www.ijecs.in
International Journal Of Engineering And Computer Science ISSN: 2319-7242
Volume 5 Issue 5 May 2016, Page No. 16383-16399

Routing Taxonomies for Network Aware Territory of Vehicles: A Review

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Abstract: ***In this task we aim to provide a through global taxonomy of VANET routing protocols. This task also aims to provide a simulation test bed enabling performance assessment of the protocols. This work also complements the previous approaches of classification. Characteristically we acknowledged following taxonomical routing protocols classification, based on their transmission approach, based on their prerequisite knowledge needed to realize routing, based on their delay sensitivity and toleration, based on their accommodating network i.e., heterogeneous and homogeneous vehicular network environment and based on their inspiration i.e., bio-inspired algorithms. Evaluation of a routing protocol in VANET is a necessary, indispensable and struggling task, so we bring assessment methods, i.e., simulation and real world research into the picture. Once the protocol passes all the simulation tests with expected results then it can be tested in the real time vehicular environments. All of this work provides a base for VANET research community to excogitate a new routing techniques.***

Keywords: VANET, Routing Protocol, IVC, ITS, WAVE, DSRC**.**

1. Introduction

VANETs was considered as an offshoot of MANETs but has now become a special area of research. Fundamentals of MANETs – the unplanned and voluntary formation of wireless network for data exchange – are applied to VANETs. Particulars and technicalities of MANETs and VANETs concede as well as contradicts. There are various similarities and dissimilarities between MANETs and VANETs. Eventually VANET has now ripen into a crucial part and parcel of Intelligent Transportation System (ITS). ITS exploits new technologies to minimize the road fatalities and maximize road's efficiency. [1] - [3] provide a comprehensive study of problems and expenses aroused because of increasing no of vehicles.

Dealing with routing take up utmost priority in giving values to VANETs applications in Inter Vehicular Communications (IVC), ITC, etc. In VANET scenario routing deals with the techniques, practices and procedures of choosing optimal journey among the paths available between packet's origin and destination vehicle. Less routing overhead, delay and high message delivery proportion are principal metrics in judging routing protocols efficiency. In VANETs high-speed of vehicles causes continuously changing network topology, process of route finding to be delayed and data packet to be lost. Because of inherent complication of VANETs there has been great passion among researchers to art a sound and effective routing protocols that for IVC, ITC, etc. applications.

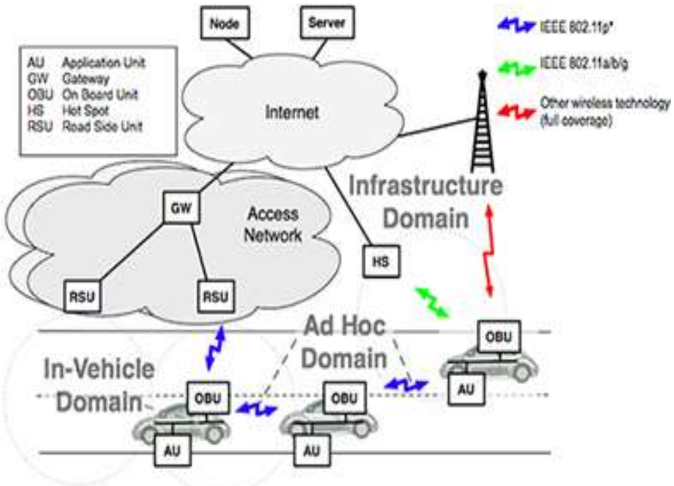


Fig. 1. VANET architecture depicted by C2C communication consortium [4].

VANETs can use any wireless networking technologies as their basis of communication in V2V or V2I mode as shown in Fig. 1 [4]. The most projected technology is Dedicated Short-Range Communication (DSRC) acknowledged as IEEE 802.11p Wireless Access in Vehicular Environment (WAVE). Fig. 2, shows the relationship between IEEE 1609 (WAVE) and IEEE 802.11p. Auxiliary technologies being used are WiMAX IEEE 802.16, Bluetooth IEEE 802.15.1, MBWA IEEE 802.20, ZigBee IEEE 802.15.4, Infrared and wireless. The main units of WAVE are On Board Unit (OBU), Road Side Unit (RSU) and Application Unit (AU). DSRC and WAVE are standards proposed for VANET routing. Upper layers of WAVE are being supported by IEEE 1609 family of standards.

In the last few years many VANET routing protocols review works, has been done but a thorough review work was felt with simulation and evaluation test bed. A routing protocol suitable in one application scenario may not be suitable in other. A routing scheme could have more than one objective.

Though the VANET routing protocols classification received their due, but the ideas associated with previous works are so recondite that a thorough classification is required – the main motivation behind this work.

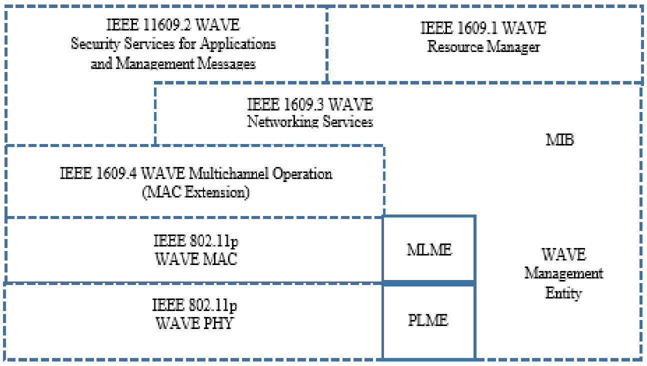


Fig. 2. IEEE 1609 (WAVE) architecture and relationship to the IEEE 802.16p MAC and physical layers

The organization of this work goes as follows. Section II discusses routing taxonomies. Various distinct aspects of classification is considered, i.e., transmission approach, knowledge needed, delay awareness, motivating inspiration and accommodating network. Performance assessment and simulation test bed are discussed in section III. Finally, section IV presents the conclusions and future orientation for the design, research and reasoning of routing protocols.

2. Routing Classification

Driver's helping hand, crash alert and collision prevention are few objectives of ITS safety applications provided to vehicles which form a VANET and it requires routing the packets between source and intended vehicles. Safety applications offered by fixed infrastructure vehicular networks such as Road-Weather Management, Crash Prevention and Alert, Freeway Management and Safety depends on safety information to be disseminated at right time. A lot time-privileged routing protocols like Dynamic Source Routing (DSR), Destination-Sequenced Distance-Vector (DSDV), Optimized Link State Routing Protocol (OLSR) and Ad-hoc On Demand Distance Vector (AODV) are changed from the MANET study. Geographic i.e., position based protocols like GPSR and then GPCR [5] were thought by researchers for frequent topology changing networks. Further, this paper describes a detailed classification of the various protocols based on some aspects mentioned in introduction of this paper Section I. We also include the timeline of the algorithms. Most of the protocols classified are applicable in a particular/common scenario and to a limited scale.

A. Based on Transmission Approach

1) Unicast Routing Protocols:

These protocols refers to packet routing from a one source to a one destination. In between source to destination protocols may use intermediate wireless nodes either by using opportunistic technique, buffering/carry-and-forward strategy or greedy forwarding technique. Greedy forwarding strategy sends packet to the far-most neighbor in the planned direction while buffering technique may hold a packet until a forwarding opportunity is available. Classically routing implies unicast routing which can be grouped according to Fig. 3, to be taken up in next sub-sections.

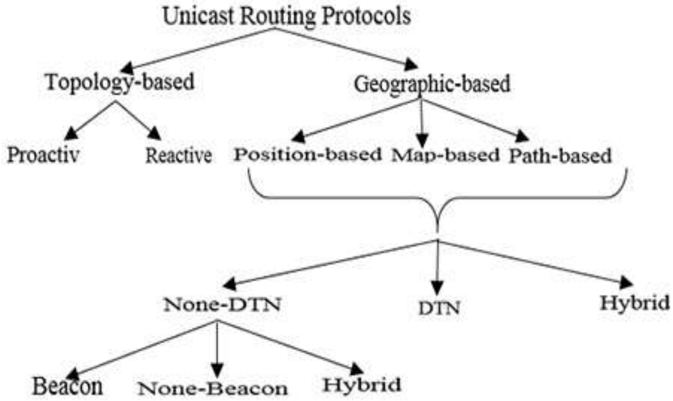


Fig. 3. Unicast Routing Protocol Taxonomy

Topology-based routing is assessed as the conventional style of routing packets as in MANETs. Commonly the topology-based routing makes bookkeeping of links information. Further, they are split up on as proactive and reactive protocols. Vehicles sends route discovery packets only on demand in case of reactive routing while repeatedly sends route discovery packets at regular intervals in case of proactive routing. AODV and DSR are renowned reactive protocols while OLSR and DSDV are proactive.

Geographic routing is more suitable in VANET environment as the algorithms uses the whereabouts of the source and destination nodes. Nodes involved in forwarding are familiar of their neighborhood. Position/path/map based routing stand in need of GPS.

2) Multicast/Geocast Routing Protocols:

a) Geocast:

Geocast refers to the transmission of packets to a batch of vehicles in vehicular network identified by their geographical locations called Zone of Relevance (ZOR). A geocast-message is only meaningful to a vehicle if it is in ZOR i.e., the vehicle necessarily meet a set of geographical/topographical norms. Another concept apart from ZOR is of Zone of Forwarding (ZOF) which is a set of geographical/topographical norms a vehicle necessarily meet to dispatch geocast messages. An instance of ZOR in VANET is shown in Fig. 4. As a contrast to pure-flooding based protocols geocast protocols allows flooding of messages only in ZOF thus causing less network congestion. Further, Geocast algorithms are split up on as Beaconless-based and Beacon-based protocols. Fig. 5, shows the taxonomy of geocast routing protocols.

Bachir et al. [6] came up with the Inter Vehicular Geocast (IVG) protocol for warning every vehicle of a roadway in case of barricade, hindrance and danger because of collision, accident or casualty. GPS helps in determining vehicles moving direction, its position and its velocity, these parameters are used by IVG algorithm for defining multicast group (risk areas) dynamically and temporally. The scenario of relay selection after an accident on highway has been depicted in Fig. 6. The vehicle which has met with accident starts to broadcast an alarm/emergency message and the way by which a node is nominated as relay is established on the defer-time, which is given by the equation,

$$\text{Defer\_time}(x) = \text{MaxDeferTime}.\ \frac{(R - D_{sx})}{R}$$

Where R is radio radius and D_{sx} is the separation between the vehicle 's' and 'x'.

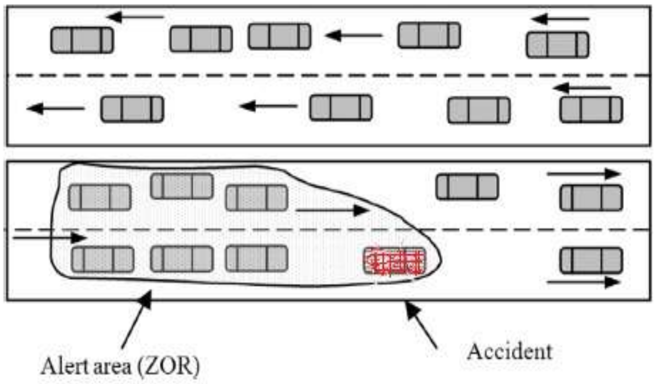


Fig. 4. ZOR, Multicast-group in Geocast Routing.

Following algorithm is executed by each relay node.

begin
when an emergency packet received by node(x)
if m is not important
then discard it
else node(x) defer-time has been set
when the timer ends it rebroadcast the packet
end

As IVG uses GPS for packet delivery to risk areas which uplift the costly operations for dense-dynamic situation for maintaining multicast tree such as neighbour estimation and routing. The simulation outputs done with Glomosium in [6] showed that the IVG protocol is scalable and reliable.

Maihöfer et al. [7] came up with the idea of caching unforwardable messages which a node cannot forward because of network segregation and torublesome neighbors. Having small cache at the network layer decreases network load and lag. Beaconing subsystem is used to be able to find the information about neighbour nodes. The cache holds the table of neighbour nodes and whenever there is any change among the neighbour nodes then the cached messages is scanned to find whether there is any packet which can be delivered according to changed table configuration.

Joshi et al. [8] came up with the idea of Distributed Robust Geocast protocol (DRG) which uses the distance-based backoff algorithm on the , more distant is more reliable, principle of selecting relay nodes. Its algorithm maintains restricted and directed flooding of messages and is completely distributed and stateless so the overhead is minimal and at the same time simulation results shows that its reliability is equal to the full-flooding protocols. Among the contending nodes the farthest node gets the chance as the babackoff time is conversely proportional with the last sender distance. Formula for calculating the backoff time based on distance is

$$BO_d\left(R_{tx}, d\right) = MaxBO_d.S_d\left(\frac{R_{tx} - d}{R_{tx}}\right)$$

where BO_d, R_{tx}, d, $MaxBO_d$ and S_d are the backoff time depending on the separation, the effective communication radio radius, the separation of current and last transmitter node, the maximum back off time and the distance sensitivity factor used respectively.

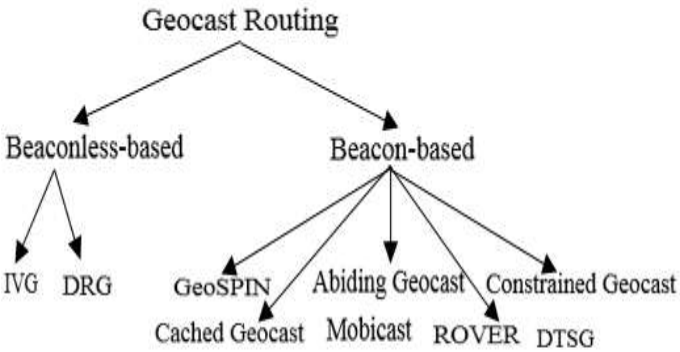


Fig. 5. Geocast routing taxonomy based on relay selection.

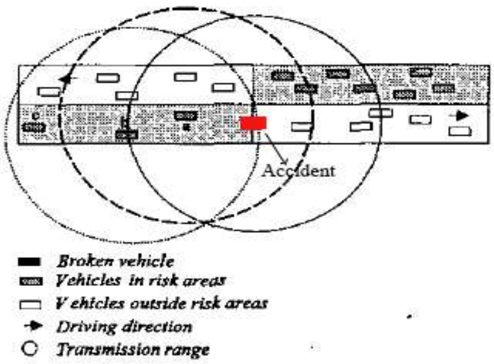


Fig. 6. IVG protocol relay selection after an accident.

The Reliable Geographical Routing in Vehicular Ad-hoc Networks has been studied by Khil et al [9], where they presented a <u>RO</u>bust <u>VE</u>hicular <u>R</u>outing (ROVER) protocol. They addressed the problem of broadcasting with flooding-based geocast algorithms that depends upon multicast communications with end-to-end Quality of Service (QoS). Like AODV, ROVER also floods control messages in the ZOR while the data packets are unicasted. In this protocol each vehicle is identified by a unique Vehicle Identification Number (VIN) and the ZOR is of rectangular shape with their corner coordinates specified. ZOF includes the source and the ZOR.

ROVER's packet format is a triplet [A, M, Z] where A, M and Z corresponds to Application, Message and ZOR. The message, M is meant for all the vehicles within a Z, ZOR from an Application, A. Multicast tree is built from the source vehicle to all other vehicles that lie inside ZOR by route determination operation which begins upon receipt of a message by network layer pushed by application layer. ROVER is very much suitable for the scenario where it needs end-to-end QoS.

Maihöfer et al. [10] came up with the idea of Abiding Geocast which is a time stable geocast, requiring the transmission of messages to all vehicles within a ZOR during the geocast lifetime. Fig. 7, gives the building block of the design space of Abiding Geocast. These building blocks can be mingled in three different ways to achieve the Abiding Geocast. First one is the Server Approach in which storage is done by server and message hand over is not required at all. In the second approach a node is elected in the ZOR to perform message storage requiring the handover of messages before this elected node leaves the ZOR. In the third approach each node performs peer-to-peer task of storage and keeping the neighbor information with handover of messages to the new node entering the region.

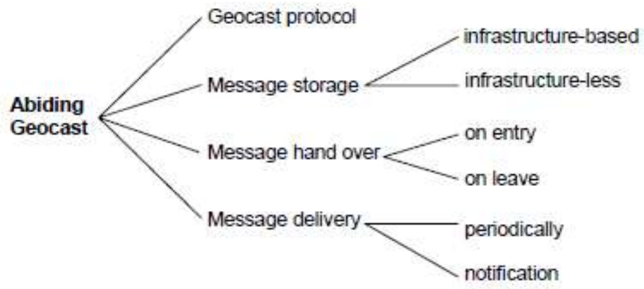


Fig. 7. Building blocks of the design space of abiding geocast.

Celes et al. [11] came up with a geocast routing, GeoSPIN, considering the data mining methods on individual vehicle's daily trajectories records acquired through GPS. The trajectories information is the spatial information which is used in conjunction of sort-carry-and-forward method explored with the opportunistic contacts of vehicles for message dissemination. The GeoSPIN approach is split in two steps. In the first step i.e., *clustering of trajectories*, data mining is done on the daily trajectories of the vehicle's movement for calculating the likelihood of the moving vehicle to take a particular route. In the second step i.e., *message forwarding*, after each node has a trajectory pattern, calculated in first step, GeoSPIN disseminate message on the *Encounter (n, r)* and *Convergence (n, r)* assumptions.

Rahbar et al. [12] came up with a Dynamic Time-Stable Geocast Routing (DTSG) protocol aiming to keep a message persistent within a geographical area for specified time interval which can be scaled up, scaled down and even aborted, hence the authors claimed the protocol as dynamic. The simulation results of protocol showed it's free-wheeling with the vehicles density, speed and wireless range. The message can be contained over a particular geographic area for some time. In protocol description authors coined four types of vehicles i.e., *source*, *intended*, *helping* and *leader* vehicles respectively. The two stages of the protocol are pre-stable period in which the region is populated with the messages and stable period in which the protocol gets stabilizes within that region. The DTSG protocol works well in sparse networks as it is shown by the simulation results.

Constrained Geocast to support Cooperative Adaptive Cruise Control (CACC) Merging was proposed by Wolterink et al. [13] based on the probable vehicle's position in immediate future time instead of the vehicle's instantaneous position. This protocol adapts well with the increase in traffic but has performance issues with other metrics. The application of this protocol is to guide the joining of new vehicles inside a currently moving linear batch of vehicles i.e., array of vehicles.

Chen at al. [14] came up with a Mobicast routing protocol which is suitable for the application that needs space-time ordination in vehicular networks. Vehicles in some geographic zone i.e., ZOR_t, receives packet at time t, disseminated by a source. ZOR_t is defined as a time function under certain time-interval. As sometime vehicles miss to receive the packet because of high velocity/mobility which is termed as temporal network fragmentation and can be taken up by accurately estimating dynamic forwarding zone. Three different but related zones were coined as ZOR_t (Zone of Relevance at time, t), Fig. 8, ZOF_t (Zone of Forwarding at time, t), and ZOA_t (Zone of Approaching at time, t). ZOR_t defines a region with event vehicle in the center such that all vehicles that are nearby be able to collect the mobicast packet from event vehicle successfully. ZOF_t defines a region in which each vehicle within the ZOR_t forwards the mobicast message collected by event vehicle. ZOA_t defines a zone for forwarding close to a destination vehicle which forwards packets collected from event vehicle. The spatio-temporal mobicast protocol is divided into three steps of ZOR_t creation step, then mobicast message delivery step and finally the ZOA_t growing phase. The first step identify the ZOR_t as a function of time, the second step continuously disseminate control packets and the third step solves the problem of temporal network fragmentation.

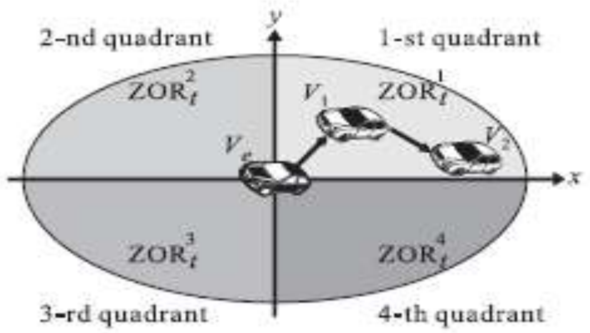


Fig. 8. Mobicast Zone of Relevance at any time instant

b) Multicast:

Conventional multicast routing algorithms are not applicable for the VANETs as they were devised for the physically connected wired networks. Many MANETs multicast protocols are also suitable for VANETs since both are wireless but in the latter case there is consideration of high mobility, frequent topological changes etc. In multicasting a single node identifies a group of nodes for information dissemination by multihop communication. Based on the routing structure of the involved nodes multicast routing algorithms gets broadly divided into tree and mesh based routing algorithms. In the tree based protocols claim packets are flooded by the host using the optimal flooding techniques and involved nodes responses back to the host along the backward path to form a multicast tree rooted at the host. In mesh-based approach a mesh is sustained consisting of connected part of the network that takes in all recipients in a group. Senders and receivers constitute multicast-group members and together with the forwarding nodes (relay nodes) termed as tree or mesh nodes. Fig. 9, gives the anatomy of multicast routing protocols.

DOI: 10.18535/ijecs/v5i5.12

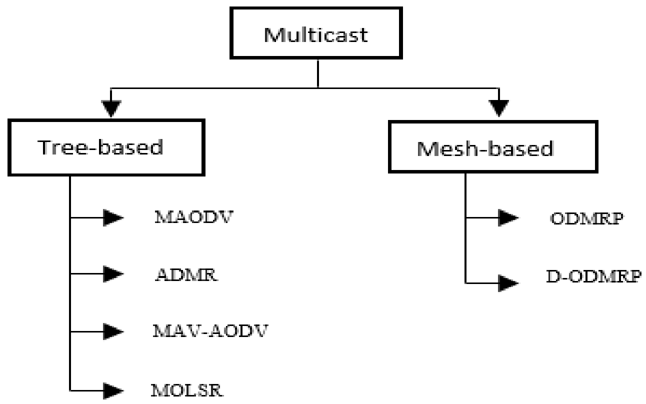


Fig. 9. Mobicast Zone of Relevance at any time instant

In MAODV the AODV protocol is extended for multicasting. For multicast AODV has to maintain a table i.e., multicast route table, having the fields such as *group sequence, next hop, group leader identification number, multicast group identification number, hop count, lifetime* etc. MAODV uses broadcast technique for determination of routes. As depicted in fig. 10 (a), when a mobile node either desires to attach in a multicast group or needs to transmit data and it does not have a routing path to that group, then it delivers a *Route Request (RREQ)* message. The message is retransmitted by the nodes till it gets received by a mobile node which is a member of the multicast group tree which in turn sends the *Request Reply (RREP)* message via unicast as shown in fig. 10 (b). The relay nodes also mark the address of the mobile nodes from which they collected *RREQ* packet in their routing table so that they can make a backward route to the originator node of *RREQ* packet. In case the originator node may receive multiple *RREP* packets then the shortest route on the basis of hop-count metric will be selected to forward the *Multicast Activation (MACT)* packet, as shown in fig. 10 (c). After this exchange of message the vehicle turn into a multicast group member and every vehicle along the selected path from this vehicle to the vehicle that recieves the *MACT* message becomes a forwarding vehicle. The connectivity condition of the formed tree is monitored by the first node to request membership, i.e., it becomes the group leader. Link breakage eliminates the forwarding node from the tree and the tree is repaired by re-establishing branches and reconnection to the base tree is initiated. MAODV have simple implementation but has many disvantages in VANETs scenario i.e., long delays, overheads, low delivery ratio etc.

Adaptive Demand-driven Multicast Routing was proposed by Jetcheva and Johnson aiming to reduce any non-on-demand behaviour within the portions of on-demand protocols. In ADMR protocol, for every source-destination pair a source-based frowarding trees are generated. Multicast source-applications are monitored for link breakage in trees and to monitor the sources that have become inactiv. Two approaches for repairing the link breakage are followed i.e., local repair approach and global repair if former gets failed. For inactive members the state is quietly ceased without any message.For temporarily inactive senders the ADMR sends keep-alive packets with increasing inter-packet intervals but when the source becomes permanently inactive then the entire tree is terminated. No control messages for tree maintainence is required because the nodes are able to guess on the basis of inter-packet time, the arrival of next multicast packet. Also individual paths within a tree can be cut back when they are not needed for forwarding. With the increase in mobility within the network ADMR switches to flooding mode and after short time it settles again on the multicast mode. Packets are transmitted using MAC-layer shortest delay path via the multicast forwarding state. So in short ADMR does not use network-wide floods, adapts its behaviour and the high mobility can be detected without the assistance of GPS.

Another tree based multicast protocol named MAV-AODV will be discussed in next section.

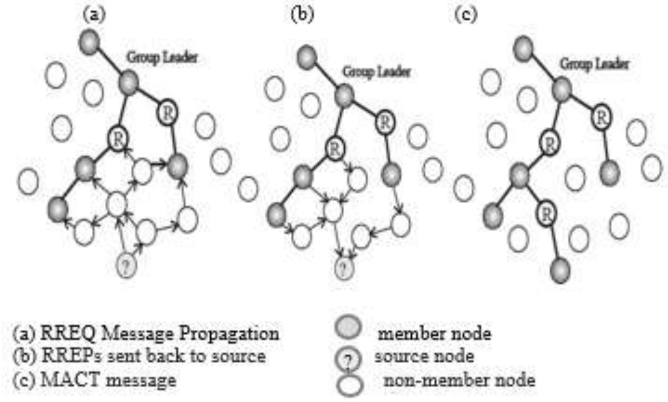
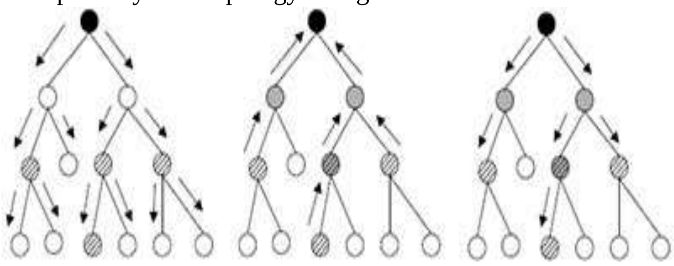


Fig. 10. MAODV join operation

The proposal of Multicast Optimized Link State Routing (MOLSR) is based on OLSR. The MOLSR is benefited by gathering information of topology collected by OLSR protocol which utilizes its topology control packets to form multicast tree. For any source vehicle of multicast group, a multicast tree is maintained in a distributed mode i.e., without any central management. The multicast tree implements the shortest direct paths from source to the members of multicast tree and on detection of topology change the tree gets updated. The overview of the protocol can be divided into three parts viz., tree building as shown in fig. 11, tree maintenance and tree detachment. MOLSR protocol is classified under source-tree based protocols. During tree building phase *MC_CLAIM* packets are broadcasted to the entire network by the multicast routers and this is done periodically. Source announces its presence, whenever it requires to send message to a specific group, by sending a *SOURCE_CLAIM* packet which lets the members be connected to the tree. Optimized flooding of OLSR is used for the flooding of messages in the network. Upon receiving the *SOURCE_CLAIM* message by a member which is not the part of tree, it explores in its table of multicast routing to find the subsequent hop to reach the source and making the subsequent hop its parent in the multicast tree by delivering it the *CONFIRM_PARENT* packet. The tree maintenance is done by *SOURCE_CLAIM* and *CONFIRM_PARENT* packets by OLSR methodology. For tree detachment a node (leaf node) it dispatches a *LEAVE* packet to its parent.

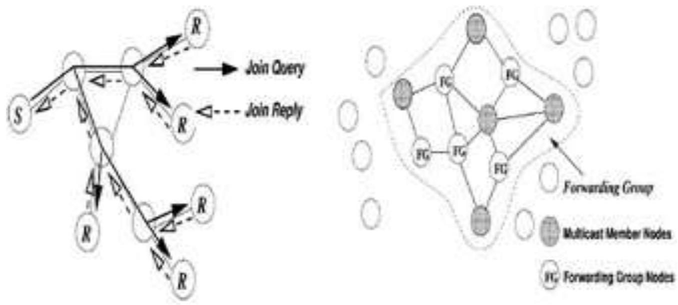
On Demand Multicast Routing Protocol (ODMRP) uses forwarding group concept that comes under mesh-based multicast protocol i.e., a subset of nodes forwards the multicast packets through scoped flooding. Similar to reactive unicast protocols, the ODMRP can be split in two steps i.e., request-phase and reply-phase. In ODMRP, group membership, establishment and updating of multicast group is done by the source. When a source vehicle wants to deliver packet, it floods the JOIN_QUERY packet with data piggybacking and these packets are regularly advertised for the route updating and membership information. Upon interception of JOIN_QUERY packet by non-member, initially it is checked for duplicity and if it is not the case then upstream node ID is stored and then it rebroadcast the message. Upon receiving the JOIN_QUERY message by the multicast receiver it broadcast JOIN_REPLY message. Upon receive of JOIN_REPLY message by a vehicle, protocol checks for if the next vehicle ID agrees with its ID and if it is the case then it authorizes itself by setting a flag to become a forwarding vehicle and floods in the network its JOIN_REPLY packet. Fig. 12, shows the membership structuring and conservation with the forwarding concept. For the nodes that desires to abandon the group the protocol quietly ceases dispatching of JOIN_QUERY messages and the route gets dropped upon not being refreshed i.e., a soft-state approach. Main advantages of ODMRP is low bandwidth usage and adaptability with topology changes



(a) source_claim Flooding.(b) confirm_parent msg.(c) source multicast data.

●-source ● - multicast tree participant ⊄ client group

Fig. 11. MOLSR tree building process.



(a) Join_query and Join_reply (b) Forwarding group concept

Fig. 12. ODMRP join operation, membership setup, maintenance and group forwarding concept.

Destination-driven On Demand Multicast Routing Protocol (D-ODMRP) is based on ODMRP which aims to enhance the efficiency of multicast forwarding. In this protocol the destination path is tendentious with those paths which traverses another multicast destination and among them the path with less cost is selected. The protocol implementation can be split into three steps viz., join query process, join reply process and data forwarding process. Here, all processes repeats at regular intervals of time. In this protocol the Join Query phase is somewhat modified from the ODMRP by adding supplementary deferring-time at every mobile node which receives the message. The deferring-time is calculated upon how distant this received Join Query has left from the last contacted group member and is proportional to the distance. The deferring-time allows the Join Query to propagate quickly through the less costly routes. During Join Reply phase, upon the receiving of Join Query message by a multicast member it waits for an interval hoping to receive more such messages to select the best Join Query among the multiple Join Queries available. Join Reply message are unicasted back to the neighbor accordingly after the interval. During the data forwarding step source dispatches messages to the forwarding nodes which checks its flag to see whether it is in the forwarding group or not for that multicast session and if it is the case then it broadcasts the received packet. As compared to ODMRP this protocol has less extra overheads.

c) Broadcast Routing Protocols:

Broadcasting refers to the dispatching of messages to all nodes within the broadcast domain. This technique is acknowledged as the most applicable technique for sharing information about traffic, climate, emergency, accidents and announcements. Common technique used in broadcasting is flooding which leads to broadcast storm problem and redundant message retransmission resulting in channel congestion and decrease in reliability. Selective flooding eliminates the redundant message retransmission as it lets only selected relay nodes to perform retransmission of messages. Each node has the responsibility of identifying the duplicate packets to be discarded. Unicast protocols also use broadcasting approach in their route discovery phase when source don’t have direct transmission range to the sender. All the major broadcasting protocols proposed by researchers are given in the Fig. 13, with their category but the discussion of each individual protocols is beyond the scope of this work, however we will discuss some protocols of each category.

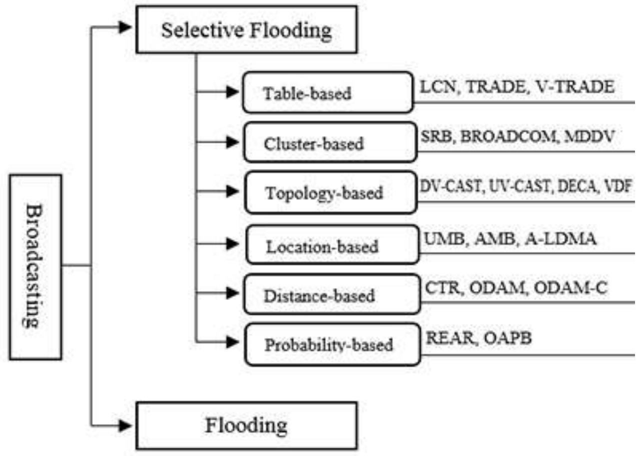


Fig. 13. Broadcasting routing protocol taxonomy

In table-based approach of broadcasting, each mobile node holds directory of neighbors that is regularly updated by the query and reply processes. The cluster-based approach of broadcasting scheme splits the road topology in many clusters and choose a cluster leader among the nodes forming the cluster and then it exclusively performs broadcasting. Topology based broadcasting protocols use network information, for example density of nodes and connectivity of links to perform broadcasting. Based on geographic areas messages are disseminated in case of location based broadcast. In location based approach each sending nodes adds its location which is used by the receiving nodes. Distance based methods considers the neighbor’s relative distance and hop counts between source and destination to decide whether to rebroadcast or not. Two phases are there, first one is estimation phase and the second one is broadcast phase. The probability based broadcasting protocols assigns a predefined fixed probability to reduce collisions and re broadcast by adopting persistence schemes. The probability based approaches gives good results in dense networks but has trifle significance in case of sparse networks.

Yu *et al*. [15] presents a Least Common Neighbor (LCN) based table driven selective flooding protocols for disseminating emergency messages for vehicular safety applications. LCN method decreases the number of relay vehicles that are in the same wireless range. Every sender's message consists of its own neighbors directory and the receiving vehicles matches its own neighbors directory against the received message to determine whether it has least common neighbors to be selected as relay nodes. If the common neighbors are mostly same then the receiving node does not broadcast the packet. Sun *et al*. proposed GPS-based Message Broadcast for Adaptive Inter-vehicle communication [16]. They used the term TRAcking DEtection (TRADE) protocol for their approach to organize the neighboring vehicles into distinct categories to choose less number of vehicles for re-broadcast. Vehicles are put into three different groups namely *same_road_ahead*, *same_road_behind* and *different_road*. Then protocol selects the farthest vehicles (border vehicles) from *same_road_ahead* and same road behind group. Every vehicles are selected from *different_road* group. The sender transmits the message with the border vehicles ID's and all the receivers then decide whether to re-broadcast the message or not by comparing the ID's within the message and its own ID.

Vengi *et al.* proposed Selective Reliable Broadcast (SRB) [17] protocol for safety applications in VANETs. The protocol proposes to minimize the broadcast storm complication for the congested traffic scenarios where packet collisions occurs. The whole vehicular network is partitioned into clusters with one node among them elected as cluster head. Vehicles within a cluster are independent of other clusters and they can't communicate directly but via cluster heads as shown in Fig. 14. A sender only forwards the messages to the cluster heads. Arrival angle of the Clear-to-Broadcast (CTB) packet is measured for the detection of cluster, which enables the source vehicles to estimate the distances which if less than the predefined threshold value then the vehicles are considered in the same cluster. Within a cluster farthest vehicle is elected as a cluster head and the whole process of cluster detection with electing head is automatic and here the algorithm outperforms the traditional approaches of broadcasting.

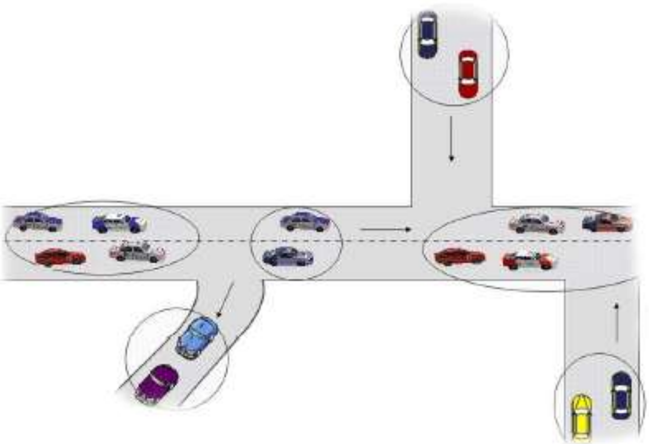


Fig. 14. Separated clusters of vehicles because of space among clusters

Durresi *et al.* [18] presents a protocol called BROADCOMM which aims to improve the quality of broadcast in IVC with low network load maintenance. The whole vehicular network is partitioned into virtual moving cells and these cells move as the vehicles move. There are two levels of categorical grouping in the vehicles viz., first level comprises of all the nodes in a cell and second level is represented by few geographically centered nodes with sensors installed on it. Cell nodes can have inter cell communication but with which they are in radio communication range. Second level grouping's communication takes place when sensor installed nodes communicates with nodes within the cell. The hierarchical structure gives the protocol a choice of differentiated service and good QoS and here is the advantage of BROADCOMM when compared to the traditional broadcasting protocols.

Tonguz et al. [19] proposed a protocol by the name DV-CAST which is a distributed broadcast protocol for VANETs. The protocol works in multi-hop broadcast fashion to work in regular, sparse as well as dense traffics. The protocol is pure ad hoc in nature with no infrastructure support and each vehicle has GPS. The communicating device periodically sends out hello messages at a frequency of 1 Hz. The per-hop routing with local connectivity information assures the maximum reachability of broadcast packets. Some routing parameters are defined in the protocols viz., *DFlg* - for determining whether intended recipient is moving in the same direction as the source, Message Direction Connectivity (MDC) - for determining whether it is the last vehicle in the group (cluster) and Opposite Direction Connectivity (ODC) - for determining if it is in connection with at least one vehicle moving in the reverse direction. For vehicles which has *DFlg* set to 1 ignore duplicate packets and if it has *DFlg* set to 0, then vehicle act as a relay node and should do routing (per hop routing). The steps followed by the protocol for appropriate manipulation of broadcast packets depends on the density of vehicles (network).

Based on the work of DV-CAST Viriyasitavat et al. [20] proposed Urban Vehicular BroadCAST protocol (UV-CAST) which was acknowledged as the first work in broadcasting routing protocols for urban scenarios. UV-CAST eliminates broadcast storm and fragmented network complexities in downtown sides to a large extent. The work was evaluated against the metrics of network reachability, network overhead and received distance, simulated in Manhattan mobility model and real city of Pittsburg. Other topology based broadcasting protocols are Vehicle Density-based Forwarding (VDF) [21] and Density-aware reliable broadcasting in vehicular ad hoc networks (DECA) [22].

Urban Multi-hop Broadcast (UMB) proposed in [23] aims to eliminate the issues of hidden nodes, reliability and broadcast storm in urban scenarios. The protocol is divided into two steps viz., the first one is directional broadcast and the second one is intersection broadcast. In directional broadcast sender vehicle sends the packet to the far off node in the broadcast direction and this does not require any topological information. In second phase of intersection broadcast the repeaters installed at intersection point has the responsibility to disseminate the packet in all directions. The UMB protocol works without local information's message exchanges thus reduces the overhead of network. Intersection broadcast handling is shown in Fig. 15, where node A reaches node B via directional broadcast as it is out of the communication radio radius of repeater C installed at intersection. As B is in communication radio radius of C, so it can communicate with C and upon receiving of message by C from B, C initiates the directional broadcast in the south and north directions. D being in the transmission range of C also receives the packet in east direction. Their further work presents an Ad-hoc Multi-hop Broadcast (AMB) [24] which is an ad-hoc extension of the UMB protocol. It does not require the repeaters that are the greatest drawback of the UMB protocol. When there is a street junction in the message dissemination path, the vehicle closest to that junction performs a fresh directional broadcasts to all road segments through a fully ad-hoc algorithm.

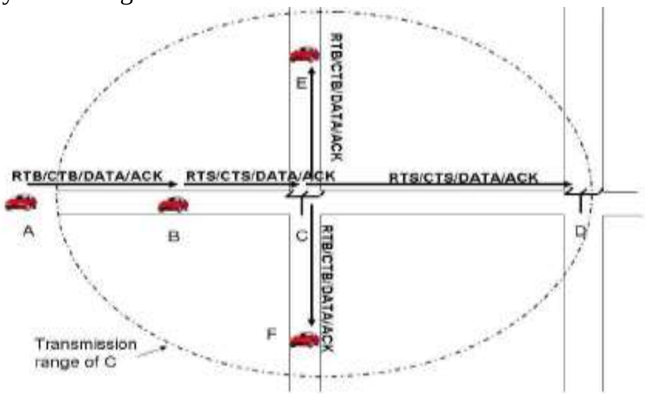


Fig. 15. UMB protocol's intersection handling [51].

Choi et al. [25] proposed Adaptive Location Division Multiple Access (A-LDMA) protocol aiming to disengage beacon traffic from the broadcast storm to accomplish more persistent reliability of safety messages. Access of medium to the vehicles is based on their location-to-time mapping and their geographic location. The protocol reduces the contending transmitters based on a TDMA schedule which is a simple MAC level algorithm since it uses location-based deterministic slot allocation approach.

Akkhara et al. [26] proposed Multi-Channel Cut-Through Rebroadcasting (CTR) protocol for safety packets transmission with the aim of minimizing the rebroadcasting vehicles and overlapped rebroadcasting using multiple channels of the available bandwidth. They gave the idea of giving preference to the far off vehicle in the communication radio radius from source vehicle to rebroadcast the message. Vehicles have two transceivers installed and distinct channels are allotted to vehicles for different hops to avert the collision during broadcast. This protocol proposes the utilization of multiple channels available from the total bandwidth.

Sun et al. [27] proposed broadcasting algorithm called ODAM-C based on Optimized Dissemination of Alarm Messages (ODAM) [28] aiming to improve the message delivery proportion. The protocol employs two approaches based on the forwarding aspects of ODAM viz., distance-based approach for reducing the probability of losing packet by calculating the angles between sources, forwarding and receiving vehicles and redundancy approach for improving packet delivery proportion.

Alshaer et al. proposed a probability and restricted zone based broadcast scheme called as Optimistic Adaptive Probabilistic Broadcast (OAPB) [29] to eliminate the broadcast storm complication. The motive of their algorithm is to reduce forwarding or rebroadcasting set of nodes to an optimal choice. Each vehicles rebroadcast probability adaptively changes within two hops depending on its local information. Periodic hello messages enables the nodes to get local information for the estimation of local vehicles density based on which nodes dynamically calculates its rebroadcast probability. Vehicles with larger probability value are assigned a shorter delay time to rebroadcast.

Reception Estimation Alarm Routing (REAR) [30] guesses the reception possibilities of alarm packets for the moving vehicles. Instead of selecting those nodes as relays which are far off this protocol gives preferences to those vehicles which has highest probability to relay packet based on real wireless channel. Periodical beacons are used to collect information regarding location and size among the neighbors to maintain neighborhood list. The alarm message also contains the neighborhood directory table and direction of message propagation. Those vehicles which received the alarm packet and are moving in the same direction of alarm source vehicle can participate in relay node election. Calculation of contention lag based on receipt possibilities of neighbors leads to contention phase. The time taken for relay of packet by the node is proportional to the contention delay and when the vehicle is trying to relay packet to other vehicle and hears the alarm packet, it cancels its contention phase and hence redundant broadcasting is avoided in this way.

B. Based on Prerequisite Knowledge

1) Topology-Based Routing:

Fig. 16 shows the taxonomy of topology based routing which can be categorized as proactive (table-driven), reactive (on-demand) and hybrid routing protocols. Proactive algorithms apply the concept of shortest path algorithm for unicasting the packets. Neighboring nodes information are stored in tabular form which gets shared between the vehicles for the updation of the network's topological changes. On-demand or reactive algorithms catches routes on demand by flooding network with route request messages which sometimes leads to network clogging and there is delays in route discovery but is suitable for VANETs as the topology changes very frequently with time. In hybrid protocols the aim is to combine the goods of both proactive and reactive algorithms. The routing is originally settled by proactively discovered routes then after routing is served using reactive algorithms.

DSDV is one of the earliest ad hoc routing protocol adapted from MANETs and is based on Bellman-Ford algorithm. DSDV guarantees the loop free paths and decreases the convergence time compared to its earlier protocols. The protocol maintains a table for each node where each table contains information about all accessible network nodes with the count of hops to reach them and each table entry is marked with sequence counters by the destination nodes. The sequence number is even if the link is ok otherwise it is odd. Consistency maintenance of routing tables is maintained by regular broadcast of routing tables to the neighbor nodes when there is a change in topology or new information is available.

Global State Routing Protocol (GSRP) proposed in [31], maintains a global knowledge of the network topology by exchanging vectors of link states between neighbors during routing information exchange. Initially every node have unfilled table of neighbor nodes and unfilled topology table but

DOI: 10.18535/ijecs/v5i5.12

they pick ups information about their neighbours by scanning the sender field of each message in its inbound queue. In Fisheye State Routing (FSR) [32] the GSRP protocol is improved. In FSR each node has unique ID and maintians three tables viz., next hop table, distance table and topology table. It also have a list of neighbour. Neighbor list contains adjacent node IDs and topology table has two parts for each destination which indicates the link state condition noted by the destination and the time stamp indicationg the time destination node has noted that link state condition. The distance table provides the shortest path between pair of nodes. Adjacent nodes are frequently updated with respect to the further nodes and the updated messages do not hold information about all nodes hence utilizes bandwidth properly.

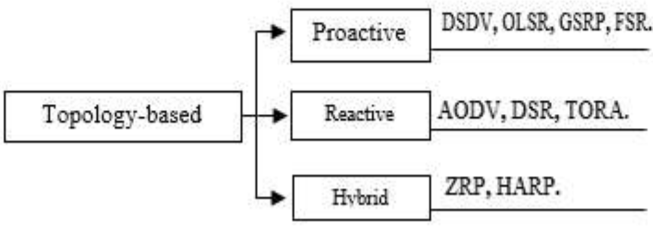
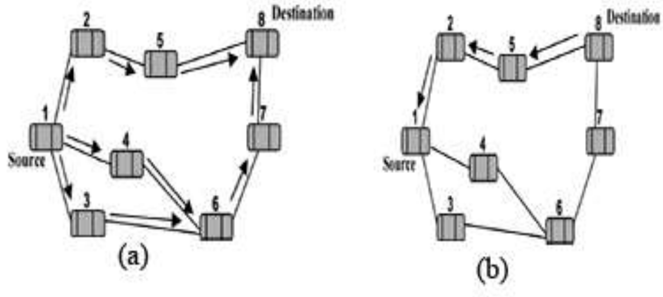


Fig. 16. Topology-based unicast routing taxonomy

OLSR is the modification of old LSR protocol cutom-fit to the wireless requirements. The idea is to select multi point-relays (MRPs) by each node among its neighbor nodes for minimizing the packet streams overhead in the same area. The neighbor which are not selected in the MRP set only receive the message but do not retransmit it again. Regular hello messages are transmitted for link information collection. The criteria for MRP selection is simple in the way that the packets retransmitted by these nodes should be received by all nodes which are two hops away from the sender.

TORA [33] is a distributed routing protocol where route optimality is sacrificed in favor of lower numbers of overhead messages. The protocol's implementation is separated in three basic functions of route creation, maintenance and elimination.The modelling of network is done as a set of finite nodes and undirected links. Due to the nodes mobility the set of links changes with respect to time. Each initially undirected link may subsequently changes to undirected and directed link from one node to other and vice versa. For route creation undirected links are changed to directed one when sender has no route leading to destination with the help of query-reply messages and a Directed Acyclic Gaph (DAG) is constructed rooted at the destination. TORA reacts to maintain routes for any topological changes so that the routes leading to destination can be established within a limited time interval. When network partitioning isolates the destination node then the directed link are changed to undirected. This protocol ensures loop free routing as the packets are dropped by the neighbors of the sender if it has no downward link to the destination.

AODV and DSR are other on-demand protocols adapted from MANET. In AODV some nodes initiates a route discovery process to reach destination only when needed. Counting-to-infinity complication of other distance-vector algorithms is avoided in AODV by adopting the DSDV concept of sequence numbers. AODV can be used for both unicasting and multicasting. In case a source needs to transfer a message to a node and has no routing clue then the route discovery process is initiated by broadcasting RREQ packets which is rebroadcasted by its neighbors until it reaches the destination as shown in fig. 17. When RREQ packet reaches destination it responds back with RREP beacon through the path which the protocol learned by backward learning.



(a) Propagation of RREQ (b) RREP path to the source

Fig. 17. AODV route discovery process.

DSR is a reactive algorithm sharing similarities with AODV as it also forms routes on basis of demand by sender. The sender maintains the whole route within the header of the packet meant for destination node. Retransmission of packets by intermediate nodes is based on the route captured in the header. In case sender don't have any information about the route to destination then process of route discovery is initiated and sender broadcast the route request packet to the neighboring nodes to be broadcasted again till it is captured by the destination. Sender host receives a route reply message if the route discovery process is successful with the listing of network hops sequences. For maintaining routes no explicit packets is transmitted and in case of broken route the source can attempt with other known route or again initiate the route discovery phase.

Zone Routing Protocol (ZRP) [34] is based on the idea of routing zone which is a group of nodes whose radius is referred as the zone radius. Routing zone is defined for each node and it has to know the topology of only its own zone and they get updates of topological changes of their corresponding zone only. So a large network is partitioned in zones and the updates are broadcasted locally. There is an intra-zone communication between the nodes but if a sender from one zone wants to send information to the other zone's node then it sends the query messages to its border nodes which again retransmits the message to its border nodes until it reaches the destination or the hop-count reaches zero.

Hybrid Ad hoc Routing Protocol (HARP) [35] was proposed by Nikaein et al. which combines some features of both reactive as well as proactive protocols. In this protocol inter as well as intra zone routing is performed which depends on whether the communication to be performed is within the same zone or outside the zone. The inter zone communication is reactive in nature while the intra zone communication are proactive. Distributed Dynamic Routing (DDR) algorithm is used for zone creation which is a logical structure with respect to the network properties.

2) Position-Based Routing:

These routing algorithms relies on geographic position information of all nodes and their neighboring nodes using GPS devices. The geographic position information is used for routing decision and don't require to manage any routing table. They are further split upon as non-delay tolerant network (non-DTN) and delay tolerant network (DTN) which we will discuss in latter section.

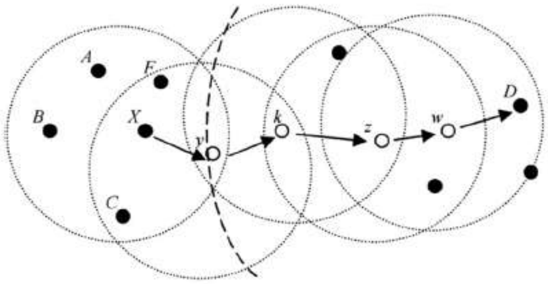


Fig. 18. Greedy forwarding approach of GPSR.

Greedy Perimeter Stateless Routing (GPSR) was proposed by Karp et al. in which the forwarding of packets is based on the routers and destination's position. GPSR uses two different algorithm for packet forwarding namely greedy forwarding and perimeter forwarding. In greedy forwarding the sender sends the packet to the neighbor which is closest to the destination because the packets are marked with the destination's position. Thus a greedy choice is employed in every hop for forwarding the packet until it reaches the destination. Fig 18 shows the greedy forwarding approach. The positions of all nodes are determined by the simple hello messages containing sender's ID and position. Nodes are purged from the table if for a long time no hello messages is received from them. Perimeter forwarding is done when greedy forwarding fails in case when the sender is physically closer to the destination than its neighbor but is not in the direct range with the destination i.e., a problem of local maximum. In this case the graph with sender, its neighbors and destination is traversed by right hand rule.

Greedy Perimeter Coordinator Routing (GPCR) [5] is based on GPSR but alleviates the problem posed by the obstacles which causes network partitioning. Like GPSR it also has two different algorithms with the same aim but its greedy forwarding scheme is somewhat restricted and a recovery algorithm when it's greedy forwarding algorithm fails. The algorithm uses road's junction point as vertices and streets as edges to construct the planner graph without any map support so no algorithms is required for the graph construction. When there is no local maximum problem the algorithm uses its greedy forwarding approach. The packets are routed only along the streets and the decisions are made at junction points of streets and this alleviates the problem of blockage by buildings etc. Fig. 19, shows the contrast between the normal greedy approach and restricted greedy approach in which if regular mode is used then the packet has to follow the path, S -> 1a -> 1b -> 2a -> 2b -> D but in case of restricted greedy approach the packet will follow the path, S -> 2a -> 2b -> D. The nodes which are at the junction are called coordinators, which are chosen randomly by the sender or forwarder, and each coordinator broadcast their position's information. The recovery algorithm do greedy routing to the next junction point where the decision of which route to be taken by the packet is made. Thus the decision making is done by coordinators nodes only which are located near junction point.

Space Division Multiple Access (SDMA) approach was proposed by Bana et al. which allows the medium access control with bounded delay for all users. The area where vehicles are located are divided into smaller areas with one-to-one mapping between the bandwidth divisions using any TDMA, CDMA or FDMA technique. SDMA is self-starting and self-maintaining protocol.

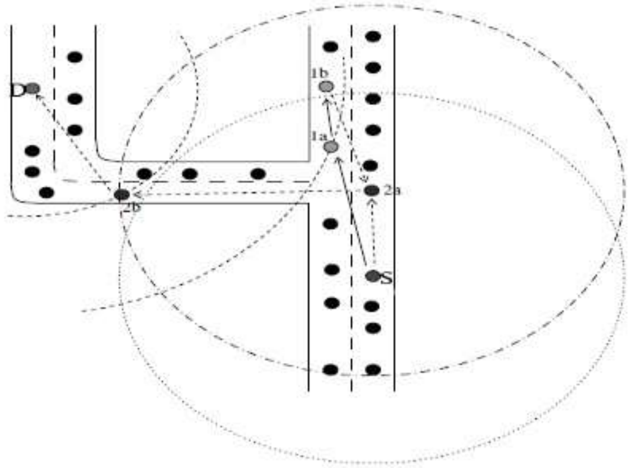


Fig. 19. Greedy forwarding approach verses restricted greedy forwarding.

Connectivity Aware Routing (CAR) [36] was proposed by Noumov et al. which locates destination and finds connected paths between source and destinations. The CAR protocol has four parts viz., destination location with path discovery, data forwarding along discovered path, maintenance of paths and recovery for broken links. Beacons are used for direction and speed information and caching of successful routes between various pairs of source and destination is also used.

Edge-node Based Greedy Routing (EBGR) [37] was proposed by Prasanth et al. in which the edge nodes of transmission range are selected as a next hop node for forwarding data with considering the nodes which are moving in the same direction as the destination node. So the protocol has three parts viz., neighbor node identification for collecting all direct neighbor information, node moving direction identification for identifying the nodes which are moving in the destination's direction and edge node selection for selecting next forwarder of data packet. Contention Based Forwarding (CBF) [38] proposed by Füßler et al. is a greedy position based beaconless protocol which exploits the trail method for next-hop selection. The sender sends its packet to all its direct neighbor and let them select the next forwarder by using the proposed distributed timer-based contention process. Each CBF packet has ID and position of its sender and final destination. Upon receiving of CBF packet by a neighbor which if not a final destination a timer is set for forwarding the packet based on the progress towards destination. Since no beacons are used so it utilizes the bandwidth more efficiently.

We will discuss Intersection based Geographical Routing Protocol (IGRP) which is a position based unicasting algorithm in latter part of this section under bio-inspired routing algorithm. Position based routing are further classified based on delay sensitivity and toleration which is also discussed further in this section.

3) Map-Based Routing:

Multi Hop Routing Protocol (MURU) [39] presented by Mo et al. introduces new reliability metric called as Expected Disconnection Degree (EDD) for finding robust path for urban

VANETs scenarios. EDD uses the factors such as position, speed and trajectory for route quality estimation. MURU is pure ad hoc in nature without any infrastructure support. The main aim of MURU is to eliminate the problems caused by buildings and other wifi interferences. Each vehicle knows its position using GPS and uses external static roadmap. Shortest trajectory is calculated using roadmap by the sender to its intended destination.

Geographic Source Routing (GSR) [40] proposed by Lochert et al. was the first protocol which was evaluated over a realistic vehicles trajectory pattern which aims to alleviates the problems faced by the general position based routing protocols because of radio obstacles. The protocol is ad hoc in nature and uses city map. A Reactive Loaction Service (RLS) is used for finding the positions of nodes. The sender uses street map for the knowledge of sequences of junctions the packet has to travel to reach the destination and the packet header contains these junction sequences. The sender optimally floods the network with request packet to know the position of destination which responds back by replying its position so that the GSR protocol finds the route to destination using map.

Shortest path based Traffic light Aware Routing (STAR) proposed by Chang et al. which considers the traffic lights and traffic pattern for routing decisions. It considers the effect of traffic lights on the mobility of vehicles with the prior knowledge of road topology as vehicles gets stopped by the red lights and move when there is green light. Before reaching the street junctions packets are forwarded in normal greedy approach. At the street junction STAR protocol checks for if the destination is connected or not if not then the packet is forwarded to the closest green light segment with the destination.

Anchor based Street and Traffic Aware Routing (A-STAR) proposed by Seet at al. which addresses the problem of local maximum and also uses the route information of city buses for finding anchor points with good connectivity for packet dissemination. Like STAR protocol also takes traffic lights and prior knowledge of road topology into account. The source packet is marked with the anchor points through which the packet has to travel in order to reach the destination and in between greedy forwarding technique is used. The street maps are statistically rated with the number of city buses that ply on a particular route. The protocol inner core idea is based on the already discussed GPCR protocol.

Road Based using Vehicular Traffic (RBVT) was proposed by Nzouonta et al. with proactive and reactive versions of the protocol. The RBVT protocol takes advantage of real time vehicles trajectory information for creating road based path with junctions providing connectivity between them. Each vehicle in RBVT has GPS system, maps and navigation system that gives position of node on road. In reactive version of RBVT the path is made of road segments divided by junction points with vehicles providing connectivity between junction points. In proactive version of RBVT the periodical discovery and dissemination of road-based network topology is done to preserve steady state of network connectivity at each node.

4) Path-Based Routing:

Vehicle Assisted Data Delivery (VADD) proposed by Zhao et al. is a path based routing protocol for VANET. The idea of protocol is based on the fact of carry and forward until a new node comes enough close to make the forwarding or delivery of the packet. VADD is particularly suited for the sparse network. Each node know its position and is equipped with the statistically rated digital map. VADD uses wireless radio channels to forward the packet but the nodes with higher speeds are preferred with periodical path maintenance all over till the packet is delivered. VADD synthesize three types of packets viz., straightway_mode, intersection_mode and destination_mode on the basis of nodes location carrying the packet as shown in fig. 20. VADD delay model employs stochastic model to guess delivery postponement.

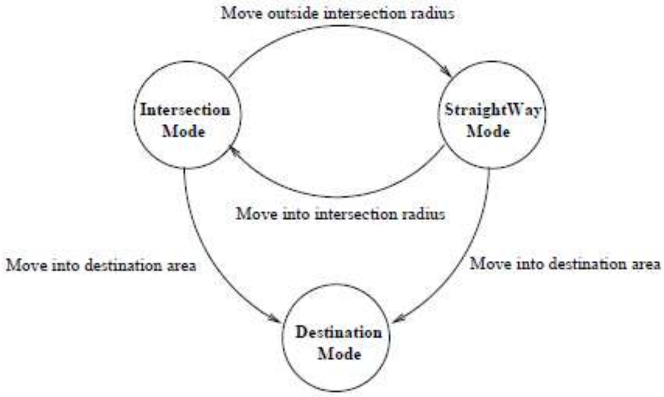


Fig. 20. Packet modes in VADD

C. Based on Delay Sensitivity and Toleration

1) DTNs:

DTNs find their applicability in disaster area, military operation and emergency response networks. Distributed Adaptive Routing (DAR) proposed by Khanna et al. which aims to achieve high network connectivity with less network transmissions. DAR uses gossip protocols pioneered by Xerox PARC for DTNs to show the phase transition characteristic of delivery ratio in DTNs. Adaptive gossip probability algorithm uses phase transition value for gossip probability computation for every node. The computed probabilities limits network transmissions by letting each node to decide probabistically whether it should rebroadcast the packet or not. We have already discussed VADD in path based protocols which is also a DTNs routing protocol.

Scalable Knowledge-based Routing (SKVR) Architecture for public transport networks proposed by Kanere and Ahmed is based on the analysis of vehicles trajectory trace files which shows that the public transport has the characteristics of DTNs. They have proposed the public transport arrival-departure timings knowledge as an aid to routing protocols and partitioned these knowledge in static and dynamic one. Static knowledge corresponds to the fixed planned timings of public transport whereas dynamic knowledge corresponds to the variations in the static knowledge. The network of public transport has hierarchical structure with inter-domain routing among different public transport routes and intra-domain routing within a particular public transport route.

Social-based Privacy-preserving forwardING (SPRING) [41] is a routing protocol for DTNs which uses RSUs for packet forwarding assistance. RSUs are used only when no reliable next-hop vehicle is available, i.e., SPRING has V2I communication. In this protocol social degree of each road junctions/intersection points is introduced which is defined heuristically for the placement of RSUs at the intersection points which have high social degree. RSUs placed according to the value of social degree of intersection point provides high connectivity because maximum number of vehicles will cross from these junctions and at the same time reduces the cost. SPRING also takes authentication, privacy and attack resistance into account.

Geographical Opportunistic (GeOpps) Routing protocol [42] is a geographical with delay tolerancy approach which uses opportunistic contact between vehicles for data forwarding. Information from the navigation system is used for the choice of next hop which takes radial separation from the final destination of the packet as its basis. Every forwarding node calculates its nearest point to destination using the navigation system to decide whether to keep the packet or to forward it to a neighbor on the basis of estimated minimum-time required by the packet to be intercepted by the destination. The calculation of minimum-time is done by using a utility function given by the authors.

GeoSpray proposed by Soares et al. uses a hybrid approach between single and multi copies store and forward approach with node's geographhical position data. It asynchronously spreads limited bundel copies which are IP datagrams packets to be processed by bundle layer between network and MAC layer. GeoSpray is inspired from GeoOpps as it also uses navigation systems for the node's position information. Once the multiple bundle copies are spread in the network the protocol switches to single copy forwarding scheme. All nodes when interacts with other node exchanges information for the deletion of bundles that have already been delivered then they check whether the packet they are holding has final destination among them or not, if it is then those bundles are delivered and purged from the buffer. In the next step they exchange information about the bundles they are holding to determine the best carrier node for each bundle stored with them. The algorithm is symmetric as same is running between the interacting nodes.

Spray and Wait protocol introduced by Spyropoulos et al., is a tradeoff between full-fledged broadcasting and optimal broadcasting approach with epidemic routing in combination. This protocol can also be viewed as a adjustment in between multi copies and single copy plans. In this protocol a number of data packets are sprayed as the sender encounters other nodes then the sender waits for some time. Binary Spray and Wait technique is used which can be defined as "Source node originally begins with 'M' copies of message and any node 'N' having n > 1 copies of messages if meets another node 'X' that have no copies then 'N' hands over to X ⌊n/2 ⌋ keeping ⌈n/2⌉ messages but when there is only a copy left, then it goes for the direct transmission" In wait phase the author states that "If spraying phase is not able to discover the destination then every node having message copy goes for the direct transmission (i.e., will forward the message only to its destination)."

D. Based on Bio Inspiration

Bio-inspired algorithms can be defined as those algorithms which takes a more evolutionary approach to learning by taking ideas from life science and tries to copycat the behavior of natural breeds. The protocols which we discussed in the previous subsections takes traditional computational approach for routing solutions. These algorithms can further be divided into swarm intelligence, genetic algorithms and evolutionary algorithms. Swarm intelligence is the unified habits of distributed but self-coordinated communities like ant community, bird flocking, animal herding, fish schooling, etc. It consists of a community of simple operating agents which interacts restrictedly with one another and follows some rules. Swarm intelligence pattern examples are particle swarm optimization, ant community optimization (ACO), bee community optimization (BCO), bat algorithm, river formation dynamics, etc. Below we discuss some of the bio-inspired algorithms.

A delay sensitive vehicular routing protocol using ACO proposed by Li et al. [43] falls under DTNs routing protocol which uses ACO techniques to choose the least delay path for forwarding packets. This protocol uses streets/highways junctions as anchor points i.e., RSUs for data delivery assistance. ACO algorithm is used for alleviating the problem of hard non-deterministic polynomial in routing. Initially optimal paths are established between source and destination using unicast or optimal broadcast transmissions with reactive approach. For route maintenance and path extension the protocol takes table-based proactive approach. GPS, navigation system and maps are pre-installed on each vehicles so that the vehicles can know their geographical positions when needed. Links relaying quality is estimated based on the additive relaying delays between two junction points. Reactive forward ants of ACO concept is used to find possible paths from source to the closest junction which generates the reactive backward ants back to source. The reactive backward ant's packets marks pheromone at each junction using the delay values. These pheromone values are used to select the best junction's RSU among the available to relay the packet with simple greedy or carry forwards between the junctions along road segments. The algorithm uses reactive, proactive and V2I approach for its implementation.

Mobility-aware ant colony optimization routing called as, MAR-DYMO was proposed by Correia et al. [44] also uses ACO techniques for making routing decisions in urban scenarios. Kinetic graph framework devised by Harri et al., is used in this protocol for collecting information regarding vehicle's position and speed. The routing table at each node maintains the information of pheromone in it and represents the route qualities which is high if the route request and reply packets are both received at the same node. During packet forwarding the pheromone levels of routes are considered to select the best path between the source and destination. The route discovery process of MAR-DYMO is reactive compared to DYMO and uses kinetic graph framework.

Multicast with Ant Colony Optimization for Vanets based on MAOVD (MAV-AODV) proposed by Souza et al., also uses ACO for building optimized and stable multicast trees. In this protocol beacon packets act as pheromone of real ants. Neighbors within its radio range send beacon messages at regular intervals among themselves to know positions and their mobility in the form of position vector and velocity vector. Link lifetime calculations is based on the exchanged position vector and velocity vector. Route request packets are broadcasted for multicast group member's discovery from the source for the destination. Each route request packet stores the route lifetime estimated earlier for making stable multicast trees. Upon receiving of route request packet by a multicast group member it replies to source node along reverse path using unicasting by taking route's pheromone level and hop count into consideration as shown in Fig. 21. The MAV-AODV simulation results are better than DYMO discussed earlier in this sub section and generates stable multicast tree than other conventional multicast protocols such as MAODV.

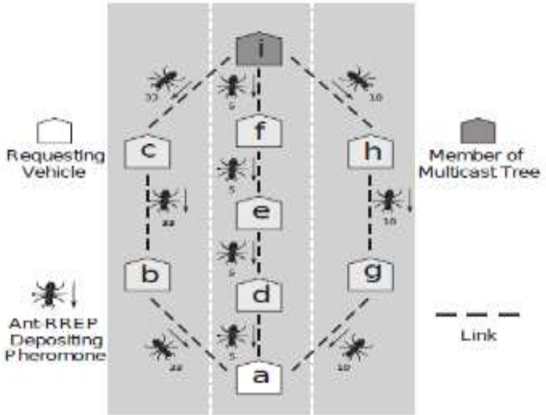


Fig. 21. Route reply example of MAV-AODV [39].

Intersection-based Geographical Routing Protocol (IGRP) proposed by Saleet et al., is based on genetic algorithm in way that the protocol makes selection of street junctions to forward the packet to the internet gateway. The work of Saleet et al. aims to provide effective and reliable communication. Every vehicle in this protocol is assumed to have the GPS, digital map and navigation system. The street junctions are considered as vertices and the roads connecting these junctions are the edges of the graph abstracted for the street map. In this protocol the whole network is considered to be network among mobile vehicles and fixed internet gateways installed at the street junctions as shown in Fig. 22. The aim of this protocol is to forward the packet from source to the nearest internet gateway as soon as possible with taking QoS, bit error rate (BER), connection probability etc., into account. The purpose of the installed gateway is to supply the information about the best route for forwarding the packet. Gateways has all the information of local network topology made up of all the nearby vehicles as all nearby vehicles gives updates of its mobility to its nearby gateway. Gateways acting as the location server helps in constructing the routes between itself and other vehicles. Between two gateways the mobile vehicles will transmit the packets but the routes between them are not stable because of mobility, so IGRP takes the approach of backbone routes consisting of street's junction point only. The gateway selects that backbone which has highest probability of connection and also sufficient traffic and sends this information to the source so that these information should be added in the packet header. The packet header's route information helps the forwarders to geographically route the packet to the ultimate destination. The authors of IGRP also gave equations for calculating connectivity probability, bit error rate, delays, hop counts and transmission range.

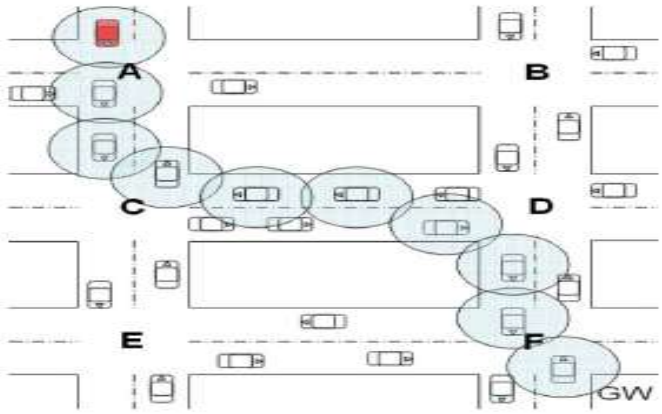


Fig. 22. Message routing in IGRP [69].

E. Based on Accommodating Network

1) Homogeneous Network:

For V2V and V2I communications IEEE proposed a standard by the name of DSRC which has WAVE as its core part. DSRC is comprised of the set of IEEE 1609.x standards built over the IEEE 802.11 standard as shown in fig. 2. When all the vehicles uses same underlying wireless access technologies then it is the case of homogeneous network. Vehicles can communicate with the technologies like cellular, WiFi, WiMAX, satellite, Bluetooth, LiFi and DSRC/WAVE. However DSRC is best for vehicular communication as it is specifically designed standard to meet the extremely short latency requirement of vehicular environment. DSRC and WAVE are sometimes used interchangeably.

Ho et al. [45] presents DSRC system implementation. Many projects have been undertaken and some are going on to bring homogeneity in vehicular environment for computing and communication. Table I enlists objectives and references of the projects undertaken as well as going on projects for bringing standards and homogeneity among VANETs communication. To alleviate the issues of heterogeneity, security, cost, etc., David Padi [46] proposed Vehicular Information and Communication Technology (VICT) system to set out technological solution for robust, resilient and secure communication with managerial accountability in vehicular environment. Hung et al. [47] used Worldwide Interoperability for Microwave Access (WiMAX) for implementing video based safety application. Particularly WiFi and WiMAX are suitable for non-safety applications that require video streaming as it gives high data transfer rate of up to 63 Mbps in downlink and upto 28 Mbps for uplink.

Jaber et al. [48] proposed the combined usage of WiMAX and DSRC for vehicular communication with the aim of providing broadband internet access to DSRC enabled vehicles being served in WiMAX region. Another technology that have place in vehicular communication is Light-Fidelity (LiFi) [49] which uses visible light communication (VLC) technology to a further extent. Bluetooth is also becoming popular for vehicular communication but till now it has not been recommended as the replacement for on-board communication interface of DSRC/WAVE.

2) Heterogeneous Network:

When vehicles uses different radio access technologies then it is the case of heterogeneous vehicular environment. The main challenge of routing protocols in heterogeneous environment is inter-communication understanding of different underlying wireless access technologies. The simulation results gives good performance when it is assumed that all vehicles and associated infrastructures uses same technologies. Routing in heterogeneous vehicular environment especially needs to overcome the challenges of handoff, computational complexity, transmission time, cost, coalition management, mobility management and topology control problems. Vertical handoff can be defined as a "mechanism of switching between the categories of connections a mobile node uses to have access of supporting infrastructure". In simple language it can be stated as the change from one type of network technology to the other type is called vertical handoff. Nodes mobility is usually supported by the mechanism of vertical handoff techniques.

TABLE I
Summary information on representative VC projects, consortia, and working groups [86].

Project Name	Period	Funding Agency	Description
AKTIV	2006-10	Ministry of Economics and Technology Germany	***Objective***- "Design, development, and evaluation of driver assistance systems, knowledge and information technologies, efficient traffic management, and V2V and V2I communication." ***Reference***- "*http://www.aktiv-online.org/index.html*"
Car to Car Communication Consortium (C2C-CC)	Ongoing	N/A	***Objective***- "Development of a European industry standard for VC communication systems, active safety applications prototyping and demonstrations, harmonization of VC standards worldwide, realistic deployment strategies and business models." ***Reference***- "*http://www.car-2-car.org/*"
CityMobil	2006-10	European Union	***Objective***- "Integration of automated transport systems in the urban environment, based on real-life implementations." ***Reference***- "*http://www.citymobil-project.eu/*"
CyberCars2	2006-08	European Union	***Objective***- "Cooperation between vehicles running at close range (platooning) and at intersections (merging, crossing)." ***Reference***- "*http://www.cybercars.org*"
GeoNet	2008-09	European Union	***Objective***- "Specifying, developing and testing IPv6 geo-networking that can be used within a cooperative architecture (e.g., CVIS)." ***Reference***- "*http://www.geonet-project.eu/*"
IEEE P1609	Ongoing	N/A	***Objective***- "Standard for wireless access in vehicular environments (WAVE)-Resource manager, physical and medium access control, security services, networking services, multichannel operations for V2V and V2I communication." ***Reference***- "*http://www.standards.its.dot.gov/fact_sheet.asp?f=80*"
NoW: Network on Wheels	2004-08	Ministry of Education and Research Germany	***Objective***- "Protocols and data security algorithms for V2V/V2I communication, active safety scenario, V2I electronic payment, introduction strategies, and business models." ***Reference***- "*http://www.network-on-wheels.de/*"
PATH	Ongoing	California Department of Transportation (CalTrans)	***Objective***-Multidisciplinary research program administered by the UC Berkeley Institute of Transportation Studies and CalTrans; activities in four areas: policy and behavioral, transportation safety, and traffic and transit operations research." ***Reference***- "*http://www.path.berkeley.edu/*"
IntelliDrive Previously known as the VII consortium (VIIC)	Ongoing 2005–08	Department of Transportation USA	***Objective***- "Initiative of the ITS Joint Programs Office (JPO) at the DoT's Research and Innovative Technology Administration (RITA) VC technologies and applications, V2V, V2I, mobility, and policy research." Reference – "http://www.intellidriveusa.org/"
VSC	2002–04	Department of Transportation USA	***Objective***- "DSRC demonstration and safety beaconing for V2V and V2I communication."

Shafiee et al. [50] proposed an optimal distributed vertical handoff for heterogeneous vehicular networks based on assumption that vehicular network involves cellular system and WLAN. Kim et al. [51] proposed fuzzy logic based handoff for minimizing transfer time and cost. Their work proposes the selection of best communication technologies available around vehicle. Li et al. [52] proposed algorithms for topology control in wireless network that can be effectively used for heterogeneous vehicular environment also. They proposed Directed Relative Neighborhood Graph (DRNG) and Directed Local Minimum Spanning Tree (DLMST) algorithm both of which are localized topology control procedure which lets each node to select its neighbor and also tune its transmission power. Another approach of cluster formation that withstand the mobility pattern can also alleviate the problems inherent with heterogeneous networks. Clustering algorithms can be divided into mobility based and non-mobility based which includes direction of movement, signal strength, transmission range, probabilistic approach, etc., as cluster formation parameters. A cluster head is selected by the nodes that constitute a particular cluster which act as a gateway between different network technologies. For connecting a source vehicle to 4G LTE advanced infrastructure Zhiona et al., proposed a clustering algorithm. The algorithm uses some information collected by source viz., signal strength, load and connectivity for choosing the gateway. Amalgamation of routing techniques with different tradeoffs can also solve the problems faced by heterogeneous vehicular network environment. One such proposal were made by Shaifee et al. [50] in the paper titled WLAN-WiMAX Double-Technology Routing (WWDTR).

3. Assessment Approaches for VANETs

As we mentioned earlier that evaluation of a routing protocol in VANETs is necessary, indispensable and struggling task, so in this section we bring some assessment methodologies into picture. Mostly protocols are accessed using simulators because conducting live real-time experiments are costly, tedious and risky events. Once the protocol passes all the simulation tests with expected results then it can be tested in the real time vehicular environments. Before deploying any protocol in real world we should have enough facts and figures that it will attain the proposed aims without any risk. For assessment we need network simulator and vehicular mobility simulator with integration of these two.

DOI: 10.18535/ijecs/v5i5.12

A. Vehicular Mobility Simulator

TABLE II
Network Simulator Comparison

Simulator	License	Development Language	Simulation Language	Supported OS	Source Code Availability	Inclusion of Mobility Model	Mobility Model Supported
ns-2	GNU GPLv2	C++	C++/OTcl	Windows(Cygwin), Linux, FreeBSD	Yes	No	VanetMobiSim, SUMO
ns-3	GNU GPLv2	C++	C++/Python	Windows(Cygwin), Linux, FreeBSD	Yes	No	VanetMobiSim, SUMO
OMNeT++	Academic	C++	C++	Windows, Linux	Yes	No	VanetMobiSim, SUMO

Vehicular mobility model is required to study the effects of number of vehicles, density of vehicles, speed change of vehicles, clustering of vehicles at junction points and moving direction of vehicles on the routing protocols. The choice of appropriate mobility model is very crucial as it determines the accuracy and reliability of the simulation results. Fig. 23 gives the classes of mobility models at a glance so far proposed by researchers. In synthetic modelling mathematical exemplary models like stochastic, traffic stream, car following, queue and behavioral are used whereas in survey modelling whereas in survey modelling extracted survey data are used for mobility pattern generation. Trace based approach of modelling directly uses real mobility traces generated by various sources. In traffic simulator based approach traces of mobility pattern form traffic simulator is used.

Simulation of Urban Mobility (SUMO) [53] is designed for urban traffic simulation and is open source technology. With macroscopic vehicular mobility it can simulate large number of vehicles simultaneously plying under the given street topology constraints. SUMO can be used both in command mode and GUI mode. VanetMobiSim [54] is also a popular traffic simulator published by university of Stuttgart and is a Java based application supported on Windows, UNIX and Linux platforms. VanetMobiSim is an enhancement to the CanuMobiSim [55] and allows to define street topologies using TIGER map and clustered Voronoi graph with input as XML file. STRAW [56] is another mobility simulator developed as a part of "Car-to-Car Cooperation" (C3) project and defines the streets topology using real maps. STRAW also supports the implementation of lane changing, traffic signs and traffic lights.

B. Network Simulator

Network simulator is required to study the effects of communication range, interference, medium access and topology changes. Among the available network simulators OMNeT++, ns-2 and ns-3 are most popular discrete event driven simulation tools. While ns-2 and ns-3 comes under GNU GPLv2 licensing, OMNeT++ is for academic purpose. Table II gives a comparison of these network simulators.

C. Integrated Simulation Environment

Traffic simulators generates what we call trace files and introduction of these trace files to the network simulator is the approach for VANETs application or routing protocols simulation. On these basis we have two different kind of approach i.e., tightly assimilated approach and loosely assimilated approach. Both approaches are used for VANETs simulation but the difference lies in the mobility generation. Tightly assimilated approach assimilates both network simulator and traffic simulator into one with latter having the responsibility of vehicular mobility and former having the responsibility of wireless communication. In loosely assimilated approach the trace files independently generated are introduced into the network simulator for mobility.

ITERIS and Veins are most popular tightly assimilated framework for VANETs simulation and gets easily combined with SUMO. Both ITERIS and Veins have two way communication and while former uses ns-3 as network simulator latter uses OMNeT++ as network simulator with full featured WAVE model support. Both of these also gives GUI based visualization.

4. Conclusion

VANETs research and projects started as an offshoot of MANETs feeling the need of inter-communication between vehicles for safety application, traffic warning and to eliminate or minimize the accidental hazards. With the maturity of technologies VANETs got their place in safety, non-safety, commercial, non-commercial, entertainment, platoon management and parking system applications. Many researchers, universities, government and non-government organizations came forward for the realization of VANETs applications. The core of all the application lies in the exchange of data in such mobile and dynamic environment and for this many routing protocols were contributed by the researchers. Some routing protocols were successfully implemented with the current technologies and some will become feasible latter with the advancement of technologies and standards. In this work we discussed the existing and ongoing technologies which VANETs require such as WAVE, DSRC, WiMAX and devices like GPS, OBU and RSU.

The aim of this work was not to produce a voluminous work but to give an insight into the various classification strategies one can go with. We have discussed major existing protocols and many not because of limited space. Routing techniques employ various graphical, probabilistic and hybrid approaches for its realization and implementation. Classification taxonomy were based on transmission strategies, knowledge needed, delay awareness, accommodating network and motivating inspiration.

Based on transmission approach, unicast, multicast, geocast and broadcast routing protocols were included. Unicast routing routes packets from single source to single destination while multicast and geocast routes packet from source to multiple destinations. Geocast uses the concept of ZOR and on the other hand multicast may be tree or mesh based on the routing structure of involved vehicles and its road networks. Broadcasting protocols tries to eradicate the problems of broadcast storm, redundant retransmission and channel congestion.

Many routing protocols needs some prerequisite knowledge about the vehicular environment for their realization like topology-based, position-based, map-based and path-based routing protocols. Further they are hierarchically classified as proactive, reactive and hybrid routing protocols depending on the methodologies they employ. Topology based routing employ the concept of shortest path algorithms like Dijkstra's and Bellman Ford's algorithm. Position based routing relies on geographic position information of all nodes and their neighboring nodes using GPS devices.

DTNs routing protocols find their applicability in disaster area, military operation, etc., while non-DTNs routing protocols is suitable for emergency response network which gets further classified into beacon and beaconless protocols. Some protocols uses bio processes as source of their inspiration such ACO, BCO, swarm intelligence and genetic processes. Some protocols based on ACO, BCO and genetic selection processes were successfully simulated and implemented. Routing in heterogeneous environment also poses some challenges like handoff, computational complexity, transmission time, mobility management and topology control and thus we discussed some protocols which take these issues into account.

Other aspects like implementation complexity, practical and experimental popularity, density of vehicles, distinct dimensions suitability and QoS can be delved to classify the routing protocols. In future works we will try to cover these aspects also for classifying VANETs routing protocols.

We also glanced at the various tools and technologies available for the VANETs application's assessment. We discussed mobility and network simulators. We also discussed some integrated simulation environments like ITERIS and Veins. In future works we will try to enlist some real world experiments so far conducted in the realm of VANETs applications.

5. References

[1] W.H.O, Road traffic injuries, October-2015. [Online]. Available: http://www.who.int/mediacentre/factsheets/fs358/en/

[2] H. Cai, L. Yan, D. Zhu, Using multi-regression to analyse and predict road traffic safety level in China, in *Proc. 3rd Int. Conf. Transportation and safety,* June 2015.

[3] N. F. G. C. Ferreira, J. A. G. Fonseca, Improving safety message delivery through R.S.U's coordination in vehicular networks, *IEEE World Conference Factory Commn. Systems,* pp. 1-8, May 2015.

[4] Technical committee, CAR 2 CAR Communication Consortium Manifesto, December 2007.

[5] C. Lochert, M. Mauve, H. Füßler, H. Hartenstein, Geographic routing in city scenarios, ACM SIGMOBILE Mobile Computing and Communications Review, volume 9, 2005, pp. 69-72

[6] A. Bachir, A. Benslimane, A multicast protocol in ad hoc networks inter-vehicle geocast, in: Proceedings 57th IEEE Semiannual Vehicular Technology Conference, volume 4, 2003, pp. 2456-60.

[7] C. Maihofer, R. Eberhardt, Geocast in vehicular environments: Caching and transmission range control for improved efficiency, in: Proceedings IEEE intelligent vehicles symposium, 2004, 951-56.

[8] H. P. Joshi, M. L. Sichitiu, M. Kihl, Distributed robust geocast multicast routing for inter-vehicle communication, in: Proceedings *WEIRD workshop on WiMax,* 2007, pp. 9-21.

[9] M. Kihl, M. Sichitiu, T. Ekeroth, M. Rozenberg, Reliable geographical multicast routing in vehicular ad-hoc networks, in: Proceedings international conference WWIC, 2007, pp. 315-25.

[10] C. Maihofer, T. Leinmuller, E. Schoch, Abiding geocast: time-stable geocast for ad hoc networks, in: *Proceedings. ACM International workshop vehicular ad hoc networks*, 2005, pp. 20-29.

[11] C. Celes, C. T. De Oliveira, R. B. Braga, A. A. F. Loureiro, R. M. C. Andrade, GeoSPIN: An approach for geocast routing based on SPatial INformation in VANETs, in: *Proceedings. IEEE Vehicular Technology Conference*, 2013, pp. 1–6.

[12] H. Rahbar, K. Naik, A. Nayak, DTSG: Dynamic Time-Stable Geocast Routing in vehicular ad hoc networks, *IEEE Computer Communication Symposium*, 2010, pp. 198-203.

[13] W. K. Wolterink, G. Heijenk, G. Karagiannis, Constrained geocast to support cooperative adaptive cruise control (CACC) merging, in: *Proceedings IEEE Vehicular Networking Conference*, 2010, pp. 41-48.

[14] Y. S. Chen, Y. W. Lin, S. L . Lee, A mobicast routing protocol for vehicular ad hoc networks, in: Proceedings *IEEE* GLOBECOM , 2009, pp. 1-6.

[15] S. Yu, G. Cho, A selective flooding method for propagating emergency messages in vehicle safety communications, in: *Proceedings of International Conference on Hybrid Information Techchnology*, 2006, pp. 556-61.

[16] M-T. Sun, T-H. Lai, W-C. Feng, , H. Okada, K. Yamada, GPS-based message broadcast for adaptive inter-vehicle communications, in: *Proceedings 52nd Vehicular Technology Conference*, 2000, pp. 2685-92.

[17] A. M. Vegni, E. Natalizio, A. Stramacci, SRB: a selective reliable broadcast protocol for safety applications in VANET, in: *Proceedings International Conference on Selected Topics in Mobile & Wireless Networking*, July 2012.

[18] M. Durresi, L. Barolli, A. Durresi, Emergency broadcast protocol for inter-vehicle communications, in: *Proceedings Intertational Conference Parallel and Distributed Systems*, 2005, pp. 402–06.

[19] O. Tonguz, F. Bai, V. Sadekar, N. Wisitpongphan, P. Mudalige, Broadcasting in VANET, in: *Proceedings Mobile Networking in Vehicular Environ*ment, pp. 7–12, 2007.

[20] W. Viriyasitavat, O. K. Tonguz, F. Bai, UV-CAST: An urban vehicular broadcast protocol, in: *Proceedings. IEEE Vehicular Networking Conference*, pp. 25–32, 2010.

[21] J. Huang, Y. Huang and J. Wang, Vehicle density based forwarding protocol for safety message broadcast in VANET, *The Scientific World Journal*, pp. 1-9, 2014.

[22] N. N. Nakorn, K. Rojviboonchai, DECA: Density-aware reliable broadcasting in vehicular ad hoc networks, in: *Proceedings IEEE Computer Telecommunications and Information Technology*,pp. 598-602, 2010.

[23] G. Korkmaz, Ü. Özgüner, F. Özgüner, E. Ekici, Urban multi-hop broadcast protocol for inter-vehicle communication systems, in: *Proceedings ACM Intertational Workshop Vehicular Ad Hoc Net*works, pp. 76–85, 2004.

[24] G. Korkmaz, F. Özgüner, E. Ekici, An efficient fully ad-hoc multi-hop broadcast protocol for inter-vehicular communication systems, in: *Proceedings IEEE ICC*, 2006, pp. 423-28.

[25] Y. H. Choi, F. Bai, P. Mudalige, R. Rajkumar, Adaptive location division multiple access for reliable safety message dissemination in VANETs, in: Proceedings 6th Intertational Conference Symposium Wireless Communication System, pp. 565-69, 2009.

[26] P. Akkhara, Y. Wakahara , Y. Sekiya, , Efficient alarm messaging by multi-channel cut-through rebroadcasting based on inter-vehicle communication, *Intertational J. Computer Science*, May 2009.

[27] W. Sun, F. Xia, J. Ma, T. Fu and Y. Sun, An optimal ODAM-based broadcast algorithm for vehicular ad-hoc networks, IEEE *Transactions Internet and Information System*, December 2012, pp. 3257-74.

[28] A. Benslimane, Optimized dissemination of alarm messages in vehicular ad-hoc networks (VANET), in: *Proceedings IEEE International Conference High Speed Networks Multimedia Communication*, 2004, pp. 655-66.

[29] H. Alshaer, E. Horlait, An optimized adaptive broadcast scheme for inter-vehicle communication, in: *Proceedings IEEE VTC*, pp. 2840-2844, 2005.

[30] H. Jiang, , L. Chen, H. Guo, Reliable and efficient alarm message routing in VANET, in: *Proceedings ICDCSW*, 2008, pp. 186-91.

[31] T. W. Chen and M. Gerla, Global state routing : a new routing scheme for ad-hoc wireless networks, in: *Proceedings IEEE International Conference Communi*cation, 1998, pp. 171–175.

[32] G. Pei, T. W. Chen, M. Gerla, T. W. Chen, Fisheye state routing in mobile ad hoc networks, in *Proceedings IEEE International Conference Communi*cation, 2000, pp. 70-74.

[33] V. D. Park, M. S. Corson, A highly adaptive distributed routing algorithm for mobile wireless networks, in: *Proceedings IEEE INFOCOM*, pp. 1405–13, 1997.

[34] Z. J. Haas, "A new routing protocol for the reconfigurable wireless networks," in: *Proceedings IEEE Conference on universal personal Communication*, pp. 562–566, 1997.

[35] N. Nikaein, N. Nikaein, C. Bonnet, HARP-hybrid ad hoc routing protocol, in: *Proceedings International Symposium telecommunications*, pp. 56–67, 2001.

[36] V. Naumov, T. R. Gross, Connectivity-aware routing (CAR) in vehicular ad-hoc networks, in *Proceedings IEEE INFOCOM*, pp. 1919-27, 2007.

[37] K. Prasanth, C. Chandrasekar, K. Jayasudha, K. Duraiswamy, Minimizing end-to-end delay in vehicular ad hoc network using edge node based greedy routing," in: *Proceedings International Conference Advanced computing*, pp. 135-140, 2009.

[38] H. Füßler, W. Effelsberg, H. Hartenstein, J. Widmer, M.Mauve, ,Contention based forwarding for street scenarios, in: *Proceedings International WIT Workshops*, pp. 155-159, 2004.

[39] Z. Mo, N. Pissinou, K. Makki, H. Zhu, MURU:a multi-hop routing protocol for urban vehicular ad hoc networks, *in: Proceedings International Conference mobile and ubiquitous systems - networking and services*, pp. 1-8, 2006.

[40] C. Lochert, H. Füßler, J. Tian, H. Hartenstein, D. Hermann, M. Mauve A routing strategy for vehicular ad hoc networks in city environments, in: *Proceedings IEEE*, pp. 156–161, 2003.

[41] R. Luy, X. Sheny, X. Linz , SPRING: A social-based privacy preserving Packet Forwarding Protocol for vehicular delay tolerant networks, in: *Proceedings IEEE*, pp. 1-9, 2010.

[42] C.Mascolo, I. Leontiadis, Geopps:geographical opportunistic routing for vehicular networks, in *Proceedings IEEE*, pp. 1-6, 2007.

[43] L. Boukhatem, G. Li, A delay-sensitive vehicular routing protocol using ant colony optimization, in: *Proceedings*, pp. 49–54, 2013.

[44] J. C. Junior, O. Cherkaoui, S. L. O. B. Correia, Mobility-aware ant colony optimization routing for vehicular ad hoc networks, in; *Proceedings IEEE* pp. 1125–30, 2011.

[45] K-Y. Ho, C-H. Lin, C-H. Hsu, P-C. Kang, Implementation of WAVE/DSRC devices for vehicular communications, Computer Communication Control and Automation, 2010, pp. 1-4.

[46] David Padi, "Vehicular information and communications technology (VICT) system," IEEE, 2009, pp. 1-5.

[47] J.S. Huang, F. Lawal, O. Yang, "Sending Safety Video over WiMAX in Vehicle Communications," in: Proceedings Future Internet, pp. 535-567, 2013.

[48] N. Jaber, N. C. Doyle and K. E. Tepe, " New combined WiMAX/DSRC infrastructure design for efficient vehicular networking," EURASIP Journal Wireless Communication and Networking, 2012, pp. 1-26.

[49] H. Haas, L. Yin, Y. Wang and C. Chen, "What is LiFi?," IEEE Journal Lightwave Technology, 2015, pp. 1-12.

[50] K. Shafiee, V. C. M. Leung, A. Attar, "Optimal distributed vertical handoff strategies in vehicular heterogeneous networks," *IEEE Journal*, pp. 534–44, 2011.

[51] J. Kim, J-D. Cho, J. Jeong, J-Y. Choi, B-H. Song and H. Lee, "Fuzzy logic based handoff scheme for heterogeneous vehicular mobile networks, "*IEEE Int. Conf. HPCS*, 2014, pp. 863-870.

[52] N. Li and J. C. Hou, "in *Proc. IEEE INFOCOM Workshops*, vol. 1, 2004, pp. 232-243.

[53] DLR Institute of Transportation Systems, "Simulation of Urban Mobility (SUMO)," [Online]. Available: http://sumo.dlr.de/wiki/Main_Page

[54] VanetMobiSim project, [Online]. Available: http://vanet.eurecom.fr

[55] CANU project, [Online]. Available: http://canu.informatik.uni- stuttgart.de

[56] STRAW as part of C3 project, "STreet RAndom Waypoint," 2008 [Online]. Available: http://www.aqualab.cs.northwestern.edu/projects/STRAW/index.php