the neighboring nodes. The message forwarding is done keeping in view the category in which vehicle falls like, in case of well-connected, broadcast suppression techniques are used, in case of sparse connectivity, store and forward approach is used whereas fully disconnected neighborhood vehicular node stores messages to be forwarded till the time another node enters in the communication range, in case the time expires then packet is discarded. Authors evaluated the proposed approach in terms of broadcast rate, network reachability and network overhead. In well-connected scenario, the protocol achieves broadcast rate of 100% but when the number of vehicles are less, success rate falls to as low as 20%. DRIVE [5] disseminates the information in dense as well as sparse environments. To disseminate information in the area of concern, this protocol selects vehicles from within the sweet spot as relay node so that maximum vehicles can receive information during rebroadcast thus mitigating the issue of broadcast storm problem. DRIVE addresses the issues of network partition and temporal network fragmentation as well. To validate the proposed approach authors compared their results with existing approaches like SRD, DV-CAST, AID, DBRS, Flooding on the basis of metrics like coverage, delay, packets transmitted and number of collisions. DRIVE delivers information to all the vehicles in the area of concern as the traffic density increases. In terms of delay, DRIVE performs better in comparison to others except Flooding. The collision count increases slightly as vehicle density rises but DRIVE in comparison to Flooding and DBRS performs exceedingly better. Chaqfeh and Lakas [77] proposed three variations for broadcast suppression - speed adaptive broadcast (SAB), slotted speed adaptive broadcast (SSAB) and grid speed adaptive broadcast (GSAB). In these approaches, traffic is dynamically detected using speed data. Depending upon traffic conditions, every vehicle evaluates its probability for rebroadcast or waiting period. Further to implement broadcast suppression, a separation in time slots among vehicles results in sufficient amount of time for vehicles to make decision regarding rebroadcasting or discard the forwarding process after message is received. Further to avoid same time slots being assigned to vehicles moving in different lanes, a dissemination delay is added among the vehicles of different lanes to further decrease data redundancy and collision in GSAB.

Authors have evaluated the proposed approach on the basis of parameters like PDR, broadcast overhead per message, dissemination delay and average number of hops propagated and performed comparison with approaches like weighted p-persistence and slotted 1-persistence.

Simple and efficient adaptive data dissemination (SEAD) [78] protocol controls broadcast storm issues in sparse environment. In this approach, upon receiving a message the receiving vehicular node verifies weather it was received earlier as well or not and accordingly the decision is taken regarding rebroadcasting or discarding the message. The GPS location of vehicle from where the message is received is taken into account before taking decision regarding rebroadcasting. SEAD results in high PDR and low delay. Emergency degree broadcast (EDCast) protocol [79] is the one where the emergency degree of the packet is the decisive factor for prioritizing the packet broadcast, so that safety related information can be disseminated accurately and in time. Higher broadcasting probability and smaller size contention window is assigned to the packet with higher emergency degree value. The performance of EDCast is evaluated with metrics such as delay, redundancy, broadcast efficiency, PDR of emergency, broadcast efficiency of emergency and delivery delay of emergency. Authors have compared the results of proposed approach with Mflood, Farthest and Slotted-p. The simulation results reveal that delay increases as the traffic density increases, still in comparison to Mflood, EDCast performs three times better. In terms of redundancy Slotted-p though performs better than EDCast at lower vehicle density, but the performance of EDCast is much better at higher density scenarios. In direction based urban broadcast (DUB) [80] the information is disseminated in the specific region while keeping in consideration the direction of movement of forwarding vehicles forwarding vehicle. Vehicles are pre- loaded with street maps and priority for forwarding is allotted to the vehicles which are at the intersection or near to it with the aim to deliver information in all the directions. Adaptive data dissemination protocol (AddP) [81] is a routing scheme that adjust the beacon frequency keeping in consideration the local density. At higher density the beaconing rate is less whereas in sparse situation the beaconing rate is higher. It selects the forwarding node for data dissemination depending upon vehicles in the local periphery and the distance from the neighboring vehicles. Due to controlled beaconing the communication medium is free and can be utilized for delivery of data packets. The approach performs well for both highway and urban scenarios. Adaptive beacon broadcast in opportunistic routing (ABOR) [82] is a beacon control strategy where periodic beaconing broadcast is carried keeping in consideration the position, speed and direction. Beaconing frequency is decided upon calculating the life time of link between two nodes. The vehicles that has received the packet twice consecutively and in a high ranked node in the forwarding pool of vehicles is refrained from forwarding the beacons in subsequent transmission interval. Table X shows comparison of broadcast routing protocols.

Table- X: Comparison of broadcast routing protocols

Protocol	PDR	Latency	Control Overheads	Pros/Cons
UMB	H	ND	ND	Performs better with higher packet density, addresses hidden node problem, repeaters required at the intersection for better performance
BROADCOMM	H	L	L	Performs better than flooding based approaches, minimum communication time, issue of network partition or network fragmentation, perform only in a simple highway environment
Flooding	H	L	H	No broadcast suppression technique employed
DV-CAST	L	H	H	Suitable for dense and sparse environment, controls broadcast storm and network fragmentation, in high mobility performance depends upon beacon frequency, high dependency on GPS
UV-CAST	H	L	M	Addresses broadcast storm problem, uses gift wrapping algorithm which is highly complex
HyDi	H	M	H	Performs efficiently in well-connected and patchy situations
DRIVE	H	M	H	Eliminates the broadcast storm , network partition and fragmentation problem, division of transmission region may lead to selection of insignificant next forwarding node
SAB	H	L	L	Beaconless approach, uses speed of vehicles in the vicinity to gather traffic density, under sparse conditions data dissemination is inefficient
SEAD	H	M	L	Beaconless mechanism for gathering traffic density, does not address sparse traffic conditions and intermittent connected networks
DUB	H	L	M	Data dissemination in multiple directions, beacons needs to be broadcasted periodically.
AddP	H	L	L	Controlled beaconing depending vehicle density in vicinity, message aggregation using network coding reduces the number of messages, infrastructure support needed
ABOR	M	L	L	Improved quality of service, lesser overheads

L-Low, M-Medium, H-High, ND- Not Determined

Finally in Table XI, we have presented a summary of the routing protocols discussed in the previous section in terms of forwarding strategy, architecture and simulation tools used.

IV. MOBILITY MODEL AND SIMULATION

VANET simulation models in general treat all nodes identically. The purpose of a realistic mobility model is to evaluate the routing performance and predict the subsequent positions of the vehicle and accordingly make routing decisions as well. The mobility model specifies the moving pattern of nodes, their current location, velocity and change in acceleration with the passage of time [83]. On the basis of this information simulator generates random topology. The mobility model framework includes topological maps i.e. streets and lanes, roads, obstacles, speed of the as per vehicular densities and communication model etc. To generate realistic models, one way is to generate pattern from traces of mobility. Mobility model comprises of traffic pattern and motion pattern.

Motion pattern depends upon the driver's behaviour, pedestrians and movement of the vehicle. To create mobility pattern different types of model are created like:

Table- XI: Summary of various routing protocols in VANET

Routing Protocol	**Communication and Forwarding Strategy**	**Positioning System**	**Architecture**	**Simulation Scenario**	**Network Simulator**
ABOR	Position based opportunistic routing	✓	V2V	Urban	NS2
ACAR	Hybrid, Greedy, Store and Carry	✓	V2V	City	NS2
AddP	Multihop, Distance and Density based, Store and Carry	✓	V2I	Urban & Highway	OMNET++,
AODV	Unicast, Reactive, Multihop	✗	V2V	Free Place	OPNET,NS2, NCTUns, GloMoSim
A-STAR	Unicast, Geographic, Greedy	✓	V2V	Grid City Model	NS2
BROADCOMM	Broadcast, Distance and Local Topology based, Geographic Multihop, Prioritization	✗	V2V	Highway Model	Authors Own
CAR	Single Path, Geographic Greedy	✓	V2V	Urban & Highway	NS2
CBF	Non Delay Tolerant, Positional Greedy	✓	V2V	Urban	NS2
CBR	Multihop	✓	-	Urban	Not Simulated
CGR	Geocast based Multicast, Reactive, Geographic Store and Forward	✓	V2V	Urban & Highway	NS2
COIN	Cluster based Multicast, Unicast, Multihop	✓	V2V	Highway Model	Authors Own
Constrained Geocast	Geocast based Multicast Geographic	✓	Hybrid	-	OMNet++/Mixim
CPB	Direction based clustering and Probabilistic broadcasting	✓	V2V	Highway	NS2
CRLLR	Link reliability and Ant colony based optimization routing strategy	✓	V2V	Highway	NS3 and MATLAB
DBA-MAC	Geocast, Hybrid, Combination of collision and contention based forwarding	✓	V2V	Highway	NS2,SUMO
DRIVE	Position, Distance and Delay/Timer based, Store and Carry Forward	✓	Hybrid	City & Highway	OMNet++, SUMO, VEINS
DSDV	Proactive, Multihop	✗	V2V	Urban	NSTUns, GloMoSim, NS2
DSR	Unicast, Reactive, Multihop	✗	V2V	-	OPNET,NS2, NCTUns, OMNet++,
DTSG	Geocast based Multicast, Reactive Multihop Geographic	✓	V2I	Highway	.Net framework using C#
DUB	Broadcast based, Multihop, Store and Carry	✓	V2V	Urban	NS3
DV-CAST	Broadcast, Position and Local Topology Based, Multihop, Store and Carry Forward	✗	V2V	Highway	NS2
EBGR	Greedy	✓	-	Urban	NCTUns
EDCast	Broadcast, Distance based, Delay/Timer based, Store and Carry Forward		V2V	Highway	NS2, SUMO
FSR	Proactive, Multihop	✗	-	Urban	GloMoSim
Geocache	Geocast based Multicast Reactive, Geographic/ Store and Carry	✓	V2V	Urban	RTSim
GPCR	Unicast, Geographic Greedy	✓	V2V	Real City Model	NS2
GPSR	Unicast Geographic Greedy	✓	V2V	Highway Model	NS2
GRANT	Position Based Greedy Forwarding	✓	V2V	Urban	Authors own
GSPR	Unicast Proactive Greedy	✓	V2V	-	NS2
GSR	Unicast Geographic Shortest path intersection based	✓	V2V	Real City Model	NS2
GSRP	Multihop	✗	-	Urban	C++
GyTAR	Geographic Improved Greedy	✓	V2V	Urban	QualNet
HARP	Hybrid	✗	V2V	-	Not Simulated
HLAR	Broadcasting Hybrid Greedy Forwarding	✓	V2V	Highway	OPNET
HyDi	Broadcast, Multihop	✗	V2V	Highway	OMNeT++

IVG	Geocast based Multicast, Position, Distance, Delay/Timer based Greedy Forwarding	✓	V2V	Highway	GloMoSim
JBR	Single Path, Geographic Greedy	✓	V2V	Urban	NS2
LORA-CBF / R	Unicast, Reactive, Multihop	✓	V2V	Urban & Highway	OPNET
MDDC	Multiagent based dynamic clustering	✓	V2V	Urban	C programming
Mobicast	Geocast based Multicast, Multihop, Position, Distance, Delay/Timer based	✓	V2V	Urban	NSTUns
MURU	Multihop Greedy	✓	-	Urban	NS2
ODMRP	Multicast Proactive, Mesh Based Multihop	✗	V2V	Urban	GloMoSim, QualNet
OLSR	Proactive Multihop	✗	V2V	Urban	OPNet, QualNet
PassCAR	Broadcast	✓	V2V	Urban & Highway	NS2, MOVE
PBR	Predictive Store and Forward	✓	Hybrid	Highway Model	Author Own
PRODV	Unicast, Reactive	✗	V2V	Simple Highway Model	NS2
PRODV-M	Unicast, Reactive, Multihop	✗	V2V	Simple Highway Model	NS2
SAB	Distance and Delay/Timer based	✓	V2V	Highway Model	OMNET++, SUMO, VEINS
SADV	Multipath, Reactive, Store and Forward	✓	V2I	City Model	Authors Own
SRD	Reactive, Position, Distance, Local Topology based, Store and Carry Forward	✓	V2V	Highway	OMNet++
SEAD	Distance and Delay/Timer based, Multihop	✓	Hybrid	Highway	NS3, SUMO
TASR	Geographic, Greedy Forwarding	✓	Hybrid	Urban	Not Defined
TFOR	Geographic, Improved Greedy	✓	V2V	Urban	GloMoSim
TORA	Broadcast, Reactive, Multihop	✗	-	Urban	NS2, OPNET
TrAD	Broadcast based, store and carry	✓	V2V	Urban & Highway	OMNET++
UMB	Broadcast, Position, Distance and Delay/Timer based, Multihop	✓	Hybrid	Intersection Road	Matlab, CSIM
UV-CAST	Broadcast, Position, Distance based, Store and Carry Forward	✗	V2V	City	NS2,SUMO
VADD	Single Path, Reactive Greedy	✓	V2V	Urban	NS2
VDLA	Junction based Geographical Greedy Forwarding	✓	V2V	Urban	NS2
VMaSC	Broadcast, Reactive Distance based	✓	Hybrid	Highway	NS3, SUMO
VWCA	Broadcast, Reactive, Store and Forward	✓	V2V	Highway	MATLAB
ZRP	Broadcast, Hybrid, Flooding	-	V2V	Urban	QualNet, GloMoSim

In many survey models, the data collection is done on the basis of human behaviour and actions performed. The UDel mobility model [84] simulates the urban mobile wireless network that takes into consideration the obstructions in mobile nodes and generates graphs for urban area. The event driven models monitor human as well as vehicular movements and generate traces according to their location and motion. Probabilistic mobility models can be developed by event driven models that reflect real movement on a map [85]. Synthetic model are based upon mathematical equations to obtain realistic mobility models. They are categorized as [86]: i) Stochastic model: depends fully on random movement ii) Traffic Stream model: inspects the mechanical aspects of mobility model iii) Car following model: keeps track of the vehicle to vehicle communication iv) Queue model: deals with cars as if they are standing in queues and roads as buffers for these queues v) Behavioural model: examine the effect of movement due to human interaction. Software oriented model - simulators like VISSIM [87], CORSIM [88] perform traces of urban traffic level, can be used depending upon situation. Random way point model [89] is the simplest mobility model where nodes picks up its destination randomly and proceeds towards it at uniform speed. This model lacks actual mobility as the movement of vehicle is street dependent. Saha and Johnson [90] used road information from topologically integrated geographic encoding and referencing (TIGER) and proposed a real street mobility model with the assumption that every node begins from random point and move towards a random goal using some smallest route algorithm. They convert a map into graph. The outcome of routing protocols in VANET is measured using various simulation tools. Some of these simulators can use mobility models and mobility trajectory traces. Programming languages like Java and C++ are used to build simulators. Fig. 8 provide classification of simulation software. Street random waypoint (STRAW) application model [91] for vehicles in urban scenario treats vehicles as nodes with properties like max speed, acceleration and reaction time.

Retrieval Number F8779088619/2019©BEIESP
DOI: 10.35940/ijeat.F8779.088619
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

It can be used to model individual vehicle, intersections on roads and traffic control mechanism. STRAW architecture comprises of three interactive components which

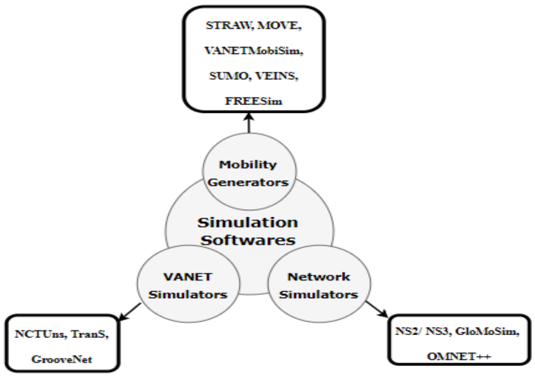

Figure 8. Classification of Simulation Software

includes intra-region mobility model, inter-region mobility model, route management and execution model. This model behaves well for wireless simulation but the cost of computation is more when the vehicles are large in number. The drawback of this model is that it is unable to allocate and deallocate nodes and change lanes dynamically. MOVE [92] is developed in Java language. In MOVE mobility traces can be generated from Google Earth or TIGER databases. MOVE itself does not simulate networks, but parse traces which can be processed by network simulator. VANETMobiSim [93] supports both V2V and V2I communication. Road and traffic topology can be obtained using parser from TIGER, GDF and random & custom topology. The trace file generated is parsed and is passed to network simulator. Simulation for urban mobility (SUMO) [94] is highly portable, space continuous, time discrete simulated environment for flow of traffic. It supports a variety of applications and is used in designing a detailed microscopic traffic simulation model. Variety of parameters related to road networks and vehicles like the number of lanes on the road, road length, maximum speed limit etc. are configurable in SUMO. Vehicles in network simulation (VEINS) [95] framework is based upon OMNET++ [96] and SUMO. TCP connections are used for exchanging simulation commands and mobility traces in these modules. FreeSim [97] under general public license is a freeway simulating tool which models free flowing traffic systems. Its GUI runs on web browser that gets connected to java based server application through sockets. The shortest and the fastest path can be determined in this on the basis of distance and present speed. National Chiao Tung university network simulator (NCTUns) [98] is GUI supported simulator built using C++ language. It combines both traffic and network simulators in one module. It can simulate IEEE 802.11a, 802.11b, 802.11c and 802.11g standards. The number of nodes supported by NCTUns is limited. The traffic and network simulation (TranS) [99] environment is based upon Java with visualization that integrates SUMO and NS-2. TranS supports network centric as well as application centric modes of simulation in which simulation is done for statically determined traffic flows [100] and dynamically generated events like sudden braking respectively [101]. TranS is flexible and supports real world maps. GrooveNet [102] provides communication between simulated vehicles and real vehicles so that they exchange information. It allows to explore DSRC based standards and simulation across multiple channel interfaces. It supports multiple vehicle trip and mobility models for various network links and physical models. It also supports different messages like GPS messages, warning messages etc. GrooveNet connects to the OBU's of vehicles and read diagnostic codes. NS2 [103] is written in C++ with OTcl (object tool command language) interpreter, is discrete event, object oriented simulator to carry out network research. User gives input to NS2 using OTcl scripts as input commands and trace files are obtained as output. Network Simulator 3 (NS3) [104] is a freeware available for both researchers and developers, is written in C++ and is available for various platforms like Linux, Unix, OS X, Windows. Global mobile simulator (GLOMOSIM) [105] is developed in Parsec as a freeware and can run on a shared memory symmetric processor in which network can be divided in separate modules, with each module executing a different process. The commercial version of GlomoSim is QualNet which is quite popular. OMNET [96] is modular component based C++ library with GUI support that is available freely for non-commercial usage. OPNET [106] simulates the behavior and performance of networks with various protocols. The OPNET modelling structure is split into three domains Network, Node and Process which includes subnets, devices and source codes respectively. QualNet [107] is a simulator for large heterogeneous networks and distributed applications. It can be used for creating virtual models for different networks to simulate the behavior under a variety of user defined scenarios and traffic patterns. It is highly scalable as it can accommodate thousands of nodes for sophisticated design and analysis and provides faster real time simulation.

V. FUTURE DIRECTIONS AND CONCLUSIONS

Intelligent Transport System is performing a key role in designing the future of vehicles and VANET has surfaced as a new technology in the last decade with applications that not only takes care of human safety but comfort as well. Information gathering and its timely dissemination has been the area where the researchers have been focusing quite lot [17]. In this study, we had tried to discuss various aspects of VANETs – architecture, applications, communications techniques, surveyed various MAC and routing protocols, mobility models and simulation tools as well. Further, VANETs are not impacted by memory, storage or limitations of energy. But the use of traditional wireless solutions do not work perfectly due to the volume of data generated, variation in density and mobility of vehicles. The OBU sensor protocols should be able to perform with lower channel utilization so that vehicles can easily access the information, also the information collected from different sources be aggregated so that redundancy can be avoided, channel bandwidth can be better utilized. The vehicle sensors should detect exact vehicle position, environment and road situation so that same can be shared with other vehicular nodes in the network.

The network disconnection is a major issue faced by inter vehicle routing protocols, especially where the density of the vehicle is low. On the other end in dense traffic scenarios, broadcast approaches results in channel contentions, packet collision and delay in delivery of information. A hybrid communication comprising vehicle-RSU-vehicle can address this issue, provided the wireless technologies can address the interoperability of heterogeneous nodes. Bandwidth contention is another area where VANETs performance is largely impacted. A number of routing protocols are proposed, still keeping in view the highly dynamic environment in VANET, various issues are yet to be addressed or more efficient routing mechanisms are required which should be able to acquire accurate geographic information, handle the obstacles in the urban environment which disrupts the communication, deal with prioritization and delivery of safety information without any delay to potential recipients, selecting of intermediate vehicles for forwarding packets containing information with minimal replication of transmission. Scalability is an another area that needs to be addressed as the number of vehicles that can be the part of VANET will be on the rise with the increase in spending power of individuals and also lower cost of vehicles in the years to come. At the end we can say that ITS is an essential building block in the modern society and researchers are working extensively in this field, but still a number of issues are there which deserve considerable attention and this survey paper will familiarize the budding researchers with different aspects of VANET.

ACKNOWLEDGMENT

The authors gratefully acknowledge IKG Punjab Technical University, Kapurthala, India and Amritsar College of Engineering and Technology, Amritsar, India to carry out this work.

REFERENCES

1. M. Chaqfeh, A. Lakas, and I. Jawhar. (2014). "A survey on data dissemination in vehicular ad hoc networks". *Vehicular Communications*. 1(4), pp. 214–225.
2. B. T. Sharef, R. A. Alsaqour, and M. Ismail. (2014). "Vehicular communication ad hoc routing protocols: A survey". *Journal of Network and Computer Applications*. 40, pp. 363–396.
3. "The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised) 1". *Annals of Emergency Medicine*. 66(2). pp. 194–196.
4. "2015 Urban Mobility Scorecard.pdf".
5. L. A. Villas, A. Boukerche, G. Maia, R. W. Pazzi, and A. A. F. Loureiro. (2014). "DRIVE: An efficient and robust data dissemination protocol for highway and urban vehicular ad hoc networks". *Computer Networks*. 75, pp. 381–394.
6. S. Al-Sultan, M. M. Al-Doori, A. H. Al-Bayatti, and H. Zedan. (2014). "A comprehensive survey on vehicular Ad Hoc network". *Journal of Network and Computer Applications*. 37, pp. 380–392.
7. F. Li and Y. Wang. (2007). "Routing in vehicular ad hoc networks: A survey". *IEEE Vehicular Technology Magazine*. 2(2), pp. 12–22.
8. J. J. Blum, A. Eskandarian, and L. J. Hoffman. (2004). "Challenges of Intervehicle Ad Hoc Networks". *IEEE Transactions on Intelligent Transportation Systems*. 5(4), pp. 347–351.
9. M. Nekovee. (2005). "Sensor networks on the road: the promises and challenges of vehicular ad hoc networks and grids".
10. B. Bako and M. Weber. (2011). "Efficient Information Dissemination in VANETs".
11. Y. Toor, P. Muhlethaler, and A. Laouiti. (2008). "Vehicle ad hoc networks: Applications and related technical issues". *IEEE communications surveys & tutorials*. 10(3), pp. 74-88.
12. J. Guo and N. Balon. (2006). "Vehicular ad hoc networks and dedicated short-range communication," *University of Michigan*.
13. [13] F. Cunha *et al*. (2016). "Data communication in VANETs: Protocols, applications and challenges". *Ad Hoc Networks*. 44, pp. 90–103.
14. Vegni, A.M., Biagi, M., & Cusani, R. (2013). Smart Vehicles, Technologies and Main Applications in Vehicular Ad hoc Networks.
15. D. Jiang and L. Delgrossi. (2008) "IEEE 802.11 p: Towards an international standard for wireless access in vehicular environments". *Vehicular Technology Conference. VTC Spring 2008. IEEE*, pp. 2036–2040.
16. J. B. Kenney. (2011). "Dedicated Short-Range Communications (DSRC) Standards in the United States". *Proceedings of the IEEE*, 99(7), pp. 1162–1182.
17. S. Zeadally, R. Hunt, Y.-S. Chen, A. Irwin, and A. Hassan. (2012). "Vehicular ad hoc networks (VANETS): status, results, and challenges". *Telecommunication Systems*. 50(4), pp. 217–241.
18. E. Karamad and F. Ashtiani. (2008). "A modified 802.11-based MAC scheme to assure fair access for vehicle-to-roadside communications". *Computer Communications*. 31(12), pp. 2898–2906.
19. N. Torabi and B. S. Ghahfarokhi. (2017). "Survey of medium access control schemes for inter-vehicle communications". *Computers & Electrical Engineering*. 64, pp. 450–472.
20. S. Gräfling, P. Mähönen, and J. Riihijärvi. (2010), "Performance evaluation of IEEE 1609 WAVE and IEEE 802.11 p for vehicular communications". *Second International Conference on Ubiquitous and Future Networks (ICUFN).* pp. 344–348.
21. Su Yang, H. H. Refai, and Xiaomin Ma. (2005). "CSMA based inter-vehicle communication using distributed and polling coordination". *Proceedings of IEEE Intelligent Transportation Systems.* pp. 167–171.
22. K. Bilstrup, E. Uhlemann, E. G. Strom, and U. Bilstrup. (2008). "Evaluation of the IEEE 802.11p MAC Method for Vehicle-to-Vehicle Communication". *IEEE 68th Vehicular Technology Conference*, pp. 1–5.
23. F. Yang, Y. Tang, and L. Huang. (2013). "A novel cooperative MAC for broadcasting in clustering VANETs". *International Conference on Connected Vehicles and Expo (ICCVE)*. pp. 893–897.
24. Y. Bi, K.-H. Liu, L. Cai, X. Shen, and H. Zhao. (2009). "A multi-channel token ring protocol for QoS provisioning in inter-vehicle communications". *IEEE Transactions on Wireless Communications*. 8(11), pp. 5621–5631.
25. X. Xie, B. Huang, S. Yang, and T. Lv. (2009). "Adaptive Multi-Channel MAC Protocol for Dense VANET with Directional Antennas," *6th IEEE Consumer Communications and Networking Conference.* pp. 1–5.
26. S. Bharati and W. Zhuang. (2018). *Link-Layer Cooperative Communication in Vehicular Networks*. Springer International Publishing.
27. M. S. Almalag, S. Olariu, and M. C. Weigle. (2012). "TDMA cluster-based MAC for VANETs (TC-MAC)". *IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM).* pp. 1–6.
28. C. E. Perkins and P. Bhagwat. (1994), "Highly dynamic destination-sequenced distance-vector routing (DSDV) for mobile computers". *ACM SIGCOMM computer communication review*. 24, pp. 234–244.
29. T.-W. Chen and M. Gerla. (1998). "Global state routing: A new routing scheme for ad-hoc wireless networks," *IEEE International Conference on Communication*, 1998, vol. 1, pp. 171–175.
30. G. Pei, M. Gerla, and T.-W. Chen. (2000). "Fisheye state routing: A routing scheme for ad hoc wireless networks". *IEEE International Conference on Communications. vol.* 1, pp. 70–74.
31. D. B. Johnson and D. A. Maltz. (1996). "Dynamic source routing in ad hoc wireless networks". *Mobile computing*. pp. 153–181.
32. V. D. Park and M. S. Corson. (1997) "A highly adaptive distributed routing algorithm for mobile wireless networks". *Sixteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Driving the Information Revolution (INFOCOM'97).* vol. 3, pp. 1405–1413.
33. E. M. Royer and C. E. Perkins. (1999). "Multicast operation of the ad-hoc on-demand distance vector routing protocol". *Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking*. pp. 207–218.
34. V. Namboodiri, M. Agarwal, and L. Gao. (2004) "A study on the feasibility of mobile gateways for vehicular ad-hoc networks". *Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks.* pp. 66–75.

35. Yong Ding and Li Xiao. (2010). "SADV: Static-Node-Assisted Adaptive Data Dissemination in Vehicular Networks". *IEEE Transactions on Vehicular Technology*. 59(5), pp. 2445–2455.
36. Z.J. Haas. (1997). "A New Routing Protocol for the reconfigurable Wireless Networks". *6th International conference on Universal Personal Communication*. pp: 562-566.
37. N. Nikaein, C. Bonnet, and N. Nikaein. (2001). "HARP - Hybrid Ad Hoc Routing Protocol".
38. M. Al-Rabayah and R. Malaney. (2012). "A New Scalable Hybrid Routing Protocol for VANETs". *IEEE Transactions on Vehicular Technology*. 61(6), pp. 2625–2635.
39. B. Karp and H. T. Kung, "GPSR: Greedy Perimeter Stateless Routing for Wireless Networks£," p. 12.
40. L. Briesemeister, L. Schafers, and G. Hommel. (2000), "Disseminating messages among highly mobile hosts based on inter-vehicle communication". *Proceedings of the IEEE Intelligent Vehicles Symposium*. pp. 522–527.
41. [41] C. Lochert, H. Hartenstein, J. Tian, H. Fussler, D. Hermann, and M. Mauve. (2003). "A routing strategy for vehicular ad hoc networks in city environments," in *Intelligent Vehicles Symposium.* pp. 156–161.
42. [42] H. Füßler, J. Widmer, M. Käsemann, M. Mauve, and H. Hartenstein. (2003). "Contention-based forwarding for mobile ad hoc networks". *Ad Hoc Networks*. 1(4), pp. 351–369.
43. [43] B.-C. Seet, G. Liu, B.-S. Lee, C.-H. Foh, K.-J. Wong, and K.-K. Lee. (2004). "A-STAR: A Mobile Ad Hoc Routing Strategy for Metropolis Vehicular Communications". *Networking Technologies, Services, and Protocols; Performance of Computer and Communication Networks; Mobile and Wireless Communications*, vol. 3042, Springer Berlin Heidelberg. pp. 989–999.
44. [44] M. Jerbi, R. Meraihi, S.-M. Senouci, and Y. Ghamri-Doudane. (2006). "GyTAR: improved greedy traffic aware routing protocol for vehicular ad hoc networks in city environments," *Proceedings of the 3rd international workshop on Vehicular ad hoc networks.* pp. 88.
45. [45] Z. Mo, H. Zhu, K. Makki, and N. Pissinou. (2006), "MURU: A Multi-Hop Routing Protocol for Urban Vehicular Ad Hoc Networks," pp. 1–8.
46. [46] V. Naumov and T. R. Gross. (2007) "Connectivity-aware routing (CAR) in vehicular ad-hoc networks," *26th IEEE International Conference on Computer Communications.* pp. 1919–1927.
47. [47] S. Schnaufer and W. Effelsberg. (2008). "Position-based unicast routing for city scenarios". *International Symposium on a World of Wireless, Mobile and Multimedia Networks*. pp. 1–8.
48. [48] K. Prasanth, K. Duraiswamy, K. Jayasudha, and C. Chandrasekar. (2009). "Edge node based greedy routing for VANET with constant bit rate packet transmission". *International Journal of Recent Trends in Engineering*. 2(4), pp. 14–19.
49. [49] Jing Zhao and Guohong Cao. (2008). "VADD: Vehicle-Assisted Data Delivery in Vehicular Ad Hoc Networks". *IEEE Transactions on Vehicular Technology*. 57(3), pp. 1910–1922.
50. [50] S. Tsiachris, G. Koltsidas, and F.-N. Pavlidou. (2013). "Junction-Based Geographic Routing Algorithm for Vehicular Ad hoc Networks". *Wireless Personal Communications*. 71(2), pp. 955–973.
51. [51] C. Zhao, C. Li, L. Zhu, H. Lin, and J. Li. (2012). "A vehicle density and load aware routing protocol for VANETs in city scenarios". *International Conference on Wireless Communications and Signal Processing (WCSP)*, pp. 1–6.
52. [52] I. A. Abbasi, B. Nazir, A. Abbasi, S. M. Bilal, and S. A. Madani. (2014). "A traffic flow-oriented routing protocol for VANETs". *EURASIP Journal on Wireless Communications and Networking.* 2014(1).
53. [53] H. Ghafoor, I. Koo, and N.-D. Gohar. (2014). "Neighboring and Connectivity-Aware Routing in VANETs". *The Scientific World Journal*. pp. 1–10.
54. [54] S. Khan, M. Alam, M. Fränzle, N. Müllner, and Y. Chen. (2018). "A Traffic Aware Segment-based Routing protocol for VANETs in urban scenarios". *Computers & Electrical Engineering.* 68, pp. 447–462.
55. [55] J. Blum, A. Eskandarian, and L. Hoffman. (2003). "Mobility management in IVC networks," in *Proceedings IEEE Intelligent Vehicles Symposium.* pp. 150–155.
56. [56] R. A. Santos, A. Edwards, R. M. Edwards, and N. L. Seed. (2005). "Performance evaluation of routing protocols in vehicular ad-hoc networks". *International Journal of Ad Hoc and Ubiquitous Computing*. 1(1/2), pp. 80–91.
57. [57] Y. Luo, W. Zhang, and Y. Hu. (2010). "A New Cluster Based Routing Protocol for VANET". *Second International Conference on Networks Security, Wireless Communications and Trusted Computing*, pp. 176–180.
58. [58] A. Daeinabi, A. G. Pour Rahbar, and A. Khademzadeh. (2011) "VWCA: An efficient clustering algorithm in vehicular ad hoc networks". *Journal of Network and Computer Applications*, 34(1), pp. 207–222.
59. [59] R. S. Schwartz, R. R. R. Barbosa, N. Meratnia, G. Heijenk, and H. Scholten. (2011). "A directional data dissemination protocol for vehicular environments". *Computer Communications*. 34(17), pp. 2057–2071.
60. [60] M. S. Kakkasageri and S. S. Manvi. (2012) "Multiagent driven dynamic clustering of vehicles in VANETs," *Journal of Network and Computer Applications*, 35(6), pp. 1771–1780.
61. [61] S.-S. Wang and Y.-S. Lin. (2013). "PassCAR: A passive clustering aided routing protocol for vehicular ad hoc networks". *Computer Communications.* 36(2), pp. 170–179.
62. [62] S. Ucar, S. C. Ergen, and O. Ozkasap. (2016). "Multihop-Cluster-Based IEEE 802.11p and LTE Hybrid Architecture for VANET Safety Message Dissemination". *IEEE Transactions on Vehicular Technology*. 65(4), pp. 2621–2636.
63. [63] L. Liu, C. Chen, T. Qiu, M. Zhang, S. Li, and B. Zhou. (2018). "A data dissemination scheme based on clustering and probabilistic broadcasting in VANETs". *Vehicular Communications.* 13, pp. 78–88.
64. F. Abbas and P. Fan. (2018). "Clustering-based reliable low-latency routing scheme using ACO method for vehicular networks". *Vehicular Communications*. 12, pp. 66–74.
65. A. Bachir and A. Benslimane. (2003). "A multicast protocol in ad hoc networks inter-vehicle geocast". *The 57th IEEE Semiannual Vehicular Technology Conference, 2003.* vol. 4, pp. 2456–2460.
66. C. Maihofer and R. Eberhardt. (2004). "Geocast in vehicular environments: caching and transmission range control for improved efficiency". *IEEE Intelligent Vehicles Symposium.* pp. 951–956.
67. Y.-S. Chen, Y.-W. Lin, and S.-L. Lee. (2009). "A Mobicast Routing Protocol in Vehicular Ad-Hoc Networks".
68. L. Bononi, M. Di Felice, and S. Pizzi. (2009). "DBA-MAC: dynamic backbone-assisted medium access control protocol for efficient broadcast in VANETs". *J. Inter. Net.*, 10(4), pp. 321–344.
69. A. Lakas and M. Shaqfa. (2011). "Geocache: Sharing and Exchanging Road Traffic Information Using Peer-to-Peer Vehicular Communication". *IEEE 73rd Vehicular Technology Conference (VTC Spring)*, pp. 1–7.
70. Sung-Ju Lee, M. Gerla, and Ching-Chuan Chiang. (1999). "On-demand multicast routing protocol," in *WCNC. IEEE Wireless Communications and Networking Conference.* pp. 1298–1302.
71. Laouiti, A., Jacquet, P., Minet, P., Viennot, L., Clausen, T.H., & Adjih, C. (2001). "Multicast Optimized Link State Routing".
72. H. Rahbar, K. Naik, and A. Nayak. (2010). "DTSG: Dynamic time-stable geocast routing in vehicular ad hoc networks," *The 9th IFIP Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net)*. pp. 1–7.
73. W. K. Wolterink, G. Heijenk, and G. Karagiannis. (2010). "Constrained geocast to support Cooperative Adaptive Cruise Control (CACC) merging". *IEEE Vehicular Networking Conference*. pp. 41–48.
74. G. Korkmaz, E. Ekici, F. Özgüner, and Ü. Özgüner. (2004). "Urban multi-hop broadcast protocol for inter-vehicle communication systems," *Proceedings of the first ACM workshop on Vehicular ad hoc networks.* pp. 76–85.
75. M. Durresi, A. Durresi, and L. Barolli. (2005). "Emergency Broadcast Protocol for Inter-Vehicle Communications," *11th International Conference on Parallel and Distributed Systems (ICPADS'05)*. vol. 2, pp. 402–406.
76. O. Tonguz, N. Wisitpongphan, F. Bait, P. Mudaliget, and V. Sadekart. (2007). "Broadcasting in VANET," *Mobile networking for vehicular environments.* pp. 7–12.
77. M. Chaqfeh and A. Lakas. (2016). "A novel approach for scalable multi-hop data dissemination in vehicular ad hoc networks". *Ad Hoc Networks.* 37, pp. 228–239.
78. I. Achour, T. Bejaoui, A. Busson, and S. Tabbane. (2016). "SEAD: A simple and efficient adaptive data dissemination protocol in vehicular ad-hoc networks". *Wireless Networks*, 22(5), pp. 1673–1683.
79. W. Wang, T. Luo, and Y. Hu. (2016). "An Adaptive Information Quantity-Based Broadcast Protocol for Safety Services in VANET" *Mobile Information Systems*. 2016, pp. 1–12.

80. G.-S. Li, X.-H. Chen, K.-S. Wu, and R. Chen. (2018). "Direction-based urban broadcast protocol for vehicular ad hoc networks," p. 180-192.
81. R. Oliveira, C. Montez, A. Boukerche, and M. S. Wangham. (2017). "Reliable data dissemination protocol for VANET traffic safety applications". *Ad Hoc Networks*. 63, pp. 30–44.
82. M. Naderi, F. Zargari, and M. Ghanbari. "Adaptive beacon broadcast in opportunistic routing for VANETs". *Ad Hoc Networks*. 86, pp. 119–130.
83. F. Bai and A. Helmy. (2004). "A Survey of Mobility Models". Wireless Adhoc Networks.pp. 30.
84. R. Jain, A. Puri, and R. Sengupta. (2001). "Geographical routing using partial information for wireless ad hoc networks". *IEEE Personal Communications*, 8(1), pp. 48–57.
85. C. Tuduce and T. Gross. (2005). "A mobility model based on WLAN traces and its validation". *Proceedings IEEE 24th Annual Joint Conference of the IEEE Computer and Communications Societies*. vol. 1, pp. 664–674.
86. M. Fiore. (2007). "Mobility Models in Inter-Vehicle Communications Literature," p. 13.
87. "PTV Vissim." [Online]. Available: http://vision-traffic.ptvgroup.com/en-us/products/ptv-vissim/. [Accessed: 21-Mar-2019].
88. "TSIS-CORSIM™ – McTrans." [Online]. Available: https://mctrans.ce.ufl.edu/mct/index.php/tsis-corsim/. [Accessed: 11-Mar-2019].
89. J. Broch, D. A. Maltz, D. B. Johnson, Y.-C. Hu, and J. Jetcheva. (1998). "A performance comparison of multi-hop wireless ad hoc network routing protocols," *Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking - MobiCom '98*. pp. 85–97.
90. A. K. Saha and D. B. Johnson. (2004). "Modeling Mobility for Vehicular Ad-hoc Networks". *Proceedings of the 1st ACM International Workshop on Vehicular Ad Hoc Networks*. pp. 91–92.
91. D. R. Choffnes and F. E. Bustamante. (2005). "An integrated mobility and traffic model for vehicular wireless networks". *Proceedings of the 2nd ACM international workshop on Vehicular ad hoc networks - VANET '05*. pp. 10.
92. F. K. Karnadi, Z. H. Mo, and K. Lan. (2005). "Rapid Generation of Realistic Mobility Models for VANET". *IEEE Wireless Communications and Networking Conference*. pp. 2506–2511.
93. "VanetMobiSim - Newcom | Institut Eurecom | Politecnico di Torino." [Online]. Available: http://vanet.eurecom.fr/. [Accessed: 26-Feb-2019].
94. D. Krajzewicz, J. Erdmann, M. Behrisch, and L. Bieker. (2012). "Recent Development and Applications of SUMO – Simulation of Urban MObility". pp. 128–138.
95. C. Sommer, R. German, and F. Dressler. (2011). "Bidirectionally Coupled Network and Road Traffic Simulation for Improved IVC Analysis". *IEEE Transactions on Mobile Computing*. 10(1), pp. 3–15.
96. A. Varga and R. Hornig. (2008). "An Overview of The OMNET++ Simulation Environment". *Proceedings of the First International ICST Conference on Simulation Tools and Techniques for Communications Networks and Systems*.
97. J. Miller. (2007). "FreeSim – A Free Real-Time V2V and V2I Freeway Traffic Simulator. *IEEE Intelligent Transport System Conference*," pp. 18-23.
98. S. Y. Wang *et al.* (2003). "The design and implementation of the NCTUns 1.0 network simulator". *Computer Networks*, 42(2), pp. 175–197.
99. M. Piorkowski, M. Raya, A. L. Lugo, P. Papadimitratos, M. Grossglauser, and J.-P. Hubaux. (2008). "TraNS: realistic joint traffic and network simulator for VANETs". *ACM SIGMOBILE mobile computing and communications review.* 12(1), pp. 31–33.
100. G. F. Riley and T. R. Henderson. (2010). "The Network Simulator," in *Modeling and Tools for Network Simulation*, Springer, pp. 15–34.
101. S. Rampfl. (2013). "Network simulation and its limitations".
102. R. Mangharam, D. Weller, R. Rajkumar, P. Mudalige, and F. Bai. (2006). "GrooveNet: A Hybrid Simulator for Vehicle-to-Vehicle Networks," *3rd Annual International Conference on Mobile and Ubiquitous Systems - Workshops*. pp. 1–8.
103. "The Network Simulator - ns-2." [Online]. Available: https://www.isi.edu/nsnam/ns/. [Accessed: 17-Mar-2019].
104. "NS-3 Network Simulator," [Online]. Available: https://www.nsnam.org/docs/release/3.29/manual. [Accessed: 11-Mar-2019].
105. "GloMoSim: a library for parallel simulation of large-scale wireless networks - IEEE Conference Publication." [Online]. Available: http://ieeexplore.ieee.org/document/685281/. [Accessed: 27-Dec-2017].
106. "OPNET," *Riverbed*. [Online]. Available: https://www.riverbed.com/in/products/steelcentral/opnet.html. [Accessed: 11-Mar-2019].
107. "SCALABLE Network Technologies." [Online]. Available: https://www.scalable-networks.com/. [Accessed: 11-Mar-2019].

AUTHORS PROFILE

Sandeep Kad received his Computer Science Bachelor in Engineering and Master in Technology degree from IKG Punjab Technical University Jalandhar, India. He is currently working toward the Ph.D degree in Computer Science and Engineering from IKG Punjab Technical University Kapurthala, India. He has published more than 45 research papers in various international journals and conferences. He has reviewed paper of IEEE Wireless Communication Magazine and Gazi University Journal of Science. His research interest includes Vehicular Ad hoc Networks, Wireless Sensor Networks and Soft Computing.

Vijay Kumar Banga is a Professor in the Department of Electronics and Communication Engineering at Amritsar College of Engineering and Technology, Amritsar, India. He received his Ph.D from Thapar University, Patiala, India. He has published more than 90 research papers in various international journals and conferences. His area of interest includes Artificial Intelligence, Robotics and Automation and Ad hoc Networks. He is a reviewer of International Journal of Robotics and Autonomous systems, IEEE Transaction on Evolutionary Computation, Elsevier Journal of Applied Soft Computing. He is a member of Member of World Academy of Science Engineering and Technology (WASET), Scientific and Technical Committee & Editorial Review Board on Natural and Applied Sciences, IEEE, Institution of Engineers (IEI), International Association of Computer Science and Information Technology (IACSIT).